PB-219 702

DEVELOPMENT OF AGRICULTURAL MECHANIZATION TECHNOLOGIES AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

Amir U. Khan, et al

International Rice Research Institute
Los Banos, Laguna, Philippines

January 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. FEA-631.3-K45	2.	3. Recipient's Accession No. PB 219 702

4. Title and Subtitle
"Development of Agricultural Mechanization Technologies at the International Rice Research Institute"

5. Report Date
January 1973

6.

7. Author(s)
Amir U. Khan, and Bart Duff

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
International Rice Research Institute
Agricultural Engineering Department
Los Banos, Laguna, Philippines

10. Project/Task/Work Unit No.

11. Contract/Grant No.
AID/csd-2541

12. Sponsoring Organization Name and Address
Department of State
Agency for International Development
Washington, D.C. 20523

13. Type of Report & Period Covered
7/65 - 1/73

14.

15. Supplementary Notes
Presented at Woodrow Wilson School, Princeton University 9/20-23/72. Presented at Council for Asian Manpower Studie at Penang, Malaysia 1/3-5/73.

16. Abstracts
The Institute recognizes the urgent need for suitable farm machines for tropical agriculture and the catalytic role that machinery design and development activities can play in the establishment of an indigenous farm equipment manufacturing industry in the South and South-East Asian region. The IRRI program of machinery development is therefore sharply focused towards providing designs of agricultural machines for the production and processing of rice with two major objectives in mind. One, the machines must meet the requirements of the 2-to 10-hectare farmers who can neither afford to use imported mechanization technology nor work efficiently with traditional methods. Two, the machinery designs must utilize, to a maximum extent, locally available manufacturing methods, materials, labor and other resources of the region.

Some of the machines that have been developed under this program are shown in attached illustrations. Commercial production has commenced for many of these machines.

17. Key Words and Document Analysis. 17a. Descriptors

Details of illustrations in this document may be better studied on microfiche

17b. Identifiers/Open-Ended Terms

*Mechanization in agriculture, *Agricultural machinery, (*Innovations, Agriculture)

17c. COSATI Field/Group 631

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 25
	20. Security Class (This Page) UNCLASSIFIED	22. Price 3.25

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

PB 219 702

PAPER NO. 72-02

DEVELOPMENT OF AGRICULTURAL MECHANIZATION TECHNOLOGIES AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

Amir U. Khan and Bart Duff
Agricultural Engineering Department
The International Rice Research Institute
Los Baños, Laguna, Philippines

For presentation at a seminar on

Priorities for Research on Innovating and Adapting Technologies for Asian Development

Woodrow Wilson School
Princeton University
Princeton, New Jersey 08540

September 20 through 23, 1972

and

Conference on Technology, Employment and Development

Council for Asian Manpower Studies (CAMS)
at
Penang, Malaysia

January 3 to 5, 1973

· AGRICULTURAL ENGINEERING DEPARTMENT ·
THE INTERNATIONAL RICE RESEARCH INSTITUTE
P.O. BOX 583 ∘ MANILA ∘ PHILIPPINES

Reproduced by
NATIONAL TECHNICAL INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

DEVELOPMENT OF AGRICULTURAL MECHANIZATION TECHNOLOGIES AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

Amir U. Khan and Bart Duff*

Introduction

The Agricultural Engineering Department at The International Rice Research Institute (IRRI) is engaged in the development and extension of an appropriate agricultural mechanization technology for the rice-producing countries of Asia. Funded through a research contract with the U.S. Agency for International Development, the IRRI project is patterned after commercial R&D activities in the industrialized countries. To encourage indigenous manufacture of agricultural equipment in the Southeast Asian region, R&D services are provided free of cost to small machinery manufacturers who individually cannot support activities of this type.

This paper discusses the program in the following four sections:

Mechanization Strategy
Product Planning
Machinery Design and Development
Technology Transfer and Diffusion

---

*Head and Associate Agricultural Economist, respectively, Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines.

Mechanization Strategy

In most countries of South and Southeast Asia, 50 to 90 percent of the population are engaged in agriculture. Rice is the major crop, with the largest share of production being grown using wetland cultivation practices. Both land and labor productivity in agriculture are low, resulting in a poor standard of living for a majority of the rural population. During the '60s, developments in seed-fertilizer technology, however, have demonstrated that crop yields can be raised severalfold in the tropics. These developments are now helping to increase land productivity in the region.

To develop and realize the full potential of the new seed-fertilizer technology, however, more intensive production practices are generally necessary. In many countries of Asia, labor shortages are beginning to occur in certain periods of peak labor demand. Many farmers are finding that they cannot effectively till, plant, and harvest their crops with traditional methods. For such farmers mechanization is suddenly becoming a means of supplementing both available labor and land resources. The rise in seasonal labor costs in many Asian countries has created a favorable climate for agricultural mechanization.

To provide a decent standard of living to the rural population of the region, it is essential to increase both land as well as labor productivity. One can argue that labor productivity could be increased through the introduction of more intensive manual cultivation practices; however, such an approach has many obvious limitations. The high cost of human energy, the seasonal nature of demand for agricultural labor, and the critical necessity for timeliness in cultural operations, particularly in double or multiple cropping areas, present serious limitations to exclusive reliance on labor-intensive methods. The potential for providing additional power from animal sources is also rather limited. In addition, animals usually compete with the human population for scarce land resources and their opportunity value as a source of food has increased the costs of maintaining them exclusively for draft purposes.

It therefore seems highly doubtful that labor productivity can be increased substantially in the tropical Asian region through greater use of manual or animal power. The practical option for raising labor productivity appears to lie in introducing some degree of selective agricultural mechanization in the region. Thus, with the introduction of the seed-fertilizer technology, and the need to increase the productivity and standard of living of the rural population, mechanization of agriculture has acquired new significance and is becoming an important issue in many tropical countries.

In the light of the developments that have occurred during the last decade, the question confronting many Asian countries is not whether to mechanize or not to mechanize agriculture. The more fundamental and urgent issue now concerns the correct strategy that must be followed in the mechanization of tropical agriculture. Questions relating to the type of mechanization technology that can be applied in the region without creating drastic economic and social imbalances, and the factors affecting the development and extension of such a technology, are of major contemporary concern. This paper discusses some of the issues related to this important topic and describes the strategy that we, at The International Rice Research Institute, believe is necessary to ensure a degree of mechanization which is compatible with overall development objectives such as equity, expanded employment opportunities, and increased incomes.

From the data on crop yields and power input per hectare of selected countries of the world, Giles (1967)*concludes that a minimum power input of 0.5 hp per hectare is necessary in the less developed countries. The current level of power availability in tropical Asia is on the order of 0.17 hp per hectare as compared to about 1 hp per hectare in the United States and 3 hp per hectare in Japan. Since the end of World War II, some countries in Asia have attempted to increase their power input in agriculture through substantial imports of tractors and other agricultural machines. Such equipment has been developed for conditions of either large farm holdings with high labor costs such as in the West, or small farm holdings and highly subsidized farm incomes such as in Japan.

