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9. ABSTRACT

From 1965 to 1969 the International Rice Research Institute conducted a study designed to determine the amount, adequacy, and cost of power used on rice production in the Philippines and other Far East and South Asia countries. Research was conducted on the economics of mechanization in three major rice-growing areas of the Philippines, including studies of hand tractors and extra-wide rotary tillers for wetland cultivation. In 1969 USAID initiated a new research contract with IRRI to develop new agricultural equipment for tropical rice cultivation. From 1969 to 1974, a wide range of agricultural machines was developed, some of which were successfully commercialized in the Philippines. These machines are now produced regularly and have received widespread acceptance in Southeast Asia. The IRRI-developed machines have spurred development of an organized small farm equipment industry in the Philippines, where 18 companies are producing the IRRI machines. Production of IRRI machines has also started in 11 other countries in Asia and Africa. Industrial extension of the machines is being emphasized in most of the developing countries where rice is an important crop.

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Terminal Report
for
USAID / IRRI Projects No. csd-834
and csd-2541

May 21, 1975

AGRICULTURAL ENGINEERING DEPARTMENT
THE INTERNATIONAL RICE RESEARCH INSTITUTE
P.O. BOX 933 MANILA PHILIPPINES

TERMINAL REPORT

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The development of demand-oriented agricultural machines that are commercially marketable is costly and requires a high degree of professional competence, funds, and other resources. The generous and long-range support provided by the U.S. Agency for International Development (USAID) made it possible to assemble these resources at IRRI. We wish to acknowledge with thanks the wholehearted support and encouragement of Dr. Douglas Caton, Dr. Omer Kelley, Mr. Michael Galli, Mr. James Urano, Mr. Carl van Haeften, and others of the Office of Agriculture, Bureau for Technical Assistance, USAID/Washington.

Mr. Loyd Johnson, my predecessor, negotiated the first AID/IRRI research project, which served as a foundation on which the present program was built. The unrestricted freedom extended by Dr. Robert F. Chandler, former IRRI director, and Dr. Colin A. McClung, former associate director, made it possible to reorient the activities of the earlier research project toward hardware development and served as a key element in laying the program's foundation. The continued support and encouragement of Dr. Nyle C. Brady, IRRI director, and his special concern for transferring the IRRI machines to developing countries, has helped to ensure a wider dissemination of the small-farm mechanization technology.

Product development is a complex function that requires a team effort; many members of the project staff and others contributed significantly to this program. Appendix II lists the staff members and consultants who were associated with this program. The contributions of Dr. Stanley S. Johnson and Mr. Bart Duff to the economic studies and of Mr. Fred Nichols to machinery evaluation, were especially important and helped maintain the program's sharp focus. Mr. Duff's sharing of the administrative responsibilities during the later part of the program expedited matters. Dr. William Chancellor and Dr. Judson Harper, short-term con-

sultants, and Mr. Joseph K. Campbell, visiting scientist, brought fresh ideas and new perspective to the program. Staff from other IRRI departments and many senior scientists gave informal suggestions which were helpful in design improvements.

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Amir U. Khan
Development Engineer & Project Leader
IRRI/AID Contract No. csd-2541

Los Baños, Laguna, Philippines
May 21, 1975

TERMINAL REPORT

Introduction

The USAID/IRRI project, No. csd-834, "Research on Farm and Equipment Power Requirements for Production and Processing of Rice and Associated Food Crops in the Far East and South Asia," was initiated at the International Rice Research Institute (IRRI) in 1965. The contract envisaged a diversified research effort encompassing different engineering and economic aspects of rice mechanization. The main objective was "to perform research directed towards determining the amount, adequacy and cost of power used on rice production in the Philippines and other Far East and South Asia countries."

During the first two years research was conducted on the economics of mechanization in three major rice-growing areas of the Philippines. Considerable economic and agronomic data were collected. Work on the engineering aspects of mechanization included a study of hand tractors for land preparation and an experimental design and evaluation study of extra-wide rotary tillers for wetland cultivation with large tractors. With the hiring of the project design engineer and the remainder of the design team in late 1967, the professional expertise was assembled and the focus of the project was subsequently changed.

A review of the past research at IRRI and other agricultural engineering institutions in the South and Southeast Asian countries indicated that research results were not reaching the farm level. Most agricultural engineering research in the LDC was directed towards increasing the knowledge of mechanization or the utilization of imported farm machines. The information-gathering and technology assessment approach did not appear to be adequate since it focused on only one component of the overall mechanization problem. The mechanization of agriculture and the production of farm machines are two facets of the same problem which must be considered simultaneously in the developing countries.

The involvement of small metalworking firms in production of appropriate agricultural machines was essential to the mechanization of tropical agriculture and thus project activities at IRRI were oriented accordingly. The development of demand-oriented small farm machines which could be indigenously produced in the developing countries was emphasized and gained considerable momentum during the latter part of the project.

In 1969 USAID initiated a new research contract, USAID/IRRI Contract No. csd-2541, entitled "Agricultural Equipment Development Research

for Tropical Rice Cultivation." The new USAID project at IRRI was patterned after the product development activities in industry with primary emphasis on the development of hardware rather than research for knowledge. It provided a sharper focus on the development and commercialization of appropriate rice production and processing machines in the developing countries.

Between the years 1969 to 1974, a wide range of agricultural machines were developed, some of which were successfully commercialized in the Philippines. These machines are now produced regularly and have received widespread acceptance in Southeast Asia. As of December 31, 1974, eight cooperating Philippine manufacturers have reported hiring 700 additional workers in the actual production of IRRI-developed machines. Data on the amount of indirect employment generated by this program are being gathered in the Philippines. The impact of this program has been particularly dramatic in the Philippines where an organized small farm equipment industry has now been established with 18 companies producing the IRRI machines. Production of some of the IRRI machines has also started in 11 other countries in Asia and Africa, although manufacturing progress in these countries has not been as rapid as in the Philippines. A total of 22,000 IRRI-developed machines were commercially produced in Asia (fig. 1) as of December 31, 1974. Industrial extension of the machines in most of the developing countries where rice is an important crop is being emphasized.

Since the inception of this program, 19 semiannual reports have been issued by the IRRI Agricultural Engineering Department. Copies of the semiannual reports have been submitted regularly to the USAID/TAB/AGR, Washington, D.C. and are available at the IRRI library. During the two contract periods, more than 400 semiannual reports were mailed biannually to academic, research and business organizations worldwide. This terminal report briefly reviews the rationale, objectives, organization, achievements and constraints of the USAID-supported program at IRRI. Some suggestions and recommendations are offered in the hope that they can help in the organization of other technology development projects for problems faced by developing countries. Readers interested in further information are requested to refer to the semiannual reports or write to the IRRI Agricultural Engineering Department for the publications listed in Appendix I.

Program rationale

Tropical regions are characterized by low farm incomes, small farm holdings, and low labor costs. Recent increases in crop yields, as a result of the advances in agricultural production technology, are beginning to increase farm incomes and providing greater inputs to the mechanization of tropical agriculture.

It has been argued that a wide range of farm equipment is readily available from industrialized countries and thus the problems of tropical agricultural mechanization are primarily of proper selection and use of farm equipment. A closer analysis, however, reveals that this rationale is based solely on crop production practices and machine functional capabilities. To be successful, mechanization technology must meet the functional needs of the farmer and must also fit the economic, social, cultural, and industrial structures of the society in which it is applied. Creation of new employment, shortage of foreign exchange, desirability of indigenous production and utilization of local resources are all important factors which must be considered in the developing countries.

Generally, the selling price of most imported farm machines for the tropical farmer is approximately two to four times the price of the machines in the industrialized countries. Furthermore, this expensive equipment competes with manual labor which is usually a fraction of what it is in the industrialized countries. The serious foreign exchange shortages that most developing countries face also limits the possibilities for any large-scale importation of farm equipment..

The appropriateness of the imported modern mechanization technologies for application to tropical agriculture is being seriously questioned today. In the industrially advanced countries, two distinct agricultural mechanization technologies, the western and the Japanese, have evolved to suit different sets of agricultural, socioeconomic, and industrial conditions. The western approach emphasizes dryland farming on large farm holdings with high-powered equipment. This capital-intensive technology has been developed primarily to replace human labor with machines. Application of such technology in most developing countries would have adverse impact on employment. Many attempts have been made since the last World War, however, to introduce such a technology in Asia with marginal results, mostly on a small number of larger farms. In India, where tractors of over 35-hp size have been produced locally since the early 1950s, such tractors are used on less than 2 percent of the total arable land.

Rice is a major crop in Japan which is produced on small farms under wetland conditions somewhat similar to those in the tropics. The high price support for rice, coupled with the rapid industrial growth and a rising standard of living, has resulted in the mechanization of agriculture with small but fairly sophisticated farm machines. Such equipment has been developed to meet the requirements of the relatively rich Japanese farmers, most of whom earn a substantial part of their income from off-farm part-time jobs in industry. The Japanese mechanization technology is uneconomic and far too complex for the farmers in tropical Asia. Many of the farm machines that are widely used by Japanese farmers -- the combine harvesters, reaper binders, paddy transplanters, and circulating farm dryers -- are excellent examples of functionally suitable but economically unfeasible machines for the tropical regions.

Continuing developments in machinery designs in the industrialized countries are widening the gap between the available farm machines and the need for simple farm equipment in the developing countries. In the western countries, there is a trend towards larger-powered and more automatic control systems. To some extent, machinery developments in Japan are following a similar trend towards larger equipment with ever-increasing complexity in their equipment designs. These developments are making it even more difficult to transfer imported mechanization technologies to the developing countries.

With the introduction of new crop varieties, problems of crop drying and processing have assumed new proportions. Technology for drying and processing crops in large quantities has been well developed and is available from the industrialized countries. The establishment of large centralized plants, however, requires a well developed infrastructure which is frequently lacking in the tropics. The development of economical drying and processing systems for village- and farm-level operations is an urgent problem that requires attention in the developing countries.

Almost 5 percent of the farm holdings in tropical Asia are greater than 10 hectares in size. Farms with such holdings have the resources to acquire the type of agricultural equipment that are available from the industrialized countries. Appropriate machines to suit the remaining 95 percent of the holdings is not available from the industrialized countries. Generally the traditional manual or animal-drawn farm implements can effectively serve the needs of the less-than-2-hectare size farms. Thus farm holdings between the 2- and 10-hectare sizes are too large to be adequately served with traditional equipment and are too small for the large imported tractors and other farm machines. Such farms have the resources to acquire an intermediate level of mechanization, but technology to meet their needs is not available.

Experience indicates that efforts directed primarily towards the introduction and utilization of available farm machines from the advanced countries are not likely to succeed in the developing countries. The mechanization of tropical agriculture and the development of an indigenous farm equipment industry are interrelated and must be approached simultaneously in the developing countries.

The lack of appropriate machinery designs which could generate commercial demand and could be produced with the available metalworking technology has impeded the development of local farm machinery industries in the developing countries. Farm equipment in the industrialized countries is designed for production with capital-intensive mass production methods. In the developing countries, production technology to economically manufacture such designs is not available, nor are their markets sufficiently developed to justify establishment of mass-producing industries. Unless appropriate agricultural machines are made available at low costs to small farms in the developing countries, mechanization will continue to be a luxury only for a handful of large farmers. The design of a machine and its production processes are closely interrelated. In order to offer low-cost machines, it is necessary to provide suitable machinery designs that could be economically manufactured in the developing countries with available low-volume production methods.

Farm equipment manufacturers from the industrialized countries often point out that sufficient demand does not exist in the developing countries to justify local production. Nevertheless, in South and Southeast Asia, many examples exist of low-volume production of machines that are traditionally produced only with highly capital intensive production technology in the industrialized countries. Generally such production involves some redesign and adaptation for labor-intensive production methods. The case of the jeepney and the power tiller in the Philippines, the air-cooled engine and power tillers in Thailand, and the three-wheeled motorized vehicles in Taiwan are excellent examples of the role of product design in developing local industries.

The development of new equipment is a costly process and generally requires a high level of engineering expertise. In the industrially advanced countries, new machines are developed primarily by industry and these machinery manufacturers find it unattractive to develop new equipment for the developing countries. Their preferred strategy is to develop new equipment for the home markets and to expand their sales in the tropical regions. In the developing countries, small metalworking shops will play a significant role in the production of agricultural machines. Such firms, however, do not have the resources or the knowhow to develop new farm equipment. The public sector industrial and academic

institutions, which are the primary recipients of research funds in the developing countries, must therefore serve the research and development needs of the small-scale industrial sector.

The IRRI agricultural machinery development program was focused towards meeting this specific industrial R&D need in those developing countries where rice is a major crop. Because of the international character of the Institute's activities and the level of expertise available to the program, emphasis was placed on the development of fairly modern, mechanically powered agricultural machines which could successfully compete with the type of farm machines that are being imported in many developing countries. Manual and animal-drawn implements have a high degree of location specificity and do not require as much technical as well as other resources for their development. Such equipment could perhaps be better developed by the national institutions in the developing countries.

Organization and objectives

The main objective of the USAID/IRRI program was to provide simple agricultural equipment for small farms which could be manufactured by local metalworking firms in the developing countries. The program activities were divided in three major areas: 1) machinery design, 2) test and evaluation, and 3) economics of mechanization. The project staff consisted of three expatriate senior staff members and about 35 other engineers and technicians from the Philippines (Appendix II). The objectives of the three parts of the program were:

1. Machinery design and development:- To modify, improve and adapt commercially available machines for tropical farming; to design and develop low-cost agricultural machines which could be manufactured in the LDC for land preparation, seeding, transplanting, weeding, fertilizing, harvesting, threshing, drying and processing operations in rice and related crops.

