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AGRICULTURAL MECHANISATION: THE TROPICAL FARMER'S DILEMMA

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The agricultural revolution that is taking place in most developing countries calls for considerable changes in agricultural production technology. The phenomenal increases in crop yields ~~resulting from recent advances, particularly in the plant breeding area~~, are increasing farmer income and providing possibilities for more mechanisation inputs. Mechanisation through improvement of animal-drawn implements can only be of marginal benefit because of the limitations of the source of power. Imported power-driven equipment from regions with different agro-climatic and socio-economic conditions has many problems which limit its applicability.

~~On recognising a need for the production of farm equipment in the developing regions, the US Agency for International Development awarded a contract to The International Rice Research Institute in the Philippines. Under the contract~~, The Institute has been engaged in the development of new farm equipment for the production and processing of rice in the tropics. Some of the accompanying figures (figs 1-12) illustrate a few machines that have been released to manufacturers or are currently under development. Interestingly enough, in addition to production in developing countries, some of these machines are now being produced in the industrialised countries for their home markets.

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Dr Khan is head of the Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines. He was born in 1927 in India, where he worked part time in a family-owned trucking and machine shop business. He completed undergraduate studies there, before going to the USA to obtain Master's degrees in General Agriculture and in Agricultural Engineering. Dr Khan returned to India in 1952 to own and operate a farm machinery manufacturing business, principal products of which were corn shellers and grain threshers. Six years later he became a Deputy Director in the Ministry of Commerce of Industry, responsible for the development of handicraft industries. In 1959 he joined Voltas Ltd, Bombay, as a design engineer in charge of agricultural machinery development, where he was responsible for a range of animal drawn equipment. Dr Khan returned to the USA, to obtain his PhD in agricultural engineering at Michigan State University in 1967, after which he joined the Ford Tractor Division. Subsequently he became a Program Advisor to the Ford Foundation, and was assigned in 1967 to the IRRI, where he is Project Director of the USAID/IRRI contract on machinery development for tropical agriculture, as well as Head of his Department

The agricultural revolution that is taking place in most developing countries calls for considerable changes in agricultural production technology. The phenomenal increases in crop yields resulting from recent advances, particularly in the plant breeding area, are increasing farmer income and providing possibilities for more mechanisation inputs. Mechanisation through improvement of animal-drawn implements can only be of marginal benefit because of the limitations of the source of power. Imported power-driven equipment from regions with different agro-climatic and socio-economic conditions has many problems which limit its applicability.

Agricultural mechanisation: the tropical farmer's dilemma

Dr Amir U. Khan

TROPICAL REGIONS are characterised by small farm holdings, low farm incomes, and cheap labour. Attempts are being made to mechanise tropical agriculture with equipment originating from the industrialised countries of the temperate regions. Such equipment is basically developed for conditions of either larger farm holdings and high labour costs as in the United States, or for smaller holdings and high farmer incomes from a subsidised agriculture as in Japan. Such equipment has not been well accepted under the set of agro-economic conditions prevailing in the developing countries as it has in the country of origin. Consequently, mechanisation of tropical agriculture is slow and is limited primarily to the larger farm holdings which constitute a very small segment of the total agricultural land.

In the absence of equipment suitable for individual ownership by small farmers, efforts have been made to introduce large equipment through various forms of joint use. With the exception of Malaysia and Thailand, such efforts have met with little success in Asia. In these two countries, land preparation by both large and small tractor hire services has gained popularity. Chancellor[1] studied these operations in Malaysia and Thailand and concluded that the owners of the four-wheel tractors in Thailand and the two-wheel tractors in Malaysia were losing money in custom work. Only the four-wheel tractor custom operations in Malaysia were making some profits. Interestingly enough, the study indicates a rapid increase in the sales of two-wheel tractors in Malaysia even in the face of the availability of economical larger tractor hire services. It seems that the desire to retain full control of the production operations and the prestige of owning his equipment are quite important to the tropical farmer. The ownership of a small two-wheel tractor also permits more versatility of operation to the farmer for he can use the tractor for haulage and personal transport in addition to his agricultural operations.