Western mechanization technology was primarily developed for dryland farming with a major emphasis on minimizing agricultural labor inputs. A remarkable reduction in labor inputs and increase in labor productivity has been achieved in the West through the use of large, high-powered equipment which allows integration of many different field operations. In light of the rapidly increasing population and the current employment problems in tropical Asia, many social scientists understandably question the application of such a capital-intensive mechanization strategy in the region.

It is interesting that in spite of nearly 20 years of efforts to introduce Western mechanization technology in the Asian region, the ownership and use of such equipment remains beyond the means of a majority of the farmers. India is an excellent example where production of 35-40 hp four-wheel tractors began in the early '50s. There are currently seven companies in India marketing over 30,000 tractors annually (Jain, 1971). While 96 percent of the total farm holdings in India are below 10 hectares in size, only 4 percent of the total tractor owners have farm holdings between 0 to 10 hectares (Verma, 1972).

---

*Complete citations for articles mentioned in the text are found in the attached list of references.

If we exclude landless custom tractor hire operators, the percentage of tractors sold to farms below the 10-hectare category would be considerably less than the 4 percent level.

Thus, 96 percent of the tractors are being sold to farmers that own more than 10 hectares of land. The benefits accruing from modern mechanization technology are therefore concentrated in a subsector composed of a few, larger, prosperous farmers and have not benefited the majority of small farmers in India. If agricultural mechanization is to be an agent for economic and social change in the region, it must meet the needs of the majority of the farmers and be compatible with the prevailing set of economic, social, and industrial conditions of the region.

In contrast to India, Japan has been able to mechanize its agriculture within the framework of small farm holdings and high population density, in the short period of only 15 years. Rice is a major crop in Japan which is grown under wetland conditions on small farm holdings. Japanese agriculture has the world's highest power input per hectare. Small farm size presented little difficulty in the mechanization of Japanese agriculture. Almost all of the equipment used in Japan was designed and developed to meet local resource and economic conditions.

Table 1 lists some selected statistics from 11 rice-producing countries of Asia. The information presented in the table indicates that, with the exception of Korea, Japan has the smallest average arable land area per holding and, except for Nepal, the highest agricultural working population per hectare in the region. The horsepower per hectare, both in terms of land area and per agricultural worker, is also highest in Japan. In spite of the high level of mechanization in Japan, the agricultural working population per hectare and the labor input in rice cultivation are still among the highest in Asia. These figures indicate that mechanization did not displace large numbers of agricultural workers in the case of Japan. The machine technology of Japanese mechanization has been based on low-powered machines which permit intensive cultivation without substantial reductions in labor requirements for crop production.

After World War II, several unsuccessful attempts were made to introduce large-scale Western mechanization in Japan. Following these abortive attempts, a major effort was made to develop an appropriate mechanization technology taking into account the special needs of the local farm communities and the capabilities of the indigenous farm equipment industry. In Japan the high support price of rice and the growth of the farm equipment industry were two major factors in the rapid mechanization of agriculture with individually owned, low-powered, but highly sophisticated machines.

In recent years, attempts have been made to introduce Japanese mechanization technology in other Southeast Asian countries. While Japanese machinery is well suited to the scale of farming and cultural practices found in many of these countries, it is often too complex and uneconomic for the tropical Asian farmer. In addition, most of the Japanese farm equipment cannot be produced locally with the low-volume manufacturing technology that is currently available in the Southeast Asian region. The Japanese paddy transplanters, harvester-binders and combines which have gained widespread popularity in Japan, are excellent examples of functionally suited but economically and industrially unacceptable machines for tropical Asia.

The two types of mechanization technologies from Japan and the temperate regions are undergoing increasingly rapid refinement and change to meet changing economic and technical conditions. These developments are, no doubt, further widening the gap that exists between the capabilities of the available technologies from Japan and the temperate regions and the needs of the farming communities of tropical Asia.

Unfortunately, the hypothesis that technology to mechanize tropical agriculture is readily available and that mechanization problems in Asia are primarily of a socio-economic nature is widely held by many authorities. A closer analysis, however, reveals that this assumption is based on an insufficient understanding of the complex problems involved. Even if one were to accept the argument that a wide variety of machines are already available to perform every farming operation in the tropics, it must be recognized that a machine's function is only one of a series of factors in the mechanization process. The compatibility of a machine with its economic, social, and industrial environment is just as significant, if not more so, than its function.

The oversimplified assumption that the agricultural mechanization technology of the temperate regions can be successfully applied to mechanize tropical agriculture has led to a number of unrealistic conclusions. One such effect has been to rely exclusively on the use of imported agricultural equipment. Major emphasis has been placed in most Asian countries on evaluating, adapting, marketing, operating, and servicing of agricultural machines from the temperate regions. Unfortunately, the development of appropriate designs and the indigenous manufacture of suitable machines has received only minimal attention from the public and the private sectors in the tropics.

Importation of equipment has been costly since most countries of the region do not have the foreign exchange to import sufficient equipment for widespread mechanization of their agriculture. Sakai (1972) indicates the magnitude of the expenditure which would be required by the Philippines to import sufficient farm equipment to raise

the power inputs in agriculture to the current Japanese level. He concludes that if the Philippines were to allocate foreign exchange to the importation of agricultural machinery at a level commensurate with its present allocation for automobiles, it would take over a hundred years to import the necessary equipment.

We believe that effective and efficient mechanization of tropical agriculture is possible only through the development of an appropriate mechanization technology and the concurrent growth of the indigenous farm equipment industry in the tropical region. The real need in tropical Asia is not the wholesale transfer of mechanization technologies from the temperate regions but the development of an appropriate mechanization technology which is compatible with the local factor endowments of the region.

One often hears the argument that economical manufacture of agricultural equipment is possible only when a mass demand exists and that the tropical Asian farmer is too small to justify such local production. There is no doubt that economies of scale in manufacturing are extremely important in countries where labor costs are high. For this important reason, most machines in the industrialized countries are designed for capital-intensive, mass production methods. It is, however, unrealistic to apply the same yardsticks of machine design and production techniques when considering manufacture of agricultural machines in the capital-deficient and labor-surplus regions of Asia.

The relationship between product design and manufacturing technology is not well recognized by many scientists. The design of a product is so intimately related to the manufacturing process that once a design is finalized, the manufacturing methods which are available to produce it become well defined and, in many cases, limited. For this reason, the development of a labor-intensive farm equipment industry in Asia greatly depends on the availability of suitable machinery designs that can be economically produced with available labor-intensive production methods.

There are many encouraging signs of progress in this direction throughout the tropical Asian region. There are many examples which indicate that low volume production of relatively complex products is possible in Asia provided suitable product designs are made available. The manufacture of the jeepney and the McCormick type threshers are excellent examples of such products in the Philippines. The manufacture of propeller type, motorized lowlift pump in Laos, Cambodia, Thailand and Vietnam provide an additional example. In Thailand, numerous small shops produce simple power tillers of indigenous design. The small-scale manufacture of diesel engines, lathes, and other relatively complex products in India, Pakistan, and Thailand are excellent examples

of low-volume, labor-intensive production. Similarly, in Taiwan, the production of three-wheeled automotive vehicles and farm trucks and power tillers are good examples of low-volume production. Invariably, each of these developments occurred as a result of the efforts of local entrepreneurs who were able to adapt or develop suitable products to meet the requirements of the local market while at the same time using the simple production methods that were available to them. We believe that a similar strategy is necessary to accelerate the pace of agricultural mechanization throughout tropical Asia.