2. Test and evaluation:- To conduct research studies related to the mechanization of agriculture and the utilization of agricultural machines in the developing countries; to assess farmers' needs and develop specifications of machines which should be developed; to provide ongoing test and evaluation support to the machinery development group; to encourage manufacturers to produce the project-developed machines; to provide technical assistance in commercializing IRRI-developed machines.

3. Economics of mechanization:- To investigate the economics of mechanization and to establish the economic relationships between farm machines and end-users, manufacturers, dealers and distributors in the developing countries; to study the impact of agricultural mechanization and of IRRI-developed machines on employment in the developing countries; to establish and maintain liaison with industry, research and academic organizations interested in agricultural mechanization; to make comparative economic studies on IRRI-developed and other commercially available machines; to estimate production costs, prepare production feasibility studies, prepare sales estimates, and develop manufacturers' costs and returns on IRRI machines; to prepare bills of materials and cost breakdowns on IRRI prototype machines prior to their release to manufacturers; to evaluate machinery marketing practices in the farm equipment industry in the developing countries and to develop guidelines for cooperating IRRI manufacturers.

Project Highlights

Machinery development

In paddy production, peak labor and demand occurs during the land preparation-transplanting or harvesting-threshing operations. In the double-cropping areas, the harvesting-threshing of the first crop and the land preparation-transplanting of the second crop are so close together in time that shortages of labor are becoming serious constraints in most developing countries. Therefore the program was directed towards the development of simple power tillers and paddy threshers to break this constraint. Machines were also developed for direct seeding, fertilizing, mechanical and chemical weed control, grain cleaning, drying, and processing operations. The following major machinery development projects were undertaken during the period covered by the two USAID projects at IRRI:

Project	Fig.	Project status
1. Experimental 3-m wide rotary tiller for large tractors	2	Experimental project
2. Rotary harrow for small tractors	3	Experimental project
3. Differential slip tiller	4	Experimental study
4. Extendible-blade tractor lug wheel	5	Commercially produced, highly successful
5. 5-7 hp tiller	6	Commercially produced, highly successful

Project	Fig.	Project status
6. 5-7 hp tiller attachments	6-a	Commercially produced, highly successful
7. 5-7 hp tiller steering clutches	7	Continuing project
8. 8-14 hp tiller	8	Introductory stage; commercially produced
9. Four-wheel 15 hp riding tractor	9	Continuing project
10. Single-hopper paddy seeder	10	Commercially produced; fairly successful
11. Multihopper seeder	11	Commercially produced; fairly successful
12. Deep-placement granular fertilizer applicator	12	Introductory stage; commercially produced
13. Deep-placement liquid chemical injector	13	Introductory commercial stage
14. Anhydrous ammonia applicator	14	Experimental project
15. Rotary power weeder	15	Commercially produced; highly successful
16. Contact herbicide applicator	16	Introductory stage; commercially produced
17. Stripper harvester	17	Continuing project
18. Drum-type paddy thresher	18	Commercially produced; unsuccessful
19. Table-type paddy thresher	19	Commercially produced; unsuccessful
20. Axial flow thresher	20	Commercially produced; highly successful
21. Tractor PTO-driven thresher	21	Continuing project
22. Rotary power grain cleaner	22	Commercially produced; unsuccessful
23. Manually operated grain cleaner	23	Experimental project
24. Oscillating screen-air cleaner	24	Continuing project
25. Test tube miller	25	Commercially produced; limited demand
26. Improvement of Engleberg rice milling machine	26	Continuing project
27. Grain moisture meter	27	Introductory commercial stage
28. Heated-sand parboiler	28	Continuing project

Project	Fig.	Project status
29. Rice hull furnace for drying paddy	29	Commercially produced; fairly successful
30. Batch-type dryer with oil burner	30	Commercially produced; highly successful
31. Lowlift bellows pump	31	Commercially produced; limited demand
32. Jet-flow pump attachment	32	Continuing project
33. Tubular pump	33	Continuing project
34. Vertical-axis windmill	34	Continuing project
35. Solar energy collector	35	Continuing project

The patents issued and awards received for the machines designed and developed by the project staff members are listed in Appendixes III and IV, respectively.

The projects listed above have been discussed in detail in the semiannual reports. The commercially popular machines are discussed briefly in this report.

Six machines, the 5 hp-7 hp tiller, the axial flow thresher, the rotary power weeder, the tractor lug wheel, the batch dryer, and the rice hull furnace, have received excellent commercial response in ten Asian countries. Manufacturer interest in Africa and Latin America, where some of the project's machines are being evaluated, is growing rapidly.

5 hp-7 hp tiller. This tiller was developed to match the specifications of the simpler imported power tillers. The machine was designed to make maximum use of standard machine components that are readily available in most developing countries. The engine, roller chains, sprockets, bearings, and seals used in the power tiller are imported in most Asian countries for other uses. The remaining components of the power tiller are fairly simple and can be produced by small metalworking shops in most of the developing countries. A range of power tiller attachments (fig. 6-a) has been developed for use with the machine for cultivating upland and lowland crops, for transport, and for irrigation. The power tiller is now produced by 12 companies in six Asian countries and is sold for approximately half the price of imported power tillers of comparable size. A total of 6021 units of the 5- to 7-hp tiller have been produced commercially as of December 31, 1974 in Asia. The power tiller gained popularity rapidly in the Philippines. A survey in 1972 indicated that only 18 months after the power tiller

design was released by IRRI, 85 percent of the Philippine farmers had learned about the power tiller. This power tiller is also produced commercially in Sri Lanka, Vietnam, Indonesia, Korea and Thailand.

The favorable response to the IRRI 5 hp-7 hp tiller and the farmers' desire for power tillers with additional features led to the development of a larger 10 hp-12 hp tiller. This machine is equipped with a diesel engine, three forward and one reverse speed geared transmission, and steering clutches. The design of this tiller (fig. 8) was released to six Philippine companies for limited production. The manufacturers are to fabricate their prototype machines and submit them to IRRI for testing and evaluation.

Axial flow thresher. Experience with two early IRRI paddy threshers -- the drum-type and the table-type threshers -- indicated that farmers were not particularly interested in the hold-on type threshers because of their low output. Farmers were more interested in high-capacity throw-in type threshers which could be used to thresh many different crops. This led to the development of the axial flow thresher which has rapidly gained popularity and is now commercially produced in eight countries. This thresher has an output of about 1 t/h when operated with a three-man crew. It can thresh rice, sorghum and soybeans. It is being adapted to thresh wheat; this should offer a much larger market in the semi-arid areas.

Rotary power weeder. This is a three-row, engine-powered machine light enough to be lifted off the ground by one man for turning at the end of the plant rows. Since most paddy fields in the developing countries are quite small, headlands for turning a machine at the end of the rows are not available. Because of this limitation, power tillers and other heavier machines have not been successfully used for weeding. A Japanese company has been producing this weeder since 1971 and it is sold for weeding and for cultivating both low and upland fields. The company has developed a wide range of attachments for this weeder (fig. 15) and has increased its sales steadily during the last four years. Two other Japanese companies are now planning to produce machines based on the IRRI concept. Since this weeder requires a lightweight -- 1 hp to 1.5 hp -- high-speed gasoline engine, production has so far been limited to Japan. Recently engines of this type have begun to be produced in India for use with backpack power sprayers; an Indian company is now evaluating this weeder under local conditions.

Tractor lug wheel. Fixed-blade tractor cage wheels have been widely used for paddy cultivation in Southeast Asia to improve machine mobility and to puddle wet fields. The rigidly fixed blade wheel design has no provision for adjustments to suit varying soil and field conditions. During the last few years, an extendible wooden strake wheel has gained some popularity with tractor contract operators in Malaysia. These strake wheels have six 10.2- x 10.2-cm (4x4 in.) wooden strakes mounted on frames which are bolted to the rims of the tractor rear wheel. The tip diameter of the strakes can be changed by extending or retracting the strakes radially to suit varying field conditions. The strakes are, however, quite narrow and do not take full advantage of the ground reaction. The wooden strakes absorbe moisture from the wet field and are difficult to adjust.

The IRRI extendible lug wheel was developed by combining the desirable features of the fixed steel blade and of the adjustable wooden strake wheels. It has 30.5-cm (12 in.) wide metal blades to provide good ground reaction. The blades can be radially extended to improve traction and mobility under difficult field conditions. If the tractor is bogged, one or two lugs can be fully extended to extricate the tractor through its own power. Bogging of tractors is a serious problem for tractor custom operators since extracting a bogged tractor requires many hours of work and involves other towing equipment which may be difficult to obtain in the countryside. The IRRI extendible lug wheel has been quite well accepted in the Philippines and all larger tractors are now sold with such wheels for paddy cultivation in the Philippines.

Batch dryer. Drying of paddy, particularly during the wet season, is a serious problem in most tropical countries. Simple batch dryers are popular for farm-level drying in Japan; however, such dryers are too expensive to import and difficult to fabricate in the developing countries. The IRRI batch dryer has been designed with features somewhat similar to those of the Japanese batch dryers; however, it can be easily fabricated by most small metalworking shops in the developing countries. The dryer consists of a grain bin with a perforated floor and a fan-burner assembly. It has a simple pot-type oil burner, an axial flow fan, and an automatic fuel cut-off valve system for safer operation. The machine can dry 1 ton of paddy from 26 percent to 16 percent wet basis in 5 to 6 hours. The standard dryer has a sheetmetal grain bin. Plans are available, however, for a lower-cost wooden grain bin which can be fabricated locally by farmers. Six companies are manufacturing the IRRI batch dryer in the Philippines and production of this dryer has also started in Taiwan.

Rice hull furnace. All over Asia, rice hulls, a by-product of rice milling, are dispensed with by burning in piles at rice mills. The high cost of burner fuel prompted the development of a rice hull furnace which could be used with the IRRI batch dryer. The furnace consists of an inclined grate burner, a hopper for rice hulls, and an ash trap. Hulls are fed either manually or automatically through an eccentric drive feed mechanism connected to the blower. The oil-fired dryer can be changed to rice hull operation by just removing the oil burner. This furnace is now manufactured by most dryer manufacturers and its market in the Philippines is increasing.

Test and evaluation

The test and evaluation part of the IRRI program conducted field studies to establish performance, design criteria, and power and labor efficiencies on a wide range of IRRI and other commercially available machines, primarily to assess their ability to meet the needs of farmers in tropical Asia. Extensive field evaluation of IRRI prototype machines, before and after their release to manufacturers, to pinpoint operational and production defects was a continuing program. Based on these evaluations, recommendations were made for changes in the design or production processes as required.

Detailed information on the field studies and test programs was presented in the semi-annual reports. The following summarizes briefly representative projects.

Power tiller survey. A survey was conducted to determine the technical factors which influence the selection and utilization of power tillers. The data gathered will be used to establish parameters for future tiller designs. The survey also evaluated technologies employed by local tiller manufacturers and included personal interviews with power tiller owners and manufacturers.

The farmers' choice of a tiller was mainly influenced by the presence of local dealers and by the brand introduced first into his area. Cost and availability of spare parts affected his choice only slightly. Heavy weight and the resulting handling difficulty and the high incidence of belt, steering clutch, and engine failures were the major complaints of the owners. Expanded surveys of power tiller owners are planned.

Comparative test and evaluation of threshers. A field study of the threshers which are popularly used and locally manufactured in the

Philippines was made to determine their suitability for small and medium size farms. Machine components such as oscillating screens, rotary screens, number of threshing drums and blower arrangements, etc. were evaluated for performance.

The results indicated that the single-drum thresher with a blower and a separator (of the IRRI axial flow thresher type) are desirable because they combine high threshing output per horsepower and per man-hour with minimum threshing losses.

Rice transplanter tests. A locally manufactured hand-operated transplanter which plants five rows at 20-cm spacing was field-tested to determine performance. The number of seedlings per hill were quite variable; spacing between hills also varied because it was dependent on the operator's judgment. The test results were sent to the manufacturer with recommendations for machine improvement.

A Japanese engine-driven transplanter was evaluated to determine its suitability for Philippine conditions. It was difficult to maintain straight rows because of the imbalance caused by the oscillating seedling trays. Producing seedlings of the proper size proved to be difficult under local soil conditions.

Rice milling tests. The Engleberg type steel huller mills are widely used throughout Southeast Asia but these machines have very low recovery rates. Tests were performed to determine potential modifications to improve milling efficiency. Unital tests on a production model showed 63 to 65 percent total recovery and 25 to 30 percent head rice recovery. Modifications to the screen cylinder, blades, and discharge produced 66 to 68 percent total and 33 to 35 percent head rice recoveries, respectively. Additional development work is planned so that improvements could be incorporated in new as well as in older rice mills that are already in use.

The information obtained in the test and evaluation section was provided to the design group and was distributed to manufacturers. This proved helpful in the improvement and further development of the IRRI-developed machines.

Technical assistance was provided to the manufacturers of IRRI-developed machines in evaluating and further improving their production machines. Cooperating manufacturers were also assisted in demonstrations of their machines at different locations in the Philippines and in assessing the reaction of the farmers to their machines.

Descriptive leaflets and operator's manuals (Appendix I) prepared for the commercialized IRRI-developed machines were furnished to manufacturers to assist them in the preparation of literature and manuals.