Even if it were assumed that custom operation would be popularly acceptable for land preparation and threshing, it seems that such an approach could only be an interim solution to the mechanisation of tropical agriculture. The other crop production operations, haulage of farm produce, and personal transport will continue to favour individual ownership of equipment by the farmers in the tropics. For these reasons, it would appear that the demand for single-purpose tractor hire services will tend to taper off as soon as better suited equipment for individual ownership is available for the small farmer in the tropical regions.

The small and medium size farm holdings (2–10ha) constitute a very large segment of arable land in the tropics. Such holdings are almost completely non-mechanised. In spite of all the advances of modern technology and the new developments in farm equipment, it is ironic that such a large group of farm holdings in the tropics have the least access to suitable power-driven equipment. According to a recent study[2] of 12 countries of the ECAFE region, 95% of farm holdings are below 10ha in size. While it may seem difficult to mechanise the smallest of such holdings, there is a large number of smaller farm holdings which fall between 2–10ha in size that offer a good potential for an intermediate level of mechanisation. If mechanisation is to be successful in the tropical region, it will have to be introduced on the smaller holdings and must be considered within this particular frame of reference.

Two technologies

Two distinct agricultural mechanisation technologies have evolved in the world to suit different sets of agricultural and socio-economic conditions. The western approach emphasises dry land farming using large, high-powered equipment with great emphasis on labour saving. Mechanisation in Japan

has not followed the western pattern. Rice is a major crop in Japan which is grown under wet land conditions. The small farm holdings, high price support for rice, coupled with rapid industrial growth has resulted in the mechanisation of Japanese agriculture with relatively small, low-power machines. Such equipment has been developed to meet the many complex requirements of the Japanese farmer and is often too sophisticated and uneconomical for the tropical farmers. Recently introduced Japanese combine harvesters and paddy transplanters are excellent examples of functionally well-suited but economically unacceptable machines for the tropical regions.

The western and the Japanese agricultural mechanisation technologies have been successfully introduced in other temperate regions wherever similar conditions exist. Australia, Canada, and many small European countries have successfully adopted the western approach. We are now seeing a rapid introduction of the Japanese agricultural mechanisation approach in some temperate areas such as Korea and, to some extent, in Taiwan. The slow pace of agricultural mechanisation in the tropical regions is, to a large extent, due to the inadequacy of the two available technologies to meet satisfactorily the overall requirements of the tropical regions

Recent developments reflect a widening gap between the farm equipment originating from the industrialised countries and the needs of the developing regions. Farm equipment in the western countries is decidedly undergoing a trend towards larger and larger sizes. To some extent, developments in Japan also indicate a similar trend, in addition to the increasing complexity of their designs. These developments will no doubt further hamper the introduction of such agricultural machines in the developing regions. It seems reasonable to contend that to mechanise rapidly their agriculture, the tropical regions will have to develop a mechanisation approach which must suit their own set of agricultural, economic, social and industrial conditions.

It is often argued that a large array of equipment is already available in the temperate regions and that the problems of tropical agricultural mechanisation lie primarily in the proper selection of equipment. Such statements are based only on functional considerations and fail to recognize some of the other aspects of agricultural equipment which are just as important, if not more so. In addition to its function, a farm machine must meet the economic and sociological needs of the farmer. It must also fit in well with the level of industrial and technological development of a region. A closer analysis of the requirements of the tropical regions reveals an urgent need for a variety of new equipment which is currently not available from the developed countries.* In the absence of suitable equipment, smaller farmers in the developing regions are faced with the dilemma of either accepting the equipment originating from the industrialised countries or continuing with uneconomic traditional methods.

The equipment originating from the industrialised countries is designed for better educated and more mechanical-minded farmers than those in the tropics. In addition to the complexity in operation, such equipment is designed to be manufactured by capital - intensive, mass-producing techniques which require a highly developed production technology, which is not easily available in the tropical regions.

The price

The tropical farmer pays a price which is approximately two to four times that paid by a farmer in an industrialised country for the same piece of equipment. Furthermore, this equipment must compete with rural labour, which costs a fraction of that in the industrialised countries. The economic relationships on which a machine is originally based in the temperate regions no longer apply in the developing regions.