Considerations related to the availability and allocation of foreign exchange, the generation of expanded employment and income opportunities in manufacturing, and the potential for large-scale labor displacement in agriculture are all elements which should enter decisions relating to the use of an imported mechanization technology. The approach at IRRI has been to adapt, innovate, and invent new machines which are complementary with on-farm resources and have the inherent advantage that they can be produced, utilized and maintained using local resources and skills.

One advantage of this strategy is that, for certain operations, it makes available an added alternative which is considerably less expensive than imported models. This is shown in fig. 1 which illustrates the comparative total cost curves for two small power tillers. One represents an imported model currently selling for slightly more than ₱7,000 in the Philippines. The second model, representing a design recently released by IRRI, sells for about ₱3,500. The machines are identical in performance specifications, but the significant advantage introduced by lowering the initial investment cost has considerably expanded the effective market for the small locally built tractor. Note that the threshold acreage at which the tractor meets all costs relative to the current custom rate has been reduced from 27.6 hectares using the imported machine to 16 hectares when employing the indigenously produced machine. There are several firms now producing this tractor in the Philippines, and sales during the previous three months have been greater than the combined sales of all imported tillers over the past 1-1/2 years.

It is not always possible to reduce costs as dramatically as in the case of the small tractor, but many of the considerations mentioned above make local designs tailored for local production extremely attractive to economic planners.

Product Planning

A major problem faced by all research and development programs is the selection of procedures to delimit both the number and type of projects to ensure compatibility with available research resources and program objectives. As the range and scope of R&D objectives broadens, the establishment of priorities for the allocation of research resources becomes increasingly difficult. Even the narrowly defined and sharply focused objectives of the IRRI rice mechanization program do not allow use of precise or clearly defined guidelines in choosing among design projects. The international character of the program tends to further accentuate these difficulties, becuase of the high degree of variability in physical, social and economic conditions found throughout the Asian region and between regions within countries in the region.

Unfortunately, there are as yet few analytical tools available which embody the precision flexibility and economics necessary to map out priorities leading to efficient sequences in the development, innovation and adoption of technologies. Most quantitative economic models employed in the developing countries are much too aggregative to offer little more than a suggestion of where investments in research and development will lead to high rates growth in productive activities. The existence of distortions in relative factor and product prices due to overvalued exchange rates, legislated wage rates, and concessionary credit terms tend to further confuse the issue. Many of the techniques found in the field of operations research offer considerable promise when utilized for product planning, but their application has been hampered by a lack of readily available data.[1/]

Until recently, much of the product planning in the IRRI engineering program has been carried out by employing a combination of intuition and experienced judgment supported by a limited number of economic surveys combined with field test and evaluation work. An effort is now underway to develop a more systematic and precise method for evaluating promising areas for adaptive and innovative product development. The objectives are to provide the designer with specific information regarding the task the machine is to perform, required performance characteristics including size, labor productivity and

---

[1/]The literature reveals that these problems are not confined to situations encountered in the developing nations, but are a dilemma facing all firms and institutions engaged in activities focused on the development and marketing of new products (Karger and Murdick, 1971).

efficiency, the investment and operational costs, and the potential rate of return on investment for particular resource situations.

To establish these general design parameters, it is necessary to assemble and analyze data describing the potential market, the state of existing technology in the task for which the product is to be designed, and the technical and economic environment in which the machine will be produced and operated.

Demand Constraints

As was mentioned in the section describing the strategy of the IRRI mechanization development program, a major objective is to produce machines which are compatible with the resource endowments and social-economic environment faced by small- and medium-sized rice producers in tropical Asia. This classification has been further refined to mean farms in the 2- to 10-hectare size range; a categorization which generally applies to over 60 percent of the rice farms and encompasses in excess of 50 percent of the total rice area.

To examine the characteristics of these farms, IRRI has conducted numerous field surveys, market studies and comparative test and evaluation work, principally in the Philippines.[2/] Many of the field studies have been specifically designed to examine and assess the comparative economic and technical features of individual farming operations such as land preparation, seeding and transplanting, weeding, and harvesting-threshing. Analysis of information describing operations by farm size, type and institutional arrangement permits precise definition of those operations where technological improvements will result in the alleviation of labor, power or other resource bottlenecks and/or will reduce losses and lower costs. The necessary performance requirements for a new machine can be determined by detailed comparisons with existing techniques. Upper limits on investment and operational costs are set by the minimal rate of return that a farmer will accept as an incentive to adopt the improved technology.

[2/]For more information on the nature and contents of these studies, one is referred to the bibliographies of the Departments of Agricultural Economics and Agricultural Engineering, The International Rice Research Institute, Los Baños, Laguna, Philippines (1972).

Supply Constraints

Explicit attention is given to the production capabilities of indigenous manufacturers in the evolution of machine designs. A deliberate effort has been made to utilize, whenever possible, components which are readily available or can be produced from locally available materials. Machining and fabrication methods which lend themselves to the short-run, labor-intensive production techniques characterizing small- and medium-scale firms are employed.

Because a product's design so clearly influences the nature of the process used to produce it, a knowledge of the capabilities and capacity of local industry is an essential element in the designer's specification of a new machine. An effort is made to work closely with interested manufacturers at an early stage in the evolution of a design to ensure minimum redesign in the transition to the production stage. Assurance of an adequate and reliable supply of raw materials and component parts is also a necessary input at the design stage. The non-availability of materials or a high procurement cost can act as a strong disincentive to potential manufacturers. [illegible] should also be flexible enough to accept substitute components [illegible] those specified are not available. Lastly, the designer should be aware of policies which may affect the acceptability of a particular design. Taxes on gasoline or diesel fuel will affect the choice of engines used in a particular machine. There are many such examples which can be cited.

The industrial subsector which makes up the agricultural machinery industry is composed of a heterogeneous mixture of firms. Many are not producers, but merely act as local agents for the larger multinational equipment suppliers. Those actually engaged in manufacture of equipment are usually small- to medium-scale in size, have few trained engineers and allocate almost no financial resources to R&D activities. Figure 2 illustrates a few relevant characteristics of small- and medium-scale industries in the Philippines. Note particularly the high percentage of firms in this category and their prevalence in provincial areas. For rural-based industrial development, these firms embody many advantages in the production of simple agricultural machinery.

Lack of participation by local industry in research and development stems from a number of sources. Perhaps paramount is the lack of an incentive structure which makes activities of this type profitable and attractive. Lack of incentive-oriented tax policies, suitable engineering talent, enforceable patent protection, or coordinated national policies and leadership have all conspired to hinder creative development work in the private sector.[3] Until quite recently, one

[3] A full explanation of many of the factors influencing growth and innovative activity in the small- and medium-scale industrial sectors in developing countries is found in Nelson (1970).

could also argue that the lack of an effective demand for farm machinery at the farm level also acted indirectly as a disincentive.[4/]

The reticence to accept or adopt new products is a pervasive feature of many small and medium-scale manufacturing firms. Without the benefit of a product planning or market research wing, many firms face considerable uncertainty regarding the potential size and form of returns to be derived from the production and marketing of new products. Lack of risk capital for product and market development, a tight cash balance position and the unfamiliarity of many producers with agricultural products have required that the IRRI program develop a comprehensive extension program.

