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# AMA

## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.27, NO.2, SPRING 1996

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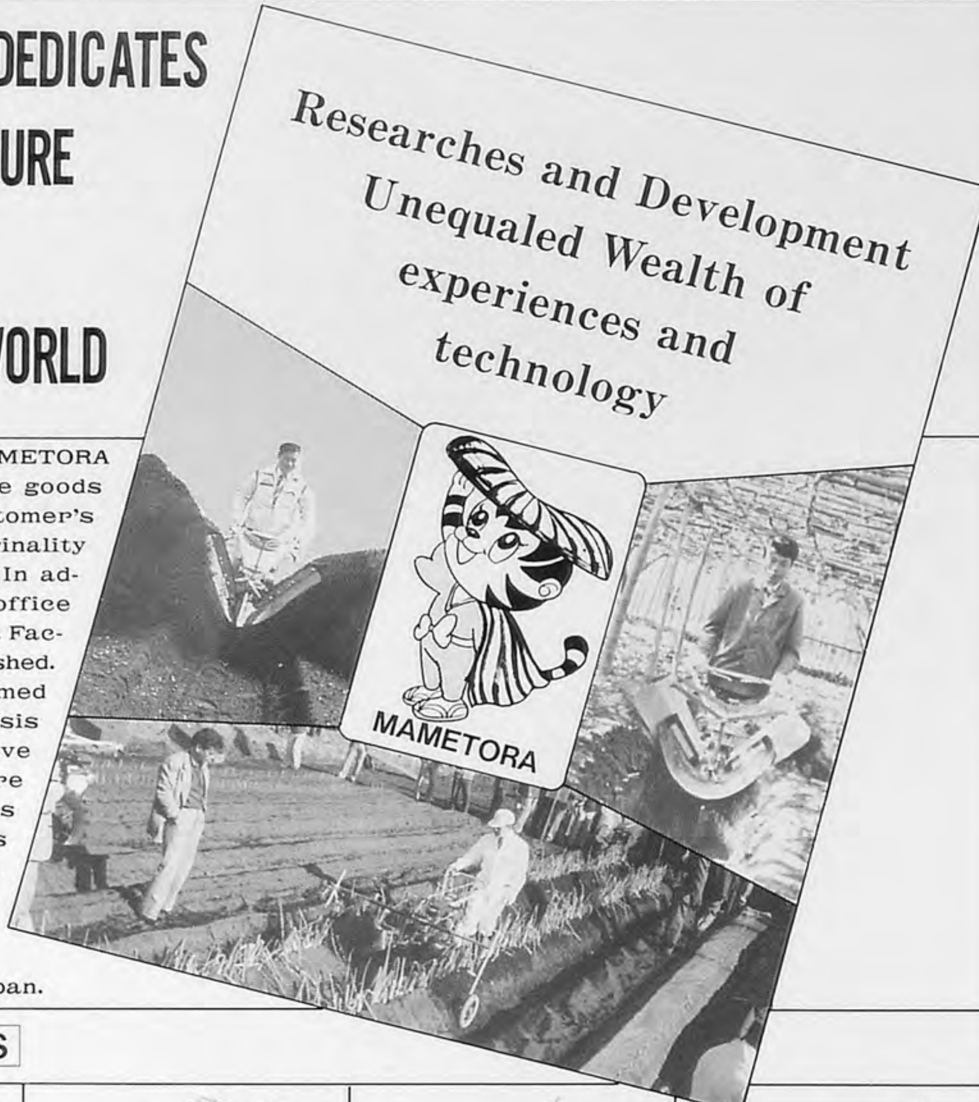


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This publication, published quarterly, has an objective to promote agricultural mechanization in developing countries. Its readers consist of so many people in various fields such as farmers, dealers, manufacturers, researchers, government officials, students, etc. not only in Asia but also in the whole world. To enrich contents and to reflect many opinions, we want contributors for **Agricultural Mechanization in Asia" Africa and Latin America**. Articles, comments, investigations, reports and so on will be received with open arms. If you hope to contribute, contact us without delay.

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YOSHISUKE KISHIDA

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## EDITORIAL

China, having the largest population in the world, has turned into the import country of main cereals since it banned the export of all cereals and other food. A research institution in the United States reported that the increase in world population last year was more than 100 million. If it goes on increasing at the present rate, the world population in 2015 is estimated to be 14 billion, 2.4 times as much as present population, the report says.

Problem of food and population increase has been a subject of discussion for a long time, and now it is actually creating the serious food shortage problem. This food situation had an effect on recent cereals price in Chicago market. The price of wheat, which has been under 4 dollars for many years, rose to 5 dollars or more per bushel. Corn price from 3 dollars to about 4 dollars per bushel. The world whole cereals consumption last year was 1 745 million ton, which exceeds its whole production 1 679 million ton. The stock is 230 million ton, 22% less than former year.

The increase in population is also creating environmental problems. Whether earth eco-system will be able to support increasing population in the future is going to be a matter of serious concern. Though China is adopting strict birth control policy, its population is estimated to be over 1.5 billion in 2025. India, the second largest population country in the world, has over 0.9 billion at present, and it is estimated to grow nearly 1.4 billion in 2025.

Under this circumstances, the disparity in wealth, in technology and in food distribution is more and more expanding. In view of these realities, the most important objectives assigned to us is to improve land productivity. In order to raise land productivity, with controlling the amount of fertilizers and chemicals, it is of primary importance to develop mechanization system which allows farmers to make timely operation.

It was twenty-five years ago, in spring 1970, that the first issue of AMA was published with the title of ''Agricultural Mechanization in Southeast Asia''. During these 25 years, the state of development in agricultural mechanization has been entirely different with countries. Hereafter we need to provide the full support for the countries with poor agricultural productivity. AMA continues to place special emphasis on the problem in such countries. Further support by AMA readers would be appreciated.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1996

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## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

**Vol. 27, No. 2, Spring 1996**

# Effect of Forward Speed and Rear Shield on the Performance of Rotary Tiller

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## Abstract

The experiment was carried out in order to study the effect of rear shield and forward speeds on the performance of a rotary tiller in sandy clay loam at soil moisture 16.26% and bulk density 1.433 g/cc at the Latif Experimental Farm, Sindh Agriculture University, Tandojam in 1993. The mounted rotary tiller (Howard rotovator) was tested at two positions of rear shield and three forward speeds. The travel reduction was mostly similar at both positions of the rear shield. It was found that by increasing the forward speed, the travel reduction increased negatively. The soil inversion of the rotary tiller was good. However, soil inversion was higher when the position of the rear shield was up and at higher forward speeds. The position of rear shield and forward speeds have affected the soil aggregation and soil pulverization. High percentage of small soil aggregates were produced at lower forward speed and down position of rear shield. The down position of the shield and lower speed produced a very fine seedbed.

## Introduction

Seedbed preparation in single pass and reduced draft are among the most frequently mentioned reasons for rotary tillage. By applying engine power to the soil through power take off rather than tractive force through tires, less power is lost and tractor weight and soil compaction are reduced.

Rotary tillers generally work on the horizontal shaft and less commonly on a vertical or series of vertical shafts. Rotary tillers powered by tractor take off are the most common types on the farms. The rotary tiller is used to prepare fine seedbed in single pass; replace the plow; disk and harrow; shred stalk and mix with the soil; cultivate row crops; renovate pasture; reclaim waste land; till orchards and vine yards and landscape and strip tilth while planting.

The blades on the rotor shaft are mounted with three right-hand and three left-hand blades per flange but coarser work may be accomplished by using only two right-hand and two left-hand blades per flange. High rotor speeds tend to give greater pulverization. The lower the tractor gear choosen the finer the tilth. The rear shield is also an important part of the rotary tiller, the height at which has a dramatic effect on the tilth. It should be set down for better pulverization or up for a cloddy tilth. It also acts as a levelling board on the soil and barrier against which clods are broken. The rotary tiller produces a fine seedbed up to a depth of 10 inches. The degree of soil break up depends on the ratio of rotor speed to forward speed, the magnitude of the speeds and shape and arrangement of the tines. The degree of soil pulverization is as great as that obtained by successive use of the moldboard plow, a disk harrow (twice over) and a spike tooth harrow. The rotary tiller is an excellent mixing device for distributing organic matter or other materials throughout the tilled soil but coverage is not as complete as with a moldboard plow. The surface trash is usually well cut up, with varying amounts left on the surface (Bainer et al. 1955).

Keeping in view the importance of a rotary tiller as once-over seedbed preparation tillage implement, it was decided to study the effect of forward speed and rear shield on the performance of the rotary tiller. The objectives of the study were to determine the effect of forward speed and rear shield on the performance parameters of a rotary tiller, and to recommend and suggest suitable speeds and positions of the rear shield for seedbed preparation.

## Procedures and Methods

The experiment was conducted in a rectangular plot measuring 250 m × 150 m. The performance parameters studied were travel reduction, soil inversion, soil aggregation and soil pulverization at two positions of the rear shield of the rotary tiller and three forward speeds.

All the parameters were measured and recorded according to the recommendations of ASAE Engineering Practice: (ASAE EP236; Regional Network of Agricultural Machinery Test Codes and Procedures for Farm Machinery, Technical Series No. 12, 1993; Bukhari et al. 1981 and 1990).

The instruments and machines used in the research were Ford 6610 diesel tractor, mounted rotary tiller (Howard rotavator), ranging poles, steel tapes, electronic stop watch, core soil sampler, soil sample containers, half meter square frame, set of sieves, dial balance, polythene bags, electronic oven, tool box, white chalks and camera.

The mounted regular and offset Howard rotary tiller has seven flanges. In two ends of the flanges, all six speed type blades were bolted in one direction only. However, on the other five flanges the blades were mounted with three right hand and three left hand blades per flange. The distance between flanges was 25 cm. The thickness (gauge) of blades was 6 mm. The rated width of rotary tiller (Howard rotavator) was 154 cm. The length of the adjustable rear shield was 159 cm and the width

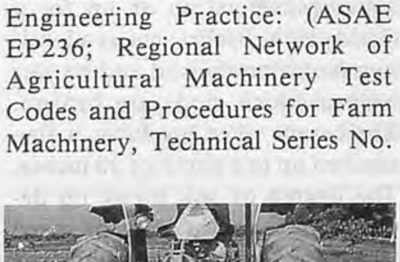

Fig. 1 Rear view of rotary tiller (Shield down).

Fig. 2 Rear view of rotary tiller (Shield up).

Fig. 4 Right side view of rotary tiller.

Fig. 3 Left side view of rotary tiller.

Fig. 5 Rotary tilller in operation (Shield up).

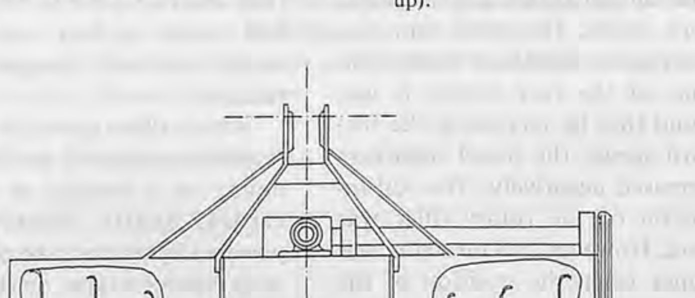

Fig. 6.1 Line diagram of rotary tiller.

Fig. 6.2 Side views of rotary tiller.

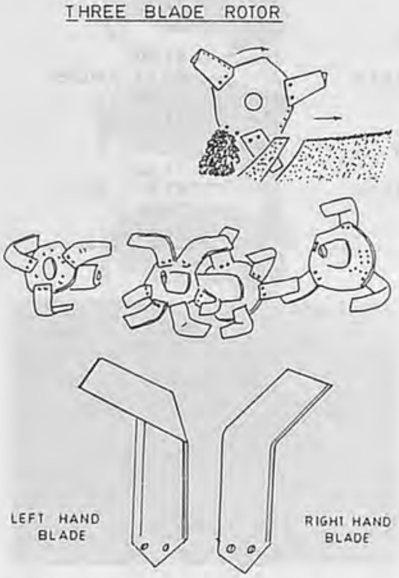


Fig. 6.3 Blades of rotary tiller.

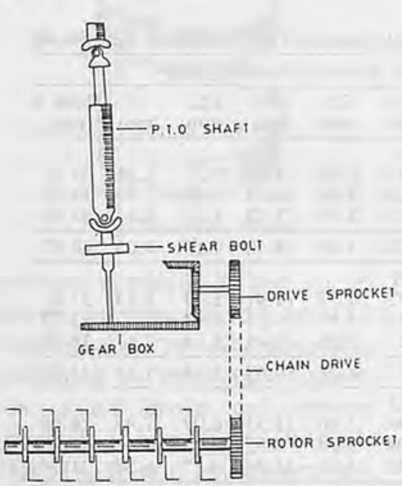


Fig. 6.4 Tiller drive mechanism.

was 54 cm. The diameter of rotor shaft was 76.6 mm. The rotary tiller was provided with shear pin for protection of the machine. The speed of the rotor shaft can be adjusted by the gear box of the machine. The depth shoe was present for adjustment of the depth of cut. The rotary tiller is shown in **Figs. 1** to **6**.

## Results and Discussion

Rotary tiller performance and operating accuracy differ considerably according to the type of blades, angle of blades, number of blades, position of shield, type of soil, soil moisture, weed infestation, speed of operation and depth of operation. The examination and measurements of the rotary tiller performance parameters were taken for field characteristics and rotary tiller performance.

### Field Characteristics

The observations and measurements of the rotary tiller performance at three forward speeds and two positions of rear shield were: general characteristics of experimental plot; detailed analysis of the soil; soil moisture content; and bulk density of the soil.

### Rotary Tiller Performance

The measurements taken to study the effect of forward speed and rear shield on the work quality produced by rotary tiller were: travel reduction; soil inversion; soil aggregation; and soil pulverization.

### Characteristics of the Experimental Field

The field characteristics of the experimental field were: soil type, sandy clay loam; pH value, 8.4; E C, 350 micro m hose/cm and 1.5 soil-water ratio; organic matter, 0.54%; soil moisture, 16.26%; soil bulk density, 1.433 g/cc; and soil temperature, 17.45°.

## Rotary Tiller Performance

Data were collected in order to determine the overall performance of a rotary tiller (Howard rotavator). The performance parameters taken into consideration were travel reduction; soil inversion; soil aggregation and soil pulverization. The performance parameters were measured and recorded according to the recommendations of RNAM (1983), Agricultural Engineer's Yearbook 1981-82, Bukhari et al. (1981 and 1990).

### Travel Reduction

The data on travel reduction of the rotary tiller are tabulated as shown in **Table 1** as follows: at forward speed-I and up position of rear shield, was travel reduction to −1.40%; at rear shield down and forward speed-I, −1.07%; at rear shield up and forward speed-II, −1.50%; at rear shield down and forward speed-II, −1.45%; at rear shield up and forward speed-III, −1.58%; and at rear shield down and forward speed-III, −1.52%. It was observed that the rotary tiller produced a nega-

**Table 1.** Travel Reduction at Different Forward Speeds and Positions of Rear Shield

| Observations numbers | Distance Travelled Without Load | Position of Rear Shield | | | | | |
|---|---|---|---|---|---|---|---|
| | | Up | | | Down | | |
| | | Distance travelled withload | Travel reduction | Mean travel reduction | Distance travelled withload | Travel reduction | Mean travel reduction |
| | m | m | % | % | m | % | % |
| Speed-I | | | | | | | |
| 1 | 45.29 | 45.90 | −1.35 | | 45.95 | −1.47 | |
| 2 | 45.23 | 46.10 | −1.92 | −1.40 | 45.52 | −0.65 | −1.07 |
| 3 | 45.25 | 45.67 | −0.93 | | 45.75 | −1.10 | |
| Speed-II | | | | | | | |
| 1 | 45.40 | 45.05 | −1.43 | | 46.06 | −1.45 | |
| 2 | 45.62 | 46.35 | −1.60 | −1.50 | 46.49 | −1.91 | −1.45 |
| 3 | 45.49 | 46.17 | −1.49 | | 45.95 | −1.01 | |
| Speed-III | | | | | | | |
| 1 | 45.20 | 45.98 | −1.72 | | 45.88 | −1.50 | |
| 2 | 45.62 | 46.57 | −2.08 | −1.58 | 46.35 | −1.59 | −1.52 |
| 3 | 45.48 | 45.92 | −0.96 | | 46.15 | −1.47 | |

tive travel reduction which improved the traction of the tractor and that by increasing the forward speed the travel reduction increased negatively. The travel reduction was mostly similar at both positions of the rear shield. However, there was a slight negative increase in travel reduction as speed was accelerated.

### Soil Inversion

**Table 2** shows the data relating to soil inversion at different forward speeds and positions of rear shield. The presence of weeds before rotary tiller operation is shown in **Fig. 7** and the after rotary tiller operation in **Fig. 8**. The mean soil inversion at speed-I and rear shield position up was 76.64%. The average soil inversion at speed-I and rear shield position down was 75.65%; at speed-II and rear shield position up, 81.18%. The mean soil inversion at speed-II and rear shield down was 80.89%.

The average soil inversion at speed-III and rear shield position up 85.75% and at speed-III and rear shield down, to 80.41%.

The crop residue, weeds and other materials were mostly covered and the seedbed was free of weeds.

**Table 2.** Soil Inversion at Different Speeds and Positions of Rear Shield

| Replications | No. of weeds before Operations | Position of Rear Shield: Up — No. of weeds on the tilled surface after operation | Up — Soil inversion % | Up — Mean soil inversion % | Down — No. of weeds on the tilled surface after operation | Down — Soil inversion % | Down — Mean soil inversion % |
|---|---|---|---|---|---|---|---|
| | | | Speed-I | | | | |
| 1 | 160 | 30 | 81.25 | | 32 | 80.00 | |
| 2 | 141 | 20 | 85.81 | 76.64 | 34 | 75.88 | 76.65 |
| 3 | 150 | 38 | 74.66 | | 39 | 74.60 | |
| 4 | 165 | 58 | 64.84 | | 45 | 71.72 | |
| | | | Speed-II | | | | |
| 1 | 160 | 22 | 86.25 | | 20 | 87.50 | |
| 2 | 141 | 30 | 78.72 | 81.18 | 27 | 80.85 | 80.89 |
| 3 | 150 | 24 | 84.00 | | 39 | 74.00 | |
| 4 | 165 | 40 | 75.75 | | 31 | 81.21 | |
| | | | Speed-III | | | | |
| 1 | 160 | 28 | 82.50 | | 40 | 75.00 | |
| 2 | 141 | 17 | 87.94 | 85.75 | 20 | 85.81 | 80.41 |
| 3 | 150 | 32 | 78.66 | | 36 | 76.00 | |
| 4 | 165 | 10 | 93.93 | | 25 | 84.84 | |

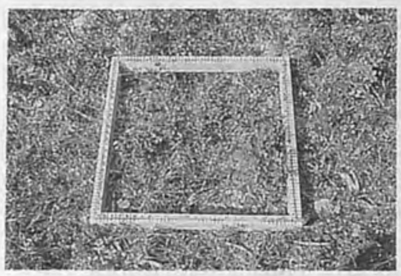

**Fig. 7** Experimental field before operation of rotary tiller.

**Fig. 8** Experimental field after operation of rotary tiller.

### Soil Aggregation

In evaluating the soil aggregation, one is interested in the size distribution, quantity and stability of the aggregates. Direct dry sieving of soils, as occurs in the field has been used to evaluate the distribution of clods and aggregates. The percentage of clods retained on the sieve is an appropriate measure of soil aggregation (Lambe 1951).

The data related to soil aggregation produced by rotary tiller at three speeds and up position of rear shield is shown in **Table 3** and the soil aggregation instruments are shown in **Fig. 9** and **Fig. 10**.

**Table 3.** Soil Aggregation Produced at Different Speeds and Up Position of Rear Shield

| Replications | 75 mm | 63 mm | 50 mm | 37.5 mm | 31.5 mm | 25 mm | 16 mm | 12.5 mm | 8 mm | Under 8 mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percentage of Clods Retained on Sieve Sizes | | | | | | | | | |
| | | | | Speed-I | | | | | | |
| 1 | 4.31 | 6.01 | 5.34 | 4.05 | 3.15 | 2.95 | 15.45 | 9.21 | 8.21 | 41.32 |
| 2 | 5.21 | 5.21 | 5.49 | 4.25 | 3.24 | 3.35 | 16.74 | 9.35 | 7.79 | 39.37 |
| 3 | 5.05 | 5.35 | 4.71 | 4.47 | 3.21 | 2.85 | 17.32 | 8.85 | 8.15 | 41.04 |
| Average | 4.85 | 5.52 | 5.18 | 4.25 | 3.20 | 3.05 | 16.50 | 9.13 | 8.05 | 40.57 |
| | | | | Speed-II | | | | | | |
| 1 | 8.59 | 9.82 | 7.23 | 8.14 | 4.75 | 4.52 | 11.91 | 5.43 | 8.14 | 31.47 |
| 2 | 8.57 | 9.62 | 8.28 | 5.07 | 5.30 | 4.64 | 9.55 | 5.97 | 6.37 | 53.72 |
| 3 | 9.51 | 10.35 | 6.56 | 7.83 | 3.51 | 3.95 | 10.45 | 5.84 | 7.47 | 34.53 |
| Average | 8.89 | 9.93 | 7.36 | 7.01 | 4.52 | 4.37 | 10.63 | 5.74 | 7.32 | 33.90 |
| | | | | Speed-III | | | | | | |
| 1 | 17.28 | 6.77 | 2.57 | 6.49 | 5.44 | 7.00 | 13.55 | 6.07 | 7.47 | 28.00 |
| 2 | 16.88 | 4.76 | 4.63 | 9.14 | 5.91 | 6.18 | 9.95 | 6.18 | 5.38 | 31.01 |
| 3 | 18.53 | 4.71 | 3.14 | 7.21 | 5.85 | 5.13 | 11.31 | 6.17 | 6.33 | 31.04 |
| Average | 17.56 | 5.41 | 3.44 | 7.61 | 5.73 | 6.10 | 11.60 | 6.14 | 6.39 | 30.01 |

It is evident from the data of clod percentage produced by rotary tiller that as the forward speed is increased the bigger clod percentage is also increased and smaller clod percentage decreased. The improved soil aggregation was obtained at lower speeds. The soil aggregation produced by the rotary tiller at rear shield up and

**Fig. 9** Soil aggregation instruments.

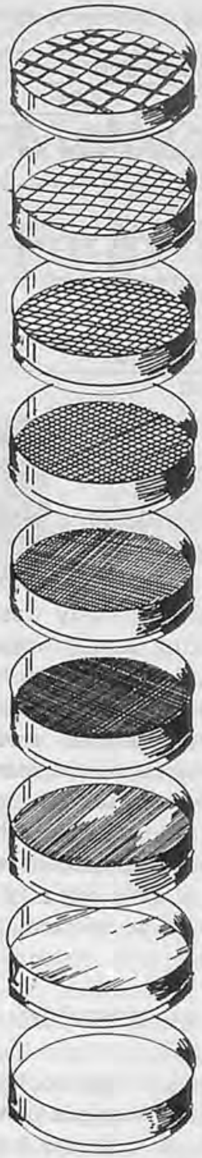

Fig. 10 Set of sieves.

**Fig. 11** Rotary tilled plot at speed-I and rear shield up.

**Fig. 12** Rotary tilled plot at speed-II and rear shield up.

**Fig. 13** Rotary tilled plot at speed-III and rear shield up.

**Fig. 14** Rotary tilled plot at speed-I and rear shield down.

**Fig. 15** Rotary tilled plot at speed-II and rear shield down.

**Fig. 16** Rotary tilled plot at speed-III and rear shield down.

forward speeds-I, II and III are shown in **Figs. 11, 12 and 13**, respectively. The soil aggregation produced by the rotary tiller at rear shield down and forward speeds-I, II and III are shown in **Figs. 14, 15 and 16**, respectively.

The soil aggregation produced by the rotary tiller at three forward speeds and down position of rear shield is given in **Table 4**. The data indicate that in these treatments the large soil aggregation were absent and all the soil aggregates fall in the sieve sizes from 25 mm and less than 8 mm which were considered to determine the soil pulverization. This means that the down position of the rear shield produced very fine soil aggregation. It is also clear from the data that as the forward speed was increased the bigger soil aggregates percentage was also increased and the smaller soil aggregate percentage decreased. It proved that at higher speed the coarser seedbed is prepared and at lower speed the finer seedbed was obtained. The average soil aggregation is shown in **Table 5** which compares the aggregation at two positions of the rear shield and three forward

**Table 4.** Soil Aggregation Produced by Rotary Tiller at Different Speeds and Down Position of Rear Shield

| Replications | Percentage of Clods Retained on Sieve Sizes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 75 mm | 63 mm | 50 mm | 37.5 mm | 31.5 mm | 25 mm | 16 mm | 12.5 mm | 8 mm | Under 8 mm |
| Speed-I | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 21.61 | 13.02 | 0.52 | 12.76 | 52.09 |
| 2 | 0 | 0 | 0 | 0 | 0 | 25.51 | 10.25 | 5.47 | 10.02 | 48.75 |
| 3 | 0 | 0 | 0 | 0 | 0 | 22.42 | 11.23 | 1.21 | 11.52 | 53.62 |
| Average | 0 | 0 | 0 | 0 | 0 | 23.18 | 11.50 | 2.40 | 11.43 | 51.48 |
| Speed-II | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 26.51 | 12.56 | 5.12 | 9.30 | 46.51 |
| 2 | 0 | 0 | 0 | 0 | 0 | 27.79 | 10.94 | 7.74 | 7.52 | 46.01 |
| 3 | 0 | 0 | 0 | 0 | 0 | 26.17 | 11.84 | 6.71 | 8.41 | 46.86 |
| Average | 0 | 0 | 0 | 0 | 0 | 26.82 | 11.78 | 6.52 | 8.41 | 46.86 |
| Speed-III | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 33.05 | 15.48 | 7.95 | 10.31 | 32.21 |
| 2 | 0 | 0 | 0 | 0 | 0 | 34.21 | 14.85 | 8.01 | 11.01 | 39.93 |
| 3 | 0 | 0 | 0 | 0 | 0 | 35.05 | 15.13 | 9.32 | 11.25 | 29.25 |
| Average | 0 | 0 | 0 | 0 | 0 | 34.10 | 15.15 | 8.42 | 10.85 | 33.79 |

**Table 5.** Soil Aggregation Produced at Different Speeds and Two Positions of Rear Shield

| Observations | Percentage of Clods Retained on Sieve Sizes | | | |
|---|---|---|---|---|
| | Rear shield position up | | Rear shield position down | |
| | Sieve sizes 75mm - 31.5mm | Sieve sizes 25mm & <8mm | Sieve sizes 75mm - 31.5mm | Sieve sizes 25mm & <8mm |
| | | Speed-I | | |
| 1 | 22.86 | 77.14 | 0 | 100 |
| 2 | 23.86 | 76.60 | 0 | 100 |
| 3 | 22.79 | 77.21 | 0 | 100 |
| Mean | 23.02 | 76.98 | 0 | 100 |
| | | Speed-II | | |
| 1 | 38.53 | 61.47 | 0 | 100 |
| 2 | 36.85 | 63.15 | 0 | 100 |
| 3 | 37.76 | 62.24 | 0 | 100 |
| Mean | 37.71 | 62.29 | 0 | 100 |
| | | Speed-III | | |
| 1 | 38.55 | 61.45 | 0 | 100 |
| 2 | 41.32 | 58.68 | 0 | 100 |
| 3 | 39.44 | 60.56 | 0 | 100 |
| Mean | 39.76 | 60.23 | 0 | 100 |

**Table 6.** Soil Pulverization Produced at Different Speeds and Rear Shield Position

| Repli-cation | Position of Rear Shield | | | |
|---|---|---|---|---|
| | Up | | Down | |
| | Soil pulverization % | Mean soil pulverization % | Soil pulverization % | Mean soil pulverization % |
| | | Speed-I | | |
| 1 | 77.14 | | 100 | |
| 2 | 76.60 | 77.32 | 100 | 100 |
| 3 | 78.21 | | 100 | |
| | | Speed-II | | |
| 1 | 61.47 | | 100 | |
| 2 | 62.25 | 61.99 | 100 | 100 |
| 3 | 62.24 | | 100 | |
| | | Speed-III | | |
| 1 | 61.00 | | 100 | |
| 2 | 60.28 | 60.50 | 100 | 100 |
| 3 | 60.24 | | 100 | |

speeds.

The soil pulverization data is presented in **Table 6**. All the three forward speeds and two positions of rear shield of rotary tiller produced a very fine seedbed. At forward speed-I and rear shield position up the soil pulverization was 77.33%. At speed-I and rear shield position down the soil pulverization was 100%. At speed-II and rear shield position up the soil pulverization was 61.99%. At speed-II and rear shield position down the soil pulverization was 100%. At speed-III and rear shield position up the soil pulverization was evaluated as 61.19%. At speed-III and rear shield position down the soil pulverization obtained was 100%.

When the rear shield of the rotary tiller was up, the coarser seedbed was obtained at higher speeds as compared to lower speeds. However, when the rear shield of the rotary tiller was down, the finer seedbed was obtained at all three speeds and the percentage of fine soil aggregates decreased as the speed was increased.

## Conclusion

1. Negative travel reduction was obtained in all treatments of the rotary tiller operations. There was a negative increase in travel reduction with accelerated forward speed and a negative decrease in travel reduction as the shield is lowered. This improved the traction of the tractor.

2. In the case of up position of rear shield, the soil inversion was increased as the speed was switched over from lower gear to higher gear speeds. In the case of down position of rear shield the soil inversion in speed-I decreased as compared to speed-II and III. This was due to the action of dragging of rear shield at higher speeds which have brought the buried weeds on the surface.

3. Different speeds and positions of the rear shield affected the soil aggregation. Higher percentage of small soil aggregates were obtained at lower forward speeds than higher forward speeds. Also, the down position of the rear shield has reduced large soil aggregates into small soil aggregates.

4. The position of the rear shield also effected the soil pulverization. The down position of rear shield of the rotary tiller highly pulverized the soil. The up position of the rear shield produced coarser seedbed as compared to the down position of rear shield. The lower speed produced a more pulverized seedbed than higher speed.

## Recommendations and Suggestions

The present study was aimed at evaluating the performance of a rotary tiller at different forward speeds and positions of rear shield. The lower forward speed and down position of the rear shield should be used for fine seedbed. However, for coarser seedbed, the higher forward speed and up position of rear shield of rotary tiller should be selected.

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# Maintenance Decisions for Farm Tractors in Allahabad District


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## Abstract

The present work finds the relationship of the maintenance cost with age, maintenance cost with repair rate and maintenance time with age and repair rate of International B-275, M.F.-1035, Escorts-335 and H.M.T. Zetor-2511 tractors.

The farmers from different villages of Allahabad district having the above tractors were visited and interviewed regarding maintenance cost, maintenance time and repair rate of the different age group of these tractors. All responses and other observations were recorded. The mathematical models for maintenance time with age and repair rate of the different makes of tractors were obtained through the use of multiple regression analysis programmed on SPSS/PC package of computer.

The maintenance cost was maximum for the International B-275, followed by M.F.-1035, Escorts-335 and H.M.T. Zetor-2511 tractors, respectively.


## Introduction

Most developing countries are primarily agrarian societies in which agriculture is the main source of wealth. Effective implementation and adaptation of technology to increase the output has often been the impetus to the more complex process of rural, social and economic development.

The tractor is the most important item of farm investment after the land. The use of tractors increases the productivity of labour, manures, fertilizers and irrigation. However, there is underutilization of tractors in agricultural operations in India. Further increase in agricultural production can be achieved through effective utilization of agricultural inputs. The effectiveness of the agricultural resources can be increased by using improved machineries and tractors efficiently.

The effectiveness of a tractor working system depends not only on the innate properties built into it, in the designing and production stages but also on the quality of its operation, maintenance and repair. The use of the model is to assist the farmers in decision making by using known facts more effectively, by enlarging the proportions of factual knowledge and by reducing the reliance on subjective judgement.

The cost of farm operations depends on several factors. Prominent among them are the initial costs, repair cost, operating cost and the total life of the tractors. One of the greatest challenges faced by the tractor owners is the growing need for more intelligent management of their tractors. This must be considered by analyzing the maintenance decisions. The main objectives of the present study were:

1. To establish a mathematical relationship between the maintenance cost and age of different models of tractors.
2. To establish a mathematical relationship between the maintenance cost and repair rate of different models of tractors.
3. To develop a mathematical model of maintenance time with age and repair rate of different models of tractors.

## Methodology

In order to conduct the study, a survey in the Allahabad district was undertaken. Geographical information of the area, type of soil and administrative division were collected with the help of geographical and political maps of the Allahabad district. For purposes of data collection, four commonly used models of the tractors were selected. They are, International B-275 (35 h.p.), Escorts-335 (35 h.p.), Massey Ferguson-1035 (35 h.p.) and H.M.T. Zetor-2511

Table 1. Repair Rate, Maintenance Time and Cost for Different Ages of International B-275 Tractor

| Age of tractor (years) | Repair rate, per 500 h. | Maintenance cost, Rs. | Maintenance time, h. |
|---|---|---|---|
| 1 | 0.85 | 2510 | 33 |
| 2 | 0.87 | 2770 | 38 |
| 3 | 0.98 | 3460 | 40 |
| 4 | 1.03 | 4550 | 49 |
| 5 | 1.06 | 5480 | 53 |
| 6 | 1.13 | 6110 | 65 |
| 7 | 1.25 | 7525 | 70 |
| 8 | 1.32 | 9245 | 89 |
| 9 | 1.41 | 10830 | 105 |
| 10 | 1.57 | 12550 | 125 |
| 11 | 1.71 | 15080 | 148 |

Table 2. Repair Rate, Maintenance Time and Cost for Different Ages of M.F.-1035 Tractor

| Age of tractor (years) | Repair rate, per 500 h. | Maintenance cost, Rs. | Maintenance time, h. |
|---|---|---|---|
| 1 | 0.85 | 2735 | 30 |
| 2 | 0.86 | 3285 | 35 |
| 3 | 0.95 | 3880 | 40 |
| 4 | 1.09 | 4510 | 48 |
| 5 | 1.18 | 5210 | 52 |
| 6 | 1.22 | 5915 | 62 |
| 7 | 1.31 | 7025 | 68 |
| 8 | 1.45 | 6325 | 85 |
| 9 | 1.50 | 10080 | 102 |
| 10 | 1.56 | 11125 | 120 |
| 11 | 1.68 | 13430 | 140 |

Table 3. Repair Rate, Maintenance Time and Cost for Different Ages of Escorts-335 Tractor

| Age of tractor (years) | Repair rate, per 500 h. | Maintenance cost, Rs. | Maintenance time, h. |
|---|---|---|---|
| 1 | 0.86 | 2380 | 28 |
| 2 | 0.87 | 2710 | 33 |
| 3 | 0.93 | 3275 | 37 |
| 4 | 1.05 | 3850 | 45 |
| 5 | 1.13 | 4800 | 50 |
| 6 | 1.19 | 5450 | 59 |
| 7 | 1.29 | 6300 | 65 |
| 8 | 1.40 | 7630 | 78 |
| 9 | 1.48 | 9080 | 95 |
| 10 | 1.51 | 10365 | 112 |
| 11 | 1.63 | 12150 | 125 |

Table 4. Repair Rate, Maintenance Time and Cost for Different Ages of H.M.T. Zetor-2511 Tractor

| Age of tractor (years) | Repair rate, per 500 h. | Maintenance cost, Rs. | Maintenance time, h. |
|---|---|---|---|
| 1 | 0.86 | 2143 | 24 |
| 2 | 0.86 | 2250 | 30 |
| 3 | 0.93 | 2734 | 32 |
| 4 | 1.00 | 2890 | 40 |
| 5 | 1.10 | 3410 | 43 |
| 6 | 1.14 | 3731 | 45 |
| 7 | 1.27 | 4765 | 57 |
| 8 | 1.35 | 6135 | 64 |
| 9 | 1.42 | 7400 | 81 |
| 10 | 1.50 | 8475 | 90 |
| 11 | 1.60 | 10585 | 95 |

(25 h.p.).

