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# AMA

## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.17, NO.1, WINTER 1986

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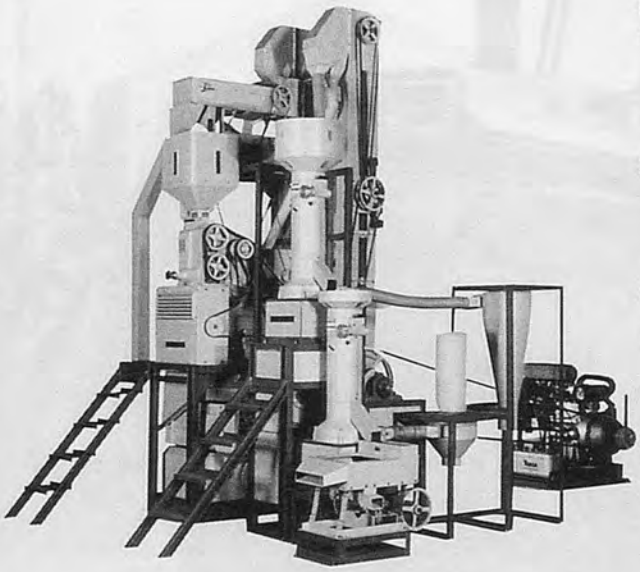

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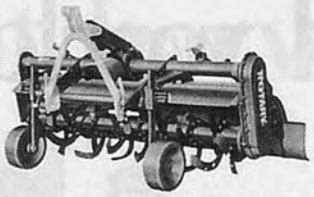

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This publication, published quarterly, has an objective to promote agricultural mechanization in developing countries. Its readers consist of so many people in various fields such as farmers, dealers, manufacturers, researchers, government officials, 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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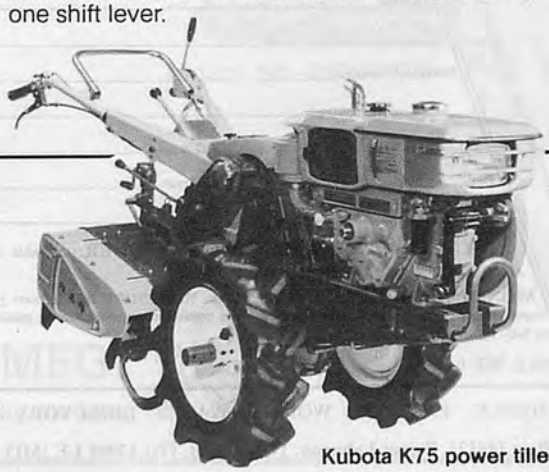

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This is the 50th issue since the issue, Spring of 1971

## EDITORIAL

**...As We Approach the 21st Century**

In wishing our readers and contributors a Very Happy New Year, we cannot help but look back with pride to the Spring of 1971 when the maiden issue of AMA came into print. AMA has come a long way indeed. And as we approach the 21st century, we also cannot help but look forward to with hope that not only 1986 but the ensuing years as well, will see AMA continuing to perform its role as an exponent of agricultural development via farm mechanization.

This strong feeling of optimism and confidence stem from the fact that AMA continues to enjoy the support of its subscribers, contributors, co-editors and the growing readership in both developed and developing countries. In a manner of speaking, the message is loud and clear: "Let AMA play its role and accomplish its mission:".

Perhaps a more positive factor that encourages AMA to go on and on is the fact that farmers who have embraced farm mechanization have prospered, by and large. They continue to raise the food from the farms in large quantities to help feed the teeming millions, particularly in the famine-stricken countries of Africa. On the other end of the spectrum, scores of other farmers in developing countries are learning fast, through effective communication and mass media (such as AMA provides) that agricultural mechanization can and does transform their farming operations into a more convenient chore vis-à-vis the traditional back-breaking job that it is and still increase productivity and profitability.

Therefore, the years ahead, as we approach the 21st century, look challenging, but not intimidating, for AMA to carry on. And AMA, with the continued support from all concerned, will carry on and strive to prove equal to the task that it has taken upon itself to undertake.

AMA wishes everyone a More Prosperous New Year and continued success!

Yoshisuke Kishida
Chief Editor

January, 1986
Tokyo

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# Problems of Agricultural Mechanization in Developing Countries

by
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## Introduction

This paper is a contribution to the discussion on the problems of agricultural mechanization in developing countries. In view of the complexity of the subject, no claim is made that this elaboration is complete, since the author just wants to discuss some aspects of agricultural mechanization which he thinks to be of special importance.

## The Setting

The majority of the developing countries (DCs) are situated in the tropics and subtropics, being roughly bounded by 30 degrees of northern and southern latitude, while the industrialized countries (ICs) are mainly located in the temperate zones.

For the DCs, the vital future problems are to secure the nutrition for their population and the supply of other energy sources (1). The seriousness of the problem of future food supply in DC becomes quite clear if we consider the facts that today about one million people in ICs are producing the same quantity of cereals as approximately three million people in DCs (2, 3) and that the increase of the world population from 4 billion today to more than 6 billion in the year 2000 will take place mainly in the DCs.

An example of development in many DCs is Tunisia (**Fig.1**), where the population has clearly increased during the past 20 years and the degree of agricultural production has changed from self-sufficiency to a heavy shortfall in production.

The possibility of importing food from abroad is often out of the question since the necessary foreign exchange is not available.

Unlike agriculture in the ICs which is mechanized to a large extent, in the DCs traditional farm practices (**Table 1**) such as manual work and use of draught animals prevail and only about 1/5 of the farmed area is cultivated with the help of tractors (4).

Agricultural mechanization in the context used in this paper is defined as the completion of farm

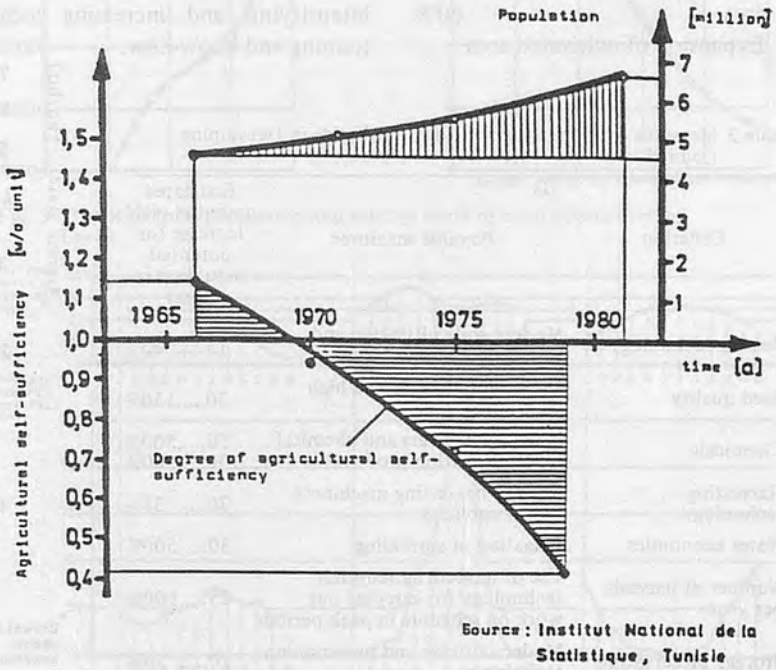



Fig. 1 Development of the population and degree of agricultural self-sufficiency in Tunisia, 1965-80.

Note: This paper was read in the plenary assembly of the 41st International Conference on Agricultural Technology, Braunschweig Nov. 10-11, 1983. Published in "Landtechnik" issue No. 1, January 1984 in German.

Table 1 Distribution of the Cultivated Agricultural Area in Developing Countries and in Industrialized Countries According to Stages of Mechanization, in 1975 (acc. to FAO, 1979)

| Item | | Stage of mechanization: Manual work | Use of draught animals | Use of tractors | Total |
|---|---|---|---|---|---|
| Developing countries | | | | | |
| Cultivated area | $10^6$ ha | 125 | 250 | 104 | 479 |
| Relative percentage | % | 26 | 52 | 22 | 100 |
| Industrialized countries | | | | | |
| Cultivated area | $10^6$ ha | 44 | 63 | 537 | 644 |
| Relative percentage | % | 7 | 11 | 82 | 100 |
| World total | | | | | |
| Cultivated area | $10^6$ ha | 169 | 313 | 641 | 1.123 |
| Relative percentage | % | 15 | 28 | 57 | 100 |

operations with a minimum use of manpower, within a short time, at a low cost and with increasing quality (5)

## Potentials for Increasing Farm Yields

There are several ways to increase field production, whose shares in the rise of production in the DCs up to the year 2000 has been forecast by the FAO as follows:

- Increase in output per cultivated area 60%
- Expansion of cultivated area 26%
- Rise of the number of harvests/year 14%

100%

This framework of targets includes various technical, biological, chemical, organisational and other measures for increasing the yields, some of which are listed in **Table 2**. Indeed, considerable potentials exist for increasing the yields or at least reducing the losses. To activate and utilize these potentials, however, some kind of input has to be made first, as a rule, in the form of material input as well as intensifying and increasing local training and know-how.

Table 2 Measures for Increasing the Net Crop Yields in Developing Countries

| Criterion | Possible measures | Estimated potential yield increase (or potential reduction in loss) |
|---|---|---|
| Sowing technology | Modern soil cultivation and sowing techniques | 15..... 35% |
| Seed quality | Use of appropriate and high yield sorts | 30.....150% |
| Chemicals | Mineral fertilizers and chemical plant protection products | 50.....500%<br>100.....300% |
| Harvesting technology | Modern harvesting machinery (e.g. combines) | 20..... 35% |
| Water economics | Irrigation or sprinkling | 50.....500% |
| Number of harvests per year | Use of modern agricultural technology for carrying out work on schedule in peak periods | 25.....100% |
| Storage preservation | Modern storage and preservation techniques | 10..... 50% |
| Transport | Effective handling technology matched to the local conditions | 10..... 30% |

In this connection, agricultural mechanization in combination with other measures is of special importance. Frequently, agricultural mechanization is necessary but not sufficient measure to achieve an increase in agricultural yields.

In increasing the number of harvests per year, then the use of engine-powered agricultural machinery and equipment will be indispensable, as a rule, since it is not possible to complete all the operations required (harvesting, tillage, and sowing of follow-up crops in the shortest time possible) on schedule with the traditional means. It is known that Egypt, for instance, could increase its number of harvests from 2 to 2.5 per year (25% more yield) if only agricultural machinery and equipment would be introduced for tillage/cultivation and harvesting.

An overall study on the effect of the degree of mechanization on yield level **(Fig.2)** proves the existence of a correlation between engine power input and yield level in various regions of the world (6).

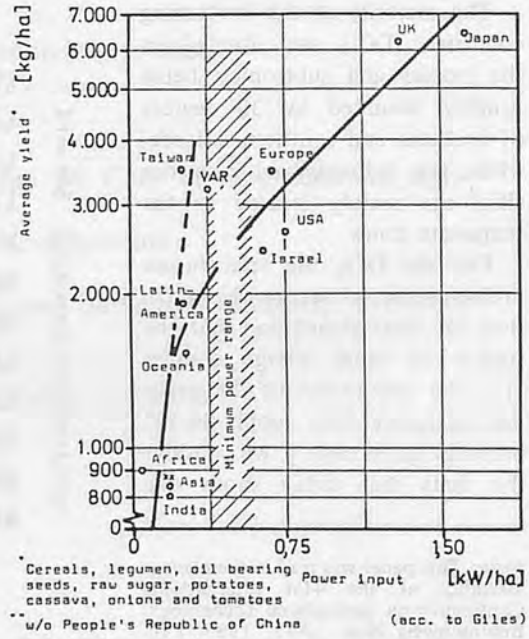



Fig. 2 Power input and agricultural yield in various regions of the world.

## Availability of Labour

The usually lower wages for labour (7) in rural areas compared to those in the towns lead to the widespread problem of rural exodus. People drift to towns even though there are only jobs available for a small number of them and the misery of most of these people will be even greater, living in the new, unfamiliar surroundings in which they are often not socially integrated. Egypt, as an example, demonstrates a trend (8), typical for many DCs (Fig.3). Furthermore, the drift from rural areas to towns becomes quite evident from the fact that the growth rate of many towns is a multiple of the general population growth (in some cities in DC the population doubles in a period of less than 10 years). Thus, the reply of Prof. Bassili, former Dean of the Agricultural Department of the University of Cairo to the question: "Why do you want to mechanize rice harvesting in the delta of the Nile even though you have so many people living in rural areas?" is not surprising at all. He said: "Yes, you are right, we have many people but no labour?"

When comparing engine-powered agricultural mechanization with competitive muscular work (of man or animal), the necessity of the former is, in addition to the aspect of increasing yields, often based on the following reasons:

i) lack of labour to carry out work in peak periods;
ii) labour being expensive (also a sign of labour shortage);
iii) no or poor settlement in areas of newly reclaimed land and/or; and
iv) work animals become competitors of man with regard to plant consumption if the acreage is limited (in Egypt, for example, 1 kg of straw costs more than 1 kg of cereals).

## Importance of Irrigation in DCs

As compared to the temperate climatic zones, large areas of the tropics and subtropics are characterized by long dry seasons, irregular and/or small amounts of rainfall. In Fig.4 some of the different climates are compared, showing that in developing countries the availability of water and irrigation technology most frequently plays a special role or is even decisive in obtaining any yields. In certain regions field production without irrigation is not feasible at all.

In its forecast the FAO (4) assumes that the area irrigated in DC will be increased from 107 million ha in 1980 to about 150 million ha in the year 2000. This expansion will require investments of considerable extent.

For the mechanization of irrigated areas, the majority of which today is still being cultivated in the traditional manner (manual work and partly use of work animals), it is very important to achieve a synthesis of cultivation techniques and the use of agricultural machinery and equipment allowing the application of engine power together with the traditional basin irrigation. Meanwhile, various projects for growing rice, e.g., of the FAO, the GTZ, the Dutch Development Aid Programme etc., present some possible approaches. The requirements of the farmers' knowledge regarding irrigation and cultivation techniques, however, are considerably high, and, therefore, any expansion of areas to be

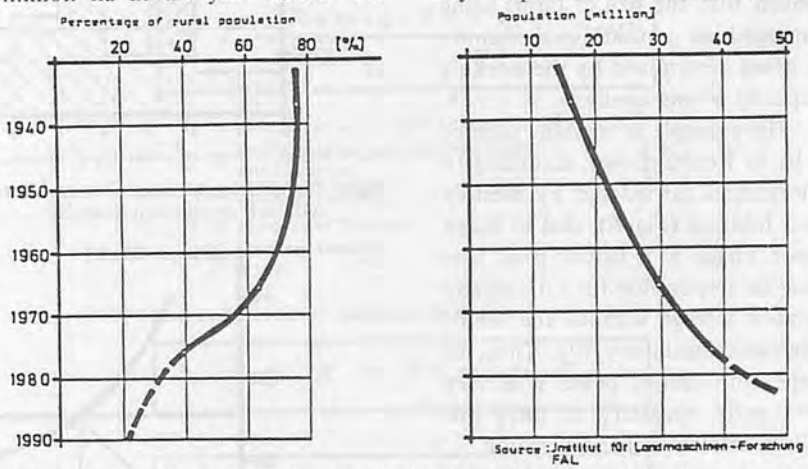



Fig. 3 Trends of total population and relative share of rural population in Egypt.

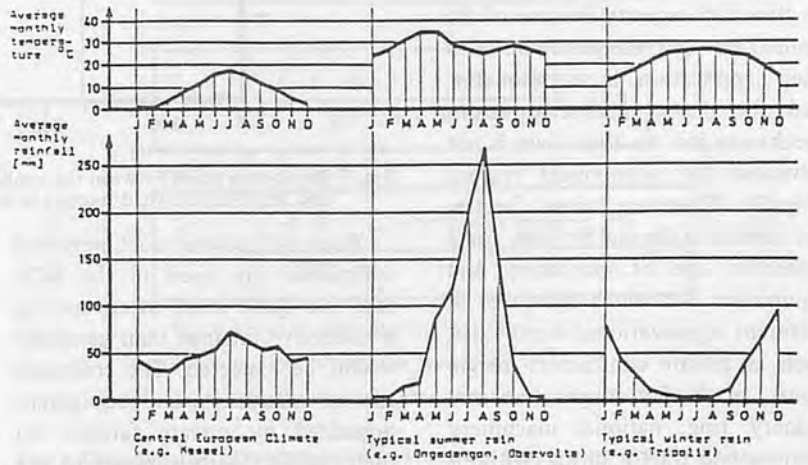



Fig. 4 Different climates (types of rainfall).

irrigated must be accompanied by an intensive training of the farmers concerned.

## Farm Size and Collective Use of Machinery and Equipment

The majority of the farms in DC are run in a traditional manner and have only small acreages, which with dry-land farming often comprise 2 to 4 ha, and with low-land rice growing are much smaller still. This fact is illustrated quite clearly in the case of Indonesia, showing the structure of farm sizes (Fig. 5): 70% of all farm units have a maximum acreage of 1 ha. More than half of these farms have an acreage of 0.5 ha as a maximum. In this connection it should be mentioned that the size of farms being managed in a traditional manner is often determined by the working capacity of one family.

The example of a model farm of 4 ha in Kenya shows, according to the studies carried out by Westley and Johnson (Fig. 6), that in many cases tillage is a labour peak that may be responsible for a drastically limited acreage without the use of adequate machinery (9). Thus, to cope with labour peaks it is very frequently necessary to carry out tillage with the help of a tractor.

Since on many farms (10) it is not possible to utilize tractors to their full capacity because of the limited acreages, the profitability of their application is questionable, and for many small-scale farms, mechanization on their own is not advisable for economical reasons (Fig. 7). Therefore, these farmers are somehow forced to look for a collective use of machinery and equipment, for which a number of different organizational forms exist, such as private contractors, neighbours, machinery cooperative, machinery ring, national machinery stations and tractor hiring (without operator).

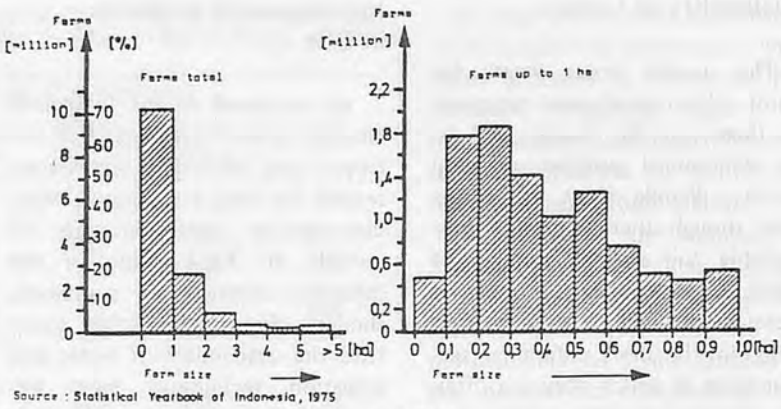



Fig. 5 Structure of farm sizes in Indonesia (1973).

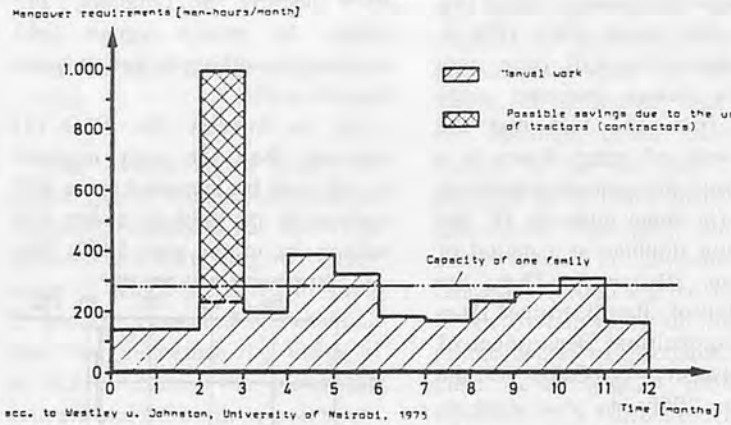



Fig. 6 Distribution of manpower requirements of a 4ha model farm in Kenya with low production intensity.

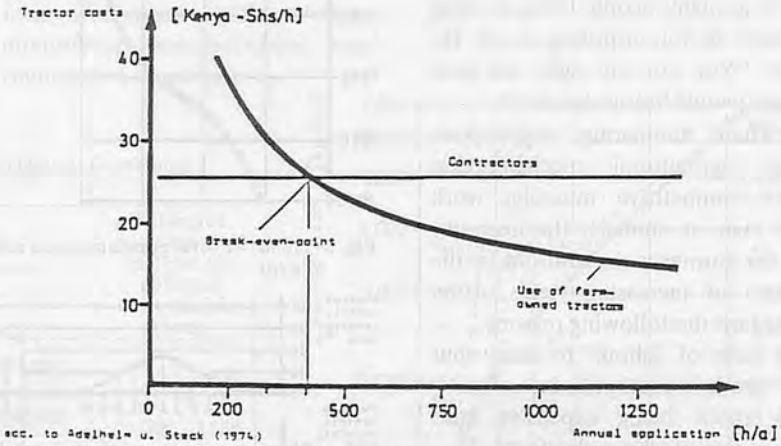



Fig. 7 Break-even point between the application of collectively-used tractors and single-farm-owned tractors in Kenya (22-23kW).

When agricultural machinery and equipment are used in the DCs, they are quite more often used in a collective manner than generally would be expected. The collective use of machinery and equipment organized by private farmers on their own is clearly superior to any form of state-controlled organization (such as machinery stations), which may be demonstrated very easily when comparing, for instance, availability/readiness for service and service life of the machines. There are examples of tractors collectively used under private-industry conditions which have a service life three times as

high as the tractors used in the national machinery station next door!

Compared to individual farm mechanization, the collective use makes more extensive demands on the farmers due to its higher degree of organization, such as:

i) A greater number of qualified farmers are necessary;
ii) Higher demands on organizing and management abilities are made;
iii) The availability of appropriate service and repair facilities has to be ensured; and
iv) Team-spirit and the willingness of the farmers to cooperate with each other (to the benefit of all and every individual person) are indispensable. (5)

## The Question of Tractor Size

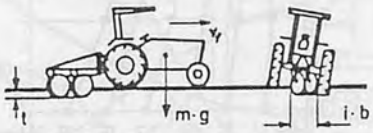
There is no general answer to the question of tractor size. For every individual case a decision has to be made separately. The minimum tractor size will be determined according to the operation for which the highest power requirement is needed. Usually, this will be tillage, which is the most important operation for tractor application in the early stage of agricultural development (11, 12).

If in the following discussion the tractor size is determined on the basis of the power requirement for ploughing, this has to be understood as an example only. It should be explicitly pointed out that there are partly substantiated arguments against the use of the plough in tropical farming (14), which are based on many years of experience. Erosion, destruction of the often extremely thin humus layer and other consequential problems cause the use of the plough to be questioned quite frequently.

The power requirement for ploughing with the mouldboard or disc plough is almost the same if equal working width, working depth and speed are assumed. In many cases, the disc plough has to be given preference in the early stage of mechanization because it is easier to handle, more robust, easier to maintain and considerably less prone to failure when confronted with coarse clods, stones, root remains, etc.

The soils of dry areas feature an extremely high value in specific soil resistance, which in some extreme cases may reach up to 20 N/cm². This results in comparatively high tractional powers and drawbar pulls for tillage which may be reduced by 'pre-irrigation' prior to tillage. This solution, however, is almost never feasible for the farmers.

From a simplified calculation




Tractive power when ploughing (acc. to Gorjatschkin)

$$F = i \cdot k \cdot b \cdot t \cdot (1 + \varepsilon \cdot v_f^2) \quad [N]$$

Tractor power requirement

$$P = \frac{(F + m \cdot g \cdot \varrho) \cdot v_f}{1.000 \cdot \eta_{tr} \cdot (1 - \sigma) \cdot \lambda} \quad [kW]$$

$k$ = specific soil resistance [N/cm²]
$\varepsilon$ = coefficient of dynamic soil resistance $\left[\frac{s^2}{m^2}\right]$
$\varkappa$ = net traction coefficient [-]
$\varrho$ = drag coefficient [-]
$\sigma$ = wheel slip [-]

Determination of tractor mass

$$k_h \cdot m \cdot g \cdot \varkappa \geq F + m \cdot g \cdot \varrho$$

or

$$F \leq m \cdot g \cdot (k_h \cdot \varkappa - \varrho)$$

thus

$$m \geq \frac{i \cdot k \cdot b \cdot t \cdot (1 + \varepsilon \cdot v_f^2)}{g \cdot (k_h \cdot \varkappa - \varrho)} \quad [kg]$$

and

$$P = \frac{i \cdot k \cdot b \cdot t \cdot \left(1 + \varepsilon \cdot v_f^2\right)\left(1 + \frac{\varrho}{k_h \cdot \varkappa - \varrho}\right) \cdot v_f}{1.000 \cdot \eta_{tr} \cdot (1 - \sigma) \cdot \lambda} \quad [kW]$$

$\eta_{tr}$ = tractor efficiency [-]
$\lambda$ = degree of engine load [-]
$k_h$ = load share of driven axle [-]

Fig. 8 Determination of tractive power, tractor mass and tractor when ploughing (rear wheel drive) - simplified.

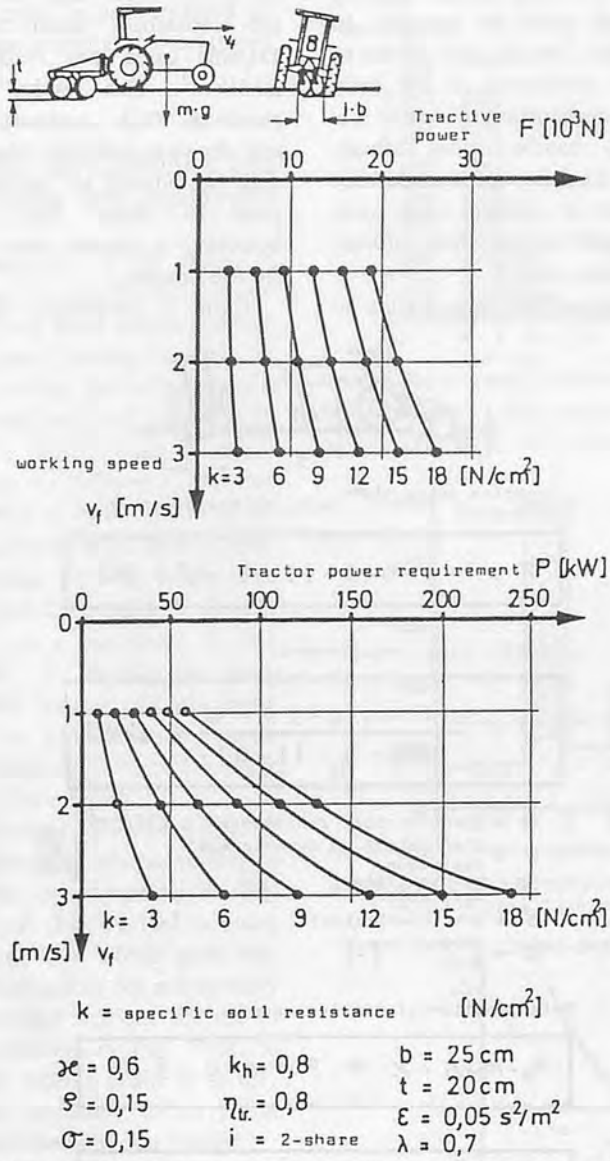



Fig. 9 Tractive power and tractor power when ploughing at different operating conditions.

(Figs. 8 and 9) it may be seen that a two-furrow plough with moderate working depth and speed, at a soil resistance of 9 N/cm² already calls for a tractor with an engine power of 40 kW. When using tine implements (dry-land farming) which are specifically suitable for dry areas due to their water-conserving effect, even larger tractors are required if the working width should correspond to the tractor width.

As a rule, for heavy tillage in dry-land farming of the tropics and subtropics, dependent on the conditions of application, tractors of at least 30 to 40 kW are required. For many other agricultural operations lower engine powers are usually sufficient in the early stage of mechanization.

The power requirements for lowland rice growing are even lower as the resistance of the wet soil is definitely less, and thus, for this application a tractor power ranging from 10 to 15 kW has to be taken as a minimum for operating a rotary cultivator (13).

Apart from the minimum power requirement, depending upon the physical conditions and the application parameters, another important problem is to determine under which conditions the use of tractors will be profitable. As a contribution to the solution of this problem a dynamic simulation model has been developed, a simplified flow diagram of which is presented in **Fig. 10**. The collective model consists of a greater number of submodels (example shown in **Fig. 11**).

On the basis of this simulation model an attempt was made to determine the profitability of different machinery sizes (in this case the tractor size, measured in engine power), for various sizes of farms, taking the costs of grain growing in dry-land farming as an example. (**Fig. 12**). This procedure must be called a first attempt to approach this problem, since a couple of simplifying assumptions had to be made to obtain a certain kind of comparability, due to the immense range of farm sizes (ranging from 2 to 200 ha) and machinery sizes (ranging from 3 to 70 kW).

The result may not be surprising but quite interesting and may be summarized as follows:

i) For any farm size there is one machinery size, producing minimum costs for an operation (in this example costs of grain growing);

ii) The minimum operation costs rise with decreasing farm sizes; and

iii) This leads to the conclusion that the mechanization on the basis of farm-owned engine-powered machinery is only economical with a certain minimum farm size, which, however, may vary from case to case (due to yields, input/output costs).

This approach to the problem of profitability, although quite different from the methods usually applied, verifies the necessity of collective use of machinery and equipment for small-structured agri-

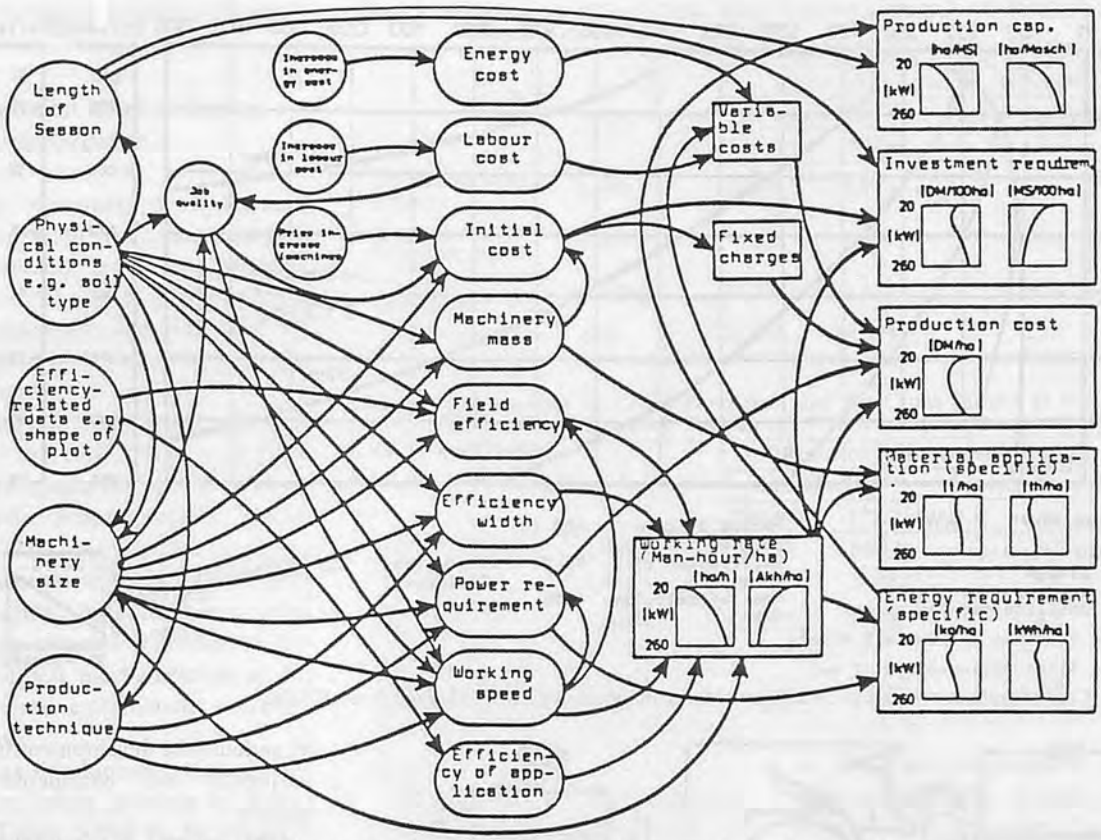



Fig. 10 Simplified flow diagram of a dynamic simulation model for planning economical grain cultivation.

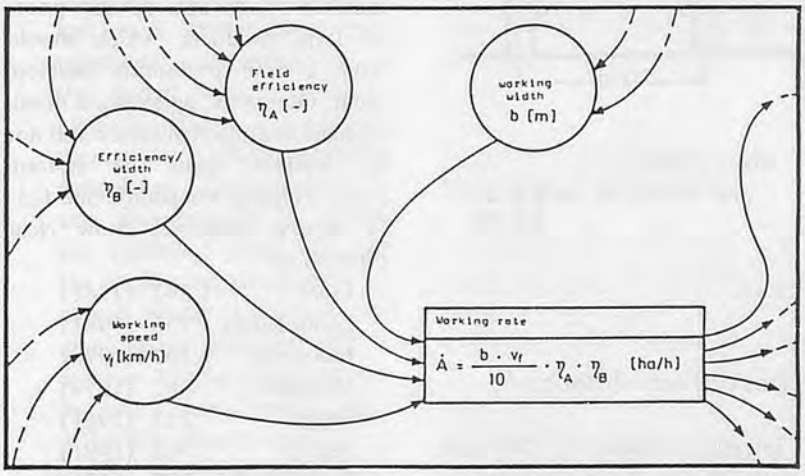



Fig. 11 Submodel 'Working rate' (Simulation model 'agricultural technology').

culture. The technical and in particular the economic correlations set forth above make it understandable that nearly all basic/small tractors developed so far did not bring about the desired success. The French BOUYER tractor (Fig. 13) which zealous experts had used and vigorously promoted in various DCs over a period of several years did not go into production at any of the initially planned sites. Some dozens of other similar developments in ICs and DCs did not go beyond the prototype, test and demonstration stage so far.

The only exception is the lowland rice growing in Asia (especially Japan, Korea, and parts of Thailand), where small tractors are being used successfully. It should be mentioned here that the prices for farm products play a specific role in those countries, a fact which will be dealt with later on.

From these technical-economic considerations it may not be surprising to know that the 3- and 4-cylinder standard tractor of 30 to 50 kW dominates in the dry-land farming of most DCs, presenting more than 80% of the total tractor population.

## Level of Mechanization of Harvesting

Cereals are the staple crops in the tropics and subtropics. Many other field crops, rice included, are still harvested manually.

While the combine harvester for cereals is already quite common in some threshold countries (such as Brazil and Algeria), the use of engine-powered harvesting machin-

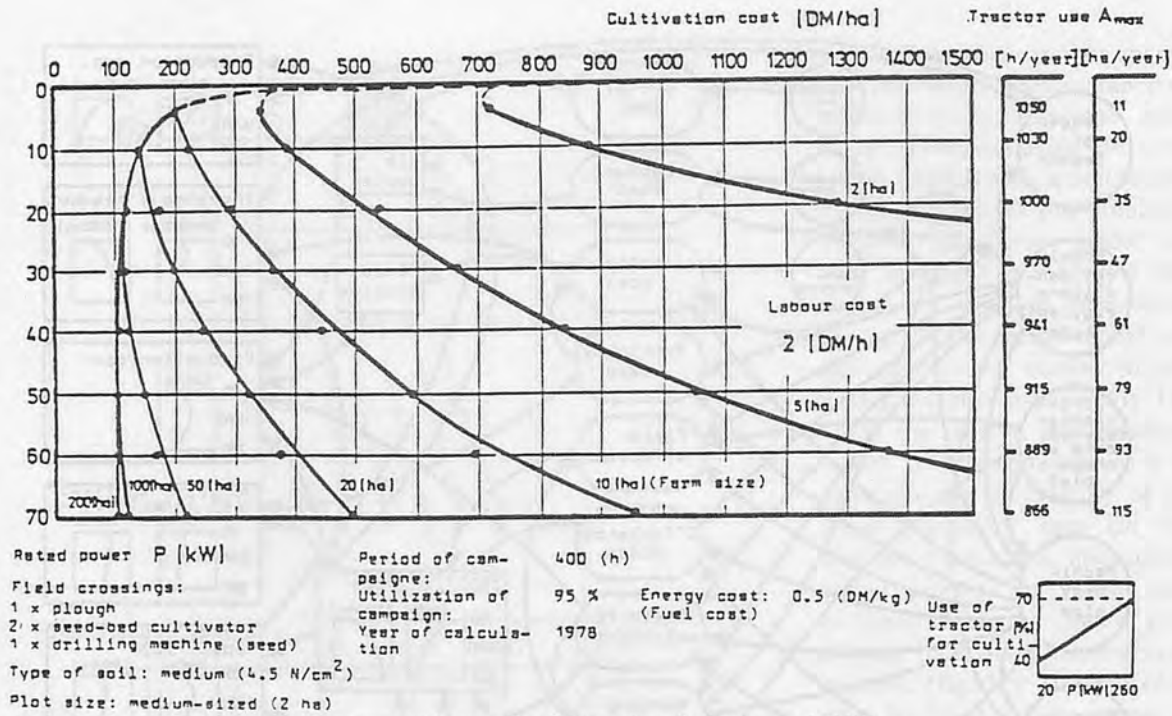



Fig. 12 Cost of grain cultivation as a function of farm and machinery sizes. (Labour cost: 2DM/h)

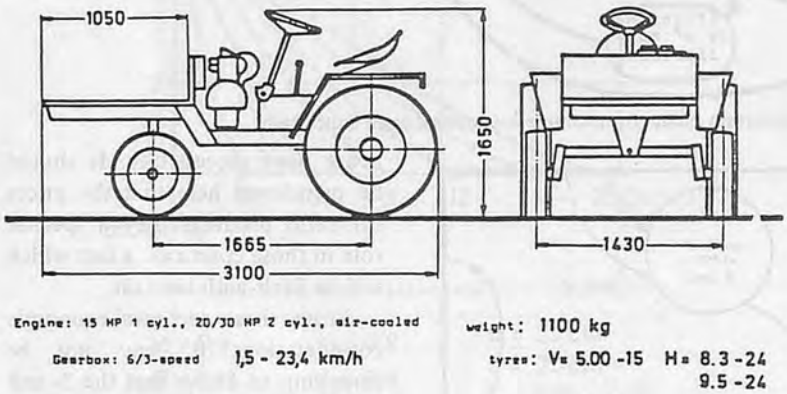



Fig. 13 Bouyer TE (French basic tractor).

ery for other field crops is almost insignificant so far.