Socio-Economic Constraints

In planning a new design, increasing attention is being given to its probable impact on employment and the probable distribution of benefits resulting from its use. At the farm level, every effort is being made to ensure that the employment effect is positive, i.e., that the labor which is displaced in the performance of a specific task has a reasonable opportunity for productive employment in other tasks or in another occupation. An overall goal is to increase the intensity and timeliness of cropping leading to an expansion in employment on the farm.[5/] Obviously, geographic location (access to non-agricultural employment) and the factor markets a farmer faces (particularly for labor) will influence the net outcome. Our experience to date has been much too limited to assess the impact of a particular machine on employment, although the local manufacture of several designs has increased employment by as much as 40 percent in some firms. In addition, it has provided a means of utilizing excess capacity which characterizes many of the small- and medium-scale firms.

Machinery Design and Development

The Institute recognizes the urgent need for suitable farm machines for tropical agriculture and the catalytic role that machinery design and development activities can play in the establishment of an indigenous farm equipment manufacturing industry in the South and Southeast Asian region. The IRRI program of machinery development is therefore sharply focused towards providing designs of agricultural machines

---

4/See Johnston (1971, 1972) for a discussion of the critical importance of these backward linkage effects.

5/Some evidence on the employment effects of mechanization in Philippine agriculture is contained in R. Barker, et al. (1972) and W. Meyers, et al. (1971).

for the production and processing of rice with two major objectives in mind. One, the machines must meet the requirements of the 2- to 10-hectare farmers who can neither afford to use imported mechanization technology nor work efficiently with traditional methods. Two, the machinery designs must utilize, to a maximum extent, locally available manufacturing methods, materials, labor, and other resources of the region.

Some of the machines that have been developed under this program are shown in the attached illustrations. Many of these machines are entering commercial production in Asia and will soon begin to contribute both to the mechanization of agriculture and the generation of new employment opportunities in the farm equipment industry.

Mechanism of Technology Transfer and Diffusion

Hayami and Ruttan (1972), in their recent book, list three stages of technology transfer -- material transfer, design transfer, and capacity transfer. The first phase is characterized by the simple transfer or import of new materials such as seeds, plants, animals, and machines. In the second phase, the transfer is made primarily through designs (blueprints, formulas, books, etc.). In the third phase, the transfer occurs through the transmission of scientific knowledge and capacity which enables the production of locally adapted technology.[6/] In the case of the 'green revolution,' the important elements of both the success and the limitations have been embodied in capacity transfers. The new seeds were the product of research conducted by scientists working in the developing countries where earlier efforts at material transfer had largely proven futile. One might cite the limited area which has benefited from the high-yielding varieties as evidence that there is still much to be gained by further strengthening adaptive research capacity at the regional and national levels.

With respect to mechanical technology, most developing countries are still highly dependent on <u>material</u> and <u>design</u> transfer. Much of the modern agricultural equipment used in the developing nations is imported. In the absence of machinery designs which are compatible with local manufacturing capabilities and consistent with farm level economic and technical requirements, importation remains the only reliable source of equipment.

[6/] Table 2 provides some insight into the relative levels of mechanization in four countries and how these levels are conditioned by factor price ratios.

Manufacturing Extension

Until very recently, extension of IRRI equipment designs was confined principally to the Philippines. This was a result of the location of the program, a lack of completed designs, and difficulty in mobilizing an effective outreach program to cover other rice-growing areas in the region. The Institute adopted the policy of providing designs, free of cost or licensing requirements, to any firm which demonstrated a genuine interest in commercial production and marketing. As more designs were released, it soon became apparent that the linkage between research and development activities and manufacturing activities would require considerable attention.

Procedures for the release of a design are not formalized but follow a more or less standard pattern. At the completion of test and evaluation work, manufacturers who have expressed an interest in a particular design are issued drawings and a bill of materials. They are requested to submit a detailed cost estimate for the fabrication of a production prototype. Based on the cost estimate and an assessment of the firm's production facilities, a selected number of manufacturers are asked to build prototypes. We feel that in all cases, there should be more than one firm involved in the initial manufacturing phase. There are two reasons for this. First, the existence of competition tends to foster cost conscientiousness in the production of the machine and keeps the market price at an acceptable level. Secondly, there is usually some attrition among firms accompanying the release of every design.

At this stage in the diffusion of designs, the IRRI staff provides technical assistance in the form of advice on the use of alternative components and assemblies, the layout of production facilities, sources of operating capital and the strategy for marketing the design. With the completion of the prototypes, manufacturers submit them to IRRI for a final series of tests. Following these tests, the manufacturer is apprised of the results and any suggested modifications or changes. At this point the firm must make a decision to proceed with commercial production and marketing of the design. IRRI provides only limited support in market development in the form of farm demonstrations and promotional materials.

International Extension

In addition to local efforts, the Institute has embarked on an international subcontract program involving agencies, institutions and firms in nine Asian countries (Table 3). Under this program, models from the IRRI design program are sent to the subcontractor's country and

tested under local environmental and economic conditions. An effort is also made to interest local manufacturers in the designs. In addition to the subcontract program, information on particular designs has been furnished at the request of numerous independent manufacturers throughout the Asian region. The initial interest generated by the program has been appreciable, and in many countries, such as Taiwan and Korea, which are reaching a stage in their structural transformation where rural wages are increasing and where there is evidence of an emerging local manufacturing capability, the provision of suitable designs may play a catalytic role in the development of a strong domestic industry. The early experience with the international program also reinforces our belief that there must exist a research capacity in each country which is capable of adapting or modifying designs to meet local needs.

By making available products in the form of progressive machine technologies for agriculture, IRRI is attempting to span a gap in the range of contemporary technologies while concomitantly filling a role which the private sector is unable to assume. The light engineering industries in each of these countries, and particularly the farm equipment industry, should hold a dynamic and ... "distinctive position in fostering competence in metal working which in turn leads to enlarged capabilities for the manufacture of capital goods. This is because of the pervasiveness of iron and steel ... in almost all modern industrial processes,' (Johnston, 1972).

References

1. Agricultural Productivity Organization, 1967. Proceedings of an expert group meeting on agricultural mechanization, Tokyo, Japan, December 12-18.

2. R. Barker, W. Meyers, C. Crisostomo and B. Duff. "Employment and Technological Change in Philippine Agriculture," International Labour Review, Vol. 106, Nos. 2-3, August-September 1972.

3. P. A. David. "The Mechanization of Reaping in the Ante-Bellum Mid-West," in H. Rosovsky (ed.): Industrialization in Two Systems (New York, John Wiley, 1966).

4. G. W. Giles. 1967. Towards a more powerful agriculture. Report to the Government of West Pakistan on its agricultural power and equipment needs. The Planning Cell, Agriculture Department, Lahore.

5. Y. Hayami and V. Ruttan. Agricultural Development- An International Perspective (John Hopkins Univ. Press, Baltimore 1971).