Economics of mechanization

The economics research conducted at IRRI was designed to support the machinery development project in a number of areas. First, a number of field survey activities were carried out to identify potential areas in the rice production and processing sequence where the introduction of improved mechanical techniques would improve output, increase incomes, reduce losses and raise resource productivity. The second objective was to evaluate the effects of mechanization and policies influencing mechanization on employment, the patterned growth of machinery use and the distribution of benefits. Third, research on small and medium-scale industry was designed to examine the constraints facing this sector in the adoption, manufacture, and distribution of improved agricultural equipment designs. Some of the projects undertaken by the economics section of the IRRI engineering program were:

Land preparation. Studies carried out in 1972 indicated that animal power remains a viable economic alternative on small farms up to 4 hectares in size. The use of power tillers is a least-cost alternative for farms of 4 to 50 hectares. Four-wheel tractors are preferred for farms larger than 50 hectares.

Empirical surveys of hand tractor use in Laguna province of the Philippines indicate a substantial latent demand for power tillers, largely on small rice farms. The development of irrigation projects permitting the expansion of double-cropped areas may expand the potential demand further because of the time constraints of double-cropping require more rapid tillage operations.

In Central Luzon, where four-wheel tractors are used extensively, over 50 percent of the farmers who own and use the tractor have more than 50 hectares. Additionally, more than 83 percent of these tractor owners use their machines for custom services which effectively increases the total area covered by an individual machine.

Yields are not significantly different for an equivalent number of horsepower-hours per hectare used for land preparation, either from tractors or from water buffalo. However, on some larger farming units, the introduction of tractors may result in a higher horsepower input per hectare.

Planting. A comparison of different methods of seeding rice indicates that while broadcast seeding itself is inexpensive, unless it is carried out in conjunction with a number of other required practices (notably weeding) yields are often lower than those attained with transplanting. Manual transplanting remains the optimum choice for very small farms with adequate manual labor available. As the size of the farm increases and the cost of labor increases, direct row seeding is preferred over manual transplanting.

Weeding. A comparison between handweeding, a manual Japanese rotary weeder, and the IRRI-designed power weeder indicates that handweeding is the least-cost method for areas of less than 0.1 hectare. Between 0.1 and 6.0 hectares, the manual rotary method is the least-cost technique. The IRRI-designed power weeder is economically feasible for areas around 6 hectares or more. Both the power weeder and the manual weeder can be used where rice is sown in rows.

Threshing. When four alternative threshing methods were compared both manual threshing using the "hampasan" or threshing frame and the pedal thresher were found to be relatively labor-intensive, resulting in a sharp rise in cost with expanded use. Conversely, the McCormick type thresher requires large capital outlays and a large volume of grain consolidated for threshing to be an attractive alternative. Its serious limitations are that it cannot thresh wet paddy and cannot be moved readily to inaccessible locations. On the other hand, the IRRI-designed table thresher increases labor productivity but with a rise in fixed costs. It will replace manual threshing at an output of around 60 tons per year. It was projected in 1973 that the table thresher would find its greatest market in areas where high yields are obtained, where labor costs are high, and where double-cropping was practiced.

With the recently introduced axial flow thresher, the annual break-even output is similar, but the output capacity has been trebled. Improvements achieved with this design, particularly in output per manhour, has been a major reason for its rapid and widespread use in contrast to the table thresher.

Milling and processing. Some aspects of traditional milling technologies can be improved without major investments in new capital equipment. Existing techniques can be upgraded through refinement and modification or through the introduction of new designs. However, incentives are needed for small and large industry to encourage them to increase recovery of rice and to improve quality. A farm level survey on post-production practices, attitudes and preferences towards alternative milling

and processing technologies reveals that processing is but one component of operation which incurs losses. Processing cannot be isolated from the effects of other operations which precede it -- harvesting, threshing, handling, drying, and storage. Farmers using the cono or under-run disk sheller expect better head rice recovery while users of the Engleberg huller or "kiskisan" seem resigned to accepting more brokens and less head rice, but a higher output of bran, brewer's rice, and ground hulls for their livestock.

It is apparent from this survey that delivery of poor quality paddy rice to the processing plant is a major cause of low recovery rates and the lack of quality in milled rice. Improvements in farm level post-production operations, particularly in timing and capacity, can improve output through reductions in quantitative losses at the field level and through improvements in paddy quality.

Our studies indicate that approximately 40 to 50 percent of the paddy produced in the Philippines enters the commercial rice trade and is processed in relatively efficient milling systems. The remaining 50 to 60 percent is consumed at or near the farm level and is processed by thousands of Engleberg-type mills. Evidence indicates that this type of mill, with its low initial cost, ease of operation, ability to handle small quantities and ease of access has a high degree of utility in rural areas in spite of its relatively low milling efficiency. This finding emphasizes the need for development of improvements in the existing design or a new technology with the same capacity, cost and operational characteristics rather than replacement with larger, more fully integrated and centralized facilities.

Mechanization and employment research. The initial steps toward mechanization of the rice sector, stimulated by government policies and the introduction of the new rice technology, have not yet resulted in any major labor displacement. Reduced labor requirements for land preparation caused by use of tractors have been more than offset by increased labor used for weeding, harvesting, and threshing.

A number of policies adopted by the Philippine Government since 1964 have influenced relative factor prices and credit availability and through these the rate of mechanization. The adoption of the floating exchange rate in 1970 has helped to restore the balance between labor and capital costs. However, the high minimum wage introduced after the floating rate is likely to provide further impetus for mechanization and may have a negative effect on employment.

Industry-related research. In developing countries like the Philippines, the role of small- and medium-sized firms supplying agricultural equipment is particularly important because of the large numbers of such firms and their inherent potential for creating employment through use of relatively labor-intensive methods of production. A completed case study undertaken in cooperation with the Harvard Advisory Group indicates that for a single proprietorship firm, management becomes a constraint as the size of the firm increases. Credit does not appear to be a major constraint, although raw materials and inventory levels were kept low to avoid tying up capital. Methods of production were relatively labor intensive and investment in plant and equipment was fully depreciated. Poorly developed marketing channels were a difficulty, although many products were built on consignment for others, thereby eliminating the need for a direct outlet.

A series of IRRI-sponsored studies of the farm equipment industry were also carried out in Thailand. These covered the manufacture and marketing of hand tractors, the economic, technical and spatial aspects of rice processing and the manufacture of gasoline engines. The latter was a case study of a small firm making two-stroke petrol engines employing labor-intensive production and assembly techniques. These research projects were undertaken to more fully identify the constraints facing equipment producers and to develop a more complete understanding of the processes of design transfer and adoption, and the choice of manufacturing technique found in the farm equipment industry.

Industrial extension

During the initial years of the IRRI program, difficulties were encountered in locating suitable manufacturers who were interested in producing IRRI-developed machines. The response was poor to advertisements placed in the major Philippine newspapers offering agricultural machinery designs free of cost to manufacturers. Subsequently, orders for a few IRRI-designed machines were placed with selected manufacturers and this helped in generating manufacturer interest. As the manufacturers developed more confidence in the IRRI machinery development program, commercialization of the machines became easier. After some of the IRRI machines became commercially successful, manufacturer interest increased substantially. Now many companies keep in touch with the program and actively seek the design of the machines that are under development.

The Institute recognizes the need for an organized industrial extension effort and steps are now being taken to correct the program's earlier

shortcomings in this area. An industrial extension contract is now being negotiated with USAID/TAB Washington, under which engineering teams will be stationed in selected developing countries to test and adapt the IRRI machines for local conditions and to encourage and assist manufacturers in the production of these machines. An industrial extension engineer will also be added to the core machinery development program at the Institute to provide backstop support to the industrial extension engineers located in other developing countries and to the cooperating organizations that are working with IRRI in the industrial extension activities in other countries.

Commercialization of the designs originating from public industrial research institutions has been a chronic problem in most developing countries. Experience indicates that distributing the engineering drawings and technical information to manufacturers is in itself not sufficient for commercialization. Small- and medium-sized metalworking firms in the LDC, who are potential manufacturers of simple agricultural equipment, are not too familiar with engineering drawing practices and prefer to work with prototype machines. Such firms have limited capital and are unwilling to take risks on a commercially unproven machine. These firms are generally reluctant to produce new machines unless there is an assured order. Once one manufacturer succeeds in marketing a few machines, other companies generally develop interest in its commercial production.

To meet the special conditions of the developing countries and to overcome production bottlenecks, a design release procedure was developed. Drawings and one prototype machine were furnished to those metalworking firms who were willing to supply a few machines to the Institute and had some potential or had indicated a desire for commercial production of the IRRI-developed machines. The manufacturers were asked to submit their quotations for supplying a few machines, generally one to six, to the Institute. On the basis of their quotations and the evaluation of their potential for commercial production by the project staff, orders were placed with selected manufacturers for a few machines. These manufacturers were keen to produce the machines for IRRI since it gave some business and provided an opportunity to evaluate their capabilities for producing IRRI machines on a commercial basis without taking any risks. Such a strategy was possible because most IRRI machinery designs were simple and did not require special tooling, materials, and processes in their production.

The selected manufacturers were given full latitude to modify the designs of the machines that were ordered by the Institute to suit their production facilities or to improve machine performance. Interestingly

every machine underwent some design modifications or improvements at this stage. An added advantage of following this strategy for releasing IRRI designs was that many design weaknesses and production problems became apparent during the initial production and these were corrected before regular production was started.

The first machine fabricated by each firm was submitted to IRRI for a series of tests to ensure that it met the performance specifications. Manufacturers were informed of any problems encountered during the tests. Modifications and improvements were made in the machine at the Institute before it was returned to the manufacturer. When the performance of the manufacturer's prototype machine was satisfactory, it was returned to the manufacturer as a guide for future production and the manufacturer was asked to produce the remaining order. The manufacturers were advised to sell any of the IRRI machines while these were being fabricated whenever an outside buyer was available. Frequently, the manufacturers were able to sell a few IRRI-developed machines before completing the IRRI order. Such sales enabled the manufacturer to evaluate the machine's commercial viability and provided a strong incentive to initiate commercial production.

During the custom fabricating stage, any inquiries received by the Institute were channeled to the manufacturers. Manufacturers were provided with leaflets, instruction manuals, and test reports on the machines to help their sales efforts. Attractive labels, indicating that the machine was based on an original design from IRRI, which the manufacturers attached to their machines helped during the introductory sales stage. The few custom-fabricated machines which were received from the manufacturers were field-tested in various parts of the Philippines and were sent to cooperating organizations in other countries for evaluation and industrial extension.

If no major problems were encountered with the custom-fabricated machines, the manufacturers were allowed to start commercial production. At all stages, manufacturers were encouraged to incorporate freely their own ideas, design changes and improvements in the machine to adapt them to their production facilities and to gain some competitive advantages in their machine. This successful strategy for introducing new IRRI-developed machines to manufacturers is now the standard operating procedure for releasing all IRRI machinery designs. The relatively small capital required to purchase a few machines has played a significant role in attracting the manufacturers to produce IRRI machines and in minimizing their risks. After the machines are made available commercially, however, farmer acceptance depends on the machine's appropriateness to

to meet his needs at an acceptable price as well as the quality controls, sales efforts and service provided by the manufacturer.

The limited resources of the program precluded the organizing of any independent international effort for commercializing the machines in countries other than the Philippines. Cooperative linkages were developed through subcontract arrangements in nine other Asian countries with organizations that have similar interests to evaluate and extend the appropriate agricultural mechanization technology in their respective countries (Appendix III). Under the subcontract programs, the Institute provided prototypes of those machines which were commercially successful in the Philippines and a modest amount of funding for hiring personnel. The subcontractor's responsibility was to evaluate and adapt the machines for local conditions and to encourage local companies to produce the machines commercially. The engineers employed by the subcontractors were given short training at the Institute to familiarize them with the full range of machines available from the program and the production techniques used by the manufacturers in the Philippines. A total of 20 engineers were trained (Appendix IV) under this cooperative program. Many of the trained engineers provided an excellent link between the core machinery development program at the Institute and the subcontractors and were highly instrumental in initiating local production of some of the IRRI machines. A few manufacturers outside the Philippines have become interested in the program and are now beginning to send their engineers at their own expense for training at IRRI.

Considerable experience has been gained in encouraging the local production of IRRI machines in other countries through the subcontract approach. The productivity of the various subcontractors varied widely and depended mostly on the type of organization and the interest of the engineers working on the subcontract project. Because of the industrial nature of this activity, most cooperating subcontractors were non-academic institutions. It was felt that universities in Asia do not have sufficient contacts with local manufacturing firms and the chances for commercialization through academic institutions are not promising. Many of the subcontractors were government machinery research and testing institutions or commercial firms engaged in the production of agricultural machinery or related products.

The agricultural machinery research and testing institutions in the public sector are primarily interested in testing and evaluating machines and are not sufficiently motivated in the commercialization of farm machines. Most industrial research institutions in the LDC provide service-type assistance and are not equipped to provide innovative product

development assistance to local industry. Private manufacturers are mostly interested in one or two machines which suit their own production plans and are reluctant to devote extension efforts on other machines.