For several reasons, however, in addition to tillage mechanization it would be of great importance to mechanize harvesting operation which represents another labour peak because in many cases, 20 to 35% of crop losses could be avoided and in a number of cases, speedy completion of harvesting work could lead to an earlier cultivation of the follow-up crop and thus to an increase in the number of harvests per year. This shows that the mechanization of harvesting may make a direct contribution to the often urgently required yield increase.

## Prices of Farm Products

In many studies in DCs and, especially when discussing the problem of developing economical models for mechanization ("small, simple, robust, favourable in price, etc."), the significance of the price level of farm products – besides other factors such as training; agricultural credit system; availability of high-quality seeds, fertilizers; plant protection products; and development of rural infrastructure, etc. for the climate and prospect of agricultural development is quite frequently not considered adequately.

The priority of agricultural development in the DCs has to manifest itself also in the prices of farm products, which should have a level promoting development. Otherwise, agricultural development and mechanization will not be feasible. Even the ex-farm prices (US$/t) for paddy rice (15) in various countries show clear differences:

| | | |
|---|---|---|
| Japan | 1 342 | (1981) |
| South Korea | 736 | (1981) |
| Indonesia | 169 | (1978) |
| Malaysia | 462 | (1979) |
| Egypt | 121 | (1981) |
| Nigeria | 562 | (1981) |
| World Market | 270 | (1981) |

Political priority, not verbally expressed but in terms of money, is essential for agricultural development. Many people have the erroneous idea that a drastic cut in prices for agricultural machinery would be sufficient to make agriculture profitable. – The contrary is true: in some cases the prices for farm products are so low that "even tractors given as a present

would not promise to be profitable".

## Agricultural Mechanization and Employment

The opponents of agricultural mechanization often maintain that an increasing agricultural mechanization in the DCs would increase unemployment. The following two examples show that this is usually not the case:

i) The International Conference of the FAO "Effects of Farm Mechanization on Production and Employment", Rome, 1975, (16) examined the abovementioned problem very thoroughly, but could not prove any negative influence of agricultural mechanization on the overall employment situation; and

ii) The development of the Northern Indian province of Punjab **(Tables 3 and 4)**, for example, where agricultural mechanization and general agricultural and rural development were promoted very intensively in the period from 1965/66 to 1975/76, shows a remarkable success (17): With increasing agricultural mechanization it was also possible to extend the cultivated areas, to raise the yield and production of cereals greatly, to improve the employment situation and to augment the per capita income in rural areas even more efficiently than in towns.

In this connection it is worth mentioning that a successful agricultural mechanization cannot be advanced in an isolated manner, but has to be in line with an overall, complex development of infrastructure such as the establishment of a local agricultural machinery industry; building of schools, hospitals and roads; reduction of the level of illiteracy of the population; and making available agricultural credit.

Table 3 Development of Some Input Data of the Agriculture in the Indian Province of Punjab from 1965/66 to 1975/76

| Item | | Development of input data of agricultural production in Punjab | | |
|---|---|---|---|---|
| | | Economic year | | Annual increase rate |
| | | 1965/66 | 1975/76 | % |
| Number of farm workers | 1.000 | 1.800 | 2.450 | 3,1 |
| Irrigated area (pumping sets) | 1.000 ha | 921 | 1.813 | 7 |
| Fertilizer consumption | 1.000 t | 236 | 1.510 | 20,4 |
| Tractor population | Unit | 10.636 | 66.394 | 20,1 |

Table 4 Development of Cereal Production and Per Capita Income in the Indian Province of Punjab from 1965/66 to 1975/76

| Item | | Agricultural production in Punjab | | |
|---|---|---|---|---|
| | | Economic year | | Annual increase rate |
| | | 1965/66 | 1975/76 | % |
| Cereal production | 1.000 t | 3.389 | 8.853 | 9,8 |
| Cereal yield | t/ha | 1,45 | 3,06 | 7,8 |
| Cultivated area (Cereals etc.) | 1.000 ha | 3.102 | 4.300 | 3,5 |
| Per capita income (real) | | | | |
| a rural population | Rs/a | 272 | 348 | 2,8 |
| a urban population | Rs/a | 768 | 965 | 2,6 |

The introduction of compulsory eduction would already keep so many children away from fieldwork that this single step would even cause a partial or seasonal shortage of labour.

## Procurement Structure for Agricultural Machinery

Agricultural machinery and equipment can be classified in five categories from simple tools to tractors/self-propelled machines **(Table 5)**. On the other hand, in respect of procurement one has to distinguish between national production on the basis of local know-how or license agreement (or both) and import.

As a rule, one may proceed from the assumption that tools of the categories 1 and 2 are locally produced by small to medium-scale manufacturers. It may be surprising to state in this connection that the cooperation among the DCs has only worked properly in very rare cases so far. In most of the cases cooperation among those countries gets stuck at the stage of mere expression of will.

Machinery and equipment of the categories 4 and 5 are usually manufactured by medium-scale to large businesses partly on the basis of local developments and partly under license. Another portion of this machinery is imported.

The procurement structure for agricultural machinery may vary greatly from country to country depending on various factors. Imports are mainly made only in countries which have foreign exchange of their own or which enjoy financial support from abroad.

Furthermore, one has to proceed on the assumption that those countries where a process of agricultural mechanization is getting under way increasingly have to prepare for a local production to meet their agricultural machinery requirements and will do so.

## Conclusion

When discussing the problem of

Table 5 Examples of Typical Sources to Procure Agricultural Machinery and Equipment of Various Categories

| Classification of tools/ machinery | | National production local know-how | | Under licence med./large scale manufacturers | Import |
|---|---|---|---|---|---|
| Category | Example | small/med. scale manufacturers | med./large scale manufacturers | | |
| Tools 1 | Hand hoe, fork, Archimedean drill | • | – | – | – |
| Implements for use of draught animals 2 | Animal-drawn hoe, water-wheel (sakis) | • | • | – | – |
| Implements for use of tractor 3 | Plough, drilling machine, two-wheeled trailor | • | • | • | • |
| Motorized, stationary equipment and small tractors 4 | Motor pump, walking tractor | – | • | • | • |
| Tractors and self-propelled machines 5 | Standard tractor, combine harvester, sugarcane harv. | – | • | • | • |

agricultural development in the DCs the impression is frequently conveyed as if agricultural development were only a technical problem. The fact that also in the DCs the individual plays a central role within the overall concept of development is often disregarded. Thus, training and education on all levels in connection with agricultural mechanization in a restricted sense and rural development in a broader sense are of immense importance.

Technology has to be matched with the conditions, of course. However, this is not only true for the DCs, but is a general rule. The term 'adapted technology' is used too extensively and many times interpreted in the wrong way. Not only does the machine have to be matched with local conditions and to man, but man, working with this technology, also has to be prepared for the handling of such technology by appropriate measures of training. No machine can be robust and fool-proof enough to eliminate defects and failure when operated incorrectly or beyond its capacity and limits. (A voluntary worker in the DCs put it this way: "The misuse of agricultural machinery in developing countries is terrible!").

Since many DCs are not capable of advancing the required agricultural development quickly enough on their own, experts' exchange, dialogue and cooperation among developing countries and industrialized countries are urgently needed. On our part, experience, discretion and willingness to serve and help are essential so that our advice will not be taken as an arrogant attitude of a 'know-it-all' but will create positive effect.

It is furthermore worth mentioning that agricultural mechanization in the DCs will always be selective (eliminating labour peaks) and that the development processes take some 30 to 50 years. The frequently mentioned threat of the DCs being swamped by technology does not exist for the very reason of non-existing financial facilities. However, if it is our target to help millions of people in the DCs to get out of abject poverty and to raise the degree of self-sufficiency even with an increasing population, then this is not possible without making changes! It is not possible to solve the tremendous problems of food supply in the DCs on the basis of traditional farming methods only and without gradual agricultural mechanization.

Successful mechanization, however, is combined to the complex processes of infrastructural development in the rural areas, based on development policy objectives such as increase in agricultural production; improvement of the employment situation; reduction of level of illiteracy and development of continuation training systems; development of an appropriate infrastructure matched with the local conditions and compatible with the country's development; impulses to economic growth of its own accord and; making rural areas more an attractive place to live in.

## Summary

(1) The rapidly growing population of the DCs is threatened by an increasing deficiency in food supply within the next two decades.

(2) The existing potentials for increasing food production require the application of appropriate agricultural machinery and equipment: seeds of high quality, more agricultural chemicals, and raising literacy levels.

(3) Agricultural mechanization is of special importance in increasing agricultural yields as it improves the quality of work; enables carrying out work on schedule; and reduces labour peaks.

(4) Agricultural mechanization in the DCs always implies selective mechanization, by which manual work and the use of draught animals are replaced only gradually – and especially in those kinds of operations where bottlenecks occur.

A sudden and abrupt shift from the traditional techniques to the application of engine-powered agricultural machin-

ery will not happen. Also, for the DCs it will take some 30 to 50 years to undergo these processes of development.

(5) Since the farms of the traditional agriculture of many DCs are often small-sized, ownership mechanization is very limited, and this fact frequently leads to the collective use of machinery and equipment on the basis of various organizational forms.

(6) Within the next 20 years, the increase in demand for agricultural machinery will mainly come from the DCs.

(7) Increase of agricultural mechanization in combination with other measures, furthering infrastructure and development, cannot only serve to raise yields in DC but also to improve employment and income – especially in rural areas. Making the rural areas attractive by developing them "curbs rural exodus" at the same time.

(8) An increasing demand for agricultural machinery in many cases results in intensified local production. It remains up to the partners to seek cooperation.

(9) The level of prices for farm products has a great influence on the climate of development, and development may additionally be enhanced by agricultural credit programmes.

(10) Cooperation, dialogue and exchange of experts between IC and DC, training and transfer of know-how in manifold forms are significant in connection with the promotion of agricultural mechanization in the DCs.

Getting involved and promoting the development of agriculture and farm mechanization in DC is a field of great challenge and a task of great responsibility: an assignment with a future.

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# Performance of Power Tiller Blades

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## Introduction

Pakistan is a country comprising of different types of cultivable areas. Rainfed ("Barani") and paddy growing areas have also promising scope for crop production provided suitable farm machinery is introduced. Large and medium tractors are on the up slope of the curve but little attention has been diverted towards the use of small tractors and power tillers which in fact can solve the acute agricultural problems of small farmers. Small tractors and power tillers have earned wider scope in the Far East. The reasons behind this are that small tractors and power tillers are suitable to agricultural conditions and farming requirements; economic conditions and management scale; and level of mechanical knowledge and management in the rural areas.

Much research work has been done on the structural features of power tillers in Japan (1, 2, 3) and various types of power tiller blades have also been manufactured and tested for rotary cultivation. Japanese research workers have also studied the performance components such as power, forward horizontal force, upward vertical force, pulverization, dispersion of surface residue, and chopping and winding of surface residue; but little research has been devoted towards the effect of rotor speed and type of soil on the performance of power tiller blades.

## The Study

An investigation was carried out on the farm of the National College of Agricultural Engineering, Silsoe, Bedford (U.K.) in 1980 to study the best possible shape of the blades to meet the needs of farmers.

The performance components studied were width and depth of soil tilled; effective field capacity; volume of soil disturbed; quality of soil manipulated; fuel consumed; and power requirements of the blades.

## Testing Procedure

Three sets of blades – new slashers, old slashers and L-shaped shown in **Fig. 1** were selected for the study and the rotor diameters of the blades were 300 mm, 310 mm and 290 mm, respectively. The tractor used for the study was Landmaster L 160 with a rear skid to control forward motion. The experiment was conducted at two sites each measuring 25 x 25 m. Cone penetrometer readings were taken on each site at eight places, each of 1 x 1 m on a zig-zag path to minimize error. The soil with high penetrometer readings was classified as hard soil and the soil with low penetrometer readings soft soil. **Table 1** shows the penetrometer

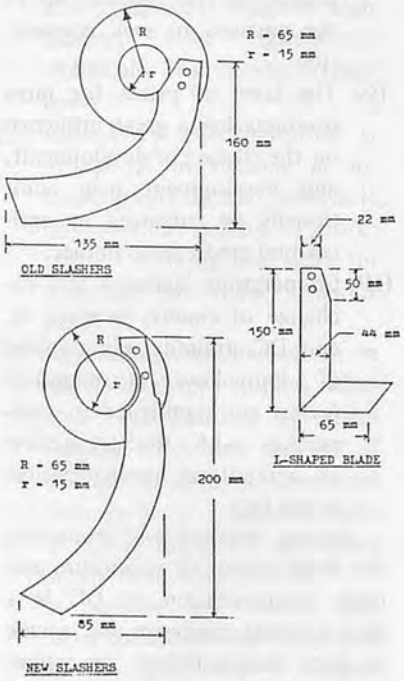


**Fig. 1** The three sets of blades.

Table 1 Penetrometer Readings

| Observations | Penetrometer Readings (lbs) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hard soil (high penetrometer readings) | | | | | | | Soft soil (low penetrometer readings) | | | | | | | |
| 1 | 14 | 20 | 21 | 18 | 28 | 16 | 24 | 16 | 8 | 10 | 5 | 8 | 9 | 10 | 10 | 5 |
| 2 | 16 | 20 | 20 | 16 | 16 | 18 | 16 | 18 | 8 | 8 | 10 | 11 | 10 | 10 | 16 | 11 |
| 3 | 16 | 18 | 16 | 20 | 28 | 28 | 24 | 20 | 13 | 18 | 10 | 8 | 13 | 9 | 16 | 10 |
| 4 | 27 | 24 | 20 | 24 | 17 | 22 | 26 | 27 | 8 | 8 | 8 | 5 | 5 | 8 | 5 | 9 |
| 5 | 18 | 20 | 24 | 30 | 28 | 28 | 18 | 22 | 6 | 6 | 5 | 8 | 5 | 7 | 14 | 7 |
| 6 | 22 | 18 | 16 | 26 | 16 | 21 | 22 | 20 | 11 | 9 | 14 | 12 | 13 | 8 | 8 | 11 |
| 7 | 28 | 23 | 30 | 20 | 22 | 24 | 22 | 23 | 12 | 8 | 10 | 18 | 12 | 16 | 10 | 8 |
| 8 | 25 | 25 | 24 | 23 | 19 | 24 | 30 | 28 | 14 | 15 | 12 | 20 | 20 | 18 | 12 | 13 |
| Mean | 20.75 | 21 | 21.4 | 22.1 | 21.8 | 22.6 | 22.8 | 21.8 | 10 | 10.3 | 9.3 | 11.3 | 10.9 | 10.8 | 11.4 | 9.3 |

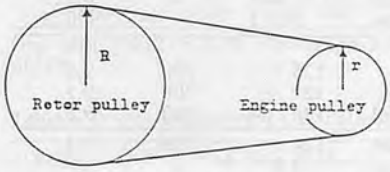


Fig. 2 Arrangement of low rotor speed.

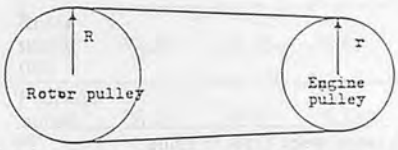


Fig. 3 Arrangement of high rotor speed.

readings. Two rotor speeds, low and high, were used and is shown in **Figs. 2 and 3**. The two ranges of rotor speed were determined with separate formulae. For low rotor speed, the following formula was used **(Fig. 2)**:

$R/r = N_1/N_2$

where,

R = Radius of rotor pulley = 100.5 mm

r = radius of engine pulley = 33.75 mm

$N_1$ = rated speed of engine pulley = 4500 rpm

$N_2$ = calculated speed of rotor pulley.

Therefore, $N_2$ calculated from the above formula was 1511 rpm. The rated speed ratio of rotor pulley and rotor was 20:1 hence the low rotor speed was:

1511 rpm x (1/20) = 75.55 rpm.

For high rotor speed, the following formula was used **(Fig. 3)**:

$r/R = N_2/N_1$

where,

r = 57.50 mm

R = 81.5 mm

$N_1$ = 4500 rpm

Therefore $N_2$ calculated from the above formula was 3175 rpm. Hence the high rotor speed was 3175 rpm x (1/20) = 158.75 rpm.

It was further decided to study the effect of the rake angle, edge curve and section of the blades on the soil manipulation. Therefore, a circle of the diameter equal to the diameter of rotor was drawn on the plane ground and the tip of the blade was brought in contact with the circumference of the circle at one point **(Figs. 4 and 5)**. A tangential line of the tip outside the surface and another at the tip locus curve were drawn. Thus the relief angle was measured. The rake angle was obtained by subtracting the relief angle value from angle OAC **(Fig. 4)**.

Regarding the section of blades, the old slashers were bevelled on both inner and outer sides, the new slashers were bevelled on inner side and the L-shaped blades were bevelled on outer side.

To evaluate the soil manipulation, the test was carried out on a 10-m long strip on soft and hard soils. A stop watch was used to record the forward speed of the power tiller. Performance results of the blades were recorded and are given in **Tables 2, 3 and 4**.

To evaluate the power requirement of the blades, the engine of the power tiller was tested on a test rig dynamometer at its maximum speed of 3664 rpm and the output of the engine was calculated to be 5.75 kW **(Table 5)**. Fuel consumed in cc/sec recorded for each test run **(Table 6)** was multiplied by 5.75 kW to obtain the power requirement for each set of blades.

Hunt's (8) equation was used to calculate the field capacity in ha/h. The field efficiency factor was ignored, since it has not yet been evaluated for different blades.

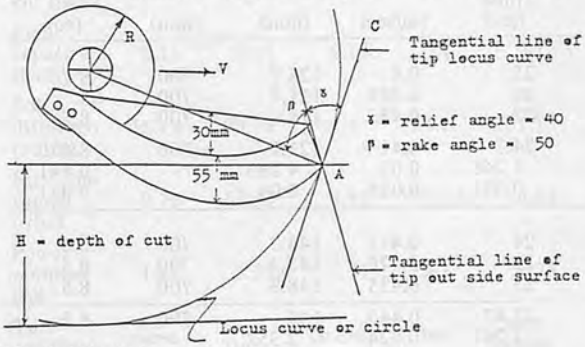


Fig. 4 Old slashers.

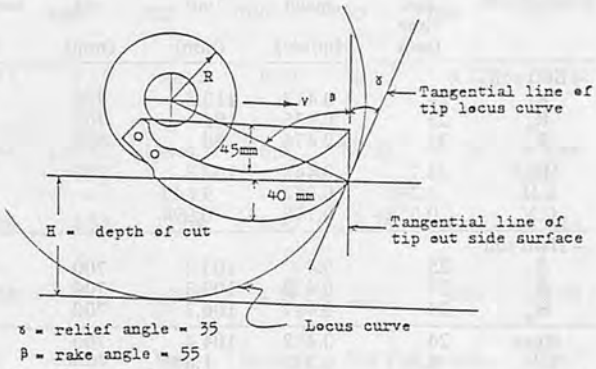


Fig. 5 New slashers.

Table 2 Performance of New Slashers

| Replications | Low rotor speed (75.55 rpm) | | | | | High rotor speed (158.75 rpm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) |
| – Soft soil – | | | | | | | | | | |
| $R_1$ | 23 | 0.435 | 113.3 | 700 | 7 | 22.5 | 0.444 | 136.7 | 700 | 9.5 |
| $R_2$ | 25 | 0.435 | 105 | 700 | 7 | 24 | 0.417 | 133 | 700 | 9 |
| $R_3$ | 24 | 0.417 | 88 | 700 | 6.5 | 25 | 0.4 | 133.3 | 700 | 9.5 |
| Mean | 24 | 0.417 | 102.2 | 700 | 6.830 | 23.83 | 0.42 | 134.3 | 700 | 9.330 |
| S.D | 0.817 | 0.014 | 10.397 | – | 0.236 | 1.027 | 0.018 | 1.679 | – | 0.229 |
| C.V | 0.037 | 0.034 | 0.102 | – | 0.035 | 0.043 | 0.044 | 0.013 | – | 0.025 |
| –Hard soil – | | | | | | | | | | |
| $R_1$ | 20 | 0.5 | 120 | 700 | 6.5 | 25.0 | 0.5 | 125 | 700 | 9.5 |
| $R_2$ | 19.5 | 0.513 | 120 | 700 | 6.5 | 25 | 0.4 | 121 | 700 | 9.5 |
| $R_3$ | 20 | 0.5 | 118.3 | 700 | 5.5 | 28 | 0.357 | 126 | 700 | 9.5 |
| Mean | 19.8 | 0.5 | 119.4 | 700 | 6.17 | 26 | 0.386 | 124 | 700 | 9.5 |
| S.D. | 0.216 | 0.008 | 0.802 | – | 0.544 | 1.414 | 0.304 | 2.6 | – | – |
| C.V. | 0.011 | 0.016 | 0.007 | – | 0.088 | 0.054 | 0.001 | 0.017 | – | – |

Remark: S.D. = Standard deviation, C.V. = Coefficient of variance.

Table 3 Performance of Old Slashers

| Replications | Low rotor speed (75.55 rpm) | | | | | High rotor speed (158.75 rpm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) |
| – Soft soil – | | | | | | | | | | |
| $R_1$ | 23.5 | 0.426 | 100.3 | 800 | 5 | 22 | 0.455 | 96.7 | 800 | 9 |
| $R_2$ | 22 | 0.455 | 100.5 | 800 | 6 | 23 | 0.435 | 101.7 | 800 | 8.5 |
| $R_3$ | 23 | 0.435 | 100.1 | 800 | 5 | 22 | 0.455 | 105 | 800 | 9 |
| Mean | 22.83 | 0.439 | 100.3 | 800 | 5.330 | 22.33 | 0.448 | 101.1 | 800 | 8.836 |
| S.D. | 0.624 | 0.013 | 0.027 | – | 0.472 | 0.471 | 0.02 | 3.412 | – | 0.236 |
| C.V. | 0.027 | 0.03 | 0.0003 | – | 0.088 | 0.021 | 0.044 | 0.034 | – | 0.027 |
| –Hard soil – | | | | | | | | | | |
| $R_1$ | 15 | 0.476 | 130 | 800 | 4 | 22.5 | 0.444 | 137 | 800 | 8.570 |
| $R_2$ | 15 | 0.435 | 135 | 800 | 3.5 | 26 | 0.385 | 145 | 800 | 9 |
| $R_3$ | 18 | 0.357 | 134 | 800 | 3.5 | 23.5 | 0.426 | 138 | 800 | 9 |
| Mean | 16 | 0.423 | 133 | 800 | 3.670 | 24 | 0.418 | 140 | 800 | 8.830 |
| S.D. | 0.817 | 0.058 | 2.16 | – | 0.236 | 1.472 | 0.025 | 3.56 | – | 0.236 |
| C.V. | 0.051 | 0.137 | 0.016 | – | 0.064 | 0.061 | 0.06 | 0.025 | – | 0.023 |

Table 4 Performance of L-shape Blades

| Replications | Low rotor speed (75.55 rpm) | | | | | High rotor speed (158.75 rpm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) | Test run time (sec) | Forward speed (m/sec) | Depth of cut (mm) | Width of cut (mm) | Fuel consumed (cc) |
| – Soft soil – | | | | | | | | | | |
| $R_1$ | 24 | 0.417 | 113.3 | 700 | 4.5 | 25 | 0.4 | 126.7 | 700 | 8 |
| $R_2$ | 23 | 0.435 | 105 | 700 | 4.5 | 26 | 0.385 | 121.7 | 700 | 9 |
| $R_3$ | 21 | 0.476 | 90 | 700 | 4.5 | 23 | 0.435 | 115 | 700 | 8.5 |
| Mean | 22.7 | 0.443 | 102.8 | 700 | 4.5 | 24.7 | 0.41 | 121.1 | 700 | 8.670 |
| S.D. | 1.248 | 0.052 | 9.642 | – | – | 1.248 | 0.01 | 4.793 | – | 0.441 |
| C.V. | 0.055 | 0.118 | 0.094 | – | – | 0.051 | 0.025 | 0.04 | – | 0.051 |
| – Hard soil – | | | | | | | | | | |
| $R_1$ | 25 | 0.4 | 103.3 | 700 | 4.5 | 24 | 0.417 | 143.3 | 700 | 8.5 |
| $R_2$ | 23 | 0.438 | 103.3 | 700 | 4.5 | 21 | 0.476 | 143.3 | 700 | 8.5 |
| $R_3$ | 24 | 0.417 | 106.3 | 700 | 4.5 | 23 | 0.435 | 148.3 | 700 | 8.5 |
| Mean | 24 | 0.418 | 104.4 | 700 | 4.5 | 22.67 | 0.443 | 145 | 700 | 8.5 |
| S.D. | 0.817 | 0.015 | 1.603 | – | – | 1.247 | 0.024 | 2.357 | – | – |
| C.V. | 0.034 | 0.034 | 0.015 | – | – | 0.055 | 0.055 | 0.016 | – | – |

Table 5 Test Rig Results

| Speed of dynamo-meter rpm | Torque on dynamo meter Nm | Time T for 1 cc petrol sec | Speed of tractor engine= Gear ratio x rpm rpm | Out put of tractor engine $=\frac{Nm \times rpm}{30000}$ kW | Specific fuel consumption $=\frac{F \times F \times 60 \times 60}{T \times kW}$ g/kWh |
|---|---|---|---|---|---|
| 2200 | 0 | 4.24 | 5038 | 0 | 13500 |
| 1900 | 18 | 4.42 | 4351 | 2.610 | 234 |
| 1700 | 35 | 5.0 | 3893 | 4.542 | 198 |
| 1600 | 47 | 1.64 | 3664 | 5.750 | 287 |
| 1400 | 52 | 1.5 | 3206 | 5.557 | 324 |
| 1300 | 52 | 1.7 | 2977 | 5.160 | 308 |
| 1000 | 45 | 1.8 | 2290 | 3.435 | 437 |
| 800 | 40 | 2.1 | 1832 | 2.443 | 526 |

Gear ratio =48/21 = 2.29. Convertion factor F = 0.075 (Specific gravity of petrol at 60°F)

Table 6 Power Requirement Calculations

| Blade | A (New slashers) | | | | B (Old slashers) | | | | C (L-shaped) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of soil | Hard | | Soft | | Hard | | Soft | | Hard | | Soft | |
| Rotor speed rpm | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 |
| Fuel consumed cc | 6.17 | 9.5 | 6.833 | 9.333 | 3.667 | 8.833 | 8.833 | 8.833 | 4.3 | 8.5 | 4.5 | 8.667 |
| Time for test run, sec | 19.8 | 26.00 | 24 | 23.83 | 16 | 24 | 22.83 | 22.22 | 24 | 22.67 | 22.7 | 24.7 |
| Fuel consumed per sec | 0.312 | 0.365 | 0.285 | 0.392 | 0.285 | 0.368 | 0.234 | 0.396 | 0.186 | 0.375 | 0.198 | 0.351 |
| Power requirement; W = fuel consumed per sec x 5.75 | 1.794 | 2.099 | 1.639 | 2.254 | 1.639 | 2.116 | 1.346 | 2.277 | 1.07 | 2.156 | 1.139 | 2.018 |

Table 7 Comparative Performance of Power Tiller Blades

| Blade Type | New slasher | | | | Old slasher | | | | L-shape | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil Type | Soft | | Hard | | Soft | | Hard | | Soft | | Hard | |
| Rotor Speed (rpm) | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 158.75 | 75.55 | 168.75 |
| Depth of cut (mm) | 102.2 | 134.3 | 119.4 | 124.0 | 100.3 | 101.1 | 133.0 | 140.0 | 102.8 | 121.1 | 104.0 | 145.0 |
| Width of cut (mm) | 700 | 700 | 700 | 700 | 800 | 800 | 800 | 700 | 700 | 700 | 700 | 700 |
| Field capacity (ha/h) | 0.11 | 0.11 | 0.13 | 0.1 | 0.13 | 0.13 | 0.12 | 0.12 | 0.11 | 0.1 | 0.12 | 0.11 |
| Soil disturbed ($m^3$/h) | 75.12 | 99.75 | 105.3 | 84.2 | 101.1 | 104.34 | 130.87 | 134.4 | 80.6 | 87.31 | 87.36 | 113.68 |
| Fuel consumed (l/ha) | 9.76 | 13.33 | 8.81 | 13.27 | 6.67 | 11.04 | 4.58 | 11.04 | 6.43 | 12.38 | 6.43 | 12.14 |
| Power required (kW) | 1.64 | 2.25 | 1.79 | 2.1 | 1.35 | 2.28 | 1.61 | 2.12 | 1.14 | 2.02 | 1.07 | 2.05 |
| Tilth condition | coarse | very fine | coarse | fine | very coarse | fine | coarse | fine | coarse | fine | coarse | fine |

## Results and Discussion

Table 2 shows the performance of the new slashers. The width of cut of the tilled soil on both types of soils at both rotor speeds did not deviate from the actual width of cut of the blades. However, deviation was found in the case of depth of cut. The average depth of cut on soft soil was 102.2 mm at low rotor speed and 134.3 mm at high rotor speed, but on hard

soil it was 119.2 mm at low rotor speed and 124.0 mm at high rotor speed.

The average fuel consumption on soft soil was 5.330 cc at low rotor speed and 8.830 cc at high rotor speed. On hard soil it averaged 3.670 cc at low rotor speed and 8.567 cc at high rotor speed.

**Table 6** shows that the power requirement of new slasher blades was affected by the type of soil and rotor speed. On soft soil it was 1.640 kW at low rotor speed and 2.250 kW at high rotor speed. On hard soil it was 1.790 kW at low rotor speed and 2.100 kW at high rotor speed.

**Table 3** shows the performance of old slashers. The average depth of cut on soft soil was 100.3 mm at low rotor speed and 101.1 mm at high rotor speed. On hard soil it was 130 mm at low rotor speed and 140 mm at high rotor speed. The average fuel consumption on soft soil was 5.330 cc at low rotor speed and 8.830 cc at high rotor speed. On hard soil it was 3.670 cc at low rotor speed and 8.570 cc at high rotor speed.

**Table 6** shows that the power requirement of old slashers on hard soil was 1.639 kW at low rotor speed and 2.11 kW at high rotor speed. It was 1.350 kW on soft soil at low rotor speed and 2.280 kW at high rotor speed.

**Table 4** shows the performance of the L-shape blades. At low rotor speed, the average depth of cut on soft soil was 102.8 mm and on hard soil 104.4 mm. At high rotor speed it was 121.1 mm on soft soil and 145 mm on hard soil. The average fuel consumption on soft soil at low rotor speed was 4.5 cc and at high rotor speed 8.667 cc. On hard soil it was 4.5 cc at low rotor speed and 8.5 cc at high rotor speed.

**Table 6** shows the power requirement of the blades. On hard soil, the power requirement of the L-shape blades was 1.07 kW at low rotor speed and 2.156 kW at high rotor speed. On soft soil it was 1.14 kW at low rotor speed and 2.02 kW at high rotor speed.

The tilth condition (**Table 7**) shows that the fine tilth condition was obtained during high rotor speed on both soft and hard soils as compared with that obtained at low rotor speed. The overall comparative performance of power tiller blades is shown in **Table 7**.

## Conclusions

1. Old slashers have the best field capacity, lesser fuel consumption and lesser power requirements as compared with new slasher and L-shape blades both on soft and hard soils at both low and high rotor speeds.
2. However, the L-shaped blades were found better than the new slashers in all respects. It is, therefore, suggested that other possible shapes of the blades be investigated so that benefit cost ratio of crop production could be increased.

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# The Combi-Plough—

# An Animal-Drawn Implement System in Kenya

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## Summary

The animal drawn Combi-plough, developed in cooperation with the Agricultural University of Nairobi, Machakos Integrated Development Project and Katumani Dry Land Research Station, can be used to make furrows and ridges.

Planting can be done in the furrow or on top of the ridge, depending on the situation. Weeding can also be done with the implement system. Because many farmers own a Victory mouldboard plough, a subframe was constructed that fits to the frame of that plough. This makes investment much lower, not exceeding US$ 35.

Another subframe fits to the Bakura II multipurpose toolframe. The system consists of a subframe, a chisel point, a furrow wing, a ridge wing and an A-blade for weeding. The construction of the parts is simple and suited for local production. Although primarily developed for the medium potential areas in Kenya, the system could be useful in other regions, A production manual is available upon request.

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## Introduction

The farm population in certain medium potential semi-arid areas in Kenya is over 1.5 million, located primarily in Machakos, Kitui, lower Embu and lower Meru districts. The areas have a bimodal rainfall regime and are characterized by a low and uncertain rainfall. Most field crops are grown in either the period of long or short rain. The average arable land area is about 5.6 ha per family holding of about 5 people. It is estimated that one family can cultivate 2 to 4 ha using current practices. Apart from the jembe (hoe) and the panga (machete), the implement most used for primary cultivation is the standard Victory mouldboard-plough pulled by oxen (Fig. 1).

This plough was, for many years imported, but now localy manufactured. It is used for the preparation of the seedbed by slow and laborious repetition of ploughing and also for weeding when the crop has grown for several weeks.

The draught requirement of the plough is high which results in a delayed tillage operation, carried out after the first rains have softened the soil. Weeding operations are carried out with the share of the plough. The weeds are cut, but the crop is covered with soil due to the mouldboard. Only after several weeks is the crop strong enough to survive this treatment, so the weeding is also delayed and insufficient. Besides, it is not possible with the Victory plough to make a rough cloddy structure to reduce run-off and to improve storage of rain in the root zone. The best alternative seems to be a furrow and ridge system, with the crop planted in the furrow. In some areas with water logging soils, planting of the crop on top of the ridge is better. (1)

Fig. 1 The Victory-plough.

## Results of Previous Work

Some years ago, the Agricultural University of Nairobi started a project in cooperation with several other organizations to develop a more suitable farming system for

the small-scale farmers. The Desi-plough from India (Fig. 2) was adapted to the Kenyan conditions. The angle of the point was changed for better penetration in the hard soil and a heel was mounted to improve stability. A chisel is used for breaking up the hard top layer before the Desi-plough makes the furrows in the dry soil.

Weed cultivation is done with a shallow sweep cultivator (1, 2). The different implements fit in a specially designed multipurpose frame named Bakura II. The price of the Bakura II set is about US$ 135 as compared to about US$ 55 for the Victory plough. Several sets of these implements were made and tested in different areas in Kenya. The construction of the Desi-plough is complicated and worn out parts, e.g., the point, can only be replaced with special tools and it is difficult to get spare parts like bolts and nuts.

## The Combi-plough

As many farmers already own a Victory plough, research was done to develop a low-cost system with implements that fit to the frame of the Victory-plough. The implements also fit the Bakura II multipurpose frame, to make possible a comparison with the Desi-plough. The Combi-plough system consists of the following parts:

### Subframe for Victory-plough

For use with the Victory-plough a subframe was constructed (Fig.3). To mount the subframe to the frame of the plough, only the mouldboard has to be removed. The subframe is fixed with a pin in one of the two holes of the beam. The thicker beam of the imported type fits into the subframe. To mount the subframe to the thinner beam of the local produced type, a steel-plate is placed between beam and subframe, to eliminate the spacing. The two holes in the beams are not always at the same distance. So only one pin is used to fix the subframe. The local price for the subframe is about US$ 10.

### Subframe for the Bakura II toolframe

The multipurpose frame of the Bakura II has a simple attachment for several implements. The subframe for the Combi-plough has the same attachment and can be fixed with two pins (Fig. 4). The local price for the subframe is about US$ 11.

### Chisel

The chisel (Fig. 5) is used for breaking up the soil. The point is made of flat spring steel from old motorcars. The material is locally available and not expensive. The wear resistance is much better than for points made from mild steel. The chisel is easily placed in the subframe and fixed with a pin. The local price for the chisel is about US$ 2.

Fig. 2 Adapted Desi-plough.

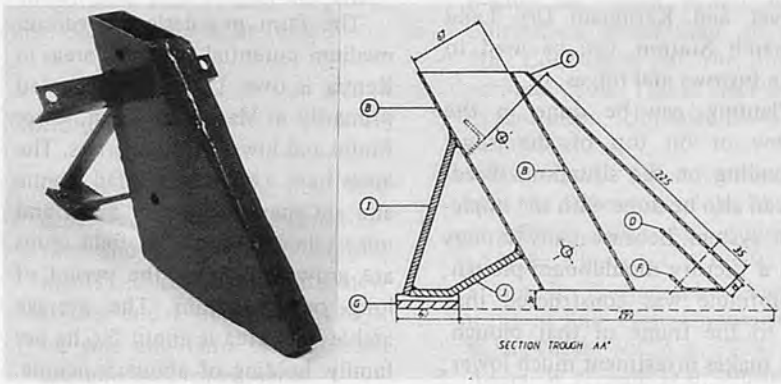


Fig. 3 Subframe for the Victory-plough.

