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# AMA

**AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA**

VOL. XIV, NO. 1, WINTER 1983

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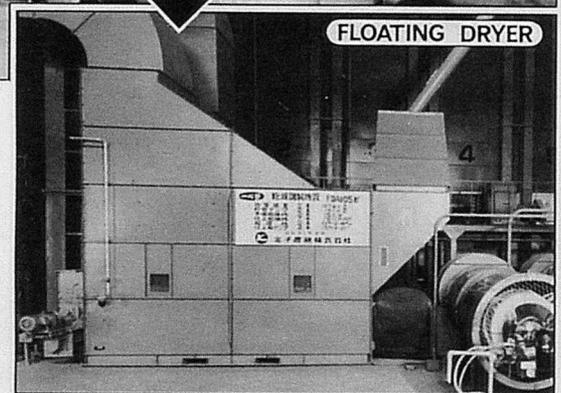
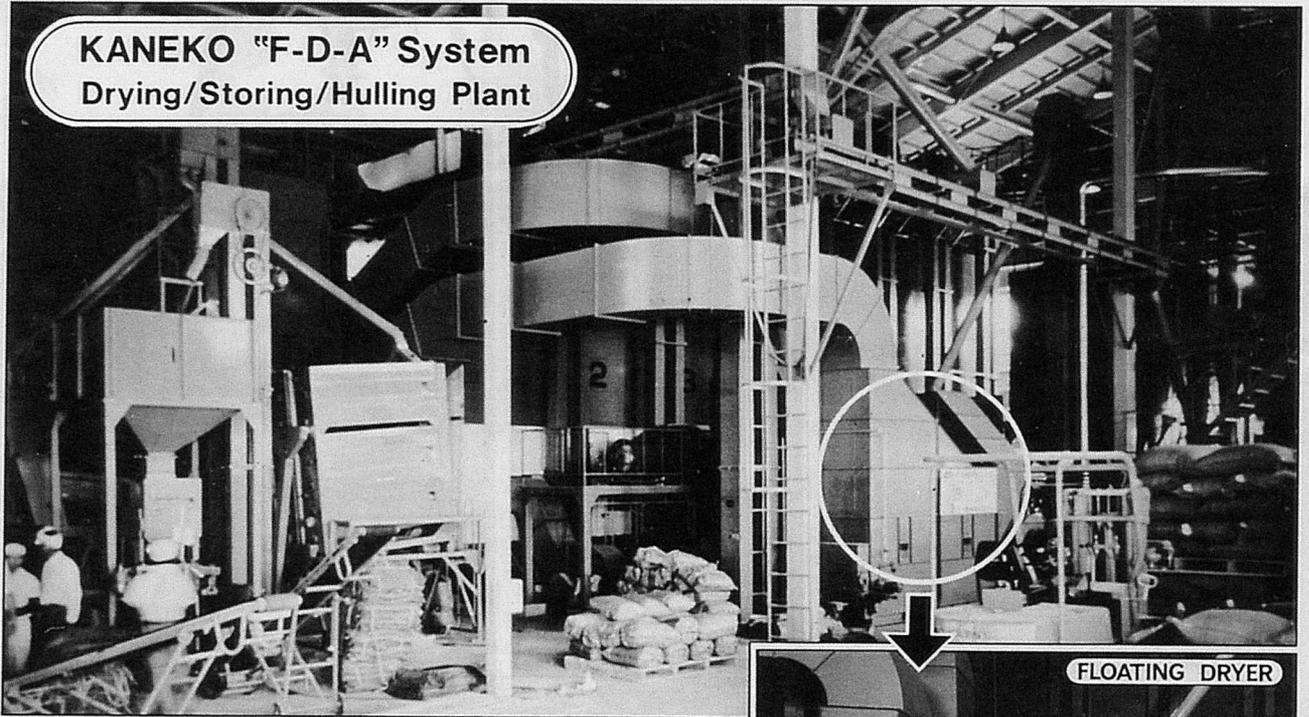
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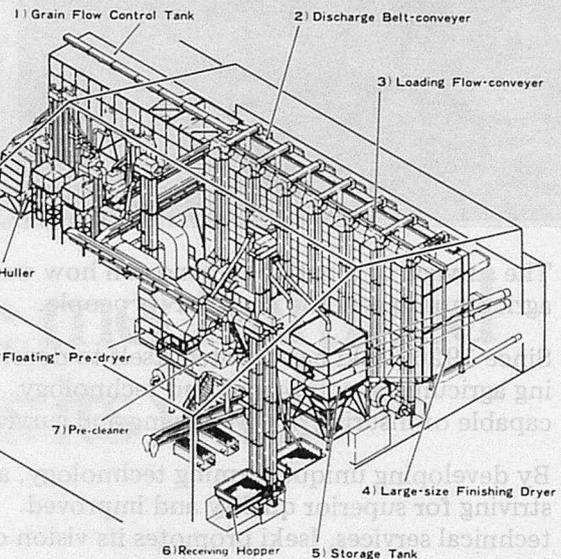
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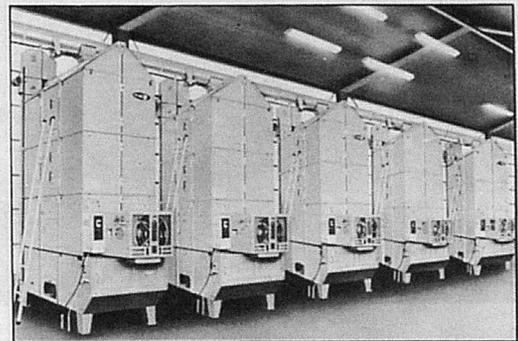
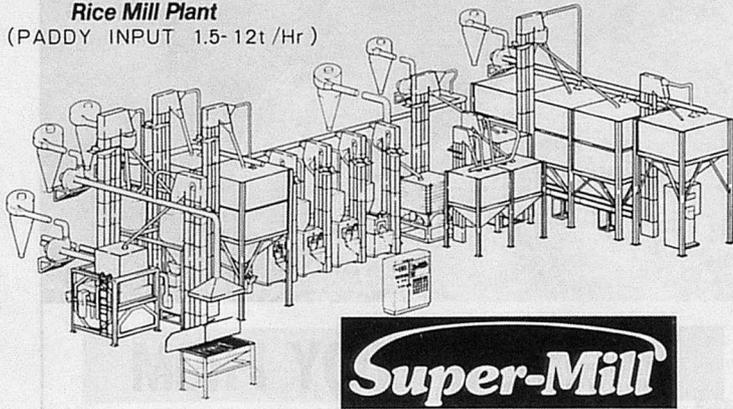
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This is the 38th issue since the issue, Spring of 1971.

## EDITORIAL

### Need for Reinforcing Communications Activities

The AMA management wishes its readers and friends continued success and happiness throughout the New Year!

As the AMA enters its 13th year of publication this year, acknowledgement is hereby made of the support and assistance that it has since been receiving from subscribers and friends during the past 12 years, particularly from its current number of 48 co-editors representing 38 different countries.

The United Nations has designated 1983 as the *Year of Communications* under which umbrella the AMA pledges to reinforce its communications activities in the promotion of agricultural mechanization — not only in Southeast Asia where it made its debut in April, 1971 — but also in all of Asia, Africa, the Americas and European countries. Without doubt, remarkable progress in agricultural mechanization has been already achieved in many countries: developed and developing. In North America, for instance, a mammoth 1,000 hp tractor is being manufactured on a trial basis, or, many new tractor models produced in many parts of the world have begun to utilize electronic computers to improve their efficiency.

But in the face of these achievements, it is rather ironical that the gap between developed and developing countries, or, between oil-exporting and oil-importing, developing countries, has hardly improved or narrowed down. The implication of this irony is that the least developed or developing countries continue to lag behind amidst progress in developed countries. The AMA has since maintained the view that progress in agriculture and agricultural technology has a major role to play in narrowing down this gap. And such progress needs to be accompanied by some government-inspired pricing mechanism for agricultural products in favor of the farmers such as those observed in Japan, the Republic of Korea and Republic of China.

The AMA for its part, shall carry on with its avowed objective of disseminating agricultural mechanization technology. In doing so, plans afoot in 1983 call for strengthening its link, through reinforced communication activities, with an even greater number of agricultural mechanization experts.

Chief Editor

Yoshisuke Kishida

January, 1983

Tokyo

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# Systems Engineering in Precision Automatic Transplanting



by  
**Barney K. Huang**

Professor  
Department of Biological and Agricultural Engineering  
North Carolina State University  
Raleigh, NC 27650, U.S.A.

## Introduction

Plantbed and field transplanting operations are among the last few farming practices in modern agriculture to resist mechanization. Although the need for mechanizing these traditional labor intensive operations has long been recognized, practical solutions to their mechanization problems remain to be developed. In the past 20 years there have been breakthroughs in the mechanization of harvesting, post-harvest handling, and curing and drying operations for most horticulture and field crops. By contrast, the propagation and transplanting of bare root plants with hand or mechanical setters is still common for obtaining a stand of tobacco, rice, tomato, celery, onions, melons, cabbages, and deciduous and coniferous trees in even the highly mechanized parts of the world. Today the propagation and transplanting of bare-root seedlings of the crops described above are the most labor-intensive operations on the farm.

For various reasons direct efforts at mechanizing hand operations in plant propagation and field trans-

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planting of bare-root plants have not resulted in viable solutions. Principal among these reasons is that seedlings of many species are extremely tender, and handling them without damage becomes a problem.

Container-grown plants offer advantages in (a) mechanical handling of the propagation of seedlings and automatic transplanting; (b) control of the plant growth during propagation; and (c) the survival and growth of the plants following transplanting (Palmer and Wilton, 1962; Cannell et al., 1966; Huang and Splinter, 1968; Huang, 1971; Morrison and Yoder, 1975; South, 1975). A further important advantage to the manufacturer of equipment and the producer is that the same basic transplanter can be used for all containerized plants regardless of specie, although there may be minor modifications and provisions for operation in various row configurations with specialty crops and for operations on rough terrain in the case of trees.

The development of an automatic transplanter has enhanced the feasibility of the container-seedling system of plant propagation and transplanting. Prototype one-row and two-row multiple drop automatic transplanters have been designed to place potted plants at predetermined intervals in the field

(Huang and Splinter, 1969). The economic production of a large number of uniform potted plants and efficient handling and transferring them to automatic transplanter had been major problems. New concepts in the design of trays and procedures for handling them were developed and provided a practical solution for the handling and transferring of containerized seedlings to the transplanter (Huang 1973). Automated methods for producing intact-root seedlings under a controlled greenhouse environment were studied for tobacco, tomato, lettuce, celery, onion, deciduous and coniferous trees. A remarkably high germination and survival rates were obtained for those intact-root seedlings with a high degree of vigor, uniformity and reliability (South, 1975; Huang, Bowers and Oppenheim, 1979).

The purpose of this paper is to show the feasibility of mechanizing the container-grown plant system into an efficient on-the-farm practice with its inherent advantages to producer and manufacturer in (a) shorter growing time for plant propagation; (b) easier handling and greater uniformity of seedlings grown under controlled environments; (c) easier handling of seedlings on the automatic transplanter; (d) reduction

of shock and improved performance of the intact-root system following transplanting; and (e) number of crops a single basic machine can successfully transplant. It illustrates the effort to accomplish the system engineering of the total cultural operations from plantbed preparation, seeding, seedling handling, to field transplanting, by integrating these operations into a highly efficient system for practical application.

### Seedling Growing and Handling System

The utilization of container-grown seedlings in conjunction with proper handling and transplanting techniques offers definite advantages in reduction of labor for total mechanization, efficient use of plantbed space, and undisturbed

seedling roots for healthy growth as compared to the conventional method. However, the use of container-grown plants involves many economical, physiological, and engineering problems such as container cost, efficient means of seeding, germination, emergence, uniform growth of seedlings, growth media, root development, moisture control, efficient means of removing containers, use of degradable containers, handling of individual seedlings, optimum container shape and size, etc. After extensive research into the above indicated problems and into their possible solution, a seedling growing and handling system was developed (Huang, 1973). The device also contemplates the automatic transplanting of the seedlings to achieve the systems engineering of the cultural practices.

The seedling growing and handling system consists of multi-opening seedling growing and handling tray and a transfer plate as shown in Fig. 1(a). The tray can be made from a thin plastic sheet or metal foil at such a low price that it can be either reused or discarded. The tray consists of many conically shaped or pyramid shaped pots tapered upwards with both ends open. Since the plant roots develop toward the bottom of the pot, a larger bottom not only provides a more desirable shape for root growth but also permits a potted plant to drop out easily at the time of transplanting as shown Fig. 2(c). This pot-shape seedling container also reduces the exposure of growth media to the atmosphere so that the moisture loss can be reduced.

Growing and transplanting seedlings involves: (a) filling the plural

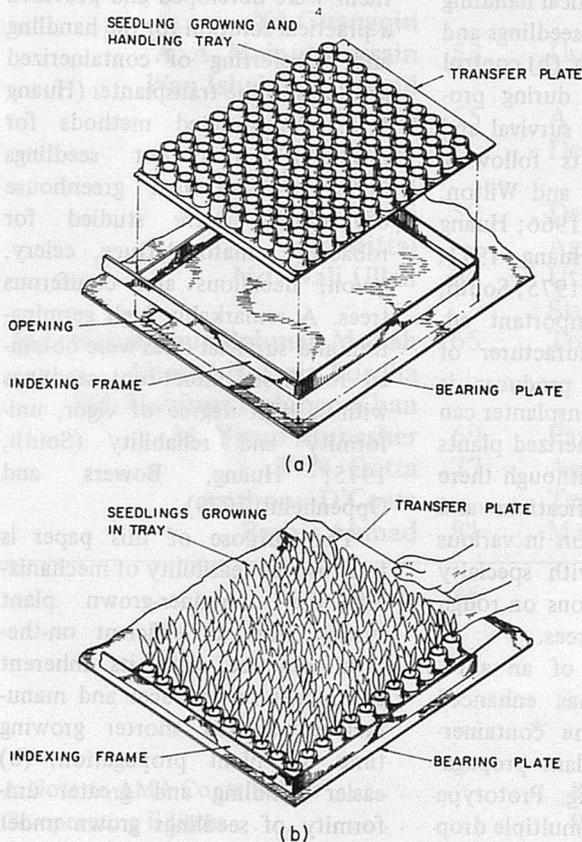


Fig. 1 Seedling growing and handling system: (a) Tray and transfer plate with indexing frame and bearing plate of automatic transplanter; (b) Seedlings and tray are being transferred into indexing frame.

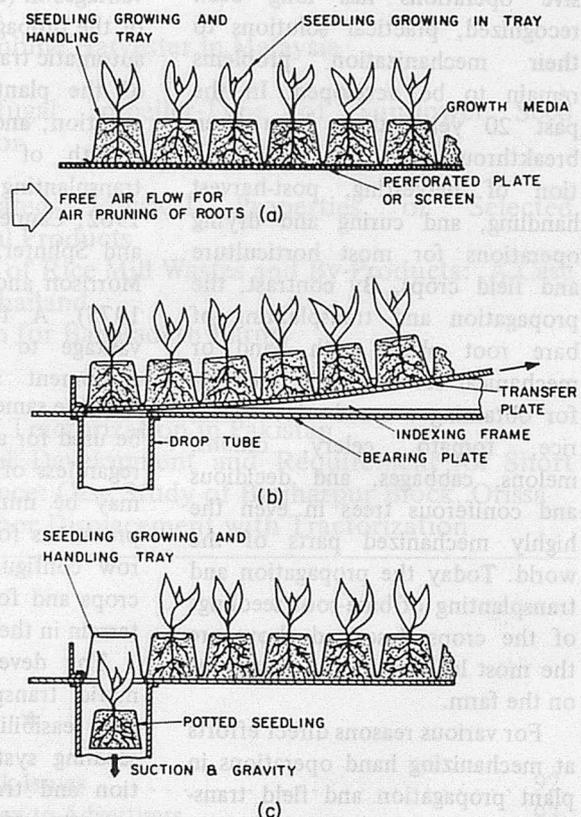


Fig. 2 Operational principle of seedling growing and handling system: (a) Cross sectional view of seedlings, tray, and perforated plate showing air pruning of roots; (b) Removing of transfer plate on transplanter; (c) Pulling and feeding of seedlings.

openings in the growing and handling tray with a growth medium such as soil mix, peat mix, vermiculite mix, growth cubes, etc.; (b) planting a seed in the individual opening or placing a pre-seeded growth medium in each opening; and (c) providing an environment conducive to seed germination and plant growth. The trays are preferably laid on a perforated plate or screen so that air pruning of roots can be performed naturally as shown in Fig. 2(a). At the time of transplanting a transfer plate is inserted under the tray and the tray is transferred to the indexing frame of the automatic transplanter by pulling out the transfer plate as illustrated in Figs. 1(b), 2(b) and (c). The tray is progressively shifted by the indexing frame of the transplanter longitudinally and laterally in increments equal to the pot distance. As each potted seedling is indexed over an opening in the bearing plate, it drops to the ground through a drop tube by gravity and with the aid of suction force. Thus, the potted seedlings in the tray can be planted directly at the rate of travel of the transplanter and the plants may be systematically planted at predetermined spaced intervals.

Field tests and observations showed that the seedling growing and handling system achieved the following results:

1. Provided a means of producing a large number of relatively uniform potted plants. The uniformly sized individual root zones allow the seedlings to grow more uniformly throughout the plantbed by restricting root-system expansion of larger plants to slow down the growth since all plants tend to maintain their proper shoot-root ratio.

2. Provided efficient and minimum use of plantbed space for the maximum number of seedlings. For example, only 20% as much plant-

bed area is needed for tobacco as compared to the conventional plantbed which requires about 100 sq yd (83.61 sq m) of plantbed area for planting one acre (0.4047 ha) of field tobacco.

3. Eliminated the laborious operation of pulling the seedlings from plantbeds and reduced labor requirements in the plant handling operations to a minimum since pulling is done automatically on transplanter at the time of transplanting.

4. Reduced moisture loss of potted plants in plantbeds by reducing the exposed surface of growth media. This in turn resulted in 2° to 3°C higher temperature in the growth media and root system giving better plant growth compared to conventional plantbeds, flats and trays (Huang and Chang, 1970).

5. Provided a seedling with efficiently shaped intact root zones. The seedlings could easily be removed from the larger bottom of the container just before transplanting. The intact root system once transplanted fanned out to insure good ground contact for excellent survival rates and good growth with minimal shock (Huang 1971).

6. Adapted to various types of growth media so that cuttings of many varieties of plants could be started. The pyramid or cone design of the tray provides good root orientation for future growth and air pruning effect at the open bottom prevents the roots from tangling thus providing better growth than conventional trays.

7. The adaptation of seedling growing and handling system to the automatic transplanter was accomplished which resulted in simplification of automatic transplanter and in improvement of the operational efficiency.

Fig. 3 shows tobacco seedlings growing in the trays ready for transplanting. The individual seedlings

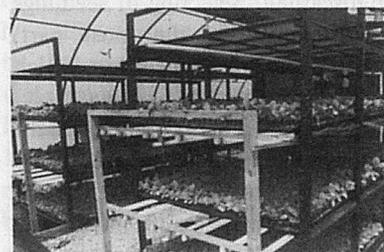


Fig. 3 Tobacco seedlings growing the trays in multiple tiers under controlled environment.

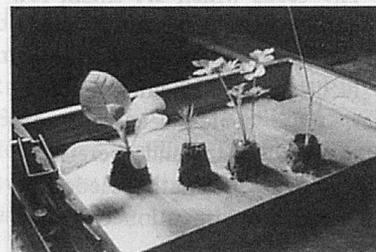


Fig. 4 Individual seedlings of tobacco, pine, celery, and onion (from left to right).

of tobacco, pine, celery, and onion are respectively shown in Fig. 4 from left to right.

### Automatic Precision Seeder

The seedling growing and handling system has made it possible to successfully overcome the major difficulties in plantbed and handling for a system operation. However, in order to grow a larger number of uniform potted plants economically, a grower also needs an automatic precision seeder which is efficient and reliable, high in seeding speed yet simple in design, durable in construction, and reasonably low in price for farm use.

Many of the important vegetable and field crops have small and irregularly shaped seeds. The common practice is to use either hand or broadcaster to release much more seeds than actually required for the crop stand. Only a small percentage of the emerging plants are selected for crop stand or transplanting to the field. The excess plants must be thinned

or discarded. Selecting of seedlings or thinning, for the most part, has been a hand operation which requires much labor. For example, a tobacco seed is extremely small. The preparation of conventional tobacco plantbed follows above mentioned practice and, in general, only about 5 to 10 percent of the total germinated plants are used for transplanting to the field.

The seeds which are small, low in density, and irregular in shape, can be coated into a spherical shape to facilitate seed singulation. However, these coated seeds are still very small in size and there is no satisfactory automatic seeder to meet the above mentioned qualifications.

The automatic precision seeder developed for the precision seeding consists of a seeder unit, metering mechanisms, drop tubes, and supporting frame as shown in Fig. 5. Since the seeder is simple and lightweight, it can be carried to the seedbed for hand operation or can be incorporated with a seedling growing and handling tray conveyor for continuous operation.

The seeder unit consists of three seed plates, hopper, and seed buffer. The operational principle is illustrated in the cross sectional view. Each seed plate is made of metal, plastic, or similar material with the thickness a little larger than seed diameter. A number of seed holes with the diameter a little larger than seed diameter are distributed on the plate as shown in the cross section of seed plates. The number of seed holes should be equal to the number of pots to be seeded at a time. The distribution pattern of seed holes on each plate should be identical. Plates 1 and 2 are movable while plate 3 is stationary. As the metering mechanism is activated the motion of plate 1 with respect to stationary seed buffer facilitates filling the seed holes of plate 1 with seeds. Plate 1 is then moved to a pre-

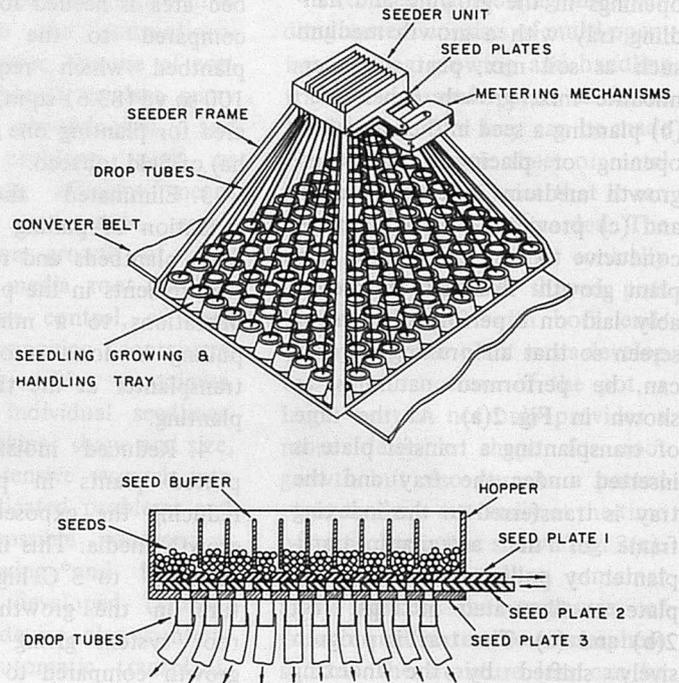


Fig. 5 Design and operational principle of automatic precision seeder.



Fig. 6 Prototype automatic precision seeder and seedling growing and handling trays.

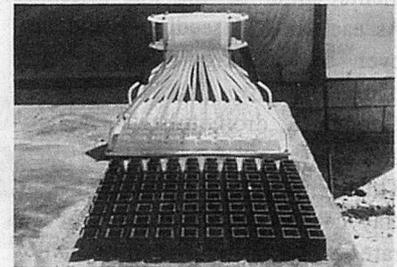


Fig. 7 Commercial version of automatic precision seeder and seedling growing and handling tray.

determined distance to match the holes on plate 2 for filling the seed holes. The mechanism then starts to move plate 2 to match the holes of plate 3 transferring the seeds so that the seeds drop through individual drop tubes to each pot. Finally, both plates 1 and 2 are automatically returned to their initial positions for the next operation. Both laboratory and field tests showed that the device was mechanically simple and provided a practical means for precision batch-singulation of seeds and placing of seeds in multiple-pots, trays, or seedbed to achieve the following objectives.

1. Performs precision batch-

singulation of a large number of seeds in one cycle prior to their placement in the growth media.

2. Combines the advantages of continuous and batch handling system to increase seeding speed, accuracy, dependability, and efficiency for total system operation.

3. Provides simplicity, durability, and economy, and is therefore, adaptable to both hand or power operations.

The average seeding performance for the prototype seeder was 98.6% with 0.05 level of significance. Figs. 6 and 7 show the prototypes and commercial versions of automatic precision seeder and seedling growing and handling

trays, respectively.

### Environmental Control for Seed Germination and Plant Growth

A seed is a potential plant living in the seed coat with stored food and awaiting favorable environmental conditions for germination and growth. The individual seeds within a lot differ in physical and physiological quality which affects germination, emergence, stand establishment, seedling mortality, plant growth and development. The microenvironment of the seedbed influences the responses of seed and the plants produced therefrom. The problem is further complicated due to the interaction of the physiological factors and the levels of environmental factors in the seedbed (Huang and Chang 1970).

Healthy seedlings of uniform size are required for transplanting in order to produce a uniform stand in the field. Since unfavorable environmental factors that place a seed-plant-growth system under stress can affect its growth performance and the microenvironment in the plantbed is unpredictable, it is desirable to control the environment to avoid any adverse effects. Basic and applied research on seed-plant-growth dynamics has shown the importance of an optimal seedbed environment for controlling the growth and time factors in the system engineering of plant production. Taking tobacco production as an example, the conventional practice is to seed early in mid-winter when low air and soil temperatures are the limiting factors in germination and growth of seedlings. Germination is sporadic and the growth is slow and non-uniform. Therefore, it is essential to determine the optimum environmental conditions for germination

and growth, including the effects of weather related variables. Growth chamber and greenhouse tests indicated that a uniform stand of plants can be obtained under controlled environmental conditions (Huang 1969). It has also been shown that under controlled environmental conditions, the growth period needed to produce seedlings of the proper size for transplanting can be reduced to less than half of that under the natural environment, thus reducing weather-induced hazards and increasing management efficiency. As shown in Fig. 3 close control of environmental factors has resulted in achieving excellent germination

rates of 97% and producing a fairly uniform stand of potted plants in the seedling growing and handling trays in multiple tiers of seedling production (Huang and Bowers 1976, 1978). Study on environmental control using a greenhouse bulk curing solar barn (Huang, et al. 1975) has also shown many advantages in providing optimal microclimate conditions in the plantbed, such as reduced risk to plantbed diseases and insect damages, and timeliness and controlled date for transplanting. South (1975) has established uniform tree seedlings (sycamore and sweetgum) in the seedling growing and handling trays under controll-

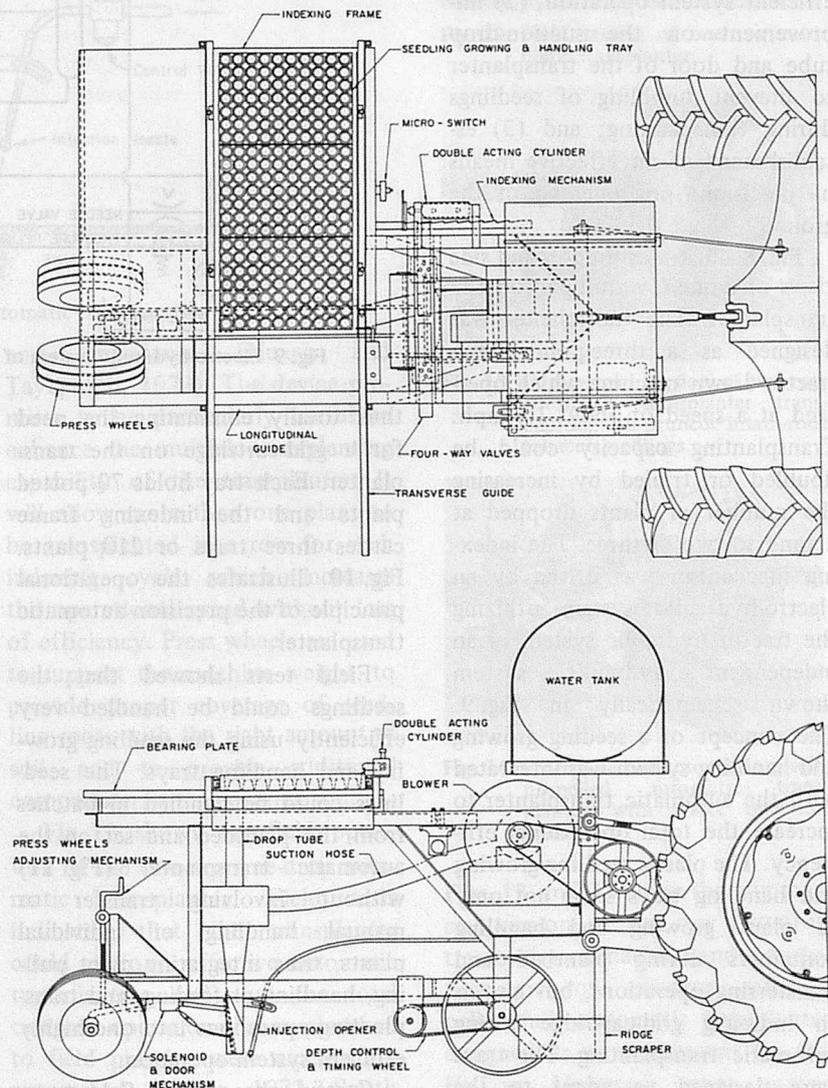


Fig. 8 Top and side views of one-row automatic transplanter.

ed environmental conditions and demonstrated the above-mentioned advantages.

### Precision Automatic Transplanter

Field performance attained with the one-row and two-row single and multiple drop automatic transplanters established the basis of fully automated transplanting using potted plants. Further research was carried out to provide technical improvements in the following areas: (1) integration of seedling pulling and handling with automatic transplanting for a more efficient system operation; (2) improvement on the suction-drop tube and door of the transplanter to prevent tumbling of seedlings during transplanting; and (3) establishment of an effective means of precision spot opening of the ground.

Fig. 8 illustrates the top and side views of a one-row, fully automatic transplanter. The transplanter was designed as a three-point hitch tractor-drawn machine which operated at a speed of about 1.5 mph. Transplanting capacity could be doubled or tripled by increasing the number of plants dropped at a time to two or three. The indexing mechanism was driven by an electro-hydraulic system utilizing the tractor hydraulic system or an independent hydraulic system shown schematically in Fig. 9. The concept of a seeding growing and handling system was integrated with the automatic transplanter to increase the total operational efficiency. The plastic seedling growing and handling trays serve not only as plant growing and handling containers during plantbed and transferring operations, but also as an indexing grid-cartridge during automatic transplanting. The trays were designed to adapt to the indexing frame of the transplanter

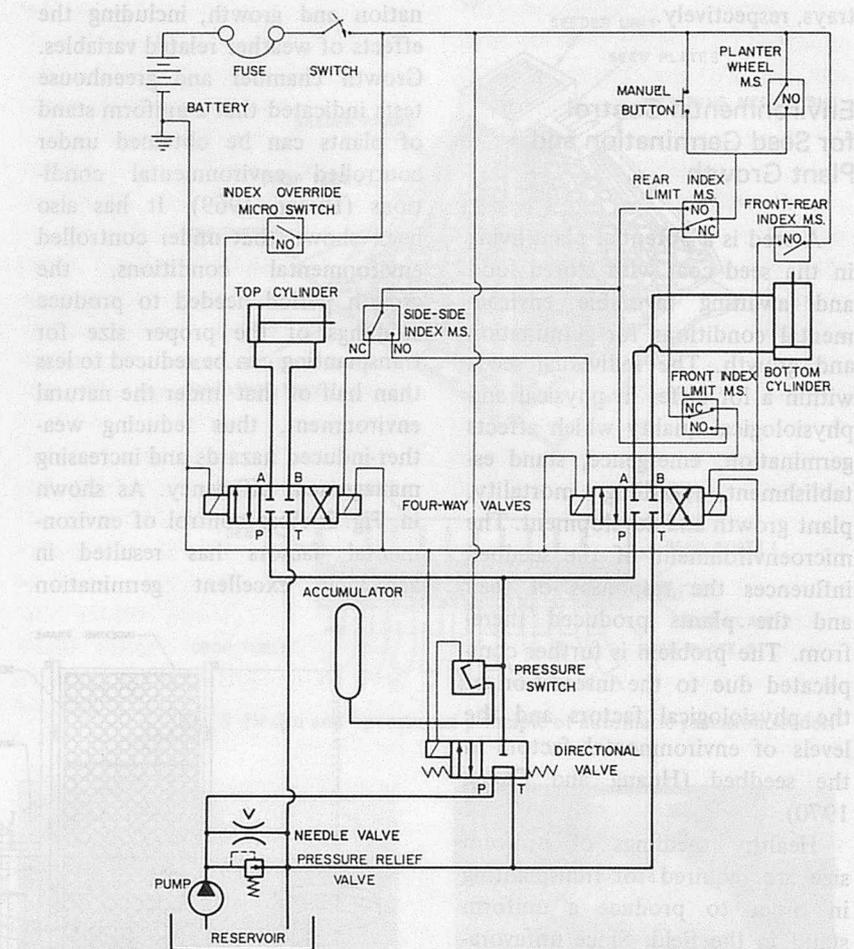


Fig. 9 Electro-hydraulic system of automatic transplanter indexing mechanism.

thus totally eliminating the need for a grid-cartridge on the transplanter. Each tray holds 70 potted plants and the indexing frame carries three trays or 210 plants. Fig. 10 illustrates the operational principle of the precision automatic transplanter.

Field tests showed that the seedlings could be handled very efficiently using the seedling growing and handling trays. The seedlings could be handled in batches from the plantbed and set on the automatic transplanter (Fig. 11) without involving transfer or manual handling of individual plants, thus integrating plant pulling, handling or feeding, and transplanting operations into one highly efficient system operation.

Careful observation, field tests, and high-speed movie analysis

indicated that any tumbling of a potted seedling during transplanting was closely related to the design of the suction-drop tube, the hinged door at the end of drop tube and the physical dimension and shape of the ground opening. Fig. 10 illustrates the cross-sectional view of the improved suction-drop design, its door mechanism, and the water injection spot opener. The hinged door is normally tightly closed due to the suction in the tube. The key improvement was to design the drop tube to match the size of pot without much air gap between pot and tube, so that suction force could effectively shoot the potted seedling onto the ground thus eliminating tumbling and obtaining of close contact between plants, roots and ground. As the indexing frame

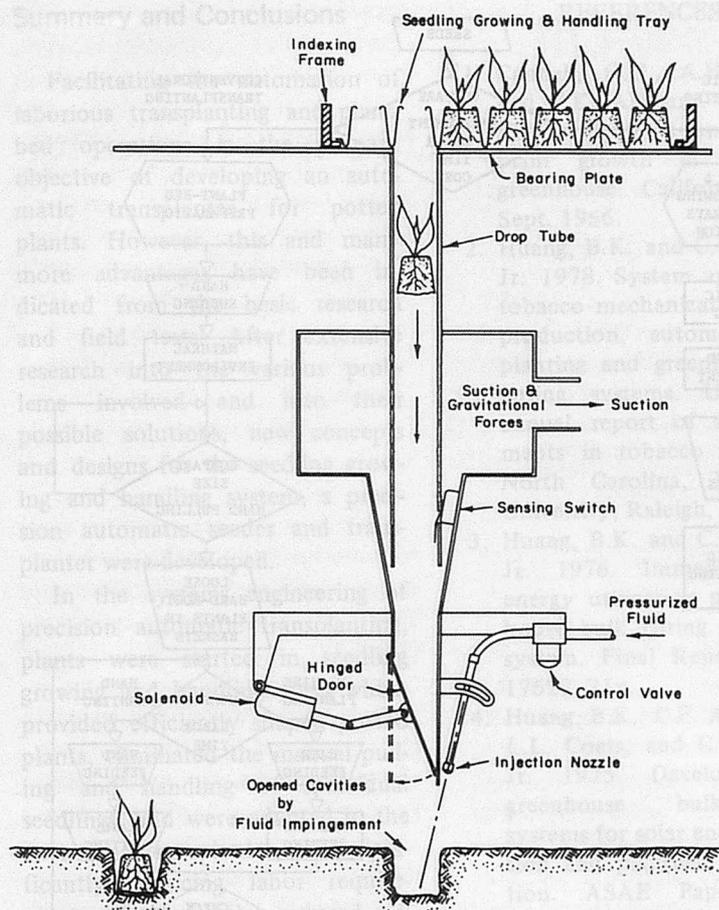


Fig. 10 Operational principle of precision automatic transplanting.

matches a potted seedling in the tray-cartridge to the tube opening in the bearing plate, the potted seedling is instantly pulled out from the bottom side of the tray and partially releases the suction in the tube. As the dropping seedling touches the sensing micro-switch or photo-senser, it instantly activates both the door opening solenoid and the water injection spot opener. This allows the injection opener to form a cavity in the ground with precise timing, and at the same time the open door allows the seedling to drop into the opened cavity, thus achieving precision transplanting. The opened door is automatically closed by the suction.

The water injection opener was found in later tests to be a very simple and effective means for opening the ground and provides improved soil moisture, aeration

and impedance (Huang and Tayaputch, 1973). The device promises to be particularly useful to enhance the multiple-transplanting capability of the transplanter. It will allow more than one plant to be transplanted in a row for each indexing cycle which increases the operational speed without loss of efficiency. Press wheels are used to support the machine weight, to provide proper coverage of seedling roots with the right amount of soil, and to provide additional compaction to the covering soil.