Since agricultural mechanization efforts necessarily involve two different types of activities -- the utilization and the local manufacture of machines -- the problems of introducing new mechanization technology are rather complex. On the one hand, most agricultural organizations in the developing countries are concerned only with the use of the machines and do not have expertise to offer manufacturing assistance. On the other hand, industrial organizations can manage the manufacturing aspects but do not have the capability to work on the utilization of agricultural machines. Assessment of mechanization technology and manufacture of appropriate agricultural machines require a well coordinated approach which the existing research organizations in the public sector are not able to provide in the developing countries. Such a program may best be implemented through a dual approach -- work with the agricultural machinery research institutions in the testing and evaluation area and then work directly with a few selected manufacturers for commercialization of specific machine in the country. The program's experience in the Philippines, Thailand and Vietnam tends to support such a dual strategy for successful commercialization of the machines and the program is now being modified accordingly.

Manufacturing developments

Progress in the Philippines has been encouraging. A sizeable number of small farm equipment manufacturers has been established to produce IRRI-developed machines. Eighteen companies are now manufacturing IRRI-designed machines in the Philippines. Production of some IRRI machines has also started in ten other countries. As of December 31, 1974, over 22,000 agricultural machines have been produced by the cooperating manufacturers in Asia. The demand for the power weeder, power tiller, and axial flow thresher increased steadily every year since their commercial introduction. Nearly half of the manufacturers of IRRI-developed machines were not producing any kind of agricultural machines previously. The remaining companies were either marketing imported farm machines or were manufacturing civil construction or rice processing equipment.

In the Philippines, a sizeable ancillary industry has developed to supply components to some of the larger firms producing IRRI-designed machines. The power tiller cage wheels, plows, harrow, and trailers

are produced by small metalworking shops and some production specialization is developing. The Institute is experimenting with a decentralized production approach and has entered into an agreement with one firm to produce only the power tiller transmission. The strategy is to provide the small metalworking firms located in the non-metropolitan areas a low-cost power transmission assembly, which requires a level of production technology that is beyond their present capabilities. The small firms can produce all the remaining components of the tiller and can market it in their neighboring areas. A decentralized production approach may lower the price of power tillers and may create more employment away from the major cities.

In the Philippines, the three larger companies, the Marsteel Corporation (fig. 36), the IGRI Industrial Sales Corporation, and the Durasteel Industries Corporation (fig.37), have developed tools, dies, jigs and fixtures to produce the power tiller and the axial flow thresher in larger quantities. The original IRRI power tiller transmission casing, which was designed for forming by manual methods, has been replaced by a stamped casing which permits large-volume production. The first two companies have replaced the primary reduction chains used in the original tiller with a spur gear transmission and are now developing steering clutches for their machines. These changes will undoubtedly improve the machine and permit more uniform production. The potential impact of these developments on the sale of power tillers produced by smaller firms which may find it difficult to incorporate these improvements has yet to be assessed.

Three Philippine companies, Oberly & Company (fig. 38), Kaunlaran Industrial Shop (fig. 39), and C&B Crafts (Fig. 40), have introduced major improvements on the axial flow thresher -- the installation of oscillating screens for better grain cleaning and a recycling arrangement for semi-threshed material. The companies in the Philippines which manufacture commercially IRRI-developed agricultural machines are listed in Appendix V.

Manufacture of IRRI machines in other countries has started with the production of either the power tiller or the axial flow thresher. These machines are now being manufactured in ten countries in Asia. Some firms in Ghana, West Africa, and Ecuador have also begun manufacturing the axial flow thresher.

In India one firm has introduced a number of changes in the axial flow thresher and is marketing it for Rs 5,500 (US$733) without the engine (fig. 41). This company is now modifying the axial flow thresher

for wheat since there is a large market for wheat threshers in India. In many countries tenderized wheat straw is used as cattle feed and their modified axial flow thresher can tenderize straw very well. The adaptation of this thresher for use on wheat opens a large market in almost all developing countries with an arid or semi-arid agriculture.

In Indonesia, one company has fabricated the axial flow thresher and is currently modifying it to handle the panicle-harvested paddy varieties which are difficult to thresh manually. Another company is fabricating a prototype power tiller. A large fertilizer manufacturer plans to produce IRRI machines in Indonesia. Five engineers from this company have visited IRRI and three have completed a two-week training course in the use and production of IRRI machines.

In Japan the market for the power weeder continues to expand. The manufacturer which has been producing this machine since 1971 has developed a wide range of attachments for weeding and cultivation. Two other Japanese companies are now planning to start production of a similar machine in Japan.

In Pakistan the axial flow thresher is being produced by Messrs. Habib Industries, Karachi, and is sold for paddy threshing in the Sind state. The company plans to adapt it for wheat and is now modifying their machine for wheat threshing. IRRI had furnished technical assistance and guidance for these modifications.

In Vietnam three manufacturers, the Vietnam Agricultural Machinery Company, the Than Nong Cong Ty, and the Binh-Duc Cong Ty, are producing the power tiller and the axial flow thresher. Manufacturer response on the IRRI machines was most encouraging in Vietnam and the information received before the end of the war indicated that many additional companies were beginning to produce IRRI machines.

In Sri Lanka, the power tiller is being produced by the Nugegoda Medium-Scale Engineering Cooperative Society, an industrial cooperative society of small machine shops, which has 22 members. The parts of the power tiller are produced by different machine shops and then assembled by the cooperative. The Sri Lanka Government has recently organized over 1,000 light industrial cooperatives and if this initial experiment proves successful, more cooperatives will soon be producing IRRI machines in Sri Lanka.

In Taiwan, one firm is producing the batch type dryer and is marketing it as the "IRRI/TARI Dryer". The Taiwan Agricultural Research

Institute (TARI) was the subcontractor on this project and has been responsible for introducing this machine in Taiwan.

In Thailand two manufacturers -- J-Charoenchai in Ayudhaya and the Anusarn Co. in Chiengmai -- are producing the IRRI tiller. Three manufacturers have started to produce axial flow threshers in which manufacturer interest is quite high.

Program implications

Increased production of the IRRI machines have brought about industrial employment in those countries where the machines are produced. As of December 31, 1974 seven manufacturers in the Philippines have reported hiring more than 700 additional workers directly for the manufacturing operation. These jobs were created at an additional capital investment of only US$200 per person. This activity has created additional jobs in production-related activities of material procurement, management, and marketing and servicing operations for which no reliable statistics are available. Many IRRI machines are being used in contract operations, creating employment at the farm level.

During the early stages, most Philippine manufacturers of IRRI-developed machines were located in the Greater Manila area, but as these machines became popular, many firms in the smaller towns have started production. Thus, decentralized production is now creating employment in the semi-urban areas. The Institute encourages the production of IRRI-developed machines in small towns by limiting the release of the machinery designs to only a few manufacturers in the Greater Manila area.

The local production of IRRI-developed machines in the Philippines effected some changes in public policies. The tariff structure of small air-cooled engines was reduced by the Government. Increased tariff was levied on the import of power tillers to encourage local manufacturers. The IRRI power tiller and the axial flow thresher were included in the list of machines approved for the International Bank for Reconstruction and Development (IBRD) loan financing and local banks are now providing loans to farmers for purchasing these machines. The changes occurred after some of the IRRI-developed machines gained local acceptance and the Philippine Government recognized the need to encourage local farm machinery manufacturing industry. No representation was made by IRRI to the Philippine Government for these policy changes.

Although the program was initially designed to meet the needs of the intermdiate-size farm holdings of 2 to 10 hectares, the IRRI-developed machines have been found to benefit the small farmers with land holdings of less than 2 hectares through the use of such machines for contract operations. The power tiller and the axial flow thresher are being widely used for contract operations and provide much-needed land preparation and threshing services through custom operation services. The contract operator makes modern mechanization technology available to the smallest farmers who cannot afford these machines.

The marketing of farm machines in the Philippines is changing rapidly. The larger IRRI-cooperating firms have their own sales organizations with a dealership network in the major rice-producing areas of the country. In the case of the smaller manufacturers, initially the proprietor handles the sales personally and usually markets the machines directly to farmers in the neighboring areas or in a few selected areas. As sales increase the small manufacturers start to market through independent farm equipment dealers or to develop their own sales organizations. Because of the increased farm machinery sales, new independent farm farm equipment dealerships are being established in most small towns and a national network of independent machinery dealers is emerging.

The project has been instrumental to some extent in stabilizing the prices of the smaller imported power tillers which often compete with the IRRI machines in the Philippines. One well known make of 4.5-hp tiller is now sold at a rather attractive price in the Philippines and competes quite well with the 8-hp IRRI power tiller. Such competition with imported machines provides an incentive for improvement in the locally produced machines.

Local production of agricultural machines has resulted in considerable savings in foreign exchange. In most IRRI machines, engine, bearings, and chains are the only imported components, and they often cost less than 20 percent of the production cost of the machine. Some of the manufacturers of the IRRI machines in the Philippines have started to export their machines to Malaysia and Indonesia and are looking forward to an increasing export market.

Conclusions

The experience gained from the IRRI machinery development program has many important implications on the transfer of technology and industrial development in the developing countries. The program has demonstrated that it is possible to develop an indigenous industry in the

developing countries through carefully tailored industrial R&D programs within a public institution. The development of low-cost, demand-oriented products which could be manufactured economically with locally available production methods is critically needed by the small-scale industries sector. The program was sharply focused towards specific R&D needs of the small metalworking firms and it has assisted these manufacturers directly.

The program's strategy was to establish an indigenous farm equipment industry rather than to conduct a wide variety of research on agricultural mechanization. The program was highly market-oriented, considering both the needs of the farmers and the manufacturers. The program's leadership continually maintained the focus on hardware development. The program highlights the importance of pre-project evaluation and market studies before initiating a product development program. Factors that bear heavily on the acceptance of new technology -- the end-users' needs, production capabilities, the economic and the industrial capability of the society -- were considered in the product development process.

Many social scientists emphasize the socioeconomic objectives in the selection of technology to the neglect of the important market factors. It would be unrealistic to introduce any technology, no matter how effective it may seem to meet the social objectives, if the technology is not commercially feasible. The popular socioeconomic criteria of employment generation, income and wealth distribution, and local material and skill utilization are all important, but must be kept in perspective of the essential market factors. The significant role that market signals play in the assessment, development, and transfer of a technology were well demonstrated by this program. Whatever social and economic benefits have accrued from this program occurred as a direct result of the commercial viability of the new technology that was introduced.

The program has demonstrated that agricultural mechanization, based on the Japanese pattern of individually owned small farm machines, can be successful in the developing countries if appropriate machines can be made available at a reasonable cost to the farmers. Indigenous production of farm machines is instrumental in lowering the cost of mechanization in the developing countries if machines are developed to take advantage of the existing low-volume production technology during manufacture. There is considerable entrepreneurial skill available in the developing countries that can be tapped through technical assistance in the critical areas which exceed the present means of the entrepreneurs.

While originally most cooperating metalworking firms only incorporated minor improvements in the machines, when competition developed, many firms made substantial improvements and some developed fairly sophisticated machines which are nearly comparable to the imported equipment from developed countries. The provision of simple machinery designs helped local firms to overcome their hesitancy to attempt to produce machines that could compete with imported equipment. The results obtained with the farm machinery sector indicates that this selective product development approach for industrial assistance offers considerable potential for the rapid development of small-scale industries for producing many other utility products in the developing countries.