Most developing countries are undergoing varying degrees of balance-of-payment problems. Their meagre foreign exchange resources are channelled to high-priority projects, and the import of farm equipment is often controlled. It seems doubtful if the balance-of-payment problems will improve substantially in the immediate future. A large-scale mechanisation of tropical agriculture with imported equipment, therefore, seems improbable in the foreseeable future.

With the introduction of new rice varieties, problems of drying and processing have assumed new proportions in the humid tropics. Technology for drying and processing rice in large centralised plants is available from the industralised countries. The establishment of such plants, however, requires a well-developed infrastructure which is often not available in the tropics. An estimated 50–90% of the rice produced in the tropical countries is consumed within the rural areas and is not handled through commercial channels. This rice is processed either by manual methods or with obsolete equipment in the rural areas resulting in substantial losses and poor quality. The development of small, modern, economic rice drying and processing systems for village or individual farm level operation is one of the challenging problems for the development engineers.

Developing new equipment

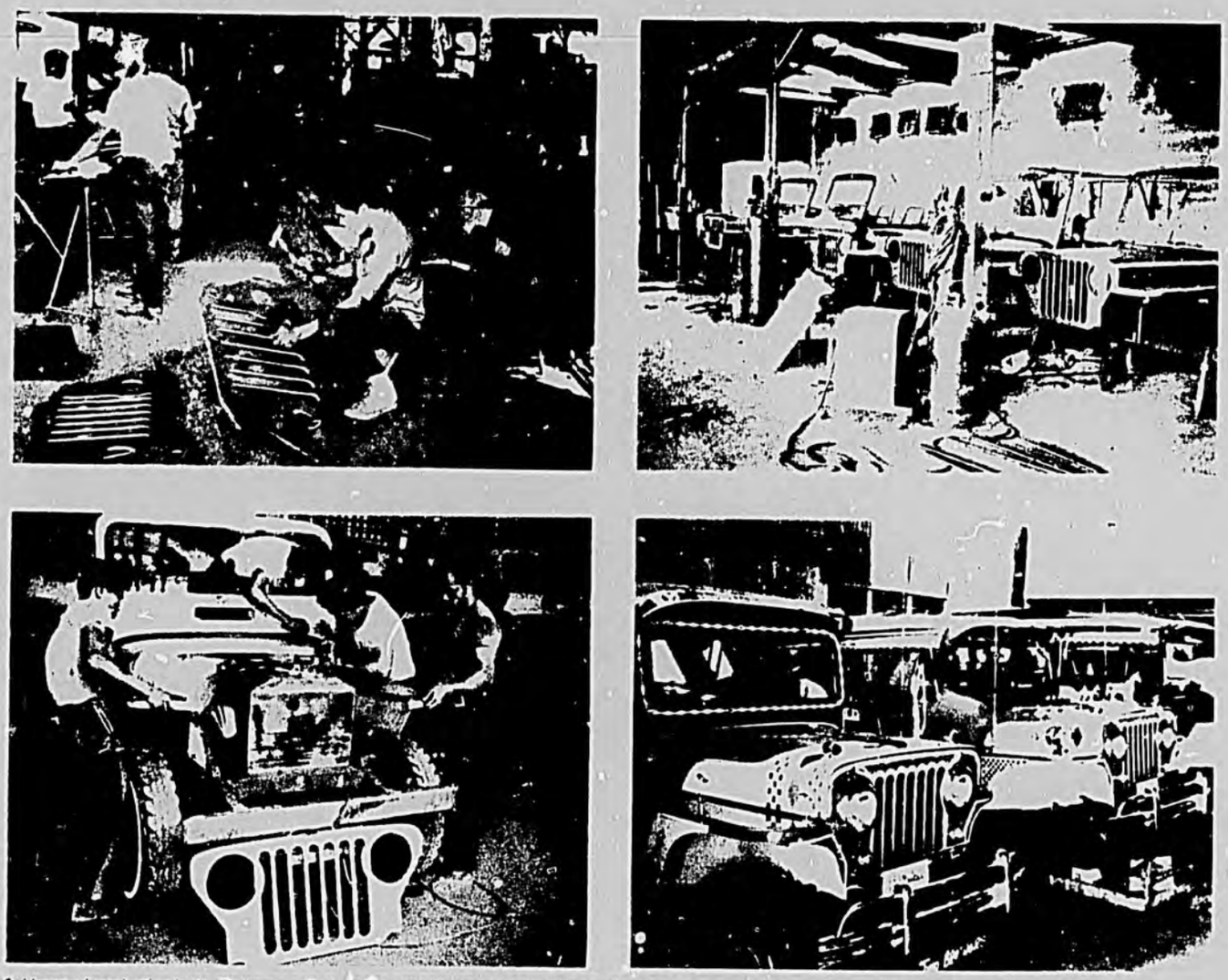
The development of new equipment is a highly specialised field requiring large resources of technical personnel and money. Equipment development is almost non-existent in the tropical countries because of the struggling state of their farm equipment industry. Equipment manufacturers in the industrial countries have the resources to develop new equipment; however, these manufacturers do not find it feasible to develop new equipment for tropical countries. Understandably, they prefer to develop equipment for their home market first and then attempt to find new markets in the tropical regions Such manufacturers generally limit their research and development efforts in the tropical regions to product evaluation and marketing studies.