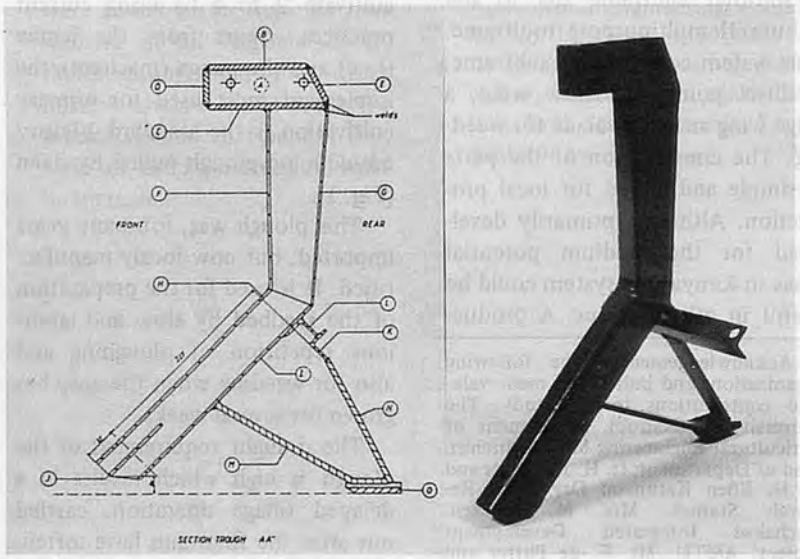


Fig. 4 Subframe for the Bakura II toolframe.

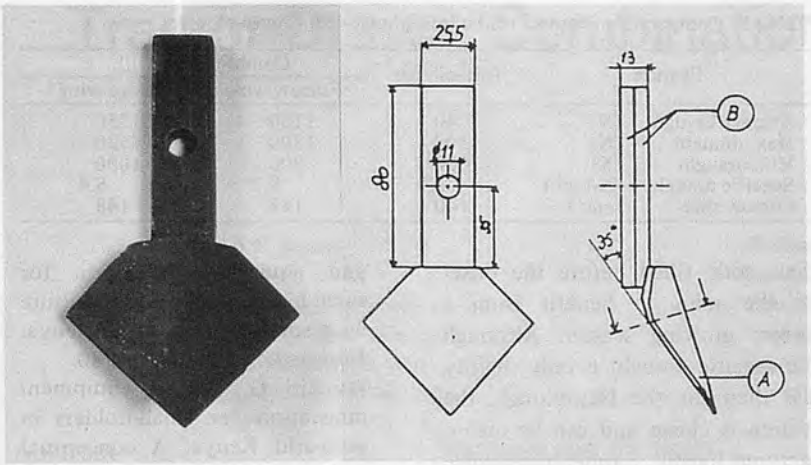


Fig. 5 Chisel

### Furrow Wing

After the chisel point has loosened the soil, the wing has to remove the soil from the furrow. The construction of the wing is simple and it is manufactured from mild-steel plate of 1/8" thick. It is mounted to the subframe with three pins, after the chisel point is in position (**Figs. 6 and 7**). The pins are secured with steel wire or nails. This implement has to be used when planting in the furrow is preferred. The local price for the furrow wing is about US$9.

### Ridge Wing

The ridge wing has to be used when planting is done on top of the ridge. The shape is adjusted to a ridge height of 25 cm and a row distance of 50 cm. (**Fig. 8**). The ridge wing is mounted like the furrow wing. The local price for the ridge wing is about US$ 10.

### A-blade for Weeding

The A-blade for weeding is used to cut the weeds between the furrows when planting is done in the furrow. When planting is done on top of the ridge, the ridge wing can be used for weeding. The width of the A-blade is 30 cm and the working depth about 3 cm. To mount the A-blade (**Fig. 9**), first the furrow wing and the chisel are removed from the subframe without tools. The A-blade is mounted like the chisel. The local price is about US$ 4.

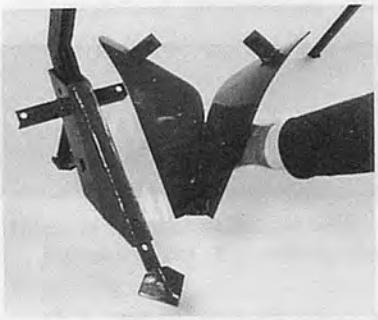

Fig. 6 Mounting of chisel and furrow wing to Victory subframe.

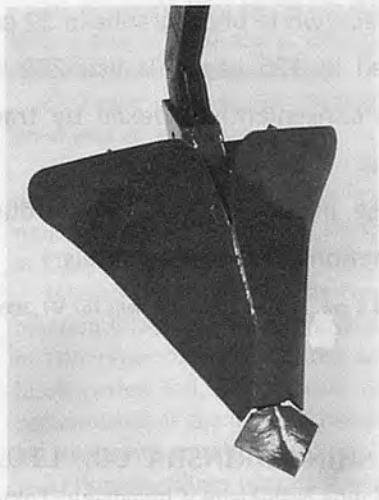

Fig. 7 Chisel and furrow wing mounted to a subframe.

## Results of Field Tests

Several sets of the Combi-plough were manufactured by the Kenya Industrial Estates (KIE) in Machakos. Jigs and a production manual contributed to a quick and accurate production of the ploughs. Tests were carried out at Machakos Integrated Development Project (MIDP) and at the Katumani Dry Land Research Station (NFDRS) (**Fig. 10**). The first tests showed that the penetration of the furrow wing is good and that the stability of the plough is comparable to that of the Desi-plough. Some of the loose soil remains in the furrow and can be used as a seedbed. The specific draught is 8% less as compared to the specific draught of the Desi-plough (**Table 1**). The specific

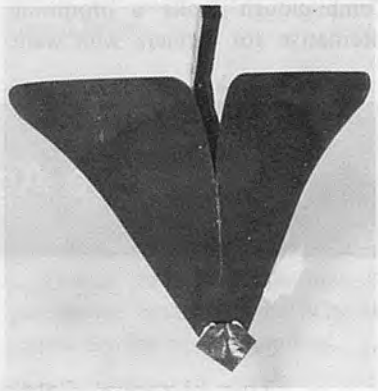

Fig. 8 Chisel and ridge wing mounted to a subframe.

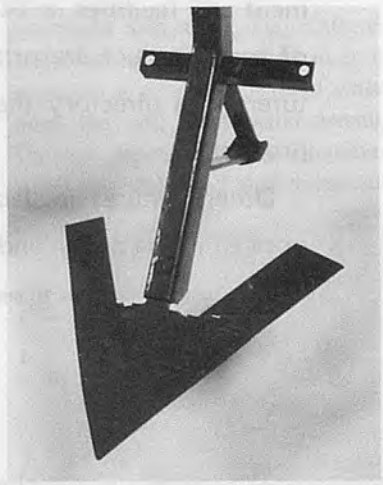

Fig. 9 A-blade mounted on Bakura II subframe.

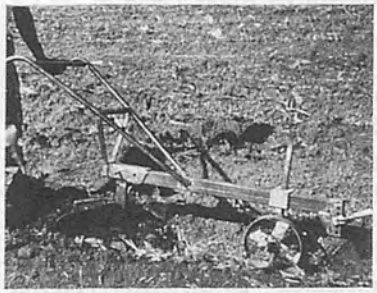

Fig. 10 Weeding operation carried out with ridge wing mounted on Bakura II toolframe.

draught of the ridge wing is 6% less than that of the Desi-plough.

As a result of the tests, some minor improvements were made. The steel bar mounting of the chisel and the weeder blade was replaced by a 1-1¼ inch pipe joint and slight alterations in the dimensions of the chisel were made to improve penetration in hard, dry soil. The Combi-plough looks a promising alternative for farmers who want their soils tilled before the onset of the rains to benefit from a longer growing season. Although the specific draught is only slightly less than for the Desi-plough, the system is cheap and can be manufactured locally. Farmer acceptance trials are carried out at 15 farms in the Machakos district. A production manual is available upon request.

Table 1 Comparative Features of the Desi-plough and Combi-plough

| Feature | | Desi-plough | Combi-plough with: | |
|---|---|---|---|---|
| | | | Furrow wing | Ridge wing |
| Average draught | (N) | 1240 | 1160 | 1250 |
| Max. draught | (N) | 1500 | 1300 | 1590 |
| Min. draught | (N) | 1030 | 900 | 1000 |
| Specific draught | ($N/cm^2$) | 8.9 | 8.2 | 8.4 |
| Furrow slice | ($cm^2$) | 140 | 141 | 148 |

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# Japanese Agricultural Machinery Catalogue '85

This bi-annual Catalogue is published in odd-numbered years. This 1985 edition introduces the latest models and designs of Japanese agricultural machines, equipment and facilities in 140 black/white photographs in 32 pages. Detailed specifications of each product are provided in 126 pages. It lists 250 leading machinery manufacturers in a directory that is conveniently indexed by trade and brand names of the product.

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# Tractor-Drawn Combination Tillage Tool

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## Abstract

The combination tillage tool does the primary and secondary tillage operations simultaneously. By using this implement the existing tractor power can be better utilized in the field. Due to simultaneous operations of primary and secondary tillage, 10 h/ha of tractor operation can be reduced when compared to conventional field preparation, viz. mould-board plough plus cultivator plus disc harrow. The energy required for the preparation of the seed bed will be reduced by using combination tillage tool.

## Introduction

Land preparation for sowing is an important operation which consumes time and energy which has to be completed within a short period to perform the sowing under optimum soil moisture. The primary tillage followed by secondary tillage operations completes the land preparation. But so long as the primary and secondary tillage operations are sequenced one after the other so long will exist time factor constraint. Hence, the development of a tool capable of performing both primary and secondary tillage operations in one pass would be highly beneficial as it will reduce the cost of seed bed preparation.

## Materials and Methods

### Implement Details

A combination tillage tool was designed and developed to combine primary and secondary tillage operations in single pass to ensure timeliness in seed bed preparation and also to utilize drawbar power available in a tractor by optimising soil-energy-tool performance. The combination tillage tool consists of the following: Cutting blade assembly; rotary assembly; power transmission to rotary system; framework to mount the cutting and rotary systems: and mounting frame to three-point linkage unit.

Following are the salient features of the unit:

a) A primary shearing blade of 23° inclination enables primary shearing of the soil;

b) A rotary unit of 50 cm dia. with a gang of 46 slicers at 130-160 rpm does the secondary tillage;

c) Power transmission through bevel gear of 1:1 ratio; and

d) The overall dimension of the unit is 200 x 100 x 115 cm and weight is 270 kg. The unit is shown in Figs. 1, 2A and 2B.

Intensive evaluation of the combination tillage tool was undertaken in two types of soils, viz. red and black cotton soil. To compare the performance of the unit the following treatments were selected:

a) Primary tillage operation with mould-board plough followed by secondary tillage operation with cultivator;

b) Primary tillage operation with mould-board plough followed by dual secondary tillage operations with cultivator and disc harrow; and

c) Combination tillage tool.

The soil parameters measured during testing of the unit are discussed below.

### Clod Size Distribution

Yorder's sieve analysis technique was used to determine the clod size distribution.

### Fineness Modulus

This is defined as the sum of percentage cumulative particles retained divided by one hundred.

### Hydraulic Conductivity

The soil samples collected in the permeability rings were saturated overnight with water. The saturated soils were serially arranged so as to maintain a constant head of water over the soil. The water passing through the soil in a stipulated time was collected and measured

Fig. 1 Soil combination tool.

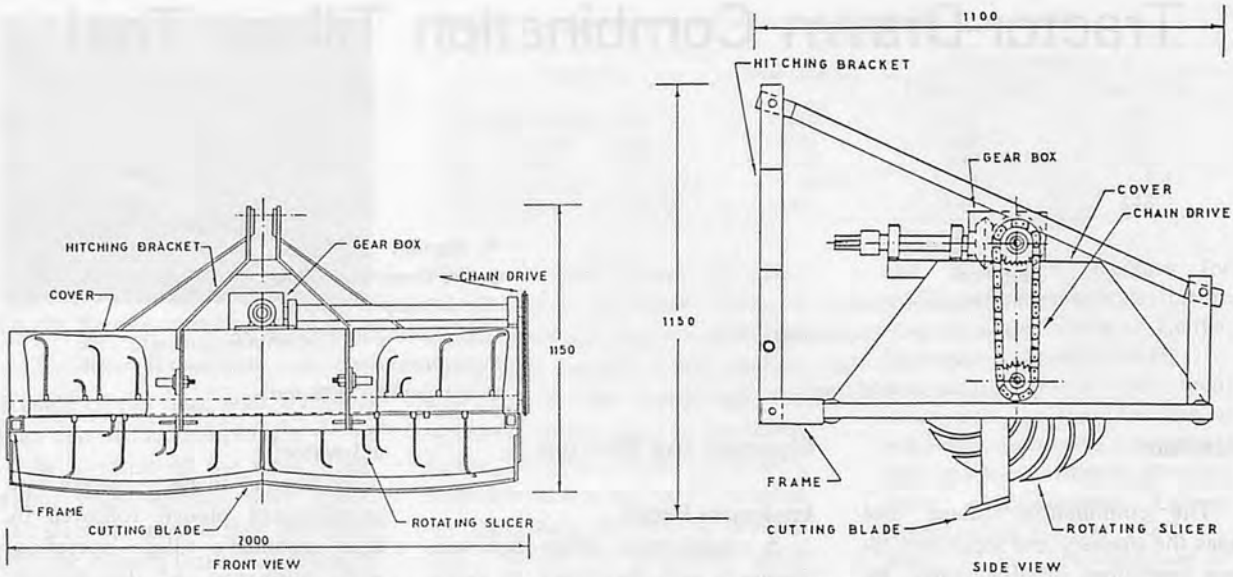


**Fig. 2** Soil combination tool, front and side views. Unit: mm

until concordant values were obtained. Then the hydraulic conductivity was calculated using Darceys equation (Dakshinamurthy and Gupta[1], 1968).

### Bulk Density

Tube core samples of 5 cm in diameter and 10 cm long fitted with rings were driven into the soil after each implement operation for required depth and core samples were collected. They were oven-dried separately for 24 h at 105°C, weighed and the bulk density was calculated (Dakshinamurthy and Gupta[1], 1968).

### Bearing Capacity of Soil

The Vicksberg penetrometer with a cone angle of 30° and cross sectional area of 5 $cm^2$ was used to determine the bearing capacity of the soil with respect to depth. The dial readings were converted into load by using the standard curve for the penetrometer and the bearing capacity was calculated by dividing it with the cross sectional area.

### Infiltration

The double ring infiltrometer as recommended by Dakshinamurthy and Gupta[1] (1968) was adopted. The outer and inner rings were filled with water to a depth of 5 cm and the water supply was opened so that a constant head of 5 cm was maintained on the soil surface. The quantity of water infiltrated into the soil at 15, 30, 60 and 120 min was recorded.

## Results and Discussion

The combination tillage tool was tested intensively with other treatments in black cotton and red soils. The following soil particle distribution was observed during the mechanical analysis.

The performance of the combination tillage tool was compared in terms of soil manipulation in both soils with the other two treatments. The study was carried out at 11.00±0.5% moisture content in black cotton and red soils.

### Clod Size Distribution

The clod size distribution for the two soils tested are furnished in **Table 2**.

In black cotton and red soils

**Table 1** Soil Particle Distribution

| Item | Black cotton soil | Red soil |
|---|---|---|
| Coarse sand | 43.30 | 54.70 |
| Fine sand | 15.70 | 29.60 |
| Silt | 22.50 | 7.20 |
| Clay | 18.50 | 8.50 |

**Table 2** Clod Size Distribution

| Implement combination | Percentage of clods retained in sieves of | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 34 mm | 28 mm | 20 mm | 17 mm | 12 mm | 10 mm | 3.5 mm | under 3.5 mm |
| a) Black cotton soil: | | | | | | | | |
| Mould-board plough + cultivator | 27.5 | 8.8 | 9.2 | 8.0 | 4.4 | 3.6 | 16.4 | 22.1 |
| Mould-board plough + cultivator + disc harrow | 24.0 | 8.2 | 7.3 | 6.0 | 7.7 | 4.8 | 5.5 | 36.5 |
| Combination tillage tool | 13.2 | 9.1 | 6.3 | 4.4 | 3.3 | 6.4 | 11.3 | 46.0 |
| b) Red soil: | | | | | | | | |
| Mould-board plough + cultivator | 21.5 | 10.3 | 9.2 | 7.6 | 5.8 | 6.2 | 8.4 | 31.0 |
| Mould-board plough + cultivator + disc harrow | 17.9 | 7.8 | 9.5 | 7.3 | 3.0 | 5.0 | 5.9 | 43.6 |
| Combination tillage tool | 8.0 | 7.9 | 10.4 | 4.2 | 8.2 | 2.5 | 4.9 | 53.9 |

clods of high dimension were left by the treatment of mould-board plough plus cultivator. The pulverization obtained using combination tillage tool is quite appreciable compared to the other two treatments. Yafsuk et al[2], 1971 obtained similar results using rotary blades. When comparing black cotton and red soil, the pulverization is better in red soil.

Fig. 3 shows (semi-log sheet) the relation between sieve aperture size and cumulative percentage passed through in each sieve. A high percentage of soil passed through each sieve in black cotton and red soil for tillage combine followed by the soil ploughed with mould-board plough plus two secondary ploughings and one secondary ploughing (Nagaiyan[3], 1983).

### Fineness Modulus

Fineness modulus of black cotton and red soils calculated for the three treatments are shown in Table 3.

From the fineness modulus values it is clear that red soil is pulverized more than that of black cotton soil. The pulverisation obtained using tillage combine in both soils is distinct.

### Hydraulic Conductivity

Table 4 summarizes the hydraulic conductivity of soils treated with different implement combinations.

Table 4 and Fig. 4 show that the combination tillage tool creates a better percentage of hydraulic conductivity in both soils compared to other treatments. Among black cotton and red soil the hydraulic conductivity is improved in red soil for all the treatments. This may be due to lower clay content of the red soil.

### Bulk Density

The bulk density obtained in different treatments are shown in Table 5.

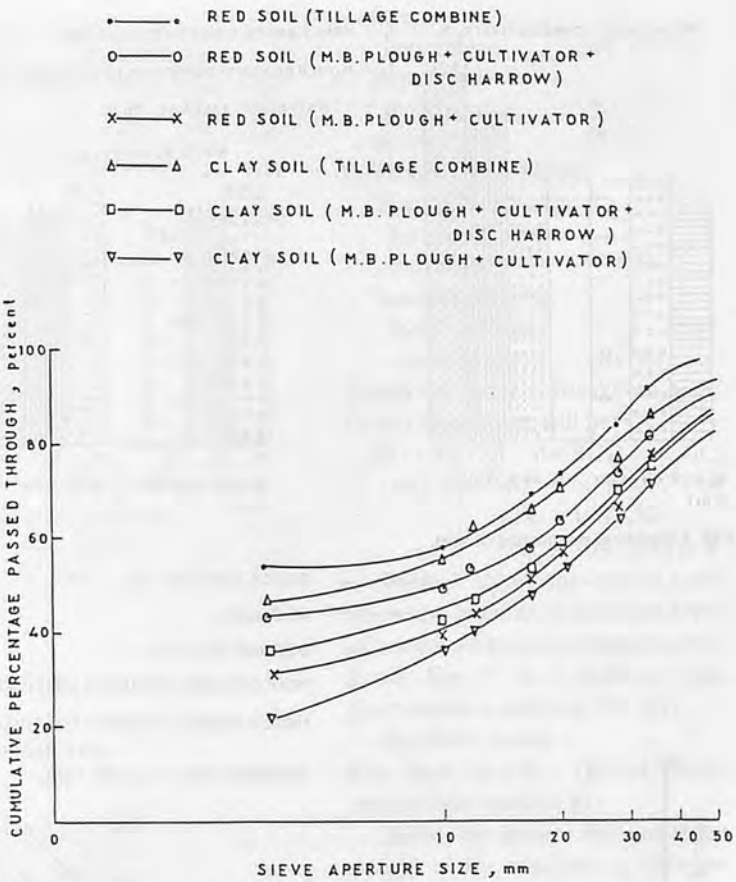


Fig. 3 Pulverization effect of different implements.

Table 3 Fineness Modulus of Black Cotton and Red Soil

| Soil type | Fineness modulus | | |
|---|---|---|---|
| | MBP + C | MBP + C + D.H. | C.T.T. |
| Black cotton soil | 4.6 | 4.16 | 3.30 |
| Red soil | 4.27 | 3.74 | 3.07 |

Table 4 Hydraulic Conductivity

| Implement combination | Hydraulic conductivity | |
|---|---|---|
| | Black cotton soil | Red soil |
| Mould-board plough + cultivator | 11.60% | 13.24% |
| Mould-board plough + cultivator + disc harrow | 12.32 | 15.56 |
| Combination tillage tool | 14.84 | 18.12 |

Table 5 Bulk Density of Soils

| Implement combination | Bulk density, g/cc | |
|---|---|---|
| | Black cotton soil | Red soil |
| Mould-board plough + cultivator | 1.49 | 1.54 |
| Mould-board plough + cultivator + disc harrow | 1.38 | 1.39 |
| Combination tillage tool | 1.26 | 1.23 |

From the values and Fig. 4 it is shown that the pulverization effect of tillage combine is more pronounced compared to the other two treatments. Hence, the combination tillage tool produced favourable tilth for the root penetration over the two implements' combination (Byers et al[4], 1960).

### Bearing Capacity

Observation was done with the cone penetrometer in the field before and after using the implement combinations. Table 6 summarizes the results. The bearing capacity of

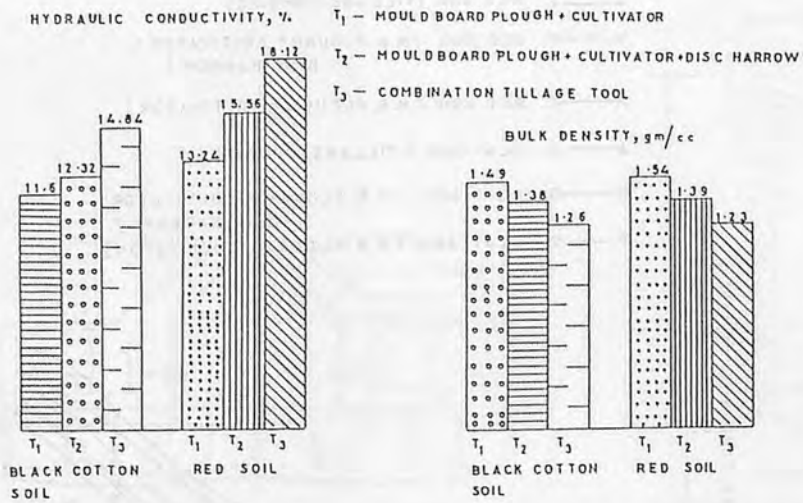


Fig. 4 Physical properties of soil.

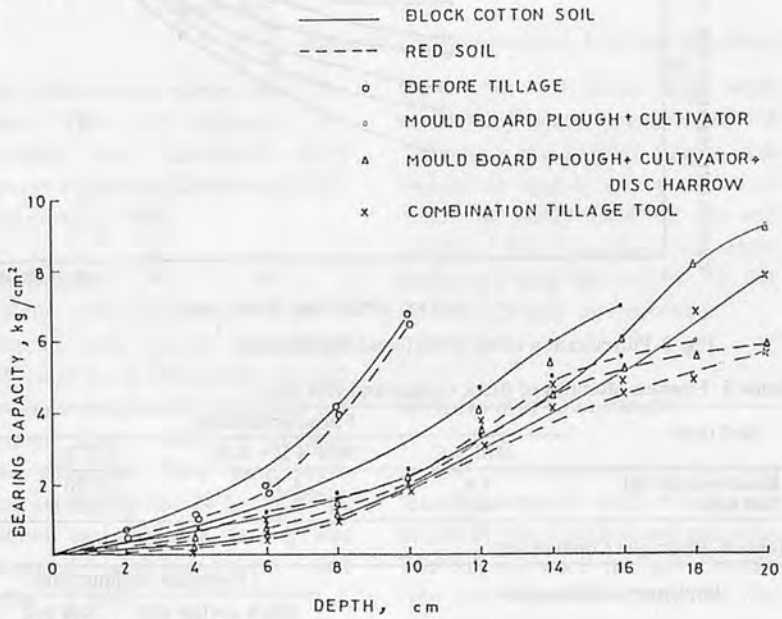


Fig. 5 Bearing capacity of soil.

Table 6 Bearing Capacity of Soil (Unit: kg/cm²)

| Depth | Bearing capacity before tillage | | Bearing capacity of B.C.S. after ploughing with | | | Bearing capacity of R.S. after ploughing with | | |
|---|---|---|---|---|---|---|---|---|
| cm | BCS | R.S | MBP+C | MBP+C+ D.H | CTT | MBP+C | MBP+C+ DH | CTT |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.70 | 0.70 | 0.40 | 0.35 | 0.10 | 0.45 | 0.25 | 0.10 |
| 4 | 1.20 | 1.10 | 0.90 | 0.70 | 0.40 | 0.65 | 0.50 | 0.20 |
| 6 | 2.00 | 1.80 | 1.40 | 1.00 | 0.60 | 1.30 | 0.90 | 0.50 |
| 8 | 4.20 | 4.00 | 1.80 | 1.60 | 1.05 | 1.55 | 1.35 | 0.85 |
| 10 | 6.80 | 6.70 | 2.40 | 2.30 | 2.20 | 2.20 | 2.20 | 2.00 |
| 12 | – | – | 4.70 | 4.10 | 3.50 | 3.90 | 3.70 | 3.35 |
| 14 | – | – | 6.00 | 5.40 | 4.60 | 5.00 | 4.50 | 4.20 |
| 16 | – | – | 6.90 | 6.00 | 4.90 | 5.50 | 5.25 | 4.60 |
| 18 | – | – | – | 8.25 | 6.90 | 6.00 | 5.50 | 4.90 |
| 20 | – | – | – | 9.20 | 7.85 | – | 5.90 | 5.70 |

the soil with respect to depth is plotted in **Fig. 5**.

The hardness of the black cotton soil is high before and after tillage when compared to red soil as reflected by the slope of the curves (**Fig. 5**). The resistance of the soil in black cotton and red soils after tillage with combination tillage tool is low compared to the other treatments. Thus it can be concluded that the pulverization effect of tillage combine is uniform up to a depth of 14 cm in both soils.

### Infiltration

**Table 7** shows the infiltration rate in black cotton and red soils. The readings were taken at intervals of 15, 30, 60, 120 min.

In black cotton soil the operation with mould-board plough followed by two secondary tillage operations favoured a high infiltration rate. The operation with combination tillage tool also favoured good infiltration rate. In red soil high infiltration rate was achieved in combination with tillage tool treatment. Hence, good infiltration rate could be possible if tillage with combination tillage tool is practised. The readings were plotted in a semi-log sheet (**Fig. 6**).

### Economic Consideration

*Cost of Tilling* – The comparative cost of operation of different treatments are presented in **Table 8**. The operating cost of combination tillage tool is calculated below:

| | |
|---|---|
| Investment cost | : Rs. 7,000/- |
| Interest rate/yr | : 15% |
| Salvage value | : 10% of the initial investment cost |
| Repair and maintenance rate/yr | : 10% of the initial investment cost |
| Housing/yr | : 0.5% of the initial cost |
| Expected machine life | : 10 years |
| Annual utilization | : 200 h |
| Contract rate | : Rs. 60/h |
| Depreciation | : Straight line method |
| A. Fixed cost, per/yr | : Rs. 1942.50 |
| Depreciation | : Rs. 630 |

Table 7 Infiltration Rate in Different Treatments

| Implement combinations | Black cotton soil, cm/h | | | | Red soil, cm/h | | | |
|---|---|---|---|---|---|---|---|---|
| | After 15 min | After 30 min | After 60 min | After 120 min | After 15 min | After 30 min | After 60 min | After 120 min |
| Mould-board plough + cultivator | 92.30 | 8.50 | 6.10 | 10.50 | 76.95 | 9.51 | 6.25 | 9.50 |
| Mould-board plough + cultivator + disc harrow | 126.50 | 9.80 | 5.40 | 12.35 | 74.85 | 6.53 | 5.75 | 8.70 |
| Combination tillage tool | 97.50 | 8.85 | 5.20 | 11.65 | 104.25 | 14.65 | 8.40 | 12.85 |

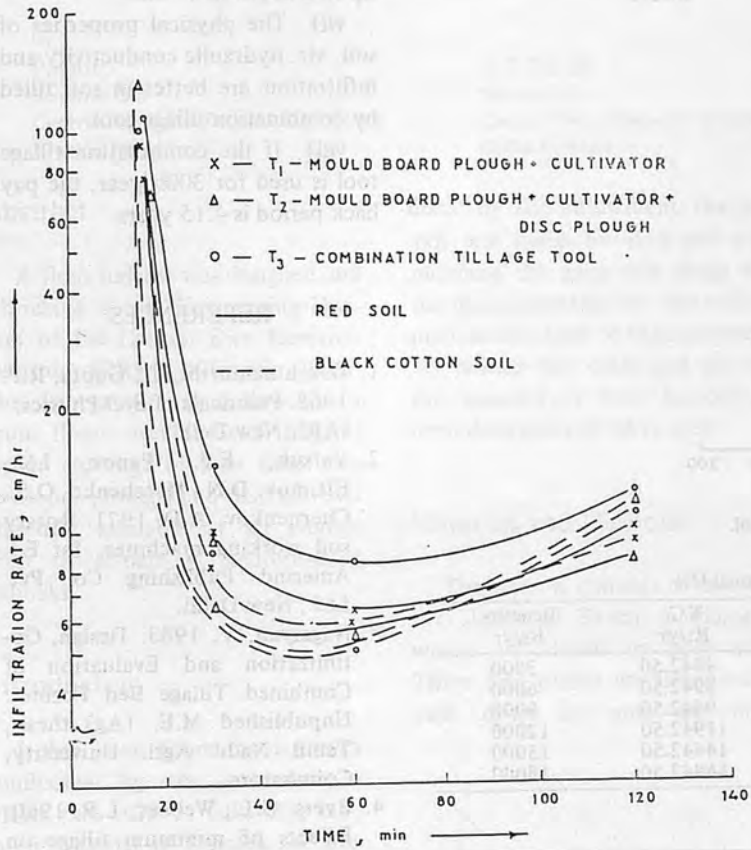


Fig. 6 Infiltration rate.

Table 8 Comparative Statement of Cost of Tilling

| Item | Primary and secondary tillage operations | | |
|---|---|---|---|
| | Mould-board plough + cultivator | Mould-board plough + cultivator + disc harrow | Combination tillage tool |
| a) Primary tillage per ha | | | |
| i) Mould-board plough, h | 6.5 | 6.5 | 4.5 (Primary and secondary tillage combined) |
| ii) Cost, Rs. | 393.25 | 393.25 | 270.00 |
| b) Secondary tillage per ha | | | |
| i) Cultivator, h | 4 | 4 | – |
| ii) Disc harrow, h | – | 4 | – |
| iii) Cost, Rs. | 213.00 | 449.00 | – |
| Total cost per ha, Rs. | 611.25 | 842.25 | 270.00 |

Cost of operation per h: Tractor – Rs. 50; Mould-board plough – Rs. 10.5; Cultivator – Rs. 4.5; Disc harrow – Rs. 7.75; Combination tillage tool – Rs. 10.00

Interest on investment : Rs. 577.5
Repair and maintenance : Rs. 700
Housing : Rs. 35

B. Variable cost, per/yr
Tractor hire charges for operating the implement : Rs. 50
Benefits (Income from machine rental per yr) : Rs. 60

*Breakeven Point* – Breakeven point of this investment will be:

$$PC + VC(X) = B(X)$$
$$1942.50 + 50X = 60X$$
$$10X = 1942.50$$
$$X = 194.25 \text{ h/yr}$$

Table 9 shows the cost of operation and benefits at different levels of annual utilization of the machine. From Fig. 7 it is inferred that the breakeven point is 194 h/yr.

*Pay Back Period* –

Pay back period = (Initial investment)/(Net benefits/yr)

Table 10 shows the pay back period of the machine at different levels of annual utilization.

From Table 10, it is inferred that the pay back period is 4.15, 2.60 and 1.90 years when the annual utilization rate is 300, 400 and 500 h, respectively.

## Conclusion

i) The combination tillage tool is an ideal implement for timely tillage practice as it requires lesser time of operation per hectare (4.5 h) when compared to the conventional tillage practice (10.5 to 14.5 h) and hence, greater annual coverage.

ii) The cost of operation per hectare with combination tillage tool is less than 55% when compared with conventional tillage practice.

iii) Only one-third of energy input is needed to manipulate the soil for satisfactory seed bed preparation.

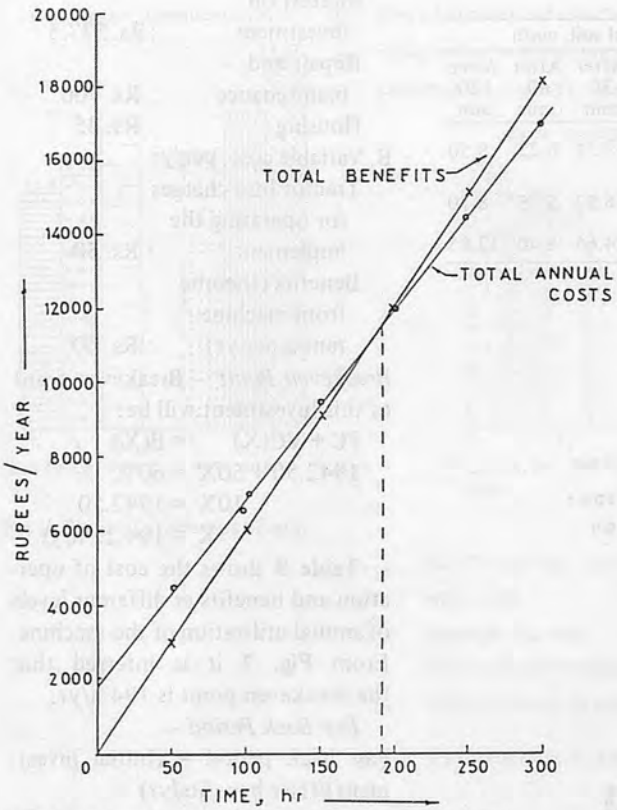


Fig. 7 Break-even analysis for combination tillage tool.

Table 9 Cost of Operation at Different Levels of Annual Use

| Use h/yr | FC Rs/yr | VC Rs/yr | T.C. Rs/yr | Benefits Rs/yr |
|---|---|---|---|---|
| 50 | 1942.50 | 2500 | 4442.50 | 3000 |
| 100 | 1942.50 | 5000 | 6942.50 | 6000 |
| 150 | 1942.50 | 7500 | 9442.50 | 9000 |
| 200 | 1942.50 | 10000 | 11942.50 | 12000 |
| 250 | 1942.50 | 12500 | 14442.50 | 15000 |
| 3000 | 1942.50 | 15000 | 16942.50 | 18000 |

Table 10 Pay Back Period

| Annual usage h | Total fixed cost Rs/yr | Total V.C. Rs/yr | Total cost of operation Rs/yr | Total benefit Rs/yr | Net benefit Rs/yr | Pay back period yrs |
|---|---|---|---|---|---|---|
| 100 | 1312.50 | 5000 | 6312.50 | 6000 | — | — |
| 200 | 1312.50 | 10000 | 11312.50 | 12000 | 688.50 | 10.17 |
| 300 | 1312.50 | 15000 | 16312.50 | 18000 | 1687.50 | 4.15 |
| 400 | 1312.50 | 20000 | 21312.50 | 24000 | 2687.50 | 2.60 |
| 500 | 1312.50 | 25000 | 26312.50 | 30000 | 3687.50 | 1.90 |

iv) The soil treated with tillage combine has lower percentage of bigger sized clods; thus finer pulverization is obtained.

v) The best favourable bulk density is induced in the soil manipulated by combination tillage tool.

vi) The pulverization effect of combination tillage tool is uniform up to a depth of 14 cm.

vii) The physical properties of soil, viz. hydraulic conductivity and infiltration are better in soil tilled by combination tillage tool.

viii) If the combination tillage tool is used for 300h/year, the pay back period is 4.15 years.

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# Float Harrow and its Performance

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## Abstract

A float harrow was designed and fabricated at the Engineering Division of the Central Rice Research Institute (CRRI), Cuttack, India. The disc gang being hollow like a drum floats over the soil. It gives higher coverage of area than conventional ploughs and disc harrows presently available at an average draft of a pair of medium-sized bullocks.

## Introduction

It has been found by a survey conducted by the scientists of CRRI that 50% of cultivable land in the District of Cuttack are prepared late for seeding. The late preparation of field results in late transplanting and hence lesser yield. The puddling equipments now used by farmers are mouldboard ploughs followed by conventional ploughs or disc harrow. The capacity of these equipments is low and the draft of the conventional disc harrow is also high. To reduce the draft, the manufacturers as well as designers reduced the size of the discs. By this adjustment, the gang axis was much lowered and while puddling the gang axis along with the discs penetrate into the soil and increase the draft of the equipment. To reduce the draft and increase the capacity, a float harrow has been designed and fabricated.

**Acknowledgements:** The authors are thankful to Dr. H.K Pande, Director, Central Rice Research Institute, Cuttack for his encouragement throughout the project and the facilities provided for the project.