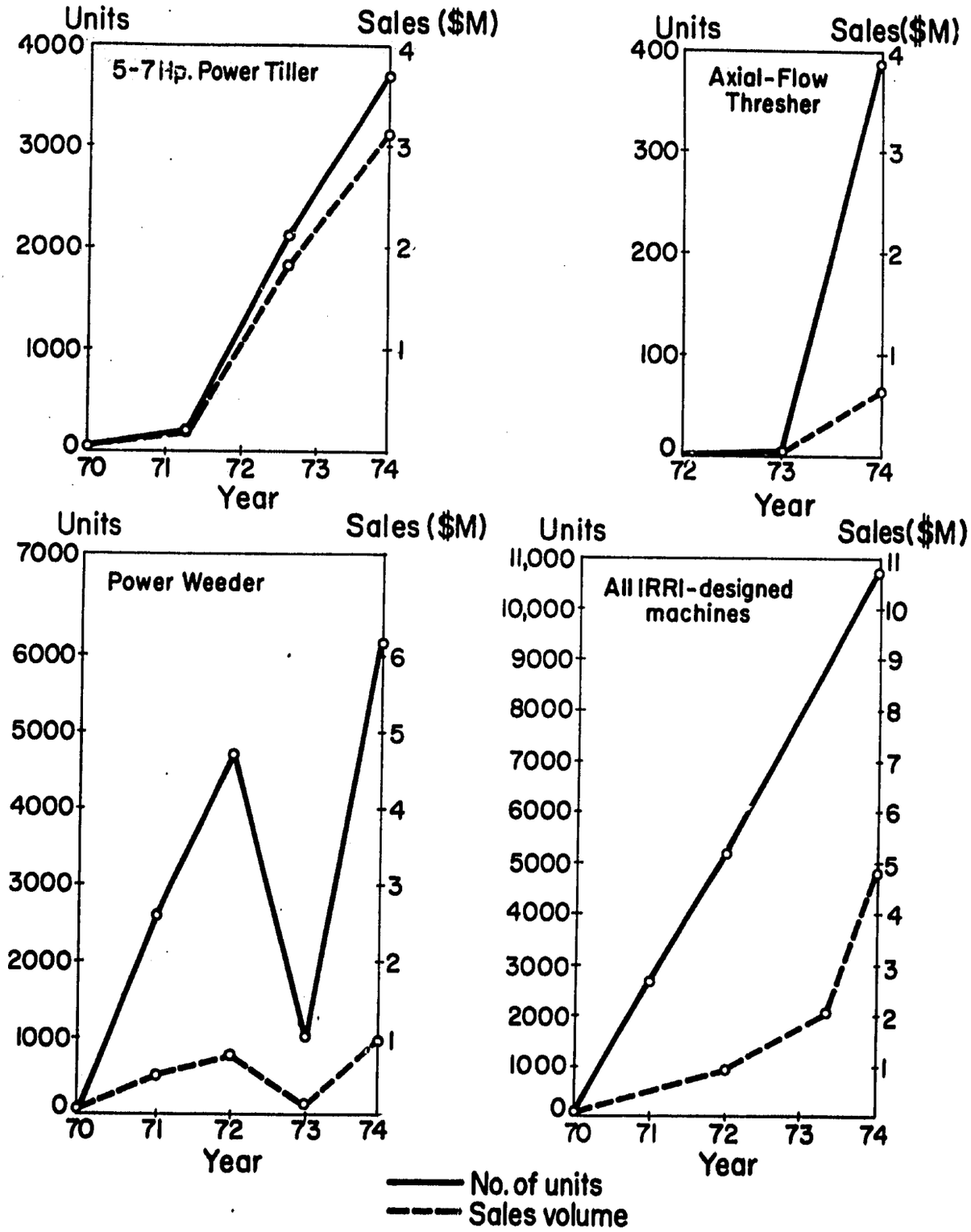


Fig. 1. Manufacturers' report - Production of IRRI-designed machines

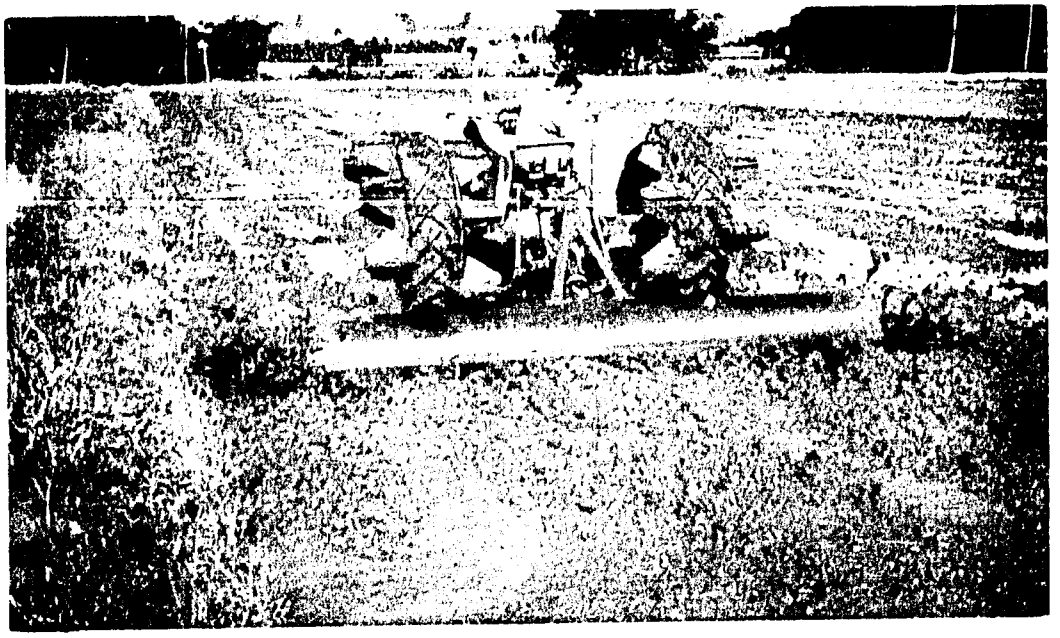


Fig. 2 3-m wide rotary tiller.

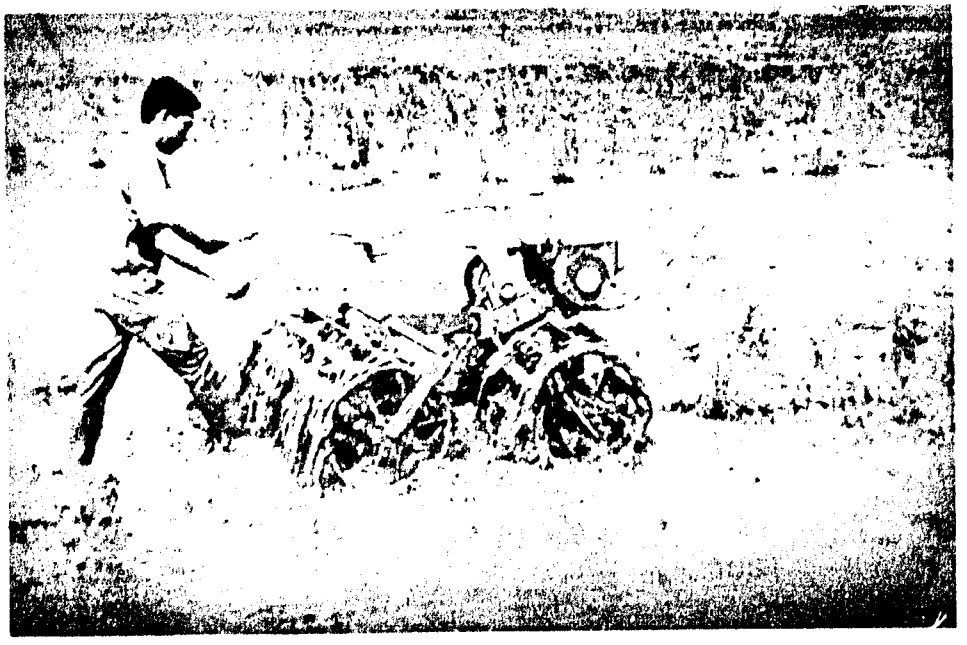


Fig. 3 Rotary harrow for small tractors.

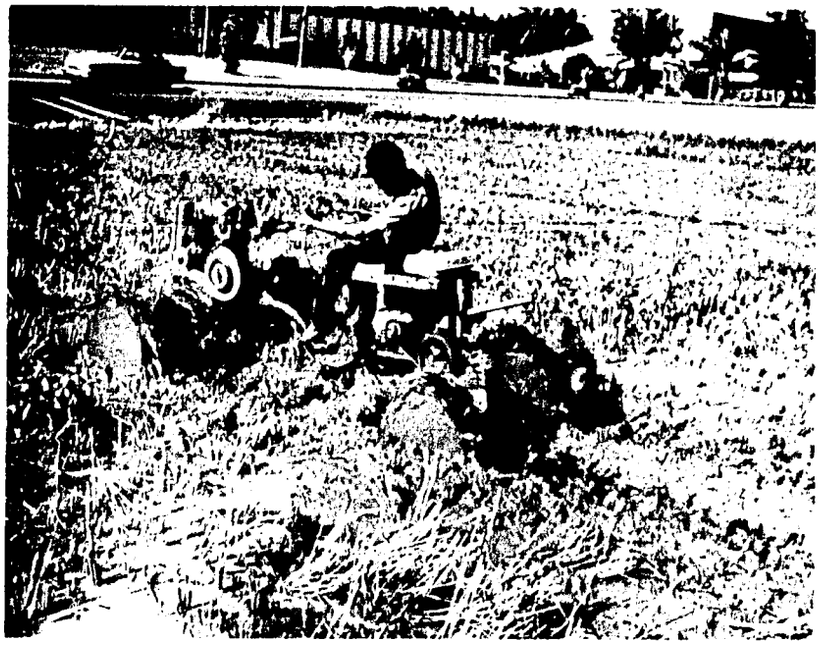


Fig. 4 Differential slip tiller.

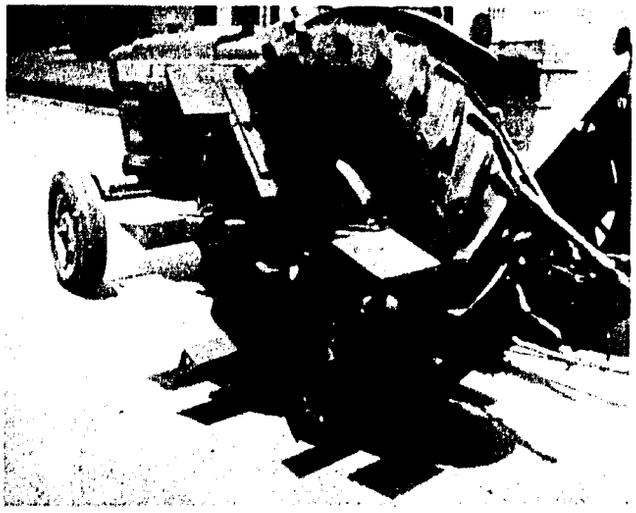


Fig. 5 Extendible-blade lug wheel.

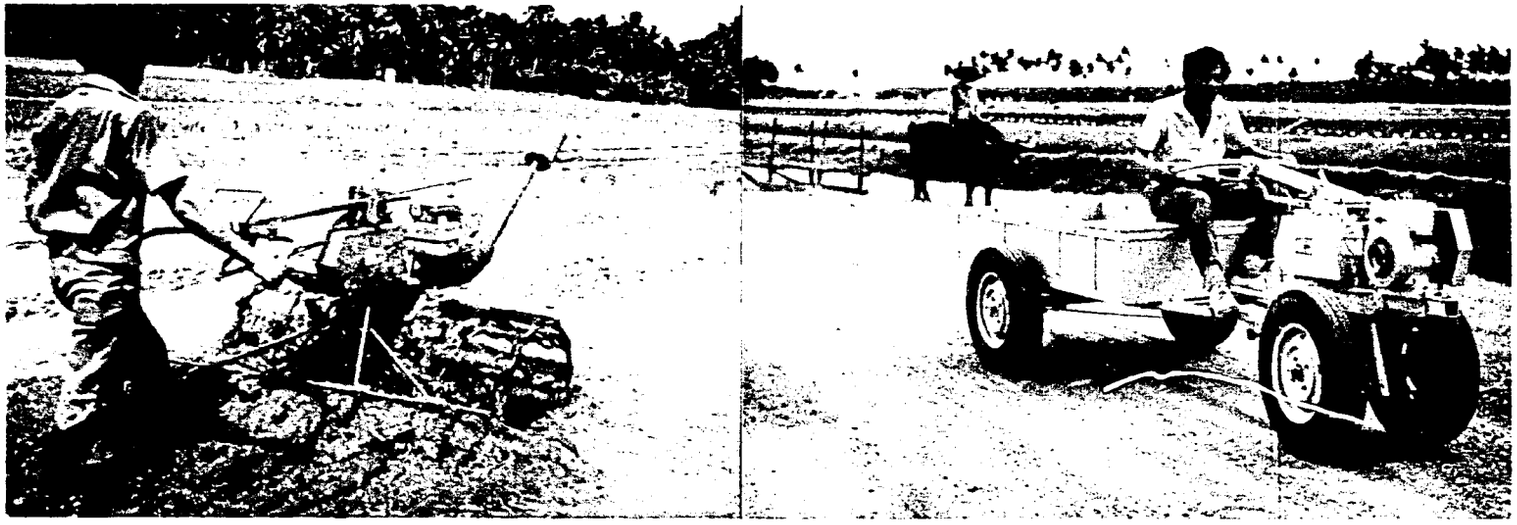


Fig. 6 5- to 7-hp tiller for land preparation and transport.

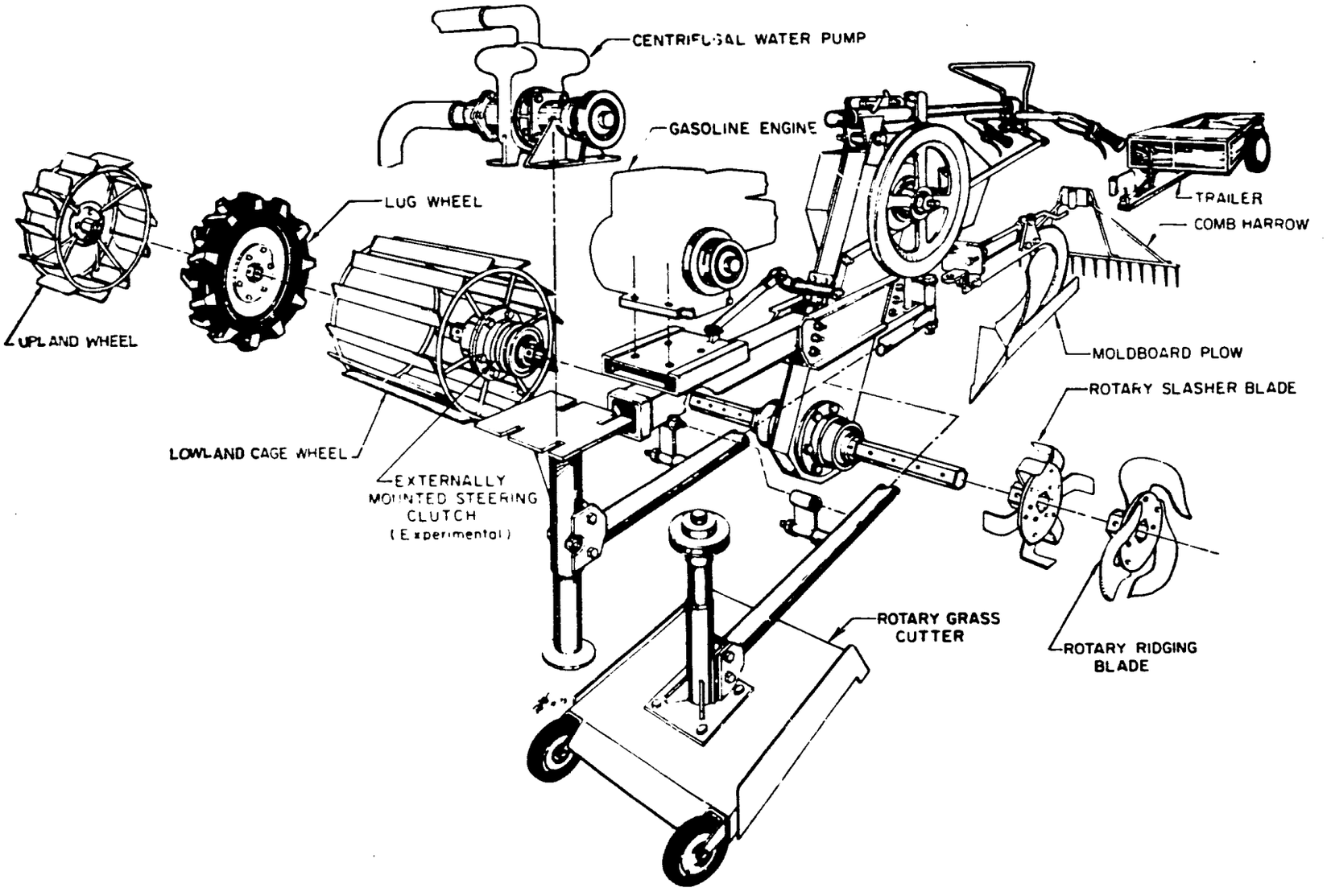


Fig. 6A 5- to 7-hp tiller attachments.