Quite often a convincing argument is put forth that sufficient demand does not exist in the developing countries for special equipment which would justify economic mass production in the industrialised countries. There is no doubt that the economies of scale in manufacturing are very important in the industrialised areas mostly because of high labour costs. Unfortunately, production planners have tended to overemphasise the economies of scale when considering the feasibility of manufacturing in the developing regions. Short-run production can be economically organised in many developing countries which have low-cost labour provided suitable machinery designs are made available for low-volume production.

A rather interesting example of economic low-volume production is found in the Philippines. A major portion of the jeepney, a modified and well-adapted version of the jeep vehicle, is manufactured by small fabricators all over the Philippines (fig 1). The vehicle chassis, complete sheet-metal body and many other components are fabricated in small machine shops with simple, labour-intensive techniques at competitive prices. The price of a jeepney is less than half of the lowerst-priced imported car in the Philippines and twice as many jeepneys are sold in the country than all the passenger cars put together. This is an excellent example which indicates that economic production of relatively complex products can be organised in a developing country provided the product is suitably adapted for low-volume production.

Many economists have understandably pointed to the dangers of displacing farm labour with large agricultural machines in the tropical regions. The adverse effects would be more serious if the tools used to mechanise agriculture are from non-indigenous sources. To minimise the problems, the agricultural sector in the tropical regions must generate new employment by using labour-intensive practices and by developing agro-business and related industries. The adverse socio-economic implications of introducing large imported agricultural machines, therefore, necessitate the indigenous production of relatively simple, small power-operated equipment. To maximise the employment generation effects, production of such equipment should preferably be limited to the small-scale industries sector in the developing countries. On a closer analysis of the problem, one cannot help but conclude that it would be improbable to mechanise tropical agriculture without a parallel growth of the indigenous pro-

*The author has used some of his own agricultural machinery designs in this article to illustrate the type of intermediate mechanisation technology which is needed for the developing regions.



1 'Jeepney' production in the Philippines. Series of pictures illustrate the production of the jeepney, a well adapted utility vehicle based on the jeep design, by small fabricators in the Philippines. Jeepney is the most important means of transport in the country. The highly successful low-volume, labour-intensive production technology belies classical concepts of economies of scale in manufacturing.

duction of the tools necessary for mechanisation. A review of the history of agricultural mechanisation of even some of the smaller countries of Europe reveals that they had to resort to indigenous production of a major portion of their equipment requirement in order to successfully mechanise their agriculture.