Fig. 12 shows the field operation of the one-row one-drop automatic transplanter. Field tests indicated that the transplanter could perform effective automatic transplanting and that the total cultural operations from plantbed to field planting were successfully automated (Huang 1972, South 1975, Huang and Bowers, 1978).

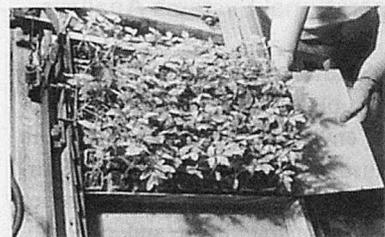


Fig. 11 Setting tomato seedlings and tray on automatic transplanter.



Fig. 12 Field testing of one-row automatic transplanter.

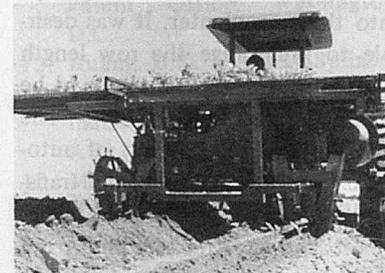


Fig. 13 Commercial version of two-row automatic transplanter transplanting air-pruned intact-root tobacco seedlings.

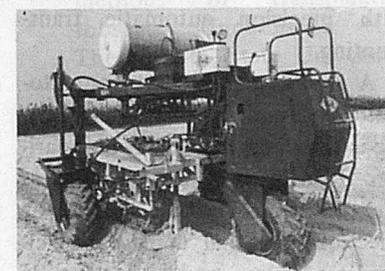


Fig. 14 Prototype two-row six-drop self-propelled automatic transplanter with water injection openers.

Figs. 13 and 14 show the commercial version of two-row two-drop tractor-drawn machine and a prototype two-row six-drop self-propelled fully automatic transplanter designed as an attachment for the Hi-Trac Universal prime mover (Powell Manufacturing Co.).

## Operational Systems Analysis

Studies of the plantbed operation, plant-growth dynamics, optimal environmental control, and the transplanting operation have furnished information on the proper growth media, plant and pot size, temperature and moisture control, fertilizer placement, and transplanting techniques to produce uniform stands of field plants without need for replanting (Huang 1969, Huang and Chang, 1970, Huang 1971). Careful evaluation of the operational parameters and requirements identifies the most efficient and economical production system. The prototype automatic transplanters were operated using a driver and two men to supply and load the seedling growing and handling trays onto the transplanter. It was desirable to prearrange the row length so that the tray-cartridges could be loaded at the ends of rows. The total systems engineering of automatic plantbed, handling, and transplanting operations has been tested for tobacco and tree seedlings from plantbed preparation to field growth. The results of these tests demonstrated that successful systems operation can be achieved with precision automatic transplanting.

A flow process chart for automatic and conventional transplanting is shown in Fig. 15 for comparison. Transplanting any crop faces the problem of labor, equipment selection, seasonal acreage capacities, scheduling and the costs of selected methods of transplanting. Tobacco is a crop requiring a large amount of manual labor in the stages of plantbed preparation, seeding, care of the plantbed, plant selection and pulling, handling, and hauling plants, hauling water, and transplanting-replanting. In the economic analysis of five mechanical methods of transplanting tobacco (Mundy 1970) careful comparison was made between

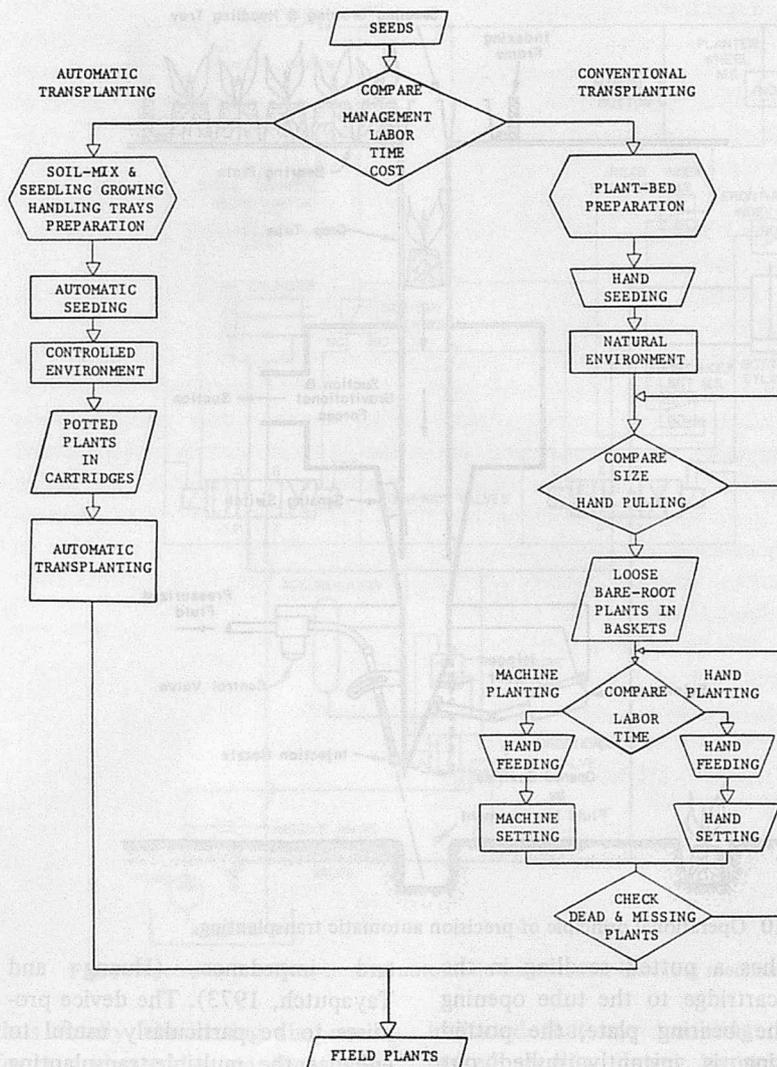


Fig. 15 Flow process chart for transplanting operations.

automatic and conventional transplanting. The activities chosen for labor and cost analysis in the study included all the above-mentioned stages. The procedure involved description, collection, computation, and analysis of the labor and machine requirements and costs of the activities. Two-row fully automatic transplanter with conventional furrow opener and two-row conventional semi-automatic transplanter were compared for labor requirements for various activities. Labor requirements for each machine were adjusted where needed to a common 6500 plant per acre population. Requirements per unit of output

for various operations in man-hours per acre for automatic vs. conventional were; 3.2 vs. 15.1 for plantbed preparation, seeding and care; 0.6 vs. 12.5 for lifting trays vs. pulling plants; 1.1 vs. 1.1 for hauling plants; 0 vs. 1.9 for hauling water; 0.74 vs. 0.40 for loading plants; 0 vs. 0.39 for loading water; 0.38 vs. 3.75 for transplanting in row; 0.10 vs. 0.56 for turning machine; 0 vs. 7.5 for replanting. These data suggest that the automatic transplanting system offers an opportunity for a significant reduction of labor requirements, where production bottlenecks exist in the current practice of tobacco production.

## Summary and Conclusions

Facilitating the automation of laborious transplanting and plantbed operations is the primary objective of developing an automatic transplanter for potted plants. However, this and many more advantages have been indicated from the basic research and field tests. After extensive research into the various problems involved and into their possible solutions, new concepts and designs for the seedling growing and handling system, a precision automatic seeder and transplanter were developed.

In the systems engineering of precision automatic transplanting, plants were started in seedling growing and handling trays which provided efficiently shaped potted plants, eliminated the manual pulling and handling of individual seedlings, and were adapted to the automatic transplanter, thus significantly reducing labor requirements. The trays also reduced soil moisture loss resulting in a higher soil-root temperature and provided air pruning of roots for better plant growth. The automatic seeder provided a practical means for precision multiple-seeding with accuracy, simplicity, speed, dependability, and economy. Significant improvements were made on the suction-drop tube and door of the automatic transplanter to prevent tumbling of seedling during transplanting. A water injection opener promises an effective means for opening precision spot cavities in the ground for better transplanting performance and plant growth. Field tests showed that the automatic transplanters performed effective automatic transplanting with a considerably lower labor requirement. These new developments made it possible to automate the total cultural operations from plantbed preparation, seeding, handling, to field transplanting.

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# Design of a Simple, Low-Lift, Wind-Powered Pump for Rural Use in Thailand



by  
**Desa Ahmad**  
 Department of Power and Machinery  
 Faculty of Agricultural Engineering  
 University of Agriculture, Malaysia  
 Serdang, Selangor, Malaysia

## Abstract

Adequate water supply is a prerequisite for successful plant growth, especially in areas situated well above the stream or water source and where water has to be pumped up for use. In some developing countries, rural water supply relies mainly on manually-operated low-lift pumps, shallow tube wells and diesel powered pumps. Although the use of diesel powered pumps is increasing in the rural areas, the rate is still very slow due to the users' low buying capacity, the ever-increasing oil price, fragmented plots, repair and maintenance facilities and most importantly, due to the lack of awareness on the part of farmers and farm managers of the possibility of harnessing power from other sources of energy.

This paper describes a study to harness windpower for pumping water in rural areas and involves the design of a simple, low-cost, low-lift, wind-pump driven by a horizontal-axis windmill, the detailed design of which is given in a separate report. The pump tested was designed using the principle of centrifugal force based on data from Tanzania and IRRI reports. The reduction in cost was suggested by adopting a substantially cheaper method of construction

based on locally available material.

## Introduction

The primary objective of water supply for rural communities is to raise the health levels although major secondary benefits related to overall development can be accrued through water supply in terms of improved rural organizational structure, agriculture and savings in time and energy in fetching water and thereby increasing productivity (Aziz A.M., 1982). In rural areas of the developing countries, the need for drinking and other domestic purposes is acute. The World Health Organization (WHO) estimates that 57% of the Third World is without clean water while 75% is without adequate sanitation (Fig. 1) and more than three quarters of these live in the rural areas. The WHO also forecasts that by 1990 the number of Third World population

who are yet to be reached by water supplies will reach 1388 millions or 75% of the total population (Table 1).

In Malaysia, the government is actively developing the water supply system and is putting emphasis on the rural areas where large amounts of water are required for crop production. Despite heavy rainfall the total available water resources are only moderate such that alternatively water deficit and water surplus occur annually with considerable month-to-month and year-to-year variation. This is particularly true in the greater part of

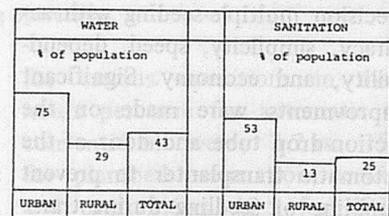


Fig. 1 Access to water and sanitation in developing countries, 1970-80 (Source: Pickford, J, 1982).

Table 1 Millions of People in Developing Countries to be Reached by 1990 for Decade's 100% Target

Region	Water			Sanitation		
	Urban	Rural	Total	Urban	Rural	Total
Asia & Pacific	203	925	1 128	355	1 136	1 491
Africa	104	310	414	130	342	472
Latin America	108	110	218	212	120	332
Europe*	14	21	35	30	30	60
Middle East	16	22	38	20	25	45
Total	445	1 388	1 833	747	1 653	2 400

\* Includes Algeria and Morocco, Source: Pickford, 1982.

the country where prolonged dry periods frequently occur during which soil moisture levels are outside the range favouring crop growth. In order to increase agricultural production it is, therefore, essential that adequate water supply and better irrigation techniques, especially for farmers in dry areas, be provided.

This preliminary study was conducted in view of the need to expand irrigated areas in order to continuously improve crop production, and to determine the possibility of using galvanized iron pipes as parts of the pump so that farmers in the rural areas can construct, install and maintain them at minimum cost.

### Theory and Design of Pump

The pump can be represented as shown in Fig. 2(a). It can rotate around the axis AB and is provided with nozzles N at the extremities of the arms and with a valve at the lower end, K submerged in water. If the pipe is filled with water and rotated in the direction opposite to the orifice in the nozzle when its operating rotational speed is reached, the water contained in the arms will be forced out through the nozzles by centrifugal force and replenished through valve D. The shape is almost similar to a horizontal centrifugal pump having rotating arms acting as impellers. The friction inside the rotating arms could be reduced by lowering the fluid velocity through constricting nozzles at their peripheries. These also help prevent air from entering and affecting the priming of the pump. As the velocity of water through the pump is low, discharge can be varied by changing the pump rotational speeds.

Using the energy design concept (Rubinski, 1955), it can be shown that if the velocity of flow through

the main pipe is  $V_1$  and the relative velocity through the nozzles as  $V_2$ , the coefficient of head loss in pipe and fittings as  $-K_1$  and in the nozzles as  $-K_2$ , we have:

$$\frac{1}{2} \rho V_2^2 = \frac{1}{2} \rho U^2 - \left( \frac{1}{2} \rho K_2 V_2^2 + \frac{1}{2} \rho K_1 V_1^2 + Wh \right) \dots \dots \dots (i)$$

where  $\rho$  = density of water,  $Wh$  = potential energy,  $U$  = linear velocity of the nozzle ( $\omega r$ ) since discharge,  $Q$  is constant and if  $C_c$  is the coefficient of construction,

$$V_2 A_2 C_c = V_1 A_1 \dots \dots \dots (ii)$$

so that

$$\frac{1}{2} \rho K_1 V_1^2 = \frac{1}{2} \rho K_1 V_2^2 \left[ \left( \frac{A_2}{A_1} \right) C_c \right]^2 \dots \dots \dots (iii)$$

substituting equation (iii) into (i) and denoting  $K_2 + K_1 \left[ \left( \frac{A_2}{A_1} \right) C_c \right]^2$  as  $K_F$ , equation (i) becomes

$$\frac{1}{2} \rho V_2^2 - \frac{1}{2} \rho U^2 - \left( \frac{1}{2} \rho K_F V_2^2 + Wh \right) \dots \dots (iv)$$

or  $V_2^2 = (U^2 - 2gh)/(1 + K_F) \dots (v)$  where  $g$  is acceleration due to gravity.

If  $z$  is the hydraulic efficiency (i.e. ratio of the useful work done in lifting a unit of the liquid to a height  $h$ , to the work delivered to this unit including the useful work, the friction losses and the kinetic energy of the liquid leaving the nozzle with absolute velocity  $(U - V_2)$ ) then:

$$z = Wh / \left[ Wh + \frac{1}{2} \rho K_F V_2^2 + \frac{1}{2} \rho (U - V_2)^2 \right] \dots (vi)$$

where  $\frac{1}{2} \rho (U - V_2)^2 / W$  is the kinetic energy. From equation (iv),

$$h = \frac{1}{2} \rho [U^2 - V_2^2 - K_F V_2^2] / W$$

substituting the above into equation (vi) gives:

$$z = \frac{[U^2 - V_2^2 (1 + K_F)]}{2(U^2 - UV_2)} \dots \dots (vii)$$

Dividing equation (vii) by  $U^2$  and letting  $V_2/U = x$ , therefore

$$z = \frac{[1 - x^2 (1 + K_F)]}{2(1 - x)} \dots \dots \dots (viii)$$

Differentiating the above equation gives

$$\frac{dz}{dx} = \frac{[-4x (1 + K_F) (1 - x) + 2(1 - x^2 (1 + K_F))]}{4(1 - x^2)}$$

Equating to zero gives,  $x = 1 - \sqrt{K_F/(1 + K_F)} \dots (ix)$

The above equation determines the value of  $x$  for maximum hydraulic efficiency while the linear velocity of the nozzles for maximum efficiency is determined by this equation

$$U = \sqrt{gh} / \sqrt{(\sqrt{(K_F^2 + K_F)} - K_F)} \dots \dots \dots (x)$$

The above equations clearly indicate that  $x$  can easily be obtained since  $V$  is known from the ratio of discharge to cross sectional area.

In this study a wind speed of 3.5 m/s was assumed to blow for 12 h whereby the expected discharge would be 69 l/min. For a pipe of given size, say,  $d$  the velocity of fluid in the pipe will be the ratio of discharge to pipe cross-sectional area. In this case

$$V = \frac{4Q}{\pi d^2}$$

where  $V$  = velocity of flow  
 $Q$  = discharge  
 $d$  = pipe diameter.

The experimental pump was fabricated from standard galvanized iron pipe of 40 mm diameter for the arms and 32 mm diameter pipe for the vertical section. A large diameter was chosen for the arms in order to contain an equally large volume of water to ensure adequate force when moved with greater acceleration. Consequently, this would create a region of low pressure which would lead to rapid suction of water as a result of atmospheric pressure acting on the surface below the pump. To overcome the problem of water draining

out of the vertical pipe when moved at lower speeds, a footvalve was installed.

### The Experimental Method

Having designed and fabricated the pump, several performance tests at various heads were conducted using an electric motor. A special test rig was constructed using a dexion frame. The shaft of the pump was supported by bearings bolted to a plywood cardboard. A polythene plastic sheet was chosen as trough for collecting discharged water and this was supported by iron bars on its inner and outer circumferences. A schematic layout of the rig is given in Fig. 2(a) while Fig. 3 illustrates the construction and arrangement of the test rig.

Figs. 2(b) and 2(c) show the improved version of the pump which is yet to be tested.

The experiments were conducted at three heads measured by the height of arm above the water level. Pump speeds were determined through a variable speed motor connected to the vertical shaft by a V-belt driving a pulley which was attached to the shaft. The power required to drive the pump was determined at various speeds by measuring the overall power requirement of the motor-transmission-pump assembly by means of a wattmeter. The total losses in power at various pump speeds are presented in Table 2. For measuring the discharge, a technique using volumetric tank was em-

ployed which necessitated the use of a stopwatch to measure the time taken for a given volume of water discharged into a storage tank. A change-over device was employed at the outlet of the delivery pipe to permit the flow to be directed to the measuring tank when the flow was steady.

### Results

#### Effect of Discharge and Power Requirement

Fig. 4 shows that the power required increased with discharge. Starting power varied slightly for all heads. At the design head of 1.7 m, the starting power was

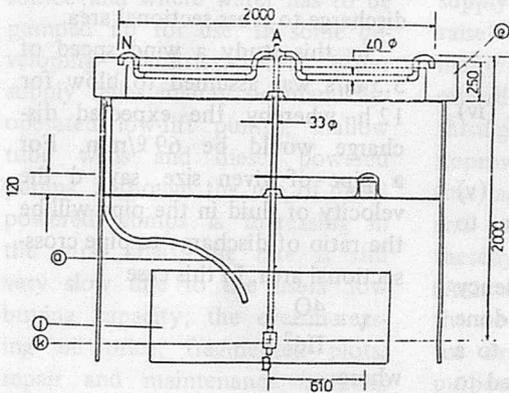


Fig. 2 (a) Schematic layout of pump and testing.

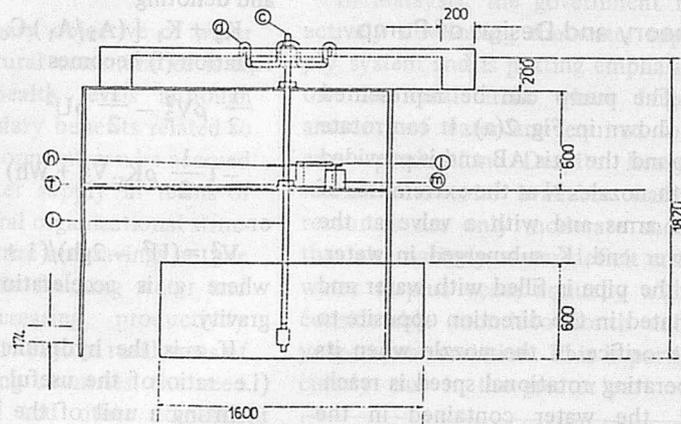


Fig. 2 (c) Future version of pump and rig (front view).

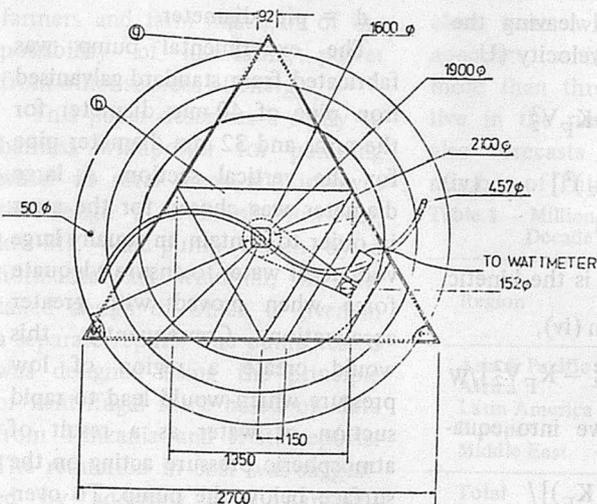


Fig. 2 (b) Future version of pump and rig (top view).

Parts nomenclature for Figs. 2 (a), (b) and (c): a—Delivery tube (Plastic), b—Supporting frame (Plywood), c—Plug, d—Tubular arm, e—Circular trough, f—Bearing, g—Dexion frame, h—Pulley, i—Pump shaft, j—Reservoir, k—Foot valve, l—AC Motor + V-Belt, m—Gear box.

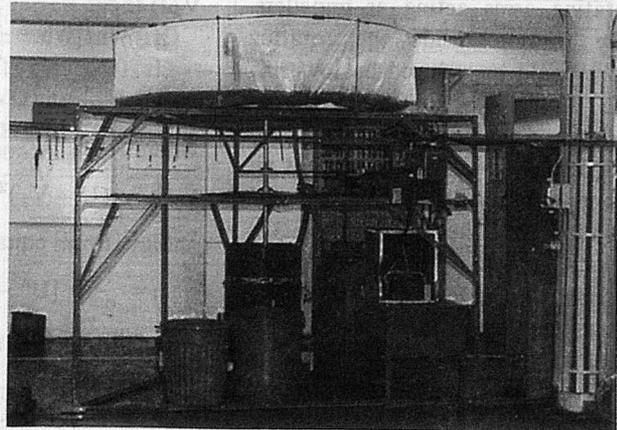


Fig. 3 Actual construction of testing rig.

**Table 2** Comparison of Power Losses and Hydraulic Efficiency for all Heads at Various Pump Speeds

Head (m)	Pump Speed (RPM)	Total Power (W)	Discharge (%)	Transmission Loss (%)	Drag and Loss (%)	Hydraulic Efficiency (%)
1.5	56	192	2.9	12.5	84.6	78.0
	59	196	4.5	14.6	80.9	76.6
	62	208	7.8	14.6	77.6	69.3
	69	240	12.8	18.6	68.6	57.3
	75	264	14.5	25.5	60.0	55.3
1.7	82	280	13.9	30.0	56.1	—
	60	212	3.4	14.6	82.0	78.8
	62	220	6.1	14.6	79.3	75.8
	65	240	7.8	16.6	75.6	71.7
	69	264	10.5	18.6	70.9	60.5
	72	288	13.4	22.2	64.4	58.8
2.0	75	300	18.2	25.5	56.3	48.2
	78	340	35.5	28.6	35.9	29.4
	65	208	4.0	16.6	79.4	81.5
	69	228	7.0	18.6	74.4	75.0
	72	248	9.0	22.2	68.8	67.5
	75	268	17.0	25.2	57.8	52.5
	78	296	20.0	28.6	51.4	45.5
	82	328	44.9	30.0	25.1	23.5

190 W, almost similar to the power requirement at a design head of 1.5 m. However, at 2.0 m head, the starting power was slightly lower. For a design discharge of 66 l/min which occurred at a pump speed of 75 rpm, the power required at 1.7 m head was 300 W whereas at 2.0 m head the power required for the same discharge increased only slightly to 310 W.

**Speed and Power Requirement**

Generally, as speed was increased, the power required also

increased. The highest power was achieved at 1.7 m head compared to 1.5 m and 2.0 m heads. At the same rotational speed the pump seemed to discharge a greater volume, hence required greater power at lower heads. Within the range of 65-80 rpm the power requirement at 1.7 m head was 1.0-1.2 times higher than that at 1.5 m head (Fig. 5).

**Speed and Discharge**

Fig. 6 shows that the pump started discharging at three dif-

ferent rotational speeds for the three different heads. At 1.5 m head, the pump started discharging at 56 rpm whereas at 1.7 m head pumping started at 59 rpm. For a 2.0 m head the pumping speed was 69 rpm. A slight deviation was observed at 1.5 m head in that as speed was increased, the discharge tended to remain almost constant beyond 65 rpm.

**Efficiency and Discharge**

Fig. 7 shows that at 1.5 m head maximum efficiency occurred at 56 rpm with a volumetric discharge of 12 l/min while at 1.7 m head, maximum efficiency was achieved at 59 rpm with a discharge of 16 l/min. For a 2.0 m-lift, the discharge was 19.1 l/min at a speed of 69 rpm. Efficiency seemed to fall rapidly at 1.7 m head compared to those at 1.5 and 2.0 m heads when running at the same rotational speed. Similar characteristics were also shown at higher discharge. For the design discharge of 66 l/min at 1.7 m head, a maximum hydraulic efficiency ( $\eta$ ) of 43% was achieved at 75 rpm. The calculated velocity ratio  $x$ , was 0.1 assuming  $K_F$  in the earlier given equations as 0.45.

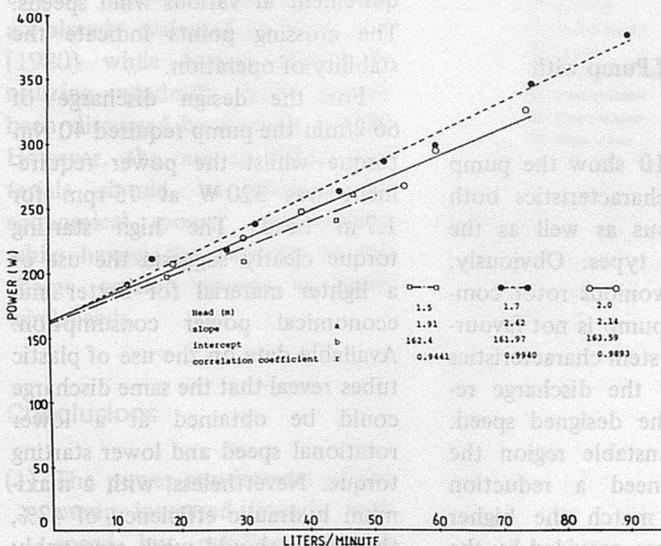


Fig. 4 Relation of power to discharge.

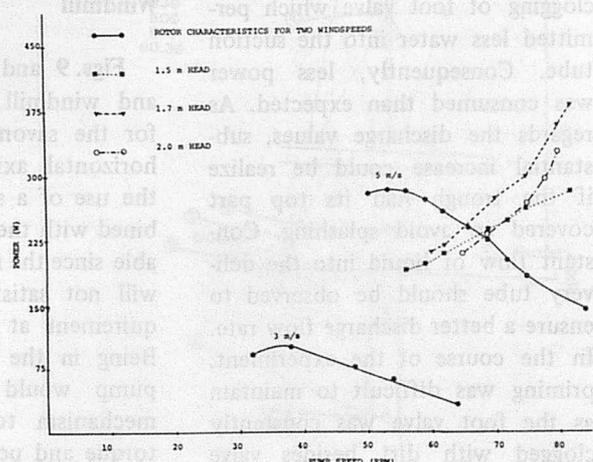


Fig. 5 Relation of power to speed.

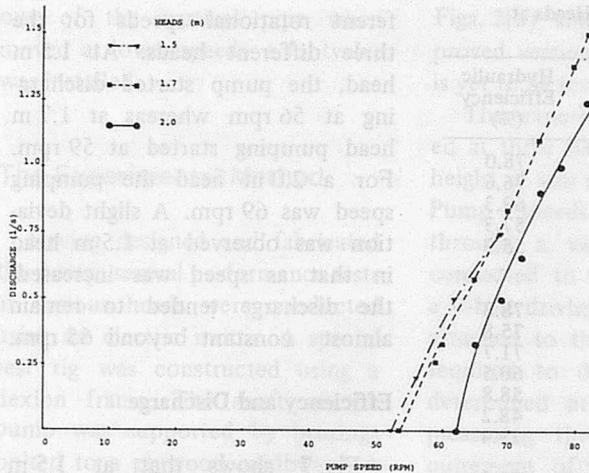


Fig. 6 Relation of discharge to speed.

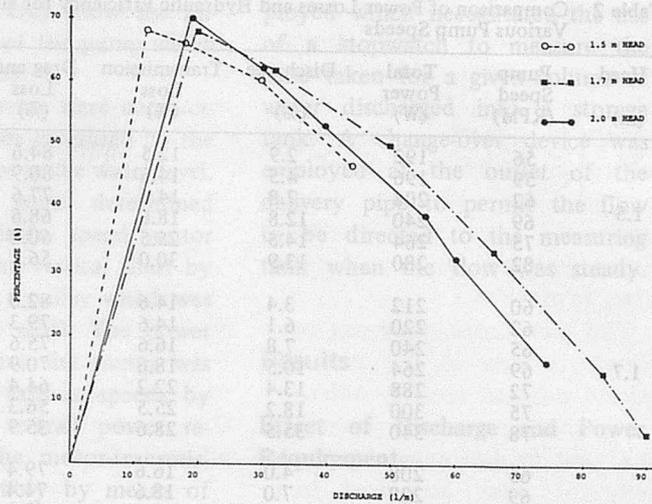


Fig. 7 Relation of efficiency to discharge.

### Losses in Relation to Discharge

It was observed that beyond the discharge value of 32 l/min (Fig. 8) the loss in power was tremendous causing a significant reduction in pump efficiency (Table 2).

### Discussions

#### Pump Performance

The pump characteristics observed seem to have a similar pattern to those of the centrifugal pump whereby the output and power requirements were shown to decrease as head was increased at the same rotational speed. However, the slight abnormality observed at 1.5 m head was due to clogging of foot valve which permitted less water into the suction tube. Consequently, less power was consumed than expected. As regards the discharge values, substantial increase could be realized if the trough had its top part covered to avoid splashing. Constant flow of liquid into the delivery tube should be observed to ensure a better discharge flow rate. In the course of the experiment, priming was difficult to maintain as the foot valve was constantly clogged with dirt besides valve loose seating which led to the

pump occasionally losing its prime. The use of a self-priming mechanism has already been suggested and this is currently being studied for further development.

#### Compatibility of Pump with Windmill

Figs. 9 and 10 show the pump and windmill characteristics both for the savonius as well as the horizontal axis types. Obviously, the use of a savonius rotor combined with the pump is not favourable since the system characteristics will not satisfy the discharge requirement at the designed speed. Being in the unstable region the pump would need a reduction mechanism to match the higher torque and power provided by the rotor in order to operate freely

in the system. On the other hand the rotor characteristics of the horizontal type windmill are better suited to the pump characteristics in terms of torque and power requirement at various wind speeds. The crossing points indicate the stability of operation.

For the design discharge of 66 l/min the pump required 40 Nm torque whilst the power requirement was 320 W at 75 rpm for 1.7 m head. The high starting torque clearly suggests the use of a lighter material for better and economical power consumption. Available data on the use of plastic tubes reveal that the same discharge could be obtained at a lower rotational speed and lower starting torque. Nevertheless, with a maximum hydraulic efficiency of 43%, the pump should work reasonably well in areas where windspeeds

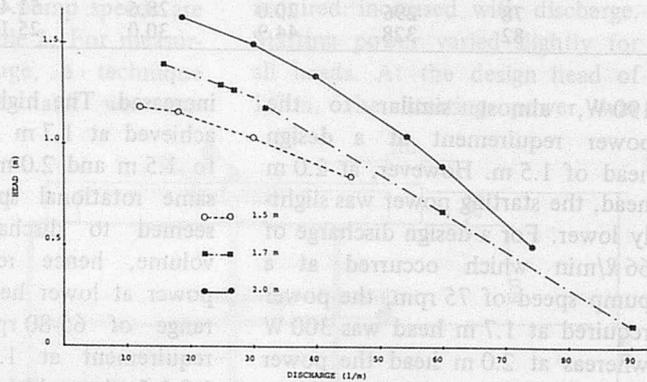


Fig. 8 Head loss in relation to discharge.

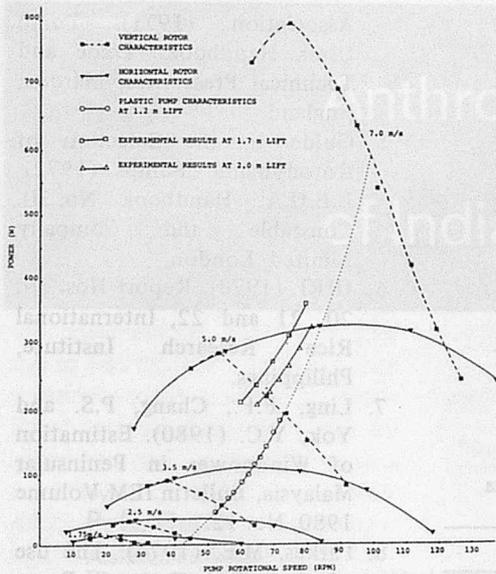


Fig. 9 Windmill/pump characteristics on power requirement (Source: Parkes, ME, 1974 at IRR Reports, 1978).

above 3.5 m/s are expected to blow. The suggested windmill pump combination is shown in Fig. 11.

### Potential Rural Application in Malaysia

The possibility of employing the pump for rural use, particularly in the east coast of peninsular Malaysia, is great since wind statistics are available (Table 3). Monthly and annual energy (Fig. 11) that can be harnessed from the wind are already evaluated by Ling, et al (1980) while factors related to utilizing windmills have already been discussed by Bardaie (1979). However, the use of lighter materials should be stressed for economical power consumption while having the capacity to discharge greater volume at lower windspeeds.

### Conclusions

- (1) The power requirement of the pump increased linearly with speed but non-linearly with discharge.

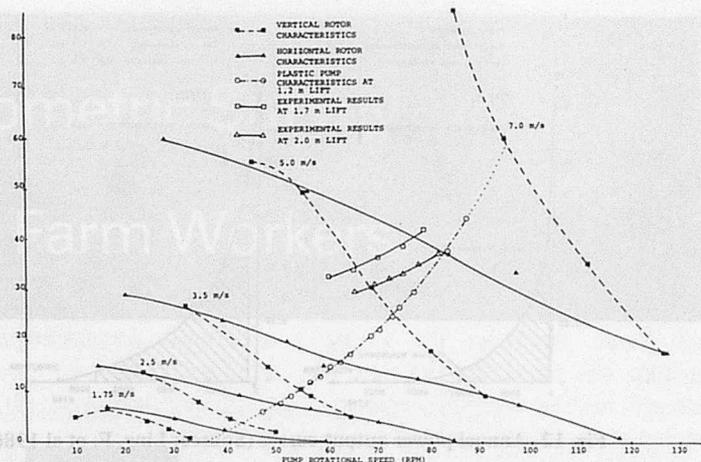


Fig. 10 Windmill/pump characteristics on torque requirement (Source: Parkes, ME, 1974 at IRR Reports, 1978).

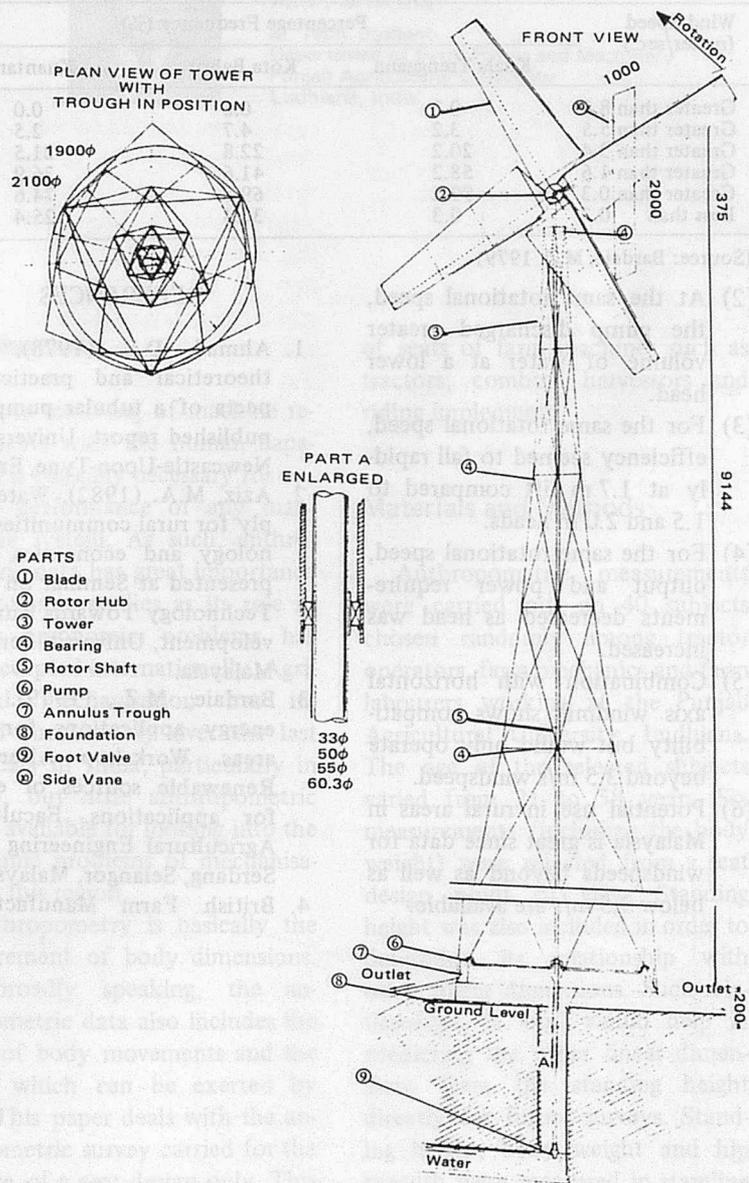


Fig. 11 Windmill front and plan views.