The individual farmers in Allahabad district owning the above mentioned models of tractors were contacted and interviewed. The authorized agencies and workshops of the tractors situated in Allahabad city were also contacted and interviewed using structured questionnaire.

A minimum of three tractors of each age group ranging from one to 11 years of age of each model were selected. The observations about the four selected models of tractors for a period of one year were recorded. The details of the age of the tractors, cost of repairing/replacement of the parts/system, Rs., cost of labour for repair/replacement, Rs., number of repairs, annual use, h, and total time taken in maintenance, h were collected. The details for each tractor are given in the **Tables 1** to 4.

Graphs were plotted to show the nature of relationship between the maintenance cost and age of tractors, maintenance cost and repair rate of tractors, maintenance cost was taken as dependent variable and age and repair rate as independent variable. The Lagrangian Method of Interpolation was used to develop the mathematical relationship. To develop the multiple regression model for maintenance time of different models of tractors, the multiple regression analysis was done. The maintenance time was taken as dependent variable and age and repair rate as independent variables.

## Results and Discussion

### Multiple Regression Model

The estimated multiple regression model for maintenance time with respect to age and repair rate for different models of tractors are as follows:

1) International B-275

$Y = -0.0851 + 12.8441X_1 + 1.7881X_2$

Where

$Y$ = maintenance time, h

$X_1$ = the age of tractor, years

$X_2$ = the repair rate of tractor, per 500 h

$R_{y.12}$ = 0.99

$F$ = 247.92

$F_{(2,8)}$ at 5% = 4.46

It is evident from the ANOVA table that the calculated vaue of F due to regression is more than the table value at 5% probability and 2 and 8 degrees of freedom, so the null hypothesis is rejected. Therefore, there is significant contribution of the variables and the dependent and independent variables are highly positively correlated.

II) Massey Ferguson-1035

$Y = -0.7424 + 9.6250X_1 + 0.1135X_2$

$R_{y.12}$ = 0.96

$F$ = 56.42

$F_{(2,8)}$ at 5% = 4.46

Hence the null hypothesis is rejected at 5% level of significance. There is significant contribution of age and repair rate on maintenance time and the dependent and independent variables are highly positively correlated.

III) Escorts-335

$Y = -0.8983 + 7.2015X_1 + 0.5424X_2$

$R_{y.12}$ = 0.97

$F$ = 74.71

$F_{(2,8)}$ at 5% = 4.46

Hence, the null hypothesis is rejected at 5% level of significance. There is significant contribution of age and repair rate on maintenance time and the variables are highly positively correlated.

IV) H.M.T. Zetor-2511

$Y = -2.8464 + 3.4088X_1 + 0.9872X_2$

$R_{y.12}$ = 0.98

$F$ = 113.99

$F_{(2,8)}$ at 5% = 4.46

Hence, the null hypothesis is rejected at 5% level of significance. There is significant contribution of age and repair rate on maintenance time and the variables are highly positively correlated.

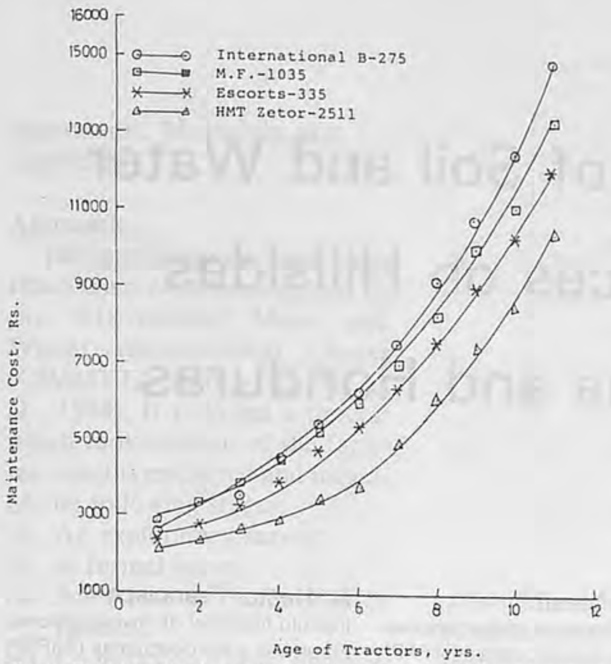

Fig. 1 Relationship between the maintenance cost and age of tractors.

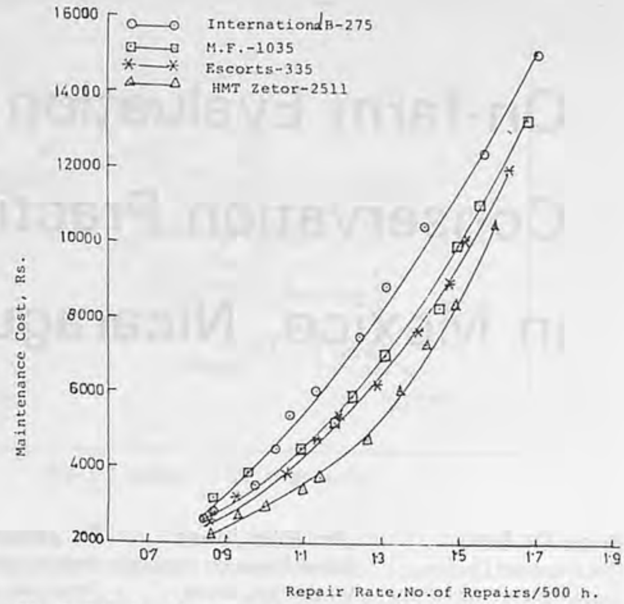

Fig. 2 Relationship between the maintenance cost and repair rate of tractors.

**Mathematical Models of Maintenance Cost with Age**

The estimated mathematical models for maintenance cost and age for the four selected tractor models are as follows:

i) International B-275:

$$Y = 0.5853X^4 - 7.4305X^3 + 88.812X^2 + 295.533X + 2222.4993$$

Where

Y = Maintenance cost of tractor, Rs.

X = age of tractor, years

ii) M.F.-1035:

$$Y = -0.3226X^4 + 11.8403X^3 - 55.4518X^2 + 622.6845X + 2221.25$$

iii) Escorts-335:

$$Y = 0.4712X^4 - 8.7152X^3 + 110.66X^2 + 106.3356X + 2141.25$$

iv) H.M.T. Zetor-2511

$$Y = 0.4909X^4 - 6.3541X^3 + 99.6876X^2 - 190.07X + 2246.25$$

The maintenance cost of the different tractors have been plotted against age as shown in **Fig. 1**. The plots for four makes of tractors under study show the exponential rise in maintenance cost with age. A comparative study of the graphs reveals that the cost of maintenance for International B-275 tractor is highest and lowest for the HMT Zetor-2511. The cost of maintenance for M.F.-1035 and Escorts-335 lies in between. The cost of maintenance of Escorts-335 is lower than M.F.-1035 tractor. The maintenance cost of HMT Zetor-2511 is lowest because this is of smaller size (25 h.p.) among all the four selected tractor models.

**Mathematical Models of Maintenance Cost with Repair Rate**

The mathematical models of maintenance cost with repair rate for different tractors was obtained using Lagrangian's method of Interpolation. The models for different tractors are as follows:

i) International B-275

$$Y = -14114.71X^3 + 55499.61X^2 - 55871.33X + 18085.17$$

ii) M.F.-1035

$$Y = 17212.82X^3 - 52819.09X^2 + 59684.29X - 22218.92$$

iii) Escorts-335

$$Y = 20167.94X^3 - 65556.45X^2 + 79748.99X - 29610.01$$

iv) H.M.T. Zetor-2511

$$Y = 8753.59X^3 - 20315.48X^2 + 20085.61X - 5566.05$$

The maintenance cost of different tractors have been plotted against repair rate as shown in the **Fig. 2**. It is evident from the plot that as the repair rate increases the maintenance cost increases.

## Conclusion

The effect of age and repair rate on the maintenance time was found to be significant. The maintenance cost of International B-275, M.F.-1035, Escorts-335 and H.M.T. Zetor-2511 tractors has been plotted against age and repair rate. The maintenance cost increases with age and repair rate and the relationship is exponential. The maintenance cost is maximum in the case of International B-275 tractor, minimum in case of H.M.T. Zetor 2511 tractor and lies in between the two for M.F.-1035 and Escorts-335 tractor. The maintenance cost for Escorts-335 is lower than M.F.-1035 tractor. ■■

# On-farm Evaluation of Soil and Water Conservation Practices on Hillsides in Mexico, Nicaragua and Honduras

by

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## Abstract

The paper describes a three-year collaborative project involving small-farm technology oriented research groups in Mexico, Nicaragua and Honduras. The project focused on hill-farming communities in the three countries from 1990 to 1993 and followed a methodical process approach, starting with exploratory surveys involving informal farmer interviews and collection of secondary information. Subsequent stages included: hypothesis formulation; formal surveys; selection of representative collaborating farmers; technology selection and on-farm evaluation.

An analysis of the farming systems identified soil and water conservation as an important technical concern amongst farmers. A major constraint experienced by all the farmers was scarcity of capital and also of labour at critical times of the year. Therefore, in the process of the selection of technologies to alleviate the technical problems, due attention had to be given to reducing the requirements for these two production factors to a minimum. To enhance the probability of successful adoption, techniques adopted by farmers in other parts of the world were assessed and discussed as options before resorting to technology development.

The principal successful technologies assessed were: live contour-barriers (of vetiver grass [*Vetiveria zizanioides*]; *Gliricidia sepium*; pigeon pea [*Cajanus cajan*]; *Pennisetum* spp. grasses); leguminous cover cropping with velvet bean (*Mucuna* spp); single equine-powered chisel-plough. All were subjected to on-farm technical and economic evaluation with the full participation of collaborating farmers.

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## Introduction

In the past, agricultural engineering research into developing country small-farm technology problems has frequently been undertaken by engineers without taking into account the multi-faceted nature of the farming systems being considered. In an attempt to redress this omission, a three-year collaborative project involving small-farm technology oriented research groups in Mexico, Nicaragua and Honduras worked with hill-farming communities in each of the three countries from 1990 to 1993. The participating groups were: The National Forestry and Agricultural Research Institute (*Instituto Nacional de Investigaciones Forestales y Agropecuarias* - INIFAP, Mexico); The National Agrarian Reform Institute (*Instituto Nacional de Reforma Agraria* - INRA, Nicaragua); The Adaptation and Development Unit (UDA) of the Ministry of Natural Resources (*Secretaria de Recursos Naturales* - SRN, Honduras).

The principal goal of the project was: to improve the productivity and net income of small hillside farmers. The specific purposes of the research were:

- To develop farmer-adoptable soil and water conservation techniques.
- To improve the productivity of the available power sources (mainly human and animal).
- To assess the social and economic impacts of the proposed innovations.

## Approach, Materials and Methods

### Approach

The methodology used benefitted from experience gained by the International Maize and Wheat Improvement Center (CIMMYT), Mexico (Byerlee, et al., 1988). It followed a process which took account of the farming systems employed and included the following stages:

i) An exploratory survey;
ii) A formal survey;
iii) Selection of collaborator farmers;
iv) Collection of farm management date from collaborator farmers;
v) Selection of technologies for evaluation;
vi) On-farm technology evaluation; and
vii) Formulation of farmer recommendations.

This logical approach to research into engineering aspects of small farming systems was adopted to improve on the tradition of fabricating hardware without taking the farming systems implications into consideration.

The paper does not attempt to present all the activities and results of the project, but highlights the most important practices that emerged.

### Materials and Methods

The hill areas studied were: Los Tuxtlas, Mexico; Carazo, Nicaragua; and El Rosario, Honduras **(Fig. 1)**. All are areas characterized by subsistence hill-farming where soil and water conservation is needed to maintain crop yields.

Following the exploratory surveys and revision of secondary source material, the formal surveys were applied (numbers of farmers interviewed in each country were between 50 and 90). The constraints identified led to the pre-selection of possible technical engineering solutions which were analyzed by researchers and farmers and subjected to on-farm evaluation on an average of five farms in each country (actual numbers varied as some collaborators dropped out of the project whilst others asked to join during the course of the on-farm evaluation).


**Fig. 1** Location of hill areas studied.

Technical and economic evaluation has allowed tentative farmer recommendations to be made. Technical appraisal involved the use of elements of farm machinery test procedures (Smith, et al., 1994) and required the development of a method for estimating erosion and productivity loss (see following section), whilst economic performance was quantified by the use of whole farm budgets; enterprise gross margins; cash flows; and labour profiles.

## Results and Discussion

### Surveys

The exploratory and formal surveys yielded information on the environmental, social and economic characteristics of the farming areas, together with the farming systems practised and constraints to production and the adoption of innovations.

The climates range from tropical sub-humid to humid with two well defined seasons: the wet season from May/June to October followed by the dry season. The total annual rainfall is in the range of 1 000-1 500 mm and there are two distinct cropping periods when the two basic grain crops of maize and beans are grown by virtually all farmers. All areas are characterized by steeply-sloping land (up to 35 degrees) susceptible to erosion. Average farm size is between five and eight hectares but the proportion of farms under 3.5 ha is high.

Human, animal and engine power sources are used in the regions, with the first two categories being the most important. **Table 1** lists the main technologies used.

Farmer awareness of the need for soil and water conservation measures was variable across the countries although a common observtion was that 'worn out' land had to be rested to allow it to recuperate. Farmers tend to regard soil erosion as a more serious problem in the area generally, rather than on their own farms.

In Honduras NGOs (non-governmental organizations) and government funded projects are encouraging the use of a number of conservation practices which require only family labour with little or no capital input. They include: contour ditches and live

**Table 1.** Tools, Equipment and Animals Available to Hillside Farmers

| Technology | Honduras | Nicaragua | Mexico |
|---|---|---|---|
| Hand tools | *Azadón*; *piocha*; *cuma*; *machete*; *chuzo*; axe; spade; crow-bar | *Azadón*; *espeque*; *piocha*; *machete*; *chuzo*; axe; spade; crow-bar | *Machete*; *espeque*; *guataca*; *tarpala*; axe; spade; post-hole digger |
| Sprayers | 10-15 litre back-pack | Back pack: 15 litre manual; motorized for coffee | 10-15 litre back-pack |
| Draft animals and implements | Oxen (1% of farmers); wooden ard plough | Oxen with ard plough | Oxen with mould-board plough. Horses with cultivator |
| Tractors | Not used | May be used on larger farms for primary tillage | Used by 10% of hill-farms for primary tillage |
| Crop storage | 200 litre drums; wooden cribs | Grain in 200 litre drums | Heaps on farm house floor, sacks or 1 tonne capacity galvanized silos |
| Crop threshing and processing | Beans and maize by flailing. Coffee pulped by motor-driven pulper. Sugar milled by animal or engine-driven extractor | Beans, rice and sorghum flailed. Maize shelled with a rubbing board | Maize shelled with rubbing board or motorized sheller. Communal mills for tortilla dough |
| Transport | Ox carts. Equines for pack | Ox carts. Equines for pack transport | Ox-carts are rare. Equines for pack transport |
| Irrigation | Hose pipe from ephemeral streams | None found | None |

Note: • An *azadón* or *guataca* is a long-handled, wide (up to 25 cm) bladed-hoe with the blade at 90° to the handle.
• A *piocha* is a pick with two blades, a short pick point for clod breaking and a hoe-blade about 18 cm wide.
• A *cuma* is a short curved billhook with both edges sharp.
• A *chuzo, espeque* or *coa* is a planting-stick with a metal blade.
• A *tarpala* is a long-handled, flat-bladed hoe.
• An *ard* plough is a traditional wooden-framed implement with a straight metal share-point.

barriers, contour planting; cover crops; and reduced tillage. However, despite sustained extension efforts, farmer adoption has not been as widespread as hoped.

In the Nicaraguan and Mexican Project areas little work of this type had been carried out at the time of the exploratory survey. In Nicaraguan one NGO was promoting similar conservation techniques to the Honduran ones, whilst in Mexico only the Project collaborators had been researching the use of live contour barriers.

**Constraints Identified**

The major constraints to increasing productivity are similar in all three countries and include:

*Land shortage* — There is a severe shortage due to small farmers being forced into marginal areas and exacerbated by population growth of over 2%/year, soil degradation and insecurity of tenure.

*Soil erosion* — Increasingly intensive use of steep slopes for crop production coupled with deforestation has led to severe and continuing erosion which in turn leads to decreasing land productivity.

*Labour* — There are labour shortages at peak times (especially land preparation and weeding).

*Capital* — Credit interest rates are high and falling real returns make capital a scarce resource.

*Farm Power* — In Honduras human power is most widely used as the terrain is not suitable for conventional ox-powered tillage. In Mexico and Nicaragua most farmers have access to draft oxen with power shortages being experienced only on the smallest farms.

*Available technology* — In all countries there is a lack of appropriate technologies for resource poor farmers. The technologies used for land preparation are little changed since the Spanish Conquest and have, usually, been designed for flat lands. Implements to facilitate adoption of soil and water conservation measures are not available.

*Water* — Dry-season irrigation is not generally possible with current water supplies. Water for both irrigation and drinking is scarce and expensive.

*Extension* — State extension services are severely constrained. NGOs are having the greatest impact, but only in the limited areas in which they operate.

*Infrastructure* — Roads are very poor in more remote areas. Often only animal and human powered transport is possible.

*Soil and water conservation technologies* — Given the importance that farmers attach to soil and water conservation, the remainder of the paper concentrates on a description and analysis of those practices selected for on-farm evaluation.

## Animal Draft Chisel Plough (Honduras)

**Technical Specifications**

The chisel-plough developed in Honduras is designed to be pulled by a single equine (horse or mule) for contour-strip tillage on hillsides. The use of oxen on steep slopes (over 20 degrees or 36%) is not favoured by farmers because of the difficulty in controlling the paired animals. In addition, many hillside farmers do not own or have access to draft oxen but do usually have a horse or mule for riding and as a pack animal.

Hillside tillage in Honduras is most commonly done by hand using a *piocha* and the recommendation only to till contour-strips is being promoted by several rural development agencies (e.g., World Neighbors and SRN). Weeds between the contour-strips can be controlled either by machete or herbicide using a back-pack sprayer. The use of available, but under-used, equine power for

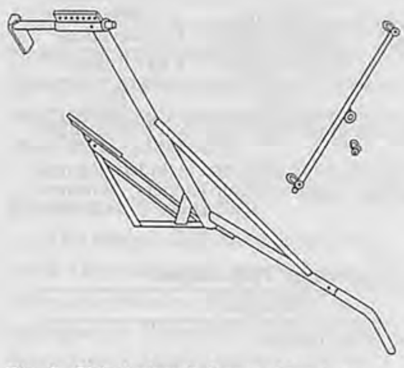

Fig. 2 Chisel-plough frame, Honduras.

contour-strip tillage is an attractive proposition for many hillside farmers.

An early prototype of the implement was subjected to technical evaluation at Cranfield Institute of Technology, UK (Douthwaite, 1989) and the version now in limited commercial production in Honduras has been developed from this work.

The chisel-plough (**Fig. 2**) is a simple implement consisting of a tubular main-frame carrying a bracket to which the share is bolted; an adjustable handle; the hake-plate for swingle-tree attachment and an adjustable depth-control skid. UDA has produced a construction manual (Santos and Meza, 1991) which gives details of dimensions and materials and Williams (1992) has reported on field trials and its economic evaluation.

The steel used in the construction of the plough is locally available on the Honduran market and the cut, bend and weld techniques used are all to be found in local workshops. Detail of the main components can be seen in **Fig. 2**, the length of the implement (excluding the handle) is 164 cm and weighs 17.3 kg.

**Field Performance**

The time to plough a hectare depends on the inter-furrow distance and on other factors including: the depth of work; texture, moisture content and specific resistance of the soil; condition, breed and weight of the draft animal and forward speed. Trials on collaborating farms reported by Williams (1992) and Williams et al, (1991) indicate an effective field capacity of 0.08 $ha.h^{-1}$ (12.5 $h.ha^{-1}$) at an inter-furrow spacing of 60 cm. This compares with 80 man-hours to do the job by hand. At a working depth of 11 cm the draft force was about 450 N which, at a forward speed of 0.8 $m.s^{-1}$, gives a power requirement of some 360 W which is within the capability of a healthy horse or mule.

**Economic Evaluation**

An evaluation based on partial budget analysis and discounting future cash flows compared the additional costs and benefits incurred when a hillside-plough replaces manual cultivation on an average-sized small-farm-producing 1.75 ha of summer maize and 1.75 ha of winter beans.

On the basis that the plough costs US$72 and is used for 50 h/year over a life-span of six years, annual benefits exceed annual costs by US$25. When the annual costs and benefits are discounted at 25% the net present value of future cash flows is US$18, with an internal rate of return (IRR) of 47% and Benefit: Cost Ratio of 1.48. On this basis, the plough is considered marginally viable for small farmers who are anxious to avoid risk.

Sensitivity analysis showed that, as the area cultivated decreases the plough becomes less economically attractive. If, however, the present price of labour were to increase from the present US$1.50/day, viability improves and at US$3/day it is very attractive.

## Contour Live Hedges and Leguminous Cover Crops

The development of leguminous contour hedges for soil and water conservation owes much to work done on alley cropping (of annual crops between perennial leguminous trees), a technique which has been developed, for example, in Central America (Kass, 1992a and b), Africa (IITA, 1985) and Asia (Wijewardene and Waidyanatha, 1984; Fujisaka, 1993). However, the practice has only recently become known to farmers in the areas covered by the present project.

The primary aim of contour live barriers is to retain soil taht moves down hill as a result of erosion and allow it to build up above the barriers and slowly form broad based bench terraces (Shaxson et al., 1989). Apart from the positive effects of reducing soil erosion and thereby improving soil moisture conservation, there are other advantages associated with this technology. Some of the more important ones are: reduction in the need for fertilizers due to the nutrients returned to the cropped area through the pruned foliage, the provision of animal fodder and, perhaps, fuel and building wood (**Table 3**). Quantification of these benefits is complicated and has not been attempted for this analysis.

The species selected for live barriers in the three countires differed according to availability and acquired experience. In Mexico, the leguminous tree, *Gliricidia sepium*, was selected, it is indigenous to the area, easy to establish, grows rapidly, has a deep root system and a high capacity for regrowth after pruning (Francisco, et al., 1992).

In Nicaragua, pigeon pea (*Cajanus cajan*) was available (**Fig. 3**). It is a prolific seed producer so farmers adopting the

Fig. 3 Field of pigeon pea, Nicaragua.

Fig. 4 Vetiver barrier established by a project farmer, Honduras.

Fig. 5 Legume field, Mexico.

**Table 2.** Summary of Results of Soil Productivity Loss and Degree of Erosion with and without Conservation on Four Collaborating Farms, Los Tuxtlas, Mexico.

| Soil Erosion Class, % Area in Each Class[1] | | | | Soil Productivity Loss, % | Soil Loss (USLE) | |
|---|---|---|---|---|---|---|
| | | | | | Without Conservation | With Conservation[2] |
| A | A/B | B/C | C | | t.ha$^{-1}$.year$^{-1}$ | t.ha$^{-1}$.year$^{-1}$ |
| 10 | 20 | 35 | 35 | 45 | 269 | 27 |

1. The FAO-UNESCO erosion classes refer to percentage loss of top soil ('A' is slight 'C' is extreme).
2. The conservation measures varied with the experimental plots and included: legume cover crops; zero-tillage; live contour-barriers; stone contour-barriers; contour-planting.

**Table 3.** Costs and Benefits Associated with Conservation Technologies

| Costs | benefits |
|---|---|
| Capital costs | Increased gross margins |
| Labour | or |
| - Family | Avoidance of gross margin decreases |
| - Hired | |
| Seed | Cost savings in reduced storm damage** |
| Fertilizer | |
| Chemicals | |
| Draft animals | (Legume) seed yield for human or livestock consumption** |
| Opewrational or Maintenance costs | Additional forage available** |
| Gross margin on land lost | Additional fuel/building materials** |
| Possible costs of controlling pests and weeds resulting from introduction of the technology** | Reduction in fertilizer required** |

plant for barriers not only produce their own seed but also provide it for other farmers wishing to start.

In Honduras two grasses, vetiver and king grass (*Pennisetum* spp) were used alone and in association with *Gliricidia*. Vetiver (**Fig. 4**) was unknown in the area at the start of the Project, although *Pennisetum* spp. barriers had been promoted in the past by NGOs and had been adopted by some farmers in the region.

The use of leguminous cover crop-maize associations by hillside farmers in Mexico and Central America has been practised for at least the last 40 years (Buckles, 1993 and 1994). The practice consists of producing a vegetative soil cover with sown legumes in order to protect the soil against erosion, control weeds, to conserve water and to provide a source of soil nutrients and organic matter (**Fig. 5**). The two species which have shown most promise in Mexico are: jack bean, *Canavalia* and velvet bean, *Mucuna* (Francisco et al., 1992), *Mucuna* was also evaluated in Nicaragua.

**Technical Evaluation**

In order to understand better the severity of the erosion problem on hillside farms, and so attempt to quantify the effects of the conservation measures, a method for estimating the degree of erosion and loss of productivity was developed (Uresti, et al., 1992). The method was developed in order to obtain an idea of the magnitude of loss of soil and productivity. It has been pointed out (Norman Hudson, personal communication) that the use of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) may not be apt under the conditions encountered, although the conclusions drawn are broadly correct.

The degree of erosion was estimated by field measurement of top-soil depth which was then compared with the un-eroded reference depth. The field data were interpreted according to the FAO-UNESCO classification of erosion and subsequently an estimate of productivity loss was made using information from the US Department of Agriculture (USDA) Soil Conservation Service (SCS) as outlined by Vásquez (1986).

In order to compare and corroborate the results obtained by the field sampling method, the USLE was used to estimate the soil loss (ton.h$^{-1}$.yr$^{-1}$) over the average of 30 years of traditional soil cultivation practices. An estimate used by the USDA SCS (cited by Vásquez, 1986) of a 15% fall in productivity for a loss of 5.08 cm (2″) of topsoil has been used. A summary of the results is given in **Table 2**.

It can be seen that there is severe erosion which has resulted in loss of soil productivity. This is borne out by farmer interviews when complaints of poor and falling yields, the need for increasisng fertilizer does the 'growth' of rocks in the fields are common. Annual soil losses calculated by the USLE far exceed the arbitary 'acceptable' level of 12 t/ha/year (chosen by the

USDA SCS). It can be concluded that soil and water conservation practices are needed to reduce the continuing soil loss and reduce the loss of productivity.

**Economic Evaluation**

The major difficulty associated with the economic evaluation of soil and water conservation technologies is the collection of data over their (usually rather long) life. The principal costs and benefits considered are shown in **Table 3**.

Quantification of some of the parameters was not a simple task and some (those marked**) could not have a value ascribed to them in the short duration of this Project. The costs of establishment can be recorded, but the annual maintenance costs have to be estimated, as does the life-span of the barriers.

Quantifying the benefit of increases, or reducing decreases, in soil productivity is crucial in the assessment of the adoptability of conservation technologies. **Figure 6** shows the trends of annual loss of soil productivity with and without barriers on different slopes. Topsoil loss was calculated usig the USLE, although it is recognized that field measurements over the life of the barriers would be preferable.

Internal rates of return were calculated for the conservation technologies in each country and the results were subjected to sensitivity analyses to ascertain the effects of possible changes in key parameters (for example: productivity, prices of inputs, labour, products, and maintenance costs).

In Honduras conservation techniques using live barriers show the greatest economic return. *Gliricidia sepium* is most attractive because of low establishment and maintenance costs.

In Mexico, legume cover crops out-performed other technologies. This was despite the additional labour required for slashing prior to main crop planting or harvesting.

In Nicaragua the poor performance of all crops was such that unless agriculture becomes profitable (through crop diversification, price increases or reduced input costs) no conservation technology will be economically attractive and soil erosion is likely to continue leading to abandonment of cropped land and further deforestation.

## Discussion and Conclusions

The process approach used in the development of the Project has been relevant and revealing. The exploratory survey component is essential to providing a thorough understanding of the farming systems, constraints and opportunities against which innovations can be evaluated. Formal surveys can be a complementary component but are expensive and intimidating to farmers.

It is our view that when an exploratory survey is carried out by experienced people, the need for a formal survey will be reduced. With active participation of local farmers, leaders, extension and research workers, with time spent on a daily basis reviewing past discussions, establishing missing information with a view to modifying future deliberations, an exploratory survey will provide more valuable information than a formal survey. Certainly if good secondary information is available, a formal survey need not be undertaken.

*Hillside chisel-plough* — The hillside-plough is technically sound and economically viable for contour-strip tillage on hillsides, when used to replace hand operations on typically small-sized farm with approximately 3.5 ha of annual crops. Viability improves

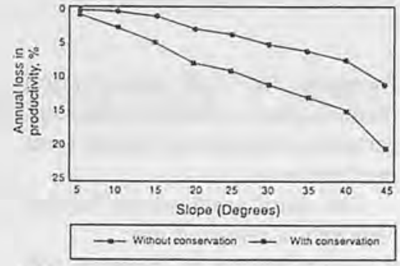


Fig. 6 Decreasing productivity with and without conservation technology for different slopes, Mexico.

when larger areas are cultivated and the price of labour is greater than US$1.50/day. On smaller areas and with lower labour costs, it is not a viable proposition.

An ergonomics evaluation of the plough compared with the traditional manual tillage systems may indicate further advantages to adoption.

*Soil conservation technologies* — Those technologies having low costs in terms of cash outlay and labour input provide the greatest economic returns. In Honduras live barriers of *Gliricidia* provided the greatest return, followed by *Gliricidia* planted with either vetiver or *Pennisetum*.

In Mexico, legume cover crops out-performed *Giricidia* whose relatively poor performance can be attributed to the high initial establishment costs (especially high labour costs for seed collection). If these were reduced the economic performance would improve substantially.

In Nicaragua, the disastrous performance of all crops was such that unless agriculture becomes profitable, no conservation technology will be economically attractive and soil erosion and deforestation is likely to continue.

*Further research work is required* — This three-year project was sufficient to establish the fact that decreasing yields as a result of declining soil fertility and soil loss is a priority concern amongst small hillside farmers in the region. Although some indication of the technical and economic performance of soil conservation technologies could be made, uncertainty exists about longer term performance.

The main areas where further research is required are:

- Determination of rates of soil loss with and without the conservation technologies and changes in soil moisture accumulation, soil fertility and organic matter influence productivity.
- Establishment of management techniques to ensure long term sustainability. This includes: selection of barrier plant species and populations; fertilization and prunning practices; factors affecting barrier health and longevity.
- Assessment of the impact on pest incidence of soil and water conservation practices.
- Continued monitoring of collaborator farms to determine the socio-economic conditions affecting the adoption of conservation technologies.

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# Development of a Direct Planter for Corn and Faba Beans

by
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## Abstract

The development and performance of a single-row direct planter especially designed for corn and faba beans is presented. The main concern of the development was to apply the proper metering principle to insure reduced damage of the large bean seeds. The planter is modular and may be attached to walking and riding tractors. The planter was designed for small and medium size manufacturers.

## Introduction

In the state of Michoacán in México the rainfall averaged 793 mm from 1981 to 1986. The rainy season normally starts in the beginning of May and extends to the middle of September. Farms are predominantly small, corn being the main crop which is harvested by hand. Early harvesting of corn for completing the drying process at the farmer's home and using direct planting for maintaining soil moisture gives the possibility of planting a legume as a second crop.

Faba beans are legumes prefered by local farmers due to the price and demand in the market. Conventional metering principles were evaluated in a bench test and were found to cause considerable damage to bean seeds (Lara et al, 1993). The metering principle that reduced damage to a negligible level with an acceptable metering uniformity was based on having a rotating disc with holes on the plane of the disc at an angle in relation to the horizontal plane. This angle, the size and number of the holes located in a concentric circle in the rotating disc were varied during the experiment to find the more convenient values of the two variables previously mentioned (**Fig. 1**). A planter prototype was produced. Field testing of the planter was done with a 9 kW (12 hp) tractor.

The purpose of this paper is to present the development process for the planter and the results of the field tests, including a calculation of the tractive requirement for the direct planter.

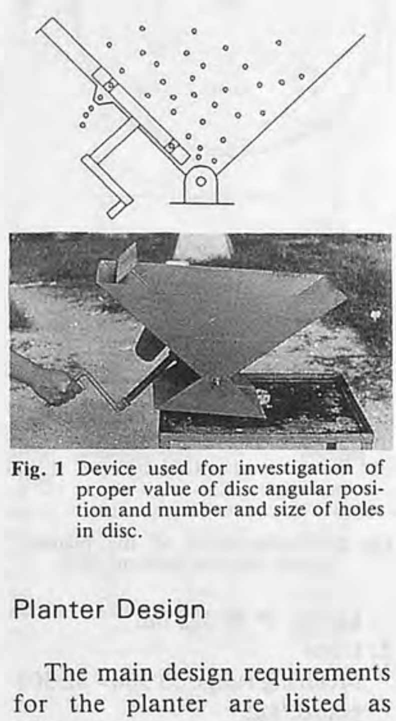

**Fig. 1** Device used for investigation of proper value of disc angular position and number and size of holes in disc.

## Planter Design

The main design requirements for the planter are listed as follows:

1. Faba beans
   Metering range 45 - 50 kg/ha, 45 000 - 55 000 plants/ha.
   Depth in dry planting 100 - 150 mm.
   Depth in humid planting 50 mm.
   Fertilizer during planting N 40

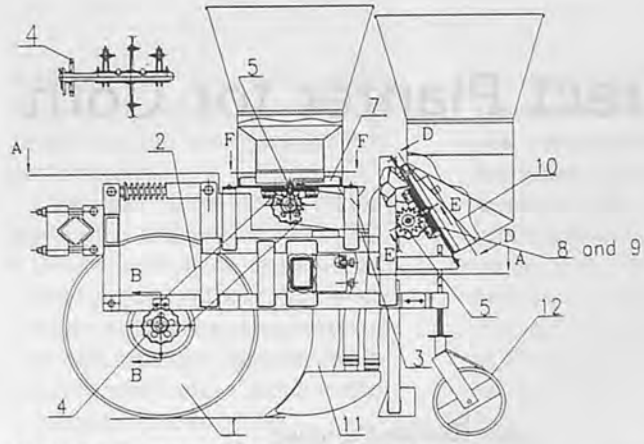


Fig. 2 Configuration of planter, cross section B-B.

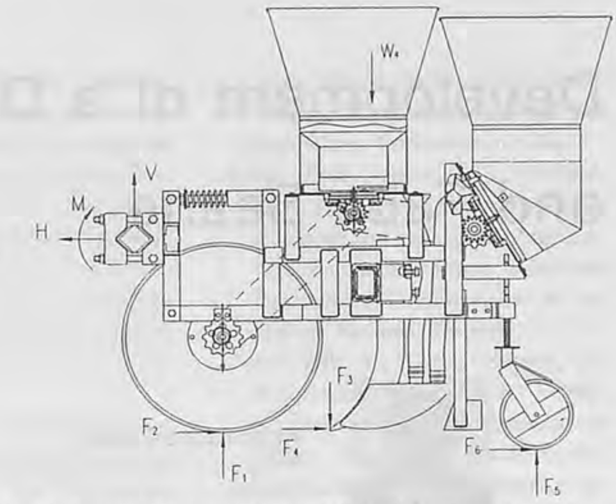


Fig. 3 External forces on planter calculated for normal operation.