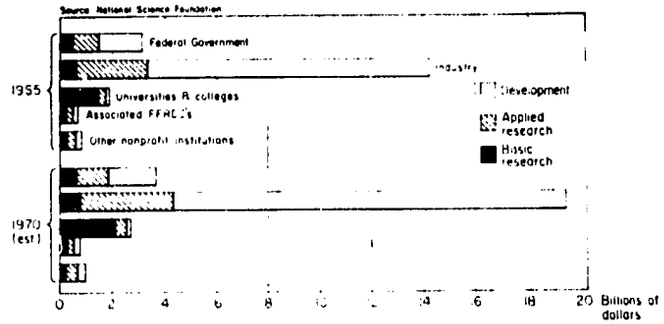
An indigenous industry

Agricultural mechanisation and indigenous production of equipment are so closely related that it is unrealistic to look at one and ignore the other. Unfortunately, however, most organisational efforts in the past have been directed only to introducing new agricultural machines in the tropics and very little effort has been made to develop an indigenous farm equipment industry. In spite of little organisational assistance, some encouraging developments, nevertheless, have taken place in the last few years in Taiwan, Korea, Thailand, India, Pakistan, and the Philippines. Small machine shops have started to produce pumps, farm implements, stationary farm machines and, in some cases, diesel engines and walking tractors. Most of their machinery designs are either locally developed or adapted to local conditions from imported equipment. The development or adaptation of designs for local production has been done by mechanics, shop owners and other entrepreneurs who have had no formal training in equipment development. To accelerate the progress of the indigenous small-scale farm equipment industry, technical assistance is urgently needed in most developing countries. Technical assistance in the form of new products to suit an intermediate level of manufacturing technology seems to offer the best possibilities for a very rapid pay-off under the present set of conditions.

The design and development of agricultural machines in the advanced countries is primarily a function of industry. The machinery manufacturers utilise the results of basic and applied research from the publicly supported institutions to develop the equipment necessary to mechanise agriculture. The pay-off of basic and applied machinery research depends on the ability to convert the research results into hardware form for application by the farmer. The development of farm equipment, therefore, is a necessary connecting link between machinery research and agricultural mechanisation. The importance of development activities in the United States can be gauged by the fact that during 1970, out of a total R & D expenditure of $27·2 thousand million, 14% was for basic research, 22% for applied research and 64% for development activities.[3]

Many Asian countries have publicly supported centres for agricultural machinery research. Efforts in these institutions have been mostly directed towards research for knowledge rather than for application. This is broadly along the pattern of research in the

educational institutions of the industrialised countries. Fig 2 shows the basic and applied orientation of research in the universities and Federally Funded Research and Development Centers (FFRDC) in the United States during 1965 and 1970. The development of new equipment in the tropical regions has, therefore, received very little attention from publicly supported research organisations or from local and foreign manufacturers. Since the farm equipment industry in the developing countries is not in a position to allocate funds for R & D activities, publicly supported research organisations must attempt to concentrate their efforts in two urgently needed areas: first, the development of functionally suited, small power-operated agricultural equipment which could be compatible with the level of production technology in their region, and, second, adaptive research on available agricultural equipment from non-indigenous sources.