6. B. K. S. Jain. 1971. Production of agricultural machinery in India. Paper presented at the International Rice Research Conference, The International Rice Research Institute, Philippines, April 19-23.

7. B. F. Johnston and P. Kilby. Agricultural Strategies, Rural-Urban Interactions, and the Expansion of Income Opportunities (OECD Development Center, Paris, 1971).

8. B. F. Johnston. "Agriculture and Economic Development: The Relevance of the Japanese Experience," Food Res. Inst. Studies, Vol. 3, 1966.

9. B. F. Johnston and P. Kilby. "Interrelations Between Agricultural and Industrial Growth," paper presented at the IEA Conference on the Place of Agriculture in the Development of Underdeveloped Countries, Bad Godesberg, Germany, August 26-September 4, 1972.

10. D. W. Karger and R. G. Murdick. "The Art and Science of Forecasting New Product Payoff." Machine Design, September 30, 1971.

11. W. Meyers, C. Crisostomo, T. Paris, B. Duff and R. Barker. "The New Rice Technology and Labor Absorption in Philippine Agriculture," The Malayan Economic Review, Vol. XVI, No. 2, 1971.

12. J. Sakai. 1972. Study and discussion on several problems for farm mechanization in developing countries. Agricultural Mechanization in Asia. Summer issue.

13. S. R. Verma. 1972. Bird's eye view of agricultural machinery research and development in India. Agricultural Mechanization in Asia. Summer issue.

Table 1. Some agricultural mechanization indicators for 11 rice-producing countries in Asia.

Country	Arable land per holding (ha)	Agricultural working population/ha	Horsepower per hectare				Hp per agricultural worker	Labor hours for rice cultivation/ha	Net domestic agricultural production US$	
			Human	Animal	Mechanical	Total			Per person	Per hectare
Ceylon	1.59	1.20	0.120	0.148	0.110	0.378	0.009	N.A.	293	352
Taiwan	1.11	1.95	0.195	0.164	0.164	0.505	0.074	1300	349	696
India	2.62	0.90	0.90	0.204	0.008	0.249	0.009	1000	148	133
Iran	6.17	0.37	0.37	0.048	0.154	0.292	0.418	N.A.	417	154
Japan	1.06	2.16	0.216	0.120	2.664	3.000	1.231	1400	626	1350
Korea	0.90	1.96	0.196	0.236	0.003	0.435	0.0013	830	244	477
Nepal	1.22	2.49	0.249	0.480	0.004	0.733	0.0016	N.A.	99	236
Pakistan	2.37	1.09	0.109	0.288	0.013	0.410	0.012	N.A.	154	169
Philippines	3.66	0.71	0.071	0.104	0.023	0.198	0.030	800	242	186
Thailand	3.64	1.10	0.110	0.184	0.054	0.348	0.050	N.A.	102	112
Vietnam	1.57	2.10	0.210	0.244	0.023	0.477	0.004	N.A.	203	421

Source: APO Expert Group Meeting on Agricultural Mechanization, APO Project SYP/III/67, Tokyo, October 1968, Vol. II.

Table 2. Selected indices of factor use and factor prices in the Philippines, Thailand, Taiwan, and Japan in the mid-1960's.*

	Philippines	Thailand	Taiwan	Japan
Cultivated land area (1000 ha)	6,042	11,267	890	5,996
Agricultural employment (1000)	5,824	10,200	1,867	15,238
Number of draft animals (1000)	2,052	5,174	360	1,782
Mechanical horsepower available	278,900	605,200	130,253	15,997,300
a) Power tillers	12,560	5,200	110,103	15,516,910
b) Tractors	266,340	600,000	20,150	480,390
Price of mechanical power ($/hp)	129	67	112	68
a) Power tillers	154	133	112	68
b) Tractors	128	66	-	-
Farm wages ($/day)	0.88**	0.53	1.04	2.60**
Factor price ratio (5)/(6)	147	126	108	26
Horsepower per agricultural worker	0.048	0.059	0.070	1.05

**Since meals were given together with money wages, money wages reported for the Philippines was raised by 33% and for Japan by 10%.

Source:

1. Philippine data refer to 1967.

Cultivated land area and agricultural employment, (1) and (2): estimated by C. Crisostomo in "Sources of Output Growth in Philippine Agriculture, 1948-1968." (Unpublished M.A. thesis, University of the Philippines, 1971, forthcoming.) Basic data from Census of Agriculture, 1948 and 1960 by the Bureau of the Census and Statistics and Philippine Statistical Survey of Households by the National Economic Council.

Number of draft animals (3): APO Expert Group Meeting in Agricultural Mechanization, APO Project SYP/III/67, Tokyo, October 1968, Vol. II.

Mechanical horsepower available (4): Bureau of Agricultural Economics, Department of Agriculture and Natural Resources, Philippines.

Prices of mechanical power (5): Tillers from N. Alviar, "An Economic Comparison Between Tractor-Operated and Carabao-Operated Rice Farms." (Unpublished M.S. thesis, University of the Philippines, 1969.) Four-wheel tractor from the Department of Economic Research, Central Bank of the Philippines.

Farm wages (6): Basic data from the Bureau of Agricultural Economics, Department of Agriculture and Natural Resources, Philippines.

2. Thailand data refer to 1963-1964 while Taiwan and Japan data refer to 1965-1966. Source of data, APO Expert Group Meeting in Agricultural Mechanization, APO Project SYP/III/67, Tokyo, October 1968, Vol. II.

*Source: R. Barker, W. Meyers, C. Crisostomo and B. Duff, "Technological Change and Employment in Philippine Agriculture," International Labour Review, Vol. 106, Nos. 2-3, Aug.-Sept. 1972.

Table 3. Regional test and evaluation subcontract activities.

Country	Cooperating Agency	Address
India	All-India Coordinated Rice Improvement Project (AICRIP) Dr. W. H. Freeman, Joint Coordinator	Rajendranagar, Hyderabad-30, AP, India Cable: RICE Hyderabad
Indonesia	Directorate of Agricultural Technique Ir. Soedharso Rawidjo, Director	Pasar Minggu, Djakarta, Indonesia
Korea	Institute of Agricultural Engineering and Utilization Han, Sung Kum, Director	Suwon, Korea
Malaysia	Malaysian Agricultural Research and Development Institute (MARDI) Anuwar bin Mahmud, Director	Jalan Swettenham Kuala Lumpur, Malaysia Cable: MARDI
Pakistan	The Ford Foundation Gordon W. McLean, Chief Advisor	2, Street 61st Shalimar-7 (P.O. Box 1043) Islamabad, Pakistan
Philippines	Nueva Ecija Land Reform Integrated Development Project Dr. B. de los Reyes, Proj. Director	Bitas, Cabanatuan City, Philippines
Sri Lanka	Browns Group Industries Limited Mr. S. N. N. Perera, Manager	481, Darley Road P. O. Box 200 Colombo-10, Sri Lanka
Taiwan	Joint Commission on Rural Reconstruction (JCRR) Dr. T. H. Shen, Chairman	37 Nan Hai Road Taipei-107 Taiwan Cable: 8515 Taipei
Thailand	Engineering Division, Rice Department Ministry of Agriculture Dr. Bhakdi Lusananda, Director-General	Bangkok 9 Thailand