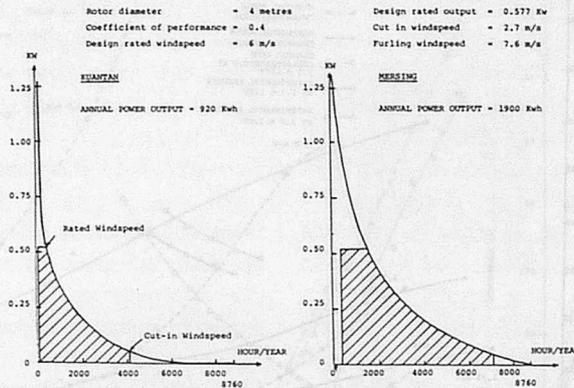


Fig. 12 Annual power output curves (Source: Ling, F. et al 1980).

Table 3 Annual Percentage Frequency of Wind Speed for Kuala Trengganu, Kota Bahru and Kuantan (1968-1977)

Wind Speed (meter/sec.)	Percentage Frequency (%)		
	Kuala Trengganu	Kota Bahru	Kuantan
Greater than 8.0	0.2	0.6	0.0
Greater than 5.5	3.2	4.7	2.5
Greater than 3.4	20.2	22.8	21.5
Greater than 1.6	58.2	41.6	36.9
Greater than 0.3	99.2	69.6	74.6
Less than 0.3	0.3	30.4	25.4

(Source: Bardaie, M.Z. 1979)

- (2) At the same rotational speed, the pump discharged greater volume of water at a lower head.
- (3) For the same rotational speed, efficiency seemed to fall rapidly at 1.7 m lift compared to 1.5 and 2.0 m heads.
- (4) For the same rotational speed, output and power requirements decreased as head was increased.
- (5) Combination with horizontal axis windmill shows compatibility but would only operate beyond 3.5 m/s windspeed.
- (6) Potential use in rural areas in Malaysia is great since data for windspeeds beyond as well as below 3.5 m/s are available.

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# Anthropometric Survey of Indian Farm Workers

by

**P. K. Gupta**

Assistant Professor  
Department of Farm Power and Machinery  
Punjab Agricultural University  
Ludhiana, India

**M. L. Gupta**

Assistant Professor  
Department of Farm Power and Machinery  
Punjab Agricultural University  
Ludhiana, India



**A. P. Sharma**

M. Tech. Student  
Department of Farm Power and Machinery  
Punjab Agricultural University  
Ludhiana, India

## Abstract

Anthropometric data is a basic necessity for proper matching of machine requirements with the human capabilities. Little data is available on Indian farm workers relative to the ergonomic problems of farm machinery. Six measurements, including body weight, were chosen for anthropometric survey from the seat design point of view. Maximum variation was found in body weight of the subjects. The collected data were quite different from the data available for other countries. As such, the data of other countries should not be used for design of farm machinery in India. The standing height was found to have linear relationship with other linear dimensions. Thus other dimensions can be found directly from the height aspect for future studies using the developed relationships.

## Introduction

Proper matching of machine requirements with the human capabilities is basically necessary for optimum performance of any man-machine system. As such, anthropometric data has great importance in ergonomic studies as its role in solving ergonomic problems has been accepted internationally. Agricultural mechanisation has increased considerably over the last few years in India, particularly in Punjab, but little anthropometric data is available for looking into the ergonomic problems of mechanisation in this region.

Anthropometry is basically the measurement of body dimensions. But broadly speaking, the anthropometric data also includes the limits of body movements and the forces which can be exerted by man. This paper deals with the anthropometric survey carried for the purpose of a seat design only. This data would be useful in the design

of seats of farm machines such as tractors, combine harvestors and riding implements.

## Materials and Methods

Anthropometric measurements were carried out on 40 subjects chosen randomly among tractor operators, farm mechanics and farm labourers working at the Punjab Agricultural University, Ludhiana. The age of the selected subjects varied from 21 to 58 years. Six measurements (including the body weight) were selected from a seat design point of view. Standing height was also included in order to determine its relationship with other linear dimensions. Such relationships, if any, would help in predicting the other linear dimensions from the standing height directly for future surveys. Standing height, body weight and hip breadth were measured in standing posture while seat height, seat

depth, elbow rest height and shoulder-seat were measured in sitting posture. The corresponding dimensions in sitting and standing postures are shown in Fig. 1. Standing posture was such that the person stands with his feet closed and his body vertically erected, while the heels, the buttocks and the shoulders touch the same vertical plane. Similarly, the sitting posture was such that the person sits with his body vertically erected, while the shoulders and head touch

the same vertical plane. The hip was kept as near as possible to the same vertical plane. In the sitting posture, the upper leg was kept horizontal and the lower leg, vertical. The sitting height was adjusted so that the feet just touched the ground completely. The subjects were asked to remove their shoes and all the clothes except the underwear. An anthropological instrument with an accuracy of  $\pm 0.25$  mm was used for the measurements.

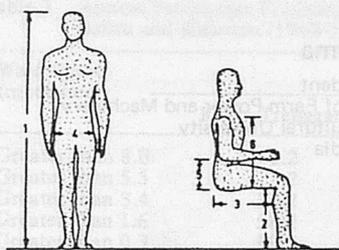
these curves and are given in Table 1.

For design purposes, either one of the boundary values or the mean value is used depending upon the type of dimensional element. For boundary values, generally, the 5th and 95th percentiles are used. For example, if the seat is designed for 95th percentile value of body weight (74.5 kg in this case), the seat will be able to take care of the weight of 95% of the population. On the other hand, for seat depth and seat height, 5th percentile values (i.e. 43.0 cm and 36.2 cm respectively, in this case) would be used for design and will also take care of 95% of the population. Thus in the complete design 90% of the population is taken into account. The 10% skipped population, outside these boundaries, will generally have large spread and it will often not be economical to take it into account.

The data were also analysed for standard deviation and coefficient of variation for each dimensional

### Results and Discussion

The data were analysed for percentile distribution from which the curves were plotted for each dimensional element. Fig. 2 shows the percentile distribution of body weight and standing height while Fig. 3 shows the percentile distribution of shoulder-seat, seat depth, seat height, hip breadth and elbow rest height. The values of 5th, 50th and 95th percentile were read from



1. STANDING HEIGHT
2. SEAT HEIGHT
3. SEAT DEPTH
4. HIP BREADTH
5. ELBOW REST HEIGHT
6. SHOULDER-SEAT

Fig. 1 Diagram of body dimensional elements measured.

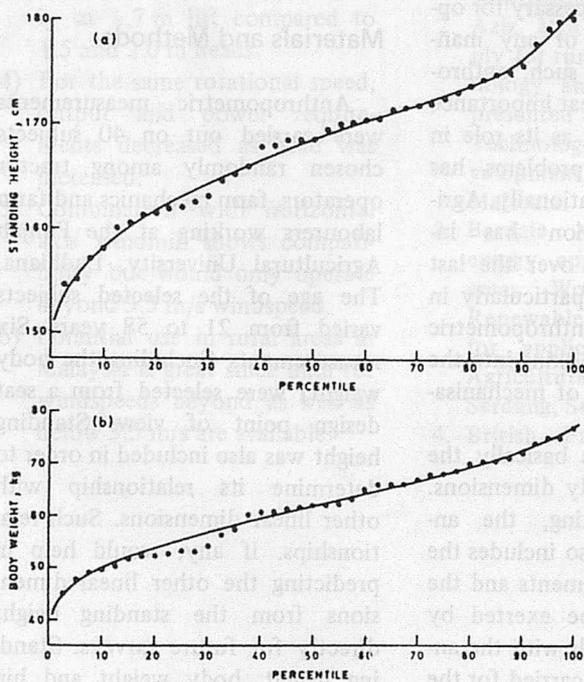


Fig. 2 (a) Cumulative percentile distribution of standing height  
(b) Cumulative percentile distribution of body weight

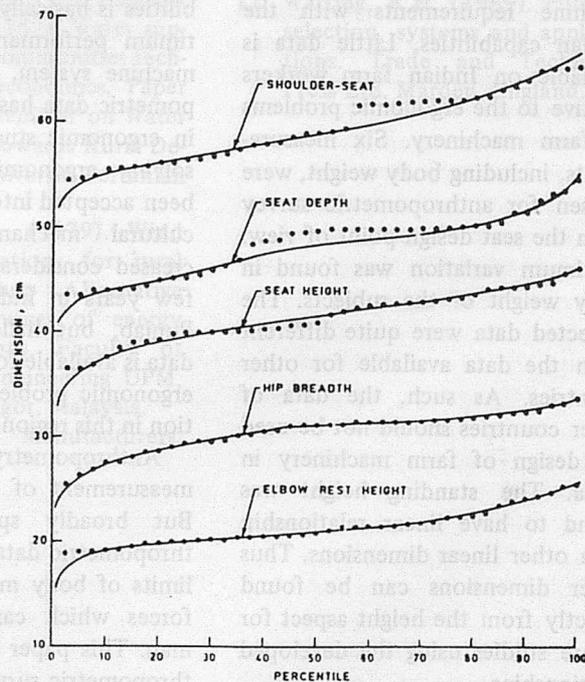


Fig. 3 Cumulative percentile distribution of elbow rest height, hip breadth, seat height, seat depth and shoulder-seat.

element and the values are also shown in Table 1. The coefficient of variation is maximum for the body weight almost similar in all other dimensional elements.

The corresponding values of the 5th, 50th and 95th percentiles of the dimensional elements for U.S. and Dutch people are given in Table 2. Comparison of Tables 1 and 2 makes it clear that the data of this region are quite different from that of other countries. Therefore, the data of other countries cannot be used for design of farm machines in India because it can result in either an uneconomical design or a design with less efficiency due to improper matching of the operator and the machine.

Range of variation (the difference between 5th & 95th percentile) of each dimensional element is also given in Table 1. The range value helps in deciding the possibility of providing an adjustable design. Seat height, being a very important aspect of seat design, should be made adjustable as far as possible. In this case, an adjustment of only 9.5 cm is required which is not a very large value. Therefore, a seat with variable height (36.2 – 45.7 cm) can be designed and should provide adequate convenience for the required height

of 90% of the population.

The data were further analyzed for linear regression between standing height and other linear dimensions except hip breadth. The predicted values and the observed values for each regression were also plotted and are given in Figs. 4 to 7. The correlation was significant in all the four cases. The levels of certainty were 99.9%, 99.0%, 95.0%

and 99.9% in case of seat height, seat depth, elbow seat height and shoulder-seat, respectively. This indicates that if only the standing height is measured for a large sample, the other linear dimensions can then be predicted from the developed linear regressions.

Table 1 Anthropometric Data for Farm Workers, Punjab State

Dimensional element	Value of 5th percentile	Value of 50th percentile	Value of 95th percentile	Total difference between 5th and 95th percentiles	Standard deviation	Coefficient of variation (%)
Standing height	115.20	168.50	179.00	23.80	6.84	4.06
Body weight	46.75	61.75	74.50	27.75	8.68	14.08
Elbow rest height	18.25	21.00	25.00	6.75	1.86	8.69
Seat depth	43.00	48.25	53.25	10.25	3.17	6.15
Seat height	36.20	41.75	45.70	9.50	2.60	6.25
Hip breadth	26.00	31.25	33.25	7.25	1.99	6.50
Shoulder-seat	54.25	59.00	65.80	11.65	3.54	5.91

Table 2 Anthropometric Data for U.S. and Dutch Males (McCormic, 1976, Woodson, 1973 and Zander, 1973)

Dimensional element	U.S.		Dutch	
	Value of 5th percentile	Value of 50th percentile	Value of 95th percentile	Value of 50th percentile
Standing height	162.0	173.0	185.0	175.0
Body weight	58.0	75.0	98.0	—
Elbow rest height	19.0	24.0	30.0	21.0
Seat depth	44.0	50.0	55.0	48.5
Seat height	39.0	44.0	49.0	45.0
Hip breadth	31.0*	36.0*	40.0*	33.5
Shoulder-seat	53.34	—	63.5	62.0

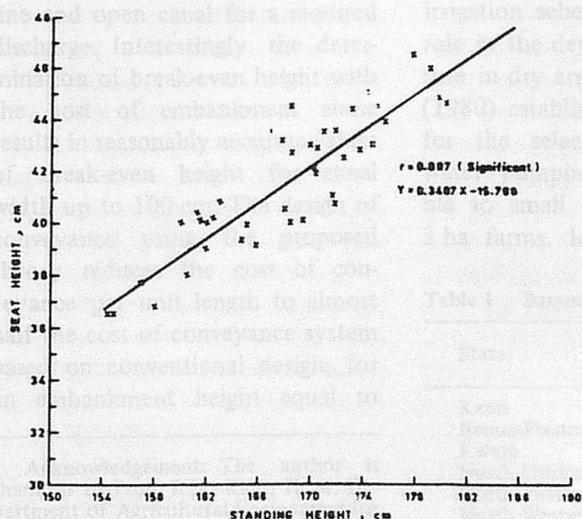


Fig. 4 Correlation between standing height and seated height.

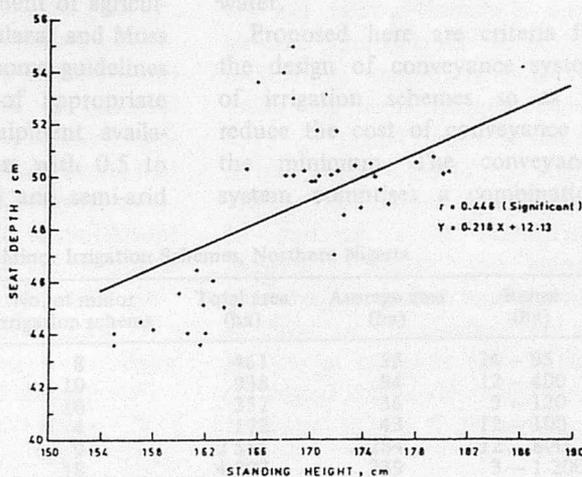


Fig. 5 Correlation between standing height and seat depth.

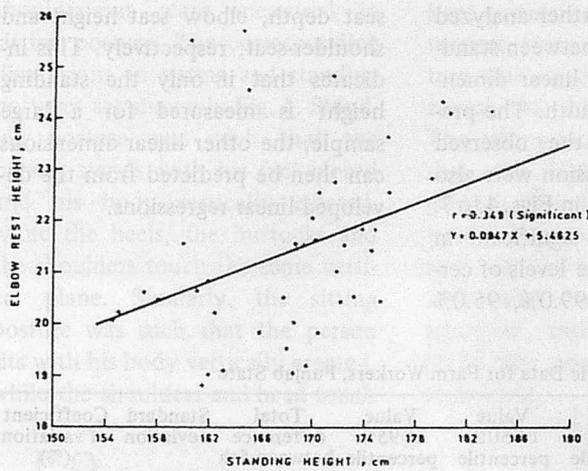


Fig. 6 Correlation between standing height and elbow rest height.

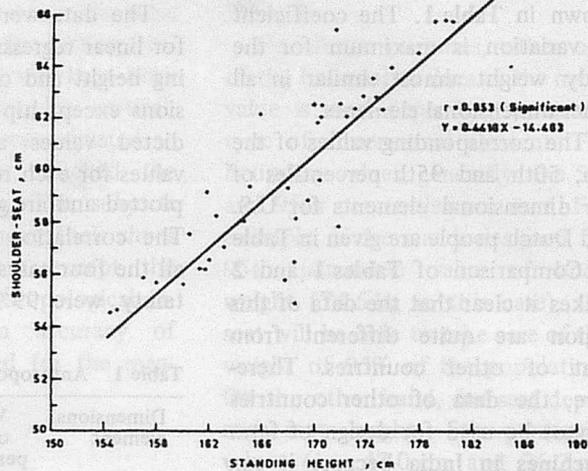


Fig. 7 Correlation between standing height and shoulder-seat.

**Conclusion**

The anthropometric data available for other countries cannot be applied in India.

Linear relationships exist between the standing height and other dimensional elements and,

hence, other dimensions can be predicted from the standing height for future studies.

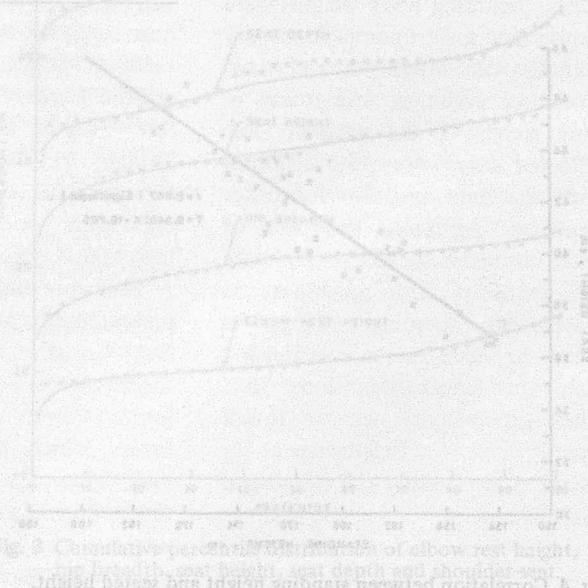
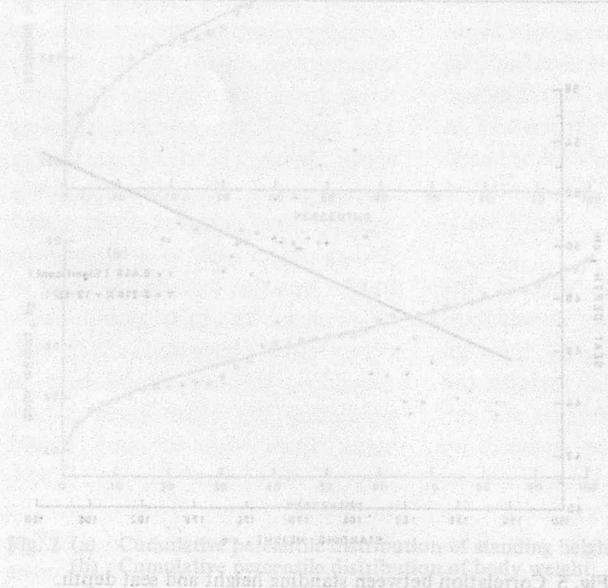
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Value of percentile	Value of percentile	Value of percentile	Value of percentile
17.0	17.0	17.0	17.0
21.0	21.0	21.0	21.0
25.0	25.0	25.0	25.0
30.0	30.0	30.0	30.0
35.0	35.0	35.0	35.0
40.0	40.0	40.0	40.0
45.0	45.0	45.0	45.0
50.0	50.0	50.0	50.0
55.0	55.0	55.0	55.0
60.0	60.0	60.0	60.0
65.0	65.0	65.0	65.0
70.0	70.0	70.0	70.0
75.0	75.0	75.0	75.0
80.0	80.0	80.0	80.0
85.0	85.0	85.0	85.0
90.0	90.0	90.0	90.0
95.0	95.0	95.0	95.0
99.0	99.0	99.0	99.0



# Water Conveyance for Farms and Minor Irrigation Schemes



by  
R. C. Yadav

Department of Agricultural Engineering  
Ahmadu Bello University  
Zaria, Nigeria

## Abstract

The high cost of conveyance is an important financial constraint for an irrigation project. A combined system of underground pipe line and surface canal has been proposed to reduce the cost of conveyance. An analysis that enables the designer to quickly evaluate the break-even height using readily available unit cost and other constants for man-machines-cost structure of an irrigation project is presented. The proposed analysis has been applied to the northern Nigerian conditions and facilitate interpolation of break-even height for a wide range of combination of sizes of underground pipe line and open canal for a required discharge. Interestingly, the determination of break-even height with the cost of embankment alone results in reasonably accurate values of break-even height for canal width up to 100 cm. The design of conveyance using the proposed theory reduces the cost of conveyance per unit length to almost half the cost of conveyance system based on conventional design, for an embankment height equal to

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one and a half times the break-even height.

## Introduction

Modern irrigation in many of the oil exporting countries such as Nigeria gained impetus in the last two decades or so. Earlier schemes in Nigeria have been supplemental to rainfall. Individual farms and minor irrigation schemes constitute the first phase of irrigation development in a country. Iqbal (1975) categorized the minor irrigation schemes in northern Nigeria as one that ranges from 2 ha to 1 200 ha.

Whereas major irrigation schemes are of national importance, minor irrigation schemes have their own role in the development of agriculture in dry areas. Salazar and Moss (1980) established some guidelines for the selection of appropriate water pumping equipment available to small farmers with 0.5 to 3 ha farms. In arid and semi-arid

countries good quality water is traceable to low valleys. For economical and easy exploitation of these water resources, an ideal approach would be to take water from the source up to the ridge of the area to be irrigated and then allow the water to flow.

Gravity canals usually require large areas of land. Iqbal (1975) indicates that minor irrigation schemes of northern Nigeria have been fed by pumped system either directly from river or lakes. These schemes though operating for wide range of command areas (Table 1) have been on the gravity lined or unlined canals. This means that a large proportion of the expenditure on the schemes have been incurred on the conveyance of water.

Proposed here are criteria for the design of conveyance system of irrigation schemes so as to reduce the cost of conveyance to the minimum. The conveyance system comprises a combination

Table 1 Summary of Minor Irrigation Schemes, Northern Nigeria

State	No. of minor irrigation schemes	Total area (ha)	Average area (ha)	Range (ha)
Kano	8	461	58	24 - 95
Benue-Plastezu	10	938	94	12 - 400
Kwara	10	357	36	3 - 120
North Central	4	172	43	12 - 100
North Eastern	9	2 555	284	12 - 800
North Western	18	4 297	239	3 - 1 200

Source: Iqbal, 1975.

of underground pipe line and lined open channel on raised earthen embankment in an appropriate proportion so as to give the most economical design of the system as a whole. The pipe length so ascertained could be designed to operate at optimum hydraulic gradient (Clark *et al*, 1977). The proposed analysis may serve as a guide to designing individual farms and minor irrigation schemes in the future.

### Analytical Considerations

Yadav (1982) presented a comprehensive analysis of cost functions of water conveyance through unlined water courses and underground pipe line.

The proposed analysis is based on factors that are pertinent to individual farms and minor irrigation schemes. The unit cost of conveyance of water in open channel ( $C_{ic1}$ ) comprises a variety of cost heads, viz., cost of channel ( $C_c$ ), cost of earthen embankment to support the channel ( $C_b$ ), cost of land lost to cultivation ( $C_l$ ) and cost of water lost in evaporation ( $C_e$ ) which could be expressed in its functional form as:

$$C_{ic1} = C_c + C_b + C_l + C_e \dots (1)$$

The cost of channel usually does not remain constant with the increase of channel section. For the purpose of this economic analysis it is taken as constant as the continuous support does not affect the size of channel length.

The cost of support, i.e., cost of earth filling needed for gravity conveyances is a function of channel size, height of channel above ground surface and intended use of embankment as road or passage. The variation in cost of embankment ( $C_b$ ) with height ( $h$ ) is polynomial. It can be expressed as:

$$C_b = kh^n \dots (2)$$

When  $k$  and  $n$  are coefficients

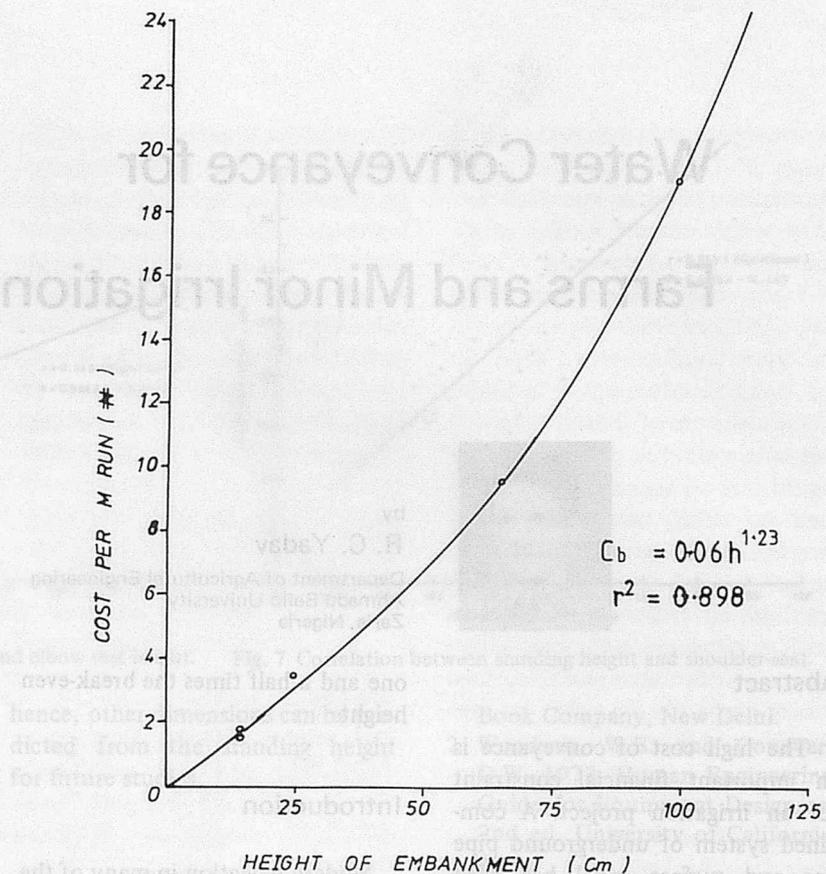


Fig. 1 Relationship of Cost and Height of Embankment

and exponent respectively. Value of  $k$  and  $n$  ascertained (Fig. 1) for a rectangular and most economical channel 38 cm wide, 34 cm deep and discharge capacity 30 l/s are 0.06 and 1.23, respectively.

The correlation coefficient for this analysis indicates that the cost of embankment is highly dependent on height ( $r^2 = 0.898$ ) and the remaining 10% on other factors (Salmon and Hanson, 1964).

For channels supported on earthen embankment, the land lost to cultivation is dependent on the intended use of the embankment; the minimum land lost to cultivation is equal to bottom width of embankment. The cost of land lost to cultivation could be calculated with unit cost of land ( $C_{uh}$ ) as:

$$C_l = (W + 2Z(h + D_c) + 0.9) \times C_{uh} \times 10^{-4} \dots (3)$$

where,

- $W$  = width of channel in meter;
- $Z$  = side slope of embankment (1:Z);
- $h$  = height of embankment in meter; and

$D_c$  = overall depth of the channel in meter

Evaporation loss from an open channel in a given environment is the function of top width. When accounted for the life of a project, evaporation losses become significantly large. Taking the case of i) most economical vertical wall channel section, ii) water runs for 100 days per year, and iii) a project's useful life of 20 years, the total evaporation loss per unit length could be calculated as:

$$C_e = W \times 1/100 \times 100 \times 20 \times C_{wu} = 20 WC_{wu} \dots (4)$$

Where,  $W$  is the width of channel,  $C_{wu}$  is the cost of water per unit volume.

Accounting for all the cost component of the foregoing analyses, the cost of conveyance with raised channel for a unit length will take the form:

$$C_{ic1} = C_c + kh^n + (W + 2Z(h + D_c) + 0.9) C_{uh} \times 10^{-4} + 20 WC_{wu} \dots (5)$$

The unit cost of conveyance of water through underground pipe-

line is ( $C_{ic2}$ ). The major cost heads for underground conduits are the cost of conduit ( $C_d$ ), cost of excavation ( $C_E$ ), and cost of gravel ( $C_G$ ). The cost of laying out and filling ( $C_{ef}$ ) and cost of project due to increase on the conduit length ( $C_{p1}$ ). In its functional form the cost could be expressed as:

$$C_{ic2} = C_d + C_E + C_G + C_{ef} + C_{p1} \dots \dots \dots (6)$$

The cost of conduit for the open channel is dependent on the length of unit of fabrication. The cost in relation to length of fabrication is not a linear function. However, for the purposes of the this analysis it could be taken as constant.

The cost of earth work could be evaluated for the expected load and bedding requirement of conduit. Taking the width of excavation based on the common rule (Okun and George, 1975) depth of placement 1 m below the surface and unit cost of excavation ( $C_{eu}$ ), the cost of earth work can be estimated as:

$$C_E = (1.5D^2 + 1.95D + 3.3) \times C_{eu} \dots \dots \dots (7)$$

Where  $D$  = diameter of pipe in meter.

Depending on the bedding type, a gravel bed of 8-10 cm is laid below and a minimum depth of 30 cm gravel layer is placed above the conduit.

For this economic analysis Type 2 bedding giving a load factor of 1.5 (Schwab *et al*, 1966) could be adopted. The cost of gravel ( $C_G$ ) could be estimated with unit cost of gravel ( $C_{gu}$ ) as:

$$C_G = (0.72D^2 + 1.14D + 0.17) \times C_{gu} \dots \dots \dots (8)$$

Soil dug in excavation of the trench is filled back and the remaining quantity of soil (waste) is disposed of suitable places. Essentially, the waste soil is equal to the difference of volume of excavation and volume occupied by conduit and gravel. The cost of laying and refill-

ing can be ascertained with unit cost ( $C_{efu}$ ) as:

$$C_{ef} = (0.18D + 3.13) C_{efu} \dots (9)$$

With the increase in the conduit length it needs additional head equal to the head loss in the conduit part. This demands strengthening of the component of the project to withstand pressure that leads to additional investment in the project. However, when taken on the unit length basis, this cost is negligible and could be dropped for the purpose of this economic analysis.

Accounting for all the foregoing analyses for underground pipe the cost of conveyance for unit length becomes:

$$C_{ic2} = C_d + (1.5D^2 + 1.95D + 3.3) C_{eu} + (0.72D^2 + 1.14D + 0.17) C_{gu} + (0.18D + 3.13) C_{efu} \dots \dots \dots (10)$$

### Break-Even Height

As the conduit follows the topography of the terrain its cost remains practically constant but the cost of conveyance through open channel is maximum near water source and decreases towards the point of use. The cost of conveyance of the two systems would be equal for a particular height, called the break-even height for conveyance. Generally, the cost of installing precast unreinforced concrete pipe is comparable with that of the concrete lined ditches for capacities less than 85 to 140 l/s and the cost of cast in place concrete pipes is comparable to that of the concrete lined channels for capacities up to 850 l/s (Booker, 1974). The break-even height of conveyance could be obtained by equating the cost component  $C_{ic1}$  and  $C_{ic2}$  (equation 5 and equation 10 respectively) as:

$$C_c + kh^n + [W + 2Z(h + D_c) + 0.9] C_{uh} 10^{-4} + 20WC_{wu} = C_d + (1.5D^2 + 1.95D + 3.3)$$

$$C_{eu} + (0.72D^2 + 1.14D + 0.17) C_{gu} + (0.18D + 3.13) C_{efu} \dots \dots \dots (11)$$

Rearranging this result in:

$$kh^n + [W + 2Z(h + D_c) + 0.9] C_{uh} \times 10^{-4} = C_d + (1.5D^2 + 1.95D + 3.3) C_{eu} + (0.72D^2 + 1.14D + 0.17) C_{gu} + (0.18D + 3.13) C_{efu} - (C_c + 20WC_{wu}) \dots \dots \dots (12)$$

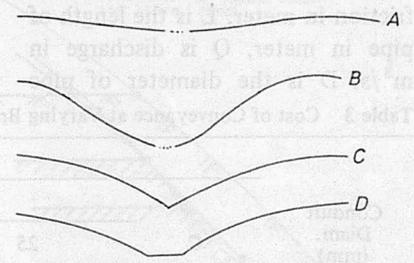
The only unknown variable  $h$  could be determined by a method of successive approximation.

A common land for savannah plains is the *dambo a nyanja*, a vernacular term literally meaning meadow but applied geomorphologically to valley floor that are continuously concave in cross profile (Young, 1972). The schematic valley form Fig. 2 has been culled from Young (1972). Though the exact shape of profile can only be obtained by surveying the form of profile it is expected to be similar to that given by Young (1972). Taking the case of flat land profile (Fig. 2), let the height of embankment be denoted by ( $h_d$ ) and distance from water source by ( $X$ ). The parameters can be correlated by:

$$h_d = a - bX \dots \dots \dots (13)$$

Where  $a$  and  $b$  are intercept and slope. The value of  $h_d$  will be equal to  $h$  at break-even point. The general break-even distance would be:

$$X = (a - h)/b \dots \dots \dots (14)$$



- A = Trough valley
- B = Throat-like valley
- C = Incised valley
- D = Flat flooded incised valley

Fig. 2 Comparative Valley Configurations

## Hydraulic Computations

Hydraulic design of open channel for a given discharge, head and channel roughness can be performed with the Manning's formula

$$Q = A/n' R^{2/3} S^{1/2} \dots (15)$$

Where Q is the discharge in m<sup>3</sup>/s; A is cross sectional area in m<sup>2</sup>; R is hydraulic mean radius in meter and is equal to A/P where A is the same as defined and P is wetted perimeter in meter; n' is Manning's roughness coefficient and S is slope (m/m), ie, H/L where H is head loss in meter and L is length of channels in meter.

The corresponding differential head between the upstream and down stream ends of the underground pipe system can be calculated by the most nearly rational relationship between velocity of flow and head loss by the Weigbach Darcy formula:

$$H = (fL/D) \cdot (V^2/2g) \dots (16)$$

Where H is head loss in meter; L is the length in meter; V is the velocity of flow in m/s; D is the pipe diameter in metre; and g is the acceleration due to gravity m/s<sup>2</sup>. Usually, engineering designs have been done with the use of one of the exponential relationships, the Hazen William Formulage given below:

$$H_f = 10.71 L Q^{1.851} / C^{1.851} D^{4.869} \dots (17)$$

Where H<sub>f</sub> is the head loss due to friction in meter, L is the length of pipe in meter, Q is discharge in m<sup>3</sup>/s; D is the diameter of pipe

in meter, and C is the coefficient for friction, depending on pipe condition, the value of C ranges from 100-150.

The effect of minor losses can be calculated as:

$$Q = A \sqrt{2gH} / \sqrt{1+K_e + K_b + K_c L} \dots (18)$$

Where K<sub>e</sub> is the entrance loss coefficient; K<sub>b</sub> is bend loss coefficient; K<sub>c</sub> is the friction loss coefficient; and remaining terms are as defined previously.

## Application of Model and Result

The cost of conveyance with underground pipe lines of diameter that can handle discharges with operating head equal to head loss in open channels of various sizes are compared. Thus there is no involvement of additional pumping cost with pipe line.

The exact value of break-even height should be worked out for specific man-machine-cost structure of the project. A range of values of

h has been estimated from equation (12) with the use of unit cost and coefficients given in Table 2. The analysis has been carried out for the rectangular (most economical) channel of different width (25, 50, 100, 200 and 400 cm) and conduit diameters (250, 500, 750 and 1 000 mm) so as to facilitate the interpolation of values of h for any combination of underground conduit and open channel to handle the required discharge. In order to ascertain the relative importance of terms in the general equation, the values of h have been evaluated for the following conditions: i) accounting for the cost of embankment only; ii) as in i) plus cost of water lost in evaporation; and iii) as in ii) plus the cost of land lost to cultivation. The break-even height values reveal that the cost of embankment alone is quite sufficient to determine the break point height up to channel width 100 cm. The cost of water lost in evaporation becomes significant for wider channels. The cost component of land lost to cultivation

Table 2 Unit Costs and Values of Constants, Nigeria Conditions

Item	Symbol	Cost	Coefficient
Unit cost of excavation	C <sub>eu</sub>	3.00	
Unit cost of laying of filling	C <sub>ifu</sub>	2.50	
Unit cost of gravel	C <sub>gu</sub>	3.00	
Cost of irrigation	N/irrigation (10cm)	10.00	
Cost of land	C <sub>uh</sub>	500.00	
Cost of conduit/cost of open channel	N/M	2.50	
Coefficient K for equation (1)	K	—	0.06
Exponent n for equation (1)	n	—	1.23

Source: Unit cost have been taken from the schedule of rate adopted by the Estate Department, Ahmadu Bello University, Zaria.

Table 3 Cost of Conveyance at Varying Break-even Heights of Embankment.

(Unit: N/m length)

Conduit Diam. (mm)	C	Cost of Conveyance N/Meter Length									
		Channel width (w) in cm									
		25		50		100		200		400	
		C <sub>1</sub>	C <sub>2</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>1</sub>	C <sub>2</sub>
250	16.41	26.55	7.81	25.82	8.36	23.81	7.99	26.20	12.83	—	—
500	22.83	36.92	10.35	35.18	11.14	34.32	12.63	29.90	15.45	24.90	21.36
750	28.46	47.98	12.18	40.34	13.95	43.15	15.23	32.62	18.34	33.34	23.65
1 000	33.19	54.44	15.18	42.27	15.85	52.19	17.35	49.40	20.39	39.98	25.90

C — Cost of conveyance N/meter length at h (break-even cost); C<sub>1</sub> — Cost of conveyance N/meter length at 1.5 h; C<sub>2</sub> — Cost of conveyance N/meter length at 0.5 h.