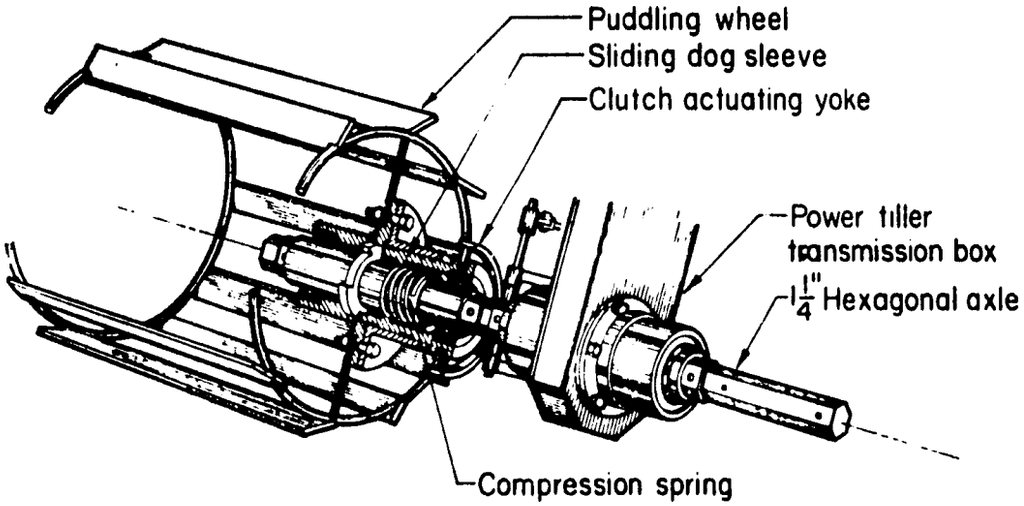


Fig. 7 5- to 7-hp tiller steering clutches.

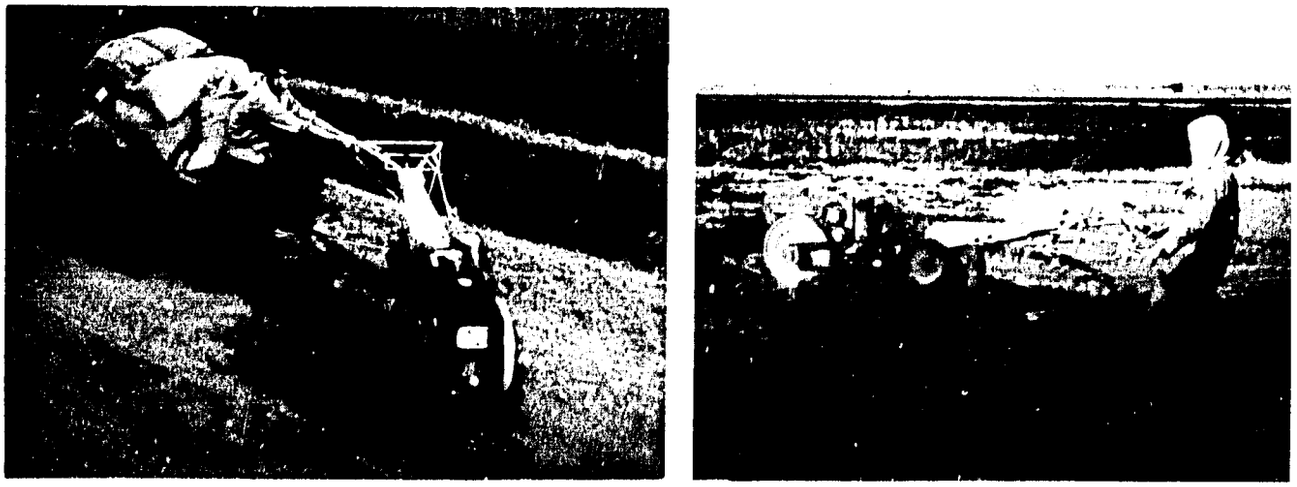


Fig. 8 8- to 14-hp tiller for transport and land preparation.

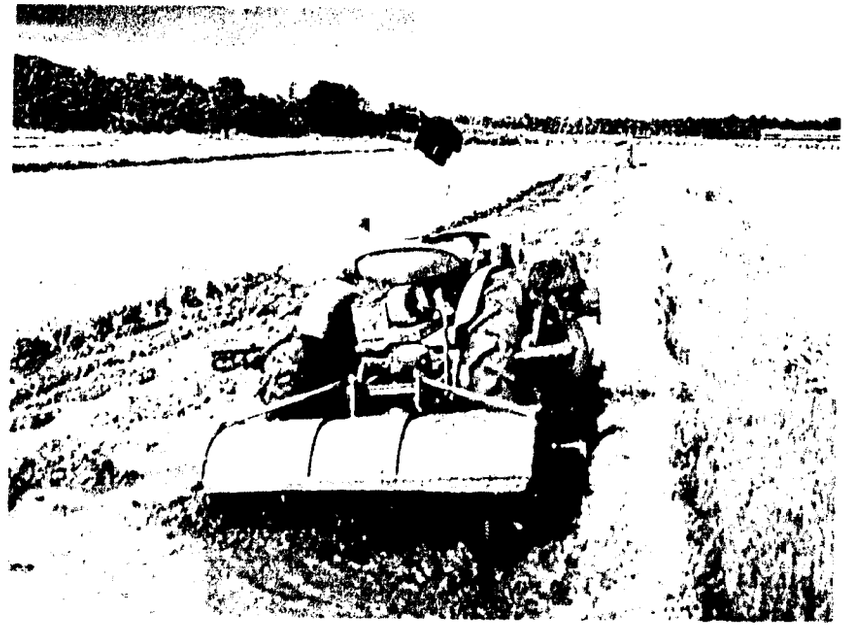


Fig. 9 Four-wheel 15-hp riding tractor.

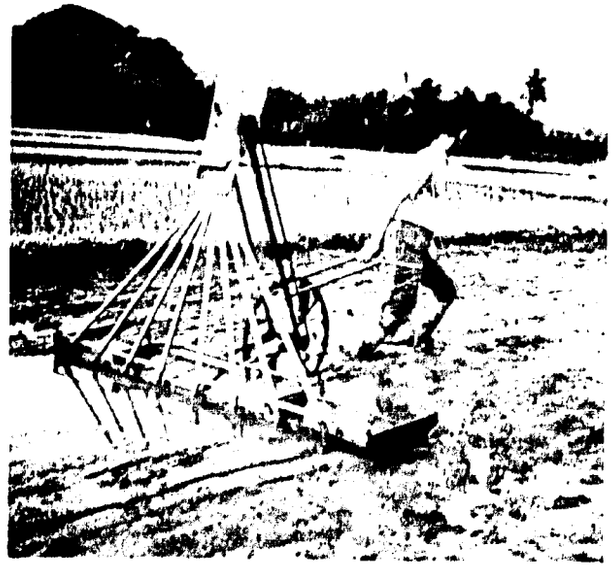


Fig. 10 Single-hopper paddy seeder.

Fig. 11 Multihopper paddy seeder.

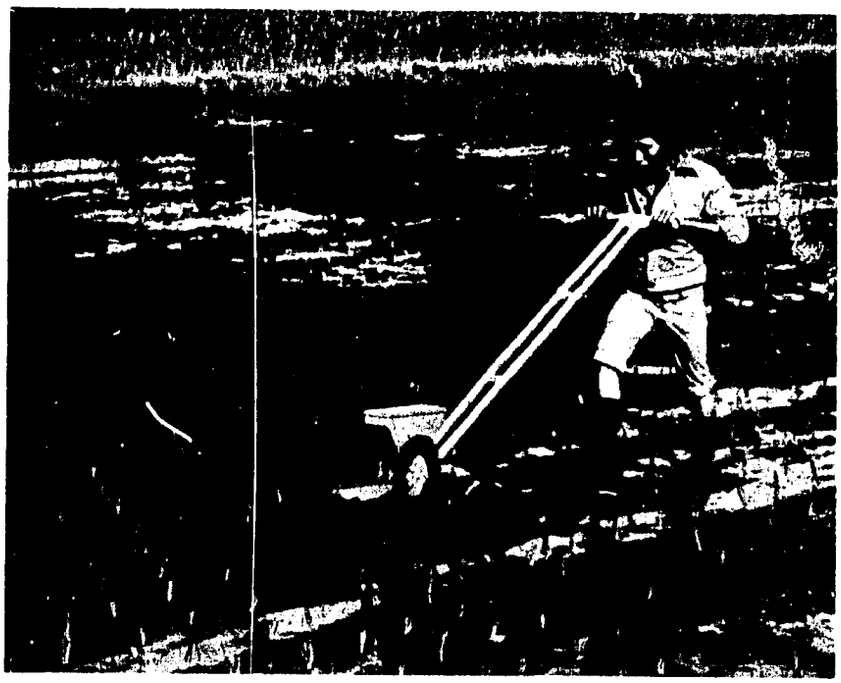


Fig. 12 Deep-placement granular fertilizer applicator.

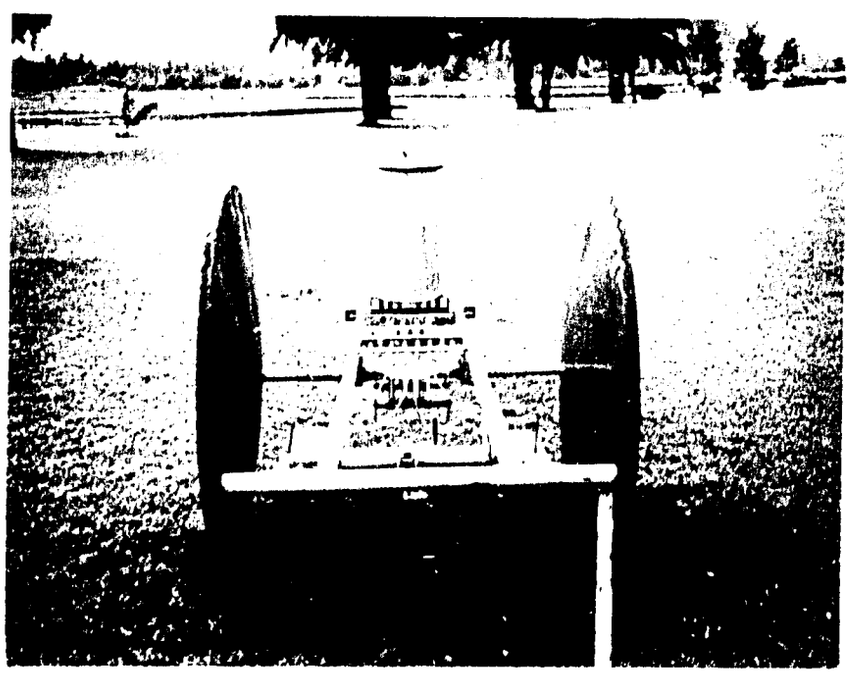


Fig. 13 Deep-placement liquid fertilizer applicator.