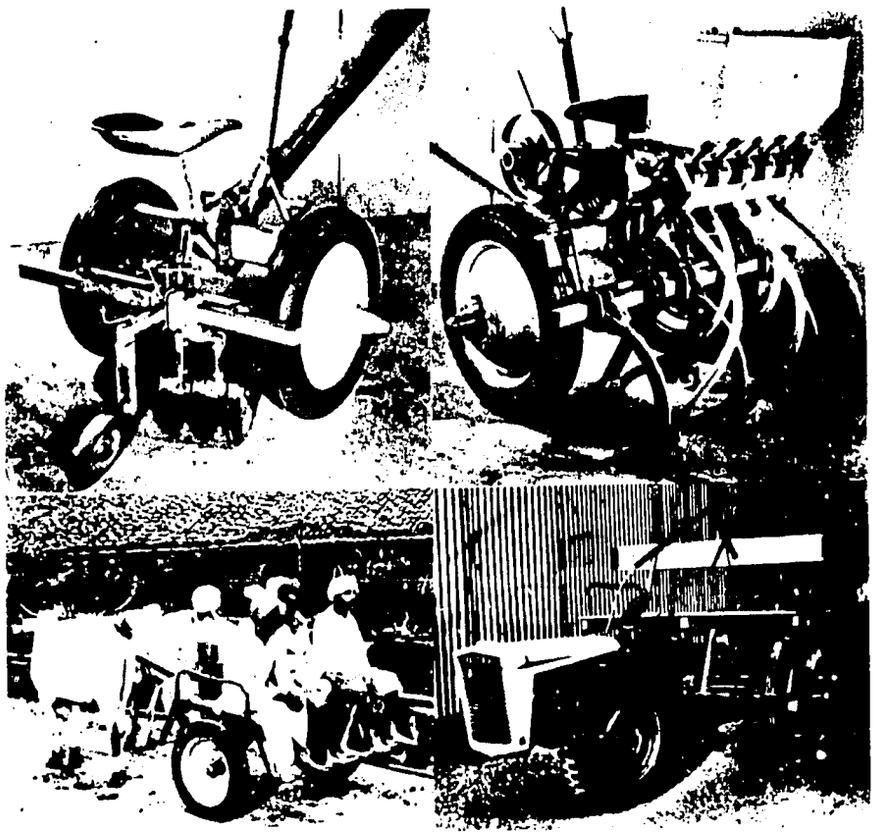


2 Funds spent on various types of research in the United States

Farm equipment designed by IRRI

On recognising a need for the production of farm equipment in the developing regions, the US Agency for International Development awarded a contract to The International Rice Research Institute in the Philippines. Under the contract, the Institute has been engaged in the development of new farm equipment for the production and processing of rice in the tropics. Some of the accompanying figures (figs 4–12) illustrate a few machines that have been released to manufacturers or are currently under development. Interestingly enough, in addition to production in developing countries, some of these machines are now being produced in the industrialised countries for their home markets.

The Institute considers the development of agricultural machinery as one of its important activities during the 1970s and looks forward to active co-operation from established machinery manufacturers in all parts of the world. The progressive farm equipment manufacturers can play a significant role in the mechanisation of tropical agriculture by co-operating with the Institute's equipment development programme and by establishing local manufacturing units in the developing regions. The tropical countries are undergoing rapid changes. Agricultural machinery manufacturers in the industrialised countries can no longer look to the developing regions as mere markets for their products without contributing to the regional development process.



3 Tool frame with attachments. This equipment offers a progressive system of mechanisation for the small dryland farmer in the tropics. The basic animal-drawn tool frame has many agricultural and transport attachments. A power attachment, which in itself is designed as a small walking tractor, can convert the animal-drawn tool frame to a riding tractive and transport machine. A farmer can progressively acquire attachments to complete a fully mechanised system to meet his farming and transport requirements

4 Differential slip tiller. Tillage of soft paddy fields with deep hardpan is a problem because of tractor bogging. Improved mobility and tillage is achieved by this experimental machine which has two pairs of cage wheels rotating at slightly different speeds. The difference between front and rear cage wheels slip provides a tilling effect under soft field conditions. The machine offers improved mobility in soft fields due to the four-wheel drive effect. Crossing levees is easier with this machine than conventional tractor-implement combinations