## Materials and Methods

The harrow consists of two hollow drums of 35 cm in diameter, which are closed on both sides. Three disc blades are mounted on each drum by nuts and bolts. They are 60 cm in diameter each. The radius of curvature of the discs are 60 cm. Each gang is mounted on an angle iron frame by means of two bearings at the end of each drum. The two frames are hinged together at one end and the angle between frames can be varied by fixing the frames to a number of holes provided on the seat. The seat is provided for the operator to control the bullocks. Between the two gangs of discs a cultivator tine is provided to cultivate the area between the two blades of the adjacent gangs (**Fig. 1**). A flat type scraper is welded on the frame over

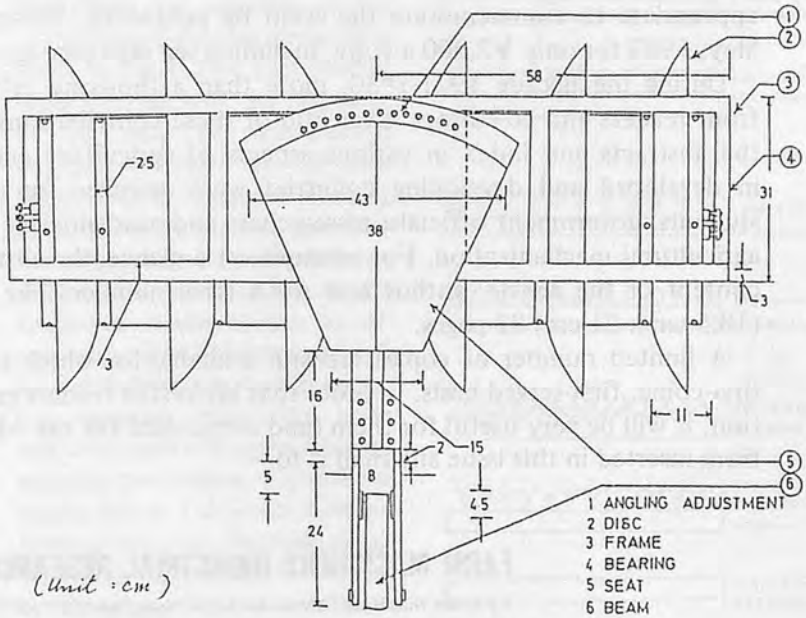


**Fig. 1** Float harrow (top view)

each disc to wipe off the puddled soil that may stick to the discs. A wooden beam is attached to the harrow by nuts and bots.

## Specification

Type of harrow: Single acting disc type with discs mounted on a hollow roller for providing floatation in saturated paddy soils.

Number of gangs : 2
Number of discs : 3 per gang
Diameter of discs : 600 mm
Concavity of discs : 83 mm
Diameter of roller : 350 mm
Disc spacing : 200 mm
Effective cutting width: 1000 mm
Method of changing angle: By changing position of two bolts in holes provided for changing disc angle up to 30°.

## Materials of Construction

Frame : 25 mm x 25 mm mildsteel angle
Disc : 2.5 mm thick m.s. plate
Roller : 2.5 mm thick m.s. plate
Type of bearing : Ball bearing
Number of bearing : 4
Pull required : 70 - 100 kg
Time required for puddling : 11.5 h/ha
Cost :Rs 700/- (approx. US$70)

## Results and Discussion

The field where the float harrow was to be tested was ploughed once in dry condition by mouldboard plough. After irrigating the field the puddling was done by float harrow. The test results are shown in the Table below.

Field Performance Results of the Float Harrow

| Area in $m^2$ | Time taken min | Capacity h/ha | Pull range kg |
|---|---|---|---|
| – 1st puddle – | | | |
| 1280 | 62 | 8.30 | 80 - 100 |
| 735 | 24 | 5.30 | 80 - 95 |
| 800 | 34 | 6.40 | 85 - 100 |
| – 2nd puddle – | | | |
| 1280 | 30 | 3.54 | 70 - 90 |
| 735 | 20 | 4.30 | 75 - 95 |
| 800 | 26 | 5.30 | 80 - 95 |

The average depth of puddle was 16 cm. The average time taken for two puddles is 11 h 30 min/ha. Two operations by float harrow gives suitable land preparation for transplanting purposes. The float harrow requires a pull of 70-100 kg which can easily be supplied by a pair of medium-size bullocks. ■■


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# Groundnut Crop Moisture Content and Rotor Speed in Stripping

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## Abstract

The performance of seven types of stripping mechanisms, namely; plain beater, star type, delta type, eye type, loop type, nail type and screw type were evaluated. The rotor speed was varied from 2.83 to 4.65 m/sec. Output and damage percentages were calculated at different levels of moisture contents of the crop ranging from 15-40% for the above rotor speeds. The study established that the screw type mechanism is the best.

## Introduction

Stripping is the most labour intensive operation in groundnut cultivation. It is also a slow process. Harvested plants are taken in lumps and by slight twisting along with pulling the pods are separated from the haulms. In certain areas solar-dried plants are beaten with a stick and the pods are separated by pouring the materials against the wind (1). Manually operated comb and drum type strippers were developed by the Tamil Nadu Agricultural University in the early seventies, but their efficiency was only 1-1.5 times that of the conventional methods (8). In Punjab, the prototypes of power-operated groundnut strippers for prime mover capacity of 10-20 HP have been developed, the cost of which are beyond the reach of an average Indian farmer (4). Hence, an intermediate technology with better efficiency was keenly felt, for which this study had been undertaken.

## Materials and Methods

An experimental stripper with a cylindrical drum of 40 cm diameter and 30 cm length was developed for this study. The peripheral speed was changed by a variable speed drive. This test rig also facilitates easy fixing and removing of different types of stripping mechanisms shown in **Fig. 1**. They were fixed at equal intervals over the periphery of the drum. The experimental thresher developed by Harbajan Singh et al (3), facilitated changing of peripheral speeds only and there was no provision for fixing different mechanisms. Chauhan et al (2) conducted similar studies in decorticator, with 3-shelling surfaces, 4-cylinder peripheral speeds and at two moisture levels. The study was conducted with seven different stripping mechanisms, 5 peripheral speeds and at 5 different moisture levels of the crop. Santhosh Singh et al (7) conducted similar studies by changing the above variables in wheat threshing.

The variety selected for the study was T.M.V. 2. The readings were recorded by keeping the moisture content of the crop or peripheral speed of rotor at a constant level for a particular study. As the farmers prefer to strip the pods immediately after harvest, for quality fodder and minimize damage, the harvest moisture content of 49% was taken as the base.

## Results and Discussion

**Figs. 2 and 3** summarizes the

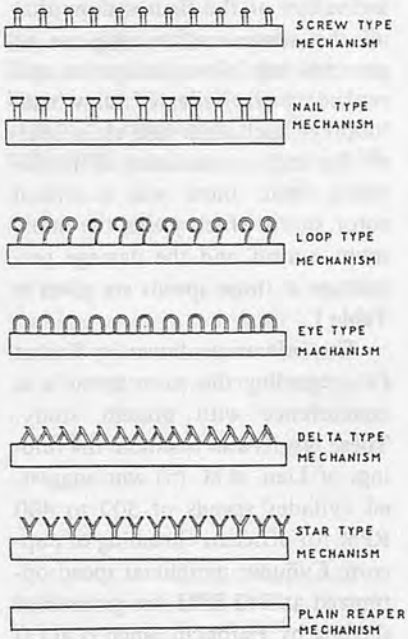


**Fig. 1** Stripping mechanisms.

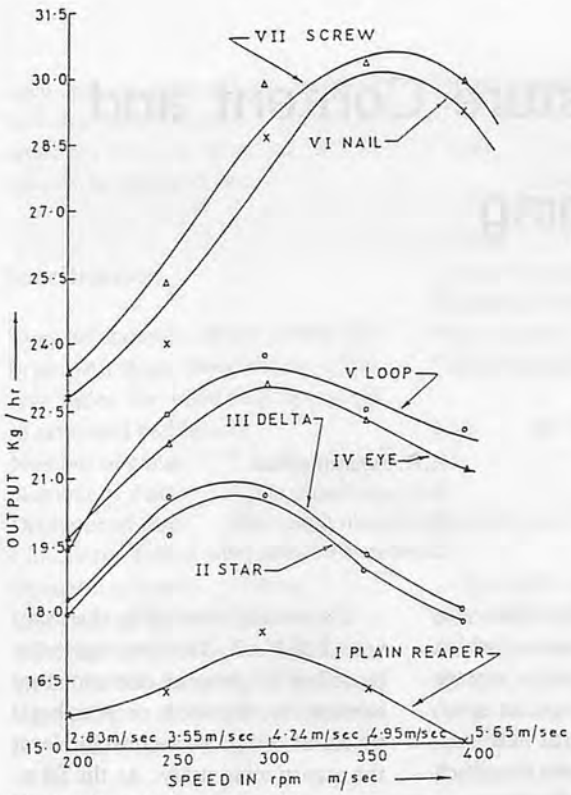


Fig. 2 Effect of speed on output.

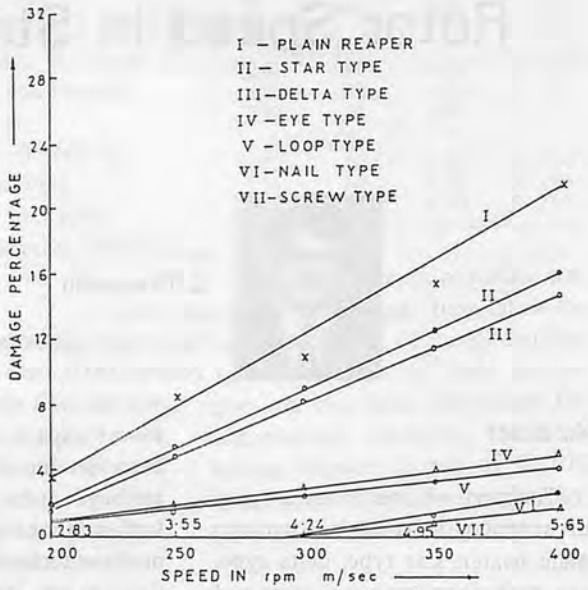


Fig. 3 Kinematic influence on damage induced by different mechanisms.

Table 1 Maximum Output and Damage

| Particulars | Plain beater | Delta and star | Loop and eye | Screw and nail |
|---|---|---|---|---|
| Critical speed (RPM) | 285 | 285 | 300 | 360 |
| Maximum output (kg/h) | 17.25 | 20.49 | 22.25 | 27.60 |
| Damage (%) | 10.90 | 8.10 | 3.20 | 0.96 |

pattern of output and damage encountered in changing the peripheral speed of the rotor. A critical examination of the figures show that all the seven mechanisms can be grouped into four categories and ranked in the order of screw/nail, loop/eye, delta/star and plain beater. For each combination of mechanisms tried, there was a critical rotor speed which yields the maximum output and the damage percentage at those speeds are given in **Table 1**.

The inferences drawn by Kalkat (4), regarding the rotor speed is in concurrence with present study. These results also resemble the findings of Lien, R.M. (5) who suggested cylinder speeds of 300 to 400 RPM for efficient threshing of popcorn. Cylinder peripheral speed optimized at 340 RPM, for groundnut shelling by Harbaran Singh et al (3) collaborated with the present finding of 360 RPM for screw and nail type mechanism. It is concluded that there exists a positive relationship between the kinetic energy required for groundnut shelling and stripping. The study on pod damage established the screw type mechanism superior than the one developed by Kalkat (4), where the pod damage was around 10%. The damage was less than 1% with the screw type mechanism.

In order to confirm the influence of moisture content on output and damage, further studies were conducted and the results are summarized in **Figs. 4 and 5**. The plain reaper mechanism reaches a constant output of 17.55 kg, beyond the moisture level of 25%. The star/delta mechanism and eye/loop mechanism indicated insignificant influence on output in relation to moisture content. The nail/screw type mechanism responded well with the change of moisture content. The damage due to change in moisture is more pronounced in the plain reaper than the rest. This difference in the performance of the mechanisms can be attributed to the nature of stress employed and type of failure experienced in stripping as explained by Mohsenin (6) and Adhoo et al (1).

## Summary

The study based on the output and damage percentage has ranked the different mechanisms in the order of screw, nail, loop, eye, delta, star and plain beater. It also has optimised the critical rotor speed for each mechanism that ranges between 280 to 360 RPM. Since much difference could not be derived in relation to moisture content and output, the harvest moisture content of 50% can be taken as the optimum, keeping the fodder value and minimum damage in mind.

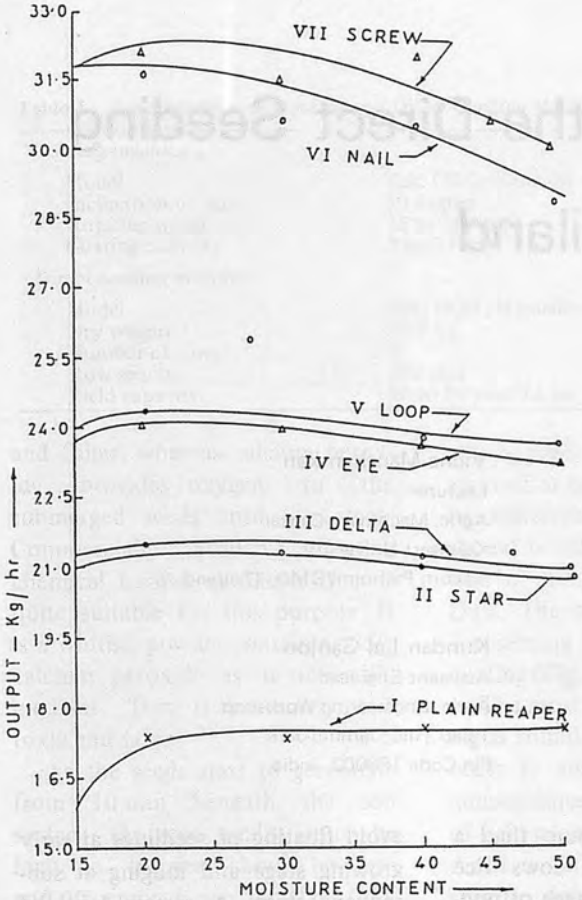


Fig. 4 Effect of moisture content on mechanism and output.

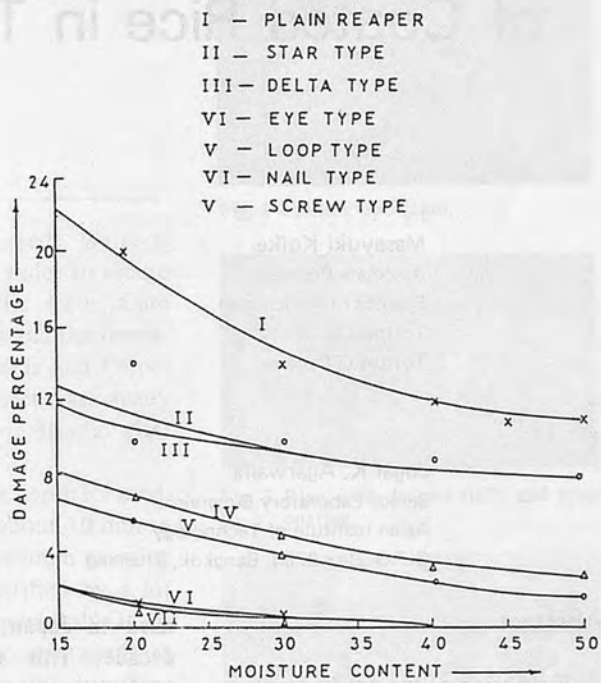


Fig. 5 Effect of moisture content on mechanisms and damage.

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# Field Investigation on the Direct Seeding of Coated Rice in Thailand

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## Abstract

Field trials of the newly developed rice-growing technology called the direct seeding with coated rice in submerged paddy (DSSP system) was extensively carried out in the Central Plain of Thailand. From agronomic and engineering standpoints, DSSP has great potentials in terms of its utilization. Some modifications of a direct-seeding machine as well as economic analysis were attempted. The feasibility of a DSSP system in the foreseeable future is also discussed.

## Introduction

In Thailand, the agriculture grew at an average rate of 5% over the past 20 years primarily through opening up new lands. Growth in the future must be derived from higher yields.

An improved rice-growing technique, the DSSP system, has been tried in Japan, for more than a decade. This method sows rice seeds either on the surface of puddled soil or at a random depth in dry soil. But there are certain drawbacks in the method. The problems encountered are lack of appropriate water and weed management, aeration, root development and poor seedling growth, and high lodging susceptibility.

Our previous work (1) has shown that the direct seeding of rice in submerged soil is feasible provided the paddy seeds are coated with calcium peroxide, which supplies oxygen for germination and sustains the initial growth of seeds. The coated seeds are placed up to a certain depth using specially designed direct seeding machines. The oxygen tends to decrease after it is puddled and is insufficient for securing any germination after the lapse of half a day. Even if healthy sprouted seeds are placed in the submerged soil, they deteriorate and their germination percentage is affected significantly. However, the DSSP method enables the seeds to germinate even when placed beneath the soil surface. Also, it may avoid floating of seedlings at early growing stage and lodging at subsequent stage. A certain level of water depth in the field reduces the rodent and bird injury, and maintains a favorable temperature of the soil. Farming management can be expected being less time-consuming and easier.

In this paper, the field evaluation of the DSSP system is highlighted.

## Methodology

The field investigation was carried out for two years, 1982 to 1983, for serving a coating machine and a direct seeding machine (**Table 1**).

The seeds are coated by a calcium peroxide-based agent which gradually decomposes to calcium hydroxide due to the presence of water and releases oxygen into the soil as per the following equation:

$$CaO_2 + H_2O \rightarrow Ca(OH)_2 + \frac{1}{2}O_2 \uparrow$$

Normally, after the emergence of first leaf, the rice seedling is capable of absorbing oxygen from the atmosphere through its stem

**Acknowledgements:** The authors wish to acknowledge the timely and essential assistance of the Hodogaya Chemical Co., Ltd , Japan and Yip In Tsoi and Jacks Ltd., Thailand.

Table 1 Specifications of Coating and Direct-Seeding Machines

| | |
|---|---|
| Coating machine | |
| Model | Taki CO-2, Manually driven |
| Inclination of pan | 50 degree |
| Rotating speed | 25 to 30 rpm |
| Coating capacity | 2 kg/15 min. |
| Direct-seeding machine | |
| Model | Taki DO-1, Manually drawn |
| Dry weight | 10.9 kg |
| Number of rows | 2 |
| Row spacing | 300 mm |
| Field capacity | 60 to 90 min/0.1 ha |

and foliar, whereas calcium peroxide provides oxygen to the submerged seeds until this stage. Commercially available coating chemical known as Calper Dust is quite suitable for this purpose. It is a whitish powder containing 35% calcium peroxide as its active ingredient. This is extremely low toxic and safe.

As the seeds start to germinate from 10 mm beneath the soil surface, the seed quality must be high, i.e., the seed should be fresh and its embryo sac must be fully grown. Seeds are selected by the use of water as is the normal practice in Thailand. Seeds that float are discarded. The use of salt water of specific gravity 1.13 could pick seeds of higher germination rate. The seeds thus obtained are kept in running or standing water for sprouting. When sprouting starts, the water is removed to stop further sprouting.

The seed's coated layer of Calper Dust should neither be peeled off during seeding nor be readily dissolved in puddled soil. As it is difficult to produce uniform coating manually, a machine has been developed for this purpose. The machine consists of an inclined rotating pan and a water sprayer. Once familiar with its operation, 6 – 8 kg of dry seeds can be coated per hour using the manually operated coating machine (**Fig. 1**).

Half the weight of the Calper Dust as that of the dry seeds is used for coating. Rice seeds to be coated are placed into the rotating pan while the Calper Dust is gradually applied to the seeds. Water is sprayed at times in order to secure its adherence to the seeds. Care should be taken to avoid the formation of lump of seeds and Calper Dust. The coated seeds are ready for seeding any time 10 min after coating (**Fig. 2**).

The most suitable depth for seeding is found to be about 10 mm in order to ensure optimum growing circumstances as testified by a lot of field trials done previously (1, 2). As it is difficult to sow seeds at specific depth manually, a pulling type direct seeding machine was provided (**Fig. 3**).

The seeds were coated with 0, 30, 40, 50, 60 and 80% of Calper Dust by weight of dry seeds. One hundred seeds from each of the above coated seeds were placed in the pots at the step of 0, 5, 10, 15, 20 and 25 mm deep, respectively. The varieties used are RD23 and RD25. The test soil was classified as clay.

The DSSP system, hand transplanting and broadcasting methods of rice cultivation have been tried at the same site, Khlong Luang Rice Experiment Station, for making a comparison. Similar field trials were performed at the rice fields of the Rangsit Rice Experiment Station and Asian Institute of Technology (AIT).

The amount of fertilizer was 75 kg N as ammonium sulphate, 40 kg $P_2O_5$ as triple superphosphate and nil $K_2O$ per ha. Herbicides and pesticides were timely applied whenever necessary. For the prevention of rodent attack, a steel-wire fence was installed encompassing each field plot.

Fig. 1 Coating operation.

Fig. 2 Rice seeds before (left) and after coating.

Fig. 3 A direct seeding machine in operation.

## Results and Discussion

The germination rate of coated seeds was not significantly affected by the seeding depth, whereas non-coated seeds failed completely to germinate when sown beyond 5 mm deep (**Fig. 4**). Even at 5 mm depth, the germination rate of non-coated seeds was very poor. Non-coated seeds did well on the soil surface only. The pot tests revealed that the range of Calper Dust application, 40 to 60%, can bring about acceptable germination percentage for practical use. Several follow-up trials confirmed that the 50% application rate can provide

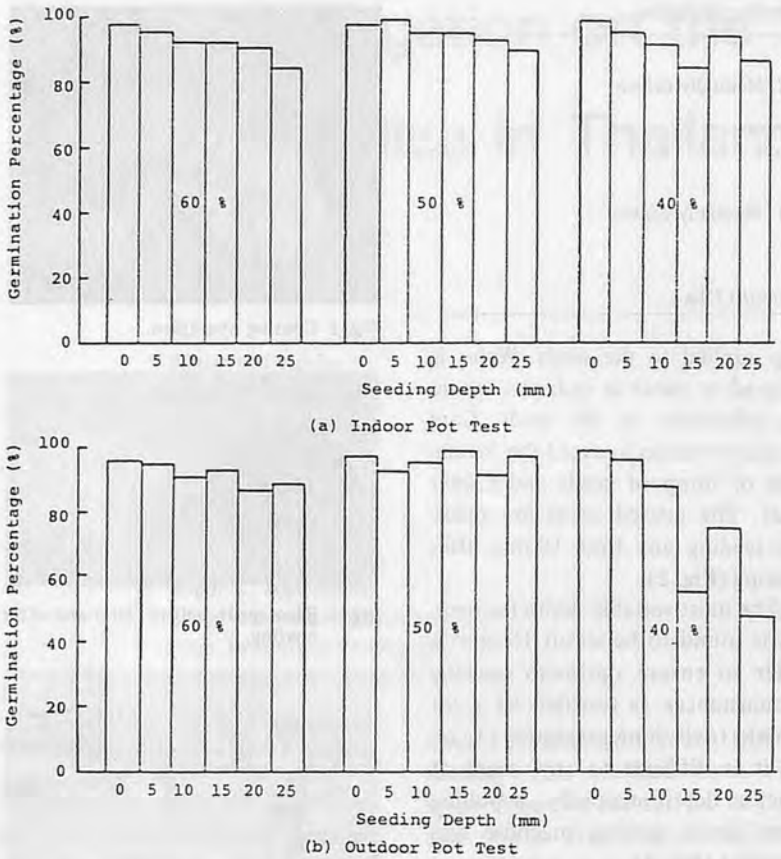


Fig. 4 Germination percentage under different coating percentage and seeding depth for RD25.

Fig. 5 Growing situation at Plot No. 2.

Fig. 6 Harvest stage.

acceptable index in terms of the target germination percentage being more than 80%.

The direct-seeding machine performed well with less fatigue in the properly levelled field. However, occasional missing of seeds occurred due to soil clogging in the outlet portion, and the machine tended to be immobile when it encountered extremely soft soil when the hard pan was beyond 20 cm deep.

The rice plants did not suffer from any serious diseases. The lodging of DSSP plot was far less compared with the other two methods. This is partly due to the robust root development which resists external disturbances. The thickness of the coated layer is approximately 0.4 mm. The amount of Calper Dust for coating is more than enough to let seeds germinate from as deep as 25 mm. The excessive amount of coating agent can function as soil conditioner in later stages.

**Figs. 5 and 6** show a certain growing stage and the harvesting period of rice plants, respectively.

The yield component factors and final yield at each testing site are presented in **Table 2.** In the DSSP trial, the percentage of ripened grains as well as the number of panicles are comparatively lower than anticipated. Strong rainfall during the flowering stage and bird attack in the milk grain stage seem mostly to be the dominant factors that influenced such low yield. Both the 100-grain weight and the number of spikelets per panicle have attained reasonable levels. The low water temperature caused poor germination percentage. At an average water temperature of 16°C, less than 20% germination was observed.

Some modifications in the seed metering devices and the soil covering devices have been made. After increasing the size of slots of the seed metering device, it was found that each slot can securely hold 3 to 5 coated seeds at a time, no matter their arrangements **(Fig. 7).** The gear ratio 10:11 and metering roller cum 7 or 9 slots are recommended combinations for better seeding performance.

Table 2 Yield Analysis of Three Different Culture Methods (Sampled from 1 m²)

| Item | DSSP system | | Hand transplanting | | Broadcasting | |
|---|---|---|---|---|---|---|
| Plot No. | 1 | 2 | 1 | 2 | 1 | 2 |
| Number of panicles | 310.0 | 315.0 | 372.0 | 203.0 | 289.0 | 254.0 |
| Number of spikelets per panicle | 53 | 79 | 60 | 91 | 26 | 59 |
| 1000-grain weight(g) | 29.3 | 28.8 | 26.6 | 26.1 | 26.5 | 27.8 |
| Ripened grain(%) | 69.8 | 74.7 | 69.8 | 82.0 | 40.9 | 81.9 |
| Estimated yield(g) | 335.8 | 535.5 | 414.4 | 395.5 | 81.5 | 341.1 |
| Actual yield*(g) | 201.3 | 346.8 | 295.7 | 280.4 | 67.2 | 177.9 |

*Based on actual harvesting from 800 m² area.

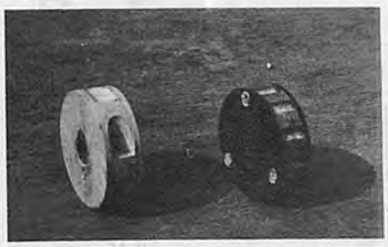

Fig. 7 Modified (left) and original metering devices.

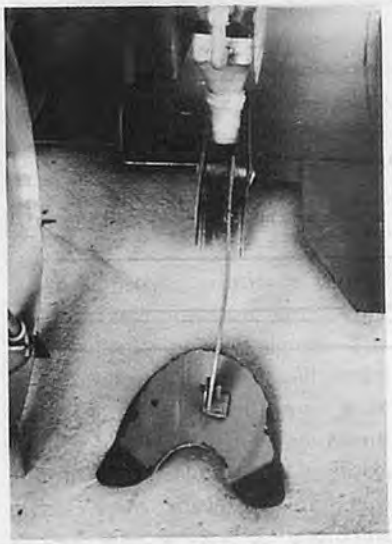

Fig. 8 Original soil covering device.

The original spring-loaded swinging-type soil covering mechanism as shown in **Fig. 8**, did not function well because of irregular soil surface profile as well as non-uniform moisture content. As a first step towards solving the soil covering problems, a 6.3 mm diameter close link hoisting chain was installed at the back of the machine **(Fig. 9)**. This improves the condition when soft soil is encountered. However, the problem with hard soil remained the same. A curved-inclined plate was fabricated **(Fig. 10)** to alter its position only when the machine is tilted either way. On hard soils, additional force can be applied by the operator by lifting the operating handle. This device has overcome problems mentioned earlier. The overall field performance of the wooden-roller type soil-covering device **(Fig. 11)** worked well as shown in **Fig. 12**, without any additional requirements of operational

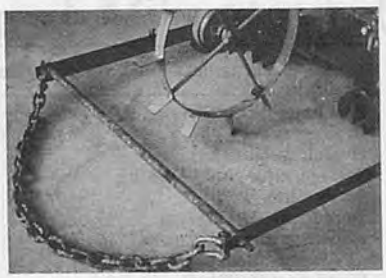

Fig. 9 Chain type soil covering device.

Fig. 10 Curved-inclined plate type soil covering device.

skill (4,5).

Thailand's average yield of rice is 1.9 t/ha and the total area of 1.8 million ha of land is cultivated each year by farmers using conventional practices. About 23% of the farmers use the broadcasting method using about 150 kg/ha of seed. This means that an equivalent 8% of yield is returned to the field for subsequent cropping. On the other hand, if the hand-transplanting or the DSSP technique is adopted, the average seeding rate would be 30 to 40 kg/ha which means a net saving of roughly 110 kg/ha of seed.

In the economic analysis for all cases, it was assumed that the various

Fig. 11 Wooden roller type soil covering device.

machinery used for farming practices are at rent basis except coating and direct seeding operations, for which fixed cost can be calculated on the basis of depreciation, interest rate, repair and maintenance **(Table 3)**. It was also assumed that the cost of field preparation, fertilizer, field management, irrigation, harvesting, threashing and drying are going to be more or less the same, irrespective of the cultivation methods adopted. From **Fig. 13**, it is observed that the DSSP system is not economical compared with the broadcasting, even if a large area might be cultivated by this method. The DSSP system may be competitive compared with the hand transplanting, if some minimum acreage of land is cultivated per year. The average size of farms in Thailand is about 3 ha which seems quite suitable and economical for the DSSP system. Before any recommendations are given, further field studies will have to be made for more reliability in terms of stable rice

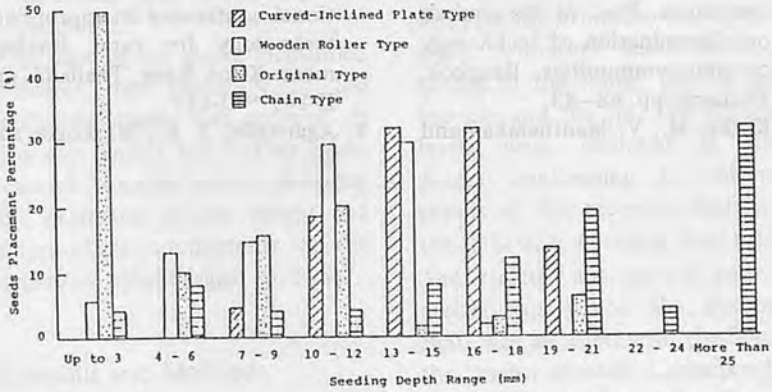


Fig. 12 Seed placement percentage vs seeding depth range achieved by using various types of soil covering devices.

cultivation.

## Conclusions

In the DSSP system, the period of vegetative stage for the rice crop is shortened as the nursery stage is eliminated. This initiates the reproduction stage and suspends the growth of higher number of nodes. These inherent growing processes play a vital role in yield increase. This direct seeding practice was found to be acceptable in field conditions when specific modifications of the machines and efforts directed to low cost technology is attained.

The DSSP system is quite economical compared with the hand transplanting method whereas there is a very little difference compared with the broadcast method.

Coated seeds can be sown in rows immediately after puddling the fields so that suspended soil particles in standing water will leave a uniform layer of soil above the seeds. This technological innovation can assist in disseminating the DSSP system at farmer's level.

Table 3 Fixed Cost Machines Used

| Particulars | Coating machine | Direct-seeding machine |
|---|---|---|
| Purchase price (US$) | 130.44 | 43.48 |
| Interest rate (%) | 18.0 | 18.0 |
| Overall weight (kg) | 10.9 | 14.0 |
| Salvage value, 0.09 US$/kg | 0.98 | 1.26 |
| Service life (yr/h) | 10/1500 | 5/960 |
| Depreciation (US$/yr) | 25.89 | 4.22 |
| Repair and maintenance, 1% of total cost | 1.30 | 0.45 |
| Fixed cost (US$/yr) | 50.67 | 12.50 |
| Total fixed cost for both machines (US$/yr) | | 63.17 |

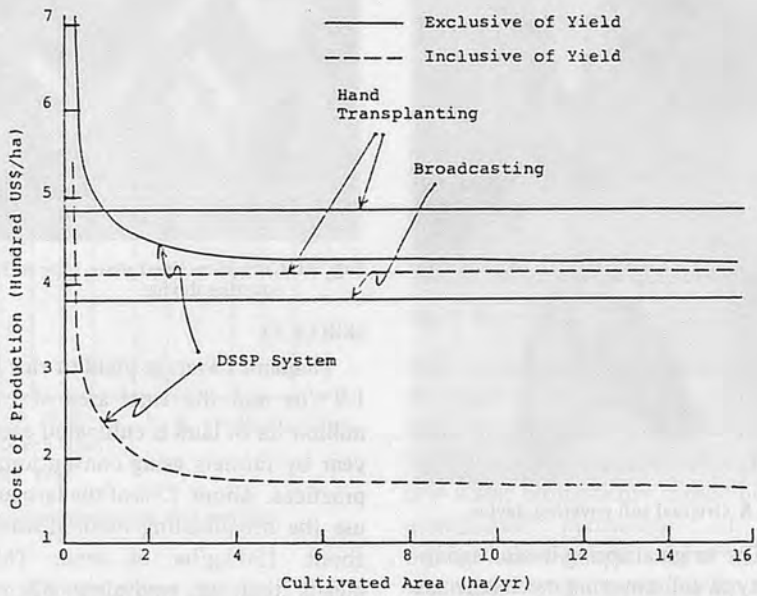


Fig. 13 Cost of production against cultivated area.


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# Performance and Vibration Control of Tractor-Mounted Oscillatory Potato Digger

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## Abstract

An improved prototype version of the tractor-drawn oscillatory potato digger was designed. The levels of vibrations in the old model and the new prototype were studied both in the laboratory and in the field. Design improvements were made in the new version with a view to improving the fatigue life of the digger. Replacement of the existing heavy blade of 29.7% by a lighter blade of 14 kg mass reduced the vibration level by 2.75%. The peak response values were reduced by 78.94% and the overall vibration levels by 66.73%. Provisions of flywheels helped in smoothening the functioning of the oscillatory digger. The values of mass moment of inertia of the flywheels were computed to limit the coefficient of fluctuation of energy to 0.050 and the coefficient of fluctuation of speed 0.100. The frame of the digger was redesigned to accommodate the two flywheels.

## Introduction

Potato is an important food and vegetable crop of India. The area planted to potato is estimated to be 0.528 million ha (4). It is estimated that it requires about 600 man-h/ha for manual digging of potatoes against 80 to 90 man-h/ha for a tractor-operated digger (7). A prototype of a single row, tractor-mounted oscillatory potato digger was developed during the years 1977-78 in the Department of Farm Power and Machinery at the Punjab Agricultural University, Ludhiana. The field testing of the unit reveals that it offered advantages in terms of reduced draft and adequate exposure of tubers. However, the following problems were encountered during the course of the working of the prototype (6, 7).

1. Excessive vibrations were transmitted to the frame of the digger as well as to the top and lower links of the tractor;
2. Failure of main shaft, on to which the eccentrics were mounted, was repeatedly experienced.

In view of the above mentioned problems, the reliability of the oscillatory digger was reduced. It obviously called for further investigations towards better designing and balancing of the rotary and reciprocatory components of the oscillatory potato digger (3, 5, 8).

## Materials and Methods

The equipment used in this study included the oscillatory potato diggers of old and new configurations, vibration measuring equipment, dynamometer for measuring the draft and speed measuring equipment. The investigations on the oscillatory potato digger were carried out both under the laboratory and field conditions. The dynamic performance of the old and new prototypes of the oscillatory potato digger was studied on a specially disigned rig under controlled conditions in the laboratory. After proper balancing, the dynamic as well as functional performance of the new configuration of the oscillatory potato digger was studied under actual field conditions. An improved version of the potato digger was redesigned as shown in **Fig. 1** and mounted on the vibration test rig. The drive to the digger was provided from the tractor p.t.o. shaft. Vibration levels were recorded at the frame, bearing caps, top pin and the rig. The vibration levels were recorded at these points conforming to different speeds of the eccentric shaft with the help of a vibration level meter. The tractor was started and the desired speed of the eccentric shaft was adjusted with the help of the tractor throttle. Corresponding to each selected speed the vibration levels were measured at all the

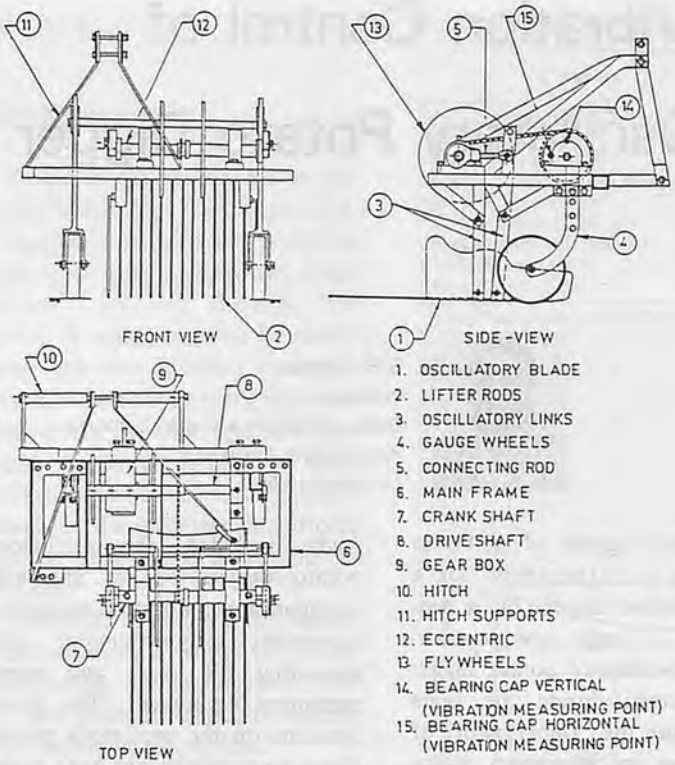


**Fig. 1** Tractor-mounted potato digger with an oscillatory blade. (New configuration)

selected points. At each point three readings of the vibration levels were taken and the average values were computed. Vibration levels at each selected point for the old configuration of the potato digger with and without upper balancing mass were measured. Similarly the vibration levels were also measured at selected points for the new configuration of the digger with balancing weights of 0.5, 1, 1.5 and 2 kg, respectively.