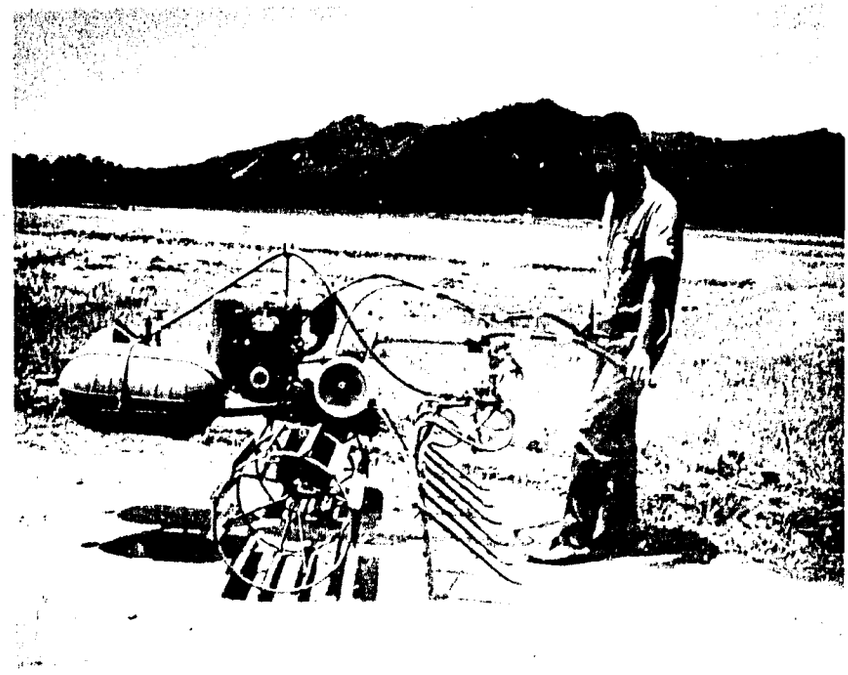


Fig. 14 Anhydrous ammonia applicator.

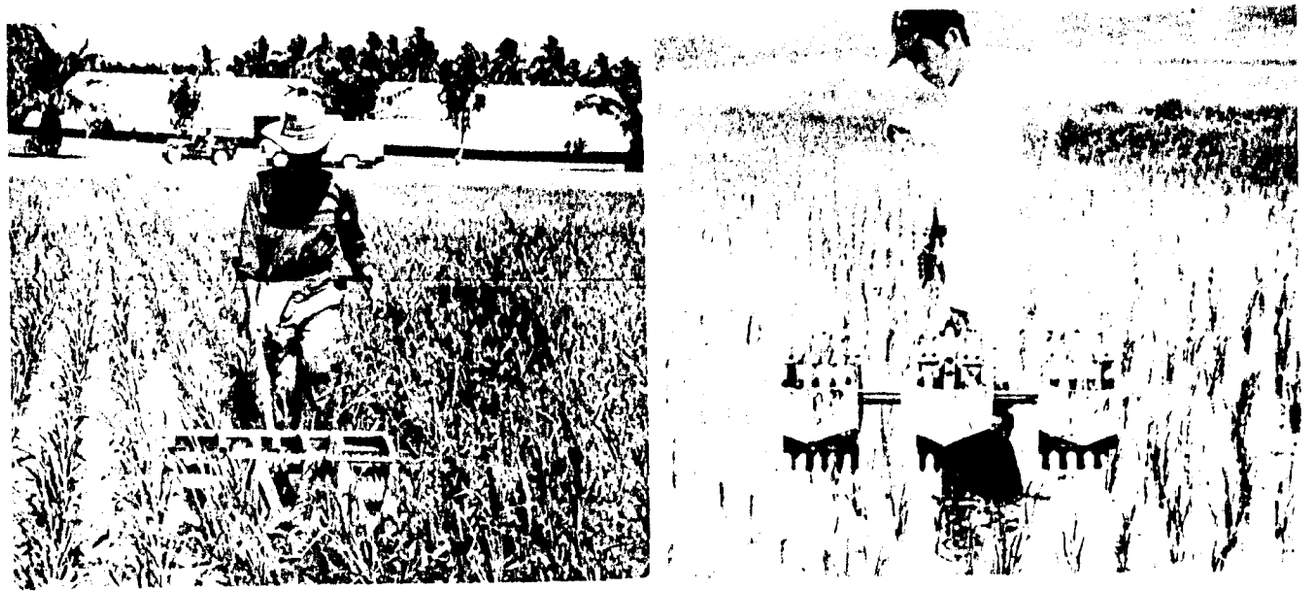


Fig. 15A Three-row power weeder; IRRI prototype and Japanese company version.

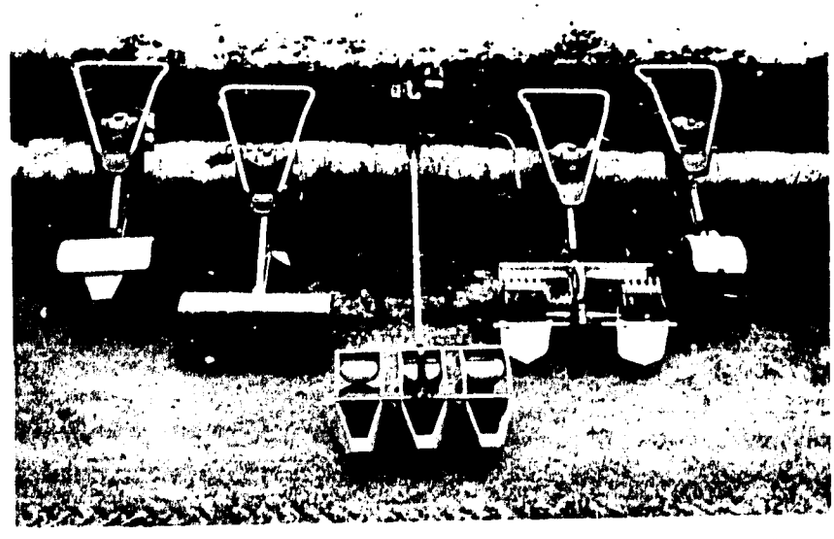


Fig. 15B Attachments developed by Ohtake Company for power weeder (IRRI prototype in foreground).

Fig. 16 Contact herbicide applicator.

Fig. 17 Stripper harvester.

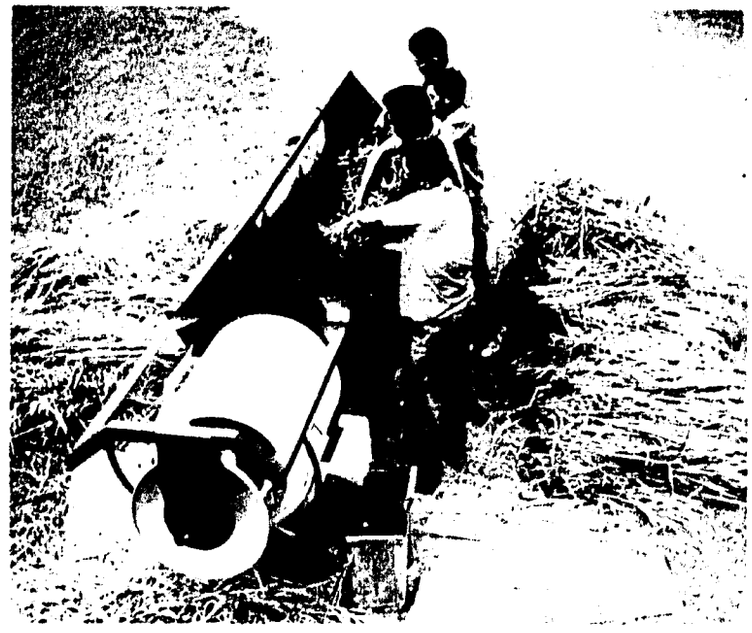


Fig. 18 Drum-type paddy thresher.

Fig. 19 Table-type paddy thresher.

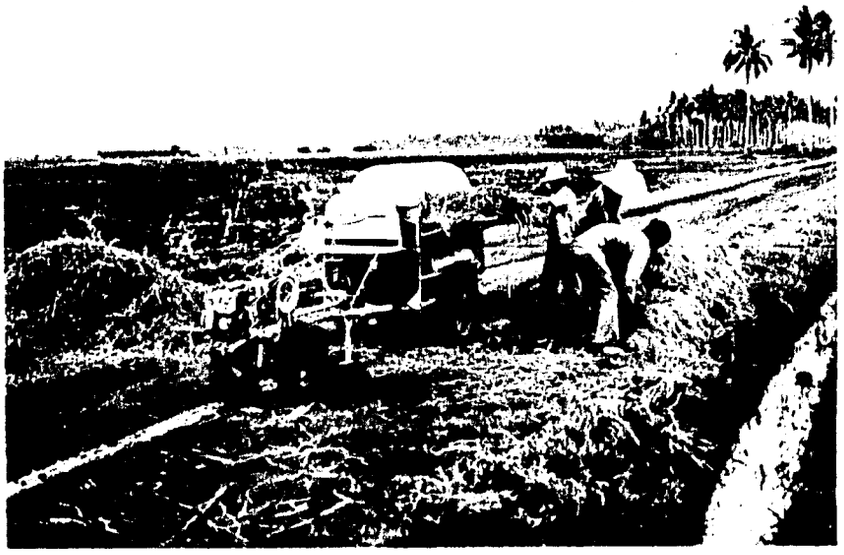


Fig. 20 Axial flow thresher.

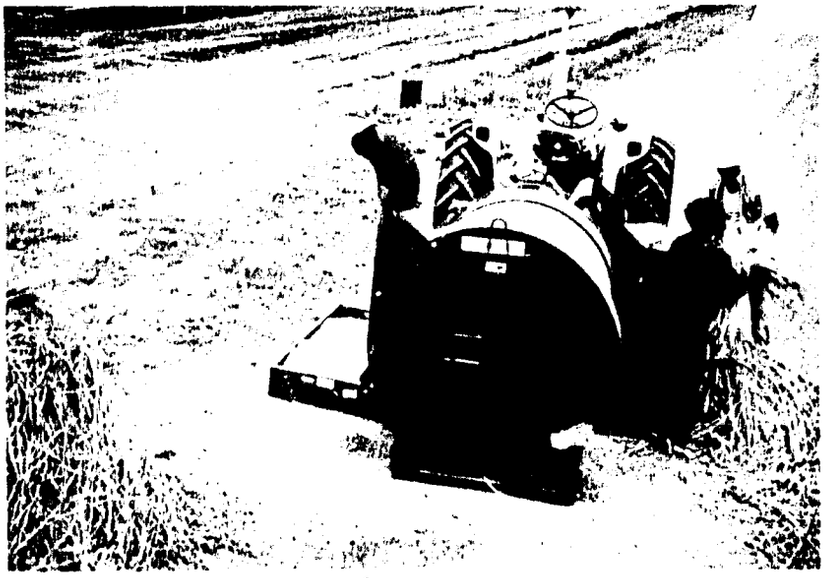


Fig. 21 PTO-driven thresher.

Fig. 22 Power grain cleaner.

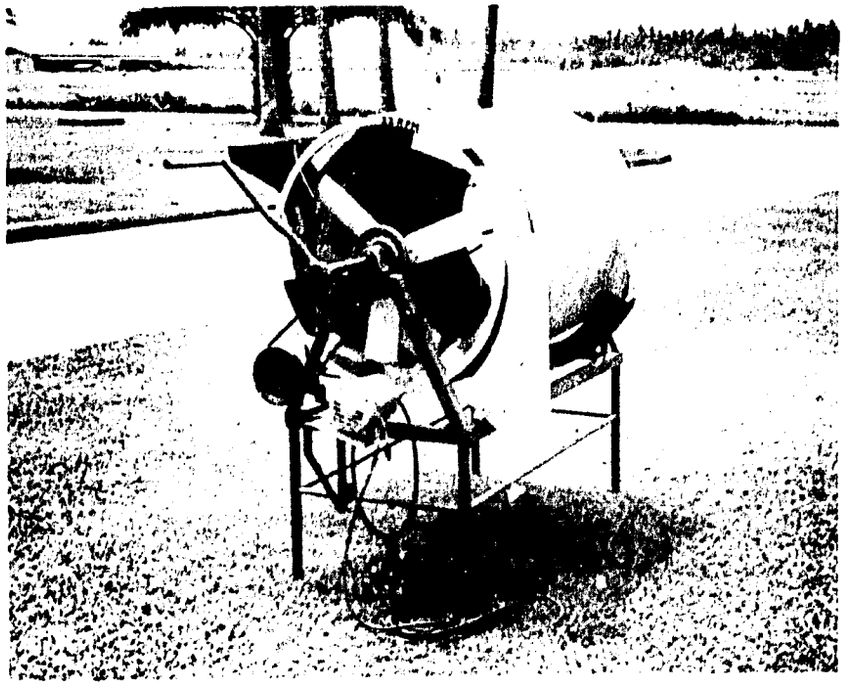


Fig. 23 Manual grain cleaner.

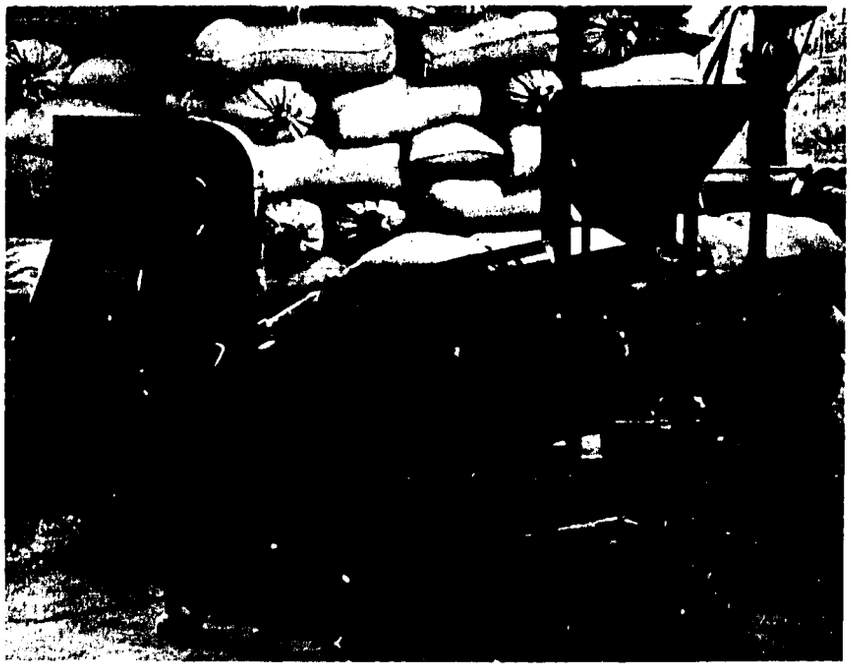


Fig. 24 Oscillating grain cleaner.