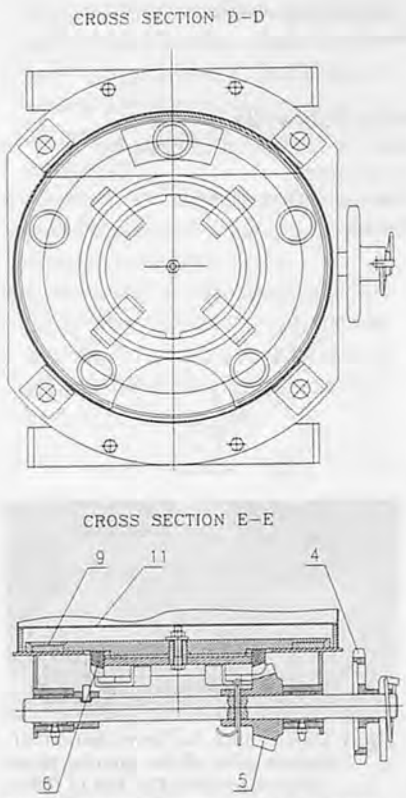


Fig. 2a Configuration of the planter, cross sections D-D and E-E.

kg/ha, P 40 kg/ha.

2. Corn
   Metering range 53 500 - 62 500 plants/ha.
   Depth of planting 25 - 50 mm.
   Fertilizer during planting N 80 kg/ha, P 40 kg/ha.
3. Possibility of being used for either direct or traditional planting.
4. Possibility of being used is stony soils.
5. Possibility of being fabricated by small and medium sized local manufacturers.

As mentioned above, several metering principles were tested in the laboratory for a preliminary evaluation of damage and metering uniformity of bean seeds. The principle of having a hollowed disc oriented at an angle with respect to the horizontal plane was selected. Acceptable results were obtained with an angle of 60° for the disc in relation to the horizontal plane and with diameter of holes of 25 mm for faba beans and 17 mm for corn.

Based on such a principle a prototype was developed. **Figs. 2** and **2a** shows the configuratoin of the planter. The planter has a coulter that opens the soil before the shoe. Such a coulter also drives the metering devices for seed and fertilizer by means of a chain drive. In stony soils, the coulter rolls over stones lifting the planter against the force of the compression spring. The vertical position of the shoe may be adjusted by using the positioning set screws. The main components of the planter are as follows:

Coulter, 500 mm O.D.

Pressed-steel, detachable-link chain, pitch 41, 1.5 m long.

Pressed-steel, detachable-link chain, pitch 41, 1 m long.

Four cast iron sprockets of 12 teeth for pitch 41 chain.

Two, 15-tooth standard cast iron bevel gear pinions.

Two, 30-tooth standard cast iron bevel gears.

Rotating-bottom metering device for fertilizer.

Circular plate 240 mm O.D. with 13 circular holes of 29.4 mm diam. spaced on a circle of 205 mm diam. for faba beans.

Circular plate 204 mm O.D. with 13 circular holes of 14.3 mm of diam. spaced on a circle of 205 mm.

Separation plate.

Hoe type opener.

Ruber or steel press wheel.

The determination of forces on the planter was of fundamental importance for predicting of the traction requirements and for the structural analysis. Forces on the planter are indicated in **Fig. 3**. Draft and vertical forces on the coulter for no tilled soils with crop residues were assumed to be in the order of 180 N and 400 N, respectively, (Kushwaha et al, 1986).

Forces on the shoe may be calculated by the following equations of ASAE Standard D497:

$$F_4 = (520 + 49.2V)\,(d/8.26)^2 \qquad (1)$$

$$F_3 = F_4 \tan 18° \qquad (2)$$

Where d is the depth that the shoe penetrates the soil in cm and V is the working speed of the tractor in km/h.

The normal force on the steel press wheel may be regulated by a preloaded spring. A value of 200 N was assumed as the normal force in the presswheel. The corresponding rolling resistance was calculated by the following equation (Richey et al, 1961).

$$F_6 = F_5\,(163.6/bd + 0.188) \quad (3)$$

Where b and d are width and the diameter in mm of the steel wheel.

The total draft is given by the following equation:

$$H = (520 + 49.2V)\,(d/8.26)^2 + F_5\,(163.6/bd + 0.188) + 180 \quad (4)$$

For a speed of 5 km/h and a working depth for the coulter and the shoe of 5 cm the required draft would be 597 N.

Once forces on the tools were calculated, a structural analysis of the planter frame was carried out. Transmission elements such as gears, shafts and chains were selected from among those commonly used for normal disc-planters.

## Test

After a number of small changes during the preliminary testing of the planter, acceptable operation was obtained in order to determine the metering characteristics and damage rate of the planter. Seeds dropped by the planter along the furrow were counted in intervals of 5 m. Fifty such intervals were considered for corn seed and faba bean seeds. Runs were carried out on grass and the seeds covering device was disassembled to facilitate inspection and counting of seeds (**Fig. 4**). One single seed of faba beans showed visible damage, not one seed of corn was damage. Metering results are summarized in **Table 1**. The test was run at 3.0 km/h.

For faba bean seeds a plate with 13 holes of 29.4 mm (1 5/32 in) in diameter was used. For corn seeds the plate has 13 holes of 14.3 mm (9/16 in) in diameter. If a smaller seed population needs to be used, it is necessary to reduce the number of holes in the plate proportionally to the desired seed population.

**Appendix Table A.** Direct Planter Metering Data for Faba Beans

| No. of Repli-cations | Seeds in 5 m a | Seed spacing b | Seed/ha c | No. of Repli-cations | Seeds in 5 m a | Seed spacing b | Seed/ha c |
|---|---|---|---|---|---|---|---|
| 1 | 21 | 238.09 | 92500 | 26 | 31 | 161.29 | 77500 |
| 2 | 19 | 263.67 | 75000 | 27 | 26 | 192.30 | 65000 |
| 3 | 21 | 192.3 | 65000 | 28 | 24 | 208.33 | 60000 |
| 4 | 24 | 156.25 | 80000 | 29 | 31 | 161.29 | 77500 |
| 5 | 20 | 192.3 | 65000 | 30 | 28 | 178.57 | 70000 |
| 6 | 24 | 185.19 | 67500 | 31 | 27 | 185.19 | 67500 |
| 7 | 23 | 208.33 | 60000 | 32 | 31 | 161.29 | 77500 |
| 8 | 24 | 192.3 | 65000 | 33 | 29 | 172.41 | 72500 |
| 9 | 19 | 161.29 | 77500 | 34 | 26 | 192.30 | 65000 |
| 10 | 25 | 200.00 | 62500 | 35 | 31 | 161.29 | 77500 |
| 11 | 23 | 200.00 | 62500 | 36 | 29 | 172.41 | 72500 |
| 12 | 25 | 217.39 | 57500 | 37 | 26 | 192.30 | 65000 |
| 13 | 22 | 208.33 | 60000 | 38 | 31 | 161.29 | 77500 |
| 14 | 19 | 172.41 | 72500 | 39 | 29 | 172.41 | 72500 |
| 15 | 22 | 227.27 | 55000 | 40 | 29 | 172.41 | 72500 |
| 16 | 18 | 161.29 | 77500 | 41 | 29 | 172.41 | 72500 |
| 17 | 20 | 185.19 | 67500 | 42 | 27 | 185.19 | 67500 |
| 18 | 25 | 156.25 | 80000 | 43 | 24 | 208.33 | 60000 |
| 19 | 23 | 172.41 | 72500 | 44 | 29 | 172.41 | 72500 |
| 20 | 23 | 166.67 | 75000 | 45 | 21 | 238.09 | 52500 |
| 21 | 23 | 178.57 | 70000 | 46 | 28 | 178.57 | 70000 |
| 22 | 23 | 172.41 | 72500 | 47 | 22 | 227.27 | 55000 |
| 23 | 22 | 200.00 | 62500 | 48 | 24 | 208.33 | 60000 |
| 24 | 20 | 172.41 | 72500 | 49 | 26 | 192.30 | 65000 |
| 25 | 22 | 185.19 | 67500 | 50 | 24 | 208.33 | 60000 |

$\bar{x}_a = 27.52 \quad \bar{x}_b = 184.04 \quad \bar{x}_c = 68800$
$\sigma_a = 3.11 \quad \sigma_b = 21.05 \quad \sigma_c = 7782$
No. of holes = 13
Diameter of holes = 29.4 mm (1 5/32 in).

**Appendix Table B.** Direct Planter Metering Data for Corn

| No. of Repli-cations | Seeds in 5 m a | Seed spacing b | Seed/ha c | No. of Repli-cations | Seeds in 5 m a | Seed spacing b | Seed/ha c |
|---|---|---|---|---|---|---|---|
| 1 | 37 | 135.13 | 92500 | 26 | 31 | 161.29 | 77500 |
| 2 | 30 | 166.67 | 75000 | 27 | 26 | 192.30 | 65000 |
| 3 | 26 | 192.3 | 65000 | 28 | 24 | 208.33 | 60000 |
| 4 | 32 | 156.25 | 80000 | 29 | 31 | 161.29 | 77500 |
| 5 | 26 | 192.3 | 65000 | 30 | 28 | 178.57 | 70000 |
| 6 | 27 | 185.19 | 67500 | 31 | 27 | 185.19 | 67500 |
| 7 | 24 | 208.33 | 60000 | 32 | 31 | 161.29 | 77500 |
| 8 | 26 | 192.3 | 65000 | 33 | 29 | 172.41 | 72500 |
| 9 | 31 | 161.29 | 75500 | 34 | 26 | 192.30 | 65000 |
| 10 | 25 | 200.00 | 62500 | 35 | 31 | 161.29 | 77500 |
| 11 | 25 | 200.00 | 62500 | 36 | 29 | 172.41 | 72500 |
| 12 | 23 | 217.39 | 57500 | 37 | 26 | 192.30 | 65000 |
| 13 | 24 | 208.33 | 60000 | 38 | 31 | 161.29 | 77500 |
| 14 | 29 | 172.41 | 72500 | 39 | 29 | 172.41 | 72500 |
| 15 | 22 | 227.27 | 55000 | 40 | 29 | 172.41 | 72500 |
| 16 | 31 | 161.29 | 77500 | 41 | 29 | 172.41 | 72500 |
| 17 | 27 | 185.19 | 67500 | 42 | 27 | 185.19 | 67500 |
| 18 | 32 | 156.25 | 80000 | 43 | 24 | 208.33 | 60000 |
| 19 | 29 | 172.41 | 72500 | 44 | 29 | 172.41 | 72500 |
| 20 | 30 | 166.67 | 75000 | 45 | 21 | 238.09 | 52500 |
| 21 | 28 | 178.57 | 70000 | 46 | 28 | 178.57 | 70000 |
| 22 | 29 | 172.41 | 72500 | 47 | 22 | 227.27 | 55000 |
| 23 | 25 | 200.00 | 62500 | 48 | 24 | 208.33 | 60000 |
| 24 | 29 | 172.41 | 72500 | 49 | 26 | 192.30 | 65000 |
| 25 | 27 | 185.19 | 67500 | 50 | 24 | 208.33 | 60000 |

$\bar{x}_a = 27.52 \quad \bar{x}_b = 184.04 \quad \bar{x}_c = 68800$
$\sigma_a = 3.11 \quad \sigma_b = 21.05 \quad \sigma_c = 7782$
No. of holes = 13
Diameter of holes = 14.3 mm (9/16 in).

**Table 1.** Metering Performance of Test Planter

| Crop | Seeds in Intervals of 5 m | | Seed Spacing (mm) | | Seeds per Hectare* | |
|---|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | Mean | S.D |
| Faba beans | 22.03 | 1.78 | 228.8 | 19.27 | 55 000 | 4 472 |
| Corn | 27.57 | 3.11 | 184.0 | 21.05 | 68 800 | 7 782 |

* A width of 0.8 m for the furrow was assumed.
Fertilizer: 0 - 1 392 kg/ha flow rate, for ammonia sulfate.

**Fig. 4** Planter prototype during test on a field with grass.

## Conclusions

1. The planter performance was in accordance with the plant population recommended for corn and faba beans.
2. The draft requirement of the planter, 597 N, is relatively low. This makes it possible to pull the planter with a small tractor or with animal draft.
3. Fabrication of the planter requires only standard manufacturing techniques, normally available in small- and medium-sized companies.

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# Centrifugal Rice Huller — An Active Device for Rice Processing

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## Abstract

In developing countries, like Bangladesh, rice is processed either by traditional methods or by Engleberg huller. But the recovery of polished rice is low (about 67%) in huller mills. The centrifugal rice huller is a husk remover combined with a polisher can easily process paddy into polished rice. An experiment was conducted to study the centrifugal rice huller and screen-roller polisher. The study showed that both the huller and polisher are suitable for parboiled paddy (milling outturn about 71%, breakage about 5%). But for raw paddy, the milling outturn is low (about 68%) and broken percentage is high (about 30%). The capacities of the huller and polisher for parboiled paddy were about 350 kg/h and 300 kg/h, respectively. The total power requirement for huller and polisher was about 7 kW. The adjustment of the huller is satisfactory but the polisher is difficult. The polisher needs some refinement. The performance of the machine is better than the existing huller which can be adopted in Bangladesh.

**Acknowledgement:** The author is grateful to the Bangladesh Rice Research Institute, Gazipur for providing laboratory facilities and to the Krishikol Corporation, Dhaka, Bangladesh for making available the huller and polisher.

## Introduction

Polished rice production is one of the largest agricultural industries in both developed and developing countries. Due to large increases in rice production, there is an increase in demand in kind and number of post-harvest equipment for rice processing. Hulling is to remove the husk from the paddy with a minimum of damage to the bran layer. Whitening is to remove the silver skin and the bran layer of the brown rice. Polishing is the final removal of the bran sticking to the surface of the rice to give it a shinier appearance. Huller is used for hulling. On the other hand, polisher is used for whitening and polishing.

Bangladesh produces annually about 28 million t of rough rice (BBS 1992) that yields about 19.5 million t of polished rice. The milling outturn is low due to inefficient processing machinery. Rice processing in Bangladesh includes parboiling, drying and milling to produce polished rice. In a few localities in the eastern part of the country parboiling practice is not followed.

About 80% of the rice is processed in villages and the rest is processed in commercial rice mills. In the village, rice is parboiled and dried by the farmer's wife and then taken to the huller mills by the farmer for milling. In the commercial rice processing, rice is brought to the mills by rice traders, parboiled, dried and milled by the millers and polished rice is returned to the traders. The commercial rice mills are of two types, huller mills and modern mills. The huller mills, in turn, are of two types depending on capacity, small or large. Rough rice is polished by the Engleberg huller which is operated by an electric motor or diesel engine. On the other hand, in modern rice mills hulling is done by rubber roll huller or disc huller (cono) and polishing in cone type or roller type polisher. Uniconsultant (1991) reported that the recovery of rice was about 69.7% in traditional 'Dheki' operation, about 67.6% in rice huller mills and about 68% in big rice mills.

FAO and BRRI (1985) reported that rice losses from harvest to milling were about 13% (**Fig. 1**). The report also shows that about 4% rice is lost during milling. Araullo et al (1976) reported that the milling recovery of rice is 63%, 67% and 70% from Engleberg, disc and rubber roll huller mills,

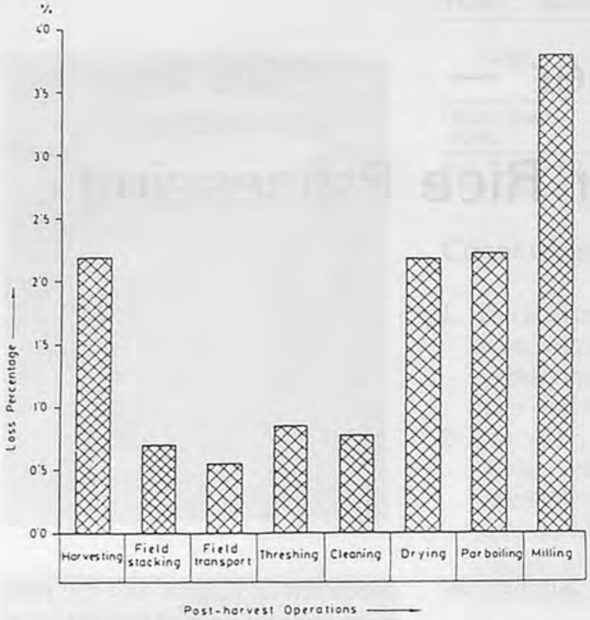


Fig. 1 Percentage of losses at various post-harvest operations.

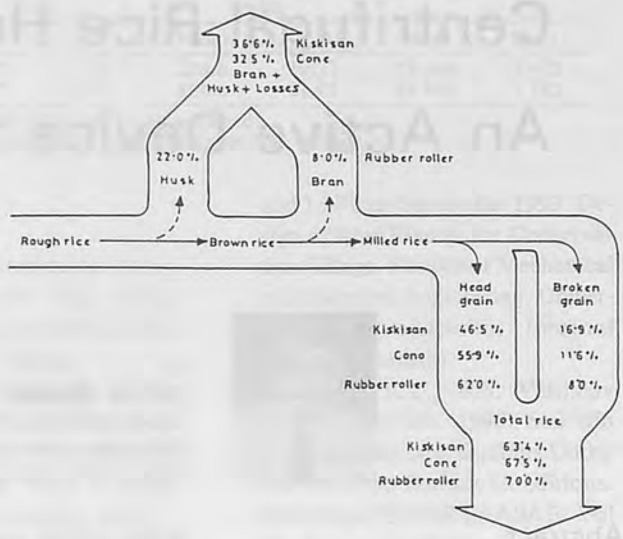


Fig. 2 Recovery efficiency for three rice milling systems (Araullo et al 1976).

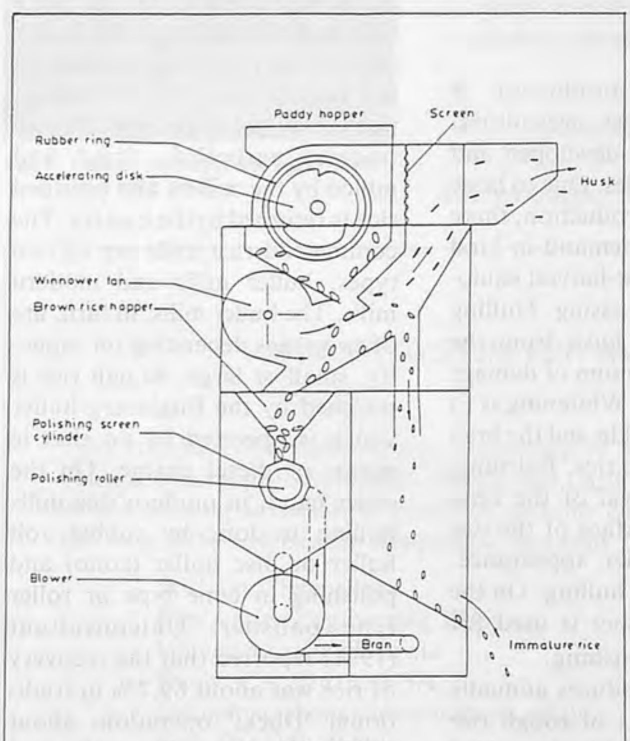


Fig. 3a Compact rice mill.

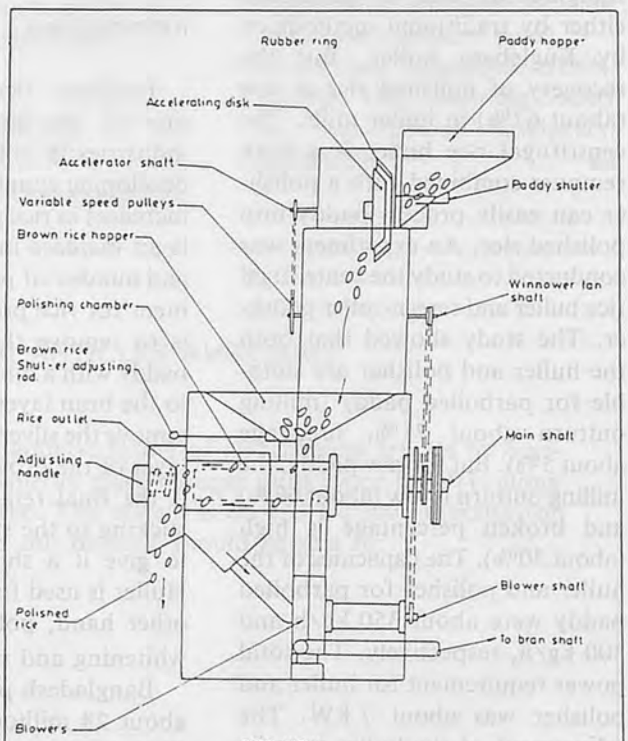


Fig. 3b Compact rice mill.

respectively, (Fig. 2). Maramba (1953) in his study of different types of rice mills, claimed that a rubber roll huller combined with an Engleberg huller which is used as a whitener, gave a low milling recovery but this was higher than the milling recovery from the Engleberg alone. In a separate study using the same machine combination, Obungen (1960) found that 1.0 % of grain was brokens in the rubber roll huller while 14% was brokens in the Engleberg machine. Wimberly (1972) in a study with steel huller reported that the Engleberg huller removes the rice hull and the bran in one operation combining friction and high pressure in the process which results in high percentage of broken grains and excessive bran production. Arboleda (1975) observed that the

**Table 1.** Capacity and Milling Outturn of Huller and Polisher

| Paddy condition | Moisture content (% wb) | Capacity (kg/h) | | Milling outturn (%) |
|---|---|---|---|---|
| | | Huller | Polisher | |
| Parboiled | 14.0 | 350 | 300 | 71 |
| Raw | 12.2 | 500 | 360 | 68 |

Paddy variety: BR3.

**Table 2.** Determination of Accelerating Disc Speed of Huller

| Speed of accelerating disc. (rpm) | Feeding rate (kg/h) | Hulling efficiency (%) | Unhusked rice (%) | Broken rice (%) |
|---|---|---|---|---|
| | | Parboiled paddy | | |
| 2 775 | 286 | 93.23 | 6.77 | 1.24 |
| 2 950 | 354 | 95.76 | 4.24 | 1.44 |
| 3 250 | 357 | 98.37 | 1.63 | 2.08 |
| | | Raw paddy | | |
| 2 750 | 400 | 85.29 | 14.71 | 28.56 |
| 2 950 | 450 | 91.02 | 8.98 | 30.14 |
| 3 250 | 491 | 96.33 | 3.67 | 36.95 |

Paddy variety: BR3.
Moisture content: parboiled paddy - 14% wb., raw paddy - 12.2% wb.

**Table 3.** Valve Adjustment of the Polisher

| Inlet valve position | Outlet valve position | Broken rice during polishing (%) | Polished rice colour | Remarks |
|---|---|---|---|---|
| | | Parboiled rice | | |
| 4.0 | 0.0 | 6.74 | Very dull | |
| 3.0 | 0.0 | 4.11 | Very dull | |
| 2.5 | 0.0 | 4.86 | Dull | |
| 2.0 | 0.0 | 7.59 | OK | |
| 4.0 | 0.5 | 7.85 | Dull | Blocked |
| 3.0 | 0.5 | 11.61 | Dull | |
| 2.5 | 0.5 | 4.28 | OK | |
| 2.0 | 0.5 | 6.27 | Sl.dull | |
| 4.0 | 1.0 | 15.58 | OK | Blocked |
| 3.0 | 1.0 | 6.97 | Dull | |
| 2.5 | 1.0 | 4.24 | OK | |
| 2.0 | 1.0 | 5.06 | OK | |
| 3.0 | 1.5 | 7.76 | Dull | Blocked |
| 2.5 | 1.5 | 6.00 | Sl.dull | Blocked |
| 2.0 | 1.5 | 6.04 | OK | |
| | | Raw rice | | |
| 3.0 | 0.0 | 21.58 | Dull | Blocked |
| 2.5 | 0.0 | 24.66 | Dull | |
| 2.0 | 0.0 | 17.16 | Sl.dull | |
| 1.5 | 0.0 | 22.47 | Sl.dull | |
| 3.0 | 0.5 | 26.18 | Dull | Blocked |
| 2.5 | 0.5 | 29.31 | Sl.dull | |
| 2.0 | 0.5 | 23.05 | Sl.dull | |
| 1.5 | 0.5 | 22.77 | Sl.dull | |
| 2.5 | 1.0 | 28.26 | OK | |
| 2.0 | 1.0 | 28.70 | OK | |
| 1.5 | 1.0 | 24.14 | OK | |
| 2.5 | 1.5 | 32.18 | OK | |
| 2.0 | 1.5 | 29.08 | OK | |
| 1.5 | 1.5 | 29.47 | OK | |

Variety: BR3.
Parboiled brown rice condition: broken rice - 2.1%, unhusked paddy - 1.7%, moisture content - 14% wb.
Raw brown rice condition: broken rice - 30.5%, unhusked paddy - 0.12%, moisture content - 12.2% wb.

steel huller rice mill has a high power requirement and it subjects the rice paddy to excessive pressure and friction resulting into heat, high kernel breakage and low output of milled rice.

The centrifugal rice huller shown in **Figs. 3a** and **3b** is a new type of husk remover from the rough rice combined with a polisher. The husk is removed by the impact action when thrown centrifugally. The performance of this new machine is reviewed in this paper.

The principal objective of this study was to adjust the machine speed, feed rate and to determine the capacity of the machine and quality of the final products.

## Description of the Machine

The centrifugal rice huller consist of an impact husking system with a blower to separate the husk from hulled rice. The polishing unit consists of screen-roller polisher with a twin blower to suck the bran from the polished rice and to keep the rice temperature low (**Figs. 3a** and **3b**). About 7 kW power is required to operate both huller and polisher. In the huller, a feeding valve controls the feed rate. On the other hand, in polisher, the inlet valve and outlet valve control the feeding rate and degree of polishing. The valveds are graduated.

## Materials and Methods

An experiment was set up at the Bangladesh Rice Research Institute (BRRI)'s Post-harvest Technology laboratory to study the centrifugal rice huller and screen roller polisher. In order to determine the hulling and polishing capacity, quality of the product and adjustment of the huller and polisher, the BRRI developed the rice variety BR3 which was used in the study. Both raw and parboiled was used as material. The huller was tested at different speeds for raw and parboiled paddy in order to determine its optimum speed (rpm). At this speed, the capacity was determined. The polisher was tested at different inlet and outlet valve adjustments for both raw and parboiled hulled rice in order for the machine to operate at optimum level. The capacity was determined at optimum adjustment level. The quality of the products were analyzed in order to find the suitable speed of the huller and the proper adjustment of the polisher. The capacity was determined at the optimum speed of the huller and the optimum adjustment level of the polisher.

## Resutls and Discussion

The speed of the huller accelerating disc for both parboiled and raw paddy is presented in **Table 2**. The hulling efficiencies were 98% and 96% for parboiled and raw paddy, respectively, at a speed of

3 250 rpm. On the other hand, at this speed, broken percentages were 2% and 37% for the parboiled and raw paddy. The result shows that the huller was suitable for hulling parboiled paddy with its speed in between 2 950 and 3 250 rpm, where hulling efficiencies were 96% to 98%. It is not suitable for hulling raw paddy due to high breakage (about 30%). The capacity of the huller is 350 kg/h for parboiled paddy which is less than that of raw paddy (500 kg/h) as shown in **Table 1**.

The position of inlet and outlet valves of the polisher needs very careful adjustment in order to avoid blockage. The test results of the polisher for both parboiled and raw hulled rice are shown in **Table 3**. The polisher is not suitable for polishing raw hulled rice due to high breakage of about 25%. It is suitable for polishing parboiled hulled rice where breakage is about 5%. The position of the inlet valve should be 2 to 3 and outlet valve 0.5 to 1.5. For getting better milling quality, the valves should be adjusted properly. The capacity is 300 kg/h paddy for parboiled hulled rice which is less than raw hulled rice of 360 kg/h paddy **(Table 1)**. The centrifugal rice huller and the screen-roller polisher are suitable for hulling and polishing parboiled paddy. Pure bran is produced without mixing the husk. But the polisher adjustment is more difficult to do than the ordinary rice huller. The polisher needs some refinement. The milling outturn was 68% and 71% for raw and parboiled paddy, respectively, which is higher than the existing rice mill (63-67%) in the country.

The total power requirement is about 7 kW which is required for the power tiller. Power tillers are available in the country, but they are being used during the land preparation season. The rest of the year they are idle. The engine of the power tilller can easily operate the centrifugal huller and polisher in the rural areas of Bangladesh.

## Conclusions and Recommendation

1. The centrifugal rice huller is suitable for hulling parboiled paddy.
2. The screen roller polisher is suitable for polishing parboiled rice.
3. The adjustment of the polisher is difficult and need refinements.
4. The centrifugal rice huller is better than the existing huller.
5. The centrifugal rice huller is recommended for the rural areas of Bangladesh.

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# Application of Finite Element Method for the Simulation of Temperature Distribution During Storage of Rough Rice in Cylindrical Bin


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## Abstract

Temperature is one of the most crucial factors limiting the distribution and abundance of arthropods and fungi that contaminate stored rough rice. A mathematical model, based on the finite element method (FEM) of calculating heat transfer, has been developed to simulate the rough rice temperatures in a cylindrical storage bin with respect to ambient air temperature fluctuations throughout a storage period. The model has been programmed in BASIC, compatible with microcomputers, thus requiring less time for computer simulation of temperatures. Temperatures predicted by the model are in very good agreement with the measured temperatures in a 0.8 diameter bin containing rough rice, located at Matsuyama, Japan. Temperatures predicted by the model are also compared with the temperatures predicted by the model develop based on finite difference method (FDM). The absolute difference between the measured and the predicted temperatures by both models are nearly identical for different locations in the grain bulk. These models can be used in the selection of geographical locations for storage bins, the design of non-aerated tall storage structures and for advice on ventilation of storage buildings.


## Introduction

Whenever the temperature in any quantity within a mass of grain differs from another part, moisture is carried from warm to cooler areas by convection and deposisted. Seasonal fluctuations in atmospheric temperature change the temperature pattern throughout the grain bin. Moreover, though grain may be stored at a moisture content generally considered safe, moisture content may also be changed in both time and space as a result of weather influences.

Temperature changes in the stored grain are caused by both internal and external sources of heat (Converse et al., 1973). Internal sources of heat are respiration of grain, microorganism, insects and mites. External sources include the changes in ambient temperature and solar radiation which varies with location of storage structure. Rate of respiration and multiplication of insects, mites, fungi, and respiration of the grain itself are largely depend on the grain temperature (Oxley, 1948). The difference between the center temperature of the grain bulk and the outside ambient temperature causes convection currents in the grain accompanied by movement of moisture from high temperature to low temperature areas (Sinai and Walleye, 1977), which further enhances the outbreak of mold growth.

A knowledge of temperature distribution in the stored grain not only helps in identifying active deterioration, but also gives an indication of the potential for deterioration.

Collecting the temperature data at various points in grain storage bins of different sizes over a period of time is one way of finding the temperature distribution. But this an inefficient method, requiring a lot of time, cost, and labor. Mathematical models, based on physical principles can potentially predict with accuracy the temperature distribution in a grain storage bin. Further, using the mathematical models, the effect of bin size, bin wall materials, location, etc., on the temperature distribution can be studied.

Many attempts (Converse et al., 1973; Loa et al., 1975; Yaciuk et al., 1975; Muir et al., 1980; Metzger and Muir, 1983; Longstaff and Banks, 1987; Manbeck and Britton, 1988; Bala et al., 1989) were made in developing mathematical models to predict the temperature distribution in grain storage bins. Most of the previous researchers solved the heat conduction problem either analytically or using finite difference method (FDM) for predicting the temperature distribution in stored grain mass. The FDM is cumbersome when the regions have curved boundaries and it is difficult to write a general computer program for the method (Segerlind 1976).

Misra et al., (1979) developed a transient heat transfer model in sphere and concluded that the finite element method (FEM) can be applied extensively for solution of practical engineering problems when it is defficult to obtain the analytical solution due to material property.

Finite difference techniques are not completely satisfactory for the engineering analysis of materials such as biological materials which have large variations in materials properties Again, application of the finite element technique are relatively new in the field of agricultural engineering. The simulation program of most of the previous researchers were in FORTRAN suitable for the main frame computer and takes more computing time. The microcomputers are convenient and have better availability than the main frame computers. But the microcomputers have relatively small memory and the speed of calculation is low. There exits an opportunity to develop a mathematical model based on FEM and to fit the program to the memory of microcomputers. This promoted the authors to develop the heat transfer model based on the FEM and to program the model in BASIC suitable for microcomputers.

The objectives of the present study are:

(i) To develop a mathematical model based on the FEM into predicting the temperature changes during storage of rough rice in cylindrical bins using micro computer and
(ii) To validate the model with experimental data.

## Theory and Model Development

The following simplifying assumptions are made for deriving the governing equation of heat flow:

(a) The physical and thermal properties of grain are uniform throughout the bin;
(b) There is no heat generation within the grain bin;
(c) Heat transfer by conduction in the vertical and circumferential directions are negligible; and
(d) Heat flow pattern is assumed to be symmetrical around the vertical axis of the cylindrical bin.

**Governing Equations**

With the above assumptions, the general governing differential equation of heat flow in cylindrical coordinate can be written as:

$$\frac{\partial T}{\partial t} = \alpha \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right) \quad (1)$$

where $0 \leqslant r \leqslant R$; $t > 0$; $T = T(r, t)$
$T$ = stored grain temperature and $\alpha$ thermal diffusivity of grain = $k/\varrho c$, where k = thermal conductivity of grain, $\varrho$ = density of grain, c = specific heat capacity of grain, R = radius of the cylindrical bin; r = radial coordinate of the grain bin, and t = time. The initial and boundary conditions associated with equation (1) can be expressed as

initial conditions:

$$T(r, 0) = T_0(r), \ 0 \leqslant r \leqslant R, \ t \leqslant 0 \quad (2)$$

and

boundary conditions:

$$T(r,t) = T(r) \text{ at } r = R, \ t \geqslant 0, \quad (3)$$

$$\pm k\frac{\partial T}{\partial r} + h_c(T - T_a) = 0$$

$$\text{at } r = R, \ t > 0 \quad (4)$$

where

$h_c$ = surface heat transfer coefficient

$T_a$ = temperature of the surrounding fluid

Since the initial and boundary conditions are different for ambient temperatures variations, it is defficult to develop and analytical solution of equation (1). As an alternative to this, numerical methods are applied.

**Derivation of Finite Element Equations**

The fundamental concept of the FEM is that any continuous quantity such as temperature, pressure or displacement, can be approximated by a discrete model composed of a set of piece wise continuous functions defined over a finite number of sub-domains. These sub-domains are called elements which are connected with each other in common points, called nodes or nodal points. The finite element formulation of equations (1-4) can be achieved either by a variational process via the Rayleigh-Ritz method or by the method based on the weighted residual procedure. Because of the availability of a functional for Equation (1), we use the Rayleigh-Ritz variational principle with the functional derived by Gurtin (1964). The functional, I, for the one dimensional heat transfer problem described by equation (1) to (4) can be written as:

$$I = \int_v \frac{1}{2}\{\alpha(\frac{\partial T}{\partial r})^2 + 2T\frac{\partial T}{\partial t}\}dv + \int_s \frac{1}{2}h_c(T - T_\alpha)^2 ds \qquad (5)$$

where

$\int_v$ = Integration over volume

$\int_s$ = Integration over surface

The FEM finds the approximate temperature profile by minimizing this integral, equation (5), at every instant in time while satisfying the initial and boundary conditions are given by equations (2) to (4). The integral in equation (5) is evaluated by breaking it into E sub integrals over each of the elements and then summing up all the E integrals, given by Mayers (1971) as:

$$I = I^{(1)} + I^{(2)} + \ldots + I^{(e)} + \ldots + I^{(E)}$$

or,

$$I = \sum_{e=1}^{E} I^{(e)} \qquad (6)$$

The integral for a typical element

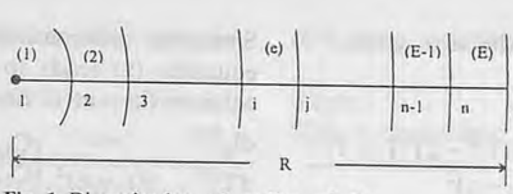


Fig. 1 Discretization of radius of the cylindrical bin into finite element.