After achieving proper dynamic balancing in the potato digger in the laboratory, the dynamic performances were studied in the field. A potato field of a test run of 100 m length was selected. The speed of the tractor used for these test was 1.285 km/h. The vibration levels on one bearing point were noted while the tractor was moving. The vibration levels at the seceond bearing point were noted. The vibration (acceleration m/sec$^2$) were recorded at different 1/3 octave centre band frequencies of the vibration level meter in the range of 2 Hz to 100 Hz. A similar procedure was followed for all the dynamic performance tests carried under actual field conditions. Vibration (acceleration m/sec$^2$) were monitored at the selected points on the frame and the bearing caps in the field for the old and new configuration of the potato digger with balanced flywheel as well as balancing weights mounted on the flywheel.

## Results and Discussion

These studies helped in acquiring an understanding of the extent of vibration levels occuring at different points on the digger. The points were carefully selected to monitor the response (acceleration m/sec$^2$) with and without balancing weight as well as the balanced flywheel with and without counterbalancing weight. The results of the frequency analysis of the old configuration of the oscillatory potato digger in respect of the bearing cap point with and without the upper mass are plotted in **Figs. 2 and 3**. It is evident from these figures that there is an increase in the response (acceleration m/sec$^2$) with the increase in centre band frequency in the horizontal direction, whereas when the upper mass is used the response continued to exhibit an increasing trend up to a centre band frequency of 315 Hz. However, the response of the vibration levels at bearing caps decreases beyond a frequency level of 1000 Hz. On removal of the upper balancing mass, a similar trend of the frequency response was observed, with minimum response at the centre band frequency of 1000 Hz. With the removal of the upper mass, it was quite clear that the vibration levels were reduced by 57% at 315 Hz centre band frequency and by 38% at 1000 Hz centre band frequency. It is also clear from these figures that the vertical response at the bearing points exhibited a decreasing trend with the increase in the centre band frequency. This could be attributed to the fact that the oscillatory potato digger and the upper mass predominantly executed the oscillations in the horizontal direction and the response at the bearing points in the vertical plane decreased at higher harmonics due to higher dynamic balancing of the digger. There is an increase in response (acceleration m/sec$^2$) with the increase in the centre band frequency in horizontal direction at the frame point. However, when the upper mass was used, the response continued to exhibit an increasing trend up to 1000 Hz. The response of the vibration (acceleration m/sec$^2$) level at the frame point decreased after the frequency level of 1000 Hz. When the upper balancing mass was removed from the oscillatory potato digger a similar trend of the frequency response was also observed. With the removal of the

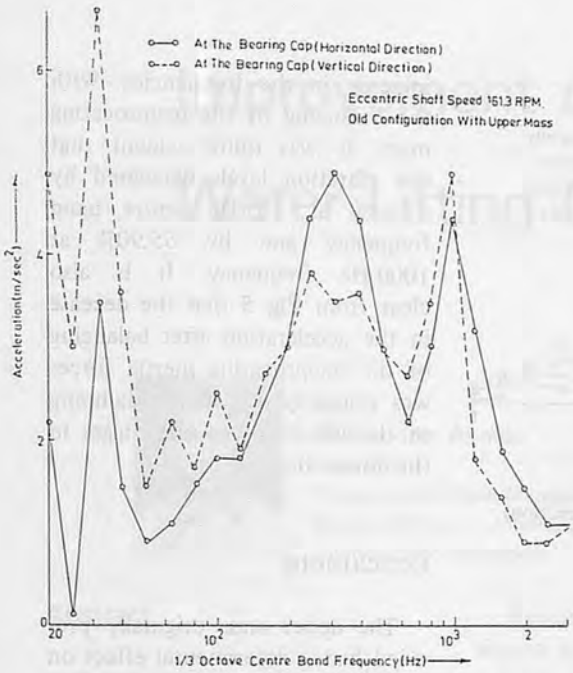


Fig. 2 Frequency anlysis of the vibration (acceleration) levels at the bearing cap for the old configuration digger with upper mass.

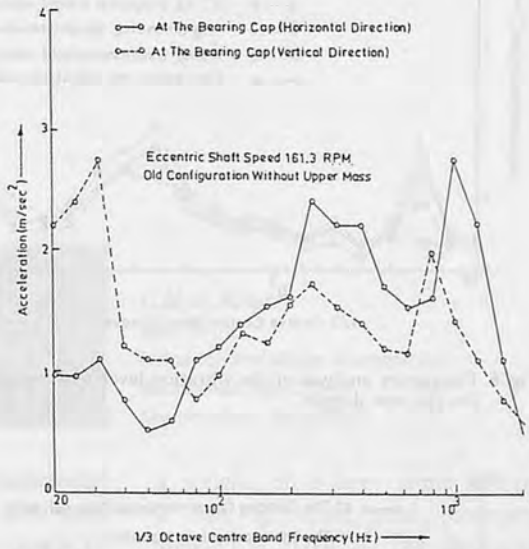


Fig. 3 Frequency analysis of the vibration (acceleration) levels at the bearing cap for the old configuration digger without upper mass.

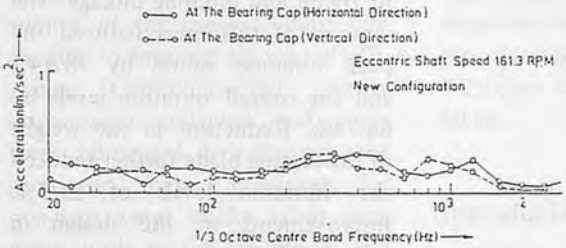


Fig. 4 Frequency analysis of the vibration (acceleration) levels at the bearing cap for the new configuration digger.

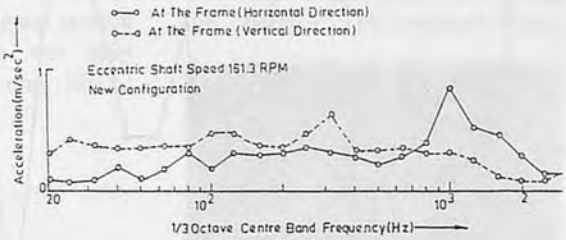


Fig. 5 Frequency analysis of the vibration (acceleration) levels at the frame for the new configuration digger.

upper mass, it was evident that the vibration levels were reduced by 31% at the frequency of 315 Hz and by 59.74% at the frequency of 1000 Hz. While using the upper mass led to the fatigue failure of the welding of the fulcrum pin provided in the digger due to the excessive inertia forces.

The results of the frequency analysis of the new configuration of the oscillatory potato digger in respect of the selected points of the bearing cap and the frame were also studied as shown in **Figs. 3 and 4.** It was found that there was a nominal increase in the centre band frequency in both the horizontal and vertical direction. The response continued to increase moderately in horizontal direction at the bearing cap up to a centre band frequency of 400 Hz and in the vertical direction up to a frequency of 315 Hz.

With the provision of the flywheel and incorporation of other design improvements it was clear from the results exhibited in **Figs. 4 and 5** that the vibration levels were reduced by 87% at 315 Hz centre band frequency and by 92.43% at 1000 Hz at the bearing caps as compared to the vibration levels in the older configuration of the digger. Similarly, the reduction in the vibration levels at the corresponding frequency at the frame point was observed to be 83 and 71.33%, respectively.

The response on the bearing cap with the varying balancing weights are plotted in **Fig. 6.** It can be seen from this graph that with a balancing of 1 kg weight the response gradually increased and the peak occured at a centre band frequency of 200 Hz. Beyond this value, there was a decrease in the response. Similarly, with a balancing weight of 0.5 kg the response corresponding to a frequency of 2 Hz abruptly increased and thereafter it exhibited a decreasing trend up to a frequency of 50 Hz. The response again increased with the increase in the centre band frequency.

The results of the dynamic performance studies, carried out under actual field conditions of the oscillatory potato digger in respect of the bearing cap point

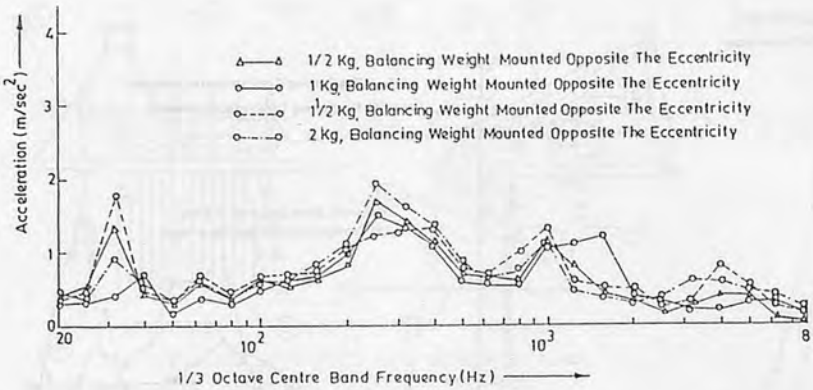


Fig. 6 Frequency analysis of the vibration levels at bearing cap (horizontal direction) for the new degger.

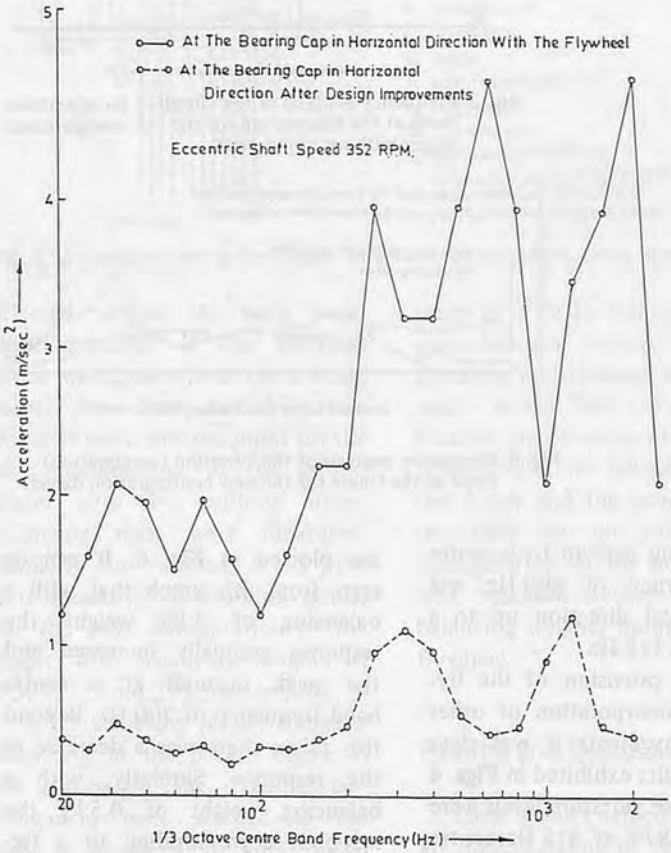


Fig. 7 Frequency analysis of the vibration (acceleration) levels at the bearing cap (horizontal and vertical direction) of the oscillatory potato digger after incorporating design improvements in the field.

are plotted in Fig. 7. It is evident from this figure that there was an increase in the response as vibration levels continued to exhibit a rising trend up to a centre band frequency to 250 Hz when the balanced flywheels only were used. However, after balancing the reciprocating inertia forces, an increase occured in the vibration levels with an increase in the frequency levels up to 1000 Hz. Beyond this level, there was a decrease in the response with an increase in the frequencies. With the balancing of the reciprocating mass, it was quite evident that the vibration levels decreased by 67.64% at 315 Hz centre band frequency and by 55.90% at 1000 Hz frequency. It is also clear from Fig. 5 that the decease in the acceleration after balancing of the reciprocating inertia forces was primarily due to the damping of the vibrations of the digger in the potato field.

## Conclusions

The upper mass originally provided had a deterimental effect on the dynamic performance of the digger and was, therefore, eliminated to minimize vibrations transmitted to frame and hitching linkage. The removal of this mass reduced the peak response values by 78.94% and the overall vibration levels by 66.73%. Reduction in the weight of the cutting blade further reduced the vibration levels of 2.75%. Improvements in the design in terms of frame structure, provision of flywheel, blade and side links also contributed towards reducing the vibration levels. The provision of the flywheels helped in smoothening the functioning of the oscillatory potato digger and in reducing the vibration levels from 66.73 to 22.63%. The overall vibration reduction was recorded under particular conditions in the laboratory by 68.83% and in the field by 80%. The shaft that drove the oscillatory potato digger did not sustain any breakage which proved that the vital components of the digger were not subjected to high dynamic loading and were thus safe and would not give way under fatigue failures. Provisions of the proper bushes and locking devices also improved the response to some extent.

*(Continued on page 54)*

# Improvement of Manually-Operated Water Lifting Device

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## Abstract

A popular manual water lifting device in Bangladesh is locally called "don" (Fig. 1). It is widely used for irrigation. It was the subject of the present study with an aim to improve its overall efficiency. Commonly-used country dons were collected and some were fabricated by changing the geometric shape. Provisions for one-way water intake valves were made both in the traditional and modified (fabricated) dons. These were tested in the field to compare the performance of different geometric shapes and to determine the practicability of using one-way valves.

It was found that the one-way valves at the intake portion of the don reduce the time and energy required per stroke and thereby increases the overall efficiency. These valves also reduce the buoyant force exerted at the bottom of the intake section.

Rectangular and trapezoidal shaped dons were found to be most suitable for making provisions of one-way valves at the bottom. The average discharge for such dons was 5.70 *l*/sec, whereas for a traditional don of triangular section the average discharge was only 3.25 *l*/sec for a common lift of 80 cm.

**Acknowledgement:** The authors wish to express their sincere gratitude to Bangladesh Agricultural Research Council (BARC), Dhaka, for financing the project "Don Improvement" and for extending all possible cooperation for the smooth of the project. The authors are also thankful to the Department of Irrigation and Water Management, Bangladesh Agricultural University, for providing office, laboratory and other equipmental facilities during the project activities.

## Introduction

For lift irrigation system water is raised from its source to the surface of the field. Whatever the source of water in a lift irrigation system, the efficiency depends on the application of sound principles in the design and construction of the utilization structure and the characteristics of the water lifting device in relation to the source of water.

The don is an efficient device for low-lift (up to 1.5 m) irrigation and plays a vital role in irrigated agriculture of Bangladesh. It is commonly used in low-lying areas for irrigating rice field. It is a manually-operated, boat-shaped wooden trough, closed at one end and open at the other known as the discharge end. The closed end of the trough is tied with a rope to a long bamboo or wooden pole which is pivoted as a lever on a post. Either a weight or a large stone and/or a ball of dried mud (counter-weight) is fixed to the discharge end of the lever. The trough is dipped into the water by applying the body weight and the force of the operator. The mechanism and

Fig. 1 Traditional country don.

Fig. 2 Counter-weight and water lifting mechanism.

Fig. 3 Counter-weight and curvature make the discharge easier.

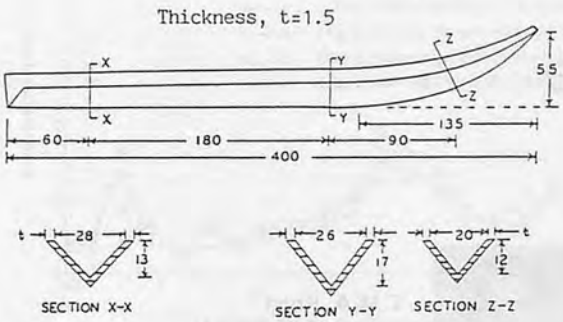


Fig. 4 Isometric view and cross-sections of don No. 2.

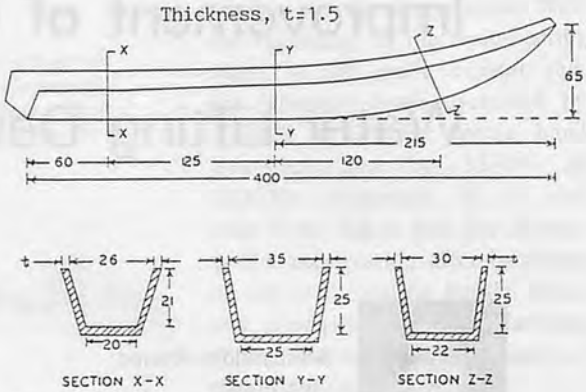


Fig. 5 Isometric view and cross-sections of don No. 6.

the counter-weight is shown in **Fig. 2**. Water is lifted by the counter-weight of the beam and is emptied automatically (**Fig. 3**).

The don ranks first in terms of area irrigated by indigenous methods. Three hundred sixty nine thousand hectares are irrigated by the don which comprises 23% of the total irrigated area of Bangladesh (Khan, 1983). The second indigenous method (in terms of area covered) of irrigation is the "swing basket" which covers only 83 000 ha (5% of the total irrigated area). Hence the improvement of the don can make substantial contribution in irrigation, hence help increase the total agricultural production.

The capital cost of each don varies from Taka 200 to 300 (US$8 to 12) only which is within the buying capacity of the poor farmers. This water lifting device is suitable for irrigating fragmented lands which is common in the country. Hence any improved modified don will directly benefit the farmers. However, very little work has been done so far. Ahmad (1981) studied only the performance characteristics of dons of different sizes.

In view of the above mentioned importance of the Don and considering the socio-economic condition of farmers in Bangladesh, an attempt was made to improve its overall efficiency.

Table 1 Don Specification

| Don No. | Length (cm) | Cross-section | No. of valves | Size of valves | Remarks |
|---|---|---|---|---|---|
| 1 | 375 | triangular | 2 | each 10 cm dia. | Purchased |
| 2 | 400 | triangular | – | – | Purchased |
| 3 | 300 | triangular | 2 | each 11 cm × 11 cm | Fabricated |
| 4 | 310 | triangular | – | – | Fabricated |
| 5 | 310 | rectangular | 2 | each 8 cm dia. | Fabricated |
| 6 | 400 | rectangular | 2 | each 13 cm dia. | Fabricated |

## Materials and Methods

Two traditional dons of triangular cross-section having 375 and 400 cm length were purchased from the local market. The cross-sectional dimensions are directly proportional to the length. Four wooden dons were fabricated in the laboratory. The specifications of these six (two purchased and four fabricated) dons are presented in **Table 1**. The isometric view and cross-sections at different points for triangular (No. 2) and trapezidal (No. 6) dons are shown in **Figs. 4 and 5**, respectively.

Provisions for one-way water intake valves were made at the sides for triangular dons and at the bottom for rectangular dons as shown in **Figs. 6 and 7**, respectively. The valves were made from low-cost discarded motor tube and small pieces of bamboo sticks and were hinged at one side so that it opens when the don touches the water surface and closes automatically when the water is discharged.

One particular labourer operated the dons during the field test in order to obtain a consistent set of data. Water was collected in a small

Fig. 6 One-way water intake valve for triangular don.

Fig. 7 One-way water intake valve for rectangular don.

controlled reservoir and the corresponding time was recorded by a stop watch. To obtain the proper lift height, the operator filled the don with water and held it in steady position without discharging water. At that position, the perpendicular height of bottom of the don from the water surface was measured and termed as the lift height. Tests were carried out for different lifts based on don length. The number of strokes was 50 for all cases.

## Result and Discussion

The performance test data is presented in **Table 2** which shows that 30-60 cm lift heights were used for don Nos. 3,4 and 5; whereas 40-100 cm were used for Nos. 1, 2 and 6. This was done due to the difference in length of dons. It is difficult to use shorter dons for higher lift.

The relation between average discharge and lift height is shown in **Fig. 8**. The discharge was greater for the dons having water intake valves with other dimensions symmetrical. The No. 6 don gave better result than No. 5 as the former was longer with bigger cross-section. The maximum average discharge was 6.75 *l*/sec for rectangular dons with water intake valves. Michael (1978) reported this value to be only 3.50 *l*/sec without any water intake valve. Minimum average discharge was recorded to be 2.80 *l*/sec for triangular dons without any valve.

The traditional country dons are triangular in cross-section as it is easier to immerse in water than the rectangular or trapezoidal shaped ones. If provision for one-way valve can be made, the rectangular or trapezoidal cross-section would be most efficient with valves at the bottom. It was also observed during the field test that it took longer time to get the intake portion filled if water enters through the valves only thereby reducing the discharge. Hence, in order to reduce the time required per stroke and to increase the overall efficiency, water should be allowed to enter the intake portion through the valves as well as over the sides of the don.

It is advisable that the valves be made circular to get the maximum area with minimum perimeter. Two valves should be used for an average size (300-400 cm

The buoyant force exerted at the bottom of the intake portion was reduced substantially if the valves were used and as a result less energy was required to operate the don. Therefore, it may be possible to operate the don for longer periods thereby lifting more irrigation water to cover greater command area.

Table 2 Performance Test Data for Dons

| Don No. | Lift (cm) | No. of strokes | Time taken per stroke (sec) | Av. discharge l/sec |
|---|---|---|---|---|
| 1 | 40 | 50 | 4.82 | 4.62 |
| | 60 | " | 5.86 | 4.15 |
| | 80 | " | 6.35 | 3.63 |
| | 100 | " | 7.45 | 3.10 |
| 2 | 40 | " | 6.73 | 4.00 |
| | 60 | " | 7.50 | 3.61 |
| | 80 | " | 8.46 | 3.15 |
| | 100 | " | 9.23 | 2.80 |
| 3 | 30 | " | 4.20 | 4.75 |
| | 40 | " | 5.00 | 4.28 |
| | 50 | " | 5.67 | 3.70 |
| | 60 | " | 6.92 | 3.25 |
| 4 | 30 | " | 5.58 | 4.52 |
| | 40 | " | 6.72 | 4.05 |
| | 50 | " | 7.80 | 3.24 |
| | 60 | " | 8.58 | 2.83 |
| 5 | 30 | " | 4.00 | 5.00 |
| | 40 | " | 5.20 | 4.40 |
| | 50 | " | 6.12 | 3.95 |
| | 60 | " | 7.00 | 3.72 |
| 6 | 40 | " | 4.50 | 6.75 |
| | 60 | " | 5.24 | 6.18 |
| | 80 | " | 6.65 | 5.70 |
| | 100 | " | 7.25 | 5.37 |

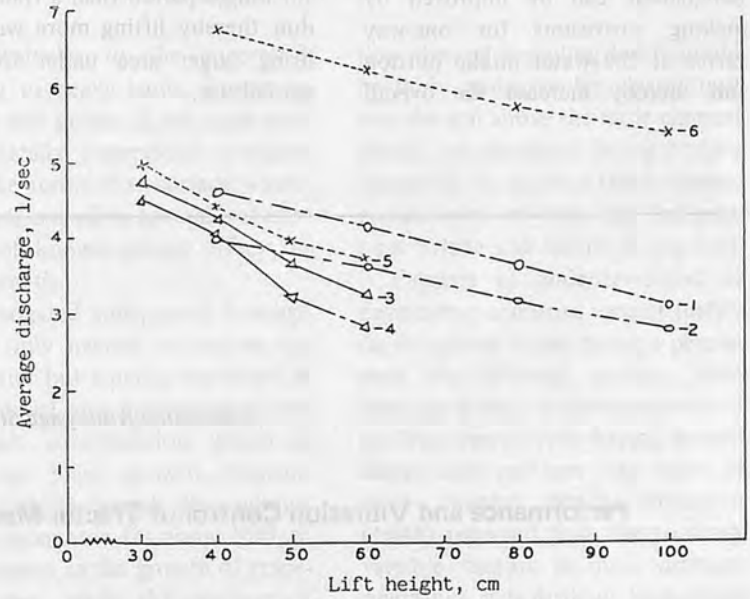


Fig. 8 Average discharge and lift height.

long) don. The valves should be placed such that they touch the water surface first when the operator dips the don into the water source. The distance between the valves will depend on their size which is again a function of don length. Care should be taken so that the mid-point between the valves coincide with the centre of the water intake portion. The curvature of traditional dons may be maintained for the improved or modified ones for easy discharge of water.

## Conclusion

The manually-operated water lifting device don which is extensively used for irrigation in Bangladesh can be improved by making provisions for one-way valves at the water intake portion and thereby increase the overall efficiency. For satisfactory use of valves, the cross-section (triangular) of the traditional dons should be changed to rectangular or trapezoidal form so that the valves may be made at the bottom. The cost involved for this modification is small and can be borne by the farmers.

The curvature of the improved dons may be similar to the traditional ones. The fabrication and necessary fittings of water intake valves may be made easily by local carpenters.

During the operation of don water entry should be allowed through the intake valves as well as the sides for quick filling of intake portion. One-way valves make the don operation easier and hence a labourer can operate for longer period than a traditional don thereby lifting more water to bring larger area under irrigated agriculture.

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*(Continued from page 50)*

## Performance and Vibration Control of Tractor-Mounted Oscillatory Potato Digger

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# Analysis of Foreces Acting on Mole Plough in Mole Drainage Practice

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## Abstract

An experimental procedure is described which allows measurement of soil forces acting on the leg and foot of the mole plough by using two extended octagonal ring transducers.

The field investigation was carried out using a randomized block experient to study the effect of using different sized expanders on the force system of the mole plough. The use of expanders does not significantly affect the force system. The ratio of leg to cartridge draught force was 3.5:1 which indicates a major contribution (78%) due to leg to the total draught.

The angle of inclination of the resultant soil force was found to be 4.1°, leg resultant acted at 9° and foot resultant at 41.5° to the horizontal for the treatment used as control. The leg experienced upward soil force.


## Introduction

Poor drainage is one of the biggest obstacles to the successful farming of heavy lands. Except in the top few inches of soil, such land is practically impervious to water, with the result that surface waterlogging is one of its natural features, with well known adverse effects on crop growth.

In irrigated soils, good drainage is not only needed to remove excess water but equally important is the removal and prevention of excess salt accumulation which is toxic to plant growth. Pearson et al (1957) found that salinity factor accounted for about 90% of the variance in the growth of grapefruit trees, while the position of water table accounted for only 4%.

Mole drainage is one of the drainage operations to prevent water from accumulating on the surface soil, particularly the root zone area. For mole draining a smooth, permanent channel of constant grade is formed in the soil. This is achieved by squeezing and compacting the soil at required depth by running an expander of required diameter behind the mole plough.

For a successful moling operation, the soil at moling depth should be fairly moist, under plastic limit and the soil above the mole channel should be shattered during moling operation to increase the hydraulic conductivity of soil. For this purpose brittle soil failure is required.

Farmers in underdeveloped or developing countries cannot justify on economic terms laying a permanent tile drainage system. Mole drainage is only an alternate method to drain heavy soils having natural slopes and uniform clay layer at mole channel depth. Nicholson (1946) reported that due to many variable factors in mole drainage operation, it is difficult to estimate cost, but certainly it is only a fraction of the total cost of tile draining. Such system is capable of being reconditioned simply by drawing moles afresh. Redrawing moles costs very little and may be repeated every five years or so.

A basic understanding of the soil force components acting on mole plough is important as they form major criteria for the economical and suitable design of the mole plough, as well as a good determi-

nant for matching power units to be used in the moling operation.

Ede (1958) conceived that the soil forces on the mole plough are the functions of soil internal friction, soil metal interface friction, soil density and moisture content. Similar observation was experienced by Wells (1951) who found that the major component of draught force was due to side friction.

No attempt has been made in the past to measure soil component forces acting on different organs of the mole plough except total draught force using a dynamometer. This study was carried out to measure and separate the force components acting on different elements of the mole plough, so that tangible suggestions and potential modifications could be made for the existing mole plough.

## The Study

Bearing in mind the handicaps of the past studies, this investigation was proposed to achieve the following objectives:

1. To determine total horizontal ($T_H$), vertical ($T_V$) forces and total moment ($T_M$) acting on the mole plough.
2. To determine the horizontal ($F_H$), vertical ($F_V$) forces and moment ($F_M$) acting on the cartridge.
3. To understand the effect of using different size and shape expanders on the mole drain consistency, make up and force system of the mole plough.
4. To assess the soil shear strength effect on the force system of mole plough.
5. To compare the results with those of earlier research workers using full scale mole plough with expanders of different diameters.

### Notations

$T_H$ = Total horizontal force.
$T_V$ = Total vertical force.
$T_M$ = Total moment.
$F_H$ = Horizontal force on foot.
$F_V$ = Vertical force on foot.
$F_M$ = Moment on foot.
$L_H$ = Horizontal force on leg.
$L_V$ = Vertical force on leg.
$L_M$ = Moment on leg.
$\vartheta$ = Angle of inclination of resultant soil force to the horizontal.

## Methodology

Expanders 4" (100 mm) diameter, 3.5" (89 mm) diameter, and 4" (100 mm) diameter with tapering end were used to determine their effect on the coherence and makeup of the channel. All expanders were used at the same depth.

To measure total force system on plough and cartridge, two extended octagonal ring transducers (designed by Godwin 1975) were used, one transducer to sense total horizontal, vertical force and moment on the mole plough and the other to measure these force and moments acting only on the cartridge.

To avoid any experimental bias, each treatment was subjected equally to different soil variations, for which a randomized block design was chosen.

### Experimental Equipment and Test Procedure

In tillage, the soil failure is symmetrical and there is no net effect of side forces. Such symmetrical soil failure consists of two orthogonal force components, a horizontal force ($F_x$) and vertical force ($F_z$) and couple of the resultant soil reaction ($M_y$) in the plane of the forces. The lateral force $F_y$ and moments $M_x$ and $M_z$ are considered as zero due to symmetrical soil failure. Prior to the tests, both transducers, one to be placed in between the plough and tractor and the other to be fitted in the cartridge were carefully calibrated using static loads equivalent to the expected soil forces in the field. The transducers were loaded by equal load increments and then unloaded, the hysteresis was zero or negligible and very minute cross sensivity was recorded.

Signal conditioning and recording equipment included i) amplifier; ii) data analyzer; iii) printer; iv) inverter and v) power source AC/DC.

Of the seven channels of the amplifier, first three channels measured total horizontal force, total vertical force and total moment whereas the other three channels sensed these forces and moments only for the cartridge. The calibration constants of each channel of amplifire was as follows: No. 1 9.9 kilo Newtons (kN), No. 2 10.4 kN, No. 3 2.94 kNm, No. 4 5.24 kN, No. 5 6.675 kN, and No. 6 0.76 kNm.

Leg measuring 25 x 220 x 1500 mm was used for the experiment. These leg dimensions were commonly used by mole plough manufacturers. The cartridge (85 mm diameter and 650 mm long) was used. The front end of the cartridge was chamfered making an angle of 30°. The cartridge was attached to leg by strong shear pins.

A 56-kW tractor was used to operate the mole plow in the field. To eliminate the effect of speed and inertia forces on draught, a speed of 1 mile/h was used throughout the study. Cushions were used in between the foundations and the instruments installed in the van to nullify the effect of vibrations on the instruments. Moreover, every attempt was made to protect the cables and transducers from the damage using suitable cover guards, etc.

### Experimental Treatments

The following treatments were considered in examining the effect of using different types of expanders on the force system of mole plough and the makeup of the mole channel. Soil shear strength was deter-

mined to evaluate its effect on the force system.

$T_1$ Mole plough with no expander.

$T_2$ Mole plough with expander of 100 mm diameter.

$T_3$ Mole plough with expander of 89 mm diameter.

$T_4$ Mole plough with expander of 100 mm diameter tapered end.

## Experimental Results and Discussions

### Summary of Results

The analysis of variance shows that there was no significant difference amongst all treatments for total horizontal, vertical, force components and moments acting on the whole plough as well as the forces and moments acting on the cartridge **(Table 1 a-f)**.

The slightest difference (although not significant) observed amongst treatments for horizontal force components, was due to variation in soil shear strength **(Table 2)**.

The ratio of mean leg horizontal force/mean cartridge horizontal force ($L_H/F_H$) was obtained as 3.53 for $T_1$ treatment incorporated as control. And the leg took 78% of the total horizontal force for $T_1$ treatment used as control **(Table 3)**.

The angle of inclination of the total resultant force, leg resultant force, and cartridge resultant force was 4.1°, 9° and 35°, respectively **(Table 4)**.

The leg experienced an upward negative force in all cases.

The variation in treatments (although not significant) for vertical force component was observed due to variation in soil bulk density and nature of soil **(Table 5)**.

The ratio of the total draught force, the draught on the leg and the draught on the foot was 4:3:1 **(Table 6 and Fig. 1)**.

Table 1 Analysis of Variance of Forces and Moments

| Source of Variance | D.F | SS | MS | F | F@5% | Remark | LSD.05 |
|---|---|---|---|---|---|---|---|
| (a) Total horizontal force, $T_H$ | | | | | | | |
| Total | 15 | 60.488 | | | | | |
| Blocks | 3 | 10.015 | 3.338 | 0.745 | 3.86 | NS | 3.38 |
| Treatments | 3 | 10.141 | 3.380 | 0.754 | 3.86 | NS | |
| Error | 9 | 40.331 | 4.481 | | | | |
| (b) Total vertical force, $T_V$ | | | | | | | |
| Total | 15 | 2.730 | | | | | |
| Blocks | 3 | 0.492 | 0.164 | 0.685 | 3.86 | NS | 0.7819 |
| Treatments | 3 | 0.085 | 0.028 | 0.119 | 3.86 | NS | |
| Error | 9 | 2.152 | 0.239 | | | | |
| (c) Total moment, $T_M$ | | | | | | | |
| Total | 15 | 11.568 | | | | | |
| Blocks | 3 | 0.650 | 0.216 | 0.189 | 3.86 | NS | 1.710 |
| Treatments | 3 | 0.626 | 0.208 | 0.182 | 3.86 | NS | |
| Error | 9 | 10.291 | 1.143 | | | | |
| (d) Horizontal force on foot, $F_H$ | | | | | | | |
| Total | 15 | 19.48 | | | | | |
| Blocks | 3 | 2.48 | 0.829 | 0.539 | 3.86 | NS | 1.982 |
| Treatment | 3 | 3.17 | 1.057 | 0.668 | 3.86 | NS | |
| Error | 9 | 13.82 | 1.530 | | | | |
| (e) Vertical force on foot, $F_V$ | | | | | | | |
| Total | 15 | 6.128 | | | | | |
| Blocks | 3 | 1.340 | 0.446 | 1.291 | 3.86 | NS | 0.941 |
| Treatments | 3 | 1.674 | 0.558 | 1.612 | 3.86 | NS | |
| Error. | 9 | 3.114 | 0.346 | | | | |
| (f) Moment on foot, $F_M$ | | | | | | | |
| Total | 15 | 0.342 | | | | | |
| Blocks | 3 | 0.0027 | 0.0009 | 0.029 | 3.86 | NS | 0.2825 |
| Treatment | 3 | 0.059 | 0.019 | 0.633 | 3.86 | NS | |
| Error | 9 | 0.280 | 0.031 | | | | |

Table 2 Horizontal, Vertical Force Components and Moments Acting on Various Components of Mole Plough.

| Treatment | $T_H$ | $F_H$ | $L_H$ | $T_V$ | $F_V$ | $L_V$ | $T_M$ | $F_M$ | $L_M$ |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 16.46 | 3.63 | 12.83 | 1.18 | 3.22 | −2.04 | 9.77 | 1.09 | 8.68 |
| $T_2$ | 16.48 | 4.14 | 12.34 | 0.99 | 2.46 | −1.47 | 9.40 | 1.00 | 8.40 |
| $T_3$ | 15.86 | 3.74 | 12.12 | 1.10 | 2.51 | −1.41 | 9.55 | 1.12 | 8.43 |
| $T_4$ | 18.01 | 4.77 | 13.24 | 1.02 | 3.01 | −1.99 | 9.91 | 1.17 | 8.74 |

Remark: All forces are in kilo Newtons (kN) and moments (kNm). Treatment mean force values are used.

Table 3 Ratio of the Draught Forces Acting on Various Members of the Mole Plough

| Treatment | $\frac{T_H}{L_H}$ | $\frac{T_H}{F_H}$ | $\frac{L_H}{F_H}$ | $\frac{L_H}{T_H}$ |
|---|---|---|---|---|
| $T_1$ | 1.28 | 4.53 | 3.53 | 0.78 |
| $T_2$ | 1.33 | 3.98 | 2.98 | 0.75 |
| $T_3$ | 1.30 | 4.24 | 3.24 | 0.76 |
| $T_4$ | 1.36 | 3.77 | 2.77 | 0.74 |

Table 4 Total Resultant Force Acting on Mole Plough and the Resultant Forces Acting on the Leg and Cartridge

| Treatment | Total resultant | | Leg resultant | | Foot resultant | |
|---|---|---|---|---|---|---|
| | Magnitude kN | $\theta$ | Magnitude kN | $\theta$ | Magnitude kN | $\theta$ |
| $T_1$ | 16.50 | 4.1° | 12.99 | 9.0° | 4.85 | 41.5° |
| $T_2$ | 16.50 | 3.43° | 12.42 | 6.8° | 4.81 | 30.71° |
| $T_3$ | 15.89 | 3.96° | 12.20 | 6.6° | 4.50 | 33.8° |
| $T_4$ | 18.03 | 3.24° | 13.38 | 8.54° | 5.64 | 32.25° |

$R = \sqrt{H^2 + V^2}$ , $\theta = \text{Tan}^{-1}(V/H)$

## Discussions

The expected force on the expander is wholly horizontal due to the symmetry and because of its freely trailing nature, it will be regarded as a contribution to the horizontal force only. This fact is in agreement with Childs (1943) who expounded that the forces on the bob are only horizontal. This could be the main reason why all treatments on the vertical force com-

Table 5 Soil Moisture Content, Bulk Density (Dry basis) and Shear Strength at Different Depths of Profile.

| Depth (mm) | Bulk Density ($g/cm^3$) | Moisture content (%) | Shear strength $kN/m^2$ |
|---|---|---|---|
| 150 | 0.968 | 61.8 | 51.3 |
| 500 | 0.828 | 102.0 | 22.8 |

Table 6 Mean Draught Forces on the Mole Plow as a Whole on the Leg of the Plough and on the Cartridge

| Treat-ment | Total | Leg | Mean draft on cartridge |
|---|---|---|---|
| $T_1$ | 16.46kN | 12.83kN | 3.63kN |
| $T_2$ | 16.48 | 12.34 | 4.14 |
| $T_3$ | 15.86 | 12.12 | 3.74 |
| $T_4$ | 18.01 | 13.24 | 4.77 |

ponents and moments was not significant.