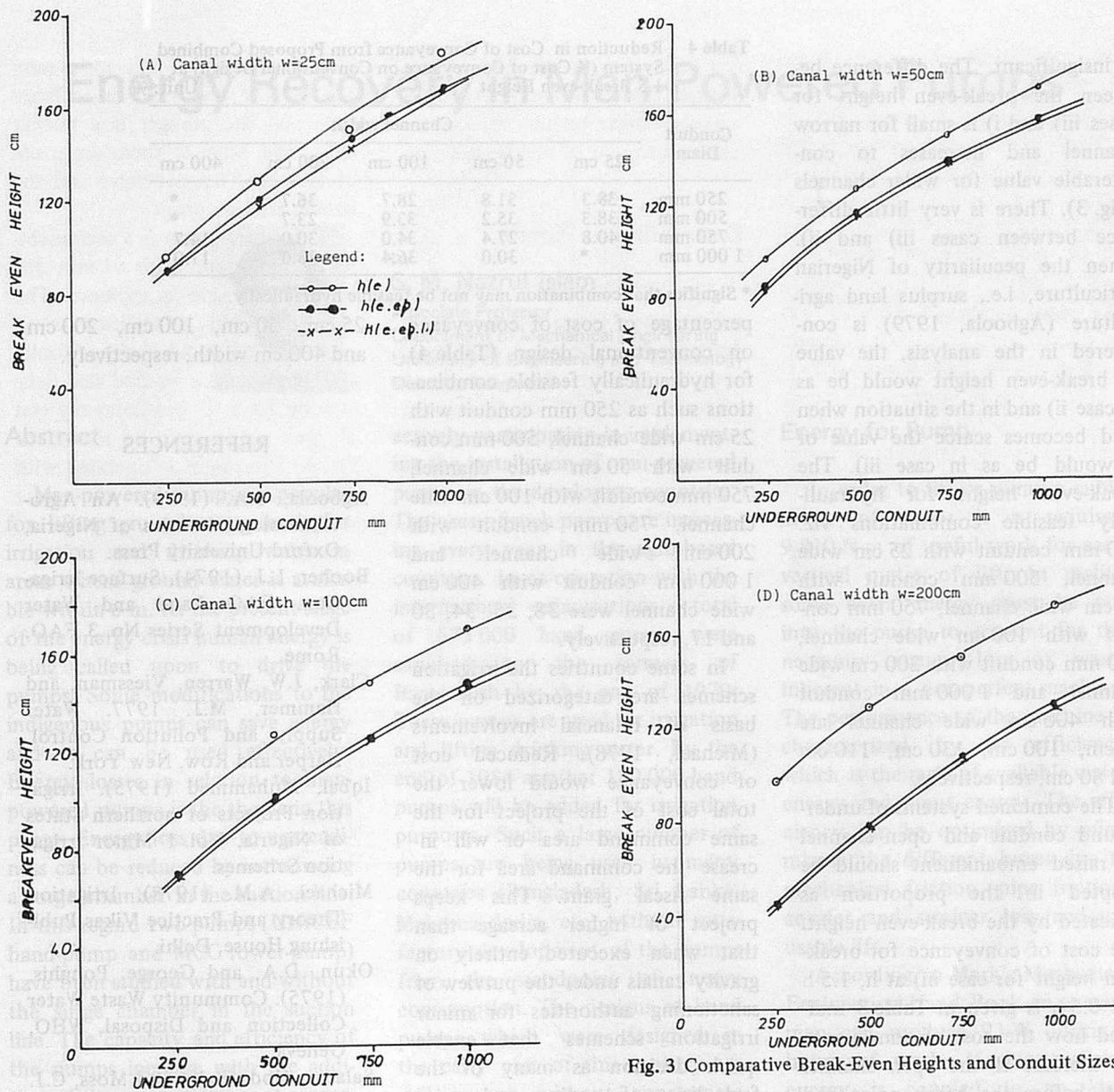


Fig. 3 Comparative Break-Even Heights and Conduit Sizes

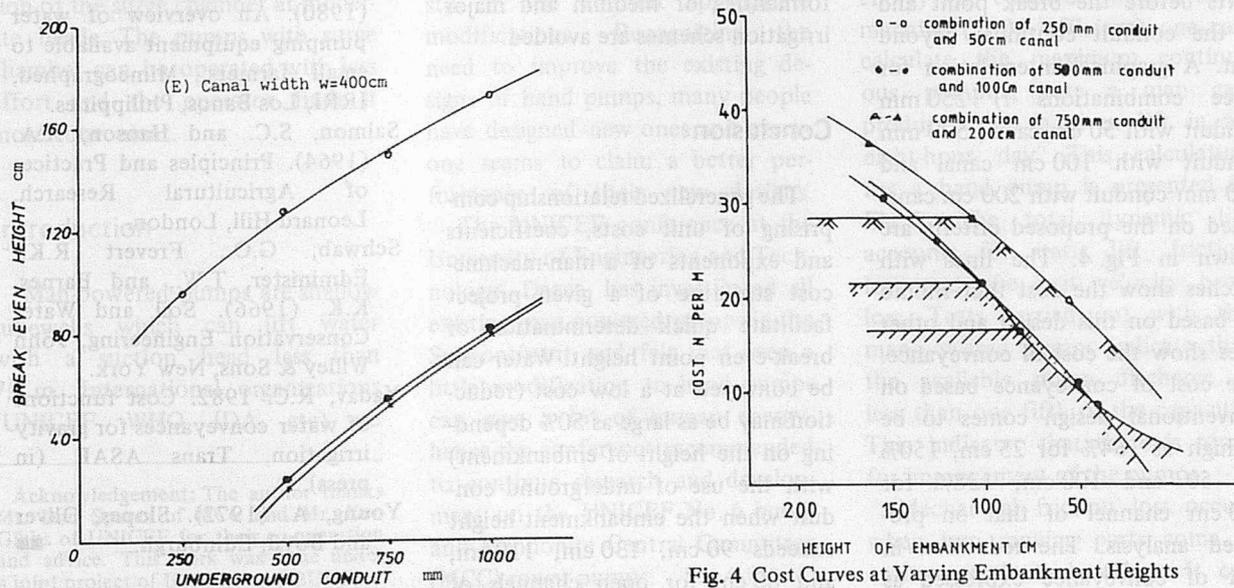


Fig. 4 Cost Curves at Varying Embankment Heights

is insignificant. The difference between the break-even height for cases iii) and i) is small for narrow channel and increases to considerable value for wider channels (Fig. 3). There is very little difference between cases iii) and ii). When the peculiarity of Nigerian agriculture, i.e., surplus land agriculture (Agboola, 1979) is considered in the analysis, the value of break-even height would be as in case ii) and in the situation when land becomes scarce the value of h would be as in case iii). The break-even height for hydraulically feasible combinations viz. 250 mm conduit with 25 cm wide channel, 500 mm conduit with 50 cm wide channel, 750 mm conduit with 100 cm wide channel, 750 mm conduit with 200 cm wide channel and 1 000 mm conduit with 400 cm wide channel are 90 cm, 100 cm, 130 cm, 110 cm and 80 cm, respectively.

The combined systems of underground conduit and open channel on raised embankment should be adopted in the proportion as indicated by the break-even height. The cost of conveyance for break-even height for case iii) at h, 1.5 h and 0.5 h is given in Table 3 indicated how the cost of conveyance will increase if the open channel starts before the break point and or the conduit continues beyond that. A graphical interrelation for three combinations i) 250 mm conduit with 50 cm canal, 500 mm conduit with 100 cm canal and 750 mm conduit with 200 cm canal based on the proposed criteria are shown in Fig. 4. The lines with hatches show the cost that should be based on this design and other lines show the cost of conveyance. The cost of conveyance based on conventional design comes to be as high as 164% for 25 cm, 150% for 50 and 100 cm, 138% for 200 cm channel of that on proposed analysis. The reduction in cost of conveyance expressed as

Table 4 Reduction in Cost of Conveyance from Proposed Combined System (% Cost of Conveyance on Conventional Design) at 1.5 Break-even Height Unit: %

Conduit Diam	Channel width				
	25 cm	50 cm	100 cm	200 cm	400 cm
250 mm	38.3	31.8	28.7	36.7	*
500 mm	38.3	35.2	33.9	23.7	*
750 mm	40.8	27.4	34.0	30.0	14.7
1 000 mm	*	30.0	36.4	33.0	17.0

\* Signifies that combination may not be feasible hydraulically.

percentage of cost of conveyance on conventional design (Table 4) for hydraulically feasible combinations such as 250 mm conduit with 25 cm wide channel, 500 mm conduit with 50 cm wide channel, 750 mm conduit with 100 cm wide channel, 750 mm conduit with 200 cm wide channel and 1 000 mm conduit with 400 cm wide channel were 38, 35, 34, 30 and 17, respectively.

In some countries the irrigation schemes are categorized on the basis of financial involvements (Michael, 1978). Reduced cost of conveyance would lower the total cost of the project for the same command area or will increase the command area for the same fiscal grant. This keeps project of higher acreage than that when executed entirely on gravity canals under the purview of sanctioning authorities for minor irrigation schemes that enable quick decision as many of the formalities of medium and major irrigation schemes are avoided.

## Conclusion

The generalized relationship comprising of unit costs, coefficients and exponents of a man-machine-cost structure of a given project facilitate quick determination of break-even point height. Water can be conveyed at a low cost (reduction may be as large as 50% depending on the height of embankment) with the use of underground conduit when the embankment height exceeds 90 cm, 130 cm, 110 cm, and 80 cm for open channels of

25 cm, 50 cm, 100 cm, 200 cm, and 400 cm width, respectively.

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# Energy Recovery in Man-Powered Pumps



by  
S. M. Nazrul Islam

Associate Professor  
Department of Mechanical Engineering  
University of Engineering and Technology  
Dacca-2, Bangladesh

## Abstract

Man-powered pumps are popular for lifting ground water both for irrigation and drinking water in areas where ground water is available within 6 m. At the present stage of the energy crisis human energy is being called upon to drive the pumps. Some modifications to the indigenous pumps can save energy and it can be used effectively. Energy losses in relation to man-powered pumps is the theme in this paper. Energy loss due to unsteadiness can be reduced by introducing a surge chamber in the suction line. In this regard two pumps (UNICEF hand-pump and MCC rower-pump) have been studied with and without the surge chamber in the suction line. The capacity and efficiency of the pumps increase with the addition of the surge chamber at moderate heads. The pumps with surge chamber can be operated with less effort and the operator finds it more convenient.

## Introduction

Man-powered pumps are shallow tubewells which can lift water with a suction head less than 7.4 m. International organizations (UNICEF, WHO, IDA, etc) are

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actively participating in implementing the installation of man-powered pumps in the developing countries. The uses of such pumps are increasing every year in the agro-based countries. In co-operation with the international organizations a total of 675 000 hand pumps were supplied to the farmers of Bangladesh by the end of 1979. These pumps are used for irrigation and lifting drinking water. By the end of 1984 another 180 000 hand pumps will be added for irrigation purposes. Such a large number of pumps are being used in many countries (Bangladesh, Sri Lanka, Malaysia, India, etc) without satisfactory development of the pumps from the standpoint of energy consumption. The designs of hand pumps which were designed in the early part of this century are still in use without appropriate modifications. Recognizing the need to improve the existing designs of hand pumps, many people have designed new ones and everyone seems to claim a better performance of their new designs.

The UNICEF conference at the University of Engineering and Technology, Dacca, has investigated all existing man-powered pumps in the Subcontinent and felt that even a little modification to hand pumps can save a lot of human energy, hence the conference recommended to continue research and development on the UNICEF No. 6 pump and Mennonite Central Committee (MCC) rower-pumps.

## Energy for Pump

In order to lift or pump a cubic metre of water it is required 9 810 N-m of useful work for each vertical metre of lift. In reality some extra energy must be put into the pump to account for the necessary energy loss or waste inherent in a non-perfect machine. The performance of the machine is characterized by its efficiency which is the ratio of available water energy and input energy. The efficiency can be optimized by minimizing the different losses due to mechanical friction, pipe friction, aquifer and strainer loss and unusable lift.

According to Mark's Mechanical Engineering Hand Book an average man can produce 93 W during 8 hours of work. If this available energy is coupled to an ideal machine (100% efficient) one can calculate the maximum continuous pumping rate a man can produce from a given lift in an eight-hour day. This calculation for a hand pump is presented in Fig. 1. The total dynamic lift accounts for static lift, friction loss and the exit velocity head loss. Tests carried out with the man-powered pumps indicate that the available pump discharge is less than one fifth of the capacity. This indicates that there is room for improvement of the pumps.

Mechanical friction loss occurs when two moving parts come in contact with each other. It can

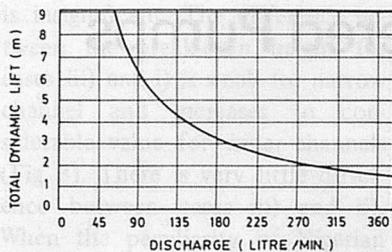


Fig. 1 Lift vs Discharge for Manually Operated Pumps

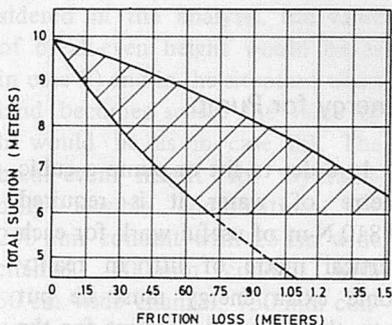


Fig. 2 Increase of Frictional Loss Due to Unsteadiness in Hand Pump

be minimized by appropriate design and precision manufacture. In all piston pumps a significant loss occurs due to friction between the piston and the cylinder wall. Dan Jenkins calculated mechanical loss to be 14% of the total energy for the UNICEF No. 6 hand pumps. This estimation was based on an ideal flow case, but in reality it may increase. The energy loss due to pipe friction, turbulence and eddy currents generated in the fluid during the flow past irregular surfaces, including check valves, reducers, fittings, etc are also important. Special care is to be taken of for the flow through valves on suction side. This becomes apparent for creating cavitation. The reciprocating motion of the piston creates unsteady flow throughout the system. This unsteady nature of flow increases energy loss and takes more input power. The increase of frictional loss due to unsteady flow is shown in Fig. 2 for UNICEF No. 6 pump with 12 m pipe in the suction side. The difference between the two curves is work lost due to unsteady flow. So, the unsteadiness within

the flow should be reduced to increase the efficiency of the pump. Surge chamber on the suction line can be adopted to reduce this loss.

### Description of Pumps

The UNICEF No. 6 pump is a reciprocating pump widely used in Bangladesh both for deep and shallow aquifers. Fig. 3 shows a schematic diagram of this pump with suction pipe. The weight of the cast iron barrel together with a cast iron handle and connecting rod is 29.8 kg. The internal diameter of the barrel is 88.9 mm and stroke length is 216 mm. The

handle is straight and 755.6 mm, 5.5 kg. The seat valve is a flange type and the plunger is a bucket type, and both of them are made of leather. The seat valve and the bucket are leak proof.

The rower-pump is a reciprocating piston pump with 51 mm diameter PVC pipe as cylinder. The cylinder barrel is inclined at an angle of 30° from the horizontal and the operator pushes and pulls directly on a 'T' handle at the end of the piston rod as shown in Fig. 4. The pump is operated with a rowing action, hence the name is rower-pump. This pump has an integral dome-shape surge chamber at the top of the vertical column

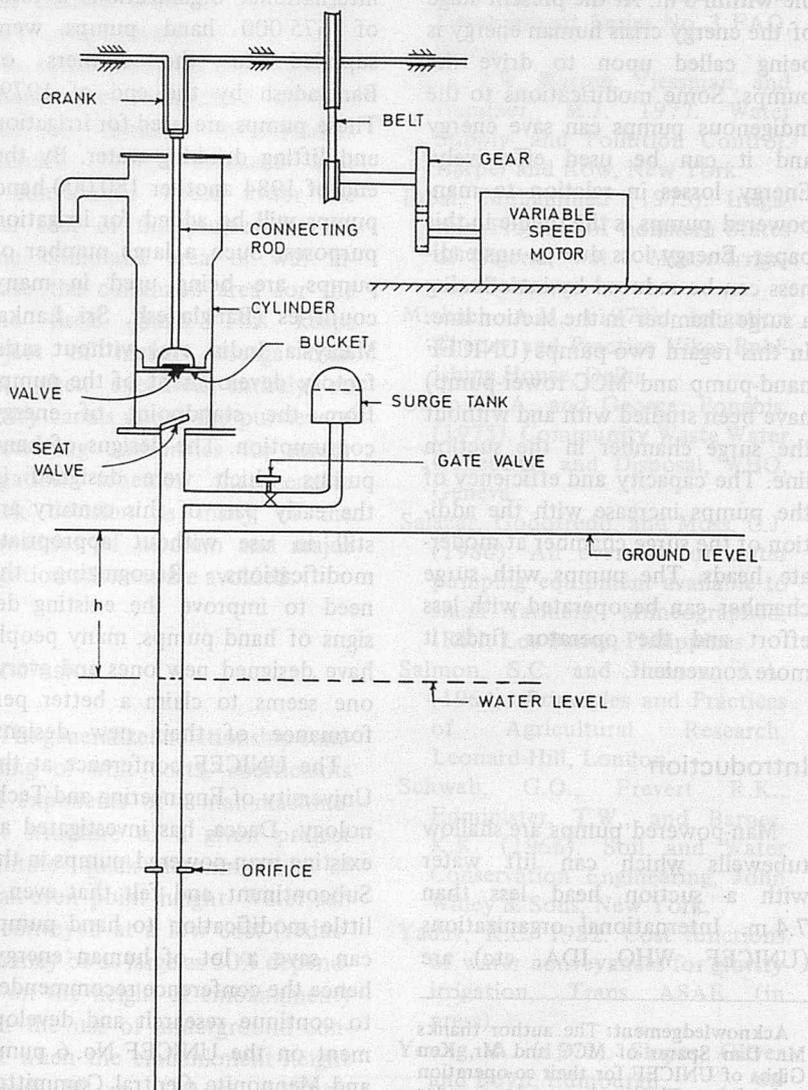


Fig. 3 Schematic Diagram of the Experimental Setup for the Hand Pump

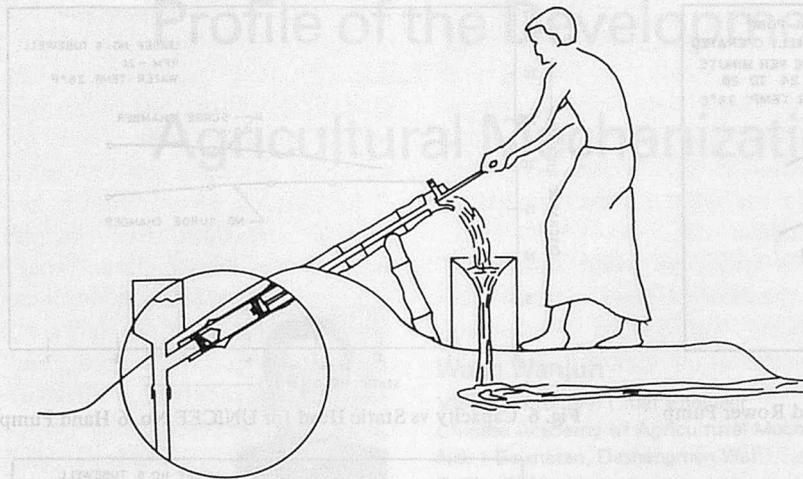


Fig. 4 Rower Pump in Operation Showing Cutaway View of Position, Foot Valve and Surge Chamber

pipe. The column pipe diameter is 38 mm with a surge chamber of capacity 3 l at the top of the column as shown in Fig. 4. The piston with a leather cuff, has a loose fit in the cylinder and can slide out easily after the piston rod guide is removed. The seat valve and the bucket are leak proof.

### Equations

The available power  $P$  given by the pump is expressed in terms of static head and discharge in the following form.

$$P = 9.81 Qh \dots \dots \dots (1)$$

Where  $P$ , is water power in kW,  $Q$  is discharge in  $m^3/sec$  and  $h$  is static head in metre. The input power,  $IP$ , to the pump is known from a calibration curve ( $IP$  vs current) and the pump efficiency,  $\eta$  can be calculated by the following equation.

$$\eta = P/IP \dots \dots \dots (2)$$

The motor together with the energy-transferring unit was calibrated mechanically by using a brake drum in the crank shaft of the pump. The calibration curve was plotted in  $IP$  vs current coordinates for convenient use during the test of pumps.

### Experiments and Uncertainty

The aim of the experiment was to eliminate the effect of unsteadiness by using a surge chamber in the suction line of the UNICEF No. 6 pump and rower-pump. A glass jar of 3 l was used as a surge chamber to the UNICEF No. 6 hand pump for experimental purpose as shown in Fig. 3. To the rower-pump a metallic surge chamber of the same size was used as shown in Fig. 4. The pump was driven by a variable speed motor through a speed reduction gear box. From the gear box the power was transferred to the crank shaft by belt and pulley. The crank was 108 mm for the UNICEF pump and the shaft was rotated at 24 rpm by a variable speed motor.

The motor, together with its driving mechanism, was calibrated mechanically by applying load to a brake drum through the belt at 24 rpm of the shaft. The input power, voltage and current in three-phase were noted. The brake power was calculated by determining the belt tension, rpm and diameter of the brake drum. The ratio of the brake power and the input power was calculated as the efficiency of the driving mechanism. The brake power was varied

by changing the load over the brake drum through the belt. A calibration curve, brake power vs input average current was plotted which was used for calculating the input power to the pump during test. The uncertainty of the calibration curve was calculated to be within 1% and the repeatability of the calibration results were also checked.

The pump was set up over a sump of cross section  $3.65 \times 2.43$  m and a height of 6.7 m. The water in the sump was recirculated and during pump operation the draw down of the water level in the sump was less than 10 mm for any head investigated. The pump was operated with a surge chamber and without a surge chamber by opening and closing a gate valve in the surge chamber line. For each operation head water was collected for half an hour and weighed on a platform scale with a precision up to 0.057 kg. At every minute both rpm and currents were recorded. The rpm was measured by a tachometer with precision of 0.1 rpm and the currents in three-phase were measured by using ammeters having a precision of 0.1 amp. During the experiments the atmospheric temperature and pressure were approximately constant.

During the experiment water was collected alternately in two identical buckets, each having a capacity of 16 l, and after weighing the water filled in bucket was poured into the tank to maintain the level constant.

### Results and Discussion

The experimental values of discharge for various static heads are plotted in Fig. 6 for the UNICEF pump and in Fig. 5 for the MCC pump. The MCC rower-pump was driven by an average-sized man every 15 minutes, and the UNICEF pump was driven by an electric

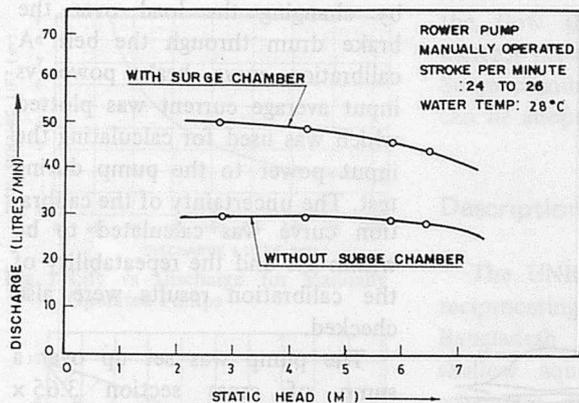


Fig. 5 Capacity vs Static Head for Hand-Operated Rower Pump

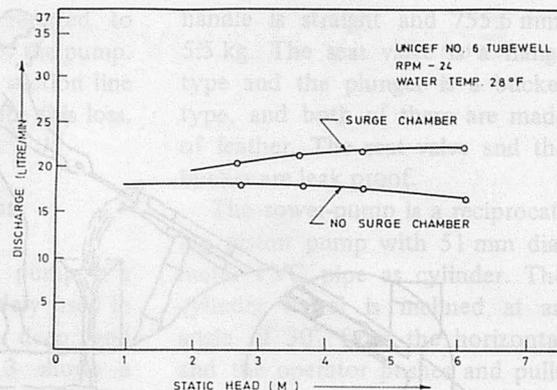


Fig. 6 Capacity vs Static Head for UNICEF No. 6 Hand Pump

motor at 24 rpm. The number of strokes applied by an average-sized man for operating the MCC pump was 22 to 24. Figs. 5 and 6 indicate that the discharge without surge chamber is less than the discharge with surge chamber in the range of lifts used in the experiment. It is also observed from Figs. 5 and 6 that the surge chamber may not improve the discharge for very low static heads. For low static head the addition of surge chamber probably does not work to delay the unsteadiness in the flow. However at moderate heads, shown in Figs. 5 and 6, the surge chamber is very useful in increasing the discharge. It is also expected that the surge chamber position and size may be more effective to increase the discharge of the pump. Fig. 6 also shows that the pump without surge chamber delivers less water with increasing head. On the other hand, the pump with surge chamber delivers more water if the head is increased. However, such an increase of the discharge with head will be stopped by cavitation at a typical value of static head. From a comparison of the results in Figs. 5 and 6, it is observed that the discharge given by MCC rower-pump is higher than the discharge of the UNICEF No. 6 pump. But the maintenance cost of the rower-pump is higher.

The efficiency of the UNICEF pump was calculated by determining the input power from the cali-

bration curve, and water power corresponding to static head and discharge. Fig. 7 shows a plotting of the pump efficiency versus static head. The upward trend of the efficiency curve will continue until cavitation occurs. The efficiency of the pump without surge chamber is less than that of the pump with surge chamber in the range of experiment. The difference in efficiency between two curves in Fig. 7 that the efficiency of the pump is low with its maximum value of 36% for the pump with surge chamber and 22% for the pump without surge chamber. So, here lies the scope for the improvement of the conventional man-powered pumps.

The maximum power input to the pump was observed to be 61 W while it was operated at a head of 6 m. According to Mark's Mechanical Engineering Hand Book a man can generate 93 W during 8 h/day. But the pump here is

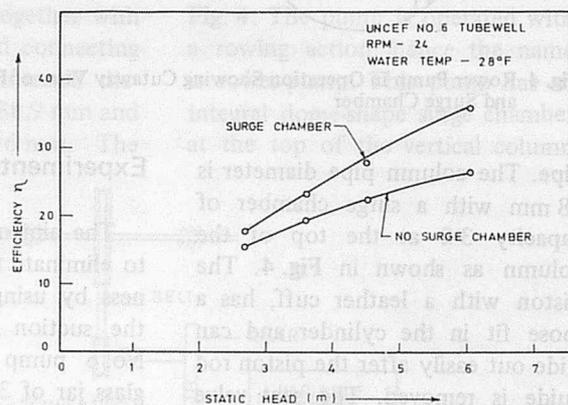


Fig. 7 Efficiency vs Static Head for UNICEF No. 6 Hand Pump

consuming only 61 W for lifting water at a head of 6 m. So, there is a scope for improvement of hand pumps to utilize human energy more effectively.

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# Profile of the Development of Agricultural Mechanization in China



by  
**Wang Wanjun**

Vice Director and Chief Engineer  
Chinese Academy of Agricultural Mechanization Sciences  
No. 1 Beishatan, Deshengmen Wai  
Beijin, China

## Introduction

Agricultural mechanization is considered in China as one of the major channels leading to the agricultural modernization. Of China's population of one billion around 800 million of them are peasants. Therefore, developing the agricultural machinery industry and gradually realizing agricultural mechanization to replace manual labour and raise the land and labour productivity is a matter of vital importance to the whole society. It offers the solution of the problem of providing the people with sufficient food and clothing and directing the peasants towards common prosperity. Farm mechanization will eventually change the outlook of agriculture as well as the whole country.

## Historical Review

The course of the development of agricultural mechanization in China may be roughly divided into 3 stages.

*Stage I (1949-1957)* – This is the stage of developing and popularizing hand tools and animal-drawn implements. During this period, the national economic rehabilitation was under way and the economy was starting to develop. The level of agricultural production was very low. The urgent task was to supply farmers with good and sufficient traditional hand tools and improved animal-drawn implements.

In 1952, China set up the first tractor station and imported some power machines as a pilot project for testing and popularization purposes. In the First 5-Year Plan, some farm implement factories were built. By the end of this stage, the number of tools and implements introduced into China's rural area came up to more than 4.6 million. At the same time, 352 tractor stations and 710 state farms were established.

*Stage II (1957-1970)* – This is the stage of laying out the foundation for agricultural machinery industry and agricultural mechanization. In the light of the prevailing agricultural and economic conditions, the development of power-operated machines through selection and adaptation from imported ones to suit local requirements was started. During this stage, the countryside had realized collectivization, the national

economy was greatly improved, and the primary foundation of the agricultural machinery industry was formed. The first tractor factory was set up and began mass production of tractors. A number of agricultural machinery plants were set up or reformed to upgrade the capability of production. From then on, China was able to produce not only animal-drawn implements, but also to manufacture, in serial production, small- and medium-sized tractors, and many power implements. In the middle of the 50's, national research institutes of internal combustion engines, tractors and agricultural mechanization sciences were established. A number of testing and research institutes at province, prefecture and county levels were also founded. For training specialists and technicians, about 10 colleges and a number of schools, majoring in agricultural machinery as well as mechanization, were established around the country. All these paved the way for further developing mechanization on sound basis.

*Stage III (1971-1982)* – This is the stage of upgrading the level of agricultural machinery industry and broadening the scope of agricultural mechanization. This period was devoted to the improvement of

\* This paper was prepared for the First Regional Consultation on the Agricultural Machinery Industry, Addis Ababa, Ethiopia, 5-9, April, 1982.

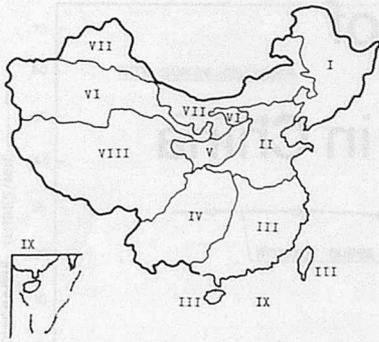


Fig. 1 The Regionalization of Agricultural Mechanization in China

I. Northeast Agriculture and Forestry Region, II. North Agriculture Region, III. Southeast Agriculture and Forestry Region, IV. Southwest Agriculture and Forestry Region, V. Northwest Agriculture Region, VI. Inner Mongolia-Xinjiang Animal Husbandry and Agriculture Region, VII. Qinghai-Xizang Plateau Cold Prairie Animal Husbandry Region, IX. Sea and Ocean Fishery Region.

machines of old model or replacement of obsolete machines and development of new types of machines to meet the newly emerging needs of agricultural production.

Through the efforts of 30 years, more than 1 900 manufacturing plants, about 2 400 repairing and manufacturing factories at county level, and numerous commune-run workshops were established. Now, China can produce tractors ranging from 3 to 160 hp, internal combustion engines from 0.5 hp (gasoline) to 10 000 hp (diesel), harvesters and combines for different crops with different sizes, deep well pumps with heads up to 300 meters, large axial flow pumps with impeller diameters up to 6 meters, various manual and power-operated crop protection implements, complete equipment for chicken farms, complete equipment for processing feed, and the basic equipment for fishery and forestry.

By the end of 1980, the total power for agricultural mechanization was estimated at about 200 million hp. There were 745 000 large and medium sized tractors, 1.87 million walking tractors, 5.9 million pump sets, and 3.42 million farm produce processing machines. The area plowed by tractors accounted for 42.4% of the

total cultivated land but the area power-planted and power-harvested accounted only for 10.9% and 3.1%, respectively. However, almost all the production brigades owned small-sized rice, wheat, oil-bearing seed and other produce processing equipments.

In order to make agricultural mechanization more rational, the country was divided into several mechanization regions and many sub-regions according to natural, agricultural, and other relevant conditions (Fig. 1).

Farm machines are developed strictly according to the local conditions. Firstly, the available machines are chosen and tested right on the farms where the machines are needed. After intensive testing and thorough evaluation, the most appropriate ones are selected and set as models for production. If the machines do not satisfy the requirements, they are modified and adapted to meet the requirements. For some special crops or special farm practices with no existing machines available, more research work is done to invent and try out the suitable machines. In summary the procedures of developing machines are "Selection, Adaptation, and Innovation".

#### Modality of Agricultural Mechanization as Determined by National Conditions

From the national view point and basing on actual requirement of agricultural production the basic principle for developing agricultural mechanization is made.

China is a vast socialist country, having a large rural population, limited farmland, weak economic foundation, complicated natural conditions and intensive cultivation traditions. The farmland per capita is less than 0.1 ha, which accounts for roughly 1/4 of the world's average, 1/8 of the United States,

1/7 of the Soviet Union, and 2/5 of India. Therefore, for a considerably long period to come, China's agricultural structure will be to produce more food by increasing the yield per unit area.

Agricultural mechanization has multiple functions such as to increase the labour productivity, to improve the working conditions, to increase the yield per unit area, to reduce the cost of farming, etc. For different countries at different stages of development, some functions will be preferred to others and the preference will affect the selection of machines. In China, although grain production has tripled in the last 30 years, this magnitude is not adequate, especially in the years of natural calamities. Consequently, much more attention is given to the development and popularization of machines that can help increase the yield. For example, in some crop growing seasons, there is too little water in the North, and too much of it in the South. To guarantee a high stable yield, there is need to develop irrigation and drainage equipment to fight drought and waterlogging conditions. This explains clearly why we have popularized about 6 million pump sets and consumed about 38% of the total rural power for irrigation and drainage. In other words, agricultural mechanization is developed "selectively", not "completely", and the yardstick for "selection" is the increment in production.

As to the size and the level of motorization of machines the principle followed is to develop hand tools, animal-drawn implements and motorized machines simultaneously; to develop small, medium and large-sized machines simultaneously. The state farms usually need large and sophisticated machines, but the people's communes, on the contrary, need small- and medium-sized machines, animal-drawn implements and hand

tools. Also, the mountaneous area makes up 2/3 of the whole territory and paddy fields make up more than 1/4 of the total cultivated land. In addition, after the realization of different forms of job responsibility, the size of field and operation unit is further reduced. In the light of these natural and economic factors, stress on the development of small and medium-sized implements is made. Nowadays, there are about 2 000 models and specifications of small and medium-sized machines, covering almost all the equipment needed by small farming units in the country.

In developing agricultural mechanization in China, two problems are faced: the funds to purchase machines and the problem of the surplus labour released by machines. Experience has shown that the most feasible way of handling surplus labour is to develop a diversified rural economy and side-line occupations. Appropriate mechanization, through carefully selected machines and good management, will certainly result in increasing agricultural production. The farm labour, released by mechanization, will be diverted to diversified economy and side-line occupations. They will create more wealth, make themselves better off and earn more money to buy more agricultural machines, which in turn, will further promote agricultural production. This favorable interaction has been verified in many provinces, even in the most densely populated areas of Jiangsu Province. In 1981, in spite of some serious calamities, China's total output of grain increased by 10 million t. Farmers increased their incomes, hence bought more machines. The number of implements purchased by farmers such as small sprayers, carts, and oil extracting machines increased by 50%, 23%, and 21%, respectively, as compared with that of 1979.

### Some Requirements in Developing Agricultural Machinery

The agricultural machines, in order to appeal to farmers, must be: i) suitable to local needs; ii) simple and easy for operation and maintenance; iii) reliable and durable; and iv) inexpensive.

An agricultural machine must be suitable to the specific conditions of the region where it is used, including natural conditions, farming system, scale of production, economic and technical level, etc.

New machines whether developed domestically or imported from foreign countries must undergo intensive testing, at least for one season, preferably longer, not only for the performance, but also for reliability, accessibility of repair, and the economic result. To make a decision in a hurry or "at a glance", as was once done in China, would certainly run the risk of failure. Therefore, intensive testing and thorough evaluation of a new type of machine can never be over-emphasized.

In developing a new machine, the right material and treatment to ensure strength and durability must be selected. Since agricultural machines are always produced in large quantities, the appropriate manufacturing technology must be carefully adopted to guarantee quality and low price of the product. Farmers always like to buy good and inexpensive machines. Another point worthwhile to mention here is "Standardization". For the last decades, the British measuring system and the metric measuring system have caused a lot of troubles in manufacturing as well as in repairing agricultural machines in China. A farmer can not match well a bolt made in inches with a nut made in millimeters, as a matter of fact, no one can do it. Developing countries cannot afford the cost of such confusion. Just a

couple of years ago, the Government made a decision to adopt, step by step, the International System (ISO), both the measuring units and standards of testing procedures and quality evaluation.

Chinese experience in farm machinery may be summarized as follows:

1. Agricultural machines were developed following the procedures of "selection, adaption, and innovation". Only after intensive field testing and thorough evaluation, based on the local conditions, can a new type machine be accepted for large scale production.

2. Machines of various sizes and different levels of motorization were simultaneously developed and popularized. However, in the light of the natural and economic conditions, the development of small and medium-sized motorized machines, as well as hand tools and animal-drawn implements was stressed.

3. In line with China's agricultural policy, field operation machines, and equipment for diversified economy and side-line occupations to increase food production as well as farmers' income were also promoted.

4. Priority is given to the quality of agricultural machines, sufficient supply of spare parts, and setting up repair shops in every county and commune, to guarantee timely repair in case of break-down.

5. In order to realize agricultural mechanization successfully, the training of qualified personnel of relevant disciplines at different levels is of vital importance. As we say in China "Between machine and man, often man is the decisive factor".