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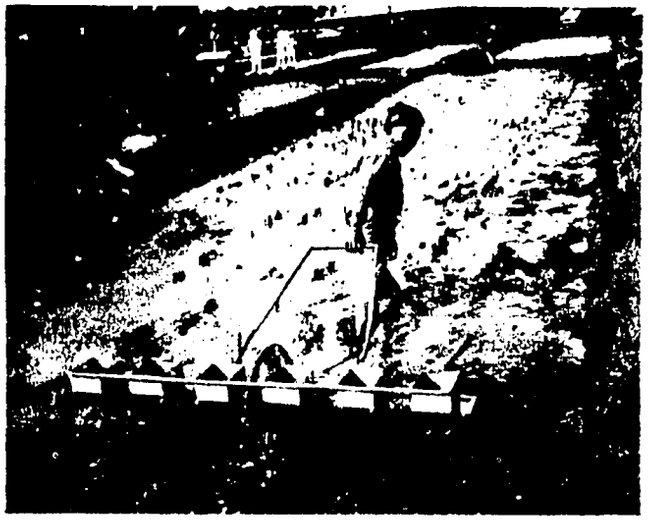
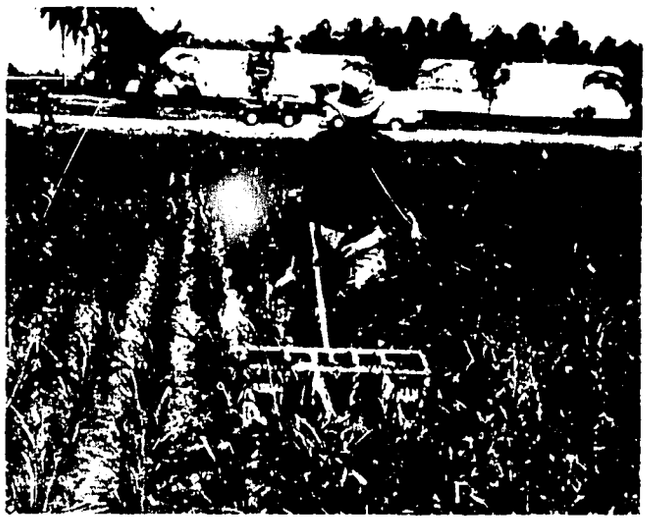
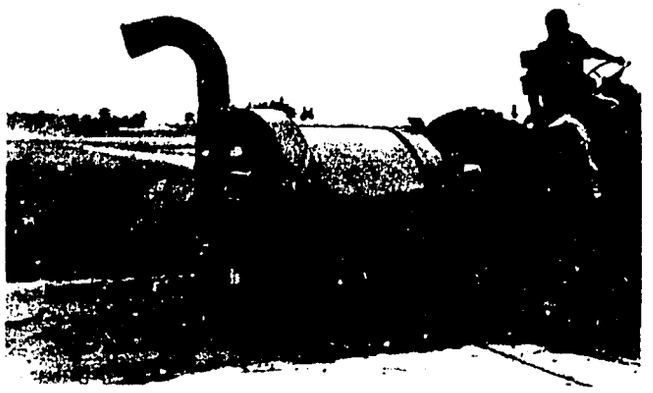


5 Row seeder. A simple six-row machine for seeding pre-germinated seed in puddled fields. Single wheel facilitates transport on narrow levees and drives the seed metering mechanism. One man can seed 1 hectare in 7hr, as compared to 120 man-hr/ha for manual transplanting



6 Power weeder. Weeding with power-driven equipment has not been possible in small paddy fields because headland is not available for turning at the end of the rows. The new portable, engine-driven power weeder permits convenient lifting of the machine for turning at the end of the rows. There are no mobility problems in soft wet paddy fields because of its light weight (14kg). A man can weed 1 hectare in 17hr with this machine as compared to 80hr for push-type weeders and 120hr for manual weeding

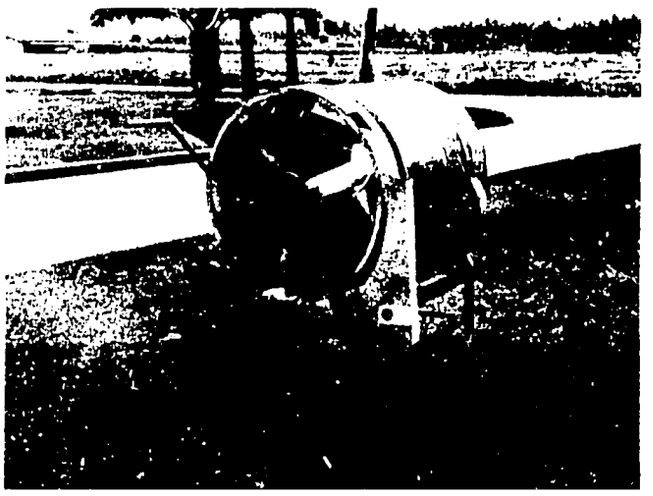
7 Table thresher. A lightweight, stationary thresher that employs a rotating table studded with threshing blades. A radial fan is incorporated on the underside of the threshing table to provide winnowing air to the grain falling through a grain separating screen. The thresher is for hold-on type feeding by four men. Threshing capacity is 300-450kg of paddy per hour