'e' can be broken up in to three part as follows (Mayers, 1971),

$$I^{(e)} = I_k^{(e)} + I_c^{(e)} + I_b^{(e)} \qquad (7)$$

where

$I_k^{(e)}$ = Integration for conduction term

$I_c^{(e)}$ = Integration for capacitance term

$I_b^{(e)}$ = Integration for boundary condition term

For a cylinder, from equation (5), these integrals are given by

$$I_k^{(e)} = \frac{1}{2}\int_v \alpha(\frac{\partial T^{(e)}}{\partial r})^2 dv \qquad (8)$$

$$I_c^{(e)} = \frac{1}{2}\int_v \frac{\partial}{\partial t}(T^{(e)})^2 dv \qquad (9)$$

and

$$I_b^{(e)} = \frac{1}{2}\int_s h_c^{(e)}\{((T^{(e)})^2 - 2T^{(e)}T_a + T_a^2)\}ds \qquad (10)$$

Integral given by equations (8), (9) and (10) are to be minimized with respect to nodal temperature, $T^{(e)}$ at every instant of time as follows (Mayers, 1971)

$$\frac{dI^{(e)}}{dT^{(e)}} = \frac{dI_k^{(e)}}{dT^{(e)}} + \frac{dI_c^{(e)}}{dT^{(e)}} + \frac{dI_b^{(e)}}{dT^{(e)}} = 0 \qquad (11)$$

For a cylinder, volume v is given by $v = \pi r^2 h$; $dv = 2\pi rhdr$ and surface area s is given by $s = 2\pi rh$; $ds = 2\pi hdr$

where h = height of the cylindrical bin

Equation (8) can be written as

$$I_k^{(e)} = \frac{1}{2}\int_{r_i}^{r_j} \alpha^{(e)}(\frac{\partial T^{(e)}}{\partial r})^2 2\pi rhdr$$

or,

$$I_k^{(e)} = \pi h\int_{r_i}^{r_j} \alpha^{(e)}(\frac{\partial T^{(e)}}{\partial r})^2 rdr \qquad (12)$$

**Fig. 1** illustrates the node location and elements for the axi-symmetrical heat transfer problem in a cylinder. The interval between two adjacent nodes is called an element and a typical element 'e' is the interval between nodal points i, and j. The temperature within an element 'e' is assumed to be a linear function of the coordinate, given by Segerlind (1976).

$$T^{(e)} = (\frac{r_j - r}{r_j - r_i})T_i + (\frac{r - r_i}{r_j - r_i})T_j \qquad (13)$$

where $T^{(e)}$ is the temperature of the element (e) between nodes i and j which have known temperature $T_i$ and $T_j$. Differentiating equation (13), one gets

$$\frac{\partial T^{(e)}}{\partial r} = \frac{1}{r_j - r_i}\{\frac{\partial}{\partial r}(r_j - r)T_i + \frac{\partial}{\partial r}(r - r_j)T_j\}$$

or,

$$\frac{\partial T^{(e)}}{\partial r} = \frac{1}{r_j - r_i}(T_i - T_j) \qquad (14)$$

Squaring both sides of equation (14), one gets

$$(\frac{\partial T^{(e)}}{\partial r})^2 = (\frac{1}{r_j - r_i})^2(T_i^2 - 2T_iT_j + T_j^2) \qquad (15)$$

Substituting equation (15) into equation (12), one obtains

$$I_k^{(e)} = \pi h\int_{r_i}^{r_j} \alpha^{(e)}\frac{1}{(r_j - r_i)^2}(T_i^2 - 2T_iT_j + T_j^2)rdr \qquad (16)$$

Integration of the term gives

$$I_k^{(e)} = \frac{\pi h\alpha^{(e)}(r_j^2 - r_i^2)(T_j^2 - 2T_iT_j + T_i^2)}{2(r_j - r_i)^2} \quad (17)$$

Differentiating equation (17) with respect to $T_i$ and $T_j$ respectively, one gets

$$\frac{\partial I_k^{(e)}}{\partial T_j} = \frac{\pi h\alpha^{(e)}(r_j^2 - r_i^2)}{2(r_j - r_i)^2} \times (2T_j - 2T_i)$$

or,

$$\frac{\partial I_k^{(e)}}{\partial T_j} = \frac{\pi h\alpha^{(e)}(r_j^2 - r_i^2)(T_j - T_i)}{(r_j - r_i)^2} \quad (18)$$

Similarly,

$$\frac{\partial I_k^{(e)}}{\partial T_i} = \frac{\pi h\alpha^{(e)}(r_i^2 - r_j^2)(T_i - T_j)}{(r_j - r_i)^2} \quad (19)$$

Adding equations (18) and (19), one obtains

$$\frac{\partial I_k^{(e)}}{\partial T_i} + \frac{\partial I_k^{(e)}}{\partial T_j} = \frac{dI_k^{(e)}}{dT^{(e)}}$$

or,

$$\frac{dI_k^{(e)}}{dT^{(e)}} = \frac{\pi h\alpha^{(e)}(r_j^2 - r_i^2)}{(r_j - r_i)^2} \times \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{Bmatrix} T_i \\ T_j \end{Bmatrix} \quad (20)$$

or, in matrix notation

$$\frac{dI_k^{(e)}}{dT^{(e)}} = [k^{(e)}]\{T^{(e)}\} \quad (21)$$

where

$[k^{(e)}]$ = element thermal conductivity matrix

$$= \frac{\pi h\alpha^{(e)}(r_j^2 - r_i^2)}{(r_j - r_i)^2} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

$\{T^{(e)}\}$ = column vector of temperatures

$$= \begin{Bmatrix} T_i \\ T_j \end{Bmatrix}$$

Similarly, differentiation of the equation (9) leads to following equation in matrix form

$$\frac{dI_c^{(e)}}{dT^{(e)}} = \frac{\pi h}{6(r_j - r_i)^2} \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \times \begin{Bmatrix} \partial T_i/\partial t \\ \partial T_j/\partial t \end{Bmatrix} \quad (22)$$

where

$C_{11} = r_j^4 - 6r_i^2r_j^2 - 3r_i^4 + 8r_i^3r_j$

$C_{12} = r_j^4 + 2r_i^3r_j - 2r_ir_j^3 - r_i^4$

$C_{21} = C_{12}$

$C_{22} = 3r_j^4 - r_i^4 - 8r_ir_j^3 + 6r_i^2r_j$

or,

$$\frac{dI_c^{(e)}}{dT^{(e)}} = [C_p^{(e)}]\{\dot{T}^{(e)}\} \quad (23)$$

where

$[C_p^{(e)}]$ = element heat capacitance matrix

$$= \frac{\pi h}{6(r_j - r_i)^2} \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix}$$

$\{\dot{T}^{(e)}\}$ = column vector of time derivatives of temperatures of an element

$$= \begin{Bmatrix} \partial T_i/\partial t \\ \partial T_j/\partial t \end{Bmatrix}$$

Since only the bin surface is exposed to the ambient air of $T_a$ in a cylindrical bin and thus there is only one node, n + 1, with a convection boundary condition (at $r = r_{n+1} = R$), $I_b^{(e)}$ reduces to,

$I_b^{(e)} = 0$ for e = 1 to E

The evaluation of $I_b^{(e)}$ yields specific results for element E with the assumption that convection coefficient $h_c$ is constant for the entire surface. So we have to find out $I_b^{(E+1)}$. From e quation (10), one obtains

$$I_b^{(E+1)} = \pi hh_c \int_{r_n}^{r_{n+1}} \{(T_{n+1})^2 - 2T_aT^{(E+1)} + T_a^2\}dr$$

$$I_b^{(E+1)} = \pi hh_c \int_{r_n}^{R} \{(T_{n+1})^2 - 2T_{n+1}T_a + T_a^2\}(R - r_n) \quad (24)$$

where

$T_{n+1}$ = temperature at node n + 1, i.e. at the surface of the inside wall.

$r_n$ = radius of the cylinder at the *nth* node which is the first node from the surface. Differentiating equation (24) and rearranging in matrix notation, one gets

$$\frac{dI_b^{(E+1)}}{dT^{(E+1)}} = 2\pi hh_c \begin{bmatrix} 0 & 0 \\ 0 & R - r_n \end{bmatrix} \begin{Bmatrix} T_n \\ T_{n+1} \end{Bmatrix} - 2\pi hh_cT_a \begin{Bmatrix} 0 \\ R - r_n \end{Bmatrix} + \{0\} \quad (25)$$

or,

$$\frac{dI_b^{(E+1)}}{dT^{(E+1)}} = [k_m^{(e)}]\{T^{(E)}\} - \{f_s^{(e)}\} \quad (26)$$

where

$$[k_m^{(e)}] = 2\pi hh_c \begin{bmatrix} 0 & 0 \\ 0 & R - r_n \end{bmatrix}$$

$$\{f_s^{(e)}\} = 2\pi hh_c \begin{Bmatrix} 0 \\ R - r_n \end{Bmatrix}$$

$$\{T^{(E)}\} = \begin{Bmatrix} T_n \\ T_{n+1} \end{Bmatrix}$$

When the equations (21), (23) and (26) are added in equation (11) the following general first order differential equations for an element results

$$[k^{(e)}]\{T^{(e)}\} + [C_p^{(e)}]\{\dot{T}^{(e)}\} + [k_m^{(e)}]\{T^{(E)}\} - \{f_s^{(e)}\} = \{0\} \quad (27)$$

or,

$$[k^{(e)}]\{T^{(e)}\} + [k_m^{(e)}]\{T^{(E)}\} + [C_p^{(e)}]\{\dot{T}^{(e)}\} = \{f_s^{(e)}\} \quad (28)$$

Equation (28) is called element

equation. It provides solution to the discrete value of $T^{(e)}$ in each element in the system.

**Generation of Global Matrix**

When the terms of equation (28) are added for all elements, as in equation (6), and matrixes of the same size are added the following general equation results.

$$[K]\{T\}+[C]\{\dot{T}\}=\{F\} \qquad (29)$$

where

$[K]$ = the global conductivity matrix $= [k^{(e)}]+[k_m{}^{(e)}]$

$[C]$ = the global heat capacitance matrix, and

$[F]$ = thermal force vector

$\{\dot{T}\}$ = column vector of time derivatives of temperatures of all the nodes

$$= [\frac{\partial T_1}{\partial t}\frac{\partial T_2}{\partial t}\ldots\ldots\frac{\partial T_{n+1}}{\partial t}]$$

The boundary condition produces two components. One component adds to $[k^{(e)}]$. The other adds to force vector. The term $[k_m{}^{(e)}]$ is the effect of the boundary condition on heat conductance and thus the contribution of $[k_m{}^{(e)}]$ to $[k^{(e)}]$ occurs only for the last element. The term $[f_s{}^{(e)}]$ becomes the force vector of the system. The term $[k_m{}^{(e)}]$ is zero for all elements except for the E*th* element so conduction matrixes for (E-1)*th* elements will be identical while the E*th* element will have one additional term accounting for convection of heat from the surface.

**Time Integration and Solution of Algebraic Equations**

Since $\frac{dI^{(e)}}{dT^{(e)}} = 0$ which leads to the establishment of the element equations with the argument that

$$\{\dot{T}\}-\{T_0\}=\{T(t)\}-\{T_0(0)\} = \{\dot{T}(0)\}$$

Equation (29) can be written as

$$[K]\{T(t)\}+[C]\{\dot{T}(t)\}=\{F\} \quad (30)$$

Additional derivatives are required because of the appearance of nodal temperature as a function of time, $\{\dot{T}(t)\}$ and the rate of variation, $\{T(t)\}$ in equation (30) requires the discritization of that quantity in the time domain as well. The discritization in time can be accomplished simply by assuming time increments $\Delta t$ in the computation of equation (30). The expression of the rate of the temperature change $\{\dot{T}(t)\}$, however, requires an optimum finite difference algorithm to achieve both numerical stability and rapid convergence (Tai-Ran Hsu, 1986). There are two time-difference schemes that are frequently used in finite element analysis: 1. the two-level explicit method; and 2. the mid-interval scheme. Here, two level explicit method is used. Following the functional variation, the usual finite difference schemes:

$$\frac{\partial T}{\partial t}\approx\frac{T(t+\Delta t)-T(t)}{\Delta t}$$

for the forward difference scheme, or,

$$\frac{\partial T}{\partial t}\approx\frac{T(t)-T(t-\Delta t)}{\Delta t}$$

for the backward difference scheme.

Assuming that the property matrices, $[K]$ and $[C_p]$, are constant within a small time increment $\Delta t$, then from overall structural thermal equilibrium equation similar to the one given in (30), the following relationship can be derived:

$$([K]+\frac{[C_p]}{\Delta t})\{\Delta T_t\} = \frac{[C_p]}{\Delta t}\{\Delta T_{t-\Delta t}\}+\{\Delta F_{e,t}\} \quad (31)$$

or, in a more compact form,

$$[K^*]\{\Delta T_t\} = \{F^*\} \qquad (32)$$

where

$[K^*]$ = equivalent conductivity matrix

$$= [K] + \frac{[C_p]}{\Delta t}$$

$\{F^*\}$ = equivalent thermal force matrix

$$= \frac{[C_p]}{\Delta t}\{\Delta T_{t-\Delta t}\}+\{\Delta F\}$$

Equation (32) provides nodal temperature within the time increment $\Delta t$.

Numerical solution of equation (32) requires the temperatures condition at the end of previous time step, hence a starting procedure is required. The equation used for the first time increment is

$$[K^*]\{T_{\Delta t}\} = \{F_{\Delta t}\} \qquad (33)$$

where $\{T_0\}$ = initial nodal temperature, $\{T_{\Delta t}\}$ = temperature increase for the first time increment, and $\{F_{\Delta t}\}$ = increase of thermal force during the first time increment. Equation (32) is very general form and can be easily solved on a digital computer. If the time step, $\Delta t$, and material thermal properties are constant with respect to temperature then $[K^*]$ can be calculated in the beginning of the program, stored and used in each succeeding calculation. Otherwise, all the calculations are to be repeated at each time step and the solution becomes lengthy. There are a number of ways to program equation (32) on a digital computer but even for a small practical problem, the storage space may become a limiting factor if all the elements of matrix $[K^*]$ are stored. An efficient use of memory space is achieved by discarding all the terms out of the bandwidth of the $[K^*]$ matrix. The resulting equation (32) is solved by the Gauss Doolittle elimination procedure

(Desai, 1979).

## Experimental Data for Model Validation

For the verification of the model a cylindrical rouglh rice storage bin is constructed. The bin is totally made of wood and completely filled up with rough rice of moisture content 15.7% (w.b.). The height and diameter of the grain bulk are 1.0 m and 0.8 m, respectively. Temperature data are collected at 3 levels (0.2 m, 0.5 m and 0.8 m from the surface of the grain bulk through the vertical axis of the cylinder). At each level one thermocouple is located and another thermocouple is also set at a radius 0.2 m from the center of the bin (0.5 m from the surface of the grain bulk). Thus 4 copper constantan thermocouple probes are connected to measure the temperature of the grains with the variation of ambient temperature. Ambient temperature is also recorded by thermocouple. Thermocouples probes are connected to an interface analog digital converter (Green kit 77A model) then to personal computer for data collection. The temperature reading from the thermocouple probes are recorded for every 1 hour. Data collected from April 1, to May 31, 1995 (1464 h.) are used to validate the model. Very little differences have been observed among the temperatures measured at 0.2 m, 0.5 m, and 0.8 m, from the surface of the grain bulk through the center of the bin. It indicates that heat transfer in the vertical direction is almost negligible in this small bin (0.8 m diameter). So temperatures collected at the center (0.5 m below the surface of grain bulk) of the bin and at a radius 0.2 m from the center of the bin are used to validate the model.

## Results and Discussions

The finite element heat transfer model is coded in BASIC to predict the temperature distribution in storage bin. The temperatures of the rough rice is simulated using 20 linear elements (21 nodes). Thermal and physical properties of rough rice are as follows: specific heat, 1.79 kj/(kg.°k); thermal conductivity, 0.106 W/(m°k) and bulk density, 579 kg/m$^3$ (ASAE,1993). Thermal and physical properties of bin wall materials are as follows: specific heat, 2.806 kJ/(kg°K); bin wall thickness, 15 mm; density, 550 kg/m$^3$; thermal conductivity 0.198 W/(m°K); and thermal diffusivity, 0.462 m$^2$/(h.10$^3$) (Mohsenin, 1980).

The initial temperature of the grain is assumed constant and equal to 15.7°C. The measured and predicted temperatures for $\Delta t = 1$ h and $\Delta r = 0.02$ m are shown in **Figs. 2** and **3**. The temperature predicted by the finite element model closely follows the measured values at the center of the bin (0.5 m from the surface of the grain bulk) and at a radius 0.2 m from the center of the bin (**Figs. 2** and **3**). The accuracy is found to be within 1.9°C at the center of the bin and within 2.1°C at a radius 0.2 m from the center of the bin. The model predicts the temperatures with a standard error of estimate of 1.01 at the center of the bin and 1.15 at a radius 0.2 m from the center of the bin.

This error of estimates are acceptable for analyzing stored rough rice ecosystems because grain temperature are also influenced by several other factors, including internal heat generation due to insect and microorganism respiration, variation in thermal properties of the grain due to moisture content of the grain at different dates and location in the bulk, internal heat generation, and foreign material content were not available. The thermal properties of the grains in space and time

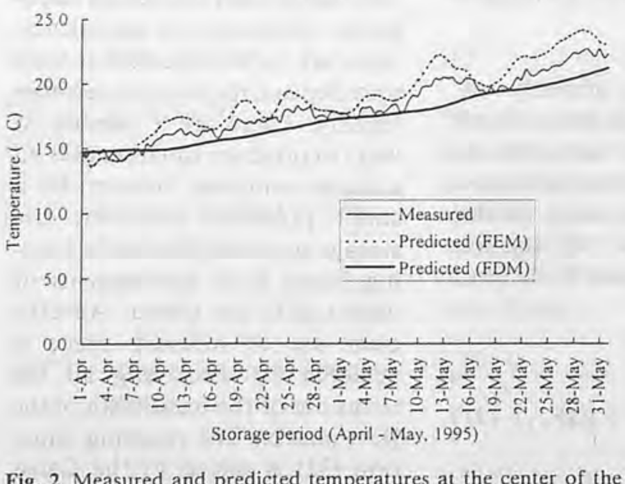


**Fig. 2** Measured and predicted temperatures at the center of the bin (0.5 m from the surface of the grain bulk).

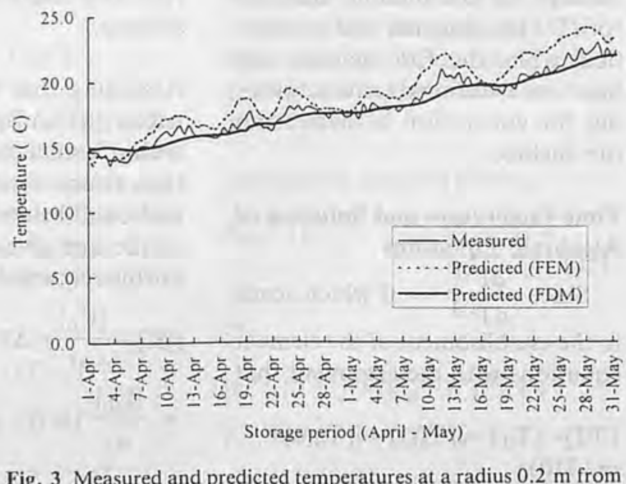


**Fig. 3** Measured and predicted temperatures at a radius 0.2 m from the center of the bin.

were assumed constant, internal heat generation was assumed to be zero. The accuracy of prediction might be improved by taking these factors into consideration.

The result of the FEM has been found to be stable and convergent for spatial element sizes in the range of 0.01 m-0.2 m and time element sizes in the range of 1-24 hour. This method gives a stable and convergent solution and reduces appreciably the volume of computer CPU time. With $\Delta r$ = 0.02 m and $\Delta t$ = 1 h, the total time for computation and printing results for a 12h interval is only 15 min in a microcomputer which is extremely lower than cited by Bala et al., (1989)

The finite difference heat transfer model is also developed with the same assumptions as have been used in the case of the finite element model to predict the temperature distribution during storage of rough rice (Basunia et al., 1994). The measured and predicted temperatures by FDM are shown in **Figs. 2** and **3**. There are almost negligible absolute numerical differences between the differences of the measured and the predicted temperatures by these two methods. In most cases the predicted temperatures by the finite difference model are slightly lower than the measured temperatures for both the locations of the bin which is very close to the theory. Because we have neglected the internal heat generation. But the main drawback is that the shape of the predicted temperatures curve by the FDM does not follow the shape of the measured temperatures curve. Measured temperature curves are fluctuating with the variation of ambient temperature but predicted temperature curves by finite difference model almost follows straight line.

In most cases the predicted temperatures by FEM are slightly higher than the measured temperatures at both locations of the bin (**Figs. 2** and **3**). But in most of the cases, the shape of the curve follows the shape of the measured temperature curve.

Even though both models predict temperatures with same degree of accuracy, the finite element model would be a better choice because of the fluctuating behavior of the predicted temperature curve with the fluctuations of ambient air temperatures. Also, it is possible to include variable thermal properties of the grain bulk in the finite element model due to moisture differentials and foreign materials.

The bin is small (0.8 m diameter) and the simulated temperature differential between the surface and the center of the bin is found to be small (about 1.5°C). This indicates that the risk of damage due to fungi and insects as a result of moisture accuumulation is minimum. Hence, if the grain is properly dried and if there is no addition of moisture through the wall of the bin, the bin would provide minimum protection for pests during a cold winter (below 20°C). Even though the temperature differentials are small during the hot summer, the temperature inside the bins are at optimum for reproduction of insects. The bin may allow more generations of grain insects, and measures should be taken to control their reproduction.

## Conclusion

A one-dimensional finite element model is developed to predict the temperature distribution in rough rice storage bin. The model with linear elements predict the temperatures in a 0.8 m diameter bin containing rough rice within an accuracy 1.9°C at the center of the bin and within an accuracy 2.1°C at a radius 0.2 m from the center of the bin. The finite element model is also compared with finite difference model but it seems to be more appropriate to use finite element model for the prediction of temperature changes during storage of rough rice.

This study also indicates that the proper design of a storage system should not only consider the structural requirements, but also the heat and moisture movement within the system to prevent or minimize the damage of grain during storage. This model can be simulated to determine the areas less vulnerable to insect infestation for long term storage of grains, and may used for advice on the selection of geographical location of Government storage facilities. This model can also be used in the design of non-aerated tall storage buildings and for advice on ventilation of the storage buildings generally.

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# Design and Development of A Continuous-flow Rotary Grain Dryer


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## Abstract

A continuous-flow grain dryer employing heated sand as heat transfer medium was designed, developed and tested for drying shelled maize. The machine performed well in drying, separating, recirculating hot sand and delivering dried grain. The principle of using a solid heat transfer medium for drying grain seemed to give definite promise of becoming a viable method of rapidly and efficiently drying grain. Results of drying experiments conducted with the equipment showed that initial sand temperature of 120°C, residence time of 21.818 sec and high moisture content of grain selected (28%) were the optimum values for efficient drying of shelled maize.


## Introduction

The prevention of food losses is of importance to the world food situation as a whole and has been given considerable attention by the Food and Agriculture Organization (FAO). Among the factors determining the extent of grain spoilage are moisture content, storage temperature and the access of oxygen to the stored material, the most important means of preventing deterioration of stored grain is the control of moisture content. Therefore, grain should be dried to a proper moisture content level before storage. The traditional method of grain drying in the country is sun-drying. It involves sufficient dry area exposed to the sun, more labor and risk of unfavorable weather conditions.

The artificial grain dryers use air as heat and moisture transfer medium. But the hot air drying has been described as an inefficient process (Foster, 1973). Grain drying in solid media has been extensively investigated and suggested to be a more effective drying method (Khan *et al*, 1974; Lapp *et al*, 1977; Mittal and Lapp, 1984; Richard, 1981a; Tessier and Raghavan 1984b; Younis *et al*, 1993).

Younis *et al* (1993) designed a mechanical-cum-manual dryer employing sand as heat transfer medium. However, it involved heating the sand in a bucket then manually pouring the heated sand and grain in the rotating drum and, finally, manually sieving the hot sand and dried grain. This caused heat loss and also was not practical for the farmers in bulk grain drying. In comparison, the dryer reported in this paper was designed and developed for continuous drying of cereal grain with heated sand.

## Design and Development of the Dryer

The continuous-flow grain dryer design is shown in **Fig. 1**. A brief description of its different components is given below.

**Drying Drum**

The drying drum, 113.4 cm long was the major component of the dryer. A helix, **Fig. 2**, that is 15.24 cm high made of 15 gauge

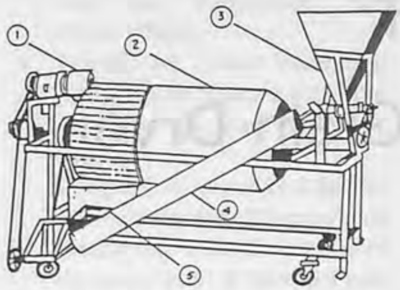


Fig. 1 A view of the continuous dryer (1. gear motor, 2. drying cylinder, 3. grain hopper, 4. augur, 5. sand pan).

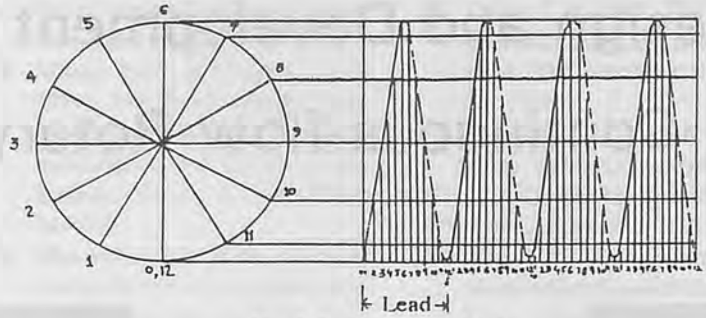


Fig. 2 Development of helix.

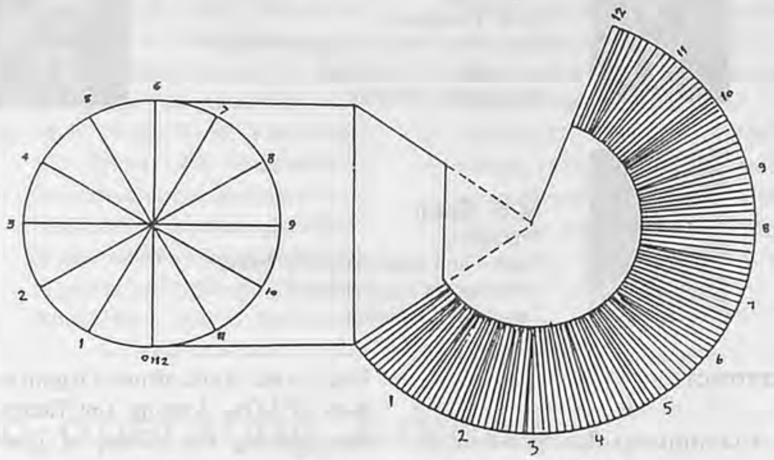

Fig. 3 Development of conical feeding and of the dryer.

mild steel (M.S.) sheet was welded inside the drum for conveying and mixing the hot sand and wet grain. It was designed in such a way that four revolutions of the drum could transfer the material from the feeding end of the drum to the exit section. The conical feeding end (46.5 cm dia.) developed for the study is shown in **Fig. 3**. The exit section of the drying drum was 28.2 cm long that controls the material on the sieving mechanism. Two 30 cm-wide, semi-circular 18 gauge M.S. shields were provided to avoid the loss of material. The lower shield had rectangular opening of 27 cm × 19.5 cm dimensions.

### Sieving System

A vibratory sieving system with adjustable sieve of 56.4 cm × 30 cm was designed. The sieve had adjustable motion in horizontal as well as in vertical directions by changing or adjusting the hangers and length of the vibrating crank (**Fig. 4**).

### Heating System

The sieve under the exit end of the drum was bolted with a rectangular 56.4 cm × 30 cm heating box. Due to vibrations and slope of the box, hot sand could be conveyed to the feeding end of the conveyor. During the conveyance of sand to the conveyor augur, the heat losses were compensated by a natural gas burner covering 1 692 $cm^2$ area of bottom face of the heating box. The burner had four distribution pipes of 2.5 cm dia. each and lengths of 40, 39, 29 and 33 cm. Holes of 0.156 cm dia. at 1.25 cm distance were drilled in these pipes for uniform distribution of flame under the heating box.

### Conveying System

This system was designed to convey hot sand from the heating system to the feeding section of the drying drum. The system was composed of a screw conveyor with spiral flighting on a pipe of 2.5 cm dia. and fitted inside the main pipe of 11.5 cm length, insulated with a mixture of asbestos and plaster of Paris to avoid heat losses in the conveyance of hot sand.

### Development of Screw Conveyor

The screw surface of augur con-

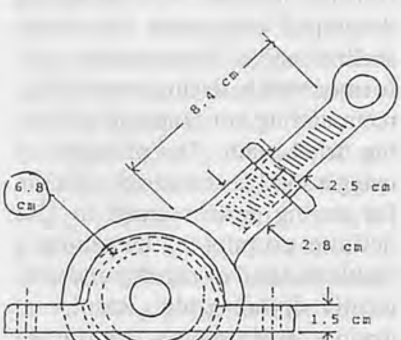


Fig. 4 Vibrating crank of sieving system.

volutions was made from 0.15 cm thick sheet metal rings of an inner and outer dia. of 3.7 and 12.5 cm, respectively (**Fig. 5**). The periphery of each ring, after bending it along the helical line, was made equal to the pitch length of the outer edge of the helical line. The inner ring length of periphery, on the other hand, was equal to the pitch length of the inner edge of the helical line. The inner edge was

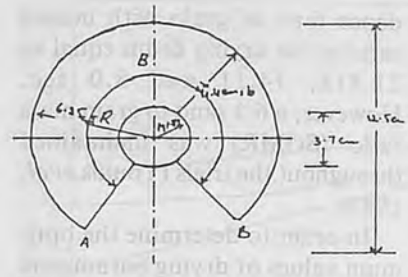

Fig. 5 Cut of sheet metal for auger convolutions.

welded to a 2.5 cm dia. 0.3125 cm thick pipe constituting the augur's shaft. The lateral edges of one ring were welded to the appropriate lateral edges of another convolute ring, thus forming a continuous helical surface of an arbitrary length.

## Conveyor Design Considerations

The convolutions of the auger are located in a tight tubular casing. The helical line represented the path described by a given point, 'A' in **Fig. 6** moving along the circle of a given radius "R" in the Plane X-Z and, also, traveling along the axis O-Y. In the moment of time considered when point "A" has taken position "$A_1$" that has simultaneously travelled over the plane X-Z were expressed by Kanafojski and Karwowski, 1976 as follows:

$X = R \cos\theta$ (i)
$Z = R \sin\theta$ (ii)
$Y = A_1B = OO_2 = V_yt$
or $Y = V_yt$
or $t = Y/V_y$ (iii)

Where,

$V_y$ = Speed of travel of the point considered along the "OY". The length on the other hand, of the arc "L" described by a considered point in the same time along the circle circumference.

$AA_1$ amounts to $L = R\,t = R\theta = AA_1$ (Where $\theta$ is in radians) substituting value of "t" from Equation (iii)

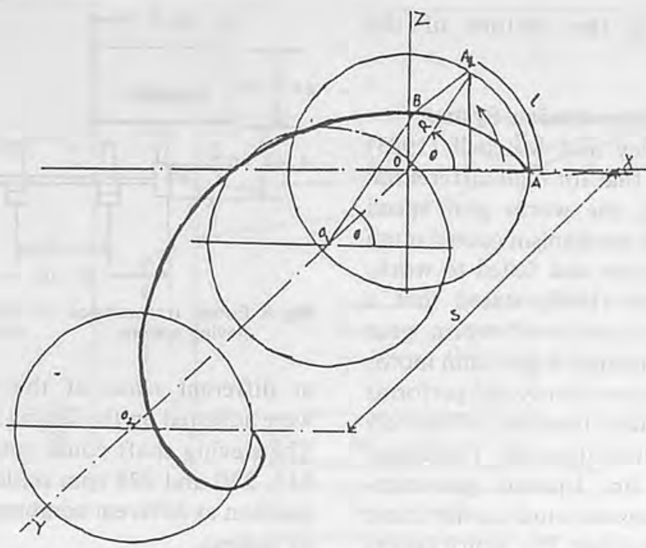


Fig. 6 Determination of coordinates of point (B) on auger convolution helical line.

$L = \omega RY/V_y = R\theta$
or $\theta = \omega y/V_y = \omega t$
or $Y = \theta V_y/\omega$
After substituting $\omega = 2\pi/T$ and $V_y = S/T$
Where,
T = Time period for a full point revolution
S = pitch of the helix.
Therefore, $Y = S\theta/2\pi = SWt/2\pi$, is the value of Y-coordinate. The speed, on the other hand, with which the considered point travels towards the axis Y amounts, is known as $dy/dt = S/2\pi = V_y$.
The operational efficiency of the augur "$\eta$" is expressed by the formula of Kanafojski and Karwowski, 1976 as follows:

$\eta = \pi D^2/4 \times qSn\gamma = \gamma F v_0$, kg/sec.

Where,
D = Diameter of the auger outer edge.
q = Coefficient of filling of auger tube.
S = Pitch of auger.
n = Number of revolutions.
$\gamma$ = Specific gravity of transported material.

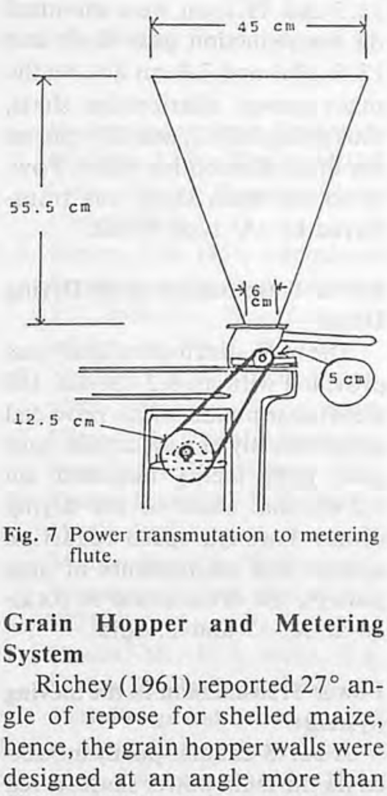


Fig. 7 Power transmutation to metering flute.

## Grain Hopper and Metering System

Richey (1961) reported 27° angle of repose for shelled maize, hence, the grain hopper walls were designed at an angle more than 27° to avoid sticking of the wet grain on side walls of the hopper. The grain hopper 55.5 cm deep and 45 cm × 45 cm upper feeding area, is shown in **Fig. 7**. About 20 kg of wet wheat could be stored in the hopper. An adjustable grain metering mechanism to supply the desired volume of grain was installed at the bottom of the hopper.