#### REFERENCE

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# Small Tractors in China

by  
Kong Depeng

Deputy Director and Chief Engineer  
Tractor Research Institute  
Luoyang, China

Ling Tongsen

Head of Technical Information Division  
Tractor Research Institute  
Luoyang, China

Xü Guangqin

Head of Technical Development Division  
Tractor Research Institute  
Luoyang, China

## Introduction

China is a country with a vast territory wherein the farming conditions and management scale vary from place to place. Except state farms, the management scale under the commune system is generally small, especially in South China. This determines that, at present, China employs tractors of large, medium and small horsepower simultaneously and puts the emphasis upon small tractors. In the process of China's agricultural mechanization, the number of small tractors is growing rapidly which in 1980 was nearly 1.98 million (including 100 000 boat-type tractors) and that of large and medium horsepower tractors in use was 745 000. The horsepower of small tractors amounted to 40% of the total tractor horsepower. Fig. 1 shows the development of small tractors in the last decade.

## Development of Small Tractors

The small tractors are walking tractors, boat-type tractors and wheel tractors under 11 kW.

The use of small tractors in China began in 1956. Then in 1958, on the basis of tests to select suitable models, Gongnong-7 walking tractor (5.15 kW) was developed, but this model was not capable of

plowing operations and the power was not enough for rotary cultivation and its structure was complex. After 1965, Gongnong-12, Gongnong-10, Dongfeng-12 and some other models (all are of 8.8 kW) have been developed. These tractors are mainly used for paddy fields of small size and can be used not only for rotary cultivation but also for plowing operation. Later on, Gongnong-5 (3.7 kW) and Gongnong-3 (2.7 kW) were developed to be used in the field of small size and in mountain area and for row crops. Three out of the above five models are now under mass production. Besides, on the requirements of North China, Hongwei-12 and Jinniu-12 (8.8 kW) walking tractors were developed. The former is mainly used for plowing in dry land while the latter is used for ridge culture area. The

annual production of those two models is over 10 000 units.

The problems of walking tractors are that with the driver walking behind the tractor it makes the operation laborious and limits the speed and the labour productivity is low. To solve those problems, small four-wheel tractors have been adopted in some provinces in North China. The structure of those tractors is simpler than that of ordinary tractors but is more complex than that of walking tractors and the initial cost is 40-50% higher than that of walking tractors. Therefore it can be said that small four-wheel tractors are an intermediate product between walking tractors and ordinary tractors. At present, there are 200 000 small four-wheel tractors in use in China's agriculture. The main models are Taishan-12 and Dongfanghong-12.

The boat-type tractor is a new concept, conceived for operation in paddy field. It utilizes the buoyancy of the boat-shaped hull to reduce the rolling resistance in

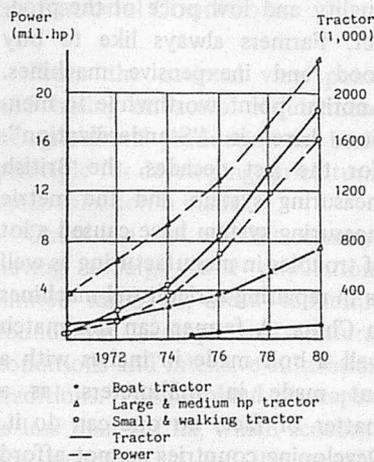


Fig. 1 Tractors and Tractor HP in China

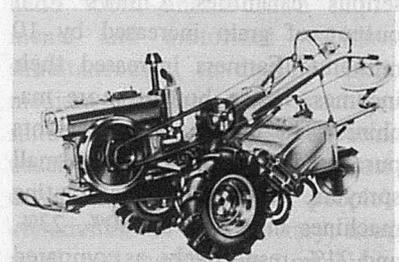


Fig. 2 Walking Tractor Dongfeng-12

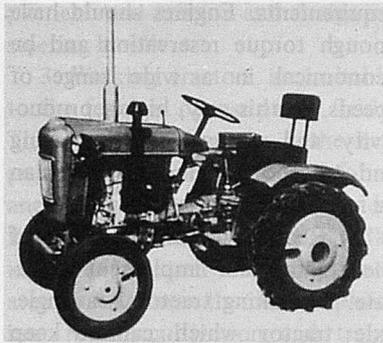


Fig. 3 Small Wheel Tractor Dongfang hong-12

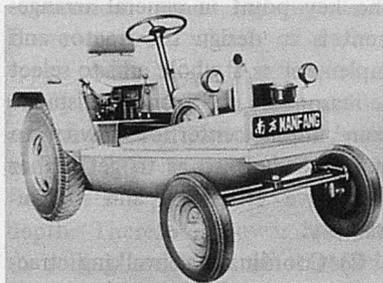


Fig. 4 Boat-Type Tractor Nanfang-12

paddy field of deep plow layer. This makes the dynamics and kinematics of boat-type tractors different from that of traditional tractors. Consequently the productivity has been distinctively improved and the conception that tractors are not suitable for paddy field of deep plow layer has been completely changed. However, the boat-type tractors also have a good adaptability in ordinary paddy field. Models now under mass production are Nanfang-12, Hubei-12 and Dongfang-12 (8.8 kW). The production of models under 6 kW is low.

### Extensive Use of Small Tractors

There are many factors affecting the use and development of tractors, such as agricultural conditions, farming requirements, management scale, economic conditions, technical level of manufacture, farmer's experience, etc. In consideration of China's agricultural conditions, small tractors are more adaptable.

1. Small tractors are suitable to agricultural conditions and farming requirements in most areas. Among the arable lands in China, the hilly area represents a great proportion. In North China management scale limits the field size while in paddy fields, land leveling limits the field size. Using large and medium tractors on small-farm sizes is uneconomical. Irrigation is an important feature of China's agriculture. Even in dry land areas in the North, irrigated land areas continue to increase. Therefore, there are many ditches on most farms and the roads between fields are narrow. As the small tractors have the advantage in size, light-weight and good maneuverability and even can be transported by boat there is no need to widen roads or strengthen bridges. Besides, experiences from paddy fields suggest that the plow layer could become deeper year after year due to constant tractor use with too heavy a weight pounding the land. This problem can be solved to a great extent by the use of walking tractors and boat-type tractors.

2. Small tractors are suitable to the economic conditions and management scale in most areas. Except for a few state farms, the management scale of agriculture in China is small. The basic accounting unit is production team. Generally, the farm land of a production team is 10-15 ha in South China, 20-35 ha in North China and 60-70 ha in North-east China where the land shared by a commune member is 0.2, 0.35 and 1.2 ha, respectively. In recent years, in order to bring about an advance in agricultural production, on the premises of collective ownership each production unit has put into practice the production responsibility system of various forms. There is a trend that management scale will become smaller. Corresponding to this, buyers and users of tractors —

mainly production brigades in the past — now have become production teams, groups of households and individual households. According to the experience from many regions, a small tractor of 8.8 kW capacity can do the work on 12-15 ha. Therefore one tractor is enough to meet the needs of the production unit. In view of the purchasing capacity of a production unit it will be acceptable if the price of a small tractor is below 4 000 Yuan.

3. Small tractors are suitable to the level of mechanical knowledge and management in rural areas. The structure of small tractors is simple and this makes the operation, maintenance and repair easy. Usually repair is done by the operator himself on the spot. Statistics show that repair and maintenance cost is 200-300 Yuan a year. Operators need not go to technical schools for years. A graduate from middle school can operate a small tractor after going through a training course of short period. It can be seen that small tractors are suitable to the reality in China's agriculture.

4. Less investments and quick returns in the production of small tractors. It is easy for small tractors to be put into commercial production and to have reliable quality because the manufacture technology of small tractors is not so complex as that of large and medium tractors and less investment is needed. There are now 17 walking tractor manufacturing plants in China each with a production capacity of over 10 000 units. In recent years the quality has been improved greatly. In 1979 three silver medals from the national government were awarded to three walking tractors for their high quality products. The product quality investigation in 1980 shows that among 15 walking tractors of high output, 10 had their products reach the excellent quality

level and the other had their products reach the first-rate quality level.

### Performance and Structural Features of Small Tractors

1. Walking tractors in 8.8 kW range holds a prominent position in small tractors in China. Walking tractors, small four-wheel tractors and boat-type tractors in 8.8 kW range are equipped with engines of similar power. As for walking tractors of smaller power, many models have been developed but the production is low.

Small tractors use diesel engines, mainly water-cooled ones. Engines of 8.8 kW have two main models. Model 195 (horizontal) and model 190 (vertical). Speed at rated horsepower is 2 000-2 200 rpm. Those engines are of the same basic version as the power source for irrigation, power generation and processing as well as the power source for boats in rural transportation. Costs are low and the supply of spare parts are available because the engines are under mass production.

The engine is connected to gear box in two ways. One is by V-belt and the other is by shaft. The former is featured by the advantage of low manufacture technology and low cost, but its driving efficiency is low and the V-belts have to be replaced periodically. The latter is just contrary to the former in these respect. Tractors with V-belt drive share the majority of sales, while the tractors with shaft drive share only 10% of the sales. According to different requirements of various regions, tires of walking tractors have three sizes: 6.00-12 (for rotary cultivator in paddy field), 6.00-16 and 6.00-17 (used in the areas where both paddy and dry land crops are planted). Small four-wheel tractors which are mainly used for plowing

in dry land and transportation are equipped with tires of 6.50-16. To meet the conditions of high draft resistance of the paddy field when plowed dry and the low bearing capacity of the wet soil surface when harvesting in paddy field, continuous tracks, half tracks and trigonal tracks have been developed for walking tractors and their traction efficiency is much improved.

2. Most walking tractors in the country are of universal types, i.e., they can be used not only for plowing operation but also for rotary cultivation. The primary operations in paddy fields in South China are plowing, rotary cultivation and transportation while plowing, sowing, harvesting and transportation are the main operations in the dry land area of North China. Performance tests show that walking tractors manufactured in the country can meet the requirements of the three main operations (plowing, rotary cultivation and transportation) without complicating the structure or increasing the costs too much. This is achieved by solving the following three problems in the period of development.

A) Choosing reasonable parameters of tractor and component structure. Each model is equipped with a 2 × (3+1) gear box so that plowing operation (and other drawbar operations), rotary cultivation and transportation have two speeds each. The 16 km/h speed (which still remains in the safe speed range) is chosen as the highest speed for transportation. To ensure the safety in transportation and to meet the requirements of high load and frequent load fluctuation in rotary cultivation, double-disk clutch or single-disk clutch is chosen instead of centrifugal one with simpler structure. Properly reserved torque capacity is built into the two former clutches. The rated engine horsepower is selected according to the need of rotary cultivation in paddy field under certain farming

requirements. Engines should have enough torque reservation and be economical in a wide range of speeds. In this way, higher productivity and economy for plowing and transportation operations can be ensured.

B) Reasonable arrangement of the tractor and implement aggregate. A walking tractor is a single-axle tractor which cannot keep itself stable. Only with matching implement can it become stable. The key point in general arrangement is to design the tractor and implement as a whole and to select a reasonable horizontal distance from initial center of gravity to the drive shaft so as to get higher draft-drive efficiency and maneuverability.

C) Coordinating walking tractors and their matching implement with each other in structure and performance. If peasants have the requirement that walking tractors of 8.8 kW should draw a trailer with a carrying capacity of 1 000 kg, a ballast has to be added to driving wheels, while brake effect is strengthened through the brake mechanism on the trailer. A key point for the stability in plowing operation is a higher ability of wheels and plows to resist lateral force as well as easy adjustment of plow body in a horizontal plane so as to ensure force balance in a horizontal plane. And the key point to ensure the quality of rotary cultivation and economic result is the coordination between travelling speed, the speed of blade carrying the axle as well as blade shape and blade arrangement. The relation of the above factors has been appropriately determined through repeated tests. Another very important point to ensure tractor-implement aggregate for better maneuverability is the coordination between structural parameter of tractor and rotary cultivator as well as the appropriate coupling mechanism between im-

plement and tractor and design of steering handle.

3. Walking tractors are suitable to the features of vast paddy fields. The wheel performance is the key point in determining the performance of walking tractors in paddy fields. Experience shows that walking tractors used in paddy field area have to meet the need of plowing, rotary cultivation and transportation. Iron wheels equipped on walking tractors are more economical than high-lug tires. However, iron wheels of various types used for draft operation in paddy field have a high rolling resistance coefficient which is between 0.2-0.3 in the flooded paddy field with a plow layer of medium depth. Therefore, power loss due to rolling resistance of tractor in plowing operation is over 30%. Additionally, slip loss is above 25%. The result is that drawbar efficiency of walking tractors with V-belt drive is only about 30%. Driving wheel loss in rotary cultivation is low, normally 6-20%. The drawbar efficiency under corresponding conditions is over 60%. So it can be seen from the above that requirements on wheels for plowing operation is stricter than that for rotary cultivation. Since the results from research of many years on the structural parameter of paddy field iron wheels show great advantage of such types as herringbone iron wheels and paddle-lug iron wheels designed for walking tractors of 8.8 kW. They have been used extensively, especially the former which have been adapted on many different models and in many paddy fields. The drawbar pull at 20-25% slip rate is about 200 kg in the paddy field with a plow layer of medium depth and the rolling resistance coefficient is the same with that of iron wheels of other types. Thus due to high drawbar efficiency, good off-road performance, high resistance against lateral force, and

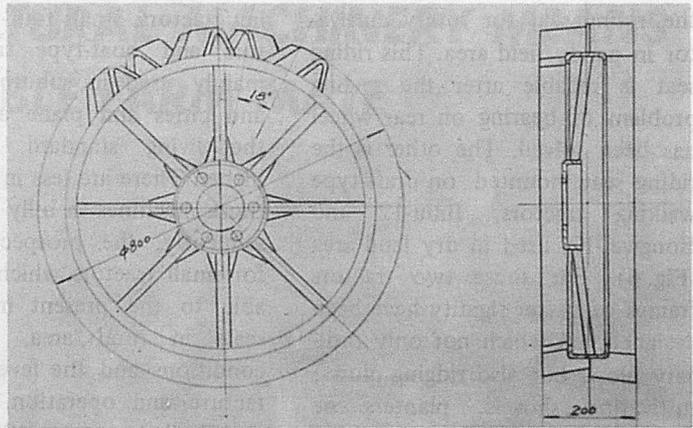


Fig. 5 Herringbone Iron Wheel

additionally, repeated improvements in design and manufacturing technology to lower the structural weight and cost, they are now used on many models and in many different paddy fields.

4. Strong structure and long working life. Tractor utilization in China's rural area is high. For some tractors it is over 1 000 h a year. When peasants buy a tractor they hope it may be used for more than ten years. Maintenance and repair are done by the peasants themselves. With these considerations in mind load intensity of diesel engine and chassis components is set at a medium level and the quality required of oils and coolants are not high. The weight per BHP for walking tractors is 35-45 kg/hp of which the low value is used for tractors used in paddy field and the high value for tractors used in dry land. The weight per BHP for small

tractors is about 50 kg/hp. In order to get high reliability and long working life, the requirement on processing accuracy and quality standards of acceptance of small tractors are similar to those of the medium horsepower tractors. The Agricultural Tractor Test Code stipulates that besides various performance tests a field test of 1 500 h must be included for walking tractors and small four-wheel tractors. The effect of this stipulation has been excellent since it was put into action ten years ago.

5. Riding seats of various types for walking tractors of 8.8 kW range. In order to alleviate the operator's hardship in field operation, manufacturers and research departments concerned have conducted a lot of researches on various types of riding seats for many years, out of which two types have been put into mass production and used extensively. One is

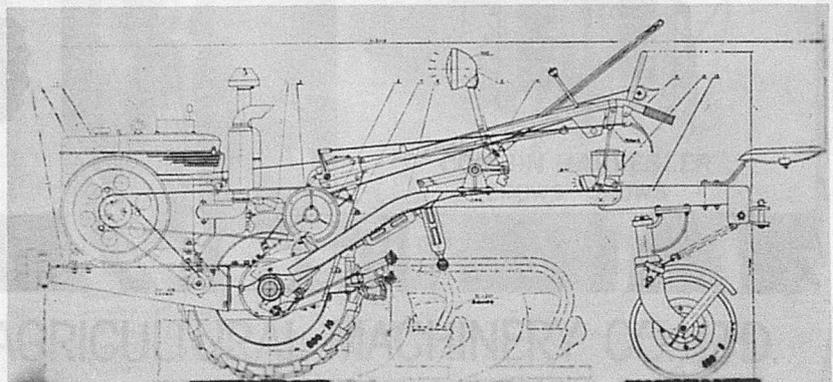


Fig. 6 Drawbar-Type Walking Tractor with Frame and Riding Seat

the riding seat for rotary cultivator in paddy field area. This riding seat is reliable after the sealing problem of bearing on rear wheel has been solved. The other is the riding seat mounted on draft-type walking tractors, Jiniu-12 and Hongwei-12, used in dry land area (Fig. 6). For those two tractors frames of better rigidity have been designed, on which not only ordinary plows but also ridging plows, cultivating shovels, planters or other implements for row crops can be mounted. Implements are controlled by mechanical lift mechanism. The driver's riding seat is mounted on the rear wheel. Several types of riding seat for plowing in paddy field have been developed but they are not adopted extensively by peasants because in paddy field plowing, conditions are severe, land size is small and manipulation is frequent.

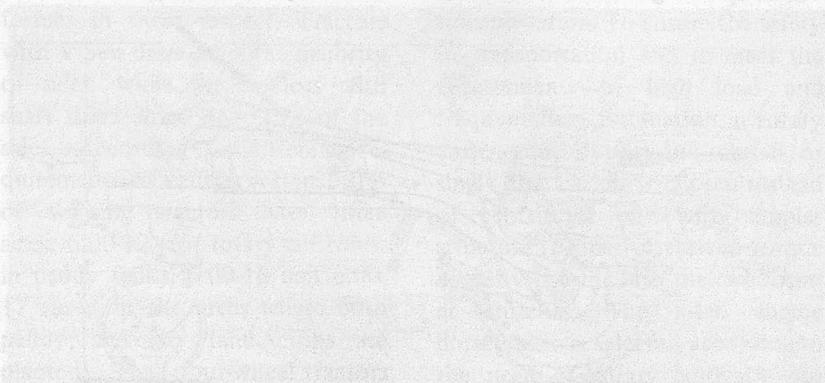
### Evaluation of Prospect of Small Tractors

The level of agricultural mechanization in China is still low. Walk-

ing tractors, small four-wheel tractors and boat-type tractors are mainly used in suburb of towns and cities and plane areas where the living standard is slightly higher. There are less in number of those machines in hilly areas. Consequently, the prospect is broad for small tractors which are adaptable to the present management scale in rural area, agricultural conditions and the level of manufacture and operation. It is estimated that up to 1985, in the period for readjusting the nation's economy, walking tractors, small four-wheel tractors and boat-type tractors will continuously play an important role in China's agricultural mechanization. The demand per year is probably about 200 000-250 000 units. The amount will reach 27-30 million units by 1985. With the development of agricultural economy after 1985, the numbers of walking tractors and small four-wheel tractors of 8.8 kW used in soil preparation and transportation may be reduced. Walking tractors in 2.2 kW range, as an auxiliary power source in agricultural mechanization, may

hold a certain position and will play an important role in the operation in hilly areas, gardens, special crop planting, crop protection, public utility, etc. In the area with better economic and natural conditions walking tractors and small four-wheel tractors of 8.8 kW will probably be replaced by four-wheel tractors with greater horsepower (such as 13 kW). Boat-type tractors will be still in use in paddy field with deep plow layer. If the research to use boat-shaped "hull" as an optional part of walking tractors and wheel tractors can succeed, the boat-type tractors will become popular further.

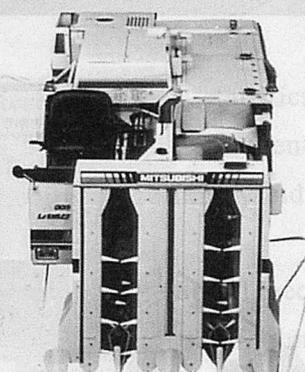
The trend of small tractors in the country is light in weight, small in size, simple in structure and cheap in price. Development work and product design should be strengthened to further reduce fuel consumption, vibration and noise level and to make corresponding improvements in structure in order to follow up with the growing demand of small tractors and various types of matching implements. ■



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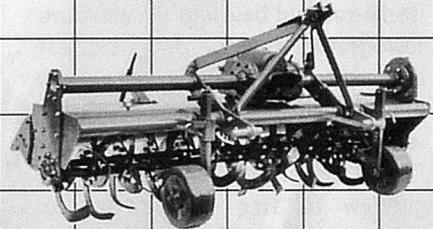
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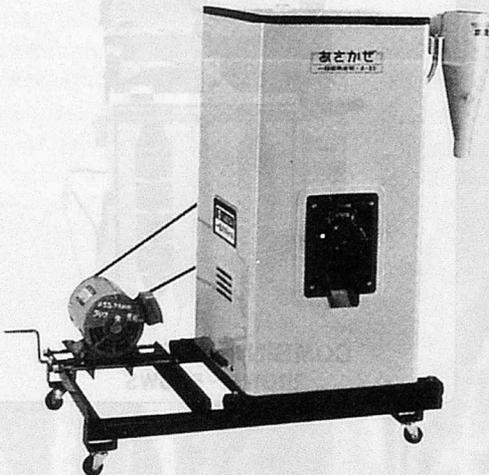


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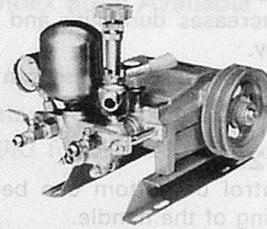
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This publication, published quarterly, has an objective to promote agricultural mechanization in developing countries. Its readers consist of so many people in various fields such as farmers, dealers, manufacturers, researchers, government officials,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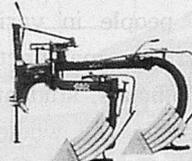
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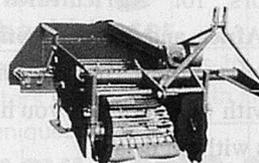
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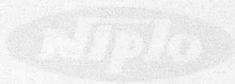
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# Use of Combine Harvester in Malaysia



by  
**A. A. Mainul Hussain**  
Faculty of Agricultural Engineering  
University Pertanian Malaysia  
Serdang, Selangor, Malaysia



**Wan Ishak Wan Ismail**  
Faculty of Agricultural Engineering  
University Pertanian Malaysia  
Serdang, Selangor, Malaysia

## Introduction

A survey was conducted in the paddy growing areas of Sekinchan, Tanjung Karang, Sungai Besar, Sawah Sempadan under the North-west Selangor Integrated Agricultural Development Project. The project covers an area of approximately 97 368 ha of which 20 000 ha is under paddy cultivation. The purpose of the survey was i) to evaluate the performance of the combine harvester in those areas; ii) identify the problems faced by the farmers and the contractors (owner) in the use of the machine; and iii) to forecast the future trend in the use of the machine. Twelve contractors and 43 farmers from various areas mentioned above were included in the survey. A questionnaire form was prepared beforehand for the farmers and contractors. A wide range of questions were asked various groups of people in connection with the use and ownership of the machine.

## Summary of Findings

The farmers interviewed had an average range farm holding of 1 to 3 ha of which 0.5 to 1.5 ha were used for cultivation of paddy. Almost all the farmers cultivated irrigated paddy with an annual cropping intensity of 200%. Only eight farmers (18.6%) reported using combine harvester for harvest-

ing and threshing their crops. The rest reported using sickle for harvesting and "tong banting" (threshing drum) for threshing. The farmers using conventional methods of harvesting and threshing used hired labour to supplement family labour for the purpose. Almost 95% of the farmers interviewed indicated that they paid M\$10-20 per sack (60 kg) of paddy threshed for harvesting and threshing. The wide range of price variation for the operation indicated that the cost of hired labour was highly variable depending on the demand and supply of labour at the time of the operation.

Most of the farmers reported that they had to depend on labourers from the locality and nearby areas for manual harvesting and threshing which is in short supply during the season. All the farmers indicated that the shortage of labour was mainly due to migration of labour force to other sectors of the economy like industries and other areas with better wage condition. Post harvest losses reported by farmers varied from 1% to 15% due mainly to inefficient threshing. The farmers who used combine harvester reported the cost of hiring to be M\$4 to M\$7 per sack (60 kg). The farmers indicated that hiring of the machine was not difficult and using it was an efficient method of harvesting and threshing. All farmers showed their preference to hire combine harvester but they cannot afford to

hire the machine because of small holding size and low income. The most important problem faced by the farmers in the use of the combine harvester was the lodging of the crop which reduced the efficiency of the machine to a great extent. The farmers using the combine harvester suggested that waterways and channels should be widened and fields properly levelled for efficient drainage of the field prior to harvesting. Some suggested using varieties of paddy which are short and do not lodge.

The power range of the combine harvesters owned by the contractors varied from 20 to 60 hp. The most popular make within the locality surveyed was Iseki and Massey Ferguson made in Japan and U.K., respectively. The reasons which made a machine most popular with owners were i) ease of handling; ii) compact and small; iii) cheap and little maintenance problem; and iv) adequate availability of spare parts. About 83% of the owners indicated that they use the machine in their own field and hire it to other farmers. Only 16% of the owners owned the machine for contract hiring. The mode of payment in all cases was cash. The area covered by the various machines varied from 300 ha for the large machine to 150 ha for the smaller ones. The main difficulties faced by the owners are i) transportation of the machine to the field; ii) moisture content of the soil at time of

operating the machine; and iii) lodging of the crop. The roads in the farm area are not wide enough for the machine and in some cases the condition of the road was very poor.

Ten of the 12 owners interviewed indicated that the combine harvester will become popular with farmers in future if adequate measures are taken to remove the difficulties and bottlenecks at present existing in the operation and maintenance of the machine. Sixty percent of the owners suggested that agents of the combine harvester should make arrangements for providing better after sale service such as i) supply of spare parts at reasonable price; ii) providing training in the operation and maintenance of the machine; and iii) providing maintenance and repair facilities for

the machine.

### Suggestions and Comments

Field condition such as levelling of the field in the farm areas should be improved so as to make the drainage and water management at the time of harvesting easier. The waterways (irrigation and drainage canals) should be cleaned regularly to maintain proper flow of water in the canals. Road conditions within the farm should be improved for easier transportation of the machine.

Farmers in the locality should be encouraged to plant the same variety of paddy at the same time. This will encourage better water management and the crops will mature at the same time making harvesting of the adjacent plots

easier. The farmers should also be encouraged to plant high yielding dwarf variety of paddy.

The farmers should be encouraged to form co-operatives to own, maintain and operate the machine and hire it at a reasonable rate to other farmers. They should also be trained by the supplier of the machine as to the maintenance and operation of the machine in the field. The supplier should also maintain and offer better after sale service to the owners of the machine as regards maintenance and supply of spare parts for the machine at a reasonable cost.

Once the measures mentioned above are implemented then it is expected that the popularity for the use of combine harvester in Malaysia will increase. These measures will also ensure the use of the combine harvester. ■■

The power range of the combine harvesters owned by the contractors varied from 20 to 60 hp. The most popular make within the locality surveyed was Isaki and Massey Ferguson made in Japan and U.K., respectively. The reasons which made a machine most popular with owners were i) ease of handling; ii) compact and small; iii) cheap and little maintenance problem; and iv) adequate availability of spare parts. About 83% of the owners indicated that they use the machine in their own field and hire it to other farmers. Only 10% of the owners owned the machine for contract sowing. The mode of payment in all cases was cash. The area covered by the various machines varied from 400 ha for the large machine to 150 ha for the smaller ones. The main difficulties faced by the owners are i) transportation of the machine to the field; ii) moisture content of the soil at time of

harvesting and threshing. The wide range of price variation for the combine harvester in those areas; ii) identify the problems faced by the farmers and the contractors (owner) in the use of the machine; and iii) to forecast the future trend in the use of the machine. Twelve contractors and 43 farmers from various areas mentioned above were included in the survey. A questionnaire form was prepared beforehand for the farmers and contractors. A wide range of questions were asked various groups of people in connection with the use and ownership of the machine.

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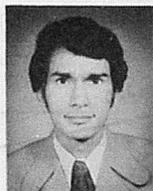
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# A Centrifugal Impeller-Type of Sunflower Seed Decorticator



by  
**K. N. Nag**  
Dean  
College of Technical and  
Agricultural Engineering  
Udaipur 313001, India



**Pratap Singh**  
Assistant Professor  
College of Technical and  
Agricultural Engineering  
Udaipur 313001, India

**Rajash Bhandari**  
Junior Engineer  
Land Development Bank  
Hathipole, Udaipur, India

## Abstract

A centrifugal impeller-type of a decorticating machine for sunflower seeds was developed. The decortication was done by subjecting the seeds at a high centrifugal force and then striking them on a hard surface. The performance of the machine was evaluated at different moisture content levels of the seeds and feed rates, and peripheral speeds of the impeller.

## Introduction

Sunflower, popularly known as "Surajmukhi", is grown in an area of about 400,000 ha in India. The other major sunflower producing countries of the world are the Soviet Union, Argentina, Bulgaria, Rumania, Turkey and South America. Sunflower's season of planting, the photo-period requirements and the altitude are not limiting factors, hence it is possible to cultivate this crop throughout the year. The crop gives a grain yield of 300-500 kg/ha under rain-fed conditions and 800-1 200 kg/ha under irrigation.

Sunflower is mainly grown for its oil. The seeds contain 28 to 50% high quality oil which is used for culinary purposes, in the prepara-

tion of "vanaspati" and in the manufacture of soap and cosmetics. It is a rich source of linoleic and oleic acids which check the cholesterol level in blood and helps to minimize heart diseases. The oil also contains about 15% high grade protein. The oil cake is an ideal feed for poultry and livestock. If the kernels are separated from husk and then the oil is extracted from them, there is an increase of about 30% in the quantity of oil. The husk can be ground and mixed with livestock feed to increase its nutritive value.

## Methods and Materials

The decorticating machine (Fig. 1) consists of a hopper, centrifugal impeller, casing, collecting chute, and a transmission system.

A conical hopper was provided for feeding the sunflower seeds to the rotating impeller and a sliding flap at the bottom for regulating the feed rates. The flap was marked for different feed rates after calibrating it.

The covered centrifugal impeller provides the force to the seeds for decortication and had six curved vanes with inlet vane angle of  $43.8^\circ$  and an outlet vane angle of  $74.5^\circ$  and a height of 3.75 cm each.

The outer diameter of the impeller was 42 cm and a hub diameter of 5.8 cm. The impeller had an opening in its upper casing which was connected to the feeding hopper.

A mild steel casing was provided around the impeller to act as a hard surface for striking of seeds. The spacing between the impeller and casing was 15 mm. Indentations were made into the casing at a spacing of 5 mm to make the surface rough. At the lower end of the casing, just below the impeller, an inclined plate was provided to collect the decorticated and undecorticated seeds. The seeds were taken out through the discharge chute.

The impeller was mounted on a vertical transmission shaft, which was connected to a variable speed motor through a gear box. The vertical transmission shaft was supported on two tapered roller bearings.

Decortication was done by rotating the seeds on the centrifugal impeller and striking them on the casing. The decorticated and undecorticated seeds were collected, and weighed to find out the efficiency. The moisture content was reduced by oven drying. Efficiency and seed damage were evaluated at different moisture content levels, feed rates and peripheral speeds. The values of the parameters are

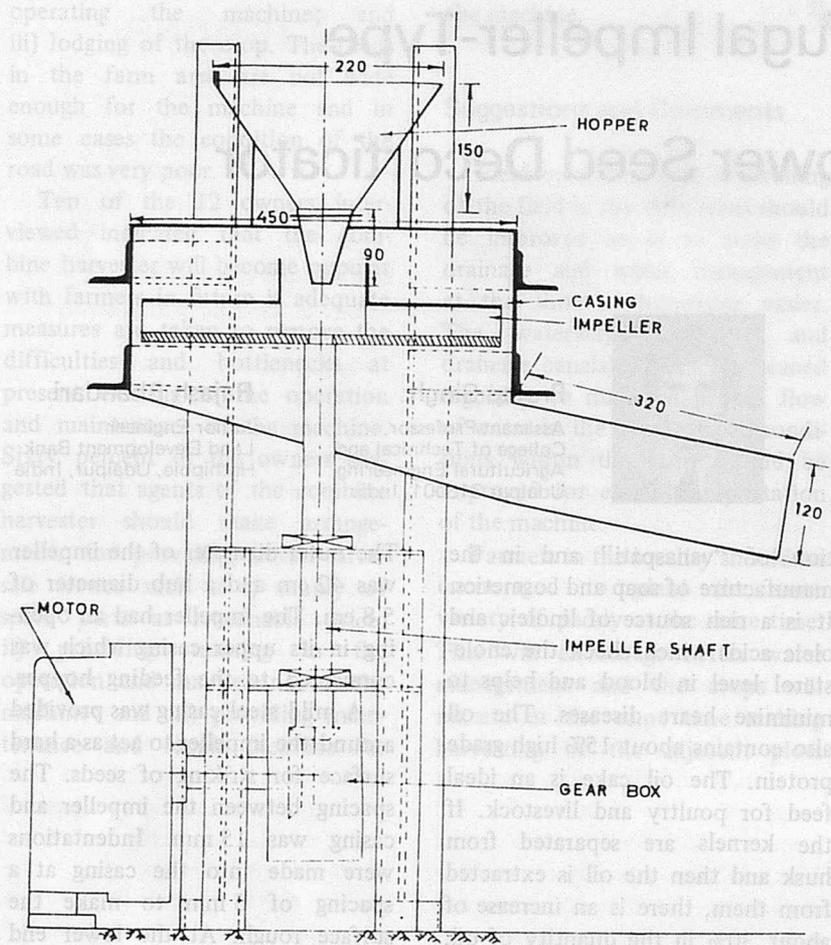


Fig. 1 Sunflower seed decorticator.

Table 1 Values of Test Parameters

Item	Test I	Test II	Test III
Feed rate, kg/hr	120	250	360
Moisture content (wet basis), %	6.7	9.2	12.5
Peripheral speed, m/min	1 320	1 650 1 980	2 330 2 640 2 900

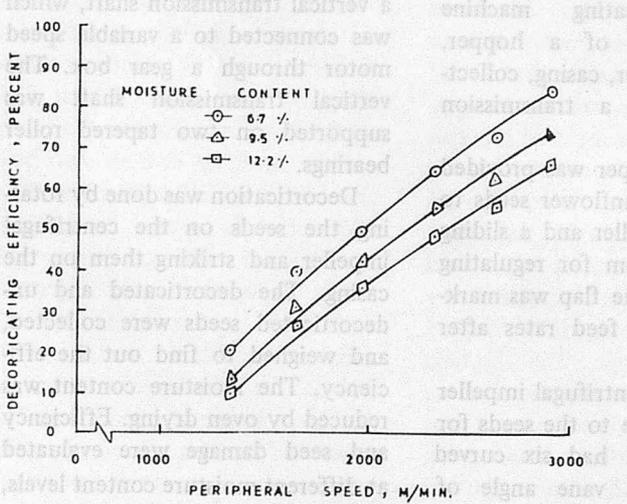


Fig. 2 Decorticating efficiency and peripheral speed of the impeller at a feed rate of 120 kg/h.

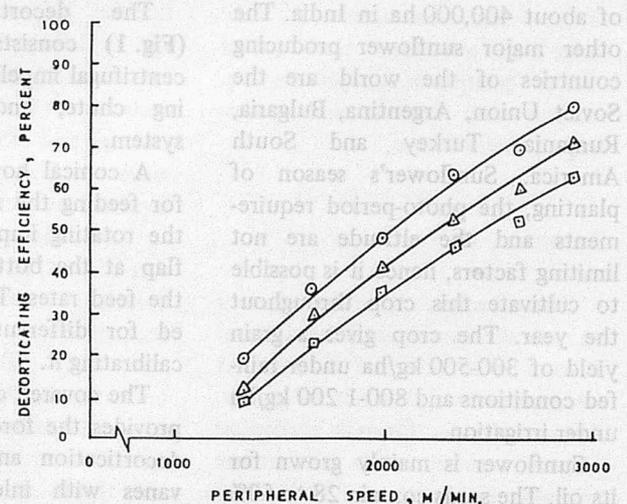


Fig. 3 Decorticating efficiency and peripheral speed of the impeller at a feed rate of 240 kg/h.

given in Table 1. The percentage decortication and seed damage were determined with the use of the following formulae:

$$\text{Decorticating efficiency (\%)} = \frac{\text{Weight of decorticated seed}}{\text{Weight of seeds fed into machine}} \times 100$$

$$\text{Seed damage (\%)} = \frac{\text{Weight of damaged decorticated seed}}{\text{Weight of total decorticated seeds}} \times 100$$

### Results and Discussion

The results are presented graphically in Figs. 2 through 7. The decorticating efficiency and seed damage were the two performance parameters selected for evaluation. The effect of moisture content of the seeds, feed rate and peripheral speed of the impeller on decorticating efficiency and seed damage were also studied.

The decorticating efficiency increased with a decrease in the moisture content of the seeds: an increase of about 18% in efficiency for a reduction in moisture content from 12.2 to 6.7% at a feed rate of 120 kg/h, and peripheral speed of 2 900 m/min or 17 and 10%, respectively, for the feed rates of 240 kg/h and 360 kg/h for similar

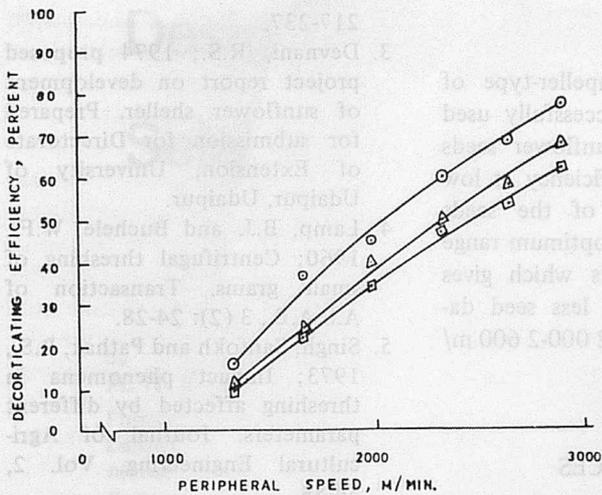


Fig. 4 Decorticating efficiency and peripheral speed of the impeller at a feed rate of 340 kg/h.