The analysis of variance shows that there was no significant difference between treatments for total horizontal force and horizontal force acting on the cartridge. The obvious reason for this is that the soil is already sheared off by the cartridge and the expander only performs the ramming function to press the already loosened soil back to the walls of the channel. The slightest variation found between treatments might have been due to soil difference and the amount of soil flowing back into the channel.

The ratio of mean leg horizontal force to mean cartridge horizontal force obtained in this test study was 3.53. This result is coincident with the result obtained by Childs (1943), who obtained this ratio as 3.77 (approximately quoted as 4) for his 1/24 of full size model study. The small difference in the result may be due to soil variation in the field. The ratio of 2.0 obtained by Oehler (1933) could not be accepted as he carried out his full sized experiment on the soil which was not very suitable.

The leg took 78% of the total horizontal force for $T_1$ treatment. This supports the work of Oehler (1933), Childs (1943), and Wells (1951), who discovered that leg force was a major component

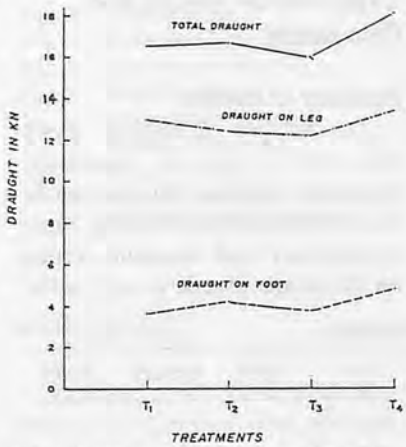


Fig. 1 Mean draught forces on the mole plough as a whole, on the leg and cartridge (foot).

contributing towards the total draught force.

The leg experienced an upward negative force in all cases. The reason for this upward force was that, at the instance soil was sliding over the leg, it was imposing frictional force on the leg. Comparing the results of the angle of inclination of the resultant force, with those obtained from the results of earlier field work done by Harrison there is considerable variation of about 4°. In Harrison's work $T_V/T_H = 1/6$, whereas in this study $T_V/T_H = 1/13$ for treatment used as control. This variation could be due to tilting of the cartridge as the tractor traversed over the undulation and irregularities present in the contour of the field.

## Conclusions

The expanders with different shape and size did not significantly affect the force system of the plough. The channels drawn with expander trailing behind the cartridge were smooth, free from sludge, and the walls of channel were more coherent and stable than those drawn without expanders.

The ratio of mean leg horizontal force/mean cartridge horizontal force ($L_H/F_H$) was 3.53 for treatment incorporated as control.

The leg took 78% of the total horizontal force, for treatment used as control.

The vertical force on leg acted upwards.

## Recommendations for Future Work

1. The skin friction of mole and blade, which accounts for high proportion of the total draught, could be reduced by using leg and mole material which will offer less sliding friction. Investigation to use such materials should be useful.
2. Soil sliding over the frontal areas of the blade and cartridge contribute about 9-10% of the total draught. This draught force can be reduced by substituting the mechanisms which could offer the reverse friction action. Such mechanisms can be rotating chains, belts, and rollers. Research on the use of such mechanisms will be useful in reducing draught.
3. To investigate the rake angle less and greater than 90°.
4. To try leg widths less than one commonly used.

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# Hill Land Mechanization in Puerto Rico

by
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## Abstract

Problems associated with hill land farming along with alternate solutions are discussed. Results of hill land mechanization research (1979 – 84) in Puerto Rico are presented.

## Introduction

Putting more land into food production while maintaining and increasing yield is the most promising approach for meeting the present and future food requirements of the world. While hill lands are considered marginal, they are practically unlimited in extent and generally available for development. Under good management it is expected that hill lands can produce the much needed food and can provide rural income. Puerto Rico has no alternative but to develop hill lands in addition to coastal areas for agricultural production.

Land use is strongly affected by factors such as population pressure, availability of capital and labor, health factors, world markets for export crops, land tenure patterns, and government incentives and support.

Hill land use possibilities vary widely, including:

1. Urban development – a) Residential use; b) Industrial use.
2. Recreation areas – a) Wildlife; b) Sports; c) Landscape scenery.
3. Mining
4. Forestry
5. Agricultural use – a) Animal production; b) Crop production; c) Combined animal and crop production.

It is important to properly identify the most effective use capability for each hill land situation in order to use this natural resource profitably for the benefit of mankind while insuring continuing productivity, thereby realizing fullest potential.

## Problems of Hill Land Farming

Using hill land for agriculture poses many problems not generally common in plain land farming. These problems can be broadly classified as physical, social, and economic.

*A. Physical problems* are those generally associated with farming steep slopes:

1. Soil erosion, sedimentation, and flooding;
2. Difficult to operate; mechanized farming operations are restricted;
3. Movement of supplies and farm products;
4. Low soil fertility; and
5. Low productivity.

*B. Social problems* are those related to the people living in the hill lands:

1. Low literacy and generally inadequate contact with other communities to see what is going on outside their immediate premises.
2. Resistance to adopting new technology which has been developed beyond their resources;
3. Inherent distrust of outsiders;
4. Few qualified researchers willing to study and find solutions to their problems;
5. Very little extension help in remote areas; and
6. Lack of an integrated government program for the effective use of hill lands.

*C. Economic problems:*

1. Improved hill land farming requires enormous capital investment;
2. Hill land farmers are barely subsistent and do not have enough capital for improving and expanding production to improve their quality of life;
3. Rich land owners are reluctant to invest in improving hill land farming because of its low inherent productivity and marginal profitability; and
4. Allocation of government funds is biased toward sectors which at present have significant contributions to national products; thus there is a lack of current programs for the effective utilization of the hill lands.

## Hill Land Improvement Techniques

With the best lands, mostly plain areas already under production, the general focus of interest is now directed to the potential use of hill land for agricultural production. This important and practically untapped resource has not received much attention until recent decades when world population has greatly expanded. However, indiscriminate use of hill lands for agricultural production will result in many serious problems, such as flooding and sedimentation, which will greatly reduce the effective capacity of storage reservoirs; and soil erosion, which will result in a permanent loss of fertility, the restoration of which is very expensive and practically impossible. Therefore, in the use of hill lands for agricultural production, great care should be taken to avoid these inherent problems. Established conservation practices and hill land improvement techniques must be implemented for long-term productivity.

The fundamental basis of hill land improvement and conservation techniques can be reduced into two main divisions:

1. Decreasing erosion – a) Mulching, cover cropping, strip cropping, multiple cropping; and b) Minimum tilling.
2. Reducing eroding forces – a) Constructing farm ponds; b) Reducing surface runoff; c) Improving watershed protection and management; and d) Reducing land slopes.

Some of the common hill land improvement and conservation techniques are for the following:

1. Hill land development and stabilization of land areas – a) Contour farming; b) Contouring of hill lands into linked narrow terraces; c) Reducing non-parallel areas to a minimum for efficient farm operation; d) Mulching, cover cropping, multiple cropping; e) Terracing, bench terracing, improving hill side ditching broadbase terracing, inverted slope terracing, grassing waterways.
2. Improving pasture management – a) Fencing; b) Controlling grazing, c) Fertilizing and liming; d) Breeding grasses and legumes for hill lands; and e) Using herbicides to control invading grass species.

## Program for Effective Utilization of Hill Lands

Hill lands constitute a great portion of the earth's surface available for development. They may become a very valuable basic resource for many countries if properly developed. Integrated and comprehensive programs for developing and utilizating hill lands require efforts directed toward solving problems common in using hill lands for agricultural production. Developing a workable program is a formidable task requiring the participation of all parties concerned. Legislation and strong financial support would greatly enhance the adoption of a socially optimum alternative for using hill lands.

Some of the most important successful programs can be:

1. Legislation for guiding the best use of hill land as demonstrated by land reform legislation of 1972 and 1976 in Sri Lanka, which has provided a unique opportunity to transform hill lands to the best economic and social advantage of the country.
2. Strong government support policy for using hill land effectively through taxation, credit, and other direct support.
3. Creation of a research agency with adequate financial support responsible for planning, supervising, and implementing the effective use of hill lands.
4. A more aggressive extension program as shown by:
   a) Rapid adjustment program in Ohio on farm demonstration showing that superior farm production and management techniques will rapidly increase farm income. Cooperators are properly screened on the basis of established guidelines. Farmers are given an incentive of $1000/farm/year which is supported by the government and industry.
   b) The Allegheny Highland Project – an experiment in package team approach technology for hill land livestock production designed to provide producers with a full complement of technical services to demonstrate and more fully utilize the area's vast potential for grassland agriculture.
5. Reorientation of the research approach that will be responsible to the needs and resource capability of hill land farmers. This is demonstrated by the interdisciplinary research in Uttar Pradesh (India), where a group of scientists researched and worked with the government on the special problems facing rural

development in Uttar Pradesh hill for the identification of priority areas requiring further research and action based on the farmer's actual need and capability.

## Materials and Methods

Promising machinery suitable for hill land agriculture was tested and evaluated in typical hilly areas of Puerto Rico for further development and operation. Emphasis was directed toward reducing farm drudgery and increasing labor productivity by mechanizing possible production operations. Where machinery was available, labor saving techniques were evaluated. Sound conservation practices such as contour farming, terracing, constructing waterways, and other con-

## Results and Discussion

### Harvesting of Cocoyams (*Xanthosoma* spp.)

Several mechanical diggers for facilitating the harvesting of cocoyams were successfully tested. The most effective unit for digging and loosening the soil is the cotton root cutter, which consists of left and right triangular flat shank cutters mounted on a tool bar. The unit is passed beneath the cocoyam cormel, leaving it loose and undamaged for picking and sorting by hand. The spacing between the 2 triangular-shaped root cutter gangs is adjustable, making this unit suitable and flexible for harvesting various root crops. The mechanical digger eliminates the drudgery of digging the tubers from the ground and makes possible the harvesting at a faster rate and at a much lower cost. It is capable of harvesting 1 ha in about 2 – 3 h, depending on field layout, with a saving of as much as 60% of the harvesting costs.

### Coffee Harvesting

Several promising methods for reducing costs of coffee harvesting were field tested: a) Collecting nets on the ground for falling berries; b) Mechanical shakers; and c) Chemical ripener.

Efforts were directed at developing an integrated system with the above three methods. On the basis of field tests, the most promising system for reducing costs and man hours for coffee harvesting was as follows: a) Harvest early maturing coffee by hand picking or by letting berries to fall onto the collecting nets provided, the field exposure time is not long enough to allow them to germinate in the field. b) Spray chemical ripener when about 95% of the remaining berries on the trees are physiologically mature; and c) Harvest all the remaining by mechanical shaking, and leave as much extraneous material as possible in the field before transporting the harvest to the processing plant.

This method is very effective and applicable for coffee plantations with flowering concentrated at 1 or 2 periods at the most. For plantations where flowerings occur at 3 or more periods, the system is not suitable because of the wide variation on the maturity of the berries. Another point that should be considered is that the use of chemical ripener and mechanical shaker induces significant defoliation which may affect the yield of succeeding crops.

Hill land farm machinery requirements vary greatly from farm to farm, depending on the size, and primarily on the type of operation. From the results of field tests and evaluation studies, minimal machinery systems were developed for reducing drudgery of hill land farming for farms with less than 1 ha; for farms over 1 ha but less than 5 ha; and over 5 ha. Machinery investment ranges from $1 000 to over $10 000. It is expected that this investment in machinery could be readily recovered in a few years through reduction of production costs and increased productivity.

### Tilting Transport

A tilting transport cart was developed capable of operating in wet conditions for moving farm products and supplies such as fertilizer and equipment, including farm workers. The use of the tilting cart as farm transport vehicle produces significant savings in operation costs and facilitates the transport of materials with less farm drudgery and at much faster rate. For perishable products, faster movement of farm products to the market is of critical importance to minimize damage and spoilage.

### Cocoyam Cultural Methods

Field experiments were conducted at the Isabela Research and Development Center for determining appropriate plant density and seed placement of cocoyam for efficient mechanization. A clonal variety, "Alela", with desirable properties for mechanization was developed. Pertinent field production data of "Alela" were submitted to the appropriate committee of the Agricultural Experiment Station for consideration as one of the cocoyam recommended varieties. Basic work on the cytokinin activity of cocoyam was also conducted. This work on hormone activity of cocoyam may lead to the development of a more suitable variety for hill land farming. Field tests showed the developed clonal variety with small and shallow tubers to be suitable for harvesting with a mechanical digger.

### Walking-type Tractor

Walking tillers of varying horsepower (5-hp, 8-hp, and 13-hp) were evaluated for hill land operation. Results of field tests showed that walking tillers have some applications for hill land operation. The tillers are relatively easy to operate

on a narrow bench terrace of about 12-foot width. In unterraced field operations, the up-down slope minimizes the stability problem. In particular, the 13-hp Yanmar TC 11 diesel walking-type tractor equipped with a 75-cm rotary tiller, front mounted mower and furrowing attachments, showed great promise for the small hill-land farmer.

### Gripping Device for Trees

The gripping device is the mechanism of the mechanical shaker that holds the coffee branch and transmits the shaking action of the machine to the tree. Such a device should minimize the bark damage imparted on the trees during the shaking operation. It is also very important that the gripping device be engaged and disengaged in the coffee branch as quickly as possible. A gripping device was developed which basically meets the above requirements. This was accomplished with the cooperation of a mechanical shaker manufacturer. Field tests on the use of the gripping device showed that minimal bark damage was imparted to the coffee trees.

### New Planting Methods

Fruit trees, bananas, plantains, and the like are typical crops found very suitable for the hill lands in Puerto Rico. The traditional method for planting these crops is manual with spade, shovel and crowbars and other similar tools. This operation is slow and expensive. Because of the difficult and the enormous manual labor required for digging, the prepared hole is relatively very small to accommodate a vigorous root development of the plants. Two types of hole diggers were introduced and tested to circumvent the above difficulties. A portable 2-hp post hole digger was found suitable for digging bigger holes for steep hill land where a tractor could not operate readily. The other type is the 18-inch post hole digger operated from the PTO of a tractor. This unit is convenient for moderate slope hill land where a tractor could operate. Results of field tests showed that the mechanical digger out-performed the traditional method for preparing holes at a ratio of 4 to 1 for an unplowed field. In addition to the faster rate, the hole prepared using the mechanical post hole digger is much bigger. This difference will result in the production of more vigorous and more productive plants.

### Miscellaneous

Slippage is a limiting factor in the pulling performance of tractors, particularly small tractors. Results of field tests on a 24-hp Yanmar 4-wheel tractor showed over 30% slippage, greatly limiting its pulling performance. A concrete wheel weight was developed, improving the pulling performance of the Yanmar 4-wheel tractor.

Limited tests of a lightweight wheel-less mower showed promise for cutting grass in the hill land and around the trees where a large heavy mower cannot satisfactorily perform the job. The mower is light and without wheels. It actually floats on a cushion of air, about 1/4 inch off the ground surface; thus it is very easy to handle in any direction. The impeller fan draws in air and pushes it to the edge of the head forming an air cushion which lifts the machine and floats the unit. Because of this floating action, the unit is easy to handle and moves in all directions, sideways, forward or backward with minimum of efforts.

A hand-operated coffee harvester implement, patented by V.M. Alexandrino (2); was tested and evaluated for capacity and efficiency and was compared to manual picking. A complete report of the study is available.

Three prototypes of coffee-separating machines (Atienza I and II and Mattei) were evaluated for overall capacity and efficiency. A complete report is available from Agricultural Experiment Station, U.P.R.

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# Graphical Determination of Cost of Operation on Agricultural Machines

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## Abstract

A set of nomographs has been designed and presented for determination of hourly cost of operation of agricultural machines. The annual use and total life of machines, interest rates, maintenance as a function of life of machine, fuel consumption, labour/operator requirements and rates of fuel and labour have been taken as variables to cover a wide range of agricultural machines and situations under which these are operated.

## Introduction

One of the important costs influencing profit in farming business is the cost of owning and operating farm machines. Machinery cost estimates play an important role in every machinery management decision and is required to be made at the research and development stage in order to guide the designer. It is made for commercial units to establish the hiring rates and to determine the cost of machinery inputs for effective crop production management. The cost of operation of a farm machine as influenced by the size, quality and physical condition of the machine needs to be estimated at the time of its selection.

The analytical method of estimation of cost of operation of farm machines involves the use of a number of formulae and a set of assumptions. A set of nomographs has been designed and presented to serve as a handy tool for quick determination of hourly cost of operation for a wide range of agricultural machines. The nomographs have been designed keeping in view the standard guidelines recommended for estimating the cost of operation of farm machinery. The nomographs will be of still greater value for those who wish to own farm machines and in making a selection of a farm machine. They can be used also for comparing different cost components.

**Acknowledgement:** The authors are thankful to Mr. V.G. Bonde, Draftsman for his painstaking efforts in making the tracings of the nomographs.

## Cost of Operation

There are two main components of cost of operation of machines – fixed costs and variable costs:

*Fixed Costs* – Fixed costs include those for depreciation, interest, taxes, shelter and insurance.

*Depreciation cost* – This cost reflects the reduction in value of the machine with use (wear) and time (obsolescence). There are three methods by which the depreciation cost of machines are calculated.

i) Straight-line depreciation;
ii) Sum-of-the-digits depreciation; and
iii) Declining-balance depreciation

For the purpose of estimating cost of operation of agricultural machines, the straight-line depreciation method is widely followed wherein an equal reduction of value is used for each year the machine is owned. The average annual depreciation (AAD), following this method, can be determined by the following formula:

$$AAD = \frac{\text{Purchase price(P)} - \text{Salvage value(S)}}{\text{Life in year(Y)}}$$

The hourly depreciation cost is

$$Cd = \frac{AAD}{H}$$

where, H is annual use of the machine in hours.

The useful life of some of the commonly used machines under general conditions of usage is given in **Table 1**.

*Interest* – This is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, the money is tied up that might be otherwise available for use elsewhere in the business.

Table 1 Useful Life of Some Commonly-Used Machinery

| Machine | Total useful life | |
|---|---|---|
| | hours | years |
| Stationary engine | 10 000 | 10 |
| Electric motor | 15 000 | 15 |
| Power tiller | 8 000 | 10 |
| Tractor (wheeled & crawler) | 10 000 | 10 |
| Combine (self-propelled) | 3 000 | 6 |
| Combine (mounted and drawn) | 2 000 | 7 |
| Seed drill | 2 500 | 10 |
| Seed-cum-fertilizer drill | 2 000 | 8 |
| Planter | 2 000 | 10 |
| Plough | 3 000 | 10 |
| Disc harrow | 3 000 | 10 |
| Cultivator | 4 000 | 10 |
| Front-mounted dozer attachment for wheeled tractor | 3 000 | 10 |
| Towed scraper for wheeled tractor | 2 000 | 10 |
| Power sprayer (knapsack and tractor mounted) | 2 000 | 8 |
| Seed cleaner | 2 500 | 5 |
| Agricultural trailer | 3 600 | 12 |
| Power thresher | 2 500 | 8 |
| Centrifugal pump | 10 000 | 10 |
| Power chaff cutter | 5 000 | 8 |
| Rotary cultivator | 2 400 | 8 |
| Ridger | 1 500 | 12 |
| Blade terracer | 2 000 | 10 |
| Puddler | 2 500 | 10 |
| Cane crusher | 10 000 | 10 |

This component of the fixed cost is proportional to the average investment and is determined by using the following formula:

Hourly interest cost $C_i$ =

$I\,(P+S)/200H$,

where I is interest rate, %.

*Insurance, Taxes and Shelter* – Insurance policies are usually carried on expensive machines while the risk is usually assumed on the simpler, less expensive machines. Taxes are paid on some machinery in the same manner as for other property. However, in India, farmers are reluctant to insure their farm machines. Providing shelter and storage helps in checking the deterioration of machine parts due to weathering. But it is debatable whether to keep all types of machines under covered sheds. The total of the above three components of the fixed cost may be taken as 3.5% of the average investment annually.

*Variable Costs* – The costs of repairs and maintenance, fuel and lubricants and labour/operator come under variable costs.

*Repair and Maintenance* – Repair and maintenance expenditures are unavoidable in keeping a machine in running condition against wear, part failure and accidents. In general, the farmers are not very conscious of the advantages of the proper maintenance schedules and replacement of worn out parts. This cost component is low when the machine is new and continue to increase as the machine gets older. This cost component varies from machine to machine. The recommended variations in maintenance cost component with age of the machine and from machine to machine have been taken into consideration in designing the nomographs. The component of the cost dictates when the machine should be replaced to avoid excessive operating expenses.

*Fuel and Lubricants* – Fuel consumption depends on the size of the power unit, load factor and operating conditions. The actual consumption can be observed while the machine is working or may be taken from the results obtained at official testing stations.

The average fuel consumption can also be estimated by the following formula:

$$f.c. = k \times P$$

where,

f.c. = fuel consumption, *l*/h

P = rated power of prime mover, kW

k = constant, 0.15 for diesel and 0.25 for petrol

A wide variety of lubricants – engine oil, grease, transmission oil and hydraulic fluid – are used in agricultural machines. However, based on a survey of the wide range of agricultural machines the cost of lubricants is recommended to be 15% of the cost of fuel (3). This value may not be so accurate for certain countries but it will be a representative figure for many situations.

*Operator/Labour Cost* – In performing field operations with a machine at least one operator is required. Sometimes the operation of a machine may involve engagement of more than one operator. The charges for unskilled labour required to assist in the operation of the machine are also included in the cost of operation.

*Overhead Charges* – This includes charges for supervision and establishment and interest on working capital.

## Nomographs – How to Use Them

A set of nomagraphs is presented in **Figs. 1-3** for estimation of cost of operation of agricultural machines of fixed and variable costs discussed above.

The following assumptions have been made in developing the nomographs:

i) Straight-line depreciation
ii) Salvage value – 10% of purchase price
iii) Insurances, taxes and shelter costs total 3.5% annually of the average investment.
iv) Lubricant costs are 15% of the fuel costs.

*Design of Nomographs* – On the basis of the above assumptions and by taking all components of fixed

and variable costs as discussed above, the hourly cost of operation of a machine can be expressed as follows:

$$H.C.O. = [(0.9/Y \cdot H + 0.55(I+3.5)/100H + F_m)\ C + 1.15 F_c \times R_f + N_o \times R_l] \cdot F_{oh}$$

where, Y = Life of machine, year

H = Annual use of machine, h

I = Interest rate, %

$F_m$ = Maintenance cost factor, per h per unit purchase price

C = Purchase price of machine, units

$F_c$ = Fuel consumption of machine, $l$/h

Rf = Fuel price, units, $l^{-1}$

$N_o$ = Number of operators required

$R_l$ = Hiring rate of operator, units (Man-h)$^{-1}$

$F_{oh}$ = Overheads factor

The set of nomagraphs (**Figs.1-3**) have been developed on the basis of the above equation. The ranges of various parameters involved have been taken considering a wide range of machines and their operating conditions.

The maintenance cost factor ($F_m$) is a parameter accounting for repair and maintenance cost, which is dependent on the type of machine and its age. The values of $F_c$ incorporated in the nomographs were derived from the accumulated repair and maintenance costs for different machines at any point of machines' life as recommended by Indian Standards Institution. The range of variables covered in the nomographs is as in **Table 2**.

The nomographs are used for determining fixed cost factor, fixed plus maintenance costs and the total cost of operations.

*An Example* – In order to illustrate the use of the nomographs,

Table 2

| | |
|---|---|
| Annual use of machine | 0-1500 h |
| Life of machine | 1-15 yrs. |
| Interest rates | 10-20% (in steps of 2%) |
| Rates of fuel | 0-12 units/1 |
| Rates of operator/ labour | 0-12 units/man-h |
| Overhead charges | 0, 10 and 20% |
| Fuel consumption | 0.25 to 7.0 $l$/h |
| No. of operators | 1 to 5 |

Table 3

| Machine | Combine Harvester (self-propelled) |
|---|---|
| Annual use | 500 h |
| Life of machine | 6 yrs. |
| Interest rate | 14% |
| Age of machine | 5 yrs. |
| Purchase price | 350 000 units* |
| Fuel consumption | 4.5 $l$/h |
| Operators required | Two |
| Rate of fuel | 3.6 units/$l$ |
| Rate of labour | 2.5 units/man-h |
| Overhead charges | 10% on all cost components |

*Units stand for currency, which will be rupees in case of India.

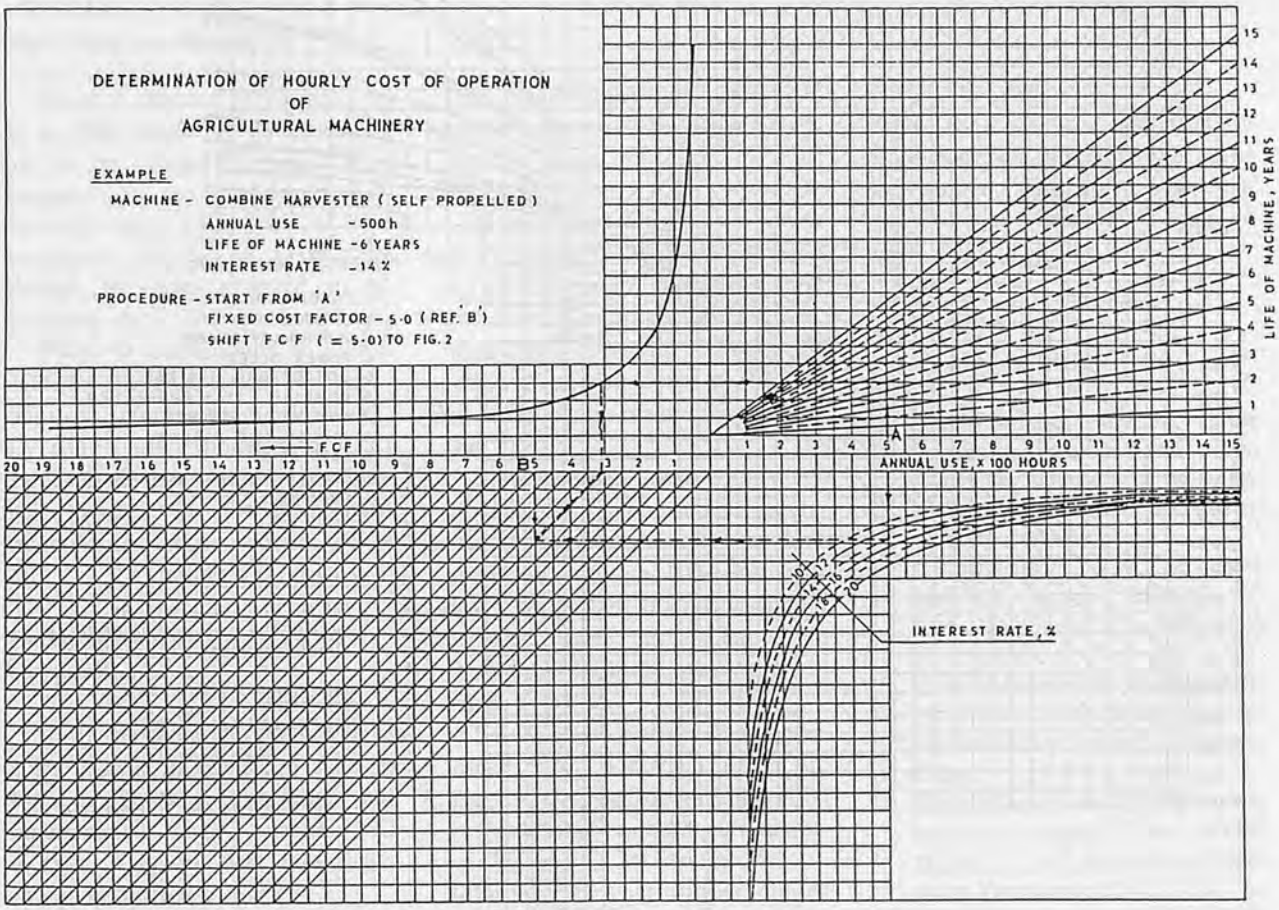


**Fig. 1** Fixed cost factor (FCF).

an example with the following input parameters is shown on the nomographs as well as explained in **Table 3**.

## Determination of Cost of Operation Using Nomographs

### Determination of Fixed Cost Factor (FCF)

The annual use of the machine is 500 h and life is 6 yrs. Determine the intersection point of 500 h annual use and 6 year life line of the machine. Project the point horizontally on to the curve in second quardrant. Project the point vertically down to the 'FCF' scale.

Start downward from 500 h annual use and 14% interest rate the intersection point of 500 h annual use and 14% Interest rate curve. Project the intersection point horizontally to third quardrant and determine the value of FCF as explained in **Fig.1**. The value of FCF comes to 5.0, for the given example.

### Determination of Fixed and Maintenance Cost (FMC)

Shift the value of FCF as determined from **Fig. 1** to FCF scale in **Fig.2**.

The machine is 5 yrs old. Find the point of intersection of '5 year use of machine' and the curve No.6, corresponding to 'combine harvester (self propelled)'. Project the intersection point horizontally to second quandrant to join with the projected point of FCF at P. If the age of the machine is more than the range covered in **Fig.2**, project the extreme point of the concerned curve to second quandrant.

The purchase price of the machine is 350 000 units which can be expressed as $3.50 \times 10^5$ (The purchase price should be expressed in form of $K \times 10^n$, where the value of K is between 1 and 10, both inclusive, and the exponent n is an integer). Project the point B vertically downward to intersect with the line of '3.5 purchase price' at Q.

Project Point Q horizontally to R at 'Zero overheads line'. Since the overheads to be taken are 10 per cent, follow dotted line from Zero to 10% overhead line at S.

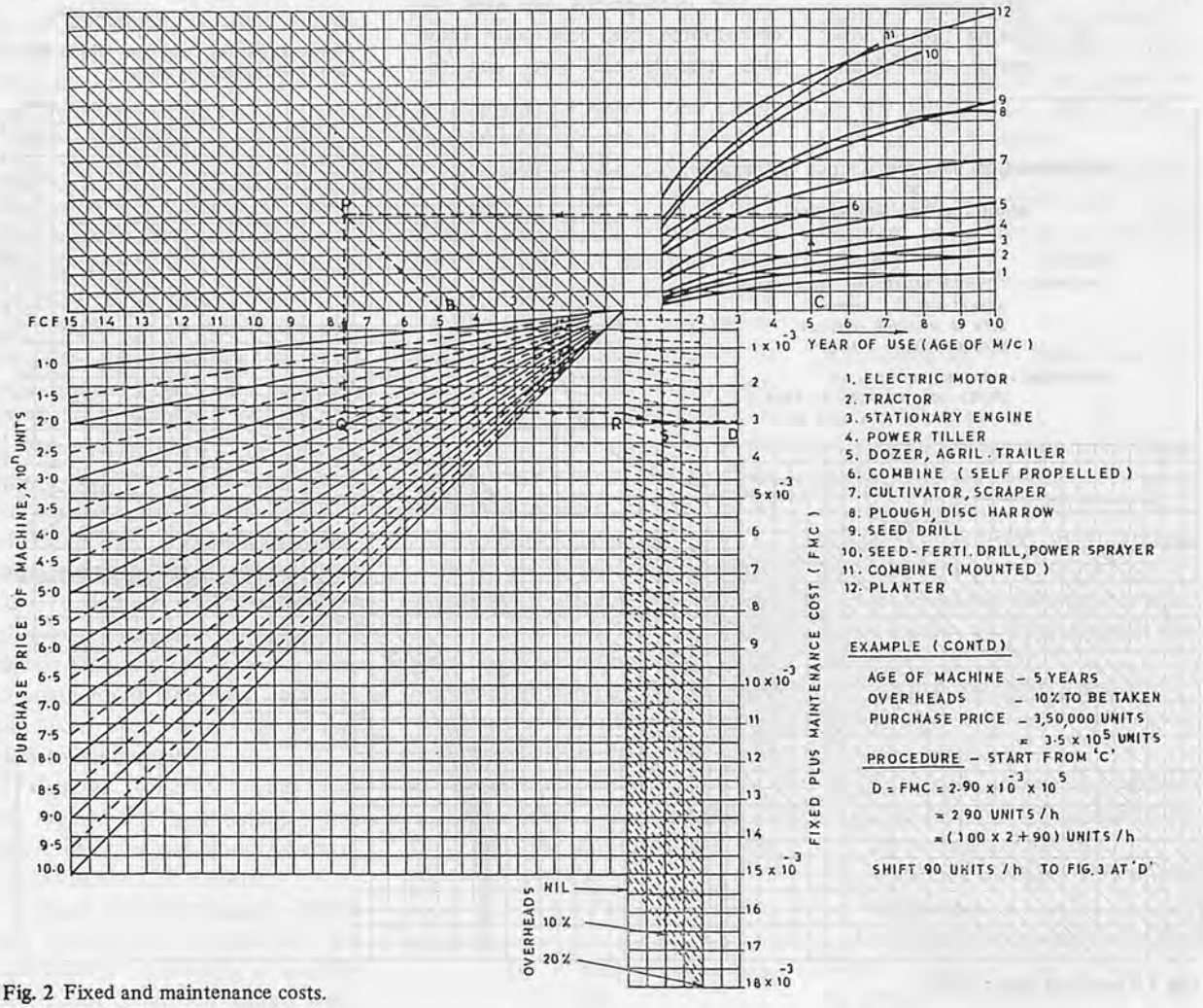


**Fig. 2** Fixed and maintenance costs.

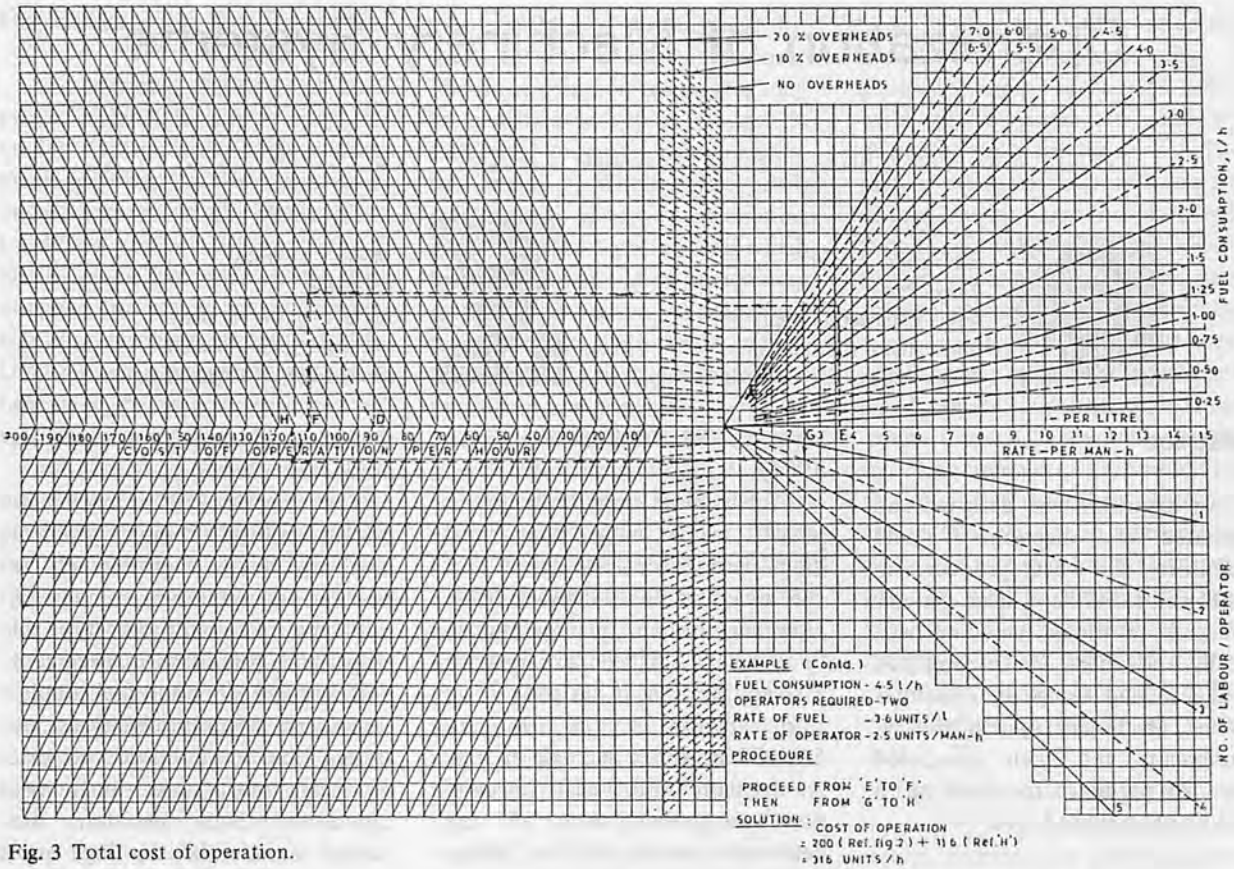


Fig. 3 Total cost of operation.

From S proceed horizontally to D at FMC Scale. If no overheads are to be taken, the point Q is required to be projected horizontally up to FMC Scale. If 20% overheads are to be taken, the dotted lines are required to be followed up to '20% overhead line'.

Point D corresponds to $2.90 \times 10^{-3}$ on the FMC scale. The exponent of 10 on purchase price was 5. By adding the exponents of 10 of value at D and that of purchase price (−3+5 =2), the fixed plus maintenance costs become $2.90 \times 10^{2}$, i.e., 290 units/h.

## Determination of Total Cost of Operation

Shift the fixed and maintenance costs to 'cost of operation' scale in **Fig.3** at D. When the fixed and maintenance costs exceed 100 units/h, only the last two digits should be shifted to **Fig.3**.

In the present case, the fixed and maintenance costs are 290 units/h, i.e., (200+90) units/h. Therefore, out of 290, 90 units should be shifted.