### Power Transmission System

Shighley and Mitchell (1983) reported that for high differential in speed, the worm gear speed reduction mechanism caused more power losses and failed to work. Pumphery (1959) stated that a better substitute of worm gear speed reduction is gear cum motor which is more sturdy and performs its intended function effectively without loss of power. Therefore, a 0.25 hp 3-phase gear-cum-motor, was mounted on the frame of the machine. The motor generated 51 rpm on the reduction gear shaft. Step pulleys with dia. of 10, 12.5 and 15.1 cm were mounted on the reduction gear shaft and 12.5, 10.1 and 7.3 cm dia. on the main power distribution shaft, thus giving 38, 61, and 105 rpm on the main distribution shaft. Power to the main shaft was transferred by 'A' type V-belt.

### Power Transmission to the Drying Drum

The main distribution shaft was provided with an 8.2 cm dia. (30 teeth) gear pinion which provided power directly to a 27 cm dia. spur gear (105 teeth) mounted on 3.2 cm dia. shaft of the drying drum. Through speed reduction system and adjustments of step pulleys, the drum could be rotated at 30, 17 and 11 rpm.

### Power Transmission to the Sieving System

A 26.75 cm dia. pulley mounted on the main power shaft served as driver pulley of the sieving system pulleys. This system has 28 cm long and 2.55 cm dia. shaft lying at 83 cm distance from the main shaft and supported by two CPS 205 bearings between pulleys and crank (**Fig. 8**). Three pulleys of 4.0, 5.3 and 10.8 cm, to transmit required speed to the system

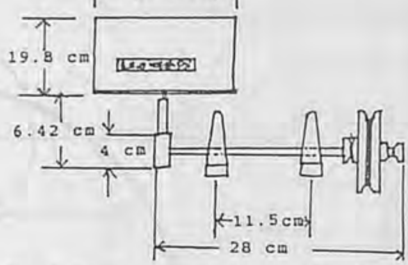

Fig. 8 Power transmission to vibrating sieving system.

at different rpms of the drum were adjusted on the sieving shaft. The sieving shaft could rotate at 310, 270 and 228 rpm on loaded position at different combinations of pulleys.

### Power Transmission to the Conveyor

The conveyor formed 35° angle in horizontal position and its shaft was supported at the ends by two CSP 265 bearings. The pulleys of the conveyor were driven by a 14.5 cm dia. pulley on the main power shaft, at 72 cm distance from the conveyor shaft. The conveyor shaft could rotate at 40, 72 and 116 rpms on different rpms of the main shaft. The speeds of conveyor shaft were matched with different speeds of the drying drum for timely conveying of the hot sand from the heating system to the feeding section of the drum.

### Power Transmission to Grain Metering System

The metering flute of the grain hopper was rotated at 28, 43 and 72 rpms on 11, 17 and 30 cm driver pulley coupled through a V-belt to a 12.5 cm dia. pulley on the drying shaft.

### Optimum Operating Conditions

After the development of the continuous flow dryer, investigations were made for drying corn grain using initial sand temperature of 90, 105 and 120°C, grain moisture content of 28, 23 and 18% wet basis (w.b.) and the residence time of grain with heated sand in the drying drum equal to 21.818, 14.11 and 8.0 sec. However, a 6:1 sand to grain mass ratio (SGMR) was maintained throughout the trials (Younis *et al*, 1993).

In order to determine the optimum values of drying parameters for shelled maize, the maximum moisture removal points and maximum efficiency points for all variables, i.e., grain moisture content, sand temperature and residence time were plotted. **Figs. 9** and **10** show that the point $O_1$ and $O_2$, where all the curves intersected, were the optimal points for moisture removal and drying efficiency for drying shelled grain. The maximum moisture content removed and drying efficiency obtained for these conditions were 3.44% (w.b) and 58.87%, respectively. Hence, it was found that a sand temperature of 120°C, residence time of 21.818 sec and high moisture content of selected grain (28%) were the optimum values for efficient and economical drying of shelled maize.

## Conclusions

As a result of this study the following conclusions were drawn:

1. Sand could be successfully adopted for drying cereal grains with an increase in drying efficiency when used in a continuous drying process.
2. The performance of hot sand as a heat transfer medium was found to be superior to conventional hot air system in drying efficiency.
3. A maximum 3.44% (w.b.) moisture content was removed on 28% (w.b.) moisture content grain at 21.818 sec time with initial sand temperature of 120°C.
4. The removal of moisture content from grain was found

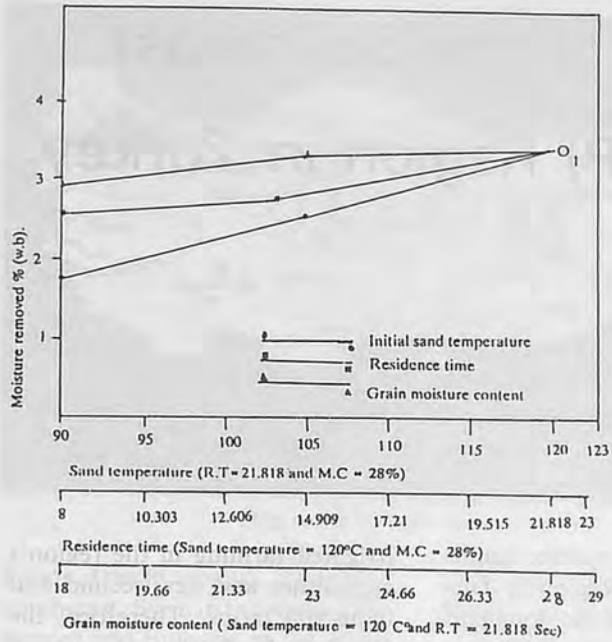


**Fig. 9** Best condition for drying corn grain in the experiment.

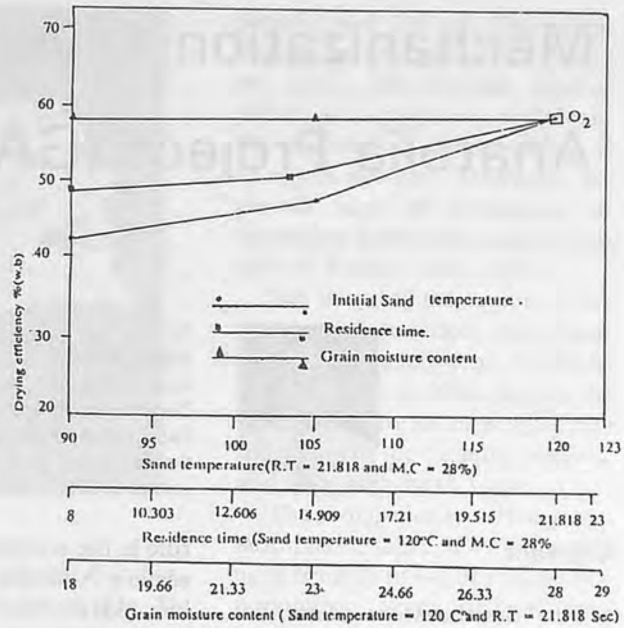


**Fig. 10** Best condition for drying efficiency for corn grain in the experiment.

proportional to the initial temperature of sand.

5. The removal of moisture content decreased with a decrease in residence time.
6. The highest drying efficiency of 58.87% was obtained with 28% (w.b.) grains moisture content at 21.818 sec residence time and 120°C sand temperature.
7. A residence time of 21.818 sec and 120°C temperature of sand were found the best conditions for drying shelled maize.
8. No difficulty during the operation of machine was experienced. The separated grains were found clean and no sand particles were observed on the grains' surfaces.
9. No change in color of dried grain was observed.

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# Mechanization Level of the Southeast Anatolia Project (GAP) Region in Turkey

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## Abstract

The Southeastern Anatolia Integrated Development Project, referred to as GAP (short in Turkish), comprising 13 energy and irrigation sub-projects, has been introduced by the Turkish Government in order to increase the region's agricultural productivity and to accelerate the industrialization and development of the region.

The GAP will produce enormous changes in the agricultural sector which has an important role in the region's economy. With the completion of the GAP project in Turkey, which will be by the year 2012, around 1.7 million ha of land (approximately 19% of the total irrigable area in Turkey) will be opened to irrigation and the national agricultural production will double.

It is obvious that the region should be described in terms of different aspects, particularly the level of mechanization at present. This paper provides some information related to the general characteristics and mechanization level of the region.

## Introduction

Agriculture plays an important role in the economy of the Southeastern Anatolia Region in Turkey. Agriculture is the dominant activity in the region contributing about 39.6% to the region's GRP (Gross Regional Product) while manufacturing contributes 11.7%. The majority of the region's population (around 70%) are earning their living from the agricultural sector (SPO, 1989). However, arid farming has been practised due to the lack of an irrigation scheme.

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With the completion of the GAP project in Turkey, which will be by the year 2012, around 1.7 million ha of land (approximately 19% of the total irrigable area in Turkey) will be opened to irrigation and the national agricultural production will double. North Mesopotamia which served mankind for thousands of years will achieve advancement again. It is obvious that the farmers will need to use extensive mechanization due to the shift from arid to irrigated farming in the region's agriculture and new second and industrial crops. Therefore, the farmers should be encouraged to choose proper agricultural machinery, particularly tractors, which are the largest farm inputs in agricultural mechanization (Kirişci, 1994).

This paper provides a brief information about Turkey and the Southeast Anatolia region. The importance of agriculture within both the national and the region's economy is also reviewed and the scope of the Southeast Anatolia Project is introduced.

## The Country

Turkey is a country at a meeting-point of Europe, Asia and the Middle East. To define it as "a natural bridge" between the continents would be appropriate not only in terms of geographical position but also due to its widespread mosaic of different cultures.

Turkey lies between the latitudes of 36° and 42° north and the longitudes of 26° and 45° east. Three sides of the country are surrounded by sea and it has a border with Georgia, Ermenia and Nahcivan in the north-east which are located in former Soviet


Fig. 1 The location map of Turkey.

Union, Iran in the east, Iraq in the south-east, Syria in the south-east, Greece and Bulgaria in the north west, with land borders of 2 753 km long (**Fig. 1**).

The total area of Turkey is 779 452 km$^2$ of which Anatolia (the Asian part) is 755 688 km$^2$ and Thrace (the European part) is 23 764 km$^2$ (SIS, 1993).

According to the 1990 census, the population of the country was about 56.473 million with an annual growth rate of about 2.17%. The average population density is 73 capita per km$^2$ (SIS, 1993).

Turkey is situated in the temperate zone. Thus, it has a variety of climatic features. The country is subject to both continental types of climate which is characterized by rainy weather throughout the year, and to a sub-tropical climate distinguished by dry summers. The average annual rainfall in Turkey varies between 325 mm and 1 200 mm depending on location and region.

## The Southeast Anatolia Project (GAP) Region

The Southeast Anatolia Project (GAP) Region covers eight provinces: Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt Şanlıurfa and Şırnak (**Fig. 2**).

The region's land area is approximately 76 263 km$^2$ which is almost 9.78% of Turkey's total land area. The area of each province and the proportion in both Turkey and the GAP region is shown in **Table 1**.

According to the 1990 census, the population of the region was about 5 158 013 which is 9.1% of the nation's total population (**Table 2**). The density in the region varies between 37 (in


Fig. 2 Location map of the GAP region.

Şırnak) and 149 (in Gaziantep) having an average of 68 capita per km$^2$. The average density differs at 5 capita per km$^2$ from the national average which is 73 capita per km$^2$. However, the growth rates of population in the region have been higher than that of Turkey since 1945.

The share of the region in the national population has been slightly increasing from 7.0% in 1945 to 9.1% in 1990, despite the intensive migration of people from the region to the big cities outside, and very high birth rates.

The economically active population has a share of 47% (people aged from 15 to 64) of the region's population. Some 70% of these are working in agriculture while services and industry sectors have 21% and 8%, respectively. **Table 2** shows that 46.3% of the region's population live in rural areas.

The continental climate, characterized by two distinct seasons of a dry and hot summer

**Table 1.** Area of Provinces in the GAP Region

| Province | Area [km$^2$] | % of GAP Total | % of Turkey Total |
|---|---|---|---|
| Adıyaman | 7423 | 9.73 | 0.95 |
| Batman | 4694 | 6.16 | 0.60 |
| Diyarbakır | 14908 | 19.55 | 1.91 |
| Gaziantep | 8015 | 10.51 | 1.0 |
| Mardin | 8594 | 11.27 | 1.10 |
| Siirt | 6186 | 8.11 | 0.80 |
| Şanlıurfa | 19271 | 25.27 | 2.47 |
| Şırnak | 7172 | 9.40 | 0.92 |
| GAP Total | 76263 | 100.00 | 9.78 |
| Turkey Total | 779452 | — | 100.00 |

Source: SIS, (1993).

**Table 2.** Population Statistics of the GAP Region and Turkey

| Province | Population | | | | |
|---|---|---|---|---|---|
| | Total | Rural Number | Rural [%] | Density [Capita/km$^2$] | Growth [%] |
| Adıyaman | 513131 | 293827 | 57.3 | 67 | 3.501 |
| Batman | 344669 | 151048 | 43.8 | 73 | 3.772 |
| Diyarbakır | 1094996 | 494356 | 45.1 | 71 | 3.170 |
| Gaziantep | 1140594 | 319467 | 28.0 | 149 | 3.304 |
| Mardin | 557727 | 308695 | 55.3 | 63 | 2.587 |
| Siirt | 243435 | 133296 | 54.8 | 45 | 1.250 |
| Şanlıurfa | 1001455 | 450331 | 45.0 | 54 | 4.616 |
| Şırnak | 262006 | 136742 | 52.2 | 37 | 3.898 |
| GAP | 5158013 | 2387762 | 46.3 | 68 | 3.732 |
| Turkey | 56473035 | 23146684 | 41.0 | 73 | 2.171 |

Source: SIS, (1993) and 1990 Census.

and a cold and rainy winter, is dominant in the region. The average annual rainfall in the region varies between 467 mm and 757 mm (Sındır, 1992).

## GAP's Position in the National Economy

The Gross Regional Product (GRP) of the GAP region in 1985 is compared with the Gross Domestic Product (GDP) of Turkey and given in **Table 3**.

So far agriculture has been the dominant production sector, claiming a share in the region's GRP of close to 40%. In this sector the region contributes around 9% of the agricultural value-added of Turkey. Manufacturing accounts for 11.7% of the GRP, contributing only 1.9% of this sector's value-added of the country.

As a whole, the region's economy claims a modest share of 4.02% in Turkey's GDP, much lower than its population share of 8.5% in 1985. The per capita GRP of the region was only 47% of the per capita GDP of the country in 1985.

## What Is the GAP?

The GAP stands for the Southeastern Anatolia Project in Turkish, an integrated development project which was originally planned by the State Water Affairs (SWA) primarily for irrigation and hydropower generation. With its 13 energy and irrigation sub-project packages, it comprises the construction of 21 dams and 17 hydroelectric power plants on the Fırat (Euphrates) and Dicle (Tigris) rivers and their tributaries.

The GAP has been introduced in order to increase mainly the region's agricultural productivity and to speed up the industrialization and development of the region. The basic features of the project, including the total land under rainfed and irrigation in the region, without and with the presence of the GAP, are illustrated in **Table 4**. Although the project has been planned to be completed by 2002, the experts interviewed indicated that this would not be possible before the year 2012.

## Present Problem Structure in the GAP Region

The GAP region at present faces many problems which vary between the most fundamental and the most immediate ones. These problems are interacting with each other. Major problems and interactions are shown in **Fig. 3**. The most immediate development problems indicating the objectives for the region's development are summarized by the State Planning Organization (SPO) as listed in **Table 4**.

More specifically, the problems may be summarized as follows:

- Low income level due to immature economic structure, characterized by a small share of the manufacturing industry sector and dominance of low productivity rain-fed agriculture and livestock,
- Migration from villages to larger cities in and out of the region.

The most fundamental ones can be enumerated as follows:

- Unfavourable topographic and climatic conditions, in particular maldistribution of water resources and low productivity land without land/water management,
- Distortion of land distribution/ownership,
- Low levels of education and health services,
- Lack of proper planning and management for resource utilization.

To overcome these problems, the main objectives for the development of the GAP region are set by the State Planning Organization (SPO) as follows:

- To raise the income levels in the GAP region by improving the economic structure in order to narrow the income disparity between the GAP region and other regions,
- To increase the productivity and employment opportunities in rural areas,
- To enhance the assimilative

**Table 3.** Gross Regional Product of the GAP Region, 1985

| Sector | GAP Billion US$ | GAP % to GAP | Turkey Billion US$ | GAP as % of Turkey |
|---|---|---|---|---|
| Agriculture | 846 | 39.59 | 9442 | 8.96 |
| Industry | 335 | 15.68 | 16898 | 1.99 |
| Manufacturing | 250 | 11.70 | 13422 | 1.86 |
| Services | 956 | 44.74 | 26864 | 3.56 |
| GDP or GRP Total | 2137 | 100.00 | 53205 | 4.02 |

Source: SPO, (1989).

**Table 4.** Basic Features of the GAP

| Item | Without Project | With Project |
|---|---|---|
| Irrigation Means (ha) | | |
| Total cultivable land | 3081182 | 3081182 |
| Land under irrigation | 120740 | 1641282 |
| Land under rainfed | 2960442 | 1439900 |
| Power Generation Means | | |
| Installed capacity (MW) | 16 | 7561 |
| Energy generation (GWh/year) | 48 | 25003 |
| Crop Production Means ('000 t) | | |
| Wheat | 1994 | 3279 |
| Cotton | 177 | 859 |
| Tomato | 215 | 1584 |
| Groundnut | — | 156 |
| Soybean | — | 316 |
| Maize | 16 | 281 |

Source: SPO, (1989).

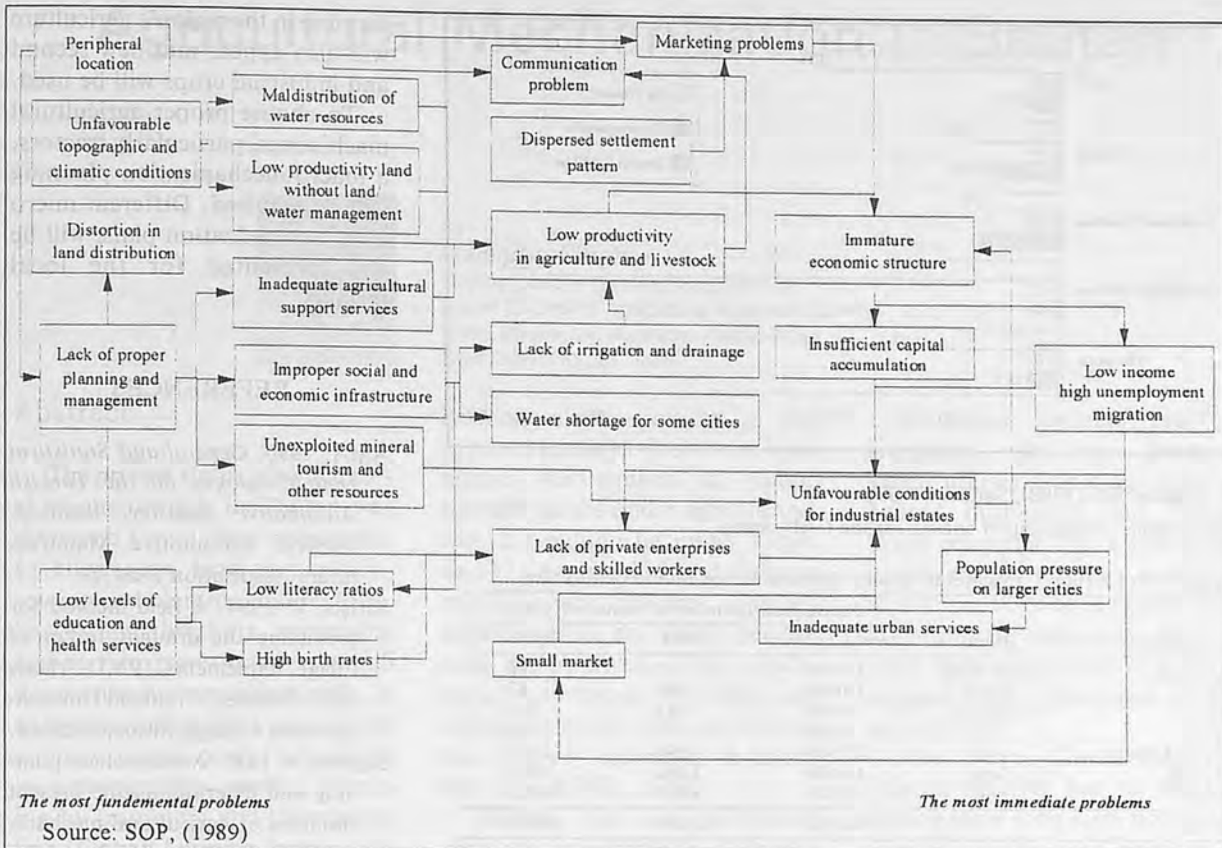



Fig. 3 The problem structure in the GAP.

capacity of larger cities in the region,

- To contribute to the national objectives of sustained economic growth, export promotion, and social stability by efficient utilization of the region's sources.

There are some major constraints to the agricultural development in the region. These are also summarized by the State Planning Organization (SPO) as follows:

- Agro-ecological conditions, i.e., low and non-uniform rainfall distribution, very hot summer season, and extended dry periods,
- The prevalence of low yield agricultural technologies with limited input use and commercialization,
- Low level of farm mechanization and modernization.

## Mechanization Level in the GAP Region

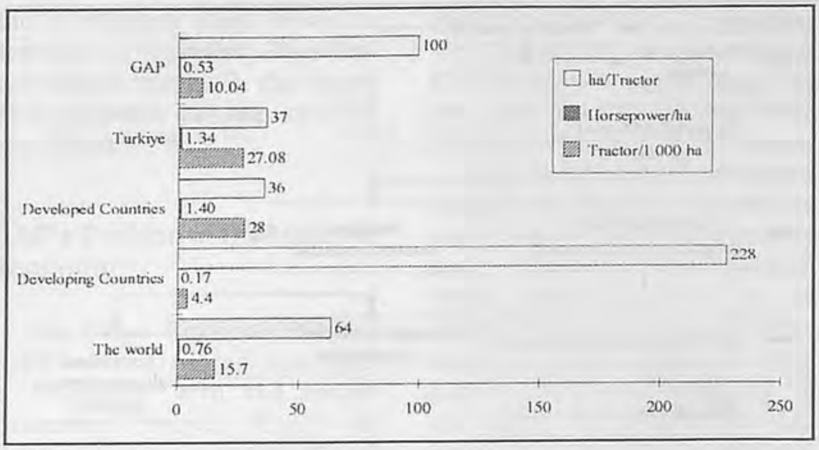
The number of tractors and machinery in the region are shown in **Table 5**. The region is relatively much less well equipped with these machinery and implements than the country as a whole. This is due to dry land farming system, fragmented land ownership and land tenure systems and the difficulty by which farmers with very low income obtain farm credit.

There are no organized tractor and machinery hiring services in the region but such services are very common in Turkey, especially for harvesting operations. For example, combine harvesters move from one region to another depending on crop maturity. Tractors and machinery are usually

**Table 5.** Number of Agricultural Machinery and Tractors in the GAP Provinces Compared with Turkey, 1990

| Machine | GAP | Turkey | GAP as % of Turkey |
|---|---|---|---|
| Tractor plough | 35 979 | 770 833 | 4.67 |
| Furrow opener | 563 | 31 243 | 1.80 |
| Rotary cultivator | 215 | 12 318 | 1.75 |
| Cultivator | 21 571 | 284 677 | 7.58 |
| Roll | 3 846 | 39 198 | 9.81 |
| Disc and other harrows | 4 194 | 152 390 | 2.75 |
| Spike tooth harrow | 1 340 | 356 171 | 0.38 |
| In row cultivator | 1 814 | 90 103 | 2.01 |
| Cereal drill | 12 069 | 162 061 | 7.45 |
| Universal planter | 493 | 58 838 | 0.84 |
| Fertilizer spreader | 15 233 | 176 015 | 8.65 |
| Baler | 18 | 7 170 | 0.25 |
| Thresher | 7 785 | 197 869 | 3.93 |
| Combine harvester | 478 | 11 742 | 4.07 |
| Mower | 1 897 | 20 104 | 9.44 |
| Knap-sack sprayer | 8 010 | 418 736 | 1.91 |
| PTO driven sprayer | 2 775 | 117 583 | 2.36 |
| Engine driven sprayer | 371 | 57 381 | 0.64 |
| Water pump | 14 061 | 418 546 | 3.36 |
| Sprinkler system | 559 | 104 224 | 0.54 |
| Milking machine | 173 | 9 636 | 1.80 |
| Trailer | 29 790 | 648 844 | 4.60 |
| Tractor | 33 111 | 692 454 | 4.78 |

Source: SIS, (1993).




Source: SIS (1988), Sağlam (1987)

**Fig. 4** Some mechanization criteria for the GAP region.

**Table 6.** Production Capacities in Tractor Manufacturing Industry in Turkey

| Company | Brand | Production [number of units per year] | | |
|---|---|---|---|---|
| | | Read Capacity | 1989 | 1990 |
| Çumitaş | John Deere | 10000 | 0 | 0 |
| Hema | Ford | 10000 | 344 | 57 |
| Iltor | Goldoni | 3400 | 463 | 648 |
| TOE | TOE | 4000 | 0 | 0 |
| Türk Traktör | Fiat | 22500 | 7594 | 12303 |
| TZDK | Steyr | 15000 | 2064 | 4474 |
| Uzel | MF | 30000 | 8419 | 14955 |
| Total | | 94000 | 18884 | 14955 |

Source: AMA (1990).

hired from local farmers in the same village.

The measure "*number of tractors per 1 000 ha*" in the GAP in 1988 was 10.04, almost one third of the national average of 27.08 (**Fig. 4**) while the average figure was approximately 28.00 for developed countries, 4.40 for developing countries and 15.70 for the whole world. Other measures, "tractor horsepower per hectare" and "area in hectares per tractor" are also shown as a comparison with Turkey, the world, the developed and developing countries.

In the region most of the machinery used in agriculture are produced locally in order to meet the local demands. However, there is no tractor manufacturing establishment in the region. All of the tractors used are provided from the tractor manufacturers in other regions which are shown in **Table 6**.

## Conclusions and Recommendations

The GAP project will open up around 1.7 million ha of land for irrigation in Turkey. As a result of this the national agricultural production is expected to double. An extensive mechanization due to the shift from arid to irrigated farming in the region's agriculture will also appear and new second and industrial crops will be used.

To choose proper agricultural machineries, particularly tractors, a macro-mechanization planning will be required. Different micro level mechanization plans will be also presented for the local farmers.

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# Agricultural Mechanization in Bhutan

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## Abstract

The present status of agricultural mechanization in Bhutan was discussed for all farm operations. In hilly areas, land preparation, sowing and planting, interculture, harvesting, threshing, processing and on farm transportation, are all done using human labour only. In valleys and Southern part of the country animal power is used for land preparation, sowing, threshing by trampling and transportation. Only a few rich farmers use mechanical power such as stationary engine, power tiller and tractor for farm operations. To overcome labour shortage and increase intensity of cropping there is an urgent need to add more mechanically powered equipment in Bhutan. Though the Agricultural Machinery Centre (AMC) was established by the government to popularize improved tools and implements, indigenous and crude tools and implements are predominant on Bhutanese farms. In this paper, criteria to be met before introducing any improved tools and equipments in Bhutanese agriculture are described on the basis of which appropriate tools and equipments for various farm operations are suggested.

## Introduction

Bhutan is a small and extremely mountainous country in the eastern Himalaya. It covers a land area of 4.65 million ha. About 632 000 ha are under agricultural use, 2.3 million ha under forest and 471 thousand ha under alpine meadows and pastures. The remaining areas are under permanent snow cover, scrub lands, rocky mountains, river beds and urban settlement. The population was recently estimated at about 600 000 (RGOB, 1992).

Bhutan has an extremely diverse agro-climate due to major differences in altitude and orography. The country has been divided into 6 agro-climatic zones based on temperature (determined by altitude) and rainfall (DOA 1990). These six zones are: alpine; cool temperature; warm temperate; dry sub-tropical; humid sub-tropical; and wet sub-tropical (**Fig. 1**).

Bhutanese farmers practice integrated subsistence farming which utilises arable agriculture, animal husbandry and forest. Rural economic life is still largely outside the monetry economy with about 90% of the agricultural products consumed locally. Over 70% of the labour force is engaged in agriculture and related activities.

The Royal Government of Bhutan (RGOB) has set the following three long term policy objectives for the crop production sector during the 7th and 8th Plan periods (1993-2002).

1. To establish sustainable production systems through improved soil fertility and by conservation of soil and water resources.
2. To increase the production of cereal and oilseed crops leading

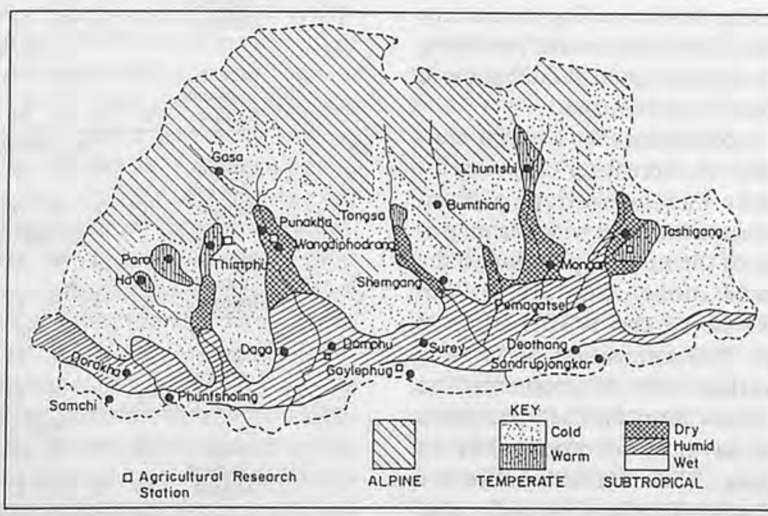


Fig. 1 Agro-ecological zones of Bhutan.

to greater rural self-sufficiency and reduced dependence on imports.

3. To increase the production of horticultural and grain legume crops both for export and for the domestic market leading to higher farm incomes, greater economic growth and increased export earnings.

The RGOB's policy of self-sufficiency in cereals and oilseeds is part of its broader policy objective of national self-reliance. Economic development has been accompanied by increased dependence on external sources for essential food commodities. It is proposed to achieve a 70% self-sufficiency in rice and wheat and 100% in oilseeds by the year 2002. To achieve this one project, "The Farm Tools and Equipment Project" is aimed at developing the Agricultural Machinery Centre (AMC) into an effective institution with the aim of providing the adoption of suitable equipment and tools to meet the varied requirements of the main farming systems in the country.

## Agricultural Machinery Centre (AMC)

The AMC was established in 1983 at Bondey Farm, Paro, charged with the objective of making labour-saving machinery available to farmers and providing a wider impact in reducing farm labour requirements.

Recognizing that a major constraint in increasing cropping intensity was the shortage of farm labour, combined with the migration of the rural population to the urban areas, the Sixth Plan 1987-92 of the RGOB directed that "Mechanization of farming practices will be accelerated to alleviate farm labour constraints and to increase productivity of labour." To achieve this objective it was further stated that "strengthning of the mechanization programme will include testing and supply of suitable farm machinery, development of traditional farm implements to increase their efficiency, establishment of regional workshops to provide maintenance and repair facilities, training of mechanics, operators and farmers, and ensuring a regular supply of spare parts." AMC, as implementor of these goals, established both a manufacturing and a training unit in 1987 and an electrical workshop in 1988.

## Labour Constraints

An analysis of requirements and availability of labour for each of three sizes of farms in the five agro-ecological zones of Bhutan was carried out by the Farm Economics team of the UNDP/FAO Mission (**Table 1**). Under prevailing management and cropping systems it appears that small (0.75 ha) and medium (1.50 ha) size land holders are able to meet their low and peak labour requirements from either their own or exchange labour resources (**Tables 2a** and **2b**). Larger farmers (4.0 ha) do experience labour shortages between July and November in most of the zones (**Table 2c**) which can only be solved by employing casual labour. If, however, increased cropping intensity will be required to meet the goal of greater national self-sufficiency in cereal and oil seeds then further crop labour inputs will be required. It is felt that this could be absorbed on smaller farms if improved tools and equipment are made available for adoption and paid for by increased yields. Larger farmers, however, will increasingly turn to mechanized

**Table 1.** Farm Labour Availability

| | Farm size | Family size | No. of family workers | Days/months per worker | Total days per month |
|---|---|---|---|---|---|
| Small | 0.75 ha | 5.5 | 1.8 | 25 | 45 |
| Medium | 1.5 ha | 7.0 | 2.3 | 25 | 58 |
| Large | 4.0 ha | 8.5 | 2.8 | 25 | 70 |

Source: CSO Agronomic Survey/AFPP Draft Report Vol. II, Plan of Action.

**Table 2a.** Monthly Labour Requirements and Family Labour Balance (mandays) on Small Farms (0.75 ha)
Availability of Family Labour = 45 mandays

| Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperate Zone | | | | | | | | | | | | |
| Labour demand | 29 | 29 | 26 | 17 | 20 | 28 | 30 | 25 | 23 | 27 | 26 | 26 |
| Balance | 16 | 16 | 19 | 28 | 25 | 17 | 15 | 20 | 22 | 18 | 19 | 19 |
| Warm Temperate Zone | | | | | | | | | | | | |
| Labour demand | 29 | 31 | 22 | 21 | 22 | 25 | 35 | 31 | 33 | 33 | 29 | 32 |
| Balance | 16 | 14 | 23 | 24 | 23 | 20 | 10 | 14 | 12 | 12 | 16 | 13 |
| Dry Sub-tropical Zone (West) | | | | | | | | | | | | |
| Labour demand | 29 | 33 | 36 | 27 | 23 | 22 | 36 | 33 | 33 | 36 | 34 | 34 |
| Balance | 16 | 12 | 9 | 18 | 22 | 23 | 9 | 12 | 12 | 9 | 11 | 21 |
| Dry Sub-tropical Zone (East) | | | | | | | | | | | | |
| Labour demand | 33 | 30 | 36 | 23 | 21 | 21 | 29 | 36 | 29 | 30 | 24 | 25 |
| Balance | 12 | 15 | 9 | 22 | 24 | 24 | 16 | 9 | 16 | 15 | 21 | 20 |
| Humid Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 33 | 34 | 37 | 22 | 20 | 19 | 28 | 27 | 30 | 22 | 25 | 26 |
| Balance | 12 | 11 | 8 | 23 | 25 | 26 | 17 | 18 | 15 | 23 | 20 | 19 |
| Wet Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 32 | 30 | 36 | 22 | 20 | 21 | 34 | 28 | 33 | 24 | 26 | 26 |
| Balance | 13 | 15 | 9 | 23 | 25 | 24 | 11 | 17 | 12 | 21 | 19 | 19 |

Source: UNDP/FAO Accelerated Food Production Programme, Bhutan 1990.