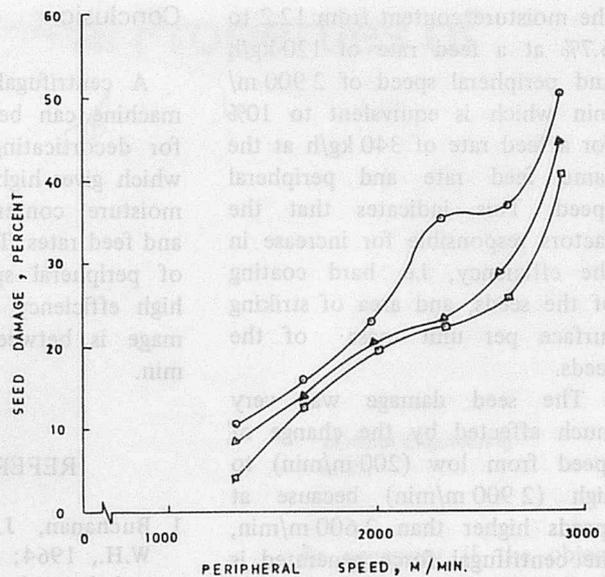


Fig. 6 Seed damage and peripheral speed of the impeller at a feed rate of 240 kg/h.

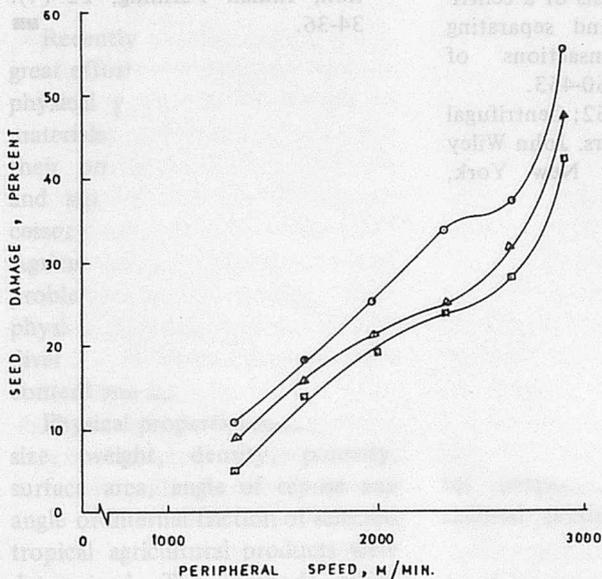


Fig. 5 Seed damage and peripheral speed of the impeller at a feed rate of 120 kg/h.

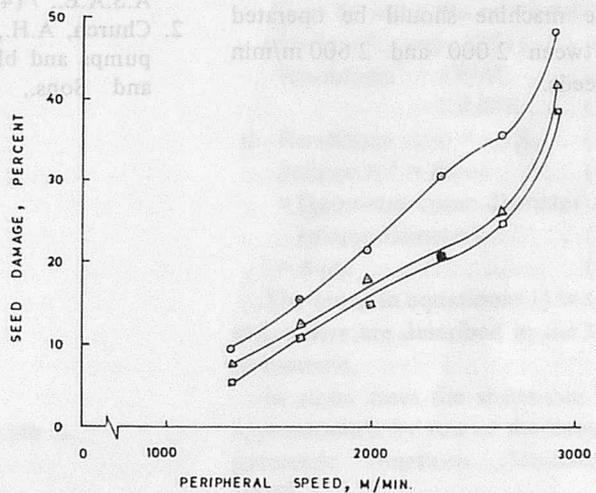


Fig. 7 Seed damage and peripheral speed of the impeller at a feed rate of 360 kg/h.

moisture content rates. When seeds are dried to reduce the moisture content, the outer coating (husk) becomes hard and brittle and separates from kernel easily.

On the contrary, the decorticating efficiency decreased with an increase in feed rates: about 5% when the feed rate was increased from 120 kg/h to 340 kg/h at a peripheral speed of 2 900 m/min. The change in the decorticating efficiency with feed rate was, however, almost constant for all the moisture content levels. At higher feed rates, the number of

seeds striking the hard surface per unit area increased. This means that when the required feed rate is high, the surface area for striking should be increased.

The effect of change in the peripheral speed of the impeller on decorticating efficiency was very prominent. The efficiency increased almost proportionally with the speed: an increase of 65% when the speed was changed from 1 320 m/min to 2 900 m/min at a moisture content of 6.7% and a feed rate of 120 kg/h. There was an increase in the efficiency with peripheral

speed at all the moisture content levels and feed rates. Even at a feed rate of 340 kg/h and moisture content of 12.2%, the increase in the efficiency was 53%. At higher speeds, the centrifugal force also increased and the seeds struck the hard surface with a greater momentum.

The effect of moisture content, feed rate and peripheral speed of the impeller on seed damage is shown in Fig. 5 through 7. The seed damage increased with a reduction in moisture content and feed ratio: by 13% for a change in

the moisture content from 12.2 to 6.7% at a feed rate of 120 kg/h and peripheral speed of 2 900 m/min which is equivalent to 10% for a feed rate of 340 kg/h at the same feed rate and peripheral speed. This indicates that the factors responsible for increase in the efficiency, i.e. hard coating of the seeds, and area of striking surface per unit mass of the seeds.

The seed damage was very much affected by the change of speed from low (200 m/min) to high (2 900 m/min) because at speeds higher than 2 600 m/min, the centrifugal force generated is very high which damages most of the decorticated seeds. For lower seed damage and higher efficiency, the machine should be operated between 2 000 and 2 600 m/min speeds.

### Conclusion

A centrifugal impeller-type of machine can be successfully used for decortivating sunflower seeds which gives high efficiency at low moisture contents of the seeds and feed rates. The optimum range of peripheral speeds which gives high efficiency and less seed damage is between 2 000-2 600 m/min.

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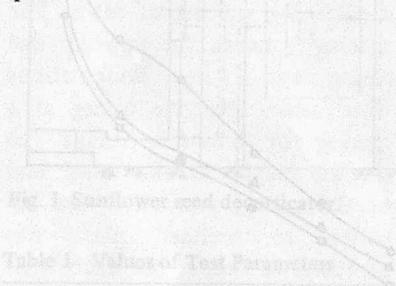


Fig. 1. Sunflower seed decortication. The graph plots decortication efficiency (%) against feed rate (kg/h) for three different peripheral speeds. The curves show that efficiency increases with feed rate, with the highest efficiency achieved at the highest feed rate and lowest peripheral speed.

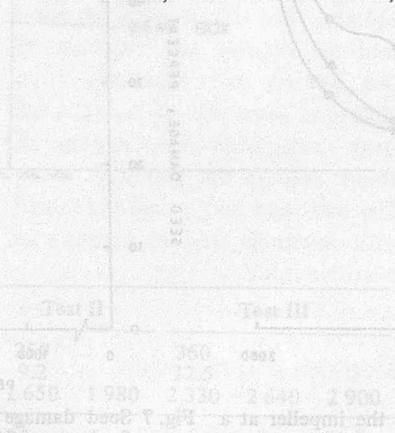


Fig. 2. Seed damage and peripheral speed of the impeller. The graph plots seed damage (%) against peripheral speed (m/min) for three different feed rates. It shows that seed damage increases sharply with peripheral speed, particularly at higher speeds, and is also influenced by the feed rate.

The effect of moisture content of the seeds, feed rate and peripheral speed of the impeller on decortication efficiency and seed damage were also studied. The decortivating efficiency increased with a decrease in the moisture content of the seeds as indicated about 18% in efficiency for a reduction in moisture content from 12.2 to 6.7% at a feed rate of 120 kg/h and peripheral speed of 2 900 m/min to 2 000 m/min.

The effect of change in the peripheral speed of the impeller on decortivating efficiency was very prominent. The efficiency increased almost proportionally with the speed: an increase of 52% when the speed was changed from 1 320 m/min to 2 900 m/min at a moisture content of 6.7% and a feed rate of 120 kg/h. There was an increase in the efficiency with peripheral speed striking the hard surface per unit area increased. This means that when the required feed rate is high, the surface area for striking should be increased.

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On the contrary, the decortivating efficiency decreased with an increase in feed rate: about 2% when the feed rate was increased from 120 kg/h to 340 kg/h at a peripheral speed of 2 900 m/min. The change in the decortivating efficiency with feed rate was however, almost constant for all the moisture content levels. At higher feed rates, the number of particles from kernel easily.

# Design-Related Physical Properties of Selected Agricultural Products

by  
A. N. Waziri

Former Student  
Department of Agricultural Engineering  
Ahmadu Bello University  
Zaria, Nigeria



J. P. Mittal

Lecturer  
Department of Agricultural Engineering  
Ahmadu Bello University  
Zaria, Nigeria

## Abstract

Recently scientists have directed great efforts in evaluating the basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in processes and control engineering. Agricultural materials pose special problems in determining their physical properties because of their diversity in shape, size, moisture content and maturity levels.

Physical properties such as shape, size, weight, density, porosity, surface area, angle of repose and angle of internal friction of selected tropical agricultural products were determined. The methods established in this study can also be used to determine the physical properties of other agricultural products similar in nature.

## Introduction

Although the recent scientific development have improved the handling and processing of biomaterials through mechanical, thermal, electrical, optical, and other techniques, little is known about the basic physical characteristics of these materials. Such basic information is important not only to engineers, but also to

food scientists and processors, plant, and animal breeders and other scientists who may find new uses (Mohsenin, 1970). In developing tropical countries like Nigeria, there are some typical agricultural products which do not exist in other developed agro-climatic zones of the globe. Needless to say, the evaluation of the physical properties of these agricultural materials should therefore be undertaken on an urgent basis to enhance the handling and processing of these products. In this study the design-related physical properties of selected agricultural products are established.

## Review of Literature

The determination of physical characteristics of agricultural products is much involved because of their irregular shape and variability in size. Presently no single standard method is applied in determining the physical characteristics of agricultural materials. Recently, scientists have studied suitable methods for various classes of biomaterials.

## Shape and Size

The shape and size are inseparable in a physical object. Both are

generally necessary if the object is to be satisfactorily described. Shape can be described either by charted standard (Mohsenin et al., 1965) or by using the relationships listed below (Curry, 1951):

- i. Roundness<sup>1</sup> =  $AP/AC \dots (1)$   
=  $\Sigma R/MR \dots (2)$
- ii. Roundness ratio =  $r_1/R_1 \dots (3)$   
Sphericity<sup>2</sup> =  $de/dc \dots (4)$   
= (geometric mean diameter)/  
(major diameter)  $\dots (5)$   
=  $di/dc \dots (6)$

The terms in equations (1) to (6) and others are described in the list of symbols.

In some cases the shape can be approximated by one of the known geometric functions (Mohsenin, 1970).

## LIST OF SYMBOLS

- $A_p$  = Largest projected area of object in natural rest position  
 $A_c$  = Area of smallest circumscribing circle  
 $\Sigma r$  = Sum of all radii of curvature  
 $R$  = Radius of the maximum inscribed circle

1. Roundness is a measure of the sharpness of the corner in the solid.
2. The geometric foundation of the concept of sphericity rests upon the isometric property of a sphere. The value of sphericity ranges from 0 to 1. Almost spherical objects have sphericity approaching 1. For example, an orange has sphericity of the order of 0.95.

- $r_1$  = Radii of curvature of the sharpest corner
- $N$  = Total number of corners summed in numerator
- $R_1$  = Mean radius of the object
- $d_e$  = Diameter of sphere of the same volume as the object
- $d_c$  = Diameter of the smallest circumscribing sphere or usually the longest diameter of the object
- $d_i$  = Diameter of largest inscribed circle
- $s$  = Surface area of fruit,  $\text{cm}^2$
- $w$  = Weight of fruit, g
- $\phi$  = Angle of internal friction, degree

The size of an agricultural material can be measured by ordinary measuring ruler in case of big objects like cabbage and sweet potatoes, by vernier callipers or micrometer screw gauge in case of relatively small objects like corn or rice grains and groundnut. For very tiny objects like millet and sorghum kernels, and seeds of certain flowers and vegetables, it is not possible to use even micrometer screw gauge.

In such situations, the material can be placed either on an overhead projector or on a shadowgraph and the outline of the projected boundary may be traced in determining the axial measurements of such materials after taking into consideration the magnification factor of projection. In the absence of an overhead projector or a shadowgraph, a photographic enlarger may be used.

Ideally, a great number of measurements in various directions should be taken to determine the average diameter of an agricultural product. However, three measurements, namely, major, intermediate and minor diameters are sufficient to determine the size of a material (Mohsenin, 1970).

**Volume and Density** – The irregular shape of most solid agricul-

tural products such as seeds and grains, and the porous nature of others such as feed pellets and wafers present certain problems in their measurement of volume and density.

The density of an agricultural material can be described in two ways. The solid density of a material refers to the density of a single grain or kernel whereas bulk density refers to the density of the material in bulk, and it depends upon the degree of packing. Loosely packed materials yield in lower bulk density in comparison to the densely packed materials.

**Porosity** – Porosity which is also known as packing factor “PF” may be calculated by the following relationship:

$$\text{Porosity} = (1 - \frac{\text{Bulk density}}{\text{Solid density}}) \times 100 \dots \dots (7)$$

The percent voids of an unconsolidated mass of materials such as silage, hay, and grain can be determined by porosity tank method (Day, 1964).

**Surface Area** – To determine the surface area of a leaf, one can trace its outline and find the area by a planimeter. Peels of some fruits and vegetables may be traced to determine surface area. Fragile materials like eggs may be dipped into a special type of rubber solution which forms a thin and uniform coat around it. This rubber coat may be peeled and traced to determine the surface area (Mohsenin, 1970).

**Angle of Repose** – The angle of repose is an angle with the horizontal at which the material will

3. Porosity is given in percentage whereas packing factor is represented in decimal form.

4. In absence of a planimeter one can trace the outline of a product on a graph paper and find the area by counting the squares which is normally an accurate but time consuming method.

stand when piled. The size, shape, moisture content and orientation of particles influence the angle of repose of a packed material.

**Materials and Methods** – Maize, sorghum, millet, groundnut, guava, orange, grape fruit and bitter lemon were selected as materials for the investigation because of their current research interest and the distinguished variability in their physical characteristics. All the materials selected for this study were obtained in Nigeria.

## Experimental Procedures

The experimental procedures selected for determining the physical characteristics of the agricultural products are summarized below:

**Shape** – For determining the shape, the material to be tested and a transparent graph paper were placed on the projection surface of an overhead projector. The projector was focussed to obtain the sharp boundary of the material. The outline of the boundary was traced and the magnification factor (MF) was calculated as follows:

$$\text{MF} = \frac{\text{Screened length of a line on graph paper}}{\text{Actual length of a line on graph paper}} \dots \dots (8)$$

The shape of the traced outline was then compared with a charted standard, and the roundness and sphericity of the material were found from equations (1) to (6) presented in the review of literature. This method was used in determining the shape of sorghum, guava and other materials.

**Size** – The following methods were used in determining the size of different classes of materials including millet, groundnut, sorghum, orange and guava.

**Vernier callipers method** – This

method was used to find the size of fruits like guava. The vernier callipers having a least count of 0.01 cm was used. Readings were taken in three axes to obtain major, minor and intermediate diameters of the material.

**Micrometer method** – The sizes of groundnut grains and pods were determined by this method. The micrometer was used which had a least count of 0.01 mm. Readings were taken to obtain the major, minor and intermediate diameters of the product.

**Overhead projection method** – This method was used to find the sizes of very small objects like sorghum and millet seeds. The object was placed in natural rest position and in vertical position to obtain major, minor and intermediate diameters.

**Weight** – For small seeds like sorghum, maize, groundnut and millet, 1 000 kernels were weighed and a parameter known as the 'thousand kernel weight (TKW)' was determined. An electronic weighing balance having a sensitivity of 0.10 g was used. Measurements were made for ten samples of each grain. Fruits like oranges and bitter lemons were weighed

individually.

**Density** – The bulk density of the material was determined by weighing the material packed under a known volume. For determining the solid density of small objects, specific gravity bottles were used. The solid density of large objects was determined by the platform scale method as outlined by Mohsenin (1970).

**Porosity** – A porosity measuring device on the lines proposed by Day (1964) was designed and fabricated during the course of this study (Fig. 1). It was checked for air leakage thoroughly. Sorghum grains were filled in Tank 2 and the air was supplied in Tank 1 closing valves 2 and 3. When a suitable manometer displacement was achieved valve 1 was closed and the steady state pressure  $P_1$  was noted. After this, valve 2 was opened keeping valves 1 and 3 closed. A steady state manometer reading  $P_2$  was recorded. The porosity of sorghum grain was found by the following formula:

$$\text{Porosity} = (P_1 - P_2)/P_2 \dots (9)$$

**Surface Area** – The surface area of orange, bitter lemon and grape fruits was measured using the peeling method. The area of traced outlines of the peels was measured by planimeter.

**Angle of Repose** – The angle of repose was measured with a cali-

brated tilting table. Glass and plywood surface were used to obtain the sliding angle of grain.

## Results and Discussions

**Shape** – Comparison of the projected boundaries of five samples of sorghum grain (Fig. 2) with the charted standard could not yield a definite result because each projection was quite different. In most of the cases, the sorghum kernels were seen as oblate. Further analysis revealed that the roundness of sorghum grains ranged from 0.43 to 0.68 whereas sphericity was 0.53.

Comparison of the traced boundary of guava (Fig. 3) with the charted standard revealed that guava was nearly spherical. The analysis showed that the sphericity of guava was 0.92.

**Size** – The sizes of the selected agricultural products are summarized in Table 1.

The size of a fruit or a vegetable depends upon its variety and maturity. The size of a guava fruit was measured by vernier callipers. The major, intermediate and minor diameters were 5.65, 5.4 and 5.3 cm, a common phenomenon exhibited by nearly spherical objects (Fig. 3).

**Weight** – The thousand kernel

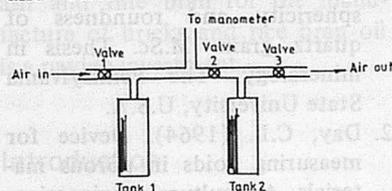


Fig. 1 Porosity Measuring Method

Orientation

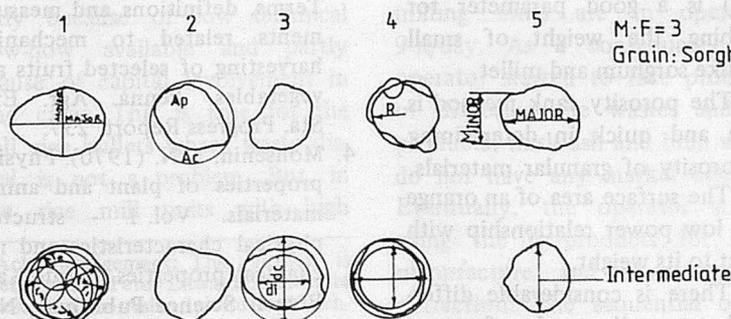


Fig. 2 Size and Shape Determination for Sorghum Grain

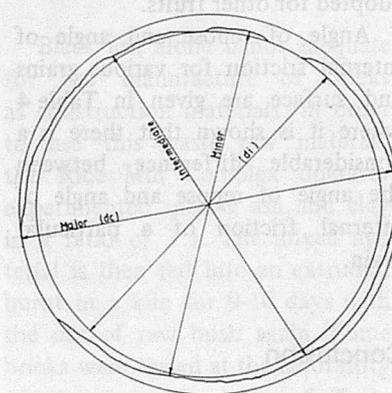


Fig. 3 Size and Shape Determination for Guava Fruit

weight (TKW) of different seeds including sorghum, millet, maize and groundnut are given in Table 2. The seed and hull weight ratio for groundnut was 2.50. The weight of a fruit may vary with its size. Hence, it would not be appropriate to find an average weight of a fruit. However, an approach described later in this paper was used to establish a relationship between the surface area of a fruit and its weight.

**Density** — The bulk and solid densities of various agricultural products are summarized in Table 3. As expected, the bulk density of this material was observed to be lower than its solid density.

**Porosity** — Porosity of sorghum grain determined by the porosity tank method was 44% whereas the theoretical porosity determined from equation (7) was 44.5%, hence both experimental and theoretical porosities are in close agreement.

**Surface Area** — An empirical relationship between the surface area and weight of an orange fruit (Variety: N.G. sweet orange) was developed and is given in equation (10):

$$S = 0.025 W^{1.25} \dots \dots \dots (10)$$

Where S = surface area of orange (cm<sup>2</sup>), W = weight of orange (g). A similar procedure can also be adopted for other fruits.

Angle of repose and angle of internal friction for various grains and surface are given in Table 4 where it is shown that there is a considerable difference between the angle of repose and angle of internal friction of a particular grain.

### Conclusion

The following conclusions are drawn:

Table 1 Dimensions of Selected Materials

Grain	Variety	No. of replicat-ions	Diameter* (mm)			
			Major	Intermediate	Minor	Mean
Sorghum	LS187	10	—	—	—	2.72±0.14
Millet	N. Composite	10	—	—	—	2.21±0.19
Ground Pod	S38	20	28.6±0.7	11.6±0.7	11.2±0.7	15.4
Largest seed in a groundnut pod	S38	20	14.1±1.4	8.1±1.4	7.5±1.4	9.5

\*Sorghum and millet kernels were approximated to be spherical and their diameters were measured by a micrometer screw gauge. Since these kernels are very small, it was not possible to measure the major, intermediate and minor diameters.

Table 2 Thousand Kernels Weight (TKW) of Various Grains

Grain	Variety	No. of replication	TKW (g)
Sorghum	LS187	10	30.51±1.18
Millet	N. Composite	10	8.51±0.36
Maize	TZB	10	278.7±23.64
Groundnut	S38	5	317.68±53.14

Table 3 Bulk and Solid Density of Agricultural Products

Grain	Variety	Bulk density (g/cc)	Solid density (g/cc)
Sorghum	LS187	0.76	1.37
Millet	N. Composite	0.74	1.30
Maize	TZB	0.72	1.29
Grape fruit	—	0.32	0.87

Table 4 Angle of Repose and Angle of Internal Friction (Unit: degree)

Surface	Maize Var. TZB	Sorghum Var. LS197	Millet Var. N. Composite
Grain to glass	24.9±1.1	35.0±1.2	32.4±0.6
Grain to plywood	34.2±0.4	31.8±2.6	27.6±1.1
Grain to grain	29.0±2.1	25.4±0.9	22.2±0.4

1. The roundness and sphericity are important parameters that determine the geometric shape of agricultural products.

2. The major, minor and intermediate diameters of agricultural products may be determined by the overhead projection method for small seeds and grains, and by the vernier calipers/micrometer screw gauge method for comparatively larger seeds, grains, fruits and vegetables.

3. The thousand kernel weight (TKW) is a good parameter for describing the weight of small seeds like sorghum and millet.

4. The porosity tank method is simple and quick in determining the porosity of granular materials.

5. The surface area of an orange has a low power relationship with respect to its weight.

6. There is considerable difference between the angle of repose and angle of internal friction of a

packed agricultural product.

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# Utilization of Rice Mill Wastes and By-products: A Case Study in Thailand

by  
Md. Wali Ullah  
Post-Graduate Student  
Institute of Agricultural Engineering  
Rolighedsvej 23, DK-1958  
Copenhagen V, Denmark

## Abstract

This paper studies the different processes of an integrated Rice Processing Complex with a view to finding their extent of dependence in terms of wastes utilization effectiveness. The utilization of wastes is being carried out at every possible step, for instance, husk as a source of fuel, black ash of husk to manufacture bricks, fine bran to produce crude oil, etc. A Dynamo Model was formulated to test different scenarios. It was found that even a high capital investment in the utilization of husk ash and fine bran is a profitable enterprise. Even buying husk ash and fine bran for the manufacture of bricks and rice bran oil is a paying investment.

## Introduction

The wastes from rice mills are hardly processed for further use, partly because of low technical know-how available and partly because of capital involvement in some cases. This is true for the small rice hullers where waste disposal is not a problem. But, in large rice mill units with high

milling capacity, waste disposal is a problem.

The rice processing complex which is the subject of the present study is a unique example of technical integration of different activities in paddy processing which converts rice mill wastes and by-products into commercial end products. At the same time, the complex gets rid of the problem of waste disposal.

The study was undertaken with the objective of determining the extent of interdependence of the different sub-units of the complex, waste utilization effectiveness and to develop some dynamic model to test the operation of the complex.

## The Rice Mill Complex

The main purpose of the complex is to mill rice for export purposes. It has a daily capacity of 500 t of paddy when its three milling units are in operation 9 h/day. As a consequence, the operator started to face problems of disposing the wastes and by-products; husk ash and bran which do not have any market demand. Eventually, the operator started using the by-products for brick manufacture and rice bran oil extraction. The sequential operations of the different processes of the complex are shown in

Fig. 1.

## Utilization of Husk

Rice husk is an efficient fuel for drying purposes. Compared with fuel oil, 3 kg of rice husk is equal to 1 kg of fuel oil (Singh et al, 1980). In the complex, the husk is burnt in the furnace for producing steam and hot water. The energy required to accomplish the parboiling process such as soaking, steaming and drying, is provided by burning the husk. However, the husk is not completely burnt in the furnace and black ash is obtained as a by-product. But even the black ash subsequently accumulates and poses a disposal problem.

## Utilization of Husk Ash

Black ash alone is not adequate for the manufacture of bricks as construction materials. In order to use this waste raw material, the Rice Mill Complex operator experimented mixing ash and clay in a ratio of 3:1. The mixed material is then fed into an extruder, burnt in a kiln for 9-10 days with the use of raw husk again. Some bricks were tested at the laboratory of the Asian Institute of Technology and the average crushing strength was found to be 50-

**Acknowledgement:** The author is grateful to Dr. Peter Edwards, Associate Professor of the Asian Institute of Technology for making proper arrangements for data collection and supervising the work.

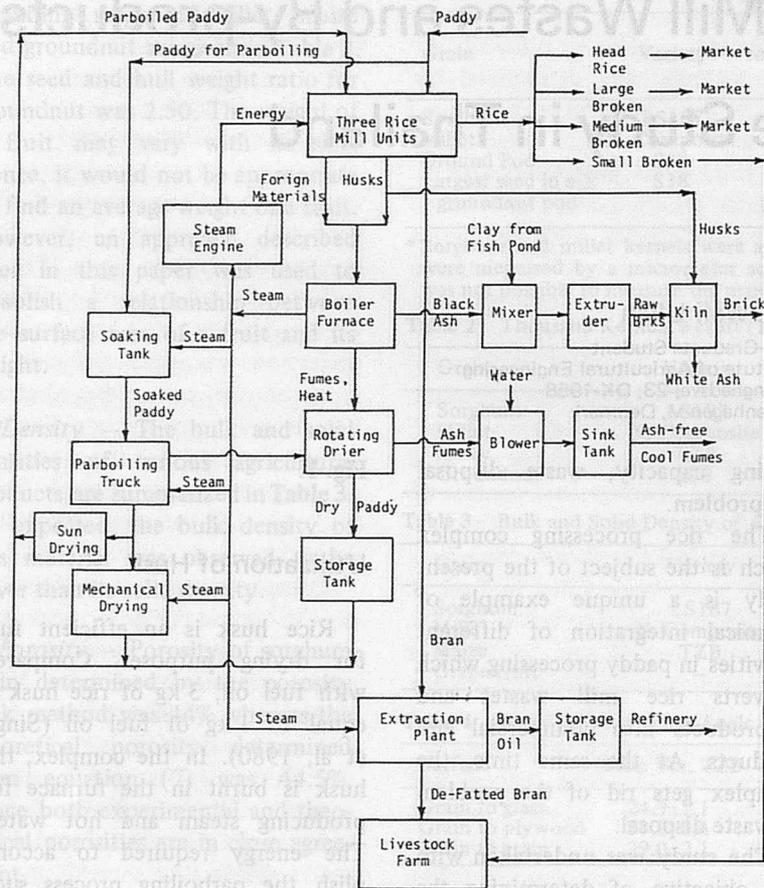


Fig. 1 Flow diagram of the Rice Mill showing the technical integration of different processes.

65 kg/cm<sup>2</sup> (Ullah, 1979). These bricks may be quite suitable for low-cost housing construction.

When the husk is completely burnt in a kiln, the ash produced is white which contains about 92-96% silica, an active source for the production of pure silicon (Singh et al, 1981) and for making glue, cement, etc.

#### Utilization of Fine Rice Bran

Rice bran contains about 18-21% crude fat (Koga, 1980). Fine bran of parboiled paddy is considered to be the best because the heat treatment of paddy during parboiling destroys, to a certain extent, the lipase enzyme that is responsible for the hydrolysis of oil (development of free fatty acids). Therefore, the oil is of a

superior quality because it has a lower concentration of free fatty acids. The Complex under study produces crude bran oil out from fine rice bran. After the extraction of oil, the defatted bran is left as a by-product which can be usefully fed to livestock. The crude oil is sold to refineries. Bran oil is superior to vegetable oils for human consumption and some industrial uses such as the manufacture of soap, wax, medicine, ester oil, etc. (Koga, 1980)

#### Model Development and Output Analysis

The diagram shown in Fig. 2 interrelates the variables which served as the basis in developing a DYNAMO model. The model was tested with the data collect-

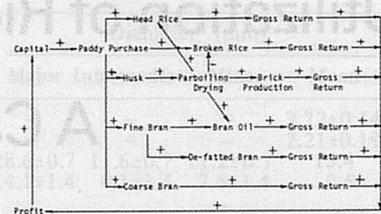


Fig. 2 Schematic diagram of the Mill Complex as basis for model formulation.

ed from the Complex and some scenarios were simulated in order to observe the effects of different sub-units on the operation, particularly the economic considerations. It was found that when the complex did not take into account the manufacture of bricks or bran oil, the operation was expensive. And even when the raw materials for brick and oil manufacture had to be purchased (in order to augment the available supply from the Complex) producing both bricks and oil was still profitable.

#### Conclusion

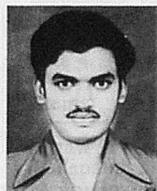
Rice bran oil is regarded as one of the best vegetable oils. As such, special attention should be paid in all rice growing countries on the manufacture of bran oil, particularly in Asia. Rice millers who cannot afford to use solvent extraction plants may otherwise use other pressing method which may be cheaper but less efficient.

Small-capacity equipment should be designed so as to be coupled directly with the existing small- or medium-scale rice mills in the developing countries.

The fuel potential of rice husk should be exploited as much as possible and the husk ash thus produced should be used for brick production (instead of being wasted) in commercial scale in the manufacture of a good building material for low-cost housing construction.

(Continued on page 68)

# Trench Silo for Bangladesh Farms



by  
**Md. Mahabubur Rahman Mollah**  
 Scientific Officer  
 Agricultural Engineering Division  
 Bangladesh Rice Research Institute  
 Joydebpur, Dacca, Bangladesh



**Ahmed Hossain Mirdha**  
 Assistant Professor  
 Department of Agricultural Engineering and  
 Basic Engineering  
 Bangladesh Agricultural University  
 Mymensingh, Bangladesh

**Md. Habibur Rahman Khan**  
 Agricultural Engineer

## Abstract

An investigation was carried out at the Department of Agricultural Engineering and Basic Engineering, Bangladesh Agricultural University in order to design and construct a lined trench silo for keeping silage for the average size of cattle for typical farmers in Bangladesh. The cost of mud covering of the silo was compared with the cost of concrete covering. The cost of concrete covering was 4.18 times greater than that of mud covering, hence not economical. On the other hand, mud covering was more profitable and the quality of silage was good.

## Introduction

Bangladesh is primarily an agricultural country and agriculture provides basic food grains to feed human beings, fibres for clothing and timber for shelter.

After land and crops, livestock is the most important asset which the farmers desire to possess hence feed and fodder for animals are of utmost importance. Livestock, specially cattle assists farmers in land preparation, in carrying goods,

and in the supply of milk and meat. The dung and urine of cattle are used as manures. Their hides have great economic use.

In the spring and autumn the livestock suffer from a great scarcity of fodder in Bangladesh, hence adequate storage of hay or fodder is essential during these seasons. Green pulses can be stored as silage for use in autumn. From late September to early October sorghum and jowar may be stored for use in the spring.

The objective of the study is to design a small-capacity, underground, lined trench silo for storing livestock feed for farmers in rural areas.

The silage was fed for 96 days in a year at the rate of 7.62 cm thickness in two consecutive days (Table 1).

The average conditions for the design were as follows:

i) Entrance conditions of

fodder	
Air temperature	30.3°C
Relative humidity	80%
Moisture content of fodder	70%
Color of fodder	Green
ii) Exit conditions of silage	
Air temperature	31.1°C
Relative humidity	74%
Moisture content of silage	65.5%
Color of silage	Gray

## The Study Design

Data were collected for body measurements of 95 individual



Fig. 1 Construction of silo.

Table 1 Size of Herd and and Silage Requirement per Day/Animal

Indigenous Animal	Body weight per animal (kg)	Number of animals	Rate of feeding per 100 kg of body weight (kg)
Cow	149.66	2	2.5
Bullock	249.43	2	3.0
Yearling	102.00	1	2.5
Calf	40.80	1	1.0

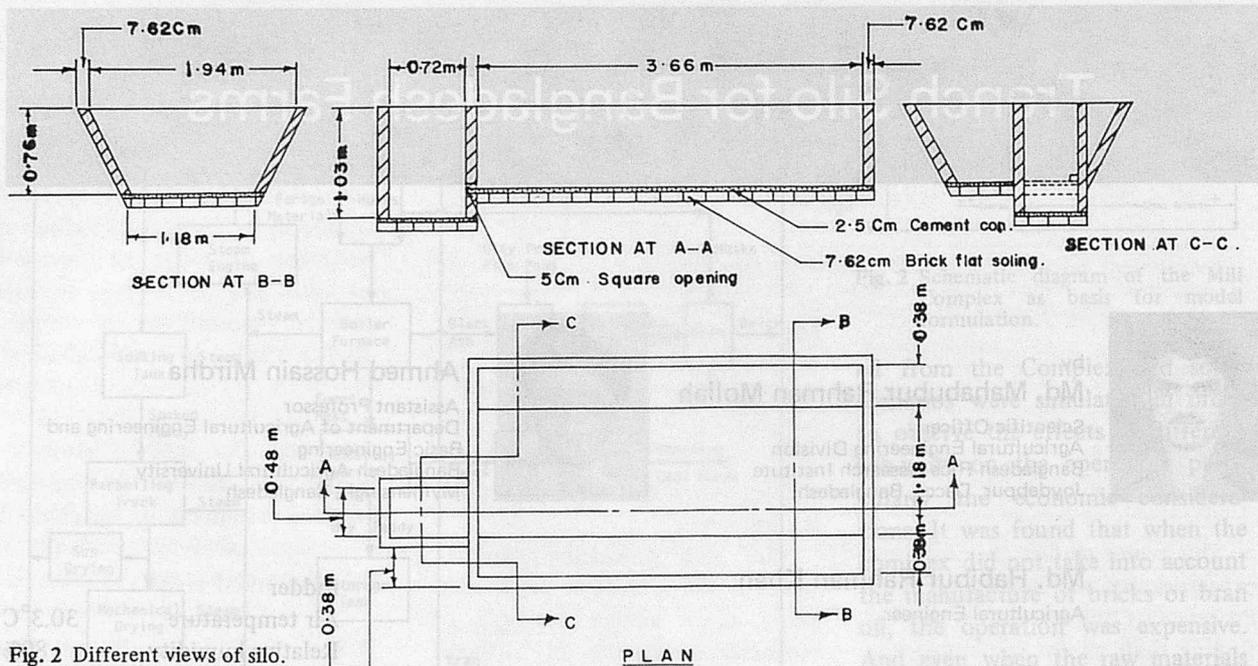


Fig. 2 Different views of silo.

animals from two different villages of Pabna and Mymensingh districts using the following formula: (1963).

$$\text{Body weight (kg)} = \frac{\text{Heat-girth (cm}^2\text{)} \times \text{Length (cm)}}{10,840}$$

The heart-girth was taken directly behind the shoulders and the length from the pin bone to the prominence of the shoulders located in mature cattle 2.5 cm back of the point of shoulder (Anderson, 1963).

The unit weight of fodder was 560.12 kg/m<sup>3</sup>. As per daily requirements per animal the calculated total volume of silage required per day was 0.045 m<sup>3</sup>. As a full area of 7.62 cm thickness of silage was fed in two consecutive days, therefore, the total length of the silo was  $\frac{96 \times 7.62/2}{100} = 3.66\text{m}$ ,

where, 96 was the period of duration in days.

Considering a 1 : 2 side slopes in the length of the silo in order to prevent caving the depth was 0.76 m. The overall designed dimensions were: length – 3.66 m; top width 1.94 m, bottom width – 1.18 m; depth – 0.76 m

A hole (0.72 m x 0.48 m x

1.03 m) was constructed by the side of the silo to receive juice or secretion formed due to fermentation in the silo. A passage of 5 cm<sup>2</sup> was made between the silo and the hole (Fig. 2).