Project the intersection point of 3.6 units/*l* of fuel rate and 4.5 *l*/h fuel consumption to second quardrant. The procedure of including 10% overheads should be followed as was done in the case of fixed and maintenance costs (**Fig.2**).

Similarly, the intersection point of 2.5 units/man-h and 2 operators should be projected to third quardrant through 10% overheads line. The cost of operation should be determined as explained in second and third quardrants in **Fig.3**.

The cost of operation as determined in **Fig.3** reads 116 units/h. The total cost of operation will be 116+200 (the amount carried forward from FMC) = 316 units/h.

Solution: The cost of operation of the combine harvester (self-propelled) is 316 units/h.

If the cost of operation of bullock-drawn implements is to be determined then in the rate of operator, the rate of a pair of bullocks shall also be included.

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# Optimization of Machinery Systems

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## Abstract

An algorithm was designed and validated for selection of field machinery for wheat producers in south central Chile. Tillage systems and crop rotations, including oats, lentils, and wheat, can be compared and evaluated using the computer model. Machinery system size requirements and their associated costs are predicted for farms up to 250 ha of cultivated area.

## Introduction

Chile has 11 million ha of arable land, 19 million ha of grassland and 23 million ha of woodland. There are also 22 million ha with no agricultural or forestal aptitude.

If only the 5 million ha without limitations, Soil Class I, were considered and the coefficients developed by Revelle (1976)* are applied, Chile would be able to feed about 100 million people. Furthermore, if only the 1.3 million irrigated hectares, whose quality is among the best in the world, were considered, Chile could feed about 25 million inhabitants. However, with a population of only 11 million people she has been importing, since 1939, an ever increasing amount of food that in 1980 reached a value close to US$ 1 000 million (FAO, 1981).

Chile's most important crop is wheat, which with other small grain cereals accounts for 80% of the area planted to annual crops. However, the area, planted annually to wheat has been experiencing a steady decline. It has gone down from 780 000 ha in 1966, to 546 000 in 1980, a decrease of 30%. At the same time, wheat consumption has gone up from 155 kg/person per year in 1965 to 205 kg/person per year in 1980, an increase of 32%. Wheat output has fallen to less than 40% of the domestic demand versus 75% a decade ago. This situation has forced Chile to import a large quantity of wheat. In 1980, 955 000 t of wheat were imported and 1.2 million t in 1981 (USDA, 1981; FAO, 1981).

A few recognizable reasons why farmers are not seeding as much wheat as during the 1960's are: changing economy, the relatively low price of wheat in the international market, and a steady rise in production costs.

Wheat production costs in Chile are heavily influenced by the cost of owning and operating agricultural machinery. It has been estimated that the agricultural machinery cost component can vary between 30 and 36% of the total wheat production cost, depending upon the cultural practices and machinery field efficiency. Crop rotations and tillage intensity also have a critical effect upon machinery system requirements and, consequently, production costs.

The selection of a machinery system is a highly complex problem involving many factors such as weather uncertainties, timeliness, soil type and conditions, type of crops and rotations, management practices and labor and fuel supply. Machinery selection decisions are among the most important that producers must make in today's agriculture. Such decisions are critical because of the high proportion of total costs attributable to machinery and the infrequency and irrevocability of such decisions.

A farmer who stays in the farming business must be a very good manager. Unfortunately, he does not have the necessary information and knowledge at his disposal to help him make sound decisions concerning machinery management and other production related activities. Furthermore, the "Ingeniero Agrónomos" (extension advisors) with whom he might consult are not adequately trained to deal with these problems. The University of Concepción, at Chillán, is strengthening its instruction in the Department of Agricultural Engineering at the undergraduate and master of science levels to prepare students to deal with these and other production shortcomings. A computer model for the machinery selection and management needs of the Chilean wheat producers could prove to be a most useful educational tool.

* These coefficients estimate that 24 persons can be fed adequately from 1 ha of high quality farmland worked at a level of agricultural technology comparable to that practiced in the Midwest of the USA.

## Objectives

The general objective of this project was to develop a computer model for simulation of least cost machinery systems for wheat producers located in the Andes Pre-Cordillera area of the province of Ñuble, in Chile. The model was designed for use as an educational tool for teaching students at the University of Concepción and assist farmers in their machinery purchase and management decisions.

The specific objectives of the project were to: 1) Develop a computer model to simulate the selection of field machinery systems for the wheat producers in the eastern part of the province of Ñuble; 2) Compare machinery requirements for production systems differing in tillage intensity and crop rotations, including wheat, oats, lentils, and subterranean clover. Besides machinery requirements the model will provide cost data on machinery, labor, timeliness and fuel.

## Machinery Selection Algorithm

Several approaches have been made towards the selection of farm machinery systems and for determination of associated costs. The most common techniques may be classified into four groups: 1) Enterprise budgets using custom hire rates; 2) Whole farm, profit maximizing linear programming models; 3) Least cost models which seek minimum cost machinery systems for given management practices, and 4) Heuristic models for selecting multiple enterprise machinery components.

Several field machinery system selection models have been developed at Michigan State University during the last 5 years (i.e., Singh, 1978; Wolak, 1981; Muhtar, 1982). These models formed the basis for the development of this machinery selection model (TRIGO), which incorporates the specific agricultural and economical conditions of wheat production in Chile. During the initial stages of model development the hierarchical structure of systems and subsystems was defined, including a crop production system and a machinery system. Within the machinery system two smaller subsystems were identified: 1) tillage and seeding subsystem; and 2) harvesting subsystem.

As a follow up to the initial system diagram, an input–output view of the machinery selection model was formulated. **Fig. 1** shows the inputs to be used, along with system parameters, and expected outputs for the model. The system parameters and desired outputs were based on data collected in Chile. The machinery system selection strategy included three constraints: 1) Only machine types and sizes available to farmers in the study area were considered 2) All operations had time limitations in accordance with agronomic requirements, 3) From the minimum size machinery system to complete the work in a given time period, a size incrementation process was used to search for a least cost system by determining the trade-offs among timeliness costs, ownership costs, and the other components of the total system cost.

**Fig. 2** presents a simplified flow diagram of the machinery selection model, showing the general approach to the problem. The machinery system selected includes the following components: two-wheel drive tractor(s), disk plow, off-set disk harrow, spike-tooth harrow, grain seeder, centrifugal fertilizer broadcaster, boom-type field sprayer, self-propelled combine, and trans-

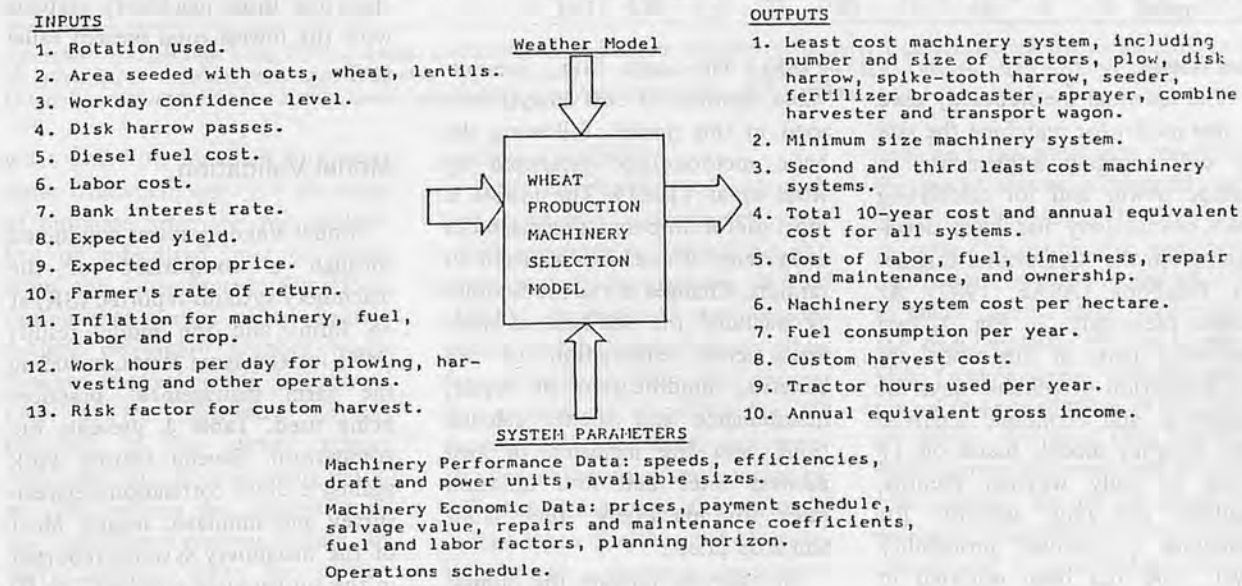


**Fig. 1** Input-output view for the wheat production machinery selection model.

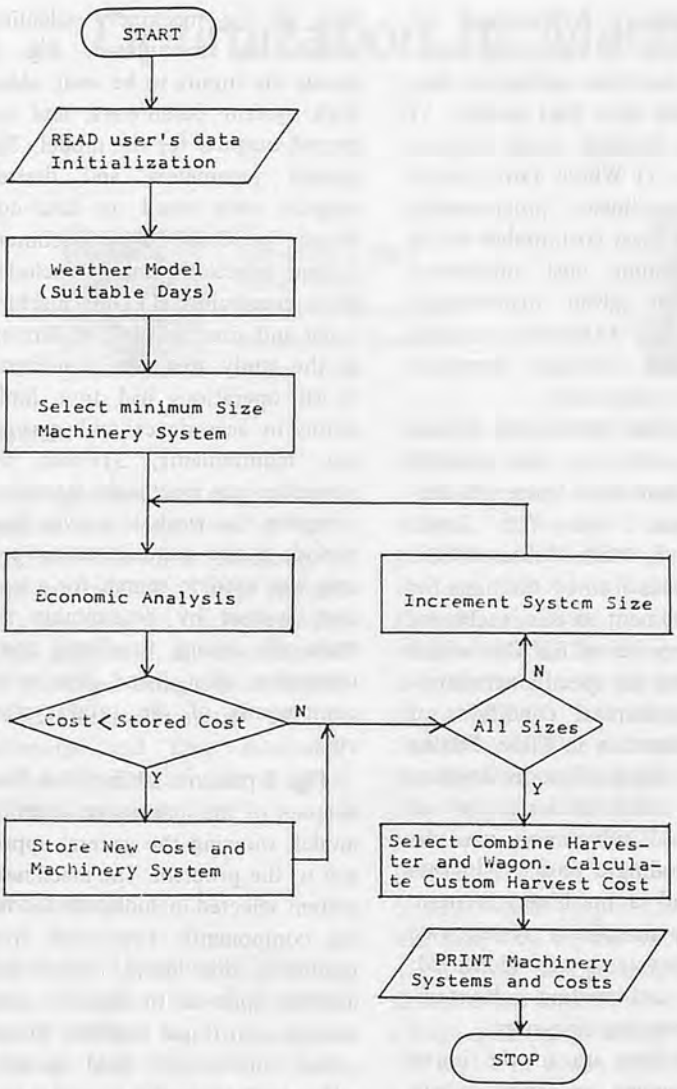


**Fig. 2** Simplified flow diagram for the wheat production machinery selection model.

port wagon.

The essential methodology used in this model for matching the size of soil engaging implements to tractor power and for calculating their productivity has been developed from the Agricultural Engineers Yearbook (ASAE, 1982). As shown previously, in **Fig. 2**, two important parts of this model are the prediction of suitable days for fieldwork and economic analysis. The weather model, based on 17 years of daily weather records, predicts the time available for fieldwork at selected probability levels, and has been reported in another publication (Hetz et al, 1983). The cash flow, present-value, method of cost analysis was used in this model, following the basic methodology presented by Rotz et al. (1981). The model is most useful for comparing machines or systems of machines available to farmers. Changes in the methodology included the addition of timeliness cost, elimination of tax benefits, modification of repair, maintenance and shelter calculations, and the inclusion of two interest rates and four inflation rates for machinery, fuel, labor and crop prices.

In order to validate the models through FORTRAN V computer programs, a data collection process was carried out in Chile in November and December of 1981. Agronomic, agrometeorological, economic and engineering data pertinent to wheat production in the study area were collected at the farm level, with the use of questionnaires previously developed and tested at Michigan State University.

Program TRIGO consists of a main program and 12 subroutines. The program was designed for interactive use and, consequently, on each run it provides directions to the user on how to enter all the required information, which has been shown on the left side of **Fig. 1**. Initially, the main program calculates the areas over which the different field operations are to be performed, in accordance with the nature of the crops, rotation and tillage intensity level being used. The main program also handles the correlation equations which predict the purchase prices for all sizes of machines available from the local farm machinery dealers in Chillán, Chile. The main program also controls the operational flow during the machinery system incrementation process. During this process the program uses a specific algorithm to compare, sort, and store the three machinery systems with the lowest total present value cost.

## Model Validation

Model Validation was conducted through a comparison of the machinery systems reported (SR) at 18 farms and the model results (MR) for the same farms, including the farm management practices being used. **Table 1** presents the comparison. Several factors work against a close correlation between survey and simulated results. Most of the machinery systems reported in the survey were acquired 7 to 10 years earlier, when the decisions of

Table 1 Comparison of Farmers' Machinery Systems and Model Results for Wheat Production Systems in South Central Chile[1]

| Farm | Area (ha) | | | | Machinery System | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Power | | Plow | | Disk. Harr | | Harr. | Seeder | | Fertilizer | Sprayer | | Combine | | Wgn |
| | O | W | L[2] | | (kW) | | Dsk | (m) | Dsk | (m) | (m) | Rws | (m) | (m) | Nozz. | (m) | (ft) | (m) | (T) |
| 2 | 12 | 55 | 3 | MR[3] | 32.1 | | 3 | 0.72 | 6 | 1.37 | np[4] | 14 | 2.49 | 10 | 14 | 7 | 12 | 3.65 | 4.0 |
| | | | | SR | 37.3 | | 3 | 0.72 | 7 | 1.61 | 4 | 13 | 2.31 | np | np | | np | | np |
| 3 | 0 | 78 | 0 | MR | 32.1 | | 3 | 0.72 | 6 | 1.37 | np | 15 | 2.67 | 10 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 48.5 | | 4 | 0.96 | 8 | 1.83 | np | 12 | 2.13 | np | np | | np | | 4.0 |
| 4 | 36 | 50 | 0 | MR | 32.1 | | 3 | 0.72 | 6 | 1.37 | np | 17 | 3.02 | 11 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 44.7 | | 4 | 0.96 | 7 | 1.61 | 4 | 16 | 2.84 | np | 12 | 6 | 12 | 3.65 | 4.0 |
| 5 | 20 | 56 | 10 | MR | 32.1 | | 3 | 0.72 | 6 | 1.37 | np | 17 | 3.02 | 10 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 37.3 | | np | | 8 | 1.83 | 3.2 | 14 | 2.49 | np | np | | np | | np |
| 6 | 20 | 60 | 12 | MR | 36.7 | | 3 | 0.72 | 7 | 1.61 | np | 17 | 3.02 | 11 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.9 | | 4 | 0.96 | 9 | 2.06 | 4 | 14 | 2.49 | np | np | | np | | 4.0 |
| 7 | 30 | 58 | 15 | MR | 42.6 | | 4 | 0.96 | 8 | 1.83 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 50.7 | | 4 | 0.96 | 9 | 2.06 | 4 | 13 | 2.31 | 10 | 12 | 6 | 12 | 3.65 | 4.0 |
| 8 | 48 | 60 | 0 | MR | 47.2 | | 4 | 0.96 | 9 | 2.06 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.2 | | 4 | 0.96 | 9 | 2.06 | 3 | 18 | 3.20 | 10 | 12 | 6 | 12 | 3.65 | 4.0 |
| 9 | 29 | 80 | 0 | MR | 47.2 | | 4 | 0.96 | 9 | 2.06 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.2 | | 4 | 0.96 | 9 | 2.06 | 3 | 15 | 2.67 | 10 | 12 | 6 | 12 | 3.65 | 4.0 |
| 10 | 16 | 78 | 15 | MR | 47.2 | | 4 | 0.96 | 9 | 2.06 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.2 | | 4 | 0.96 | np | | 4 | np | | np | np | | np | | np |
| 11 | 40 | 81 | 0 | MR | 57.6 | | 5 | 1.20 | 11 | 2.51 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.9 | | 5 | 1.20 | 9 | 2.06 | 5 | 16 | 2.84 | 12 | 12 | 6 | 12 | 3.65 | 4.0 |
| 12 | 50 | 100 | 0 | MR | 36.7 | 28.6 | 3 | 0.72 | 7 | 1.61 | np | 15 | 2.67 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 41.8 | 37.3 | 5 | 1.20 | 9 | 2.06 | 4 | 17 | 3.02 | 12 | 14 | 7 | 14 | 4.26 | 5.0 |
| 13 | 55 | 80 | 15 | MR | 36.7 | 28.6 | 3 | 0.72 | 7 | 1.61 | np | 15 | 2.67 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.9 | 44.7 | 8 | 1.92 | 8,9 | 3.87 | 4.5 | 15,17 | 5.68 | 12 | 12 | 6 | 14 | 4.26 | 9.0 |
| 14 | 56 | 80 | 20 | MR | 36.7 | 28.6 | 3 | 0.72 | 7 | 1.61 | np | 16 | 2.84 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.2 | 52.2 | 5 | 1.20 | 9 | 2.06 | 4 | 18 | 3.20 | 12 | 14 | 7 | 13 | 3.95 | 4.0 |
| 15 | 74 | 60 | 30 | MR | 32.1 | | 3 | 0.72 | 6 | 1.37 | 6[4] | 18 | 3.20 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 56.7 | | 5 | 1.20 | 10 | 2.30 | 6 | 15 | 2.67 | 12 | 14 | 7 | np | | 5.0 |
| 16 | 75 | 80 | 15 | MR | 42.6 | 28.6 | 4 | 0.96 | 8 | 1.83 | np | 17 | 3.02 | 12 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 55.9 | 52.2 | 5 | 1.20 | 12 | 2.76 | 5 | 14 | 2.49 | 12 | 14 | 7 | 14 | 4.26 | 9.0 |
| 17 | 100 | 100 | 25 | MR | 53.2 | 28.6 | 5 | 1.20 | 10 | 2.29 | np | 18 | 3.20 | 12 | 16 | 8 | 12 | 2.65 | 4.0 |
| | | | | SR | 55.9 | 43.3 | 8 | 1.92 | 9,9 | 4.12 | 6 | 18 | 3.20 | 14 | 16 | 8 | 14 | 4.26 | np |
| 18 | 27 | 200 | 15 | MR | 63.9 | 28.6 | 6 | 1.44 | 12 | 2.74 | np | 18 | 3.20 | 13 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 73.1 | 44.7 | | | | | | | | | | | | | |
| | | | | | 41.8 | | 10 | 2.40 | 9,14 | 5.26 | 4,4 | 29 | 5.15 | 14 | 16 | 8 | 24 | 7.30 | 14.0 |
| 19 | 0 | 250 | 0 | MR | 63.9 | 28.6 | 6 | 1.44 | 12 | 2.74 | np | 18 | 3.20 | 14 | 16 | 8 | 12 | 3.65 | 4.0 |
| | | | | SR | 52.9 | 52.2 | | | | | | | | | | | | | |
| | | | | | 37.3 | | 9 | 2.16 | 10,11 | 4.80 | 4,4 | 27 | 4.80 | 14 | 16 | 8 | 14 | 4.26 | 10.0 |

Remarks: (1) All runs using 0.70 as design probability level, medium intensity tillage level, a custom harvest risk factor equal 1.05, all other input variables were kept constant. (2) 0 = oats; W = wheat; L = lentils. (3) MR = Model results; SR = Survey results. (4) np = not present (5) Use a spike-tooth harrow before seeding, instead of a disk harrow.

what and how much to buy were done overwhelmingly on the basis of purchase price and the availability of subsidized lines of credit from the Government. Therefore, during that period many farmers bought machinery without much concern for real needs. In general, most of the machinery systems reported in the survey appear over-sized for the area being worked. This reflects the acquisition of the machinery systems during the early seventies when the farmers were seeding larger areas and cheap credit was available.

Despite a changing technological and economic environment, the values presented in **Table 1** present some general comparisons. Wolak (1981) emphasized that model results must be approximately what farmers expect. When this occurs, it is possible to rationalize the difference between actual and generated machinery systems because of different management alternatives.

The main discrepancies between actual and simulated machinery systems occurred in the power level and the plow size for which the model almost consistently predicted smaller units. The discrepancy with the seeder size was, however, opposite as the model selected in many cases, a larger seeder than the ones reported by the farmers. Most farmers agreed with the lower power level prediction as they had knowingly over-sized their tractors. Plows appeared over-sized because many farmers did not use the allowable period for plowing. The shorter period was, it appeared, to extend pasture utilization (Chavarria,

1981), therefore; a larger effective field capacity and a higher power level were required. For the seeder, the model selected larger sizes because of the timeliness costs associated with late seeding. Farmers, when confronted with unsuitable weather and late seeding apparently resort to spring seeding despite the lower yields and higher drought risks. With a 0.70 probability level of available days for the most common management practices followed by the farmers, the model started selecting two tractors when the cultivated area exceeded 121 hectares/year. This coincided with the number of tractors reported by the farmers in the survey. Although the model selected a combine harvester for all areas inputed, it also considered the cost of the custom harvest alternative. These results also agree closely with the combine ownership pattern among the farmers surveyed.

## Sensitivity Analysis

Program TRIGO was used to analyze the effects of various factors upon the machinery system requirements and associated costs. The computer program printed four machinery systems with corresponding partial and total costs, as well as other information: 1) least cost system, 2) second least cost system, 3) third least cost system, and 4) minimum size system. This has been done in order to be able to use the program as an educational tool in Chile.

The discussion that follows is based upon the least cost machinery system. Only the effects of the cultivated area, tillage system and crop rotation are analyzed here. The computer program had a much greater capability, enabling the user to analyze other factors, such as time available, fuel requirement, yields, crop prices and many other economic factors.

### Machinery System Cost Components

The relative importance of each of the components of the machinery system cost is depicted in **Table 2.** The combine harvester and transport wagon were presented separately because the harvester was by far the most expensive machine in the system, accounting for nearly 50% of the total machinery system cost for small areas. Private ownership costs were constantly the highest for small areas, and particularly for the combine harvester. As the cultivated areas increased from 70 to 210 ha, the relative importance of the ownership cost decreased from 41% to 36% of the total system cost, and from 75% to 48% for the combine.

The next ownership cost item of relative importance was fuel and lubrication, followd by repair and maintenance cost. These made up about 50% of the system's cost. The proportion did not change a great deal with different sized cultivated areas. Labor and timeliness costs were low in comparison with the previous items. This reflected the low wage rates earned by farm workers, the extent of mechanization of cereal crops, and the generally large amount of time

**Table 2** Relative Importance of the Machinery System Cost Components. All values in U.S.$

| Cost Component | Machinery System Present Value Cost ($/10 years) | | | |
|---|---|---|---|---|
| | Cultivated Area (ha) | | | |
| | 70 | 110 | 170 | 210 |
| 1. Machinery system without harvester | | | | |
| Ownership | 31 840 | 48 218 | 68 548 | 78 187 |
| % of total | 41 | 39 | 38 | 36 |
| Fuel & lubrication | 20 383 | 34 620 | 47 377 | 58 341 |
| % of total | 26 | 28 | 27 | 27 |
| Repairs & maintenance | 18 445 | 30 180 | 45 576 | 57 875 |
| % of total | 24 | 25 | 26 | 26 |
| Labor | 5 220 | 5 485 | 8 743 | 9 736 |
| % of total | 6 | 5 | 5 | 4 |
| Timeliness | 2 183 | 4 185 | 7 525 | 15 434 |
| % of total | 3 | 3 | 4 | 7 |
| Total | 78 071 | 122 688 | 177 769 | 219 573 |
| 2. Harvester & wagon | | | | |
| Ownership | 47 714 | 47 714 | 47 714 | 47 714 |
| % of total | 75 | 66 | 55 | 48 |
| Fuel & lubrication | 5 365 | 8 431 | 13 029 | 16 095 |
| % of total | 8 | 11 | 15 | 16 |
| Repairs & maintenance | 7 002 | 11 003 | 17 005 | 21 006 |
| % of total | 11 | 15 | 20 | 21 |
| Labor | 3 527 | 5 542 | 8 565 | 10 580 |
| % of total | 6 | 8 | 9.7 | 10 |
| Timeliness | 0.00 | 0.00 | 224 | 4 674 |
| % of total | 0 | 0 | 0.3 | 5 |
| Total | 63 608 | 72 690 | 86 537 | 100 069 |
| % System cost | 45 | 37 | 33 | 31 |
| Machinery system present Value cost ($/10yr) | 141 679 | 195 378 | 264 306 | 319 643 |
| Annual equiv. cost ($/yr) | 31 526 | 43 474 | 58 812 | 71 125 |
| A.E. gross income ($/yr) | 103 438 | 162 545 | 251 206 | 310 314 |
| AEC/AE income | 0 305 | 0 267 | 0 234 | 0 229 |

Weather confidence level = 0.70; Wheat-pasture rotation; medium tillage intensity level; Work hours/Day = 8.0; All other variables kept constant.

Table 3 Effect of the Yearly Seeded Area upon Machinery Requirements.

| Area (ha) | | | Plow (m) | Disk (m) | Harr. (m) | Seeder (m) | Fert. (m) | Spry. (m) | No. Trac. | Power | | Tractor Use (h/yr) | Combine (m) | Wagon (T) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | W | L | | | | | | | | (kW) | kW/ha | | | |
| 0 | 50 | 0 | 0.72 | 1.37 | 3.5 | 1.78 | 10 | 6 | 1 | 32.1 | 0.64 | 381 | 3.65+ | 4.0 |
| 0 | 70 | 0 | 0.72 | 1.37 | 4.0 | 2.31 | 10 | 7 | 1 | 32.1 | 0.46 | 500 | 3.65+ | 4.0 |
| 0 | 90 | 0 | 0.72 | 1.37 | 4.5 | 2.99 | 11 | 8 | 1 | 32.1 | 0.36 | 626 | 3.65+ | 4.0 |
| 0 | 110 | 0 | 0.96 | 1.83 | 5.5 | 3.02 | 12 | 8 | 1 | 42.6 | 0.39 | 601 | 3.65+ | 4.0 |
| 0 | 130 | 0 | 0.96 | 1.83 | 6.0 | 3.20 | 12 | 8 | 1 | 42.6 | 0.33 | 702 | 3.65+ | 4.0 |
| 0 | 150 | 0 | 1.20 | 1.83 | 6.0 | 3.20 | 12 | 8 | 1 | 53.2 | 0.35 | 752 | 3.65 | 4.0 |
| 0 | 170 | 0 | 1.20 | 1.83 | 3.5 | 3.20 | 12 | 8 | 2 | 81.8 | 0.48 | 886 | 3.65 | 4.0 |
| 0 | 190 | 0 | 1.44 | 2.06 | 3.5 | 3.20 | 12 | 8 | 2 | 92.5 | 0.49 | 900 | 3.65 | 4.0 |
| 0 | 210 | 0 | 1.44 | 2.29 | 3.5 | 3.20 | 13 | 8 | 2 | 92.5 | 0.44 | 955 | 3.65 | 4.0 |
| 0 | 230 | 0 | 1.44 | 2.06 | 3.5 | 3.20 | 12 | 8 | 2 | 92.5 | 0.40 | 1085 | 3.65 | 4.0 |

+ Custom cost less than combine harvester ownership.
Low Tillage Intensity Level; Wheat-Pasture Rotation; Weather Confidence Level = 0.70; Workhours/Days = 8.0 except for the 230 ha run where 9.0 h/day are needed to be able to seed all this area.

In all computer runs, unless otherwise specified, the rest of the variables are kept constant at the following values: wheat yield =3500 kg/ha; crop price = 0.25 $/kg; diesel fuel price = 0.45 $/l; labor cost = 1.00 $/h; bank interest = 18%; farmer's rate of return =18%; inflation on machinery = 18%; inflation on fuel = 16%; inflation on labor = 10%; inflation on crop price = 12%; custom harvest risk factor = 1.05.

available for fieldwork in this part of Chile.

## Effects of Cultivated Area

**Table 3** shows the variation in machinery system requirements in relation to various cultivated areas of from 50 to 230 ha. All machine sizes increased with increased areas, with the exception of the spike harrow which decreased in width when two tractors were selected. The largest change in size occured for the disk plow which changed from 0.72 m (3 disks) to 1.44 m (6 disks). Total power increased from 32.1 kW to 92.5 kW. However, the power per unit area initially decreased as the area increased but then stabilized at a value close to 0.45 kW/ha. Tractor use per year increased as the cultivated area increased, except for a small reduction at the 110 ha level. This was because implements much larger than the ones used at 90 ha were selected, thus fewer hours per year were required.

Fertilizer broadcaster and sprayer sizes did not change a great deal with changes in the cultivated area. These two machines have large effective field capacities, low purchase price and negligible power requirements; therefore, the model selected larger than minimum sizes to save on field hours, fuel consumption and labor costs.

Table 4 Effect of the Yearly Seeded Area upon the Machinery System Cost. All Values in U.S.$

| Area (ha) | | | Total Area (ha) | No. Trac. | Power (kW) | Machinery System | | |
|---|---|---|---|---|---|---|---|---|
| W | O | L | | | | Pres. Val. Cost+ ($/10 yr) | Ann. Equiv. Cost++ ($/ha)+ | ($/ha)++ |
| Low tillage intensity level | | | | | | | | |
| 25 | 25 | 0 | 50 | 1 | 32.1 | 55.661 | 248 | 511 |
| 35 | 35 | 0 | 70 | 1 | 32.1 | 65.876 | 209 | 411 |
| 45 | 45 | 0 | 90 | 1 | 32.1 | 76.401 | 189 | 357 |
| 55 | 55 | 0 | 110 | 1 | 32.1 | 86.427 | 175 | 322 |
| 65 | 65 | 0 | 130 | 1 | 32.1 | 96.961 | 166 | 298 |
| 75 | 75 | 0 | 150 | 1 | 32.1 | 108.544 | 161 | 282 |
| 85 | 85 | 0 | 170 | 2 | 60.7 | 132.613 | 174 | 287 |
| 95 | 95 | 0 | 190 | 2 | 65.3 | 151.614 | 177 | 283 |
| 105 | 105 | 0 | 210 | 2 | 71.2 | 168.011 | 178 | 280 |
| Medium tillage intensity level | | | | | | | | |
| 25 | 25 | 0 | 50 | 1 | 32.1 | 58.594 | 261 | 524 |
| 35 | 35 | 0 | 70 | 1 | 32.1 | 71.109 | 226 | 428 |
| 45 | 45 | 0 | 90 | 1 | 42.6 | 89.446 | 221 | 389 |
| 55 | 55 | 0 | 110 | 1 | 57.6 | 113.825 | 230 | 372 |
| 65 | 65 | 0 | 130 | 2 | 65.3 | 124.162 | 213 | 345 |
| 75 | 75 | 0 | 150 | 2 | 71.2 | 138.773 | 206 | 327 |
| 85 | 85 | 0 | 170 | 2 | 71.2 | 156.477 | 205 | 318 |
| 95 | 95 | 0 | 190 | 2 | 81.8 | 174.783 | 205 | 311 |
| 105 | 105 | 0 | 210 | 2 | 86.2 | 193.691 | 205 | 307 |

Remarks: + Does not include combine harvester cost. ++ Includes combine harvester cost. Weather Confidence Level = 0.70. Work hours/day = 8.0. Oats-Wheat-Pasture Rotation. All other variables are kept constant.

For all imputed areas, program TRIGO selected a combine harvester and calculated the cost of custom harvest. The asterisks in the second from the right column of **Table 3** indicate those areas for which custom cost was less than combine ownership, with a risk factor of 1.05. For the areas that can be worked with two tractors (up to 270 ha for a 10 h day) the program selected a 3.65 m wide combine. This seemed to be caused by the large amount of time available for harvesting and by the large increase in harvester purchase price per unit width increment.

The effects of the cultivated area upon the system cost are presented in **Table 4.** Total machinery value cost increased consistently as the area increased. However, the cost per unit area decreased as the seeded area increased, which is an indication of the apparent economy of scale. For the low tillage level the cost per ha decreased as area increased as long as one tractor was

Table 5 Effect of the Tillage Intensity Level upon Machinery Requirements

| Tillage Level (Disk Passes) | Area (ha) O | W | L | Total Area (ha) | Plow (m) | Disk (m) | Harr. (m) | Sdr. (m) | Fert. (m) | Spry. (m) | No. Trac. | Power kW | kW/ha | Tractor Use (h/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat-pasture rotation | | | | | | | | | | | | | | |
| Low(2) | 0 | 90 | 0 | 90 | 0.72 | 1.37 | 4.5 | 2.49 | 11 | 8 | 1 | 32.1 | 0.36 | 626 |
| Medium(3) | 0 | 90 | 0 | 90 | 0.96 | 1.83 | np | 3.20 | 12 | 8 | 1 | 42.6 | 0.47 | 544 |
| High(4) | 0 | 90 | 0 | 90 | 0.96 | 1.83 | np | 3.20 | 12 | 8 | 1 | 42.6 | 0.47 | 626 |
| Oats-wheat-pasture rotation | | | | | | | | | | | | | | |
| Low(2) | 75 | 75 | 0 | 150 | 0.72 | 1.37 | 6.0 | 3.20 | 12 | 8 | 1 | 32.1 | 0.21 | 804 |
| Medium(3) | 75 | 75 | 0 | 150 | 0.96 | 1.83 | np | 3.02 | 12 | 8 | 2 | 71.2 | 0.47 | 761 |
| High(4) | 75 | 75 | 0 | 150 | 0.96 | 1.83 | np | 3.02 | 12 | 8 | 2 | 71.2 | 0.47 | 898 |
| Oats-lentils-wheat-pasture rotation | | | | | | | | | | | | | | |
| Low(2) | 55 | 55 | 20 | 130 | 0.72 | 1.37 | 6.0 | 3.20 | 12 | 8 | 1 | 32.1 | 0.25 | 664 |
| Medium(3) | 55 | 55 | 20 | 130 | 0.72 | 1.61 | np | 2.67 | 12 | 8 | 2 | 65.3 | 0.50 | 739 |
| High(4) | 55 | 55 | 20 | 130 | 0.72 | 1.61 | np | 2.67 | 12 | 8 | 2 | 65.3 | 0.50 | 872 |

Remarks: np = not present. Weather confidence level = 0.70. Work hours/day = 8.0. All other variables kept constant.

required. When two tractors were required the cost per ha went up and remained at this higher value. When the medium tillage level was analyzed the cost per ha decreased as the seeded area increased independently of the number of tractors. There was one exception to this behavior at 110 ha where the cost went up transitorily for that one area level. As this area was near the maximum that could be worked with one tractor, the model tried to serve the maximum area without going into two tractors. The result was a large power source with a considerable higher fuel consumption rate (57.6 *l*/ha) than the tractor used for 90 ha. (50.9 *l*/ha). These results point out the need for further research on the cost of performing work with one and two tractors at the transition areas.

Table 6 Effect of the Tillage Intensity Level upon the Machinery System Cost+. All Values in U.S.$.

| Tillage level (Disk passes) | Area (ha) O | W | L | Total area (ha) | Machinery System pres. value cost+ ($/10yr) | Annual Eq. cost ($/ha) | Cost increm. ($/ha) |
|---|---|---|---|---|---|---|---|
| Wheat-pasture rotation | | | | | | | |
| Low(2) | 0 | 150 | 0 | 150 | 142 770 | 212 | 0 |
| Medium(3) | 0 | 150 | 0 | 150 | 162 770 | 241 | 29 |
| High(4) | 0 | 150 | 0 | 150 | 175 883 | 261 | 49 |
| Oats-wheat-pasture rotation | | | | | | | |
| Low(2) | 75 | 75 | 0 | 150 | 108 544 | 161 | 0 |
| Medium(3) | 75 | 75 | 0 | 150 | 138 773 | 206 | 45 |
| High (4) | 75 | 75 | 0 | 150 | 152 198 | 226 | 65 |
| Oats-lentils-wheat-pasture-rotation | | | | | | | |
| Low(2) | 65 | 65 | 20 | 150 | 107 124 | 159 | 0 |
| Medium(3) | 65 | 65 | 20 | 150 | 137 621 | 204 | 45 |
| High(4) | 65 | 65 | 20 | 150 | 151 046 | 224 | 65 |

Remarks: + Does not include combine harvester cost. Weather Confidence Level = 0.70, Work hours/day = 8.0, All other variables kept constant.

## Effects of Tillage Intensity Level

**Table 5** presents the effects of tillage level upon the machinery system size. The table shows that for all areas and rotations studied the low tillage level was the least demanding on sizes of tractor and implements. The main difference between the low level and the medium and high levels was that in the case of the low level a spike harrow was used in conjunction with the seeder instead of an offset disk harrow.

Spike harrows have a much larger effective field capacity than disk harrows (1.50 to 3.60 ha/h vs 0.82 to 1.90 ha/h for available sizes) and a considerably smaller draft per unit width (0.8 kN/m vs. 4.5 kN/m). These factors substantially reduced the size of the disk harrow needed for the first two passes and the size of the tractor, which remained at 32.1 kW for 150 ha.

**Table 6** shows the effect of tillage level upon the system cost. The effect was rather clear and logical. As the tillage intensity increased, the cost per ha also increased. The effect was especially large when the change was made from the low to the medium and high tillage levels. As the difference between the medium and high tillage levels was one disk pass, it is reasonable to conclude that the annual equivalent cost of one disk pass was $20 under the conditions used in the program runs. This cost does not include the costs associated with the higher erosion levels brought about by more intensive tillage practices, which have been found to occur in this area (Peña, 1978).