**Table 2b.** Monthly Labour Requirements and Family Labour Balance (mandays) on Medium Farms (1.5 ha)
Availability of Family Labour = 58 mandays

| Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperate Zone | | | | | | | | | | | | |
| Labour demand | 37 | 36 | 38 | 23 | 31 | 45 | 45 | 37 | 33 | 39 | 37 | 30 |
| Balance | 21 | 22 | 20 | 35 | 27 | 13 | 13 | 21 | 25 | 19 | 21 | 28 |
| Warm Temperate Zone | | | | | | | | | | | | |
| Labour demand | 35 | 38 | 32 | 31 | 33 | 39 | 58 | 50 | 52 | 51 | 43 | 41 |
| Balance | 23 | 20 | 26 | 27 | 25 | 19 | 0 | 8 | 6 | 7 | 15 | 17 |
| Dry Sub-tropical Zone (West) | | | | | | | | | | | | |
| Labour demand | 35 | 43 | 46 | 41 | 36 | 34 | 60 | 53 | 53 | 57 | 54 | 34 |
| Balance | 23 | 15 | 12 | 17 | 22 | 24 | −2 | 5 | 5 | 1 | 4 | 24 |
| Dry Sub-tropical Zone (East) | | | | | | | | | | | | |
| Labour demand | 44 | 37 | 47 | 34 | 33 | 32 | 45 | 59 | 46 | 44 | 34 | 37 |
| Balance | 14 | 21 | 11 | 24 | 25 | 26 | 13 | −1 | 12 | 14 | 24 | 21 |
| Humid Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 43 | 44 | 58 | 33 | 30 | 28 | 44 | 42 | 48 | 31 | 35 | 38 |
| Balance | 15 | 14 | 8 | 25 | 28 | 30 | 14 | 16 | 10 | 27 | 23 | 20 |
| Wet Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 40 | 37 | 48 | 32 | 29 | 32 | 56 | 44 | 53 | 35 | 37 | 38 |
| Balance | 18 | 21 | 10 | 26 | 29 | 26 | 2 | 14 | 5 | 23 | 21 | 20 |

Source: UNDP/FAO Accelerated Food Production Programme, Bhutan 1990.

**Table 2c.** Monthly Lavour Requirements and Family Labour Balance (mandays) on Large Farms (4.0 ha)
Availability of Family Laobur = 70 mandays

| Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperate Zone | | | | | | | | | | | | |
| Labour demand | 55 | 53 | 74 | 39 | 55 | 86 | 86 | 71 | 61 | 74 | 71 | 37 |
| Balance | 15 | 17 | −4 | 31 | 15 | −16 | −16 | −1 | 9 | −4 | −1 | 33 |
| Warm Temperate Zone | | | | | | | | | | | | |
| Labour demand | 48 | 60 | 62 | 57 | 62 | 78 | 129 | 107 | 118 | 111 | 84 | 59 |
| Balance | 22 | 10 | 8 | 13 | 8 | −8 | −59 | −39 | −48 | −41 | −14 | 11 |
| Dry Sub-tropical Zone (West) | | | | | | | | | | | | |
| Labour demand | 46 | 65 | 69 | 79 | 68 | 62 | 129 | 110 | 112 | 121 | 111 | 62 |
| Balance | 24 | 5 | 1 | −9 | 2 | 8 | −59 | −40 | −42 | −51 | −41 | 8 |
| Dry Sub-tropical Zone (East) | | | | | | | | | | | | |
| Labour demand | 69 | 49 | 73 | 62 | 61 | 58 | 89 | 128 | 93 | 88 | 59 | 68 |
| Balance | 1 | 21 | −3 | 8 | 9 | 12 | −19 | −58 | −23 | −18 | 11 | 2 |
| Humid Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 70 | 71 | 84 | 63 | 53 | 50 | 87 | 81 | 86 | 55 | 71 | 71 |
| Balance | 0 | −1 | −14 | 7 | 17 | 20 | −17 | −11 | −16 | 15 | −1 | −1 |
| Wet Sub-tropical Zone | | | | | | | | | | | | |
| Labour demand | 63 | 50 | 78 | 55 | 51 | 59 | 117 | 89 | 113 | 65 | 71 | 75 |
| Balance | 7 | 20 | −8 | 15 | 19 | 11 | −47 | −19 | −43 | 5 | −1 | −5 |

Source: UNDP/FAO Accelerated Food Production Programme, Bhutan 1990.

assistance as has already happened in the Paro, Bumthang and Wangdi-Punakha Valley. However, the economics of, for example, power tiller ownership, increasingly depend upon the income which can be derived from hire charges for both agricultural and non-agricltural purposes. The constraints on adoption of mechanized power sources in the east and south of the country are the rugged nature of the terrain and the lower hired labour wage rates as well as poor workshop and service facilities and shortage of spare parts plus trained mechanics.

## Present Equipment Supply

### In-country Manufacture

The sale of AMC manufactured items to farmers up to 1990 is given in **Table 3**. Of all the items manufactured, it is perhaps a salutary fact that the same or similar items are available from India at less cost than that of home manufacture.

### Importation

Importation of tools, equipment and machinery essentially is from two sources: a) Japanese equipment brought into the country under grant aid; and b) items bought from India.

Whilst the flow of Japanese equipment and machinery commenced in earnest in 1983-84 equipment from India has been brought both in before and since 1970.

### Subsidy Policy

The current subsidy policy for tools, equipment and farm machinery can be traced back to the policy document issued in September 1983 by the Department of Agriculture on the establishment of AMC. The key basis for farm mechanization was to be ownership of machinery and equipment by farmers with the government giving incentive through subsidies. The subsidy provided on the tools and equipment and, especially on power tiller, seem to have stimulated local economies in Paro, Thimphu, Wangdi and Punakha valleys not only through contributions to the agriculture sector but also to other sections of the economy mainly through transport activities.

**Table 3.** Sale of AMC Manufactured Items to Farmers

| Item | Quantity |
|---|---|
| Paddy weeder | 1 524 Nos. |
| Line planting rope | 950 Nos. |
| Reversible plough | 11 Sets |
| Winnower | 116 Sets |
| Solar dryer (trial and demonstration) | 7 Sets |
| Water canes | 99 Nos. |
| Garden rakes and hoes | 724 Nos. |
| Sickles/bush cutting | 1 373 Nos. |
| Hot frame/plastic house | 80 Nos. |
| Fork | 258 Nos. |
| Hand shovel | 10 Nos. |
| Plough shares/soles | 154 Nos. |
| Wire fence | 1 968 $m^2$ |

## Present Status of Agricultural Machinery Used in Bhutan

Agricultural operations, both pre-harvest and post-harvest, are performed using power (energy) from the following sources:

i) Human power to operate hand tools, e.g., sickle, spade, hoe, axe, knife, shovel, hammer and rake; and equipment, e.g., weeder, sprayer, duster, maize, sheller, pedal thresher, seeder, transplanter and water lifting devices. Certain operations are performed without any tools or equipment, e.g., broadcasting, weeding and threshing.
ii) Animal power to operate land preparation implements, e.g.,

plough, harrow, leveller and planker; seed drill, planter, cultivator, water lifting devices, harvesters (potato digger and reaper), and transport carts. Some operations like threshing of grains are performed by trampling on by animals.

iii) Mechanical power from mobile sources (tractors and power tillers) to perform field and transportation operations; and stationary power sources (diesel and petro engines and electric motors) to power stationary equipment (thresher, rice mill, flour mill, oil expeller, sheller and water pump). Tractors and power tillers are also used to power stationary equipment. Some equipment are self-propelled, e.g., power reaper, and combine harvesters.

The following observations on various operations are based on field visits and interviews held with farmers and officials in seven districts, namely; Tashigang, Mongar, Bumthang, Tongsa, Wangdi, Punakha and Paro.

**Land Preparation**

In the case of shifting cultivation (tsheri) land is normally cleared by burning and cutting trees and bushes by hand tools. In most cases land slope is very steep (>30°) and land preparation is done using hand tools, mainly spade and hoe, particularly in dry lands with steep slopes.

Most of the farmers in Bhutan use bullock-drawn implements for land preparation. A few rich farmers use power tiller and tractor-powered equipment. The majority of the farmers own a pair of bullocks. A significant proportion of farmers own only one bullock and some do not own any. A farmer owning only one bullock exchanges his bullock with a neighbouring farmer. In Eastern Bhutan where two (sometimes even three) operators are required

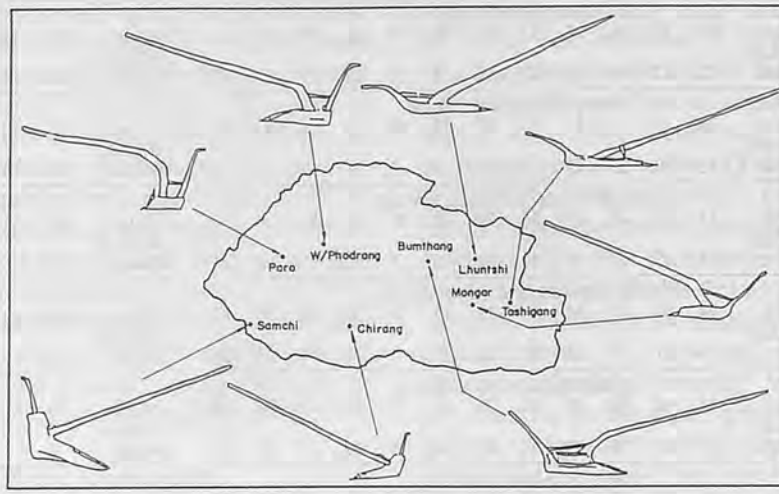


**Fig. 2** Local plough used in Bhutan.

in ploughing, both bullock and farmer labour are exchanged. One (sometimes two) persons control the bullocks and another handles the plough. A farmer owning no bullocks has to hire in all his bullock requirements. In this case a farmer provides his own labour in exchange for bullocks. In the villages visited by the team, one-to-one exchange of labour for bullock was a common practice. Due to these very flexible systems of exchange and sufficient number of bullocks even the small farmers who do not own any bullocks were able to get their land prepared without any serious difficulty or delays. Even if a farmer did not own a bullock, at least he owns a plough.

Almost no nose rope is used for controlling bullocks, especially for turning. Only verbal command and plough orientation are used for control. The plough is lifted of the ground at turns. Only in a few cases does the team find use of a head or nose rope on one bullock in a pair.

Most of the traditional ploughs used by the farmers are soil stirring type and are very crude. Traditional ploughs used in various parts of Bhutan are shown in **Fig. 2**. The traditional ploughs in eastern Bhutan (Tashigang and Mongar) are probably the crudest. Most ploughs use only wooden shares (preferably hardened oak) which may last one to three hours to depending upon the quality of wood and field conditions, especially soil type. In abrasive sandy soils, a share may not last even one hour, while in hard and stony soils these shares may break very often. The plough bottom of a traditional plough may last one season or less depending upon the quality of wood, field conditions and extent of ploughing. The lower part of the beam which is engaged in the soil also wears out and on an average lasts about one year.

The traditional ploughs in South and Western Bhutan and, to some extent, in Central Bhutan use metal shares of different shapes and sizes and may last one or two seasons. This is a significant improvement over the wooden share which lasts only a few hours. A metal share, if properly sharpened, requires less cutting force thus resulting in lower draft power requirements. Other improvements found in the traditional plough, as one moves westward, was in its handle which becomes more vertical. This provides a better control on the plough, requiring less effort and easier to operate, e.g., Paro

Table 4. Agricultural Machines Supplied by AMC to Various Dzongkhags, 1983-90

| Item | Chirang | Gayleg-phug | Paro | Puna-kha | Tashi-gang | Thim-phu | Wangdi-phodrang | Others | Total |
|---|---|---|---|---|---|---|---|---|---|
| Ford tractor (50hp) | 0 | 0 | 5 | 2 | 1 | 10 | 6 | 14 | 38 |
| Kubota tractor (38hp) | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 4 | 9 |
| Kubota tractor (16hp) | 0 | 0 | 8 | 0 | 0 | 5 | 1 | 4 | 18 |
| Kubota power tiller | 2 | 4 | 85 | 16 | 8 | 26 | 13 | 16 | 170 |
| Kubota power thresher | 6 | 5 | 23 | 17 | 1 | 16 | 8 | 9 | 85 |
| Kubota power reaper | 0 | 2 | 8 | 4 | 0 | 1 | 1 | 2 | 18 |
| Power sprayer | 2 | 0 | 4 | 0 | 1 | 4 | 4 | 3 | 18 |
| Rice mill set | 36 | 20 | 61 | 89 | 137 | 42 | 76 | 154 | 615 |
| Oil expeller | 5 | 2 | 2 | 7 | 4 | 3 | 11 | 13 | 47 |
| Hand-operated winnower | 3 | 13 | 59 | 6 | 8 | 3 | 13 | 19 | 124 |
| Pedal thresher | 2 | 2 | 202 | 244 | 19 | 28 | 90 | 13 | 600 |
| Rotary paddy weeder | 4 | 25 | 500 | 634 | 38 | 137 | 57 | 78 | 1473 |
| PP equipment | 84 | 0 | 233 | 72 | 4 | 223 | 38 | 69 | 713 |
| Tools and implements | 4382 | 1606 | 8418 | 2467 | 5971 | 6550 | 3546 | 16776 | 48535 |
| Water pumps | 1 | 0 | 16 | 5 | 1 | 7 | 3 | 3 | 36 |

Table 5. Per Acre Labour Required in Land Preparation Operations (Paro Valley)

| Operation | Method | Time required |
|---|---|---|
| Ploughing | Pair of bullocks with plough and one operator | 3 mandays or 18 manhours |
| Ploughing | Power tiller with mouldboard plough and one operator | 1 manday or 6 manhours |
| Clod breaking | Manually using hand tools | 10 mandays or 60 manhours |
| Planking | Pair of bullocks with wooden planker and one operator | 1 manday or 6 manpowers |
| Rotary tilling | Power tiller and one operator | 3 manpowers |

plough. While to operate an eastern plough (Tashigang), the farmer has to almost kneel to the ground which causes tremendous drudgery. In such cases farmers take turns in handling the plough and bullocks.

The other most commonly used animal drawn implement in land preparation is a planker. In dryland preparation it is used for breaking the clods formed in the ploughing operation and levelling. In wet land preparation, this same planker, sometimes with a few big holes to allow water and mud to pass through them, is used for puddling and levelling the fields after the soil has been loosened by ploughing.

The use of power tillers for land preparation is very common in Paro valley as 50% (85 out of 170) of power tillers have been purchased by the farmers of this district (**Table 4**). Other districts where power tillers have made their presence felt are Thimnphu (26 units) and Punakha (16 units). Based on the information collected during field visits in Paro, the labour required to perform various land preparation operations on per acre basis is given in **Table 5**.

The use of large tractors for land preparation is negligible in Bhutan except for a very limited use in Bumthang (12 units) and Wangdi (9 units) in relatively flat highlands where potato is grown as a cash crop. The use of small tractors is also negligible in land preparation. Of a total of 18 units, 8 are in Paro and 5 units in Thimphu. The steep topography and very small field and farm sizes are not at all suited to 4-wheel tractors for field operations.

## Seeding and Planting

Most of the grains (except paddy) and oil crops are seeded by broadcasting in a ploughed field and then mixing and covering the seed by animal-drawn planker. Maize is normally sown in a furrow made by a traditional plough. Many farmers in Eastern Bhutan intercrop soybean and pumpkin with maize by dibbling their seeds in between maize rows using a pointed stick or hand shovel to make a hole for seed placement.

Potato is also planted manually. Furrows are made using spades and seed potatoes are placed in furrows and covered by soil again using spades. It is a very labour intensive operation and farmers overcome the labour constraint mainly by exchange of labour and, in some cases, by hiring labourers on cash payment along with meals. Throughout Bhutan paddy seedlings are mostly transplanted randomly with the exception of line transplanting in Paro, Punakha and Thimphu using a marked nylon rope.

Line transplanting is extremely useful for proper plant density and is of great help in weeding using a mechanical weeder.

## Inter-cultural Operations

These operations include weeding, earthing of potato crop, and application of fertilizers, herbicides and other plant protection chemicals. Weeding in dry field conditions is normally done using a hand hoe in which weeds are cut and the soil is loosened to improve aeration and water holding capacity. In the case of paddy it is normally done by pulling weeds by hand. In the case of line transplanted paddy, some farmers use hand operated rotary weeders also. Most of the manually operated rotary weeders were bought by farmers in Paro (500), Punakha (634), and Thimphu (137) where line transplanting has gained some acceptance (**Table 4**).

Earthing of potato crop is done using a spade. Fertilizer's basal dose is normally broadcast in the field just before the last land preparation operation. Top dressing dose of fertilizer is also normally broadcast by hand. In the case of a crop with plants spaced apart, like maize, a small quantity of fertilizer is placed around each plant by hand. In some cases, a knapsack sprayer is used to apply fertilizer solution (mainly urea) in paddy crop.

In grain crops almost no pesticides are used. However, the use of herbicides for weed control, especially in paddy crop, is increasing rapidly. Herbicide is normally applied by using a hand operated knapsack sprayer. Pesticides are normally applied to orchard crops using sprayers and dusters. Most of the plant protection equipment (including 18 power sprayers) are used by farmers (**Table 4**) in Paro (237 units), Thimphu (227 units), Chirang (86 units), Punakha (72 units) and Wangdi (42 units).

**Harvesting and Threshing**

All crops are harvested manually. Although a serrated sickle is commonly used in South Bhutan, unserrated sickle is the most common hand tool used throughout the country for harvesting grains like paddy, wheat, buckwheat, barley and oil crop like mustard. Maize cobs are normally picked by hand from a standing crop. Potatoes are harvested using spades and hoes. Up to 1991 only 18 reapers have been sold and 8 of these are in Paro and 4 in Punakha. About 30 reapers are available with AMC, Paro as these have not been sold.

Although most of the threshing is still done manually either by beating the crop or trampling it by feet (and in certain areas in southern Bhutan, animals are used for threshing by trampling), the use of threshers is becoming popular. Pedal threshers are very commonly used to thresh paddy (**Table 4**) in Punakha (244 units), Paro (202 units) and Wangdi (90 units) and, to some extent, in Thimphu (28 units) and Tashigang (19 units). The use of these pedal threshers is linked mainly with the introduction of high-yield paddy variety which is very difficult to thresh manually. As the area planted to paddy is increasing, the demand for pedal threshers is also expected to rise.

The use of power threshers is very limited. Of a total of 85 units sold so far, 23 are in Paro, 17 in Punakha, 16 in Thimphu, 8 in Wangdi, 6 in Chirang and 5 in Gaylegphug (**Table 4**). These threshers are used for threshing paddy and other grain crops like wheat, buckwheat and barley. Although the farmers like the thresher, they have many problems associated with it. It is expensive, very difficult to transport and repair and maintenance is a very serious problem. It takes six people to transport the thresher. Due to many moving parts and complicated mechanism, the thresher breakdown is very frequent. Due to lack of spare parts as well as long delays in getting spare parts for the power thresher, farmers prefer to buy pedal threshers which are relatively cheap, light, simple mechanism and easy to repair.

**Transportation**

Almost all transport activities between farmer's house and fields as well as within and between fields are done by human labour. There are no bullock carts for farm transport due to the hilly terrain. Even the farm yard manure, which is applied in large quantities is transported to the field on human backs. Due to the high bunds of terraces, even power tiller and tractor owners make only limited use of them for on-farm transport.

Most of the farm communities in Bhutan do not have access even by a feeder road to transport various inputs and outputs. Lack of these is one of the most serious bottlenecks in the development of agriculture. Construction of feeder roads to connect all farm communities in the country should be assigned a very high national priority.

The use of power tillers and tractors is very common for transport on road both for agricultural and non-agricultural related activities. No statistics are available on the use of tractors for road transport activities. On some rural roads which become impassable for trucks during the wet season, tractor-trolley is the only mode of transport available in these areas.

Based on the remarks of the tractor owners, it can be said that more than 90% of use is for transport activities. Custom hiring for transport purposes is the main sources of cash income for tractor owners. In a study by Wangdi and Rai (1985), they found that use of power tillers was highest for transport activities (40%) followed by rotary tilling (32%) and ploughing (23%). In the case of power tiller owners also, custom hiring for transport activities is the largest source of cash income.

**Processing Operation**

Although a large number of people still use traditional methods of rice hulling by pounding, flour making from wheat, maize and other grains using stone grinders and expelling of oil by compression, the use of rice mill sets, flour mills and oil expellers is becoming very popular. Traditional methods are slow and demanding as well as very inefficient. Most of these operations are performed by women.

Most of the rice hullers, flour mills and oil expellers are powered by stationery engines (Kirloskar Diesel) and in some case by electric motors. Most of this processing equipment are owned by economically better-off farmers who normally own both a rice mill set and a flour mill powered by the same engine. There are 615 rice mill sets spread throughout the Kingdom (**Table 4**) with the majority of them in Tashigang (137), Punakha (89), Wangdi (76), Paro (61), Thimphu (42), Chirang (36) and 27 units each in Lhuntshi, Mongar and Tongsa Dzongkhags.

The production of oil crops, mainly mustard, is increasing due largely to the high price and promotional efforts by the Royal Government. Many owners of rice mill units and flour mills have also installed oil expellers. Of a total of 47 oil expeller units (**Table 4**), 11 are in Wangdi, 7 in Punakha, 5 in Chirang, 4 each in Tashigang and Haa and 3 each in Thimphu and Tongsa. The number of expellers is expected to grow rapidly as the production of oil crops increases.

The traditional methods of butter and cheese making are extremely slow and laborious. The introduction of simple rotary churners (rope driven) from the south will reduce labour requirement in these activities significantly.

## Needs and Potential for Introducing Improved Agricultural Tools and Equipment

Under prevailing socio-economic and agro-climatic conditions, the introduction of any improved agricultural tool or equipment must meet one or more of the following farmers' criteria:

*i) Increased economic returns to farmers through*

a) Increased production through timely operations, better quality of work, precision in application of inputs, increasing cropping intensity and reducing post-harvest losses;

b) Lower cost of operations mainly through savings in labour cost; and

c) Additional income from custom work on on-farm and off-farm activities.

*ii) Reduction of drudgery*

*iii) Improved dignity of farmers*

Based on the criteria mentioned above, a list of potential improved agricultural tools and equipment to be introduced as well as further promotion of already introduced tools and equipment is given below:

**Land Preparation**

i. Metal shares for traditional animal drawn ploughs;
ii. Improved animal drawn ploughs;
iii. Comb harrow for puddling as wetland preparation for paddy;
iv. Tine cultivator;
v. Improved planker for clod breaking;
vi. Rope control for bullocks; and
vii. Forked spade or rake hoe.

**Seeding and Planting**

i. Line transplanting of paddy using a marked nylon rope;
ii. Manual jab seeder for maize and soybean on sloppy lands; and
iii. Seed-tube attachment to animal drawn plough.

**Intercultural Operations**

i. Hand-operated dryland weeder with long handle for maize, soybean and potato crops; and
ii. Manual rotary paddy weeder.

**Harvesting and Threshing**

i. Improved serrated sickle;
ii. Pedal thresher;
iii. Power thresher; and
iv. Hand-operated winnower.

**Processing Equipment**

i. Improved rice mills; and
ii. Rotary churnes for butter and cheese making.

It is to be cautioned that tools and equipment mentioned are possible candidates for testing and thorough evaluation on farmers' fields. Only after demonstration and acceptance by farmers to purchase any item, that item should be imported or manufactured locally in small quantity. The number of units of any item to be made available must be related to farmers' demand. Under no circumstances should an item of machinery be imported or manufactured in large quantity without proper evaluation, demonstration and acceptance by the farmers.

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# Increasing Honey Production in Tanzania Through Mechanization

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## Abstract

Beekeeping is a natural resource of abundant potential. The resource is renewable and with appropriate techniques it can be exploited without a detrimental effect on the environment. Many reports indicate, however, an under-exploitation of the resource in most parts of the world. The degree of under-exploitation is much greater in tropical compared to sub-tropical and temperate zone countries.

This paper examines the economic viability of a mechanized honey processing plant designed to suit the current beekeeping conditions of Tanzania based on a case study in the Babati district of the country. The viability test was based on 1992 prices for products, corresponding costs and exchange rates. The designed system was capable of processing 42 t per annum and was proved to be very profitable with a break-even point at only 12 t annual production.

## Introduction

Beekeeping provides a high energy food in the form of honey. Beeswax is also produced from honey. Both products are important items of world trade both in terms of industrial and domestic use. Other products derived from beekeeping include pollen, royal jelly, bee venom and propolis. Apart from their direct economic benefit, bees play an important role in agricultural development in providing a pollination service to certain plants while collecting nectar. Crane (1990) stated that the benefit to agriculture was very much greater than the beekeepers income. Reports from the USA quantified this benefit to be up to 100 times as the honey itself, Hon. Omamo (1988).

Tanzania is one country where the equatorial climate is considered to be favourable for beekeeping with very high potential. There are two rainy seasons and two dry seasons in the country. Each rainy season is followed by a honey flow period which peaks at the end of May and in November, honey harvesting would normally follow these peaks (Crane, 1990). Tanzania has a large area covered by a wide variety of nectar source plants which blossom in different seasons. Recent estimates reveal that there are 4 million bee colonies in Tanzania. This accounts for an annual production potential of 60 to 100 thousand t of honey and 4 to 6 thousand t of beeswax Ntenga (1983). Despite this potential the level of honey production in Tanzania is very low. The average annual honey and beeswax production in Tanzania in the period 1981 to 1991 were 5 447 and 592 t, respectively. Production levels are illustrated in **Table 1**. Kihwele (1992) estimated the average production level for that period to be 22% of the potential production for honey and 21.6% for beeswax.

A further example of under-exploitation is illustrated in the situation in the Babati district of northern Tanzania. The district has an annual production potential of about 1 250 t of honey and 75 t of beeswax. In 1987/88 the actual production fluctuated between 60 and 90 t of honey, equivalent to 8% of the total production capacity. The beeswax was discarded, causing a further loss of about 1.8 to 2.7 million Tanzanian shillings (Tsh), (US$5 400 to US$8 100), Ntenga (1991).

Apart from under-production the export levels of bee products from Tanzania are very low. One of the principal reasons for this is the poor quality of the products, especially honey which fails to meet export market standards. It is extremely difficult for small-scale honey producers with poor technology to process the crop to

Table 1. Tanzania's Honey and Beeswax Production and Export 1981-1991

| Year | Production | | Export | | Percent of production | |
|---|---|---|---|---|---|---|
| | Amount (Tonnes) | | Amount (Tonnes) | | Exported | |
| | Honey | Beeswax | Honey | Beeswax | Honey | Beeswax |
| 1981 | 4 420 | 663 | 0 | 0 | 0.00 | 0.00 |
| 1982 | 2 329 | 451 | 39 | 148 | 1.67 | 32.86 |
| 1983 | 3 663 | 460 | 35 | 312 | 0.96 | 67.82 |
| 1984 | 5 200 | 520 | 0 | 114 | 0.00 | 21.92 |
| 1985 | 5 600 | 560 | 2 | 100 | 0.03 | 17.86 |
| 1986 | 8 900 | 890 | 3 | 106 | 0.03 | 11.91 |
| 1987 | 3 100 | 310 | 18 | 216 | 0.57 | 69.68 |
| 1988 | 4 830 | 480 | 20 | 324 | 0.42 | 67.50 |
| 1989 | 7 060 | 700 | 33 | 203 | 0.47 | 32.86 |
| 1990 | 7 020 | 702 | 38 | 234 | 0.54 | 33.33 |
| 1991 | 7 790 | 772 | 123 | 690 | 1.58 | 89.38 |

Source: Kihwele (1992), Personal communication, Forestry & Beekeeping Division, Ministry of Lands, Natural Resources and Tourism, Dar-es-Salaam, Tanzania.

Table 2. Effect of Moisture Content and Yeast on Fermentation of Honey.

| Moisture Content | Liability to Fermentation |
|---|---|
| Below 17% | Safe regardless of yeast content |
| 17.1-18.0% | Safe if yeast count < 1000/g |
| 18.1-19.0% | Safe if yeast count < 10/g |
| 19.1-20.0% | Safe if yeast count < 1/g |
| Above 20.0% | Always in danger |

Source: Crane, 1990

meet these market requirements. For example, pressed honey tends to be rejected because it contains many water soluble particles which cause it to granulate more quickly than centrifuged honey (Vorwohl; 1976). Heating the honey can also be hazardous to its quality. Traditional beekeepers in Tanzania, which account for 99% of the producers, use heating and pressing methods to process their honey. Clearly, in addition to increasing the output of honey, the quality of the product needs to be improved if they are to compete in high value markets.

## Honey Quality

Honey is defined in the Article 1 of the EEC Council Directive of July 22nd 1974 on the harmonization of the member states relating to honey (74/409/EEC). Honey is in it's purest form when still sealed in the comb. From the moment the extraction process begins honey becomes contaminated with undesirable substances ranging from pieces of wax, parts of bees, dirt, fibres from straining clothes and air bubbles. All of these substances have to be removed if the honey is to be of saleable quality. According to Vorwohl (1984) the main points in assessing honey quality are:

1) Absence of adulteration; only the product of primary natural materials; nectar and honeydew may be described as honey.
2) Cleanliness.
3) Absence of residues, for example, pesticides or environmental pollutants such as the heavy metals cadmium and lead.
4) Careful processing and storage to conserve the natural constituents of honey and a pleasant consistency; a clear liquid or with fine, smooth granulation.
5) Low water content, ensuring a good keeping quality, without fermentation.
6) Good appearance as to colour and clarity.

Pollen and residues are removed by filtration and purification methods. As already stated, the presence of suspended particles speeds up its granulation. Added to this is the increased likelihood of spoilage through fermentation. Granulation increases the amount of free water in honey, an increased moisture content creates a suitable environment for yeast growth. Crane (1990) gives the combined effect of moisture content and yeast on the fermentation of honey as illustrated in **Table 2**.

## Honey Markets

Three markets are available for honey produced within Tanzania: local, urban and export markets. Each has it's quality requirement that must be fulfilled by the supplier. Local markets for honey exist in areas neighbouring to beekeeping. In this market the main use is in brewing beer, the requirement is for crude honey, (honey mixed with comb). Honey with a higher moisture content is preferred as it ferments more quickly, in some areas a genuine beer is assessed by identification of wax comb in it, Ntenga (1991). Whenever the demand for honey in this market is high, the beekeepers do not extract their honey, however, the price is very low and a large amount of beeswax is lost. For example in 1987/88, 20 ℓ of crude honey would be priced at 2 500-4 000 Tsh (US$7.50-US$ 12.00), which 300 g of extracted honey would be sold for around 300 Tsh within the urban market. Some 20 ℓ of crude honey would produce 18 kg of clear honey which would have a market value of 18 000 Tsh (US$54). It should, however, be remembered that additional expenses would be incurred in extracting, purifying, bottling, packaging and transporting the honey.

The urban market requires honey of table quality, that is extracted and well refined. In order to exploit the market, processing facilities would be required. The scarcity of such facilities has caused an under-exploitation of this potential market. Granulated honey is not acceptable in this market, therefore, honey must be thoroughly purified before it is packed. The most stringent quality standards are for the export market. The supplier of bee products needs to know the customers quality requirements as the risks of loosing the crop is much greater. If a consignment is rejected by the export market it is likely to be dumped rather than incur the cost of shipping back to the suppliers. In addition, a steady supply of the product as agreed between the supplier and the buyer is needed in order to create a stable market.

## Mechanizing Honey Processing

When selecting a honey processing method, consideration must be given to a number of factors. Flavour, colour, taste and enzyme content of honey are affected by over heating Crane (1990). Eckert (1976) studied the hygroscopicity of honey and strongly recommended to always keep honey in airtight equipment even when processing. One of the most important properties of honey in relation to processing is it's viscosity. When the viscosity is high it's processing becomes difficult, especially if it involves flow through pipes and filtering medium. Heating the honey can help in this regard but there are many dangers associated with it. Good process control must be exercised.

Crane (1990) defined honey processing as "All handling activities of honey during which its physical or chemical properties are purposefully altered temporarily or permanently in order to improve certain qualities of honey." Based on this definition, honey processing includes:

(1) Warming of honey to 32°C-35°C,
(2) Uncapping the combs and dealing with the cappings,
(3) Extracting the honey from the combs,
(4) Clarifying the honey by passing it through a strainer and/or baffle tank,
(5) Flash heating of honey.

In an effort to increase productivity and efficiency three key areas of processing were examined with a view to mechanizing the process. These were uncapping, extracting and clarifying the honey. Extraction of honey from the comb can be done by either pressing or by using a centrifugal spinning method. A number of pressing machines are available depending on the desired capacity. They generally take the form of a simple hinged press or a press with a spindle which is used to move one plate down onto the other to squeeze the honey from the comb. One such example is the heather honey press as it is referred to in the U.K. The main problems associated with pressing is the low extraction efficiency, 58% according to Ng'atigwa (1989) when examining hand pressing, as well as low work rates. Centrifugal extraction utilizes a rotational motion to extract the honey from the comb. The centrifugal forces resulting from this motion throws the products outwards and a filter medium is used to separate them. Two specific methods are used:

1) Utilizing a straining material to separate the solids and liquid where the honey is allowed to pass out while the wax is retained in the straining material on being spun; and
2) Mechanically confirming the wax comb and allowing the honey to flow out of the comb on being spun

In the first category the honey combs are generally crushed, forming honey mashes, before being loaded into the machine. The filtering medium could be a nylon cloth or coconut mat wrapped on the inside of the inner cylinder. The honey passes through the filtering medium and inner perforated cylinder to the outer cylinder where it can be collected. Wax products are trapped on the straining material and can be collected later after stopping the machine. The machine is provided with an opening in the lid to enable continuous feeding. This class of machine is referred to as the "Spinner Honey Extractor." It must be firmly bolted to the floor at all times and feeding must be done at a steady, even pace.

The second class of machine known as centrifugal honey extractors are essentially cylindrical metal or plastic barrels containing a central rotor into which the framed combs are placed. The rotor is geared to a handle for manual operation or a small electric motor in larger machines. When the rotor is spun, honey is thrown outwards to the barrel and runs down to be collected at the bottom. This method requires the combs to be uncapped. Uncapping is done by a variety of methods, from plain and serrated edged knives, electrically heated knives and uncapping planes are used as it steam. In commercial beekeeping electrical uncapping machines are used. If a spinner honey extractor is used, however, there is no need for uncapping.

The main objective of clarifying the honey is to remove wax solids remaining after extraction and other foreign matter whose presence in honey speeds up it's granulation and eventual fermentation. This is usually done using a combination of settling tanks and filtration. The handling of honey also needs to be given some consideration. Honey supers need to be handled prior to processing, honey must be filtered during processing, moved and subsequently packed into shipping containers. All of these factors need to be considered when designing the layout of the plant and store room.

## Mechanization System Design

The traditional beekeepers of the Babati district in Tanzania, **Fig. 1**, have been used as a case study for the design for the following reasons:

1) The traditional beekeeping in the area has been previously studied by Ntenga (1991) and relevant information for the design was available.
2) The level of exploitation of the beekeeping resource in the district was only 8% of the total production potential. This is almost 50% less than the national level. This low level of exploitation left maximum scope for development.
3) Babati is practically a microcosm of the whole country in terms of its diverse climates, topography, vegetation and soils as well as human activities (Ntenga, 1991). Therefore, it is hoped that a mechanized system design for this area would be suitable for other parts of the country.

In any system design certain assumptions have to be made. In this case the assumptions were:

a) The production potential of the district is equally distributed among the 19 villages in the district studied by Ntenga (1991).