Assuming the soil bearing capacity to be equal to 1.46 kg/cm<sup>2</sup> (Sowers, 1962) and considering that 60% of the load was transmitted to the bottom area from the side wall (Michael), the calculated total pressure on the bottom area was 0.05 kg/cm<sup>2</sup> which was much less than 1.46 kg/cm<sup>2</sup>.

A layer of flat brick sole and 2.5 cm thick cement concrete was used at the bottom to prevent extra water which might come from inside the soil. A bent iron pipe was placed in the centre of the top of

the trench to expel gases formed in the silo.

### Materials and Cost

One flat brick sole for a permanently lined trench silo was preferred. The estimated materials and cost are given in Table 2.

Based on a 50-season duration of the silo, the cost per season is an average of Tk. 22.

Polythene papers, "chatai" (made of bamboo), "khoas" cement and sand were used for concrete covering. Mud covering might be done by mud with straw and banana leaf and there should be a thatched shed over the silo. The cost of two types of covering

Table 2 Cost of Permanent Trench and Materials (US\$1 = Tk. 20)

Item	Quantity	Unit	Rate (Taka)	Cost (Taka)
Earth work in excavation	6.17	m <sup>3</sup>	3.53/m <sup>3</sup>	21.75
Brick	541	No.	0.75	405.75
Cement	6	Bag	84/bag	504.00
Sand	0.60	m <sup>3</sup>	10.5/m <sup>3</sup>	6.30
Iron pipe	0.30	m	33/m	10.00
Mason	One	–	25/head	25.00
Labour	4	–	10/head	40.00
Total cost				1 012.80
Contingency 5%				50.64
Grand total				1 063.44

**Table 3** Cost of Silo Concrete Covering per Season (US\$1 = Tk. 20)

Item	Quantity	Unit	Rate (Taka)	Cost (Taka)
Brick	128	No.	0.75	96.00
Cement	2	Bag	84/bag	168.00
Sand	0.2	m <sup>3</sup>	10.5/m <sup>3</sup>	2.10
Polythene paper	5.5	m	9.8/m	54.00
Chatai	6	No.	6/No.	36.00
Labour	2	-	10/head	20.00
Total cost				376.10
Contingency 5%				18.83
Grand total				394.93

**Table 4** Cost of Mud Shed Covering per Season (US\$1 = Tk. 20)

Items	Quantity	Unit	Rate (Taka)	Cost (Taka)
Straw	9.3	kg	1.61/kg	15.00
Kalapata	18.6	kg	0.27/kg	5.00
A nominal straw shed for the protection against direct rainfall	One	-	50/shed	50.00
Labour	Two	-	10/head	20.00
Total cost				90.00
Contingency 5%				4.50
Grand total				94.50

showed a significant difference between them (Tables 3 and 4).

When the cost of concrete covering is considered, the average per season cost increased to Tk. 417.

### Cost-Benefit Ratio

Due to loss of moisture content and spoilage the calculated final weight of the silage was reduced to 2 120 kg from 2 454 kg.

- i) The cost of the green silage (Jowar) @ Tk. 0.16/kg was  $2\ 454 \times 0.16 = \text{Tk. } 393$
- ii) Labour cost for cutting, loading and unloading @ Tk. 10/head =  $10 \times 10 = \text{Tk. } 100$
- iii) Transportation cost = Tk. 100
- iv) The relative price of silage in odd season @ Tk. 0.40/kg =  $2\ 120 \times 0.40 = \text{Tk. } 848$  (Considering that the silage would be purchased by the buyer from the silo, the gross benefit =  $\text{Tk. } 848 - (\text{Tk. } 393 + \text{Tk. } 100) = \text{Tk. } 255$

The cost of the silo with concrete covering per season = Tk. 417 and the cost of the silo per season with mud covering = Tk. 117 or a difference of  $\text{Tk. } 417 - \text{Tk. } 255 =$

Tk. 162 per season for concrete covering and a net benefit of  $\text{Tk. } 255 - \text{Tk. } 117 = \text{Tk. } 138$  per season for mud covering.

There may be two or three seasons per year depending on the type and availability of fodder, hence the farmers may have a total

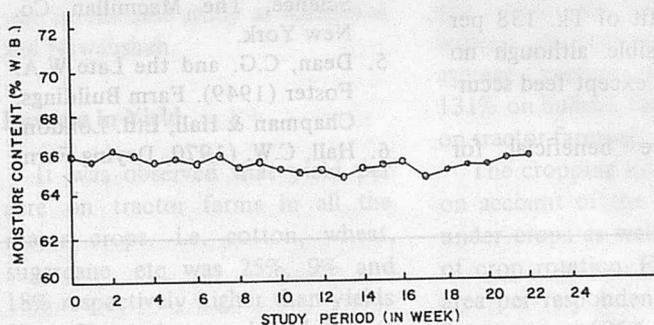
benefit of Tk. 276 to Tk. 414 per year if they used mud covering.

### Results and Analysis

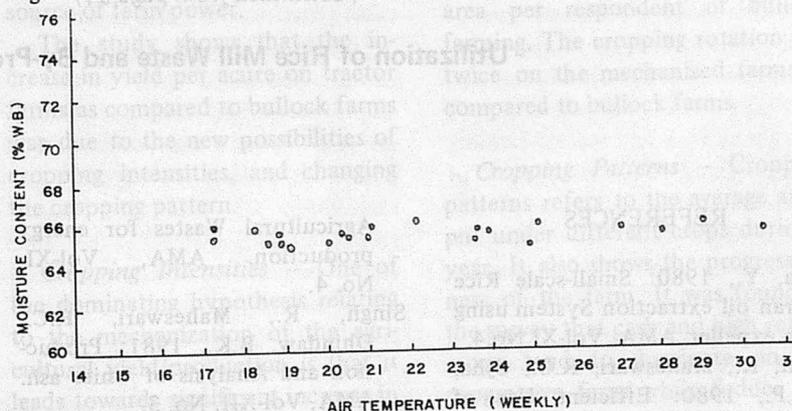
The conditions of the silage were checked every seven days for a total of 23 times. Its edibility was also tested by cattle and showed good results. Air temperature, relative humidity and the moisture content of the silage were recorded for each observation. Three graphs were plotted (Figs. 3, 4 and 5) which show that air temperature and relative humidity did not heavily affect the moisture content of the silage. The silage lost 4.5% moisture content due to fermentation.

### Conclusion

During the period of study, jowar grass was available. Other silage crops like sorghum and maize need chopping for better silage. Between each 15 cm layer of



**Fig. 3** Variation of moisture content with respect to time in week.



**Fig. 4** Variation of moisture content with respect to air temperature (weekly).

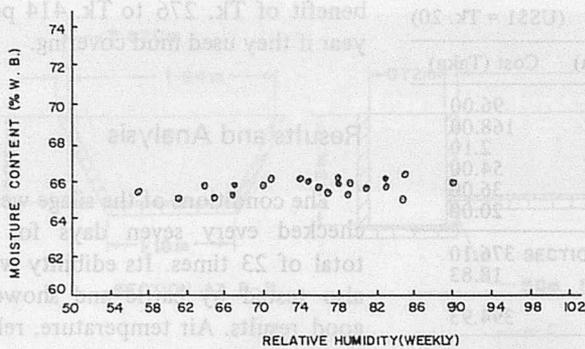


Fig. 5 Variation of moisture content with respect to relative humidity (weekly).

silage, sprinkling of diluted molasses may be added to make silage tasty and develop good smell for the cattle. Proper packing and air tightening are also necessary for good silage.

To facilitate drainage it is desirable to locate the trench silo on sloping ground.

Although the initial cost of construction is a bit high for farmers, yet considering its duration it will be possible for the farmers to utilize it economically. If necessary it can be used as green manure pit in other periods.

From the economic point of view a net benefit of Tk. 138 per season was possible although no significant profit except feed security is maintained.

It would be beneficial for

farmers to use a lined trench silo with mud covering.

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# Paradox of Tractorization in Pakistan



by  
**M. Yusuf Mubasher**

Assistant Chief Economist  
Ministry of Labour, Manpower and Overseas Pakistanis  
13-M-Almarkaz, F-7/2  
Islamabad, Pakistan

## Introduction

There is general consensus that high yield variety of seeds, chemical fertilizer and tubewells have played an important role in increasing agricultural production in Pakistan. The impact of tractorization on agricultural production as well as its impact on the employment of the farm labour force is a big controversial paradox. When some writers are of the opinion that tractorization increases agricultural production, simultaneously, on the other hand, other authors are of the view that farming through tractor does not increase agriculture displaces farm labour to some writers tractorization in agriculture displace farm labour force, on the other hand, there are agricultural experts who believe that mechanization, instead of displacing labour force, increases employment openings for the agricultural labour force. This state of affairs in a country like Pakistan, where majority of labor is living in rural areas is quite unsatisfactory and is creating doubts and frustration about the future of tractorization in the country. It was, therefore, necessary to review the position and thrash out the actual impact of tractorization on agriculture production as well as labour force.

## Crop Production

It is generally believed that tractorization on agricultural farms increases production indirectly by encouraging those factors which increase yield per acre that consequently result increase in production (e.g. efficient use of agricultural inputs) and also directly leads towards increase in production by increasing cropped areas. This thesis proved to be quite true in our case study at Khanewal and Nawabshah.

## Increase in Yield

It was observed that yield per acre on tractor farms in all the major crops, i.e. cotton, wheat, sugarcane, etc was 25%, 9% and 18% respectively higher than yields from farms that used bullocks as source of farm power.

The study shows that the increase in yield per acre on tractor farms as compared to bullock farms was due to the new possibilities of cropping intensities, and changing the cropping pattern.

**Cropping Intensities** — One of the dominating hypothesis relating to the mechanization of the agricultural yield/production is that it leads towards significant increase in cropping intensity. This effect is

supposed to stem from the introduction of the tractor, largely as a result of the capacity of the new power source to work longer and faster at those times of the production cycle, that are critical to the achievement of double cropping.

There was a substantial increase in the cropped areas and the average farmers in the survey were able to add two or three crops to his cropping programmes that were not produced when using the bullock cultivation method. The average cropping intensity was 131% on bullock farming and 134% on tractor farming.

The cropping intensity increased on account of the increase in area under crops as well as the number of crop rotation. For example, the area per respondent of the tractor farming was 105% higher than the area per respondent of bullock farming. The cropping rotation was twice on the mechanized farms as compared to bullock farms.

**Cropping Patterns** — Cropping patterns refers to the average areas put under different crops during a year. It also shows the progressiveness of the farm. It was found in the survey that cash and high return crops tend to dominate on the progressive farm while fodder and the other low income crops are

**Table 1** Cropping Pattern under Different Farming Methods and Percentage Difference in Cropping Area

Major Crop	Tractor Farm (ha)	Bullock Farm (ha)	Percentage Difference in Area under Cultivation
Wheat	2 599	565	+ 360
Rice	19	8	+ 153
Cotton	2 581	526	+ 391
Sugarcane	241	64	-280
Total	5 440	1 163	+ 368

sown on the small farms. Agriculture was being practised as way of life to cater to the family and the livestock requirements on such farms. Acreage data on the various crop show that there has been substantial increase in acreage of major crops as shown in the Table 1.

**Land Utilization** – Proper utilization of land is one of the main factors determining the increase in production and it is indicative of the economic progress of the farmers. In the survey, the total farm area was divided into cultivated area and was further split into net sown area and fallow area:

**Table 2** Pattern of Land Utilization on Tractor and Bullock Farms

Category of farm area	Percentage Areas (acres)	
	Bullock farmer	Tractor farmer
Total area available per respondent	100.00	100.00
Un-cultivable	9.55	10.24
Cultivable	90.45	89.76
Net area under crop	54.26	49.99
Fallow land	36.16	39.76

In this study the cost per unit of production means the money value of labour inputs (including family, permanent, hired and casual labour) used on bullock and tractor farming plus the fixed and running costs of bullock and tractor incurred during a year. Identification of the unit cost is very important because the method of crop production to be adopted by the farmers depends to a great extent on the comparative cost of various methods and technologies among which the farmers

have the choice.

For example, it is generally believed that in small holdings, tractor farming is not done because the unit cost of tractor is much higher than the unit cost of the bullock method. On the other hand, on the large holdings tractor farming is considered to be much beneficial than the bullock farming. As far as the case of medium size of holding is concerned, there is a lot of controversy among the farmers.

#### Computation of Input Costs

Before starting with the actual analysis, it is important to explain briefly the method used for computation of input costs in this study.

**Labour Input Costs** – The labour input consists of family labour, permanent hired labour and casual labour employed during a year for agricultural operations. For computing the cost of labour inputs, the permanent hired labour and casual labour are estimated by taking into account the actual cash or commodity paid to the hired labour. Secondly, their nature of employment and time spent daily on the farms also differ from person to person. To simplify the calculation of cost, the family labour wages are fixed at the same rate at which the farmer had hired the permanent and the casual labour. On bullock farming the cost of family labour was higher than tractor farming. But the cost of hired and casual labour was less on

bullock farming. The reason is that in bullock method the number of family labour is sufficient to deal with agricultural pursuits. Therefore, there is no hired labour or there is only fractional hired labour engaged on a regular basis. Similarly, in the odd times the family members extend their working hours and cope their job, or they seek help of their relatives. However, sometimes they employ casual labour but their number is limited.

On the tractor farming the land holdings on average are larger and production is also higher. On the other hand, the number of family labour available per acre is less than the requirement. Therefore, to meet the labour requirements, they have to employ a sufficient number of permanent and casual labour to cope with work, specially in the peak seasons.

When the total labour input costs on bullock and tractor farming are compared, it will be shown that expenditures on labour in the case of tractor method are 11% lower than the bullock method. It will also be shown that there is an inverse relationship among the unit cost and the land holding on the tractor method. On the small land holdings the tractor method has minor difference in labour cost.

**Capital Inputs Cost** – Capital input cost includes the running and fixed costs of bullocks and the tractor. These costs have been computed as follows:

i) **Cost of Bullock** – In both areas of the sample survey, the traditional methods of cultivation (bullock methods) are used for ploughing, levelling of land, sowing of crops, interculture, gur making, threshing various crops, etc. These draft animals are obtained from the cows and almost every farmer who uses bullock method of farming likes to have a cow at least for this

purpose. In view of the above, when someone wants to calculate the fixed cost or the running cost, he has to take into account not only the bullocks but also the potential bullocks, keeping in view the prevailing prices of the bullock: between 4 and 6 thousand rupees. The average life of the bullocks and a depreciation rate of 12% and interest rate of 13% is applied to their present prices for estimating the annual cost.

The recurring cost incurred on the draft animals and their potentials are the expenditures on green and dry fodder and cost on miscellaneous items such as chains, ropes, medical treatment, etc. plus the cost incurred on traditional cultivator and other instruments minus the value of farm yard manure produced by the draft animals. It is easy to understand that the costs of draft animals would be higher on larger farms as compared to smaller farms as more bullocks will be needed with an increase in the size of farms. It

is, therefore, seen that there is positive relationship between the total running and fixed cost of bullocks and the farm size (Tables 3 and 5).

ii) Costs of Tractor – Almost all the respondents in the survey had bumpy tractors of different powers ranging between 45-65 hp. They were of different models and various makes such as International, Messy Fargosen and Russian tractors. The fixed cost of a tractor depends upon its purchase price, its average life, depreciation, etc. while the running cost depends upon the number of hours a tractor is used on the farms and its consumption of oil, charges, etc.

For tractors, a depreciation rate of 10% and interest rate of 7% are applied on the original purchase price. Running charges of lubricants, fuel and repair are added to the capital cost to arrive at the total annual cost of the tractor. The depreciation of implements and tools attached with the tractor such as cultivator, disc-plough, mould

board plough, seed drill, etc, have been charged on the original purchase price.

In Tables 4 and 6 showing unit cost, the total costs were higher on the larger farms but not the per acre cost of tractors. Therefore the tractor is a costly affair on small farms but cheaper method of farming in the large farms. The cost of tractorization has particularly gone up due to increases in oil prices.

Oil is not easily available in the rural areas, therefore, the tractors have to go in cities to get diesel. Again the repair shops are also very scarce in rural areas, and they charge very high service charges.

### Employment of the Farm Labour Force

The main impact of agricultural mechanization on farm labour employment may be outlined as follows;

i) The replacement of bullocks by tractor and consequent displacement of labour associated with the working and feeding of bullocks.

ii) The performance of various agricultural operations like land preparation, weeding, seed sowing, interculture, threshing and winnowing through tractor displaced labour from the traditional operations.

iii) The adoption of machinery associated with new cultural tech-

Table 3 Cost of Bullock Farming

(Unit: Rs.)

Item	Range in farm size (acre)				Cost per annum	
	13-25	26-50	51-75	76-100	Total	Average
Family labour	6 021	12 904	20 146	24 687.5	63 758.5	15 939.5
Permanent hired labour	2 340	2 650	3 249	4 060.5	12 299.5	3 074.5
Casual labour	1 082	1 579	4 000	5 000	11 661	2 915
Total cost of labour input	9 443	17 133	27 395	33 748	87 719	21 929.5
Draft animal	6 675	12 625	19 937.5	26 740	65 977.5	16 494
Total	16 118	29 758	47 332.5	60 488	153 696.5	38 424

Table 4 Cost of Tractor Farming

(Unit: Rs.)

Item	Range in farm size (acres)				Cost per annum	
	13 - 25	26 - 50	51 - 75	76 - 100	Total	Average
Family labour	4 930	8 644	14 175	18 680	46 429	12 010
Permanent hired labour	1 790	4 080	6 305	7 650	19 825	4 956
Casual labour	1 030	2 160	3 910	6 570	13 670	3 417.5
Total labour input cost in tractor farming	7 750	14 884	24 390	32 900	79 924	20 384.5
Total labour input cost in bullock farming	9 443	17 133	27 395	33 748	87 719	21 929.5
Percentage decrease on tractor	-18.14	-12.8	-10.84	-2.53	-44.31	-11.08
Annual fixed cost of tractor	6 350	10 010	13 500	14 950	44 810	112.2
Annual running cost of tractor	5 950	10 300	8 200	14 600	44 050	11 012.5
Total fixed & running cost of tractor	12 300	20 310	25 700	29 550	88 860	222.5
Total of fixed and running cost of bullocks	6 655	12 635	19 937.5	-	65 999	16 494.5
Percentage increase on tractor	84.05	60.75	29.31	10.80	118.63	46.23
Total cost of labour & tractor	20 050	35 194	50 090	62 450	167 784	41 945.5
Total cost of bullock & labour	16 118	29 758	47 332.5	60 488	153 696.5	38 424
Percentage higher cost of tractor farming over bullock farming	24.41	18.1	5.8	3.3	51.32	10.53

**Table 5** Impact of Family Labour on Tractor Farming

Land holding (acre)	Male (h/unit)	Below 15 years (h/unit)	Total (h/unit)
13-25	15.5	—	16
26-50	18	4	22
51-75	28	3	31
76-100	37	—	37
Average	24.75	1.75	26.50

niques (fertilizer application, chemical spraying etc.) had no displacement effects and rather raised marginally the use of labour.

iv) The increased intensity of cropping (and perhaps yields) and the addition of reclaimed land consequent upon the introduction of tractor leads to the creation of employment opportunities.

v) The displacement of tenant and owner/occupier farmers and their family labour from the land added to the already large holdings.

vi) The displacement of hired labour from these farms were absorbed in other large farms.

The mechanization process initially substitutes for labour (family labour and hired workers). However, in the latter stage it may be followed by a re-employment depending on the extent to which output expansion results in new labour demand. There was, in addition, more subtle effects than just those on the number of people employed. Firstly, the farm enlargement resulted in the loss of "independent farmer" of tenant status by those whose farms were absorbed even though they were re-employed elsewhere within agriculture. Secondly, the characteristics of the agricultural mechanization package and its effect on output can result in a significant shift in the seasonal pattern of employment opportunities; the displacement of full time (family or hired) labour nullified to a greater or lesser extent by an increased demand for casual labour.

#### Impacts on Family Labour

**Table 6** Impact of Family Labour on Bullock Farming

Land Holding (acres)	Male (hrs/unit)	Female (hrs/unit)	Below 15 years (labour hrs per unit)	Total (hrs/unit)	Total displacement of labour hrs	Percentage displacement of labour hrs
13-25	29.5	1	3	33.5	17.5	50.0
26-50	30.0	5	1.5	36.5	14.5	39.0
51-75	43.0	1	.5	44.5	13.5	30.0
76-100	45.5	—	.5	46.5	9.5	20.0
Average	37.13	1.75	1.25	40.25	13.75	34.75

The survey considered the total number of family members, including the males, females and the children and the average number of hours spent per day by each member of the family in the farming activities. Then the labour hours input on the experimental as well control groups were compared. A comparison of these results was made with the data collected by using the Time Series (before and after mechanization) Approach.

The results show that the average family labour hours of all the four categories of holdings are substituted by capital investment which was used for farming. The pattern of change in labour use is generally consistent with the pattern of change in farming size and cropping intensity. The small farms that stand last in size see highest change in labour employment. The large farms which achieve the smallest gain in the cropping intensity demonstrate the smallest declines in the intensity of labour use per acre (Table 5).

Tables 5 and 6 indicate that an average of 36% labour was displaced. The maximum percentage of displacement by 52% was on the smallest holding of 13-25 acres and the minimum displacement of 21% was on the largest holding of 76-100 acres.

The two categories of displaced family labour are land owners and tenants.

The land owners may be i) small farmers, ii) owners of medium size and, iii) the big landlords. All these categories are affected by various ratios by the mechanization. The

small farmers generally have larger number of family labourer as compared to the size of their land holdings, hence their land-man ratio is poor. When they mechanize their farms a large number of family labour is displaced. For the medium size of holdings, the displacement of family labour is less than the small farms. On the large farms the displacement effect may be nominal the reason being that the number of family labour is almost similar on all sizes of the land holdings. For example, an average family of five members may have 15 acres of land (in case of small land owner) or 750 acres of land or more (in case of big land owners). Now if mechanization takes place in both cases of farming then family labour will be displaced in the first case but in the second case there may not be any displacement because of greater labour requirement in large land holdings.

The tenant's family labour is generally hard hit after the adoption of tractor by the land owners. For example, in the traditional method of farming an average family unit having one pair of bullock can cultivate only 6-10 acres of irrigated land during the year, but with tractor the same family can control up to 100 acres or more of land. It means that if an owner has 100 acres of land, in case of traditional farming, he may cultivate 10 acres of land by himself but for other 90 acres, he will have to engage almost nine families of tenants. In case he adopts tractorization, then he

may control the whole land of hundred acres by his own family members. In the past years, as farm wages have gone up and the tenant-landlord relations have not been very congenial due to some reasons there has been some tendency among the land owners to cultivate their lands themselves and eject tenants.

In the survey areas, it is interesting to note that many land owners (particularly small land owners) had started self-cultivation or intend to do so (if circumstances permit). Therefore, the farm land available for tenancy farming is shrinking and the land owners try to eject the tenant whenever they find the chance.

#### Impact on Permanent Hired Labour

Permanent hired farming labour force generally consists of wage earners who are engaged by the land owners to help them in farming activities such as ploughing and levelling of land, sowing and harvesting of crops, plant protection, gardening, interculture operations, irrigation of crops, gurmaking, storing of agricultural produce, and transportation of crops to the market, etc.

These activities may be performed by labour in all size of land holdings and both methods of agricultural farming. But it is normally found that the small landowners have limited holding and not enough resources to employ labour. On the other hand they have sufficient number of family members to perform the cultivation operations successfully. They, therefore, either do not employ permanent hired labour or if they do, it constitutes only a fraction of their family labour although at the peak time they may hire a few casual labourer for a limited period of time or seek assistance from their relatives or friends to help them in harvesting

Table 7 Impact on Permanent Hired Labour

Size of land holdings (acre)	Tractor farming	Bullock farming	Actual and percentage replacement of labour hours	
	(Labour hr required per unit)	(Labour hr required per unit)	(Actual labour hrs replaced)	(Percentage of labour hrs replaced)
13-25	10.0	9.0	.75	4.0
26-50	10.75	9.5	1.25	6.89
51-75	11.0	9.5	1.50	5.94
76-100	12.00	10.5	1.50	4.79
Total 208	43.75	38.75	5.00	21.61
Average 52	10.94	9.68	1.27	5.65

the crops.

For the large land holdings this phenomenon is on reverse order. The landlords in this group believe in mechanized farming. But as the tractor can perform only specified activities such as ploughing they are bound to employ labour for other activities such as interculture operation, irrigation, plant protection, and harvesting of crops, etc. As the landlords do not have sufficient number of family labour to perform said activities, they have to hire permanent labour.

Table 7 shows the position of permanent hired labour in both methods of farming as well as both survey areas.

From the above table it is apparent that as an average 7.5% permanent hired labour was replaced by the tractorization.

The wage of hired labour are difficult to estimate because they get wages in cash as well as in commodities. Furthermore there are many visible and invisible fringe benefits to the hired labour. But in spite of all the financial and other benefits, the hired labour was not satisfied in the survey areas. Their main complaints were as follows:

i) In the bullock method system, hired labour receive their wages in commodities. The values of commodities like wheat, rice, gur, have risen tremendously during the last decade which has led to an automatic increase in the wages of hired labour engaged in traditional

farming system. In the tractor method system, labour is generally paid in cash due to which the real wage value has inverse relation with the change in value of the agricultural commodities.

ii) Wages in rural areas are not linked with the wage change in urban areas. For example, there has occurred a substantial increase in the money wages of the urban labour while there has been only a nominal increase in the wages of the rural areas.

iii) Due to the absence of any incentive such as bonus, paid holidays, etc, the labourers are not motivated to contribute any more in production.

For these reasons, hired labour was not satisfied with their remuneration and preferred to migrate to urban areas for seeking paid employment or self-employment.

From the above discussion, it may be concluded that tractorization has a bearing on the employment opportunities as well as on the financial benefits of the unskilled hired labour. On the other hand, farm mechanization has extended the chances of employment for semi-skilled and skilled persons such as drivers, mechanics, etc. But as this category of people has better chances and attractive wages in urban areas or foreign countries, therefore, they prefer to seek employment in cities and abroad rather than to remain in rural areas. Consequently, there is severe shortage of these people in those areas.

## Impact on Casual Labour

Casual or seasonal labour means that kind of labour is employed by the farmers temporarily for carrying out urgent kind of jobs such as sowing of seed, interculture operations, spray of pesticides, harvesting, threshing and winnowing of wheat and cotton picking.

It was observed during the survey that tractorization had extended the demand for the casual labour on account of the following reasons:

i) A part of the family labour force had been displaced by tractorization and majority of these surplus persons found jobs in non-agricultural or semi-agricultural professions in the rural areas or migrated to urban areas. These people were, therefore, not available to help their family members in the peak seasons. Consequently, this labour requirement gap was filled in by the casual labour.

ii) Tractors could perform only certain basic operations of agricultural farming, e.g., cultivation, levelling of land and sowing of seed. For other agricultural operations, such as harvesting (wheat, sugarcane, cotton and rice) interculture operations, spray of pesticides, there was some scope left to employ a number of labourer. This requirement could only be met by employing casual labour.

iii) Tractorization was associated with more intensive and extensive cultivation which embraced higher crop production. Subsequently, more labour was required

in the harvesting of some crops e.g., wheat and cotton.

iv) The demand for casual labour also increased due to change in cropping pattern. In the past under the bullock farming system, the land holdings were smaller and the farmers used to grow minor crops, i.e., vegetables, fodder and pulses. The sowing and harvesting seasons of these minor crops revolved round the year and consequently, the farm labour force remained engaged throughout the year. But contrary to this, after adopting tractorization the pattern of cropping had changed in favour of major crops such as wheat, cotton, rice and sugarcane. These crops are sown and harvested in two main seasons called Kharif and Rabi. As a result the casual labour is needed in these two seasons.

On account of the above factors, it was reported during the survey that there used to emerge substantial requirement of casual labour in the months of April and May, which is Rabi season. Similarly, there was a demand for casual labour during the months of October and November which is Kharif season. A large demand of casual labour is also required in some other critical occasions during the year. On such occasions, a limited number of casual labour was required for some farming operations such as spray of pesticides and interculture. The position of the casual labour replaced by tractor in both the sample survey areas is given on Table 8.

The table shows an average of 30%

replacement of casual labour. It may, however, be noted that on the smaller land holdings the replacement was less as compared to larger land holdings. This was because on small farms there was enough number of regular labour (family and permanent hired labour) employed throughout the year. In other words, the land-labour ratio was high. In these cases, therefore, at the time of more labour requirement these small land holders could cope with the major part of their extended work by increasing the working hours of their regular labour or in addition to it, they might seek the help of their friends and relatives (Mangi basis) for a short span of time.

In comparison, for the large land holdings, the number of regular labour employed throughout the year (in family and regular labour) was limited and could only deal with routine work. In peak seasons, therefore, when there was huge quantity of work which could not be taken up by the regular labour, even the help of friends and relatives was also not enough to cope with the work. Consequently, a number of additional casual labour was hired by big land holders temporarily to deal with the urgent jobs in the peak seasons.

## Conclusion

The bright side of tractorization is that this machine increases production due to intensive and extensive cultivation. But the dark

Table 8 Impact on Casual Labour

Size of Land Holding (acre)	Tractor Farming			Bullock Farming			Replacement of Labour	
	Male (h/unit)	Femal (h/unit)	Total (h/unit)	Male (h/unit)	Female (h/unit)	Total (h/unit)	Actual (h)	Percentage (h)
13-25	63.5	36.5	100	70	16.5	86.5	13.5	15.61
26-50	140	50	190	130	17.5	147.5	42.5	28.81
51-75	215	72.5	237.5	159.5	33	190	97.5	52.5
76-100	230	75	305	180	30	210	95	45.38
Total 208	648.5	234	882.5	539.5	97	634	248.5	142.30
Average 52	162	58	220.25	134.88	24.25	158.38	62	35.84

side emerges from the extension in cost per unit and displacement of farm labour force from productive employment, particularly on small farms.

It may, therefore, be observed that tractorization is favourable in areas with better land man ratio. In such a case, mechanization in agriculture raises the productivity of labour and reduces the labour cost as compared to bullock farming. But the enquiry in the case study reveals that the economic gains of mechanization are eroded due to poor land-man ratio. This feature is very much prominent in many areas of Punjab and Sind and the findings in the survey reflect to a great extent the same situation in these provinces.

The new technology being introduced in agriculture has, of course, created some favourable and adverse effects on farming which may be described as follows:

Large land owners are following a pattern of capital intensive farming. Due to profit motive, they have partly released or are inclined to release their land from traditional tenancy either by ejecting the tenants or by converting them into wage earners. The increased opportunities for intensive and extensive cultivation have produced encouraging results in production of various crops and have created a big pull for seasonal demand of the ejected labour at peak time.

The medium and small farmers are being completely transformed into a class of self-cultivators. This group of land-owners is also partly participating to establish cottage and small scale industries.

Small owners and farmers try to cultivate their lands by obtaining tractor on rent basis.

The small farmers/tenants who fail to rent or lease land like to work in nearby urban settlements and return to their rural home areas at the peak times or at other odd work opportunities at the

farms. But in recent years there was definitely a change of attitude among the new generation in this group as most of them do not wish to be in a state of seasonal migration from urban to rural areas due to following reasons:

a) The rural migrants particularly the new generation have become used to the urban environment and they are reluctant to return to their native villages even at the time of their demand in rural areas.

b) During the last 10–15 years there has been a lot of awareness among the rural workers about their social status. As they find better social status in cities than in rural areas, they avoid going back to villages to help their farmer masters.

c) The wages in the urban areas are better than the wages in rural areas. This factor induces the migrants to remain in urban areas.

On account of these factors, agriculture is facing severe shortages of labour in peak times in the mechanical agriculture areas.

Mechanization has created tension in the tenants and landlords relations. The land owners after purchase of tractor either do not need or have less requirement of tenants' labour. As the dependency on tenant labour has decreased, therefore, treatment of the land owners towards them has become harsh. One of the evidences of unharmonious relations is shown in the increasing trend of litigations regarding land disputes among them.

In the presence of the existing pressures of the tenants associations the labour laws and traditional social bindings, there are many chances that tenants are not ejected from the land despite the change in farming method from bullock to tractor farming. Consequently, a part of the surplus labour is generally converted from fully employed to under-employed

or disguised unemployed labour. This fact is quite obvious in majority of the tractor areas as there has been tremendous increase in under-employment and disguised unemployment during the period of mechanization.

Tractorization has created surpluses of unskilled and shortages of skilled labourers like drivers, operators and mechanics.

The cost of tractorization is higher than other methods such as bullock or power tiller methods. Thus, it has created a situation in which a relatively cheap input (labour) is displaced by a relatively expensive input (capital).

Tractorization diverts capital, specially foreign exchange, from vital areas which otherwise can be employed more usefully to develop much needed physical and social infrastructure like education, health, construction and transport system. Even within the agriculture sector, increase in water supply and production of bio-chemical inputs such as fertilizers, pesticides and improved seeds have been awaiting the availability of more capital.

There is heavy under-utilization and loss of tractor power in Pakistan. As the majority of the tractor owners have small or medium size holdings most of the time the tractor is either not in operation or is used for non-agricultural or semi-agricultural purposes. Similarly, the heavy duty tractors of 60 h.p. or more are being used for those mechanical operations where a light duty machines can perform all activities as well. For example, the wheat threshing and winnowing operation need only 15–20 hp while in Pakistan, 55 hp or 60 hp tractors are used.

## Recommendations

### Selective Mechanization

Mechanical engineering technology in agriculture can embrace a wide range of different configurations involving motive power, machines and implements. There are also many ways in which one may classify mechanical engineering technology in agriculture. Most important are the following types of distinctions:

- i) Mechanization as applied to each specific operation such as ploughing, sowing seeds, interculture, threshing, and winnowing of crops.
- ii) Mechanization as introduced into a given socio-economic set-up of agriculture.

Keeping in view the above limitations, general functions of mechanization and the socio-economic conditions of agriculture, the

following suggestions are made:

Heavy tractorization may be allowed in: i) New canal areas where vast areas are to be developed by levelling lands, etc; ii) Barani areas, where extensive cultivation is possible and have the potential for additional employment opportunities, and substantial expansion in crop production; iii) In old irrigation areas heavy tractorization may be allowed on land holdings consisting of 31 acres and above. Tractors may not be provided to individual owners or cooperative owners having holdings upto 30 acres. It is pointed out that under various schemes of the government, the tractors are being provided to farmers having land holdings of 25 acres and under special schemes upto 12.5 acres of land.

Heavy tractorization may not be allowed on: i) Small farms of 1-12 acres may be provided hand driven Japanese power tillers or they may be advised to carry on their bullock farming with modern ploughing implements; ii) The farmers having land holding of 13-30 acres may be provided with Chinese or Japanese power tillers of 12 h.p. or mini-tractors to be produced locally. Small power tillers are a good substitute of heavy tractors, as these are less costly, need less skilled operators and they can be used for ploughing, levelling, sowing, threshing and winnowing crops or transporting goods from the village to the market. Thus power tillers or mini-tractor can be the harbingers of a technological revolution on the farms. ■

# Agricultural Development and Requirement for Short Term Finance: Case Study of Binjharpur Block, Orissa

by  
T. N. Datta  
Research Executive  
Operations Research Group  
Bhubaneswar, India

Anthony D' Costa  
Research Executive  
Operations Research Group  
Bhubaneswar, India

## Summary

For any agricultural development programme, the provision of adequate credit for short, medium and long term is an essential input. It is widely acknowledged that there exists a gap between demand for and supply of short-term credit in India. Taking the block as a micro-unit of study, an attempt was made to examine the present need of short-term credit vis-a-vis the existing situation. Such a situation is also examined in view of the anticipated development of agricultural activities in the block.

## Introduction

Institutional finance is a major prerequisite for development. The need for credit, however, varies between different sectors of the economy. For example, the nature of agricultural credit requirement is different from that in industrial sectors. While the former may be for short, medium or long term, the latter is always for either medium or long term. The short-term credit requirement in the agricultural sector is generally referred to crop loan. Such crop loan is the most important element of cost

of cultivation in the agricultural sector. There are two components of crop loan: viz. cash and kind. The latter component of the crop loan involves the cost of fertilisers, seeds, pesticides, etc. and the cash part is given in order to meet other expenses like labour charge, irrigation expenses and consumption purpose.

## Methods of Estimating Crop Loan

A number of methods are used in estimating the crop loan value for any area.

### The Reserve Bank of India Method

The Reserve Bank of India in its new guidelines has put forward two approaches for estimating crop loan as follows:

*Approach 1* — To estimate the total investment required to meet the cost of cultivation by applying the existing norm of finance with the cropping pattern (areas under different crops) for, say, the district under both irrigated and unirrigated conditions. It is assumed that all the farmers may not need institutional credit sup-

port to meet the cost of cultivation as they may have their own resources to meet their respective requirements. Under this approach, 50% of the cost of cultivation can be taken as crop loan requirement.

*Approach 2* — This approach suggests apportioning the total investment among the different classes of farmers, viz. small and marginal, medium and large in the same ratio as they are categorised in total farming classes. The provision for crop loan is 100% for small and marginal farmers, 50% and 25% for medium and large farmers, respectively.

### Method suggested by National Commission on Agriculture (NCA)

The scale of finance is Rs 600/ha of irrigated area and Rs 450/ha of unirrigated area of which provision should be made to provide the cost of cultivation in both irrigated and unirrigated areas. The requirement so estimated should be met by 1985 of which at least 50% is to be achieved by 1981.

### Working Group Method (Planning Commission)

The Working Group of the

Planning Commission adopts a method similar to the NCA with the difference being in the scale of finance recommended. It suggests Rs 250 and Rs 125/ha for irrigated and unirrigated area, respectively, for estimating crop loan requirement.