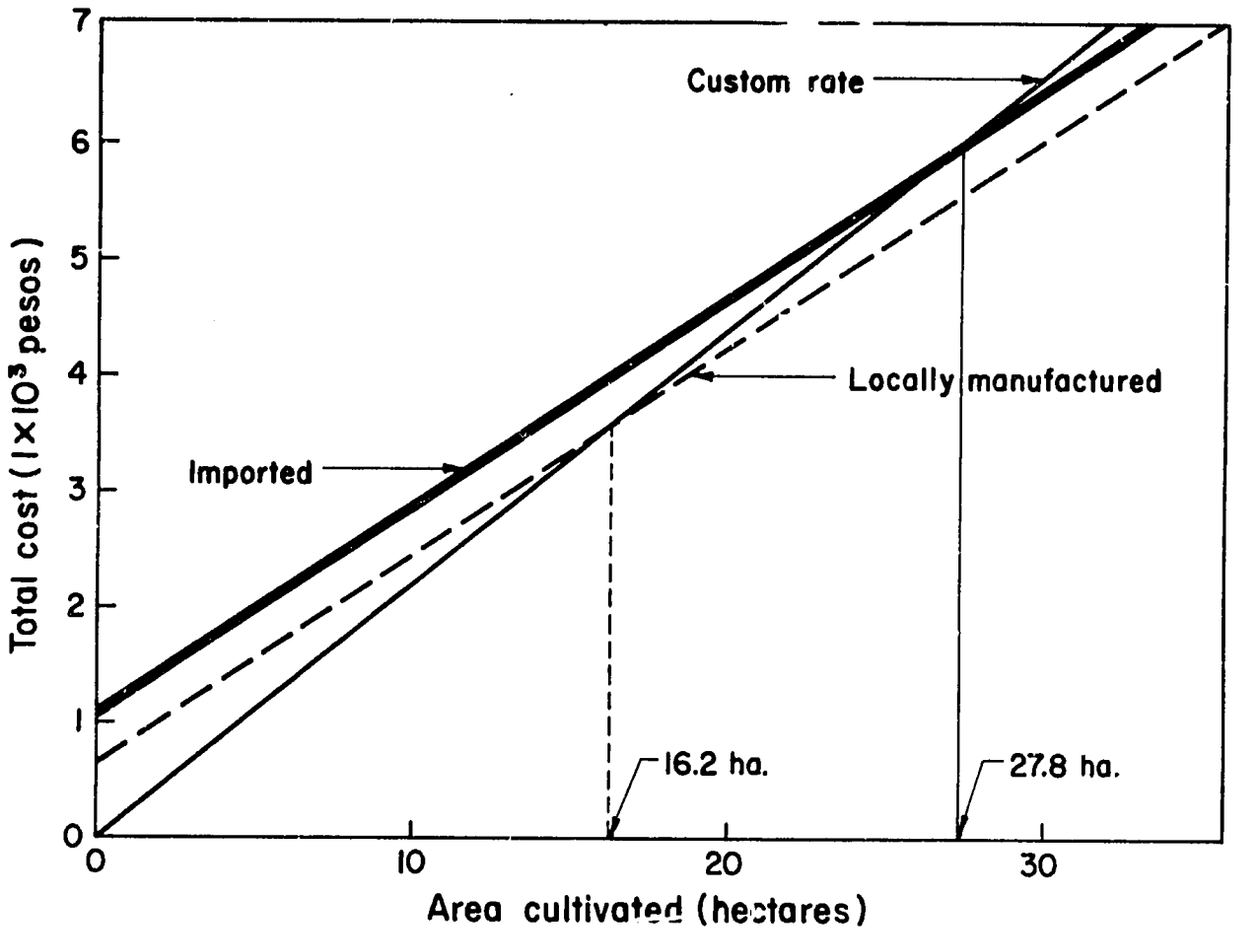


Fig. 1 A comparison of the total costs of land preparation utilizing two power tillers obtained from alternative sources.

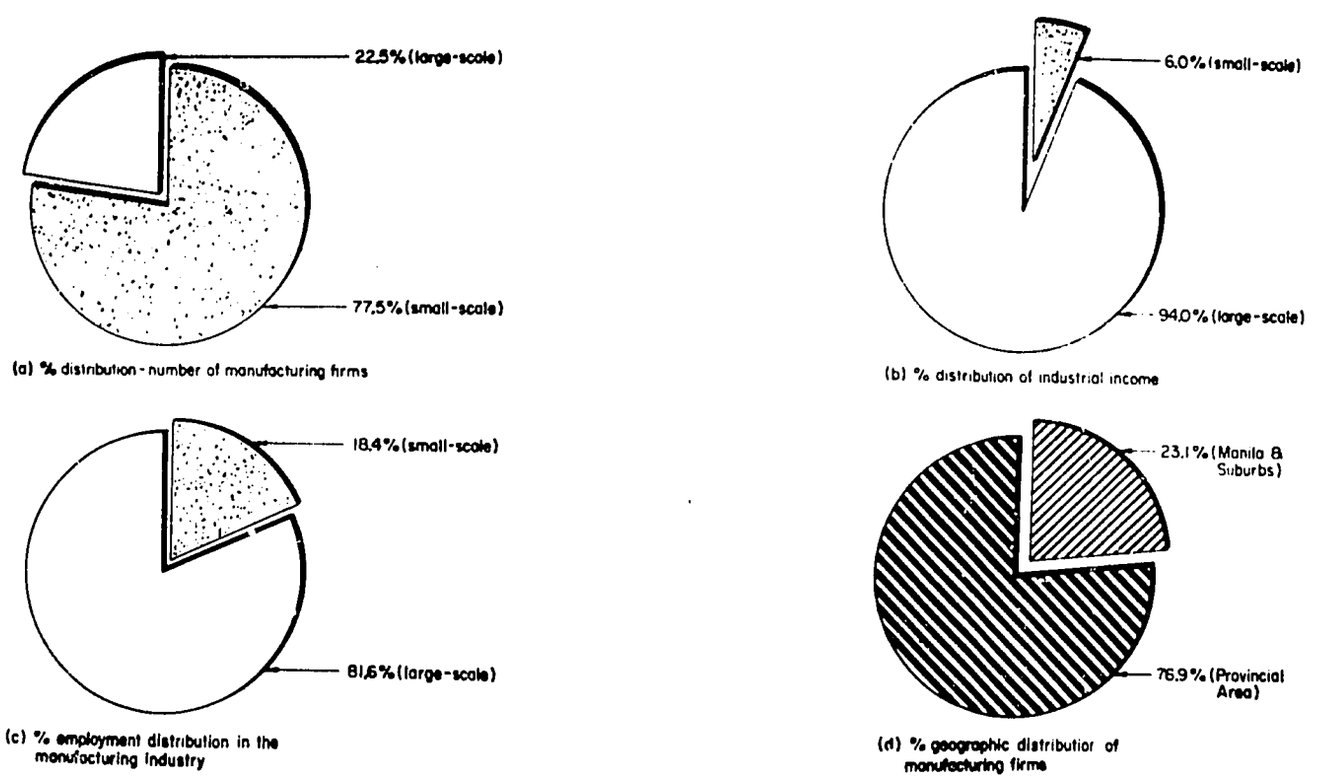
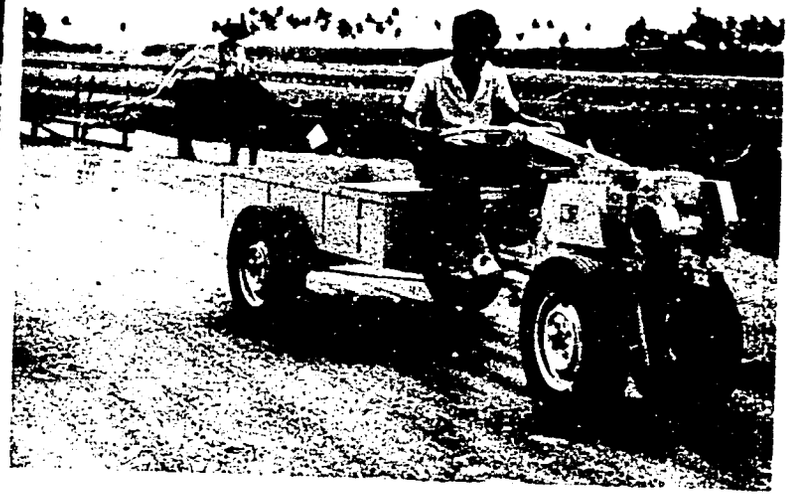