**Fig. 1** Babati district in Tanzania.

b) The mechanization plant will be centered in Babati town where necessary utilities such as electricity and water are available.
c) For calculation of transport needs it is assumed that all villages are the 'average' distance from Babati town.
d) The time available for honey extraction is two months, from mid-September to November, which is almost concurrent with the honey harvesting period, September to October, according to Lindberg (1990). This ensures that the honey is never kept too long after being harvested in order to control it's quality.
e) In every month, there are 22 working days, each with 8 h of which no more than 6.5 h will be available for machine operation to allow time for cleaning and servicing.
f) Machine costings are based on UK market prices with an additional 20% to cover procurement and shipping cost to Tanzania.
g) Hiring a transport service for honey delivery was preferred because it is cheaper than owning a company vehicle considering the short duration of peak demand. The transport charge of 200 Tsh (US$0.33)/km/t which has been widely used in Tanzania in 1991/92 was used in this study.
h) The criteria for the calculation of storage space is that no more than one-third of the total processed honey will be stored at any one time.
i) Labour has been charged at US$0.36/h, based on a monthly salary of 15 000 Tsh (US$45), for a skilled person in Tanzania in 1991.
j) All financial calculations were computed using the dominant exchange rates for 1992, at a rate of £1 = US$1.8 = 600 Tsh.
k) The design focused on the export market. Thus, bottling facilities have not been considered.
l) All-weather roads are functional during the harvesting period.

## Selection of Processing Equipment

The selection of the mechanization method was governed by the selection of the extraction machine. The spinner honey extractor was selected for a number of reasons. Although of lower capacity than the centrifugal extractor, no decapping was necessary, the machine was cheaper and unskilled labour could be used to operate it. The capacity was, however, sufficient to meet the requirements of the complete system. As with any mechanization system, machines within the system must be matched in order to avoid any bottlenecks or having machines idling because of excess capacity, the capital investment must be optimized. The mechanization system selected consists of the following equipment:

1) Spinner honey extractor.
2) Baffle tank — Used to filter honey as it comes out of the extractor. Heavy particles drop to the bottom. Floating material is strained or remains behind in the baffles.
3) Sump tank — Used to warm and cool honey for further separation of wax. This is generally water-jacketed such that warm water is continuously supplied to melt the wax which could not be trapped in the baffle tank. This allows it to float and be separated from the honey.
4) Honey pump — Used to pump honey from the sump tank to storage through the strainer and later from the sump tank to the

shipping barrels, again, through a strainer.
5) Strainer — Used for final purification of honey before packaging.
6) Shipping barrels — For storage and transport of the extracted and purified honey.

The system design criteria was the capacity of the spinner honey extractor which was 145 kg of honey per hour. All subseqent equipment was matched to that level of throughput.

## The Honey House

As with the rest of the system, the honey house must meet certain criteria. It must keep bees and other insects off the crop during processing. It must be clean and help prevent contamination of the crop, as well as protecting against other hazards such as weather, theft and vandalism. It is generally recommended to use concrete or burnt clay bricks for walls, concrete for the floor and corrugated iron sheets for roofing. The storage room, specifically, must be well-insulated preferably double walled and without windows, Robson (1992). This is necessitated by the requirement for storing honey at low temperature, 11°C, to prohibit yeast growth. Such temperatures are difficult to maintain in the tropics unless the building is well engineered. Air-conditioning for the store was not considered for this study.

The size of the processing room was determined by the number and size of machines and equipment in the system and their arrangement. In this study a clockwise sequence of operation has been used. All sump tanks were arranged in a single row, as illustrated in **Fig. 2**, allowing a space of 0.5 m between the walls and equipment and between the two rows of equipment. A minimum space of 0.15 m was provided between consecutive pieces of equipment in one row. The dimensions of the room were rounded up in order to match the strorage room which was designed to hold 14 t of honey. This is the amount expected to occupy the room at any one time. The honey was held in 300 kg capacity barrels which have a diameter of 0.5 m each.

## Transport

Transport constitutes a significant cost within the system and is required for collecting the crude honey from the beekeeping centres to the mechanized plant and to deliver the extracted honey to Dar-es-Salaam for shipment. The requirement was determined by the amount of honey to be transported and the distance from collection centres to and from Babati to Dar-es-Salaam.

## Cost Analysis

The cost analysis was categorized into four sections: processing costs; housing costs; transport costs; and other costs, such as manager's salary.

Processing costs refer to the cost incurred in owning and operating the machinery and equipment employed in honey processing. These costs can be classified into ownership costs and operating costs. Ownership costs consist of depreciation, interest on investment and insurance. The straight line method of depreciation calculation was used as it was thought unlikely that the machinery would be sold of before the end of it's useful life, which was assumed to be 15 years for most equipment. The salvage value was estimated at 10% of purchase price. An interest rate of 10% and an insurance rate of

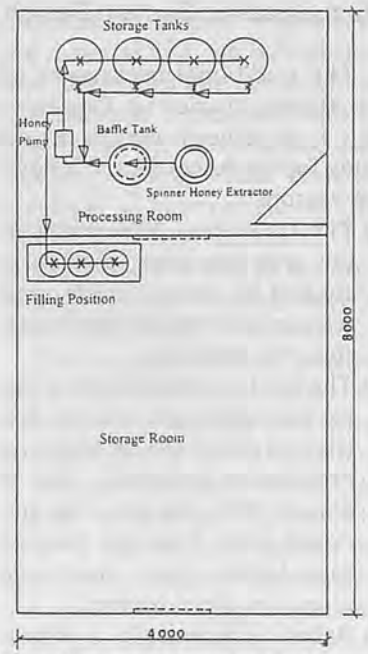


**Fig. 2** The honey house layout. (dimensions in mm.)

1.5% were also used. These figures had been used previously in relation to another mechanization study in Tanzania, Martin (1989). Operating costs included electricity, repair and maintenance and direct labour charges. Electricity was charged at 48 Tsh, (0.144 US$)/kWh. along with an annual standing charge. A repair cost at a rate of 4% of the new cost was charged for the machinery because although it was operating for relatively few hours and the nature of the work was not arduous it was not common in Tanzania and problems in repairing it may emerge. A lower rate of 1.5% was charged to equipment with no moving parts and of plastic construction. All machine and equipment prices were based on UK 1992 prices plus 20% procurement and transport fee to Tanzania. The processing costs are shown in **Table 3**.

Housing costs in Tanzania were estimated to be two-thirds of the UK cost. For the type of structure envisaged the UK cost would be £149/m$^2$ of floor area, (US$268), SAC (1992). The cost in Tanzania,

Table 3. Honey Processing Costs (Unit: US$)

| Machine & equipment | Annual costs | | |
|---|---|---|---|
| | Fixed costs | Variable costs | Total costs |
| Spinner honey extr. | 266.40 | 235.80 | 502.20 |
| Baffle tank | 109.80 | 14.40 | 55.20 |
| Honey pump | 244.80 | 34.20 | 338.40 |
| Sump tank | 134.40 | 36.00 | 338.40 |
| Strainer | 11.34 | 0.00 | 34.20 |
| Shipping barrels | 0.00 | 1 020.60 | 1 020.60 |
| Pallet truck | 63.00 | 102.60 | 165.60 |
| Other costs | — | — | — |
| Electricity (fixed charge) | 79.20 | 0.00 | 79.20 |
| Piping valves and water | 36.00 | 0.00 | 36.00 |
| Total Cost | 1 135.80 | 1 443.60 | 2 579.40 |

Table 4. Analysis of Housing Costs (Unit: US$)

| | |
|---|---|
| House: | Storage house 32m² |
| Estimated life: | 25 years |
| Annual use: | 42 tonnes |
| New cost | 5 760.00 |
| Salvage value (%) | 0 |
| Interest rate (%) | 10 |
| Insurance rate (%) | 0 |

| Ownership and operating costs | Annual cost | Cost / tonne |
|---|---|---|
| Depreciation | 230.40 | 5.49 |
| Interest | 288.00 | 6.86 |
| Insurance | 0.00 | 0.00 |
| Repair @ 1.5% of new cost | 86.40 | 2.06 |
| Total housing cost | 604.80 | 14.40 |

therefore, was £100 m², (US$180). The annual housing cost has been calculated in a similar manner to machinery and equipment, except that the estimated life is 25 years and it's salvage value is zero. The analysis of cost is itemized in **Table 4**.

Transport would be hired when required, for a standard charge of 200 Tsh (US$60)/t/km for delivering the processed honey to Dar-es-Salaam and picking up honey locally to be processed. The final cost of transport was US$437.40/t.

Other costs included owner's salary, US$3 240, general overheads, some additional labour and sales tax payable at 12.5%. The costings are given in **Table 5**. The table also illustrates the contribution of each cost centre to the total business cost. The two main contributors to cost are purchasing crude honey from suppliers; 42%;

Table 5. Summary of Costs Illustrating the Contribution of Each Cost Centre to the Total Business Costs (Unit: US$)

| Cost Centre | Annual Fixed | Variable / tonne | Total Cost Breakdown | | % of Total Cost |
|---|---|---|---|---|---|
| | | | Annum | tonne | |
| Producer payment | — | 599.40 | 25 174.80 | 599.40 | 41.59 |
| Housing | 604.80 | — | 604.80 | 14.40 | 1.00 |
| Processing | 1 135.80 | 34.38 | 2 579.40 | 61.42 | 4.26 |
| Transport | — | 437.40 | 18 370.80 | 437.40 | 30.35 |
| Salaries | 3 600.00 | — | 3 600.00 | 85.71 | 5.95 |
| General overheads | 756.00 | — | 756.00 | 18.00 | 1.25 |
| Sales tax (12.5%) | — | 225.00 | 9 450.00 | 225.00 | 15.61 |
| Total | 6 096.60 | 1 296.18 | 60 535.80 | 1 441.33 | 100.00 |

and transport 30%. The processing costs contribute only 4% to the total cost. High transport costs are due mainly to the large distance between the plant and the shipping port. The total cost of establishing the plant is US$14 880. This includes the cost of purchasing equipment and building the honey house.

Assuming a dockside price of US$1 800 and assuming no losses of product through market rejection, the annual profit for the business is US$15 064 or US$ 358.30/t, where an output of 42 t/annum is achieved. Based on all the above assumptions the break-even point for the business is 12 t/annum. This can be obtained from a minimum of 960 bee colonies where the anual production capacity is between 10 and 15 kg/colony.

## Conclusions and Recommendations

The importance of mechanization technology in beekeeping was remarked on by Sillani and Barbattini (1987). It's lack of progress in developing countries has held back their development of beekeeping. In the case of Tanzania, the virtual absence of beekeeping mechanization technology is due to the lack of interaction between engineers and beekeepers in attempting to exploit this resource. However, low productivity linked to low profitability and the very diffused nature of an industry with many producers scattered over a wide area do not make it an obvious area for the development of a mechanized system.

This study has shown that the introduction of mechanization in honey processing can be profitable and make honey processing more organized, leading to improved quality standards and increased profitability because new and more profitable markets can be satisfied. The proposed mechanization system is both technically feasible and economically viable for the current beekeeping situation in Tanzania provided that a stable export market can be established.

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*(Continued on page 66)*

# Effectiveness Study of Local Materials as Cooling Media for Shelters in Hot Climates

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## Abstract

The effectiveness of three locally available materials as cooling media was tested in laboratory-held experiments. The media considered were clay particles, wood shavings and sack with an air conditioner attached to the cooling system for supplying different ranges of dry-bulb temperatures and relative humidities. The performance of the same were evaluated through their saturation efficiencies.

For the two water flow rates and ranges of input temperatures and relative humidities considered, the study reveals that clay particles have higher saturation efficiency and temperature reduction (up to 8°C) than others. Experiments with water flow rates of 3.6 ℓ/min has higher cooling performance than 2.5 ℓ/min for the same media.

## Introduction

Evaporative cooling has been a commonly accepted and economical means of improving the environment for residences and building occupied by humans and livestock in arid climates.

When a non-saturated air comes in contact with free moisture and the two are thermally isolated from outside heat source, there is a transfer of mass and heat. Because the vapor pressure of the free water surface is higher than that of the unsaturated air, water transfers in response to the differential. The transfer involves a change of state from liquid to vapor, requiring heat of vaporization. Since no outside heat is added during the process, total heat content does not change. It is an adiabatic exchange of latent heat for sensible heat.

Efficient cooler performance is highly dependent upon the pad performance. The pads must expose the maximum amount of wetted surface area to the passing air for an adequate length of air water contact time to achieve near saturation.

Manufacturers have tried pad materials of wood, metal, mineral, glass and, more recently, plastic and cement. Aspen wood excelsior has been one of the best materials for blanket type pads in coolers. Rigid pads made of polyvinyl chloride, paper impregnated with anti-rot preservatives or cement coated bagasse are also available commercially. But all these pad materials have higher initial cost and unaffordable by most local farmers and even not available locally.

The use of locally available materials as cooling media was initiated and studied employing three different materials, two of which are used locally to cool drinks and residences in the low lands of Ethiopia.

The research reported in this manuscript had the objective of assessing experimentally the effectiveness of selected materials as a cooling media to different combinations of dry and wet bulb temperatures which are typical of hot arid climates.

## Materials and Methods

The experiments which were conducted in the summer and autumn of 1992 at the Department of Agricultural Engineering, Soil and Water Laboratory used an air conditioner attached to the cooling system to provide ventilating air with the desired temperatures, relative humidities and air velocity. Depending on the room air condition dry-bulb temperatures from 27°C to 40°C and relative humidities from 20% to 45% were

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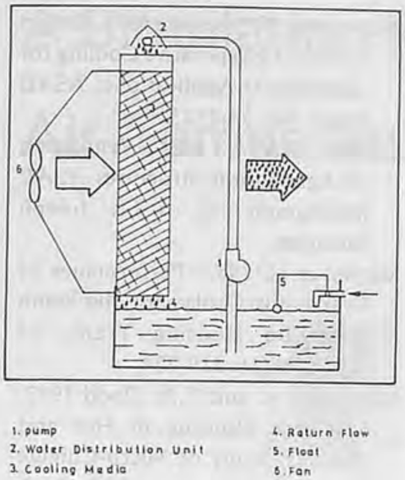


**Fig. 1** The evaporative cooling system.

**Table 1.** Summary of the Features of Cooling Media Used

| Cooling media | Shape | Average size, mm | Density gm/cc |
|---|---|---|---|
| Clay | cylindrical | d25.2 × 13.2 | 1.52 |
| Wood shaving (*Cordia abyssinica*) | irregular | 5-30 (sieve size) | 0.27 |
| Sack | — | — | 0.47 |

provided with 1.5 m/s air velocity. The experiment considered only four cases of input temperature and humidity which tended to vary slightly with the room air condition.

The average input temperatures and relative humidities considered were, (28.5°C, 41.2%), (31.4, 33.7), (34.6, 27.4), and (38.8, 21.6).

In order to assess the effect of water flow rates on cooler materials performance, two most commonly recommended flow rates were used, i.e., 2.5 and 3.6 ℓ/min.

In order to facilitate the changing of media, a chamber made from meshed wire was used where a 45 x 25-cm cooling media can be accommodated. **Fig. 1** shows the set up of the cooling system studied.

The temperature and relative humidity readings were taken before and after the media using a digital meter which can measure both parameters. **Table 1** also shows a summary of some of the important features of the selected media.

For each experiment up to 20 readings were recorded and the experiments were repeated three times and only the average values were taken for analysis and saturation efficiency calculations.

## Results and Discussions

From the observations recorded, saturation efficiencies (E) were calculated for each experiment using the relation

$$E, \% = AC/AB = A_1C_1/A_1B_1$$
(From **Fig. 2**)

This relation is the same as the ratio of change in saturation or temperature achieved to potential change in saturation or temperature.

Since temperature reduction alone cannot tell much about the cooling capacity, graphs were drawn showing wet bulb temperature against saturation efficiencies (**Fig. 3**). To draw graphs with the best fit curve regression analyses were made and those possible curves with regression coefficients near to one were taken.

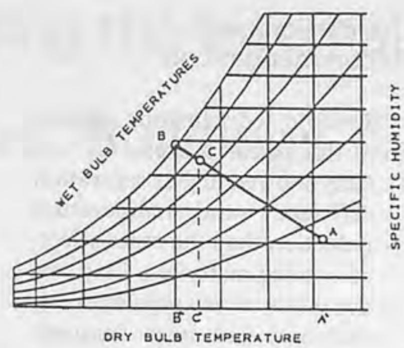


**Fig. 2** Evaporative cooling process on psychrometric chart from point A to point C.

From the results it was shown that temperature reduction up to 8°C was achieved with reasonable output relative humidity and, in most cases, not more than 76%. As shown on the graphs, clay particles with 3.6 ℓ/min water flow rate showed higher saturation efficiencies than the other experiments. It was also shown that the other two selected media not only have lower values of E but also they tended to decay through time and was necessary to change them unlike clay which does not show any sign of deterioration.

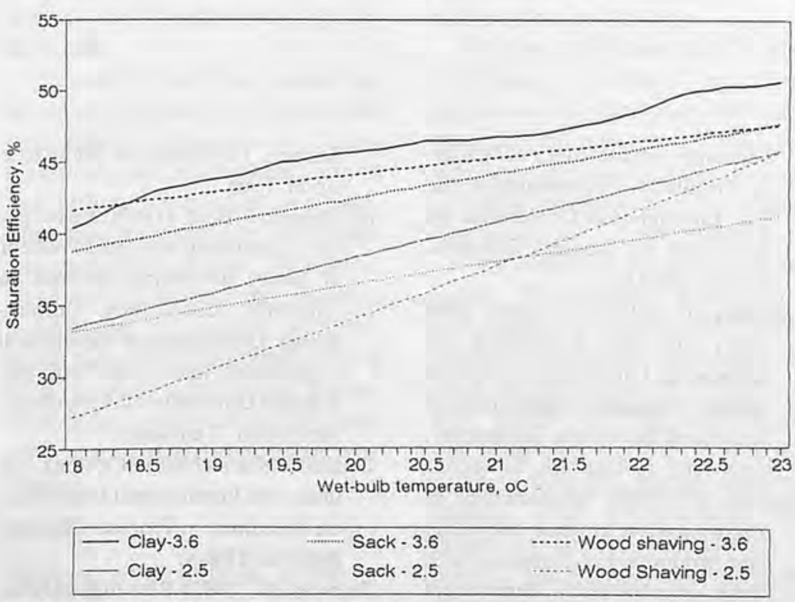


**Fig. 3** Saturation efficiency vs wet-bulb temperature.

## Conclusions and Recommendations

Specific conclusions drawn from this research are;

1) Clay showed higher saturation efficiency and temperature reduction than the other selected cooling materials. Clay was not liable to any type of decay and does not need frequent changing.
2) Wood shavings and sack showed susceptibility to decay and this limits their use unless they are treated with preservatives.
3) Experiments with 3.6 ℓ/min water flow rate showed higher performance in cooling than those with 2.5 ℓ/min for the same inputs.
4) Nearly all experiments showed smaller increase in values of E at temperatures above about 35°C.

Recommendations for further work include;

1) It is recommended that other materials for their effectiveness as cooling media should be tested.
2) Clay particles of different size and shape need consideration with different ranges of air velocity and water flow rate.
3) Extend the results to full scale and confirm the results.

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# A Simulation Model for Predicting the Internal Air Temperatures in Agricultural Buildings

by

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## Abstract

This paper reports the methods and results of a simulation model to predict the internal air temperatures of agricultural buildings. The methodology used to calculate heat gain into the structure through the building's fabric was based on the one adopted in CIBS 1979 guide.

A Fortran 77 computer programme was written to calculate the indoor temperatures. To test the model a full-scale experiment was set up in an available wooden building. The results showed that the programme reasonably predicts the air temperatures under a range of ambient conditions.

A maximum difference of 2.99°C between the predicted and measured values was obtained over four days and an overall mean square deviation of 1.24 was obtained. Possible inaccuracies could be attributed to the choice of the thermal properties of the structure and some measurement errors.

## Introduction

A majority of buildings are designed and built on a lowest-first-cost basis. This may preclude the provisions of a good thermal performance, leakage control and moisture proofing. The building's skin, comprising the walls, roof and windows, as well as the floors have the joint function of maintaining the internal micro-climate required for the use of the building.

Construction defects and the aging of the fabric of the structure may result in the building being unable to perform at design values. For this reason, it is necessary to have an analytical tool for predicting the behaviour of different types of buldings under different climatic conditions and to evaluate any building as a possible store.

The objective of this paper was to obtain expressions to predict the temperature variations of a non-insulated wooden building which had hitherto been used as a part-time classroom and for this reason was practically glazed. The work was part of a much larger research programme to enable accurate prediction of the temperature in a wide range of agricultural stores, including well-insulated and refrigerated structures, empty or loaded.

## Review of Previous Work

Many different solutions have been suggested for predicting the variations of temperatures in buildings. Jordan et al (1968) used an analog computer solution for steady-periodic temperature variations in a ventilated building. They did not, however, consider the effects of solar radiation in their analysis.

Wilson (1970) used a finite-difference method for an unventilated building. He considered the effects of solar radiation in his analysis and found that its effect tends to increase the maximum indoor temperature and shifts the occurrence of the maximum to an earlier time in the day.

Phillips and Esmay (1973) also developed a computer simulation procedure for steady-periodic temperature changes in a ventilated structure without taking into effect solar radiation and the storage characteristics of the building.

The National Bureau of Standards, Washington, developed a programme to determine heating and cooling and the fluctuating indoor temperatures of a space. It was based on the calculation methodology of the ASHRAE Task Group on energy requirements. This programme was found by Burch et al (1974) to predict realistically the thermal behaviour of an experimental building.

The Building Research Establishment has developed a microcomputer package for the prediction of building temperatures and heating and cooling loads using the admittance method. The programmes of this package were based on the BRE admittance procedure which can be found in the CIBS 1979 Guide (A5 and A9).

## The Model

The building was considered as a single uniform air mass surrounded by a number of plane surface through which heat is transferred by conduction to the air inside. The internal air is also considered to gain or lose heat by infiltration and to gain heat from any direct solar radiation incident on the building.

The essential components of the model are as follows:

1. Weather data;
2. Calculation of heat flow through the building skin;
3. Calculation of infiltration heat loss/gain;
4. Calculation of floor heat loss/gain; and
5. Calculation of direct heat gain.

**Weather Data**

Weather data required as input to the model area:

1. Time of day;
2. Outdoor temperature ($t_0$) °C;
3. Wind speed (v);
4. Solar radiation (RAD) W/m$^2$; and
5. Wind speed and solar radiation data were obtained from the Silsoe College automatic weather station.

**Heat Transfer Through the Building Skin**

The method adopted in this paper is that of CIBS which is reported in the 1979 guide and adopted by Jones (1985). The expression is represented by the equation:

$$Q_{t+1} = A \times U \times (t_{en} - t_a) + A \times U \times (t_e - t_{en}) \times f \quad (1)$$

where,

$Q_{t+1}$ = heat gain at time t + 1, W
A = area of surface, m$^2$
U = thermal transmittance, W/m$^2$
$t_{en}$ = mean sol-air temperature, °C
$t_e$ = sol-air temperature, °C
f = decrement factor
$t_a$ = inside air temperature, °C

The decrement factor provides a method for calculating the transmission of fluctuations in external conditions. It represents the attenuation of a thermal wave travelling through a building structure.

Floor heat losses:

$$Q_f = U_f \times A_f \times (t_a - t_o) \quad (2)$$

where,

$Q_f$ = heat loss from the floor, W/m$^2$
$U_f$ = thermal transmittance of the floor, W/m$^2$K
A = area of the floor, m$^2$
$t_o$ = outdoor air temperature, °C

Infiltration heat loss

This was computed from equation (3),

$$Q_{inf} = P_d \times c_p \times vol \times R_i \times (t_a - t_o) \quad (3)$$

where,

$P_d$ = density of air kg/m$^3$
$c_p$ = specific heat of air, kj/kg K
$R_i$ = infiltration rate, air changes/h

Direct solar heat gain

$$Q_{sol} = I_t \times SG \times A_w \quad (4)$$

where,

$Q_{sol}$ = solar heat gain, W
SG = solar heat gain factor for the type of glazing
$A_w$ = area of window, m$^2$
$I_t$ = total radiation on window, W/m$^2$

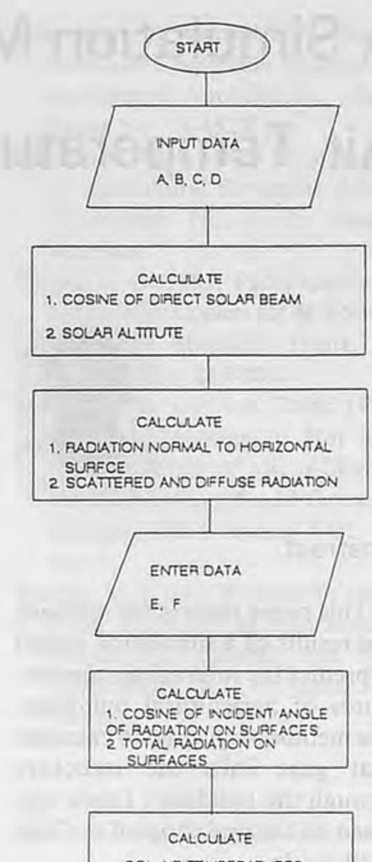


**Fig. 1** A flow chart showing the major calculation sequence.

In arriving at the value for the

total radiation the angle of incidence of solar radiation on the surface was taken into account (refer to flow chart, **Fig. 1**)

## The Building Heat Balance

The model was based on the sensible heat balance equation for the building and can be expressed as:

$$\text{Heatgain} = \text{Heatloss} \qquad (5)$$

From the components of the model, equation (5) can be written as:

$$Q_{skin} + Q_{sol} = Q_{inf} + Q_f \qquad (6)$$

In adopting this approach certain assumptions that influence the thermal behaviour of buildings as suggested by Burch et al were made. These were:

1. Conduction heat transfer through the building skin is one dimensional;
2. All the building materials are homogeneous with constant thermal and physical properties;
3. The inside air temperature is uniform at any one moment;
4. Doors and windows have a negligible heat storage capacity; and
5. Heat and mass transfer of water vapour and the latent heats of condensation are negligible.

## The Computer Programme

A Fortran 77 computer programme was written to predict the internal air temperatures of the experimental building. A flow chart showing the major calculation sequence is provided in **Fig. 1**. The input data referred to in the flow diagram are:

A - Physical dimensions of the building skin and floor;
B - Declination, latitude, hour angle, radiation heat transfer coefficient;
C - Outdoor temperature, emissivity, radiation data, wind speed;
D - Thermal properties of the building (U value, decrement factor);
E - Surface azimuth angle; and
F - Tilt angle of the surface.

## The Full-scale Experiment

**The Experimental Building (Fig. 2)**

The exterior of the building is made of 35 mm thick hardwood planks with a 4 mm wood interior lining. There is an air gap of 26 mm between the two. Glass windows are situated on both the north and south facing sides. The surfaces of these windows are unevenly coated with flaking white paint, an earlier attempt to prevent the direct entry of solar radiation when the building had been used as a class room. On the eastern side is an internal partition of plywood separating the experimental space from a store space. The western side is bounded by a shed about 2 m away. The structure has a roof of tarred roofing felt and sheets of ceiling board. The floor of this building is raised to about 30 cm above the ground and is made of plywood. The physical dimensions of the structure are: length = 7.00 m; width = 7.50 m; and height (to ceiling) = 3.00 m

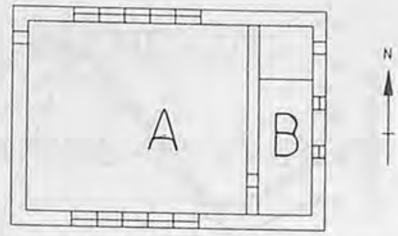


Fig. 2a Plan view of the wooden building.

Fig. 2b The experimental building.

## Infiltration Measurement

The tracer gas decay method was used to determine infiltration rates in the building. Three measurements were made at weekly intervals and the average taken as the rate.

## Temperature Measurement

Fifteen thermocouples mounted on five bamboo poles, which were supported on retort stands, were distributed inside the experimental space (A) and were connected to a Delta-T data logger which was programmed to record temperatures at five-minute intervals and give an output reading of hourly averages. The thermocouples were also placed in the adjoining space (B) and similarly connected to the data logger. The adjoining space served as the western boundary to experimental space. Ambient temperatures were obtained in a similar way but with the thermocouple shielded from direct rays of the sun by aluminium foil cups.

## Results and Discussion

**Figs. 3, 4, 5**, and **6** show the calculated and measured internal air temperatures, measured outdoor temperatures and solar radiation. The measured inside and outdoor temperatures are the mean values of all thermocouple readings at each instant. The maximum difference between the

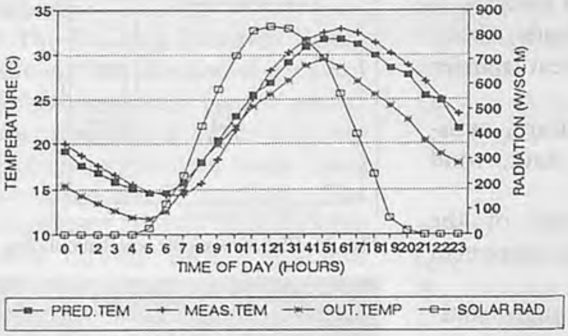


Fig. 3 Predicted and measured temperatures.

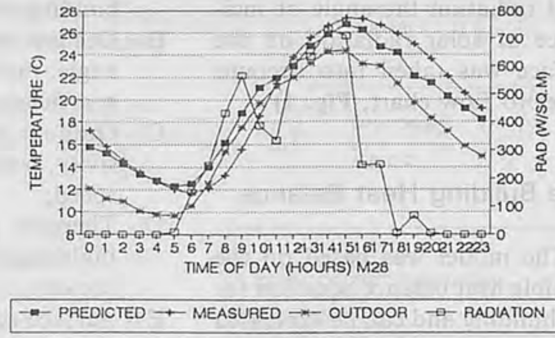


Fig. 5 Predicted and measured temperatures.

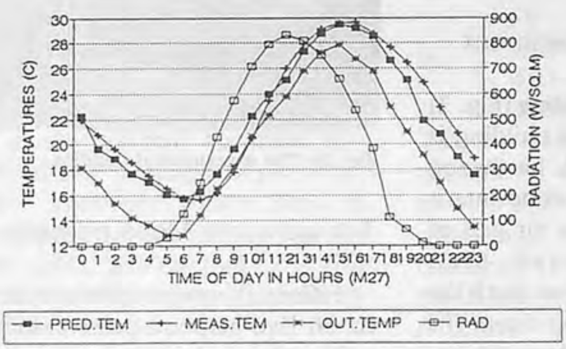


Fig. 4 Predicted and measured temperatures.

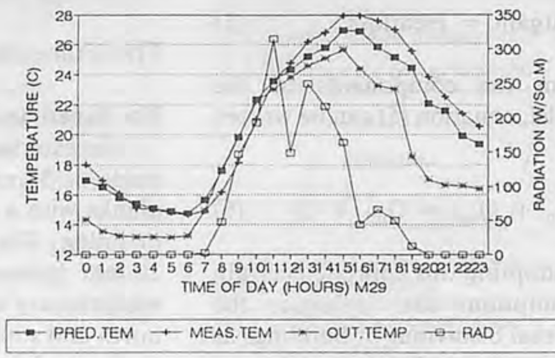


Fig. 6 Predicted and measured temperatures.

calculated and measured temperatures over the four trial days was 2.99°C with an overall root mean square (RMS) deviation of 1.24. A RMS deviation of less than 1.00 would be considered ideal but errors are likely to occur in this analysis from two main sources, namely; the choice of building thermal properties from the literature, which may not represent the actual situation, and the use of measured outdoor temperatures which in most cases did not conform to the sinusoidal pattern for which the thermal equations are based.

## Conclusion

It can be concluded from this study that reasonable predictions of internal air temperatures during the warmer months can be done without resorting to a more complex mathematical approach. Further trials are needed on other types of structures to determine a wider application of the programme.

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# Use of $CO_2$ and $NH_3$ Levels as Minimum Ventilation Rate for Poultry Houses in Winter

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## Introduction

In a broad sense, environment may be interpreted as all external conditions that affect animals. From a manager's and engineer's point of view, it is necessary to know both the optimal temperatures, $CO_2$ and $NH_3$ concentrations to be able to provide optimal management. To do so, the manager should know about the poultry environment and its effect on production and feed consumption.

Not only is the thermal environment important, but there are also other factors which effect egg production such as the chemical environment. Concentration of carbon dioxide and ammonia could also affect egg production, and cause a high mortality rate.

Winter ventilation rates commonly used are set to control moisture. Sometimes the ventilation rate is too high to maintain inside temperature in the optimal range without using supplemental heat. This means a drop in inside temperature, which also means an increase in feed consumption and may effect egg production.

Using ventilation rates below those commonly used for moisture control could help solve the problem of maintaining inside temperature in the optimal range. Moisture level could increase to the level that water condensation may occur inside the house on the walls or equipment. If this situation occurs for a short duration and frequently, corrosion of cages and other equipment or any health problems may not be a problem.

The relative humidity may sometimes exceed 85% in this situation, but according to Hellickson et al (1983) an increase in humidity will decrease production only at higher air temperature. Therefore, in general, humidity changes would not affect the response of nearly mature birds such as laying hens for environmental temperatures below 24°C.

## Objective

The objective of the study was to evaluate $CO_2$ and $NH_3$ levels as minimum ventilation rate in winter conditions in poultry houses.

## Literature Review

Growers and scientists have tried to find optimal conditions to grow checkens for both meat and egg production.

Helback and Casterline (1963) studied the effect of high $CO_2$ atmosphere on the laying hens. The layers were kept in a covered chamber to which a 5% $CO_2$ and 95% gas mixture was metered at 4 ℓ per min for a 19-hour period. Results indicated that during exposure to high $CO_2$ the shell thickness rose above pretreatment levels. However, there was no drop in egg size following the exposure.

Anderson et al (1964) found 5 000 to 6 000 ppm of $CO_2$ in a commercial poultry house. In studies reported by Longhouse (1967), $CO_2$ was as high as 10 000 ppm. Hiestand et al (1941) reported that chickens (no age and breed given) would withstand up to 6% (60 000 ppm) $CO_2$ concentration with slight inhibition off breathing, while at a 10% level, there was increased amplitude, but not an increased rate of breathing.

Charles and Payne (1966) reported the effects of ammonia on the performance of White Leghorn hens housed in various environments of defined temperature and humidity. At 18°C and 67% relative humidity, the use of atmospheres containing 105 ppm of ammonia by volume significantly reduced egg production after a 10-week exposure. No effect in egg quality were observed. However, voluntary feed intake was reduced in ammoniated atmospheres and live weight gain was lower. No recovery production occurred when the treated groups were maintained for a further 12 weeks in an atmosphere free of ammonia.

When White Leghorn hens were housed at an environmental temperature of 28°C and various ammonia concentrations, a decrease in body weight occurred. The decrease in live weight was greatest at ammonia concentration of 102 ppm, and was significant after only one week of exposure to ammonia. Feed intake of controls was approximately 25% lower at 28°C than at 18°C. The presence of 100 ppm of ammonia further reduced feed intake by more than 10%. In one experiment at 28°C, egg production was significantly reduced after 7 weeks' exposure to ammonia.

## Methodology

This study was conducted at Michigan State University Poultry Research and Teaching Farm in a commercial-type egg research facility.

The system in this study was the environment produced within a 4 100-hen operating unit. The operating unit was the house enclosing the laying hens and the equipment used to manage the operation.

The house contained two identical laying rooms. Each room was 5.5 × 31 × 2.37 m. Each room contained one row of deep pyramid reverse cages 30.5 cm × 40.6 cm. These cage rows were a modified stair-step, four-tier design that contained eight lines of cages per row and 60 cages per line. **Figure 1** shows the general cage designs for the shallow and deep cage system.

The performance of different colony sizes and different bird densities was one of the other studies. Five- and six-bird colonies were placed in the deep cages in alternating lines, and three-bird and four-bird colonies were placed in the reverse cages in alternating lines. The end result was a total of two rows of deep cages with five or six birds per cage and two rows of reverse cages with three or four birds per cage and a total of 32 lines.