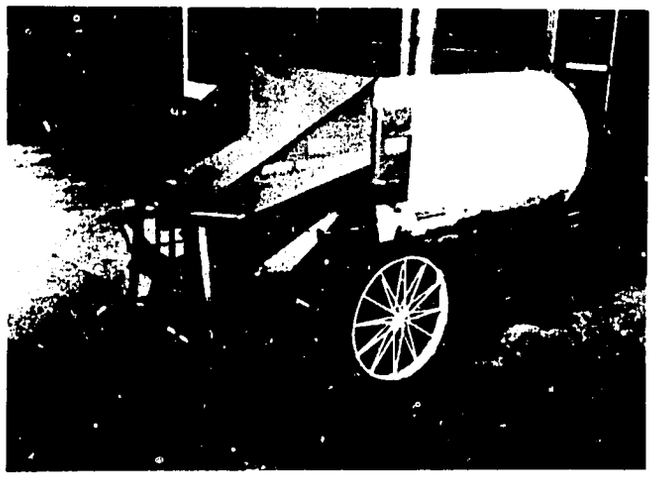


8 Tractor pto-driven thresher. A 30-60hp tractor pto driven, three-point linkage mounted multicrop thresher. This throughflow type, high-capacity thresher has excellent mobility which is desirable for custom threshing operations in the tropics. The material moves spirally through a peg-tooth cylinder and concave. The spiral movement results in over 90% grain separation at the concave. A large double-screen rotary separator with a blower separates the remaining grain from the straw. The rotary separator is lighter and better suited for wet crops

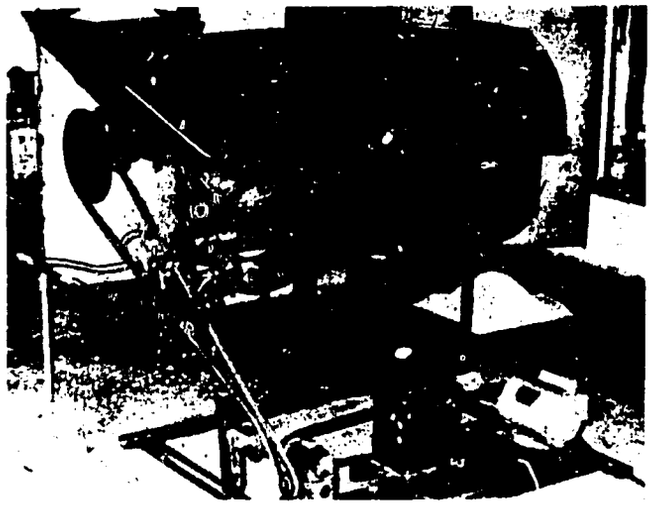
9 Stripper harvester. This experimental machine can harvest grain without cutting the paddy plant. A plant deflecting assembly composed of a pair of chains with cross members gently bend the plants onto a fast-moving threshing belt equipped with wire loops. The harvester is mounted on a two-wheel tractor and offers good mobility in soft paddy fields. The machine is undergoing further development at the Institute

10 Manually-operated grain cleaner. A rotary screen removes all the larger impurities before the grain enters a winnowing cylinder fitted with a coaxial fan. Series of pockets elevate and drop the grain through the air stream which removes the lighter impurities. Short spiral louvers inside the cylinder progressively move the grain in a counterflow direction with the air. The long exposure of the grain to the air results in improved cleaning quality





11 Rotary grain cleaner. This simple grain cleaner has two concentric cylindrica screens and a fan to blow air through the concentric clearance. Dirty grain is fed inside the inner cylinder which removes the larger-than-grain impurities. The screened grain is tumbled through an air stream in the concentric space between the two cylinders to blow the lighter impurities. The outer screen removes the smaller-than-grain impurities. The machine has a maximum cleaning capacity of 3 ton/hr



12 Heated sand dryer. An experimental continuous-flow dryer in which wet paddy grains are continuously mixed with heated sand (175–200°C) and then separated. The grain moistura drops from 30 to 18% in 15sec. The rice starch granules are gelatinised in the process which results in high head recovery and increased heed yield in milling. After separation from the grain, sand is reheated and automatically circulated through the machine

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