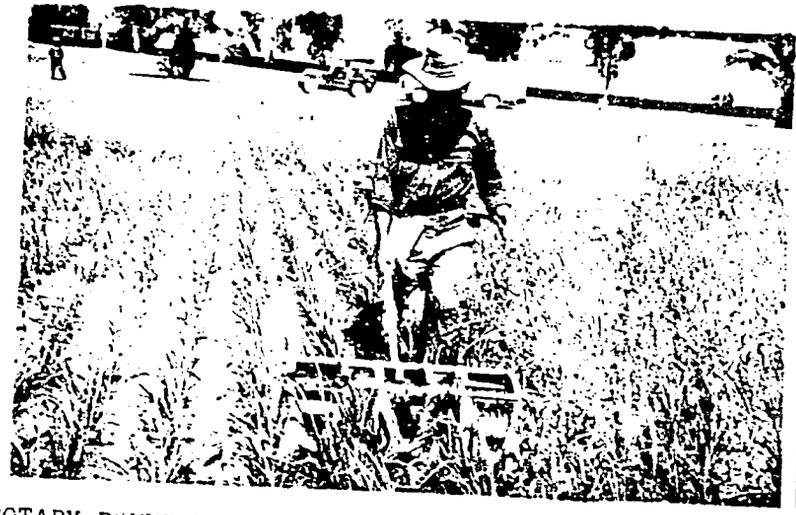
Fig. 2 Selected characteristics of small-scale industries in the Philippines.

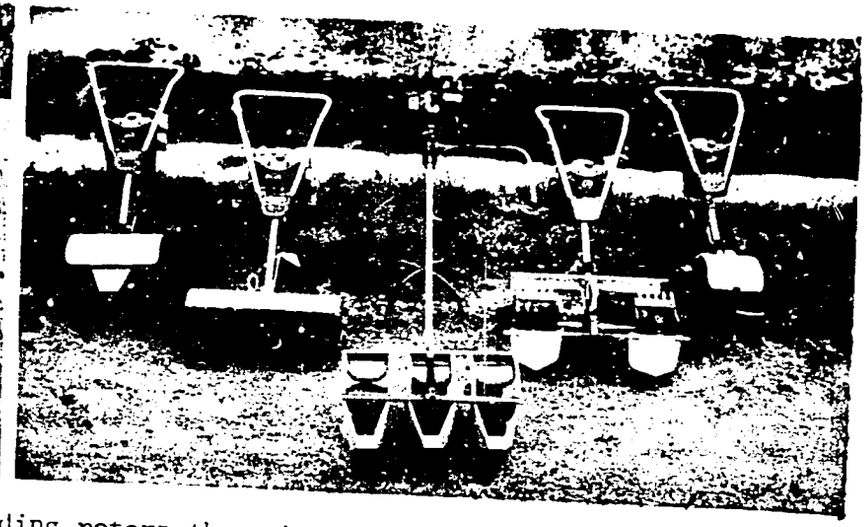


4-6 HP POWER TILLER: A simple 4-6 hp power tiller designed for fabrication in Asia, the machine uses a sealed oil-bath chain transmission and employs attachments for both dry and wetland cultivation. It is being manufactured and marketed in the Philippines at less than $600. This is one-half the price of comparable imported power tillers. (a) Puddling. (b) Transport.

SINGLE-HOPPER PADDY SEEDER: This machine sows pregerminated seed in rows on puddled soils. Five to seven hours are required to seed one hectare. The machine's single wheel facilitates transport on narrow field levees and provides the motive power for the metering mechanism. It is commercially available in the Philippines for about $45.

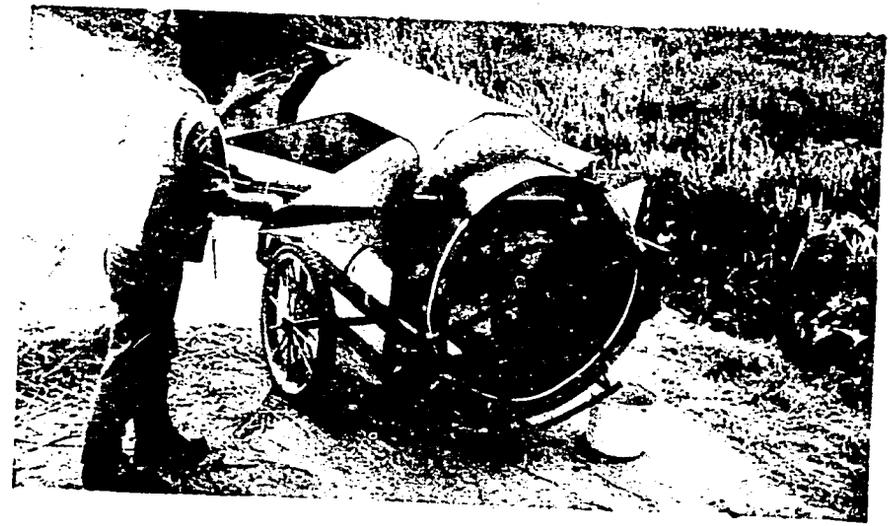
MULTIHOPPER PADDY SEEDER: This is a low-profile seeder with six independent hoppers for seeding pregerminated paddy on puddled soils. The machine has been released for commercial production in the Philippines and is expected to sell for $40.