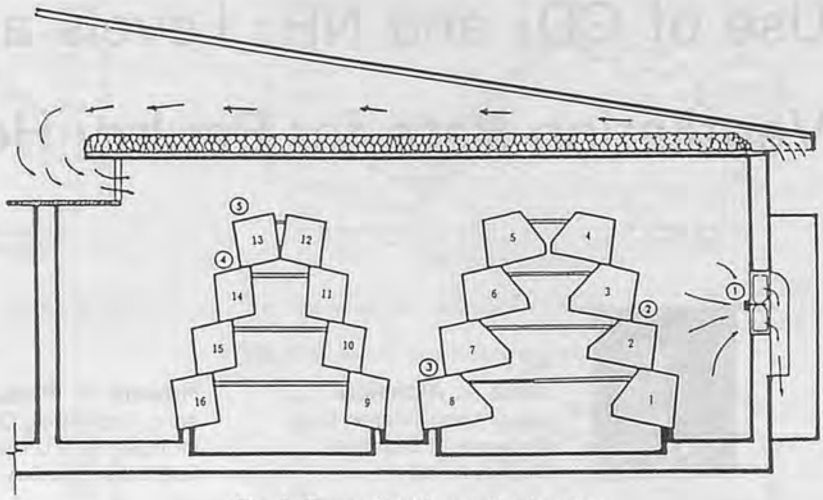

**Fig. 1** Carcon dioxide sampling locations.

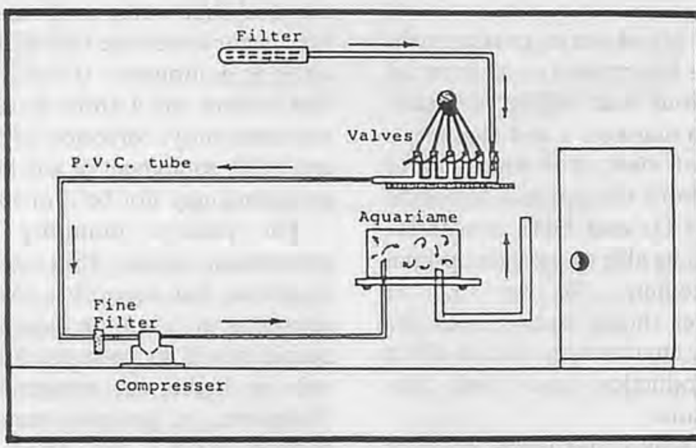


**Fig. 2** Carbon dioxide sampling instrumentation.

Ventilation in each room was provided by two 45-cm variable speed fans (4 588 $m^3/h$) and four 60 cm (4 950 $m^3/h$) fan. The 45-cm variable speed fans operated continuously and provided a total minimum air exchange of 840 $m^3/h$ (0.2 $m^3/h$/bird). The variable speed fans were fixed on that rate.

When the room temperature rose above 26°C, one 60-cm fan was turned on to maintain target temperatures. The in-house target temperature range was 22 to 26°C. This was regulated by thermostat controlling ventilation fans. The 90-cm fan operated only during hot weather conditions. Air inlets located near the ceiling along the north wall of the south (white) room were adjusted by an automatic system sensing static pressure. No supplemental heat was used.

Lights were provided by 33 (25 Watt) white, incandescent bulbs. The intensity was adjusted to 0.75 foot candles as measured from the bottom tier of the cages.

To measure carbon dioxide and ammonia concentrations in the poultry house at minimum ventilation rate, a gas system collection was designed and built in the poultry house. There was a set of filters (five) placed in different locations and different heights on the cages (**Fig. 1**). Every filter was connected to a P.V.C. tube which then connect to a main panel with valves, each valve controlling one filter. All five filter tubes led to outside the room. A vacuum compressor was connected to the main valve panel through a fine filter. The compressor then pumped the air to an upside-down aquarium (**Fig. 2**). Another tube was placed on the base of the aquarium to allow taking the samples. There was flush filter placed outside the poultry room to flush the system after each sample.

Carbon dioxide and ammonia were measured on different days of January 17 and 31, and several days in February, 11, and 21, for coldest days. Samples were taken several times a day from 9 in the morning, 3 afternoon, and from 6 p.m. until 7 a.m. of the next day, every three hours. It takes one hour to complete a scan of all five locations. The interval between each scan was about 15 min. The emphasis was on night hours when the poultry house was in stable conditions almost all the time and the ventilation rate was a minimum of 0.2 $m^3$/h/bird.

The samples were analyzed by using a commercial colormeter (chemically) with carbon dioxide tube model 126SA which ranged from 0.1 to 2.6%. The ammonia tube model 105SC ranged from 5 to 260 ppm.

After each sample, the system was flushed with clean air from an outside room for about 8 min and then proceeded to the next location. Measurements with very low readings were replaced and the average of the two were considered as representative value of the that sample.

## Results and Discussion

Carbon dioxide concentration could vary by using different ventilation rates. Allowable concentration of $CO_2$ in hen house were discussed in Kadlec (1969). Concentrations in the range of 0.25% to 0.5% have small effect on production, between 2.5% and above 5%. $CO_2$ concentration is dangerous and will affect health, production, and may increase mortality, especially with a combination of other gases and high temperature.

The minimum ventilation rate for carbon dioxide control was 0.2 $m^3$/h/bird. When air flow was reduced below that necessary for control of moisture (0.43 $m^3$/h/bird), uniform distribution of fresh air throughout the room may not be achieved.

Measurement of $CO_2$ and $NH_3$ in various locations were made to determine the adequacy of $CO_2$ and $NH_3$ removal from all locations of the room, and to appraise the air distribution.

For February 11, **Fig. 3**, **Table 1**, the $CO_2$ concentration in location #2, ranged from 0.41% to 0.7%; location #3 from 0.42% to 0.55%; location #4 from 0.30% to 0.52%; and location #5, from 0.5 to 0.6%. All these ranges fall in the allowable concentration of $CO_2$, where no effect on healthh or production would be anticipated.

The sudden drop in $CO_2$ level in location #2 was caused by the operation of second phase fan in the adjacent room (white).

Carbon dioxide could be deadly in case of electricity failure or stoppage of fans (**Fig. 4**). **Table 2** shows the quick increase in $CO_2$ concentration reaching the harmful level of 2% in about 2 h and 20 min. A combination of high levels of $CO_2$ from 2% to 5% and high temperature (30°C) in tight buildings will contribute to very high mortality. The highest level of $CO_2$ was in location #5 and the lowest at location #3 at 10 p.m.

Ammonia concentration was constant about all the time during

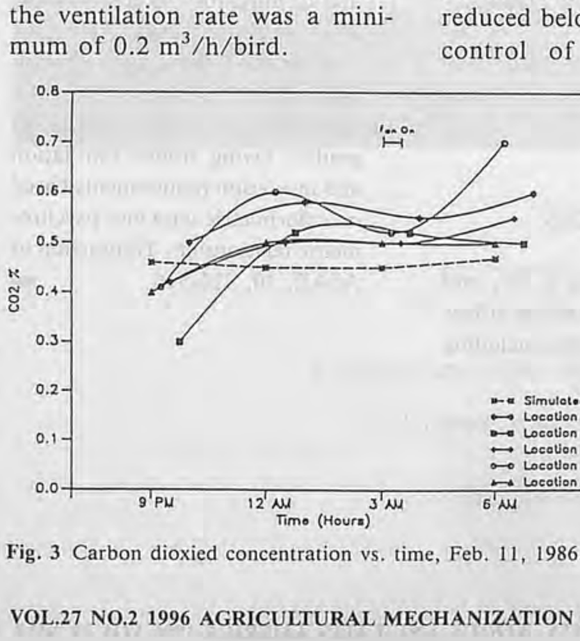


Fig. 3 Carbon dioxied concentration vs. time, Feb. 11, 1986.

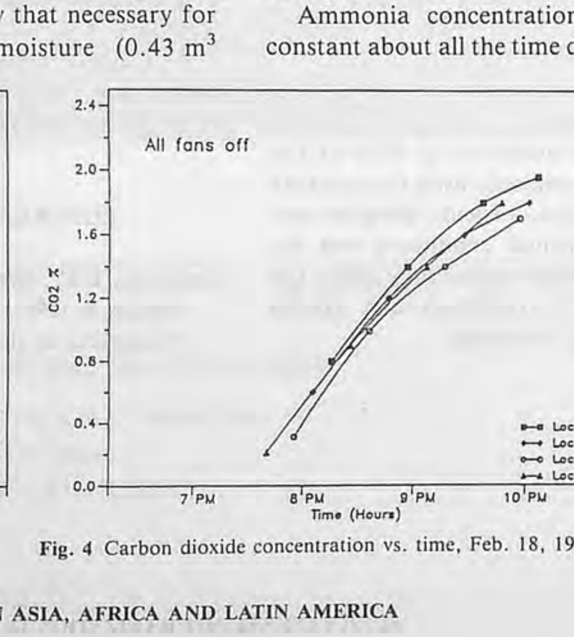


Fig. 4 Carbon dioxide concentration vs. time, Feb. 18, 1986.

Table 1. Carbon Dioxide and Ammonia Concentration, Feb. 11-12, 1986

| Time | Location | $CO_2$ (%) | $NH_3$ (ppm) | Temperature (°C) |
|---|---|---|---|---|
| 9:00 pm | 1 | 0.40 | 20 | 22.92 |
| 9:15 pm | 2 | 0.41 | 15 | 22.52 |
| 9:30 pm | 3 | 0.42 | 15 | 22.87 |
| 9:45 pm | 4 | 0.30 | 20 | 21.85 |
| 10:00 pm | 5 | 0.50 | 15 | 22.48 |
| 12:00 am | 1 | 0.50 | 30 | 23.66 |
| 12:15 am | 2 | 0.60 | 20 | 23.56 |
| 12:30 am | 3 | 0.50 | 20 | 23.66 |
| 12:45 am | 4 | 0.52 | 20 | 23.71 |
| 1:00 am | 5 | 0.58 | 15 | 23.56 |
| 3:00 am | 1 | 0.50 | 30 | 23.41 |
| 3:15 am | 2 | 0.52 | 23 | 23.41 |
| 3:30 am | 3 | 0.50 | 23 | 23.46 |
| 3:45 am | 4 | 0.52 | 23 | 23.56 |
| 4:00 am | 5 | 0.55 | 23 | 23.66 |
| 6:00 am | 1 | 0.50 | 25 | 24.39 |
| 6:15 am | 2 | 0.70 | 18 | 25.21 |
| 6:30 am | 3 | 0.55 | 18 | 25.20 |
| 6:45 am | 4 | 0.50 | 18 | 24.70 |
| 7:00 am | 5 | 0.60 | 18 | 24.63 |

Outside temperature ranged from −4.97°C at 3 pm to −18°C at 7 am.
Outside relative humidity from 96.7% at 3 pm to 93% at 7 am.
Lights off at 7 pm and lights on at 5 am. Bird's age 49 weeks.
Relative humidity inside from 84.0% at 3 pm to 78% at 7 am.

Table 2. Carbon Dioxide and Ammonia Concentration Feb. 18-19, 1986 (All fans off)

| Time | Location | $CO_2$ (%) | $NH_3$ (ppm) | Temperature (°C) |
|---|---|---|---|---|
| 7:40 pm | 2 | 0.21 | 20 | 23.21 |
| 8:20 pm | | 0.90 | | 28.90 |
| 9:00 pm | | 1.40 | | 31.45 |
| 9:40 pm | | 1.80 | | 33.47 |
| 7:50 pm | 3 | 0.31 | 20 | 26.78 |
| 8:30 pm | | 0.99 | | 29.73 |
| 9:10 pm | | 1.40 | | 31.83 |
| 9:50 pm | | 1.70 | | 33.88 |
| 8:00 pm | 4 | 0.60 | | 27.03 |
| 8:40 pm | | 1.20 | | 30.46 |
| 9:20 pm | | 1.60 | | 32.46 |
| 9:55 pm | | 1.80 | | 33.90 |
| 8:10 pm | 5 | 0.80 | 20 | 28.09 |
| 8:50 pm | | 1.40 | | 31.00 |
| 9:30 pm | | 1.80 | | 33.07 |
| 10:00 pm | | 1.96 | | 34.22 |

Outside temperature ranged from 1.48°C at 7 pm to 1.47°C at 10 pm.

the test days, and it was always below the maximum limit of 50 ppm. This could be affected by the kind of feed used, and the two time cleaning the manure pit.

Using low ventilation rate of 0.2 $m^3$/h/bird in winter as ventilation rate for carbon dioxide control (minimum ventilation rate) will give better manipulation of air exchange in the poultry house, and to maintain the temperature in the thermonutral zone, without exceeding the maximum allowable concentration of $CO_2$ and $NH_3$.

## Conclusions

1. Ventilation at 47% of the rate commonly used for moisture control to provide adequate environmental conditions was accomplihed successfully under the climatic conditions that existed during the study.

2. Lower ventilation rates helped maintain higher inside temperature which lowered feed consumption and improved revenue margins for cooler days.

3. Ammonia concentrations were well below maximum allowable concentrations (<35 ppm) even with low ventilation rate which was used in this study.

4. At a low air flow rate, mixing of outside air with the inside was very good, and adequate based on uniformity of $CO_2$, $NH_3$ and temperature in various locations.

5. Carbon dioxide did not exceed the maximum allowable level in any location.

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# From Bhutan to Tokyo via Australia

by
Grame Ross Quick, AMA Co-operating Editor

I have just returned from a fascinating trip on behalf of UN's RNAM to Bhutan, amongst other countries, and want to share some observations:

At IRRI I participated in developing a new harvester based around the British Silsoe/ Shelbourne Reynolds Stripper harvester principle—a walk-behind portable design for small paddy fields that used an 11 hp power unit. Then earlier this year, my former Graduate student as an IRRI scholar having returned to Myanmar where unbeknown to us he completed an SG800 based on IRRI preliminary blueprints.

His Minister of Agriculture saw this displayed in July along with the highest level people in the land (SLORC) and they were impressed enough to issue a directive to put it into immediate production, even though it had only harvested 1/10 ha and had a number of defects! The Ministerial directive required the production of two thousand SG800's-**by September 15, no less.**

200 were in various stages when I went over there in August. The quality of workmanship left a lot to be desired. One concern was with the quality of the **welding**, which suffered from the fact that on a number of occasions operators were seen doing arc welds without using headshields or any form of safety protection, except to shut their eyes when actually welding! (One had on sunglasses). This was a serious matter with a number of ramifications. The first was of course the risk of permanent eye damage to the welding operators, then there is the effect upon the quality of the machine itself because the welder cannot do a proper run of welding with his eyes shut. I made quite an issue over this and hopefully there will have been some action.

They are so serious that they have already published the operator's manual in a Myanmar language edition; furthermore there have apparently been national TV showings of the machine at work. I managed to get to the Minister of Heavy Industry himself to explain the situation and urged them to just complete a few machines and test them under local conditions and to get the latest improvements from IRRI into there machines: hopefully that will have saved some Burmese engineers some embarrassment. They can blame me instead!

It was satisfying to see the IRRI Engineering technologies being avidly - if in this case somewhat hastily - adopted. RNAM's programs at least look for ongoing Engineering work at IRRI.

**Bhutan** was another story. In a country with less than a million people it was astonishing to find an Agricultural Machinery Centre equipped with an array of machines like nothing seen elsewhere in SEAsia! This is due entirely to Japanese largesse, maintained over the past eleven years. The amount of grant aid provided by JICA for AMC to use to purchase farm equipment and spares last year *was almost US$3 million*. The buildings, facilities and machine tools are substantial and yet are stretched to capacity with the latest Japanese small farm machines in inventory. The four wheel drive tractors (up to 40 hp), forage choppers, power sprayers and power threshers are *state-of-the-art latest models, straight out of the Japanese catalogs - or the Kubota catalog especially*. AMC then sells this equipment to the farmers at greatly subsidised prices and in this way mechanization comes to Bhutan! A very interesting and picturesque place.

**But no more time for reveries**, as Editor its time to get back to work on *Agricultural Engineering Australia* in the remainder of this year! On Jan 31, 1995, I retired from the position of Head of the Agricultural Engineering Division of the International Rice Research Institute in Los Banos, Philippines. At IRRI we had the resources to tackle the more difficult task of trying to develop technologies for the less-advantaged members of rural societies in the developing world. That was a demanding assignment. Now I wish my successor well, and would take this opportunity through the pages of AMA to thank the people at IRRI for their good will and to all in Asia who have been helpful in those endeavours, not least being Yoshisuke Kishida, whose unflagging efforts with his publications are a vital means of communication in the developing world. ■■

## Agritech Spring 96 — The 13th International Exhibition of Agriculture in Israel

**May 12-16, 1996**
**Tel Aviv, Israel**

Agritech Spring '96 features the very latest Israeli technology for field and fruit crops, poultry and dairy farming, greenhouse cultivation, aquaculture, and many other sectors of modern agriculture.

Organized by the Ministry of Agriculture, the Israel Export Institute and the Kibbutz Industries Association. Agritech Spring '96 promises to be the largest and most varied Agritech exhibition yet. Thousands of visitors from over 130 countries have already shown an interest in the 400-exhibitor event.

Agritech Spring '96 is also the venue for congresses and workshops on water and irrigation, greenhouse technology, agro-ecology, plant protection and dairy farming.

Contact: Yitzhak Kiriati, Agritech Spring '96 Organizing Committee, P.O.B. 50084, 61500 Tel Aviv, Israel. Tel: 972-3-5142868, Fax: 972-3-5142881.

## Agromart '96

**June 5-8, 1996**
**Kasati International Exhibition Centre**
**Ho Chi Minh City, Vietnam**

The French Bureau des Opérations Internationales, the Netherlands Centre for the Advancement of Trade and Royal Dutch Fairs ('Jaarbeurs') have joined forces in the organization of the international Agromart exhibition in Vietnam. Agromart '96 will be held at the Kasati International Exhibition Centre in the Vietnamese capital, Ho Chi Minh City, from 5 to 8 June.

The intensive cooperation of these three major parties signifies a further stage in the internationalization of the Agromart, and enables Dutch businesses in the agricultural sector to present themselves to the world at a top-class event. Royal Dutch Fairs' role in this project is to create a wider international platform for this exhibition. Royal Dutch Fairs is a specialist in the organization of high-quality international trade fairs, and has organized exhibitions in such countries as Thailand, Brazil, Japan and Portugal. It enjoys an excellent reputation in this field worldwide. Since 1991, the Bureau des Opérations Internationales has organized three editions of the Agromart, alternating between Ho Chi Minh City and Hanoi. Originally a biennial event, the Agromart will become an annual trade fair and continue to alternate between Ho Chi Minh City and Hanoi.

Contact: JAARBEURSPLEIN 6 3521 Al Utrecht P.O. Box 8500 3503 Rm Utrecht the Netherlands. Telephone +3130-955911, Fax +3130-961660.

## AFIA AGROMEXICO '96

**June 13-16, 1996**
**Expo Guadalajara, Guadalajara, Jalisco, Mexico**

This will be the largest agricultural exhibition held in Mexico, and will incorporate all of the agricultural and livestock associations in the country. The event will be a 3-way partnership with the American Feed Industry Association (AFIA), Consejo Agropecuario de Jalisco and ITI, one of the leasding trade exhibition organizers serving the Latin American market. Exhibitor categories will include food processing equipment, products, services and equipment for the agriculture, forestry, aquaculture, ingredients, seeds, livestock, grains, feed, and pet supplies industries.

Contact: International Trade Information, Inc. 21031 Ventura Blvd., Suite 405, Woodland Hills, CA 91364-2203, USA Tel: (818) 340-8864, Fax: (818) 340-7017
American Feed Industry Association. 1501 Wilson Blvd., Suite 1100, Arlington, VA 22209 USA. Tel: (703) 524-0810, Fax: (703) 524-1921.

## ASP 26th Congress and AGVGA Conference

**June 14-18, 1996**
**Atlantic City, New Jersey, USA**

The 26th Congress of the American Society for Plasticulture (APS) is to be held from June 14-18, 1996 at the world-famous Boardwalk of Atlantic City, New Jersey, located adjacent to one of the most active regions of intensive horticultural crop production utilizing Plasticulture technologies in the US.

Innovative program events for the 1996 Congress include:

* Enlightening, lecture-style technical sessions,
* A Professional Improvement Workshop, consisting of an afternoon of hands-on Plasticulture demonstrations,
* A 1-day Greenhouse Crop Production Program organized by the American Greenhouse Vegetable Growers Association (AGVGA),
* Industry and farm tours that will focus on New Jersey's horticultural crop production industry,
* Trade Show, Awards Banquet, Clambake, and the Atlantic City Boardwalk that will offer ample opportunity to meet all your industry or academic colleagues for technical discussions, and for some fun.

The American Greenhouse Vegetable Growers Association (AGVGA) will convene its regular conference during the American Society for Plasticulture (ASP96) Congress. This Congress marks the first time AGVGA has met in conjunction with an ASP Congress.

Contact: Dr. Richard Snyder, Mississippi State University, Truck Crops Research & Extension Center, P.O. Box 231, Crystal Springs, MS 39059. Phone: (601) 892-3731; Fax: (601) 892-2056; internet: RickS@aac.msstate.edu

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### The Fifth International Congress on Leaf Protein Research: LEAFPRO-96

**June 17-21, 1996**
**The Don State Technical University Rostov-on-Don, Russia**

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The Congress will be held at The Don State Technical University from June 17 to 21, 1996.

The town of Rostov-on-Don is a major industrial, scientific and cultural centre in the South Russia with the population exceeding 1.2 million.

Mid- and late June here normally gives us 20-30°C, i.e. from warm to hot with occasional showers.

**Main Event**

The programme will embrace opening and closing ceremonies, section meetings, poster sessions, video sessions, technical tours to the out-of-town experimental complex of the Don State Technical University and also to some leaf protein production facilites.

Contact: N. Proydak, President of SGVR. LEAFPRO-96 Organizing Committee, The Don State Technical University, 1, Gagarin Square, Rostov-on-Don 344708 Russia. Telephon: 7 863 2 32 03 17; 7 863 2 38 15 87, Fax: 7 863 2 32 03 17; 7 863 2 32 79 53; 7 863 2 34 53 55, E-mail: root@dgtu.rnd.SU

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### The Royal Show — The World's Premier Agricultural Exhibition

**July 1-4, 1996**
**National Agricultural Centre, Stoneleigh Park, Warwickshire, England**

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Exhibitors and visitors alike have proclaimed the new Royal International Agricultural Exhibition to be an outstanding success, vindicating the decision by the Royal Agricultural Society of England (RASE), hosts and organisers of the event, to spend over £1.5 million on improvements to the exhibition site, the Royal Showground.

Visitor numbers over the four days of the Exhibition exceeded 180 000, reversing a five-year decline in attendance figures, while exhibitor numbers were also up to record levels at 1 547. The increased attendance reflects a resurgence of confidence in the role of the Royal International Agricultural Exhibition as Europe's industry showcase for farming, food and the countryside.

Contact: International Office, Royal Agricultural Society of England, National Agricultural Centre, Stoneleigh Park, Warwickshire, CV8 2LZ, England. Tel: 01203 696969. International: +44 1203 696969. Fax: 01203 696900.

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### IAMFE/France '96 — The 10th International Conference and Exhibition on Mechanization of Field Experiments

**July 8-12, 1996**
**INRA Versailles, France**

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The Institut National de la Recherche Agronomique (INRA), the Association Française pour la Mécanisation en Expérimentation Agricole (AFMEX) and the International Association on Mechanization of Field Experiments (IAMFE) have pleasure in inviting you to IAMFE/France '96, the tenth International Conference and Exhibition on Mechanization of Field Experiments.

The Conference will be held at the INRA Research Centre at Versailles, 10 km west of Paris, on July 8-12, 1996. It will be one of the scientific events marking the 50th anniversary of the creation of INRA.

A conference in France, possibly one of the leading agricultural countries in Europe, will provide scientists, manufacturers, consultants etc. from all over the world with an excellent opportunity to exchange ideas and information in the area of field experimentation. But seats are limited: you are advised to apply early!

Contact: Madame Marion Tempé Secrétaire Général, IAMFE/France '96. INRA Centre de Versailles, Route de Saint-Cyr, F-78026 Versailles Cedex. Fax: +33-1-30833458, E mail: tempe@versailles.inra.fr

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### Land TECHNIK 1996 — 54 Internationale Tagung Landtechnik

**10/11. Oktober 1996**
**Humboldt - Universität zu Berlin**

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Contact: Verein Deutscher Ingenieure **VDI**. Max-Eyth-Gesellshaft Agrartechnik im VDI, Postfach 10 11 39, 40002 Düsseldorf. Telefon: 0211/6214-522 Telefax: 0211/6214-163.

## ICAME '96 — International Conference on Agricultural Machinery Engineering

**November 12-15, 1996**
**Korea Exhibition Center, Seoul, Korea**

ICAME '96 will take place in Seoul on November 12th to 15th, 1996. The Conference will be held at the Korea Exhibition Center, Seoul.

This conference is to provide a forum for agricultural engineers who are responding to worldwide competition and challenge to explore the state-of-the-art technologies and future directions in the agricultural machinery and process engineering. The whole area in agricultural machinery and process engineering will be discussed in parallel working sessions concerning both general strategic subjects and specific technical subjects.

**Call for Papers:** All participants who wish to present papers are requested to submit an abstract in English by March 31, 1996. The abstract should be less than 400 words, single spaced, and include the title of paper, full names and addresses of all authors, objectives, methods and significant results.

Contact: Prof. Kwan Hee Ryu. Department of Agricultural Engineering. Seoul National University, Suwon 441-744, Korea. Tel: +82-331-290-2384, Fax: +82-331-294-1815, E-mail: ryukh@plaza.snu.ac.kr

## 20th International Conference of the IVth Section of the CIGR on Rural Electrification and Rational Use of Energy in Agriculture

**April 21-25, 1997**
**Agadir, Morocco**

**Topic:**
1-Rural electrification
1-1-Technical options and Financement
1-2-Renewable Energies and other production sources
1-3-Case studies
1-4-Impact of electrification on the rural population.
2-Rationalization of energy use in
2-1-Irrigation
2-2-Agricultural production
2-3-Animal production
2-4-Environment control
2-5-Conservation & processing
2-6-Horticulture

**Conference Languages:** French and English

**Call for Papers:** Abstracts and posters proposals (200 words) should be submitted to the secretariat of the conference before Mai 30th, 1996. Decision of the scientific committee will be given before September 30th, 1996. Papers should be send by December 30th, 1996. Abstract should be written in English.

**Fees:** US$300 registration fees include seminar proceedings. These fees do not include hotel accomodation and meals.

**Secretariat Address of the Conference:** A.N.A.F.I.D., 20th International Conference of the IVth Section of the CIGR: Rural Electrification. 2, Rue Haroun Errachid, 10101 Agdal, Rabat, Morocco. Tel: +212 7 67 03020. Fax: +212 7 67 03 03.

## International Symposium on Concrete for a Sustainable Agriculture

**May 21-24, 1997**
**Stavanger, Norway**

The symposium will be of special interest to those involved in research, specification, design, construction, use and application, management and maintenance of concrete for agro-, aqua- and community applications.

**Purpose of the Symposium**

The purpose of the symposium is to bring together experts in the field of agricultural engineering, concrete producers, both precast and cement manufacturers to discuss latest developments in

* innovative concrete structures for agriculture, horticulture, animal breeding, aquaculture, and community waste (water) handling, prompted by changes in environmental standards
* durability and quality aspects of concrete in such applications in relation to general environmental standards, health, energy and economy.

**Call for Papers**

Authors are invited to submit papers giving high level contributions to the scientific, economical, technical and practical aspects of the Symposium. Prospective authors are requested to announce their intention and to submit a 500 word abstract, which will constitute the basis for preliminary acceptance by the Committee. As many papers as possible will be given time for oral presentation. In the event of a large response parallel sessions presentation will be considered.

**Organized by** Norwegian Masonry- and Concrete Center in cooperation with Norwegian CIGR.

Contact: Norwegian Mansonry- and Concrete Center. P.O. Box 53 Blindern, 0313 Oslo, Norway. Phone: +47 22 96 58 60 Fax: +47 22 56 42 38.

*(Continued on page 80)*

## A Tractor Goes Farming

(U.S.A.)

*by Roy Harrington*

The American Society of Agricultural Engineers (ASAE) has just published Roy Harrington's second book — A Tractor Farming. More than 29 000 copies of his first book — John Deere Tractors & Equipment, 1960-1990, have been sold. Mr. Harrington is a Fellow and Life Member of the Indian Society of Agricultural Engineers.

'A Tractor Goes Farming' is a quality hardbound, well illustrated book for the beginner-reader. It shows and tells what the 26 most common implements do for the production of maize (corn), wheat, soybeans, cotton, grass hay, alfalfa hay, silage, cattle and hogs. The tractors and implements shown are generally the most popular brands and sizes in USA. Tractor makes included are John Deere (who now have a collaboration with Larsen & Toubro), Case-IH, Ford-New Holland and Massey Ferguson (now a part of AGCO).

Climb aboard a red, green, blue or silver tractor as you plough through the pages of this new book from the ASAE. 'A Tractor Goes Farming' begins in the spring and moves chronologically through the growing season. It helps your children (and grand-children) learn about many of the jobs a tractor performs on the farm. From pulling a plough or powering a round baler, to scooping with a farm loadr, this book shows the tractor performing tasks that many children have never seen but are part of a tractor's work day.

Author Roy Harrington has put together a wonderful new book that places the child in the driver's seat of these large vehicles. He uses short, simple sentences, and full colour photographs are sure to please everyone.

The book gives the reader an opportunity to learn what life is like on the farm for the tractor.

32 pages, 7 × 8 1/2 inches, US$ 6.95.

Bombay, Feb. 29, 1996.

## Agricultural and Food Processing Wastes — Proceeding of the Seventh International Symposium on Agricultural and Food Processing Wastes

(U.S.A.)

Even if you couldn't attend this exciting international conference held June 1995, in Chicago, Illinois, this book will provide you with the latest research findings in agricultural and food processing waste management.

Highlights include:

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- Management Techniques/Practices
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- Anaerobic Digestion/Treatment
- Food Processing Waste Treatment Systems and Management

Specialists in food processing and waste management, engineers, state regulatory personnel technicians, scientists, and others will benefit from the latest technology available on managing wastes from agricultural production and food processing facilities.

636 pages, 6 × 9 inches, softbound.

List$44.00. ASAE Member $38.00.

Published by ASAE. 2950 Niles Road, St. Joseph, MI49085-9659 USA.

## Integrated Management of Insects in Stored Products

(U.S.A.)

*edited by Bhadriraju Subramanyan, David W. Hagstrum*

This unique resource offers an up-to-date review of the identification, biology, ecology, and sampling of insect pests associated with stored foods — providing a balanced view of biological, physical, and chemical control methods used in pest management.

Covering every important method of control, Integrated Management of Insects in Stored Products:

- illustrates the insects found in stored products to permit correct identification
- supplies a pest management-oriented discussion of insect biology and ecology
- describes how insects respond to environmental conditions, such as temperature, moisture, and nutritional quality of food
- provides methods for developing and implementing insect sampling programs
- details effective physical control techniques
- discusses the past, present, and future of biological control
- lists the advantages, limitations, and current status of stored-food insecticides
- shows how insects can be tested to determine resistance, how to interpret resistance information, and how to manage resistance
- presents the key concepts and components of an IPM program

September, 1995 / 440 pages, illustrated / $165.00

Published by Marcel Dekker, Inc. 270 Madison Avenue, New york, NY1006.

## Proceedings of the Fourth Regional Conference on Mechanization of Field Experiments
(Lithuania)

IAMFE/BALTIC '95, The Fourth Regional Conference and Exhibition on Mechanization of Field Experiment, will be held in Kaunas and Dotnuva, Lithuania, on August 8-10, 1995. It is the first conference of this type arranged in Eastern Europe since the great political changes over the last few years. It will provide researchers, agronomists, plant breeders and others with the possibilities to show, and to compare, their results and traditions of field experiments.

This conference proceedings the record of Fourth Regional Conference on Mechanization of Field Experiments.

This proceedings, with more than 30 important papers from delegates from 10 countries, constitutes a valuable source of information for researchers, manufacturers and others in this part of the world.

Questions about IAMFE/BALTIC '95 or about IAMFE can also be directed to:
The International IAMFE Centre
Mr. Torbjörn Leuchovius, Executive Secretary of IAMFE, P.O. Box 7033, S-750 07 Uppsala, Sweden. Telephone: +46-18671000, Telefax: +46-18673529, E Mail: IAMFE@LT.SLU.SE
The Norwegian IAMFE Centre
Mr. Egil Øyjord, President of IAMFE, P.O. Box 5065, N-1432 Ås, Norway. Telephone: +47-64948700, Telefax: +47-64948810, E Mail: IAMFE@NLH10.NLH.NO

## Animal Traction in South Africa: Empowering Rural Communities
(South Africa)

*Compiled and edited by Paul Starkey.*

This publication contains a report of a nation-wide survey on animal power in which a multidisciplinary, multiracial team listened to the experiences and concerns of over 500 farmers and officials. The South African Network of Animal Traction (SANAT) initiated the survey, which was assisted by several organizations. The Development Bank of Southern Africa (DBSA) held a workshop to discuss the survey findings. It was concluded that animal traction could play a significant role in achieving the objectives of the Reconstruction and Development Programme (RDP) of the new South Africa. Besides describing the present use of animal traction in South Africa, the book contains chapters that provide a socio-economic analysis, an historical perspective and a review of the particular myths and misconceptions that have grown up around the donkey in South Africa.

The book, which is published by DBSA on behalf of SANAT, is illustrated by more than 140 photographs, including 55 in colour. The colour pages are also available separately as a 16-page booklet which portrays current animal traction use and summarises some of the key issues.

159 pages, 6 × 9 inches, softbound

Book preparation: Paul Starky, Animal Traction Development, 64 Northcourt Av. Reading RG2 7HQ, UK. ■■

*(Continued from page 78)*

# NEWS

## Fifth International Livestock Environment Symposium
**May 29-31, 1997**
**Hotel Sofitel Mineapolis, Bloomington**

**Sponsored by:** ASAE — the Society for engineering in agricultural, food, and biological systems.

**Purpose:** This fifth international conference will continue a tradition of bringing together experts from around the world and from every discipline responsible for creating and managing humane, sustainable, environmentally friendly, safe, economical, and productive livestock environments. The program will include invited presentations by renowned specialists from different professions, oral and poster technical presentations, and many opportunities for informal networking among participants. It will be an opportunity for participants to learn about the latest research by scientists, engineers, practitioners, consultants, economists, and other professionals interested in livestock environments.

Specific conference objectives are to: (1) assemble the latest basic and applied information about environmental requirements and systems for livestock industries around the world, and (2) foster interdisciplinary communication between scientists, engineers, practioners, economists, and other professionals with interests in livestock environments.

Contact: Susan Buntjer. ASAE Meetings & Conferences, 2950 Niles Road, St. Joseph, MI 49085-9659, USA. Voice: (616) 428-6327 (Eastern Time Zone) Fax: (616) 429-3852 Internet: buntjer@asae.org ■■

# 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 printed, 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.
h. written on floppy disc.

## 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, the main author is given an article on floppy disc with AMA true format. Co-authors can get a copy from main author.
d. Complimentary copies: Following the publishing, three successive issues are sent to the author(s).

## 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.
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## Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows.....) along with one printed copy.
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. 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
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. 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".
e. The data for the graph must also be included.
f. 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.
g. 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.
h. 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).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. 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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