## Effects of Crop Rotation

**Table 7** presents the effect of crop rotation on machinery system requirements. The three rotations compared differed in the number of crops that each rotation had. Many farmers still used the wheat-pasture rotation, although more and more farmers were changing to the oats-wheat-pasture rotation. The Extension Service personnel were trying

Table 7 Effect of the Crop Rotation upon Machinery Requirements

| Rotation | Area (ha) | | | Total Area (ha) | Plow (m) | Disk (m) | Harr. (m) | Sdr. (m) | Fert. (m) | Spry. (m) | No. Trac. | Power | | Tractor Use (h/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | W | L | | | | | | | | | kW | kW/ha | |
| Medium tillage intensity level | | | | | | | | | | | | | | |
| W-P-P | 0 | 70 | 0 | 70 | 0.72 | 1.37 | np | 2.49 | 10 | 7 | 1 | 32.1 | 0.46 | 556 |
| O-W-P-P | 35 | 35 | 0 | 70 | 0.72 | 1.37 | np | 2.49 | 10 | 7 | 1 | 32.1 | 0.46 | 461 |
| O-L-W-P-P | 25 | 25 | 20 | 70 | 0.72 | 1.37 | np | 2.49 | 10 | 7 | 1 | 32.1 | 0.46 | 429 |
| Low tillage intensity level | | | | | | | | | | | | | | |
| W-P-P | 0 | 150 | 0 | 150 | 1.20 | 1.83 | 6.0 | 3.20 | 12 | 8 | 1 | 53.2 | 0.35 | 752 |
| O-W-P-P | 75 | 75 | 0 | 150 | 0.72 | 1.37 | 6.0 | 3.20 | 12 | 8 | 1 | 32.1 | 0.21 | 804 |
| O-L-W-P-P | 65 | 65 | 20 | 150 | 0.72 | 1.37 | 6.0 | 3.20 | 12 | 8 | 1 | 32.1 | 0.21 | 771 |
| High tillage intensity level | | | | | | | | | | | | | | |
| W-P-P | 0 | 150 | 0 | 150 | 1.20 | 2.29 | np | 3.02 | 12 | 8 | 2 | 81.8 | 0.54 | 881 |
| O-W-P-P | 75 | 75 | 0 | 150 | 0.96 | 1.83 | np | 3.02 | 12 | 8 | 2 | 71.2 | 0.47 | 898 |
| O-L-W-P-P | 70 | 70 | 10 | 150 | 0.96 | 1.83 | np | 3.02 | 12 | 8 | 2 | 71.2 | 0.47 | 886 |
| Medium tillage intensity level | | | | | | | | | | | | | | |
| W-P-P | 0 | 210 | 0 | 210 | 1.44 | 2.74 | np | 3.20 | 13 | 8 | 2 | 92.5 | 0.44 | 933 |
| O-W-P-P | 105 | 105 | 0 | 210 | 1.20 | 2.51 | np | 3.20 | 13 | 8 | 2 | 86.2 | 0.41 | 856 |
| O-L-W-P-P | 95 | 95 | 20 | 210 | 1.20 | 2.51 | np | 3.20 | 13 | 8 | 2 | 86.2 | 0.41 | 839 |

Remark: Weather confidence level = 0.70, Work hours/ day = 8.0, np = not present, All other variables are kept constant.

to increase the use of the more complete and better balanced oats-lentils-wheat-pasture rotation. **Table 7** shows that the inclusion of oats and lentils in the rotation decreased the power required and the sizes of the plow and disk harrow, especially in larger areas. This was a positive result brought about by the reduction in the area that had to be plowed each year, according to the field operations calendar. Because a smaller plow was needed, less power was required and it did not pay to increase the size of the disk harrow. The power required per unit area and the plow and disk sizes for the wheat-pasture rotation were consistently larger than the ones required by the rotations that include oats and lentils. Unfortunately, the area seeded with lentils cannot be increased by larger amounts because of weather, price risks and labor bottle-necks.

**Table 8** presents the effect of the crop rotation on machinery system cost. The table shows that as the number of crops in the rotation increased, the cost per ha decreased. This result was caused by a reduction in the amount of work that needed to be performed, especially plowing. When the cost of the harvester was included, there was a small increment in the cost per ha as lentils appear in the rotation. This cost increment was caused by the slow harvesting rate of lentils (0.4 ha/h).

Table 8 Effect of the Crop Rotation upon the Machinery System Cost. All Values in U.S.$

| Crop Rotation | Area (ha) | | | Total Area (ha) | Machinery System Pres. Value Cost+ ($/10 yr) | Annual Equivalent Cost per hectare | |
|---|---|---|---|---|---|---|---|
| | O | W | L | | | ($/ha)+ | ($/ha)++ |
| Medium tillage intensity level | | | | | | | |
| W-P-P | 0 | 70 | 0 | 70 | 78 071 | 248 | 450 |
| O-W-P-P | 35 | 35 | 0 | 70 | 71 109 | 226 | 428 |
| O-L-W-P-P | 25 | 25 | 20 | 70 | 69 635 | 221 | 447 |
| Low tillage intensity level | | | | | | | |
| W-P-P | 0 | 150 | 0 | 150 | 142 770 | 212 | 333 |
| O-W-P-P | 75 | 75 | 0 | 150 | 108 544 | 161 | 282 |
| O-L-W-P-P | 65 | 65 | 20 | 150 | 107 124 | 159 | 291 |
| High tillage intensity level | | | | | | | |
| W-P-P | 0 | 150 | 0 | 150 | 175 883 | 261 | 382 |
| O-W-P-P | 75 | 75 | 0 | 150 | 152 198 | 226 | 347 |
| O-L-W-P-P | 70 | 70 | 0 | 150 | 151 622 | 225 | 352 |
| Medium tillage intensity level | | | | | | | |
| W-P-P | 0 | 210 | 0 | 210 | 219 573 | 233 | 339 |
| O-W-P-P | 105 | 105 | 0 | 210 | 193 691 | 205 | 307 |
| O-L-W-P-P | 95 | 95 | 20 | 210 | 192 776 | 204 | 313 |

Remarks: + Does not include combine harvester cost. ++ Combine harvester cost included. Weather Confidence Level = 0.70, Work hours/day = 8.0, All other variables are kept constant.

## Conclusions

1. A very good correlation (r = 0.95) was found between the yearly seeded area and the total power available on the farm. The individual tractor power per unit cultivated area is 0.5 kW/ha. This value puts these farmers at a high mechanization level, far above the country's average of 0.30 kW/ha.
2. 125 ha seems to be the upper limit that can be cultivated with one tractor, and around 225 ha when two tractors are available. These results agree very closely with the computer model predictions which give a range, including both limits, in accordance with the time available used as input in each computer run.
3. Ownership cost was constantly

the largest of the machinery system cost components, with values ranging from 41 to 36% (75 to 45% for the combine harvester) of the total system cost. Fuel and lubrication, repairs and maintenance costs, when lumped together, made up about 50%of the system's cost. Labor and timeliness costs had the lowest relative importance among the cost components studies.

4. Machinery requirements and total system cost increased with increasing increments in the cultivated area. However, costs per ha decreased as the cultivated area increased. The number of tillage operations affected both the machinery system size requirements and fuel use. The effect was especially dramatic as the change was made from the low to the medium and high tillage intensity levels.
5. As the number of crops in the rotation increased to include oats and lentils, the machinery system size requirements decreased along with the costs per ha. This result was caused by a reduction in the number of machinery tasks performed.
6. Diesel fuel requirements per ha were affected by both the tillage intensity level and the crop rotation. The tillage intensity factor was more important than the effect of crop rotation. Savings of up to 27 *l*/ha for a 110 ha farm were realized with a change from high to the low tillage intensity level.
7. The wheat production machinery selection model, program TRIGO, is a unique and useful analytical tool that can be used effectively to study the effects of cultivated area, tillage intensity level, crop rotation, available time for fieldwork, and an array of economic factors upon the machinery system requirements and associated costs.
8. The model predicts the number and size of machines required for a given set of conditions, and estimates the system's cost in accordance with different management strategies. Output values are only as reliable as the quality and reliability of the input data.

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■■

# Agricultural Machinery and Implements Industry: Problems and Status Quo

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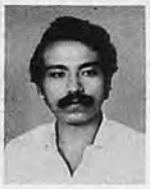

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## Abstract

The study was undertaken to assess the status quo and to highlight problem areas in agricultural machinery manufacturing industry in Pakistan. To fulfill the objective of study the data were obtained through interviews with 46 agricultural machinery manufacturers. The results reveal that the problems of the industry are: lack of trained manpower, lack of after sale service, lack of marketing research and lack of availability of standard raw materials. Various recommendations were made to overcome these problems.


## Introduction

Local manufacture of agricultural machinery and implements are given significant importance in developing countries. The development of the agriculture sector is of vital importance to the industrial growth of the countries. The agricultural machinery and implements are among the major industrial projects and provide a good scope for local manufacture. In Pakistan all the tractors and farm machines were imported until 1960. Recently, however, the imports gradually gave way to local production. However, a variety of implements are still imported from Europe and U.S.A. The five makes of tractors, i.e., Massey Ferguson, Fiat, IMT, Belarus and Ford are imported and assembled by two firms of the public sector and three firms of the private sector using about 50% local made parts.

There were 462 manufacturers of agricultural machinery in Pakistan in 1983 of which 11 could be considered as large, 40 as medium and the rest as small-scale manufacturers. The average annual turnover of a small unit was Rs.1 million and that of a medium unit, Rs.3 million.

The implements currently being manufactured in the country are: cultivators, scrapers, rear blades, land levellers, border discs, ditchers, mould board ploughs, disc harrows, seed-cum-fertilizer drills, disc ploughs, cotton/maize planters, sugarcane planters, manual and power-operated knapsack sprayers, trailers, reaper-windrowers, combines and threshers.

## Objective

The objectives of the survey follow:

i) To assess the status quo of the machinery and equipment industry.
ii) To highlight the problem areas in agricultural machinery manufacturing industry, e.g., financing, raw material supply, manpower, and marketing;
iii) To assess the level of training and skill of employees in agricultural machinery manufacturing industry; and
iv) To determine the adequacy of after-sale services.

## Methodology

To fulfill the objectives of study, the data were obtained through interviews with agricultural machinery and implements manufac-

Table 1 Classification of Manufacturers

| Size | Investment (excluding the cost of land), Rs. million |
|---|---|
| Small | < 0.5 |
| Medium | 0.5–5.0 |
| Large | > 5.0 |

turers in December, 1983. They were classified as small, medium and large on the basis of investment (Talbe 1).

A proportionate random sample of 46 firms (about 10%) of the total firms were drawn, using random sampling technique, out of which 40, 5 and 1 were small, medium and large, respectively. The interviews with manufacturers were carried out by the industrial extension engineers in local language for better communication and interpretation.

## Results

### Basic Facilities

The basic facility of electricity was available to all types of manufacturers. However, the manufacturers invariably pointed voltage fluctuation as a major problem: all of the large manufacturers; 73% of the small ones, and half of the medium-sized ones. Most of the manufacturers were satisfied with the supply of natural gas. The average monthly consumption of coal, electricity and natural gas by various categories of manufacturers is shown in Table 2.

### Machinery/Equipment

Almost all of the workshops of the small- and medium-scale manufacturers were equipped with a lathe, drilling machine, bench grinder and electric welding set. The equipment like shaper, disc cutter, power press, cutting and bending machine were available in the majority of the medium scale manufacturers and were seldom available in the small-scale manufacturers (Table 3). Most workshops had similar types of equipment. Shop layouts were rather arbitrarily made. The large manufacturers, in addition to the facilities available in the medium scale manufacturers, have adequate foundry, metal forming and forging and heat treatment facilities for the manufacture of relatively more sophisticated machines.

Table 2 Monthly Energy Consumption by Manufacturers

| Size | Coal (t) | Electricity (kW h) | Natural Gas ($m^3$) |
|---|---|---|---|
| Small | 21.0 | 1140 | 1.45 |
| Medium | 3.06 | 6425 | 92.5 |
| Large | – | 100000 | 329.0 |

Table 3 Percentage Distribution of Local Manufacturers by Types of Machine/Equipment

| Machine/Equipment | Percentage Distribution | |
|---|---|---|
| | Small | Medium |
| Lathe | | |
| a. 6 ft | 90 | 100 |
| b. 8 ft | 100 | 100 |
| c. 10 ft | 85 | 100 |
| d. 12 ft | 27 | 100 |
| Drilling Machine | 100 | 100 |
| Grinder | 100 | 100 |
| Electric Welding Plant | 100 | 100 |
| Shaper | | |
| a. 18 in. stroke | 17 | 80 |
| b. 24 in. stroke | 52 | 70 |
| c. 30 in. stroke | 10 | – |
| Milling Machine | – | 25 |
| Disc Cutter (Small) | 20.5 | – |
| Cutting Machine | 10 | 50 |
| Bending Machine | 12.5 | 50 |
| Power Hacksaw | 15 | 25 |
| Gas Welder | – | 2.5 |
| Forging | | |
| a. Power press | 52 | 100 |
| b. Hand press | 10 | 25 |
| c. Hydraulic press | 7.5 | 25 |
| Foundry | | |
| a. Cupola | 67 | 100 |
| b. Rotary furnace | 15 | 25 |

### Raw Material

At present raw materials such as cast iron, high carbon steel, mild steel, aluminium alloys, sheet metal, wood, rubber, plastic, coal and spring steel are used by the small and medium units. Table 4 shows the annual consumption and purchase prices of various raw materials. The average annual consumption of cast iron was between 95 t and 446 t by the small- and medium-units, respectively. Spring steel was mostly used by the plants which manufacture cultivators. The annual consumption was 2.3 and 200 t by small and medium units, respectively. Most of the small- and

Table 4 Annual Raw Material Consumption of Small- and Medium-Scale Manufacturers

| Raw Material | Size of Manufacturer | | Purchase Price |
|---|---|---|---|
| | Small (t) | Medium (t) | (Rs/t) |
| Cast iron | 95.2 | 486 | 4000 |
| High carbon steel | 7.85 | – | 8500 |
| Mild steel | 31.1 | 210 | 7000 |
| Al alloys | 0.07 | 0.35 | 18000 |
| Cu alloys | – | – | – |
| Sheet metal | 18 | 170 | 7500 |
| Wood | 95 | – | 500 |
| Plastic | 0.37 | 1.05 | 30000 |
| Coal | 21 | 40 | 3000 |
| Scrap | 3.4 | 35 | 6500 |
| Spring steel | 20.5 | 200 | 16500 |
| Moulding sand | 14 | 56 | 50 |
| Fire clay | 0.18 | 0.55 | 448 |
| Limestone | 0.37 | 0.65 | 226 |

medium-sized manufacturers complained about lengthy and cumbersome procedures for obtaining import licences and refund of custom duty paid on the import of raw materials used in local manufacture of agricultural machines. Another complaint reported by a majority of the small and medium-units pertain to market price fluctuation and that they were unable to purchase raw materials in bulk or at wholesale prices. Most manufacturers purchased raw materials from the local market as they could not avail of the Government concession for allowing duty free raw materials. These factors resulted in low quality and high cost of locally produced farm machines/implements.

### Manpower

The agricultural machinery manufacturing sector faces a serious shortage of trained manpower due to the continuous exodus of trained personnel, specially to the Middle East countries for better wages and good working environments. The survey shows that 57% of the small- and 75% of the medium-sized manufacturers hired managers in their workshops to look after their business activities. The rest of the firms for both sizes were owner-operated. The percentage of qualified (B.A./B.Com) managers employed by small and medium units were 20 and 25, respectively. The large units however, had qualified managers and they were well trained in marketing, making business and accounting, etc (**Table 5**). The percentage of trained foremen in the small and medium units were only 17 and 25, respectively. This is one of the factors responsible for the poor quality of locally produced agricultural machines/implements. Engineers were rarely employed by small and medium scale units while a few were employed by large manufacturers.

The absence of qualified engineers in agricultural machinery industry is a major factor responsible for poor standard and quality of farm machinery in Pakistan. The average number of workers in small and medium units were 12 and 37, respectively. Out of these 50% were unqualified (less than 5 year experience) and were required training.

Table 5 Employees of Small, Medium- and Large-Scale Manufacturers

| Category | Qualified (%) | Unqualified (%) | No. of Employees | Properly Trained (%) |
|---|---|---|---|---|
| Small units | | | | |
| Managerial | 20 | 37 | 1 | 12.5 |
| Secretarial | 5 | 2.5 | 1 | – |
| Foreman | – | 80 | 1 | 17.5 |
| Engineer | – | – | – | – |
| Workman | 50 | 50 | 12 | 50 |
| Medium units | | | | |
| Managerial | 25 | 50 | 1 | 25 |
| Secretarial | 25 | – | 1 | – |
| Foreman | – | 100 | 1 | 25 |
| Engineer | – | 2.5 | 1 | – |
| Workman | 49 | 51 | 37 | 75 |
| Large units | | | | |
| Managerial | 100 | – | 50 | 100 |
| Secretarial | 66 | 33 | 24 | 100 |
| Foreman | – | – | – | – |
| Engineer | 43 | 57 | 88 | 80 |
| Workman | 77 | 23 | 325 | 77 |

### Financing

The Agricultural Development Bank of Pakistan (ADBP), Industrial Development Bank of Pakistan (IDBP), and almost all commercial banks provided loans to the manufacturers. Some 30% of the small manufacturers obtained loans from different commercial banks and Government loaning agencies, while the rest preferred to obtain loan from relatives and friends. About 75% of the small and 25% of the medium-sized manufacturers cited that the procedures for obtaining loans was intricate. Hence, there is need to simplify loan distribution procedures, particularly for the small manufacturers. The rate of interest charged by the financial institutions varied from 12 to 15% which manufacturers generally considered high.

## Marketing

The marketing of agricultural machinery is an important issue for the agricultural machinery manufacturers. One of the main problems of manufacturers in Pakistan was the lack of market for their agricultural machinery. While potential demand was large, actual sales were low due to a combination of reasons such as lack of: market research, product planning, advertising and sales promotion, after-sale service, and financing.

Some 98% of the small-scale manufacturers sold their products locally. The majority of the medium and large-scale manufacturers partly sold their products in the local market and partly in other markets within the country. The export situation of agricultural machinery is very poor.

### After-Sale Service

The market acceptance of agricultural machinery is greatly dependent on proper after-sale service

Table 6 Mode of Sale of Products of Small, Medium and Large Scale Manufacturers

| Category | Direct sale (%) | Dealer Network (%) | Number of Dealers |
|---|---|---|---|
| Small | 97.5 | 47.5 | 6 |
| Medium | 100 | 50 | 8 |
| Large | 100 | 100 | 45 |

which consists of free essential spare parts, annual maintenance, warranty certificate, operating instruction booklet, parts catalogue and pamphlets. Generally, large tractor manufacturers had well organized dealer networks. All of them provided after-sale services, one after 50 h and the other at 200 h. In fact the amount of commission allowed to them was not enough to cover any other facility beyond these two services. Because of a low commission (Rs. 800-1500/tractor), the dealers could not establish proper workshops. Therefore, they were not in a position to properly take care of the farmers' machinery nor provide advisory service to farmers.

Even as the small and medium scale manufacturers claimed that they provided after sale service to their customers, the latter had to bring their faulty machines to the manufacturers' workshops. Rarely were mechanics deputed to attend to the complaint on the spot. Hence, majority of the customers from remote areas could not avail of the after sale service facilities. Almost all of the manufacturers provided free essential spare parts delivery services.

## Conclusions

1. As the centres of raw material and components supplied for any producer in Pakistan are Lahore and Karachi, it is necessary that both the public and private sector should set up a network of supply and distribution of raw material at least at district level in order to ensure consistent quality of raw materials supply without added transport costs.
2. The majority of the small- and medium-sized manufacturers complained about Government policies regarding raw material supply. It is recommended that government should simplify its lengthy and cumbersome procedures for issuing import licences and refunding of duty paid on the import of raw material use in local manufacturing of agricultural machines.
3. Manufacturers need to set up their production lines and workshop layout according to scientific lines.
4. Training is necessary in the following areas:
   a. Marketing and accountancy for the managerial staff;
   b. Reading/understanding of engineering drawings and other aspects of manufacturing technology for foremen; and
   c. Workers were required to be trained in machinery, fitting, turning, shaper machine operation and theoretical aspects for factory workers.
5. State-owned banks should provide loans at low interest rate and simplify their loan procedures so that small manufacturers could be served.
6. It is necessary for the small- and medium-scale manufacturers to arrange mobile teams (consisting of trained mechanics) in order to provide after-sale service.
7. Manufacturers will do well to carefully evaluate the issue of diversification of their product lines in order to improve their economic viability.

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## ERRATA

Vol. XVI, No. 3, SUMMER 1985, pages 57 and 58

The pertinent words should read as follows:

page 57 – central column, line 25 (agro-climates)

Page 58 – left hand column, line 10 (among)

line 26 (weeds)

central column line 18 (Agro-economic)

Page 57 – left hand column, line 20 should read "been reaching a period of stability."

## REFERENCE ARTICLE

# A Moral Story Handed Down in Europe

by
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A long time ago, when the plow had just started to be used in Europe, a father called his sons to his deathbed and left a will because he felt himself to die soon.

"I burried some treasures in our farming field, dear sons, so why don't you dig them out", said their father and breathed his last. As the sons could not ask their father where those treasures were burried, all of them devoted themselves to dig the big farming fields in several parties from corner to corner deeply using hoes and plows right after the autumnal harvest. However, the treasures were not found.

These sons forgot about the treasures completely, because they were too busy to keep it in mind. Soon after, Autumn had come, they found extremely good harvest unusally in their farming fields. Then, these sons became aware of the meaning of the father's will that the true treasure was "Cultivate the farming field deeply." And these sons really appreciate true love of their father.

*Awarded 4th Grade of Sunrise Prise from the Emperor as the Inventor of Innovative Power Driven Disc Plow.

Rotary Tiller has contributed to the Japanese farming because it saves time covering the cultivation and levelling at the same time. This has made a great role to the development of Japanese Industry transferring farmers' saved surplus of man power from farming areas to industrial areas.

But, on the contrary, we should not forget there were some of exemplary good farmers opposed to the introduction of Rotary Tiller, because these leading farmers were worried about the abuses of Rotary cultivation and future of soil conditions.

On the other hand, the farmers were enjoyed good harvest year by year through the progress of agricultural chemicals, fertilizer, cultivation methods and so forth. This erases the voice of bad influence of Rotary Tiller .

In North America, a large horse power Tractor brought a high productivity of farming. And it encouraged to make the size of a tractor much larger, and farmers tended to use a larger tractor with larger size of tires and it made the machine weight heavier year by year. Suppose these large machines to cultivate the field, levell and harvest for 10 years to 20 years, the soil structure gradually changed through pressing top soil where should be soft and crush capillary tubes and noncapillary pore-space in the tilth. Finally, these soil compressions started from bottom to top of tilth and soil became like a soft stone, and this makes hard to absorb rain water into the under ground. If it rains very heavily, heavy rain water becomes like a river washing off the top of tilth and destroys the farming land. It is said that The United State Government has very difficult time to take the counter measures for this problem.

I would imagine that the crop damage by cold weather and bad water drainage in Japan had been caused by continuous usage of Rotary Tiller occurring accumulated soil deterioration as the pioneering farmers worried about long time ago and insisted on the importance of deeper turning of soil and better water drainage.

The method decides the direction of where to go. If we mistake the direction, we go far, far away from where to go heading to the way where we do not expect as time goes by. It makes too hard

to take the conditions back into proper direction whatever efforts we make so hardly.

The cultivation method of the "Power Disc" is entirely different from the Rotavator. As you may know, the Rotavator runs its r.p.m. high to get centrifugal force to break and till the front soil creating packed wall soil at front by its inertia. If we make the r.p.m. of Rotavator slow, it weakens the cutting power of soil by weak centrifugal force. So that makes naturally the Rotary blades kitting the soil wall standing blocked before front soil wall is crushed. This makes the Tractor unable to go forward, and if we are going to make r.p.m. of Rotavator slower, we naturally need to have larger horse power Tractors.

Then, it requires not only waste of extra horse power, but also it brings decline of soil vitality as well as fertility. Thus, the inferiority of cultivation method could not be adjusted and recovered so easily.

**Ideal Cultivation Method "Power Disc"**

In case of the "Power Disc", the edge of round steel Disc blade is a sharp knife, and the Power Disc gains the weight of the Tractor and Power Take Off shaft drives the Disc blade with high revolution and cut soil to same direction of the Tractor going by with the slippage of Disc blades. It is not necessary to cultivate with high r.p.m. when Power Disc is used because the soil wall is not created like the soil wall stands blocking at the front side of Rotavator. This makes the resistance of cutting power extremely little, and cut in soil very lightly and easily. This is basic reason of Power Disc is ideal method of cultivation.

**The Importance of "Drainage in the Farming Field"**

The soil condition becomes bad caused by poor water drainage and is shut out of capillary tubes. This makes the rain water stop to get into the soil. It is just like we keep fish in a glass container without supplying fresh air to make them die. In the same manner, the plants also require oxygen so that we need to drain the water of under ground in the farming field. In this sense, the Vivro Drainer is the most effective implement to solve this problem. I strongly desire that the soil fertility should be improved by the research of growing bacteria much more in the soil and putting composts into the soil as well as applying the ideal cultivation method of "Power Disc". ■■

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4. Built-in muffler assures good visibility and enables operation under the trees.

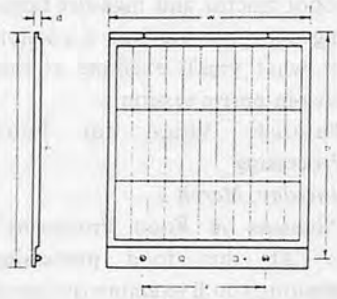
Specification:

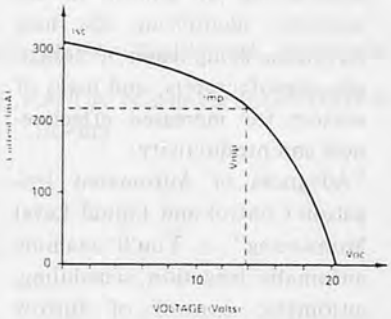
Size (LxWxH):
2 160 x 1 050 x 1 270 mm
Weight: 565 kg
Engine: water-cooled, 4-cycle, 3-cylinder, 855cc, 15.5PS
Speed: 6 forward (1.05–12.51 km/h)
2 reverse (1.47–6.58 km/h)

For further information contact:
Kubota, Ltd.
2-47, Shikitsuhigashi 1-chome
Naniwa-ku, Osaka 556-91, Japan
Tel. 06-648-2125

**Solar Trickle Charger from Chroner TriSolar, Inc.**

Model (MTS-220) harnesses the power of the sun to deliver 220 mA of current at 13.8 V, enough to overcome the self-discharge of the battery, but not overcharge it.






It can be mounted anywhere. It is small, light-weight, and virtually indestructible. Units can be grouped in series and/or parallel to obtain the voltage and current necessary.

It is mounted in a sturdy plastic frame, protecting it from the severe environment. There are no moving parts. The panel will tolerate almost any severe condition. This latest technological development is available for less than $100.00.

[Specifications]

The trickle charger is an amorphous silicon photovoltaic module designed to economically utilize the sun's power to keep a battery fully charged until needed. It is a single glass plate with laser-etched silicon film on the back side. This is packed in a rugged, shock absorbing, weatherproof plastic frame.

Size (HxWxD): 37x37x1.3 cm
Weight: 1.6 kg
Peak power: 3.0 W
Voltage at max. power point: 13.8 V
Current at max. power point: 217mA

For further information contact:
AR Associates, Inc.
P.O. Box 453
Fairfield, CT 06430
U.S.A.

**Monorail MP-1100 – Unmanned Transport for Inclined Field by Monorail Industries Co.**

MP-110D eliminates usual hard labor on a sloping farmland. The railway installation is possible even for steep and/or narrow space where road construction is not feasible. Unmanned operation brings manpower reduction and time saving.

MP-110D is fitted with a stop brake, a downhill brake and an emergency brake. It carries 200kg load at 45° slope. Riding on it is not allowed.

Size (LxWxH): 815x450x780mm
Travelling speed: 40m/min
Weight with engine: 85 kg
Engine:
Air-cooled, 2-cycle, 1-cylinder gasoline engine
Operational power, 3PS/1 845 rpm
Carriage:
Size (LxWxH): 1 150x560x635 mm
Weight: 30 kg

For information contact:
Monorail Industries Co.
No. 440-3, Fukuonji-cho,
Matsuyama-shi 790, Japan

## Storage of Agricultural Durables and Semi-Perishables

(India)

*by R.P. Kachru, B.S. Bisht and R.T. Patil*

Papers contained in this publication have been selected from those presented at the 'Seminar on Scientific Storage of Agricultural Durables and Semi-perishables' held at CIAE, Bhopal in the year 1984 and other technical meetings held in the year 1983 at the same Institute.

The publication comprises papers dealing with multidimensional problems and solutions provided by modern appropriate technologies. Five of the papers deal with rural godowns and their management. Another five analyse the process of deterioration during storage and technologies for arresting it. Importance and techniques of operations like cleaning and grading of agricultural products prior to storage have been highlighted in two of the papers. Two more papers have discussed the problems of biochemical degradation and entomological aspects during storage. Issues related to safe storage of semi-perishables like potato and onion have been covered in three of the papers.

The publication also provides useful information in Appendices by giving names and addresses of agencies in India dealing with R & D, standardisation, policy farming, extension, and administration of extension, and administration of safe storage technologies. Besides, a list has also been given about the names and addresses of manufacturers/suppliers of storage structures and technologies.

Size: 18.3 cm x 24.2 cm, 179 pp, soft cover

Price: Rs. 25.00 or US$20.00 (including postage)

Published by: Central Institute of Agricultural Engineering Nabi Bagh, Berasia Road Bhopal-462 018 M.P., India

## Theory and Design of Animal-Drawn Vehicles

(India)

*by S.D. Deshpande and T.P. Ojha*

This bulletin deals with research and development activities on animal-drawn vehicle transport in general and bullock cart in particular. Theoretical information on various aspects supported with practical design background has been given in detail. The complete volume has been divided into 10 chapters covering review studies, design of different components of bullock cart, sample test proforma, economics of operation of bullock cart, energy requirement for transport, manufacturing technology in cart operation.

General aspects such as standard terms and definitions related to rural transportation, addresses of component manufacturers of farm transport devices and addresses of institutions engaged in R & D of animal-drawn vehicles have also been covered.

Size: 30.5 cm x 20.5 cm, 73 pp, soft cover

Price: 18.00 + Rs. 5.75 postage charges, US$8.00 (including air postage)

Published by Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal 462018 (M.P.), India

## Vehicle Traction Mechanics —Developments in Agricultural Engineering, 3—

(The Netherlands)

*by R.N. Yong, E.A. Fattah and N. Skiadas*

The fundamental problem in the study of vehicle mobility is the development of traction between the vehicle and the supporting terrain. The mechanics of energy transfer will essentially control the final performance of the surficial machine. Determining and predicting the capability of a particular piece of machinery to traverse successfully a specific piece of terrain is a very complex one, particularly as the characteristics and properties of different types of terrain and terrain cover vary considerably, as do the many types of vehicles and their running gear.

The material that forms the basis of this book has been gathered over many years of study both in the laboratory and in the field. It studies vehicle traction mechanics from the viewpoint of the interaction between the vehicle and the ground surface. The types of machines covered include earth-moving, forestry, agricultural, and construction machines. In addition, the mechanisms involved in the development of traction and the working of the terrain through cultivation, construction, and surface disturbance are examined. The book also addresses the problems of off-road mobility and terrain trafficability, especially from the terrain-support and terrain interaction points of view. It is the author's aim that the book will provide the reader with the ability to both analyze and predict the traction capability of his proposed

machinery, and also to anticipate the kinds of reactions that will occur in the ground and at the ground surface.

Contents: Chapter 1. Introduction. 2. Terrain Material and Interface Reaction. 3. Mobility Elements and Requirements. 4. Analytical Methods. 5. Mechanics of Energy Transfer. 6. Finite Element Modelling. 7. Application of Finite Modelling. 8. Compaction. 9. Trafficability.

Size: 25 x 17 cm, 308 p, hard cover

Price: US$71.25/Dfl. 185.00

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

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## Bibliography—Drip/Trickle Irrigation (Supplement)

(U.S.A.)

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*by Megh R. Goyal and Luis E Rivera*

Drip irrigation is the application of water through outlets in low pressure hoses (called drippers or emitters) placed close to the crop in small amounts on a daily basis. The drip irrigation is also called trickle-, high frequency-, daily flow-, diurnal-, tension-, capillary-, continuous moisture-, point source - irrigation. There is no difference in the concept these names represent.

This volume supplements "Bibliography - Drip/Trickle Irrigation by Megh R. Goyal", NAPA Bulletin No. 3 and AES-UPR-RUM No. 1175 published by National Agricultural Plastics Association, Maryland, U.S.A. NAPA Bulletin No. 3 included 1000 bibliographical references, author index, subject index and list of manufacturers/suppliers of drip irrigation materials. Most of the information in this report was collected from the following publications: Biological and Agricultural Index; International Irrigation Information Center's Annotated Bibliography; Cooperative Regional Research Project Outline S-143 and W-128 by USDA-SEA. Author claim that the list is now complete till 1980 and would welcome suggestions for additional bibliographical references which will be included in Volume II.

Size: 27 cm x 21 cm, 52p, soft cover

Price: US$6.00

Published by College of Engineers and Surveyors of Puerto Rico G.P.O. Box 3845, San Juan, P.R. 00936-3845, U.S.A.

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## Energy Use and Management in Agriculture

(U.S.A.)

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*by B.A. Stout*

The author very capably met his objective of analyzing the energy situation of U.S. agriculture and making it understandable by an audience of people with widely different academic backgrounds. A highly technical background is not needed to comprehend the material. It is organized with problems, discussion issues and references at the end of each of its 7 chapters. The problems are sufficiently challenging for college level use. It is written in a style that is interesting and easy to read. Although it is particularly directed to students and farm advisors in agricultural production and mechanization, farmers, themselves, and various groups of energy policy makers will find the book to be very useful.

The contributions of several academic and industrial experts were brought together in a cohesive text that has the continuity of a single author presentation. Data are accurate, up-to-date, and very germaine. Focus is on issues rather than specific interests of individual contributors. The sources of information are well documented. The book can be used as a handbook on current sources of U.S. agricultural energy, agricultural energy usage, and technologies for the derivation of alternate energy supplies from agricultural products. A comprehensive index is provided to assist in this search.

The concluding chapter identifies key events, government agencies that have responded, and kinds of responses that have been made by both government and private sectors. An outline of future energy policy for the food system as formulated by the 1977 Asilomar Conference in California should help students and future decision makers understand the complexity of solutions. It is only one of many future policy recommendations that have been developed but it adequately serves an instructional purpose. The energy situation is ever changing and recommendations can be expected to change accordingly. The author recognizes this turmoil with the statement that the politics and economics of energy are much more volatile than the technical and engineering aspects – and the technologies for alternatives to petroleum are continuously being altered.

Overall, the subject of the U.S. agricultural energy situation is accurately and clearly presented with unbiased discussions of various positions that have been posed by various pro and con special interest groups.

318 pp, Price: US$24.95

Published by Breton Publishers, North Scituate, Massachusettes U.S.A. ■■

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e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
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g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5kg/ha instead of 45.4762kg/ha.
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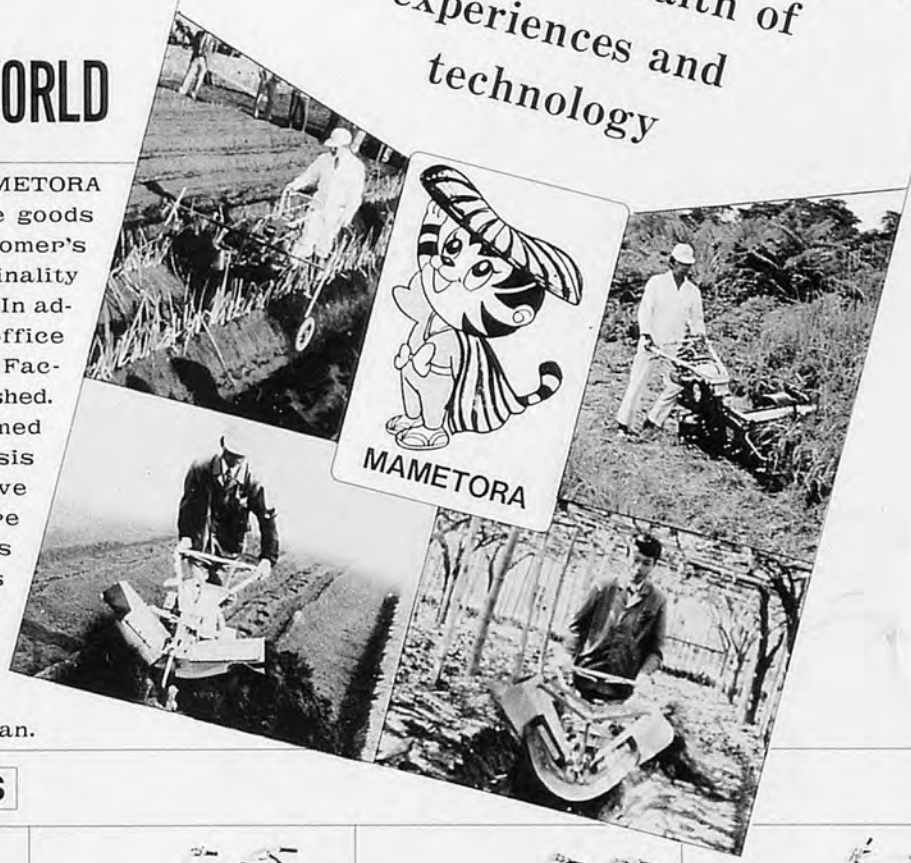


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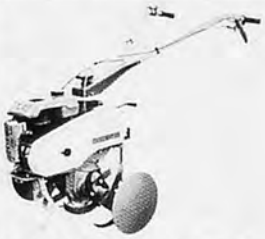

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