All these are, however, conventional ways of estimating short term credit requirement for agricultural sector. Apart from these, an attempt has been made to look into the crop loan demand of an area which is based on more of practical experience than in any given methodology. It is our general experience that Primary Agricultural Credit Societies (PACS) are the largest contributors to the crop loan finance in agriculture. This, however, does not exclude the relatively insignificant role played by the commercial banks in respect of crop loan disbursement. The ratio of commercial banks share to cooperative banks' share can be roughly assumed as 1:4\* Based on this assumption, the estimation of short term finance for an area is expected to represent a fairly good estimate. An analysis of the estimation method is given below:

#### Ratio method

The PACS are the prime agency in rural areas for short term credit disbursement and, therefore, it could be expected that the estimation of short term credit need from PACS' coverage would throw relevant light as to the extent of credit required for an area.

Under this approach, time series data of borrowing members of the PACS as a percentage of the total cultivators' families in the block is calculated. From the same source a trend had been observed. This has

\* This is based on the authors' experience on District Credit Plan (1980-82) for four districts (Cuttack, Puri, Dhenkanal and Balasore) of the State.

been assumed for the terminal year of the Sixth Plan. Again, from the time series data of effective borrowing members to total borrowing members, a similar trend has been tried out to be applied for the final year of the period concerned. The effective borrowing members thus arrived at, has been multiplied by the per capita credit requirement so as to compute the credit demand.

#### The Block

Binjharpur is one of the northernmost blocks of Cuttack district and falls within Jajpur sub-division. Of its total geographical area of 20 349 ha, 15 548 (76%) ha are cultivated. Double cropped area in the block is about 12 060 ha which is possible due to the moisture-retentive capacity of the soil where short seasoned crops are grown in large patches even without stable irrigation. The possibility of extensive cultivation in the block is limited as much of the area has been brought under cultivation. Table 1 provides an idea of land utilization pattern in the block.

Table 1 Land Utilisation Pattern in Binjharpur Block, (1980-81)

Category	Area	
	(ha)	(%)
Geographical area	20 349.0	100.0
Miscellaneous tree crops and groves	2 135.0	10.4
Permanent pastures	624.9	3.1
Land put to non-agricultural use	755.2	3.7
Barren and uncultivable land	218.4	1.1
Cultivable waste	358.4	1.8
Fallow land	708.1	3.5
Net area sown	15 548.0	76.4
Area sown more than once	12 059.0	59.2
Gross cropped area	27 607.0	-

Source: ADE Office, Binjharpur

#### Irrigation

Kharosrate is the main river of

this block besides having 8 distributaries of Jajpur canal system for irrigation. All these distributaries irrigate about 900 ha of gross cropped area of which 400 ha receive rabi irrigation. As far as kharif irrigation is concerned, canals protect the entire area under its command, but during rabi as the canals run dry no stable irrigation is possible. The reason behind uncertainty of rabi irrigation is that there is no main water reservoir in the entire region and hence proper water management can hardly be done benefiting heavy or medium duty rabi crops. As regards future exploitation of this source, no significant increase in the area seems possible since the proposed Rengali Irrigation Dam would take a long time to benefit the block. The minor irrigation projects, numbering 12, are another important source of flow irrigation in the block. This has been possible due to several natural streams, nullahas, etc. where during late monsoon period cross-bunds are erected in order to store water for rabi irrigation. It is ascertained that four more minor irrigation projects are possible in Arei, Kapila, Sisurana and Masada panchayats which could irrigate additional 125 ha.

As regards exploitation of ground water, the prospect in the block is quite good which may not be reflected by the existing utilization of the sources. That only 170 ha is presently irrigated from dugwells, filter point tubewells and deep and medium-deep tubewells is no indication to that. As per the groundwater survey report, 1 000 dugwells and 100 filter point tubewells are feasible in the block. These apart, feasibility report for deep and medium deep tubewells prepared by the Orissa Lift Irrigation Corporation puts the figure to 30 for this block. Direct lifting of water through mechanized irrigation points is presently done in

the block at 44 points. These points irrigate about 1 000 ha of gross cropped area. The constraints underlying this source such as theft of electrical wire, mechanical defects, etc. are purely local problems and, therefore, efforts are to be made to overcome them. Another hindering factor for this is the change of river course for which shifting of the points to the appropriate site appears to be the only way out. Considering all the above factors, the existing as well as expected irrigation availability in the block can be seen from Table 2.

The prospect of agricultural development in the block lies in the intensification of agricultural activity either by raising cropping intensity or productivity or both. In any case, irrigation has to play a due dominant role. That there would be additional 1 330 ha of irrigated area during the Sixth Plan period is an encouraging sign. The expected gross cropped area as well as cropping intensity is shown in Table 3.

### Cropping Pattern

Having estimated the total land resources available in terms of gross cropped area, the next step is to project the future cropping pattern for the block. For this purpose, trend data on cropping pattern have been analyzed and it has been found that variation in the cropped area is always within a close range, particularly for kharif crops where cropped area has an association with the availability of rainfall. As regards rabi crops, steady increases in area is noticed for high yielding variety of paddy, groundnut, mustard and vegetables which is due to increased use of groundwater sources. Under these circumstances a ratio method of projection is expected to give better result. The existing as well as projected cropping pattern for the

Table 2 Irrigation Sources: Present and Projected in Binjharpur Block (Unit: ha)

Source	Existing		Projected	
	Net	Gross	Net	Gross
Canal	460	860	460	860
Minor irrigation project (cross-bunds)	188	376	250	500
Dugwells	50	100	750	1 500
Filter point tubewells	100	200	200	400
Deep and medium deep tubewells	20	40	300	600
River lift irrigation points	474	948	660	1 320
Total	1 292	2 524	2 620	5 180

Table 3 Projected Area

A) Existing	
a) Net area sown	15 548 ha
b) Area sown more than once	12 059 ha
c) Gross sown area	27 607 ha
d) Crop intensity	177%
B) Projected	
a) Increase in area to be sown more than once due to irrigation	1 330 ha
b) Anticipated gross cropped area (1984-85)	28 937 ha
c) Expected crop intensity	186%

block is shown in Table 4.

As can be seen, crops like high yielding variety rabi, paddy, groundnut, mustard, vegetables are the ones which would gain substantial area due to availability of irrigation during rabi. A decline in the pulse area will be compensated by grain in the high valued crops because of expected coverage under irrigation which is a welcome sign. Among the kharif crops, especially in case of paddy, a shift towards high yielding variety over normal variety is expected. Vegetables would continue to be a major rabi crop along the river bank areas of the block, where, through light irrigation, these crops are grown successfully.

### Short Term Credit Demand

At this juncture, one should look into the existing as well as expected short term credit demand that will be required in order to realize the projected cropping pattern. The existing achievement in this regard has been collected and analyzed from all the funding agencies operating

Table 4 Existing and Projected Cropping Pattern for Binjharpur Block (Unit: ha)

Crops	Area	
	1980-81	1984-85
Paddy (Normal)	10 230	10 345
Paddy (HYV)	4 184	4 638
Wheat (HYV)	125	203
Mung	1 629	1 587
Biri	5 336	4 964
Kulthi	1 200	1 332
Other pulses	454	318
Groundnut	1 015	1 560
Mustard	510	721
Til	176	174
Other oil seeds	82	58
Jute	201	200
Other fibres	22	29
Potato & vegetables	2 101	2 344
Chilly	122	175
Other crops	220	298
Total	27 607	28 937

in the block. It may be mentioned here that Binjharpur is a block where all the Primary Agriculture Cooperative Societies (16) are ceded to the Central Bank of India, Binjharpur Branch, and, therefore, the cooperative bank's role virtually ceases to exist. The two offices of the Regional Rural Bank (Cuttack Gramya Bank) at Singhpur and Uttarkul were recently opened and thus they are yet to figure in crop loan disbursement. Under such situation, the whole responsibility is shouldered by the only branch of the Central Bank of India. Table 5 presents the short term estimated credit by various methods existing and projected vis-a-vis present disbursement which provides some insight into the efforts needed to fulfil the gap, if any.

A comparative analysis of all the methods shows that Reserve Bank of India methods put the figure at a much higher level as compared to

Table 5 Short-Term Credit Requirement for Binjharput Block, 1980-81 and 1984-85 (Rs in Million)

Methods	Credit Demand		Existing achievement	Existing gap*
	1980-81	1984-85		
R.B.I.				
a) Approach - 1	14 250	15 374		
b) Approach - 2	25 520	27 534		
N.C.A.	3 579	7 158	1 386	2 193
W.G.P.	3 766	4 265		2 380
Ratio	-	2 307		-

\* Existing gap in short term credit has not been computed for RBI method as the figure arrived at is high. Therefore, a shortfall of credit based on these methods may not give true picture.

other methods. This is because of its stress on small and marginal farmers' demand for cost of cultivation to be provided as crop loan finance. It is common knowledge that not all the small and marginal farmers are willing to approach funding agencies for meeting this cultivation cost.

Instead, they try to meet the requirement from whatever resources they possess. Besides, psychologically they are not prepared

to go in for institutional credit support in view of cumbersome terms and conditions stipulated from time to time. Among the other three methods, ratio method estimates the credit need at the minimal.

Leaving aside the reliability of estimates, even though one considers the need arrived at by ratio approach to be the need for the block, one finds that gap is widening. This calls for strengthening

the cooperative base in terms of coverage as well as recovery. In case of Binjharput block, as all the societies are ceded to a commercial bank, vigorous efforts are required to fulfil such needed credit demand of the area.

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# Manual Labor Displacement with Tractorization



by  
**Bashir Ahmad**  
Assistant Professor  
University of Agriculture  
Faisalabad, Pakistan

## Abstract

This paper is concerned with the estimation of human labor input for various major crops on tractor and bullock farms. The use of total labor input per hectare was lower on tractor farms than on bullock farms for all the major crops. The use of permanent labor was less, while that of casual hired labor was higher on tractor farms than on bullock farms. Reduction in permanent labor on tractor farms was confined mainly to plowing, planking, etc. where tractors were utilized. However, the use of casual hired labor was greater for those operations where tractors were not involved on farms.

agricultural development was concerned. Various new inputs like fertilizers, pesticides, improved seeds, etc. were introduced. Mechanical developments like introduction of tractors, however, received more government attention in recent years (Table 1). This was partially done due to increased work load on farms which resulted from the previously introduced biological and chemical technologies. Tractorization was also partially done to speed up certain critical farm operations so as to permit more intensive use of land. The importance of timing in farm operations can be well illustrated in the case of a wheat-cotton rotation over a single year. A critical aspect

of this operation is that the wheat crop must be harvested, threshed and winnowed in time for the sowing of cotton. The timely planting of cotton is essential to allow double cropping and to avoid a conflict in the use of resources.

It is argued that tractor farming causes wide-spread displacement of rural labor as it involves the substitution of capital for labor. Little is, however, known about the extent and pattern of displacement of manual labor with tractorization for major crops. The main objective of this study was to determine the amount of manual labor used on various operations of major crops on tractor farms and bullock farms in order to help the planners, policy makers and administrators in framing a better employment strategy.

## Introduction

Agricultural development in Pakistan is characterized by two distinct phases. The first phase (1947-1958) was marked by a static state of agriculture when Government efforts were concentrated mainly on the development of the industrial sector. The second phase started in 1959 and it may be called a revolutionary phase as far as

Table 1 Number of Tractors Imported in Pakistan

Year	Annual import	Cumulative number
1968-69	4,411	21,534
1969-70	5,696	27,230
1970-71	3,879	31,109
1971-72	4,224	35,333
1972-73	1,847	37,180
1975-74	5,216	42,396
1974-75	7,190	49,586
1975-76	10,809	60,395
1976-77	15,554	75,949
1977-78	11,902	87,851
1978-79	15,178	103,029

Source (1)

## Methodology

The study was conducted in the Multan zone. The area of this zone is a nearly level plain. The climate is arid sub-tropical continental. The summer is very hot and winter is very cold. The mean maximum temperature is 40°-45°C and the mean minimum temperature is

5.5°-7°C. The mean annual rainfall is 200 mm. The soil is haplic yermosols type (4).

**Sampling** — The study was confined to six villages of Burewala "tehsil" representing the average conditions for the production of crops. The selection was made after consultation with the agricultural officers and farmers. In all there were 599 holdings in these villages. A random sample representing 27% of the population was drawn for a detailed investigation. In all 150 cases were selected, 134 bullock farms and 16 tractor farms.

**Data collection** — A comprehensive interview schedule was constructed which was revised after pretesting. Raw data so collected were later on tabulated and analyzed.

Labor used on these farms was divided into two main categories, i.e., permanent farm hands and casual hired labor. Permanent farm hands included the family labor and permanent hired labor which is available on the farm throughout the year. Casual hired labor was employed during the peakload periods for specific operations like harvesting of wheat, transplanting of rice, etc.

## Results

Human labor input per hectare was compared for cotton, sugarcane, maize, rice, wheat, kharif fodders and rabi fodders on tractor farm and bullock farms. These crops accounted for 86 and 98% of the total cropped area on these farms, respectively.

Overall human employment per hectare for cotton was lower by 4% on tractor farms as compared to bullock farms (Table 2). The use of permanent labor was lower by 39%, while that of casual hired labor was higher by 80% on tractor

Table 2 Manual Labor Hours for Various Operations on Cotton Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Ploughing	PL	6.65	49.94	36.93
Planking	PL	3.09	10.65	8.18
Levelling	PL	1.83	3.63	2.45
Farm yard manure application	PL	3.31	2.62	2.87
Sowing	PL	11.12	24.87	20.40
	CHL	12.94	3.93	6.89
Harvesting	PL	0.17	0.37	1.58
Interculture	PL	7.61	11.12	10.00
	PL	14.89	43.45	34.06
Hoeing	CHL	58.42	14.84	29.17
Fertilizer application	PL	4.47	2.62	3.24
	PL	85.63	54.56	64.76
Irrigation	CHL	—	1.73	0.12
	PL	3.53	0.86	1.75
Pesticide application	CHL	0.77	0.07	0.30
	PL	11.78	55.70	41.25
Picking	CHL	129.50	92.58	104.75
Cutting and transportation	PL	19.02	23.27	21.91
	CHL	11.56	5.21	7.31
Total	PL	173.10	283.66	249.38
	CHL	213.19	118.36	148.54
PL + CHL		386.28	402.02	396.68

PL: Permanent labor, CHL: Casual hired labor.

Table 3 Manual Labor Input per Hectare for Various Operations on Sugarcane Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Plowing	PL	16.16	76.72	65.65
Planking	PL	7.94	14.99	13.71
Levelling	PL	1.91	5.06	4.50
Farm yard manure application	PL	36.69	45.05	43.52
	CHL	51.38	0.67	9.93
Sowing	PL	88.61	64.07	68.57
	CHL	45.70	65.15	61.38
Irrigation	PL	190.69	179.92	181.89
	CHL	—	0.67	0.54
Fertilizer application	PL	4.06	2.87	3.09
	PL	26.32	70.12	62.09
Hoeing	CHL	53.35	21.07	26.98
	PL	18.20	14.33	15.04
Interculture	PL	18.20	14.33	15.04
Pesticide application	PL	0.80	0.17	0.30
	PL	535.99	537.87	537.52
Cutting & stripping	CHL	129.67	139.31	137.65
	PL	806.45	836.22	830.76
Gur making and transportation	CHL	182.78	108.38	121.99
Total	PL	1 733.82	1 847.39	1 826.64
	CHL	462.88	335.25	358.47
PL + CHL		2 196.70	2 182.64	2 185.11

PL: Permanent labor, CHL: Casual hired labor.

farms as compared to bullock farms. Thus tractorization, on one hand, leads to the reduction in the employment of permanent labor component, while on the other, it promotes the utilization of hired labor. Employment of manual labor by operations shows that the reduction of employment was con-

finned mainly to plowing, planking, and levelling operations where tractors were utilized. For other certain operations like fertilizer application, irrigation and pesticide application, manual labor use was higher on tractor farms than on bullock farms.

Overall manual labor input per

hectare for sugarcane plant was of the same magnitude on both types of farms (Table 3). However, the use of permanent labor was lower by 6%, while that of casual hired labor was higher by 38% on tractor farms as compared to bullock farms. Plowing, planking, levelling, farm yard manure application, hoeing, gur making and transportation were the operations where the reduction in the use of permanent labor took place on tractor farms. However, the use of casual hired labor was higher for farm yard manure application, hoeing, gur-making and transportation on tractor farms. Thus tractorization encouraged the use of casual hired labor for those operations where the tractors were not used.

For rice, the use of overall labor input amounted to 600 h and 639 h per ha on tractor and bullock farms, respectively (Table 4). The use of permanent labor was less, while that of casual hired labor was higher on tractor farms as compared to bullock farms. The use of casual hired labor was specifically higher for transplanting, hoeing and harvesting operations on tractor farms as compared to bullock farms. Thus tractorization leads to an increase in the use of casual hired labor for the rice crop.

For maize, the overall human input was 48.3 h and 573 h/ha on tractor farms and bullock farms, respectively (Table 5). Use of permanent labor was lower by 26%, while that of casual hired labor was higher by 79% on tractor farms as compared to bullock farms. Plowing, planking, farm manure application, irrigation, cob-picking and shelling operations were responsible for the less use of permanent labor, while farm yard manure application, cobbing and shelling contributed for the higher use of casual hired labor on tractor farms than on bullock farms. Thus tractorization has a

Table 4 Manual Labor Input per ha for Various Operations on Rice Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Ploughing	PL	8.87	58.34	44.31
Planking	PL	3.14	13.02	10.20
Levelling	PL	0.57	1.95	1.56
Farm yard manure application	PL	3.70	7.93	6.74
	CHL	8.89	—	2.52
Irrigation	PL	132.22	150.36	145.22
Puddling	PL	7.51	11.95	10.72
	PL	6.59	32.73	25.32
Transplanting	CHL	120.54	97.59	104.11
Fertilizer application	PL	4.77	2.64	3.24
	PL	22.18	22.33	22.28
Hoeing	CHL	81.68	10.89	30.97
	PL	—	0.05	0.02
Pesticide application	CHL	0.22	0.03	0.07
	PL	14.05	65.87	51.15
Harvesting and threshing	CHL	161.04	128.64	137.85
	PL	9.34	25.56	20.94
Transportation	CHL	14.60	9.06	11.12
Total	PL	212.94	392.73	341.70
	CHL	386.97	246.21	286.64
PL + CHL		599.91	638.94	628.34

PL: Permanent labor, CHL: Casual hired labor.

Table 5 Manual Labor Input per ha for Various Operations on Maize Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Plowing	PL	7.11	90.85	70.54
	CHL	2.30	7.93	6.25
Planking	PL	2.86	12.80	9.86
Levelling	PL	1.56	2.69	2.35
Farm yard manure application	PL	9.71	23.71	19.56
	CHL	25.14	—	7.31
Fertilizer	PL	4.03	3.16	3.43
Harrowing	PL	0.17	0.54	0.45
	PL	0.72	0.89	0.84
Pesticide application	CHL	0.44	1.58	1.26
Irrigation	PL	51.15	67.73	64.72
	PL	92.28	65.11	65.82
Hoeing	CHL	6.03	16.42	13.36
	PL	51.84	95.39	82.47
Cob-Picking	CHL	28.18	12.35	17.04
	PL	61.65	71.41	68.52
Shelling	CHL	31.47	13.81	19.04
	PL	78.77	55.23	62.22
Cutting of stock	CHL	—	0.47	0.32
	PL	22.85	28.55	26.87
Transportation	CHL	4.77	2.37	2.92
Total	PL	384.70	518.06	477.65
	CHL	98.33	54.93	67.50
PL + CHL		483.03	572.99	545.15

PL: Permanent labor, CHL: Casual hired labor.

favourable influence on the use of hired labor.

For wheat, overall human employment per hectare was lower by 18% on tractor farms as compared to bullock farms (Table 6). The use of permanent labor was lower by 45%, while that of casual

hired labor was higher by 47% on tractor farms as compared with bullock farms. Plowing, planking and threshing were the important operations where reduction took place in the use of permanent labor. As the tractors are used heavily for these operations on

Table 6 Manual Labor Input per ha for Various Operations on Wheat Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Ploughing	PL	9.63	73.75	56.32
Planking	PL	3.85	13.93	11.19
Levelling	PL	2.35	4.00	3.53
Farm yard manure application	PL	—	6.25	4.54
Sowing	PL	17.32	14.52	15.29
	CHL	4.10	2.13	2.67
Irrigation	PL	101.64	93.64	95.81
	CHL	—	0.22	0.15
Fertilizer application	PL	1.51	2.12	1.95
Hoeing	PL	—	0.20	0.15
	PL	—	40.76	29.64
Harvesting	CHL	132.91	77.21	92.35
	PL	19.51	32.16	28.75
Threshing	CHL	29.96	30.75	30.53
	PL	0.37	5.76	4.37
Winnowing	CHL	2.74	5.11	4.47
	PL	14.42	17.83	16.90
Transportations	CHL	4.50	2.52	3.06
Total	PL	170.60	304.92	268.44
	CHL	174.21	117.94	133.23
PL + CHL		344.81	422.91	401.67

PL: Permanent labor, CHL: Casual hired labor.

Table 7 Human Labor Input per ha for Various Operations on Kharif Fodder Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Plowing	PL	5.87	42.23	34.55
Planking	PL	2.62	9.29	7.90
Levelling application	PL	1.09	1.09	1.07
Fertilizer application	PL	1.16	1.11	1.12
Farm yard manure application	PL	4.94	9.68	8.68
	CHL	2.55	0.65	1.05
Irrigation	PL	49.08	73.85	68.60
	CHL	—	0.20	0.16
Total	PL	64.76	137.25	121.92
	CHL	2.55	0.85	1.21
PL + CHL		67.31	138.10	123.13

PL: Permanent labor, CHL: Casual hired labor.

Table 8 Human Labor Input per ha for Various Operations on Rabi Fodder Growing

		Unit: h		
Operation		Tractor farms	Bullock farms	All farms
Ploughing	PL	8.25	47.57	39.62
Planking	PL	2.84	9.46	8.13
Levelling	PL	1.85	1.90	1.89
Fertilizer application	PL	1.31	1.24	1.26
Farm yard manure application	PL	22.75	36.48	33.72
	CHL	30.01	1.05	6.92
Irrigation	PL	150.00	144.97	145.98
	CHL	—	0.48	0.40
Total	PL	187.00	241.62	230.60
	CHL	30.01	1.53	7.29
PL + CHL		217.01	243.15	237.89

PL: Permanent labor, CHL: Casual hired labor.

tractors farms, therefore, this reduction was expected. However, the use of casual hired labor was 133 h/ha on tractor farms as compared to 77 h on bullock farms for the harvesting operation. This single operation accounted for the major difference in the use of casual hired labor on these farms.

For kharif fodders, tractor farms engaged 50% less labor relative to bullock farms (Table 7). The reduction amounted to 71 h/ha. Plowing, planking and irrigation were the important operations where this reduction took place. The use of casual hired labor was negligible on both types of farms.

Overall human labor input was 217 and 243 h/ha for rabi fodder on tractor farms and bullock farms, respectively (Table 8). The reduction amounted to 40 h only on plowing. As tractors are mainly used for this operation, this reduction was expected. The use of permanent labor was lower by 22%, while that of casual hired labor was higher by 20 times on tractor farms than on bullock farms. Thus tractorization leads to reduction in the use of permanent labor and an increase in the use of casual hired labor for rabi fodder.

The overall employment per cropped hectare was 396 and 474 h, respectively, on tractor farms and bullock farms (Table 9). The use of permanent labor was less by 40.5% on tractor farms as compared to bullock farms. These results were consistent with the finding of a NCAER study conducted in Andhra Pradesh, Haryana, Punjab and Uttar Pradesh (3). The use of casual hired labor was higher by 14.5% on tractor farms than on bullock farms. Similar results were reported by Kahlon in Punjab (2). Thus with tractorization the demand for casual hired labor increased while the employment of permanent labor declined in crop production.

Table 9 Labor Input per Cropped Hectare

Type of labor	Unit: h		
	Tractor farms	Bullock farms	All farms
Permanent labor	216.56	363.78	318.59
Casual hired labor	179.39	110.57	126.75
Total	395.95	474.35	445.34

Summary

The main objective of this study was to determine the amount and pattern of manual labor use on various operations of major crops on tractor farms and bullock farms. The study was confined to six villages of Burewala tehsil. In all 134 bullock farms and 16 tractors farms were randomly selected for detailed investigation. A comprehensive pretested questionnaire was constructed and used for the collection of data.

The total human input, permanent labor input and casual hired labor input per hectare were compared on tractor farms and bullock farms for major crops, i.e., cotton, wheat, sugarcane, maize, rice,

kharif fodder and rabi fodder. The use of total labor input per hectare was lower on tractor farms than on bullock farms for all the major crops. The input of permanent labor was less, while that of casual hired labor was higher on tractor farms than on bullock farms. Thus tractorization led to a reduction in the permanent labor input and promoted the utilization of casual hired labor. Reduction in permanent labor input on tractor farms was mainly confined to plowing, planking, levelling, etc. operations where tractors were mainly used. The input of casual hired labor was more on tractor farms than on bullock farms for those operations where tractors were not involved.

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## Saudi Agriculture '83 April 10-14, 1983, Riyadh/ Saudi Arabia

Agricultural self-sufficiency is a major objective in Saudi Arabia's Third Five-Year Development Plan (1980-1985). The Kingdom's commitment to the expansion of its food production programme is highlighted in the Plan by an investment of US\$2.4 billion for agricultural development over the current five years. Added to this is a substantial allocation of funds for the provision of major irrigation projects.

Saudi Agriculture '83 provides a further opportunity for manufacturers and suppliers of agricultural and related products, equipment and services to gain exposure and sell into this rapidly growing multi-million dollar market.

Saudi Agriculture '82 attracted 400 Exhibitors on 241 stands from 26 countries with major participation from Britain, Holland, Denmark, Austria, France, Canada, USA and Australia; 6450 visitors including ministry delegations from Saudi Arabia, Bahrain, Kuwait, Qatar, Oman and North Yemen.

## 1st International Conference Energy and Agriculture April 27-29, 1983, Milano/Italy

### Topics of the conference

There will be six technical sessions:

- Energy balance of agricultural-forestry systems
- Energy conservation in agriculture
- Integrated energetic systems applied to agriculture
- Technology of renewable energies:

- 1) geothermal
- 2) solar
- 3) biogas
- 4) combustion
- 5) pyrolysis
- 6) mini-hydraulic

### E. Energy crops

### F. Status of international policy on energy and agriculture

For information contact:

The General Secretary of the Conference  
c/o Milan Business Service  
Foro Bonaparte, 63  
20121 Milano, Italy

## Bio Energy '84

### Bio-Energy World Conference and Exhibition

June 18-21, 1984, Gothenburg/  
Sweden

Utilization today and strategies for tomorrow.

A. The pre-study tours, with starting points in Helsinki, primarily concerning peat for energy, Copenhagen, primarily concerning straw and energy crops, and Stockholm, primarily concerning forestry residues. The tours will include demonstrations of the whole concepts from the original resource to the final utility such as househeating, electric power or synthetic fuel.

### B. The Conference

In different seminars the total concept of biomass for energy with some accent on biomass for heating and power purposes will be analyzed. The speakers will be international and the main language is to be English. Simultaneous interpretation will be provided in French and German.

### C. The Special Topic Seminars

Parallel with the main conference, the University of Gothenburg plans

to arrange a number of highly qualified discussions.

### D. The Exhibition

Indoors the area will be filled with bio-energy devices for:

- on-site planning and preparation
- cultivation and harvesting
- handling, transport and storage
- size reduction, drying and densification
- combustion for power and heating purposes
- distribution
- synthetic fuel production (biogas, alcohol)
- system concepts for large-scale and small-scale applications for different parts of the world

### Outdoors

Field demonstrations are planned.

### E. Special study tours

During the main conference week it will also be possible to visit different interesting bio-energy sites near Gothenburg.

For further information contact:  
The Swedish Trade Fair Foundation

P.O.Box 5221  
S-402 24 Gothenburg, Sweden

## Chinese Agro-Machinery Ploughs Foreign Markets

by

Li Cheng  
China Features  
P.O. Box 522  
Beijing

When Madagascar's Ambassador to China heard recently about the "plough boat" developed to ease the grueling labor of work in the south China paddies, he told Chinese officials that when a trade delegation soon arrived in Beijing from his country it would straightaway look into the innovative machine for use in Madagascar's



Simple plough boats adaptable to paddies in hilly areas produced in Shawu county, Fujian province, South China.

deep and muddy fields.

The plough boat was designed for operation by a single man or woman and to replace the heavy plough drawn by buffalos that is the basis of cultivation through much of tropical Asia. It is boat-shaped and propelled by two paddle-wheels fitted to its sides, and in one hour it can either plough about one-fifth of a hectare, or churn soil into a fine ooze over one-third hectare of land. When the paddles are replaced by rubber wheels, the "boat" can sail over dry land to haul a trailer, seeder or roller, or to drive a thresher.

The plough boat is but one of a growing number of agricultural machines that China is marketing aggressively, and successfully, around the world. In contrast to the highly sophisticated and often extremely expensive equipment manufactured for export by highly industrialized nations, Chinese factories are making available an ever increasing number of machines that, in the simplicity of their design, ease of maintenance, and low cost are particularly adaptable to the less developed economies of the Third World.

In general, Chinese machinery may cost as little as one-third that of similar equipment made in Japan, the United States, or other advanced countries. The plough boat, for example, sells for less than US\$ 1 500, while "walking trac-

tors" sell for US\$ 1 000, and Taishan-25 tractors for about US\$ 2 500.

Internal combustion engines rank first among China's agricultural machines for export — a total of 340 000 hps were sold abroad in 1981, accounting for 40% of China's total export earnings in the agro-machine field. However, Chinese marketers also sold, in addition to the plough boat, significant numbers of reapers, diesel engines, and tractors of varying sizes, including a popular light-weight "walking" model which may be easily operated by a person. In all, China has over 2 000 types of farming machines for export.

In 1981, China exported agricultural machinery to more than 70 countries and regions. Chief among these were traditional purchasers in Thailand, Pakistan, the Philippines, Malaysia, Singapore and Hong Kong. New markets have also been developed in Iran, Cuba and other countries in the Middle East and Latin America. China's customers are, however, no longer restricted to the Asian and African countries, for sales have begun in nations such as Greece and Portugal, not to mention Australia and the United States.

The total value of China's agromachinery exports in 1981 was US\$37 million, compared with US\$24 million in 1980, and only US\$16 million in 1979.

In 1979, the last year for which complete figures are available, China had more than 1 900 large factories which manufactured farm machinery, and 2 400 smaller plants mainly for repair work but which also manufactured some equipment for export. Altogether, these factories and plants employed nearly 1.45 million workers, and had the capacity to annually

produce 135 000 large and medium-sized tractors, 332 000 small tractors, 34.46 million hps of internal combustion engines, plus a variety of other machinery and tools.

In 1981, in addition to the internal combustion engines sold abroad, China exported 704 tractors, 7 359 walking tractors, and a total of 24 000 kws of internal combustion generating units. Substantial increases occurred in the export of irrigation and drainage equipment, crop protection ware, harvesting and barnyard machinery, farm implements, various types of equipment related to livestock care, and other goods.

The Nanyue 4G-160 reaper has won particular praise from foreign agricultural experts and officials. The reaper, said Dr. Reynaldo M. Lantin, chairman of a 1980 harvester conference sponsored by the United Nations, was "very good," since it had a "simple structure," was "light and convenient" and reaped in a "quite regular" fashion. The same machine was commended by Thai, Indonesian and Malaysian experts after demonstrations in Thailand.

In 1981, China exported a total of 6 886 walking tractors with reapers and simple walking tractors to Thailand, along with 843 larger tractors, mainly of the Taishan-25 model. At demonstrations there in 1980, 1 000 walking tractors were sold on the spot to farmers and dealers, including harvesters which had been fitted with cutting and drying attachments. Purchasing personnel from about 30 Thai machinery firms were received in China later in the year.

Also in 1981, an agreement was reached with a Pakistani firm to assemble 8 500 Taishan-25 tractors over the next three



An array of walking tractors is going to the communes from Wusi Tractor Factory, Jiangsu province, East China.

years. 1 000 more Taishan-25's were scheduled for import by Pakistan during 1982. In addition, China agreed to supply another Pakistani company with the parts and components of 16 000 Dongfeng-12 diesel engines in

4 years.

Meanwhile, there is an increasing demand for small Chinese diesels and agricultural machinery from farmers in developed countries, where local manufacturers, in order to maximize profits, have largely quit making small and medium-sized farm machinery.

In recent years, the CMC Corporation of the United States has bought 2 330 Chinese diesel engines, while eight other U.S. firms have purchased 290C marine diesel engines and other diesel engines from a factory in Hubei province. Substantial numbers of gear boxes and ploughshares have also been sold in the U.S.

The Jiangxi Tractor Factory is currently fulfilling a US\$2 million contract to supply parts for the Ford Motor Company. The International Harvester of the U.S. has also contracted with a Chinese factory for the purchase of castings and components.

Foremost among European firms that have become interested in

the Chinese farm machinery industry has been the John Deere Works of the Federal Republic of Germany, which last year contracted with the China National Agricultural Machinery Import and Export Corporation (CAMC) for the sale of US\$9.7 million worth of castings, forgings and spare parts over the next nine years.

Despite China's recent successes in penetrating world farm machinery markets, a spokesman for CAMC admitted that improvements could still be made in the quality of Chinese equipment. He said that, for example, in the blistering heat of Southeast Asia the laquer too often peeled off the machines. Comparative studies also had to be made of machinery prices in the market regions, and more effective surveys had to be taken of potential clients' requirements. In some areas, Chinese agents more knowledgeable about farm machinery had to be selected, he added. ■

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### Criteria for Article Selection

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

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- b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
- c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
- d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
- e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
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### Format/Style Guidance

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  - vi) bibliography
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- f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
- g. Convert national currencies in US dollars and use the later consistently.
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**Bala Krishna Shrestha**  
Assistant Agricultural Engineer, 4/141, Pulchowk Behind the Fire Brigade Latipur, Nepal

**Allah Ditta Chaudhry**  
Associate Professor and Chairman of the Department of Farm Machinery and Power, University of Agriculture, Faisalabad, Pakistan (on leave to New Zealand: Agronomy Dept., Massey University, Palmerston)



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**Bherulal T. Devrajani**  
Principal Investigator, Sind Agriculture University, Tandojam, Pakistan

**A.A. Mughal**  
Assistant Professor, Faculty of Agricultural Engineering, Sind Agriculture College, Tandojam, Sind, Pakistan

**Reynaldo M. Lantin**  
Dean, Institute of Agricultural Engineering and Technology, University of the Philippines at Los Baños, College, Laguna 3720, Philippines

**Chul Choo Lee**  
Project Engineer, Projects Department, Asian Development Bank, P.O. Box 789, Manila, Philippines

**Ricardo P. Venturina**  
Assistant Scientist for Agricultural Research, National Science Development Board, P.O. Box 3596, Rizal, Manila, Philippines

**M.H. Abdel Aziz**  
Professor of Irrigation Engineering and Head, Agricultural Engineering Dept., Riyadh Univ., Saudi Arabia

**S. Illangantileke**  
Head, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka

**Suppiah Kathirkamathamby**  
Head, Agricultural Engineering Research and Development Division, Dept. of Agriculture, Peradeniya, Sri Lanka

**Tien-Song Peng**  
Specialist, Plant Industry Div. Joint Commission on Rural Reconstruction 37, Nanhai Road, Taipei, Taiwan

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**Giuseppe Pellizzi**  
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**Adrian Moens**  
Professor & Head, Dept. of Agricultural Engineering, Agricultural University, Dr. S.L. Mansholtlaan 12, Wageningen, Netherlands

**John Kilgour**  
Lecturer in Engineering Drawing and Design, National College of Agricultural Engineering, Silsoe, Bedford. MK45 4DT, U.K.

*dr. Peter Cowell*

## New Co-operating Editor



**Muhammad Siddique Chaudhry**

**Date of Birth:** April 15, 1941

**Nationality:** Pakistan

**Qualification:**

M.Sc. Agr. University of Agriculture, Faisalabad, Pakistan, 1966

M.S. Agr. Mech. American University of Beirut, Lebanon, 1974

**Experience:**

Aug., 1968 to Dec., 1974.

District Agricultural Engineer

Sept., 1960 to July 1966. In-

structor/Res. Assistant, University of Agriculture, Faisalabad, Pakistan

**Present Position:**

Jan., 1980 to date, Assistant Professor and Jan., 1975 to Dec., 1979, Lecturer, Department of Agr. Engineering, Alfateh University, Tripoli, Libya. Teaching courses of farm power and machinery.

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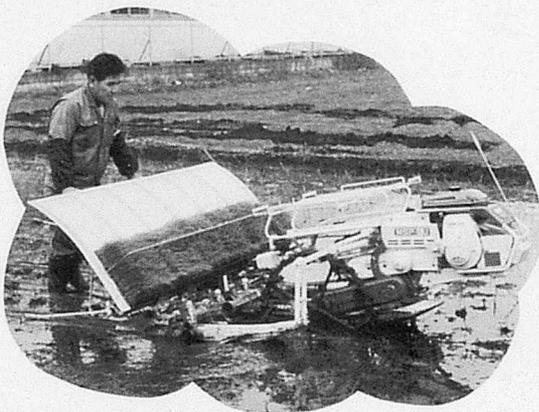
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