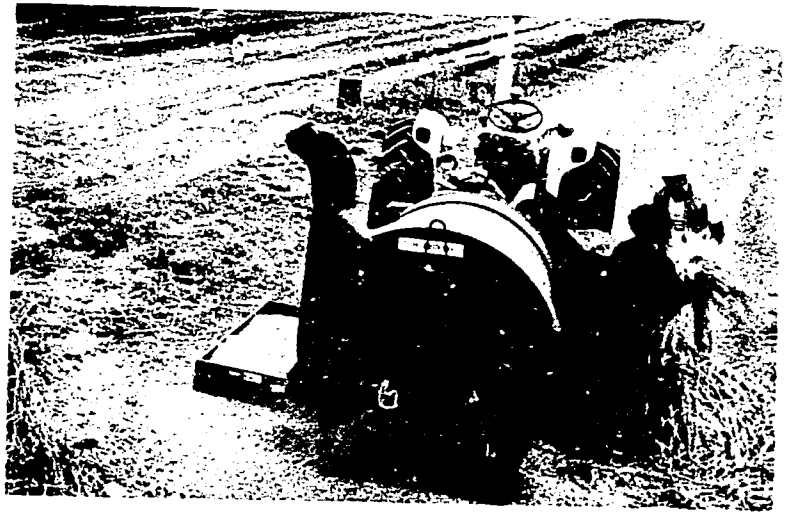


ROTARY POWER WEEDER: A 1 hp engine powers the weeding rotors through a worm reduction box. The rotors uproot and bury the weeds. The machine requires only 17 man-hours to weed a hectare as contrasted to 70 man-hours for manual rotary weeding and 120 man-hours for handweeding. The machine is manufactured and marketed by a company in Japan with a series of attachments at about US$140. (a) IPRI prototype. (b) Manufacturer's models.

TABLE THRESHER: Powered by a 3 hp aircooled engine, this machine has a flat circular threshing surface with an integral fan on its underside. It can thresh dry or freshly harvested high-moisture paddy. Four to five men can thresh about 350 kg of paddy per hour. The machine is commercially produced in the Philippines.

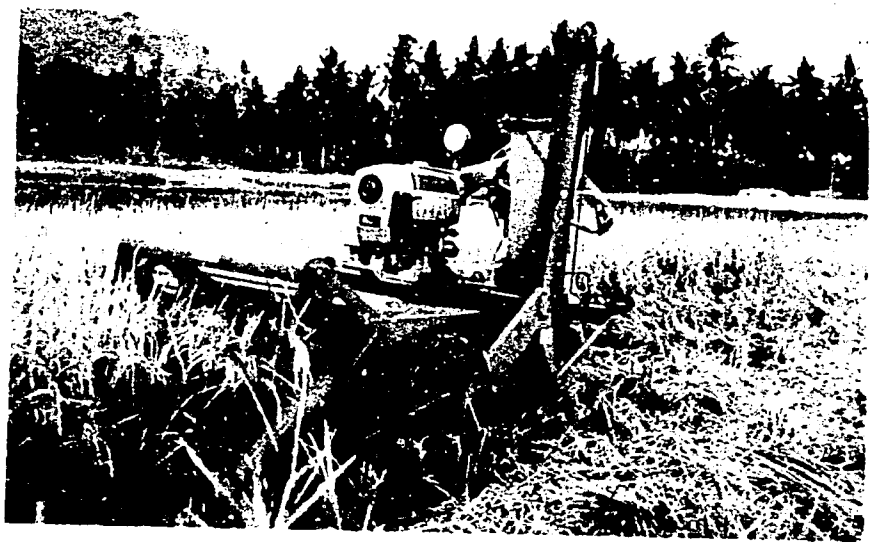


AXIAL-FLOW THRESHER: This is a multicrop throw-in type thresher with an output of 650 kg/hr. The threshed material moves spirally through an oval concave and a blower winnows the separated grain. Further development work is continuing.

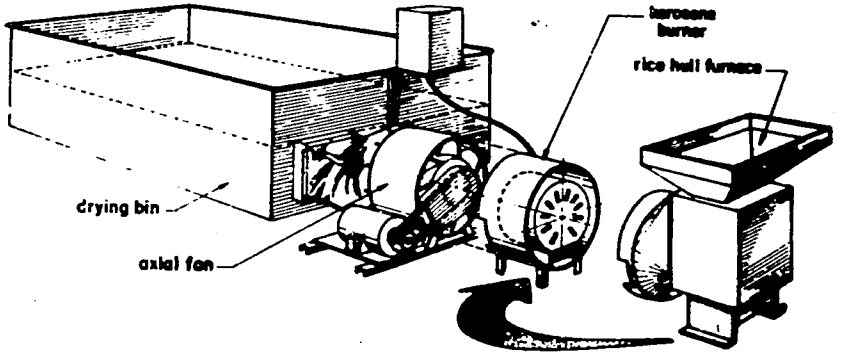


TRACTOR PTO THRESHER: This machine is being developed for custom threshing of rice and other grain crops in Asia, With a capacity of 1½ tons/hr of dry as well as freshly harvested crop, the thresher is light enough for lifting with standard three-point linkage hydraulic systems.

POWER GRAIN CLEANER: Dirty grain is screened first for large and small impurities in two concentric rotary screens. The grain is then tumbled as it moves through a counterflow airstream to remove lighter impurities. Up to 3 tons per hour output has been obtained. The machine is commercially available in the Philippines.

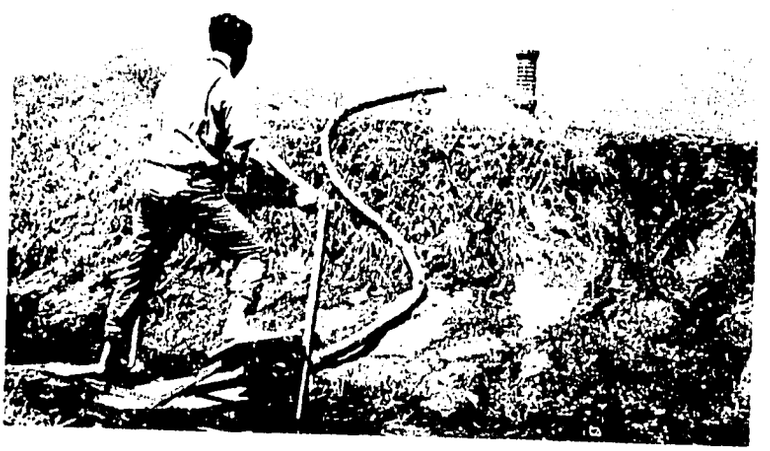


STRIPPER HARVESTER: This four-row machine harvests paddy in the field without cutting the plants. Since straw is not handled through the machine, it is light and compact. Further development work is underway.



RICE HULL OIL FIRED BATCH DRIER: A simple batch type drying system is being developed for the Asian farmers. The system has interchangeable furnaces using oil, rice hull, and other fuels. Further development work is continuing.

HEATED-SAND CONDUCTION DRIER-PARBOILER: The machine mixes wet paddy with heated sand for about 20 seconds in a drying-parboiling chamber and then automatically separates them. The machine can remove 12 percent moisture with a 20-second exposure. If sufficient moisture is initially present in the grain, a parboiling effect is obtained.



LOW-LIFT BELLOWS PUMP: Using two canvas bellows, each equipped with an inlet and exhaust valve, the pump delivers up to 50 gal/min at a 1.5 meter pumping head. The mechanism is actuated by placing the pump in the water source and alternately compressing and expanding each of the bellows through a rhythmic transfer of the operator's weight. The machine is currently produced and marketed in the Philippines at a price of under $40.