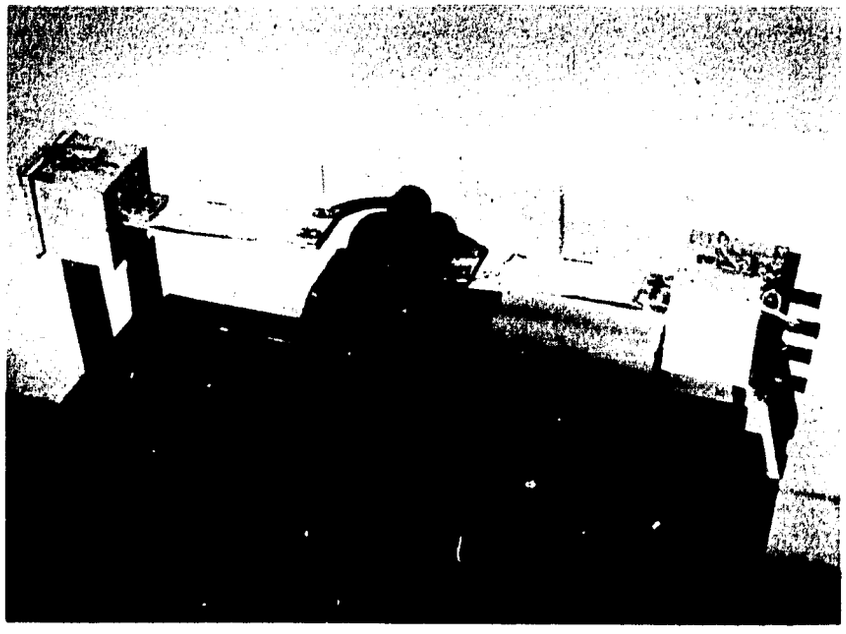


Fig. 25 Test tube miller.

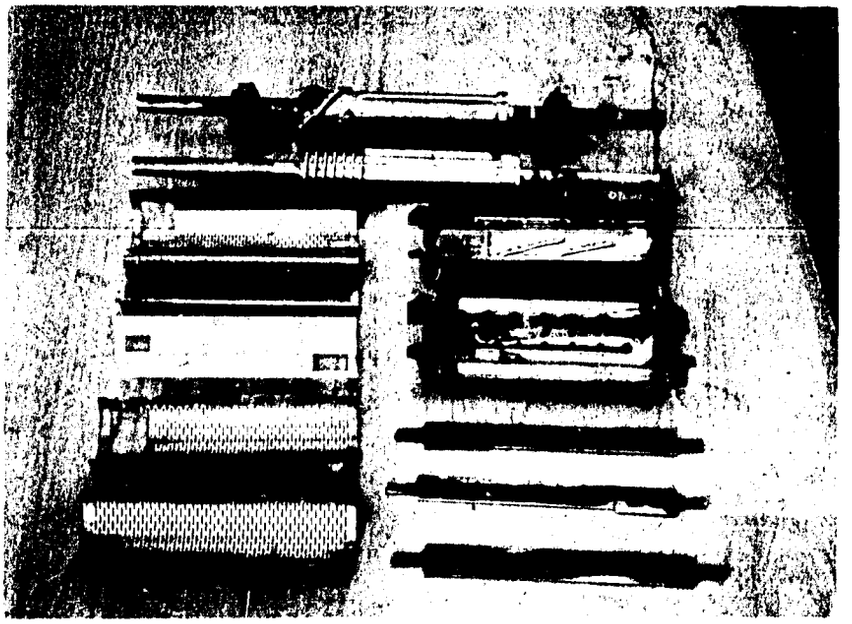


Fig. 26 Engleberg milling machine improvements.

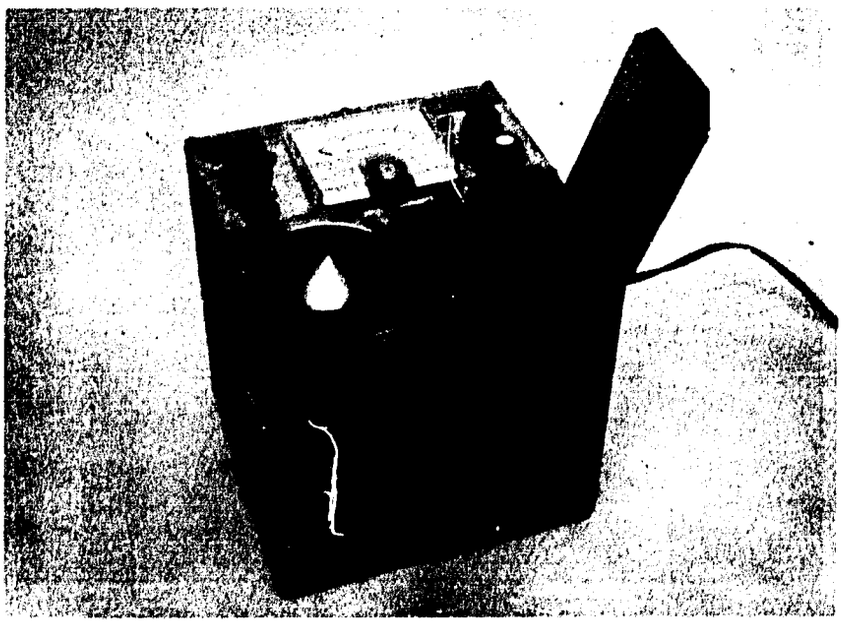


Fig. 27 Moisture meter.

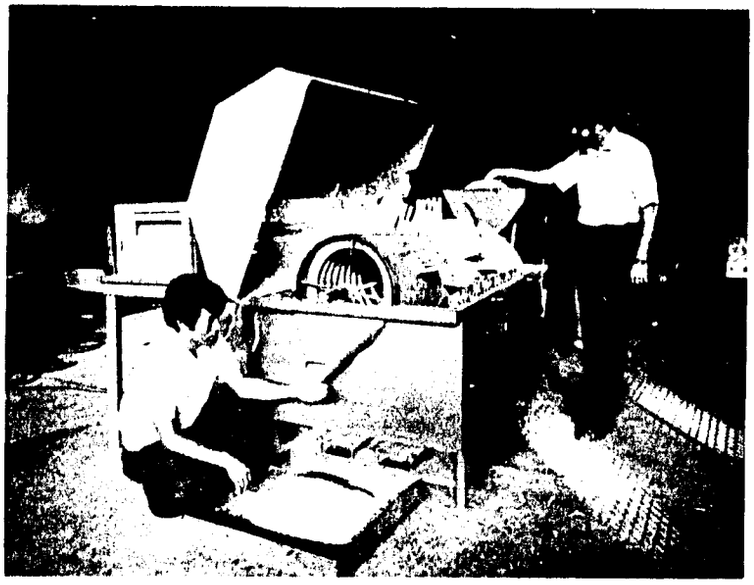


Fig. 28 Heated-sand parboiler.

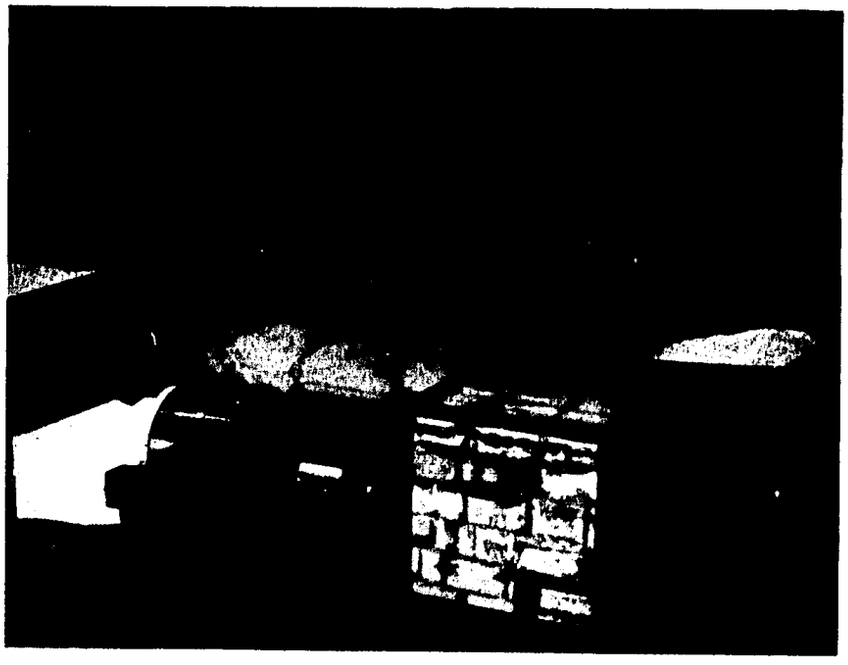


Fig. 29 Rice hull furnace for batch dryer.

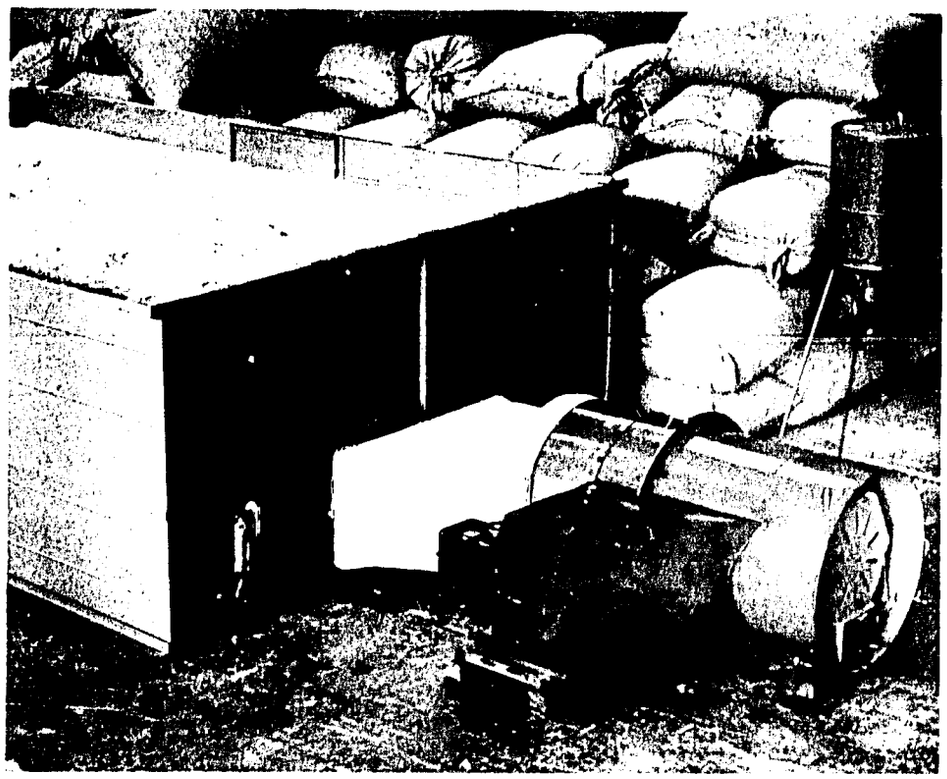


Fig. 30 Batch-type dryer with kerosene burner.

Fig. 31 Lowlift bellows pump.

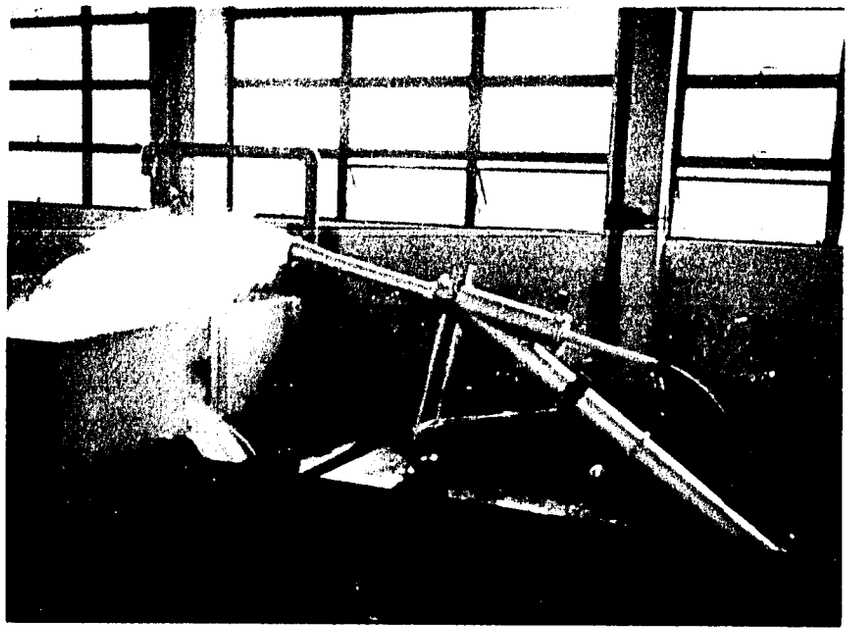


Fig. 32 Jet flow pump attachment.

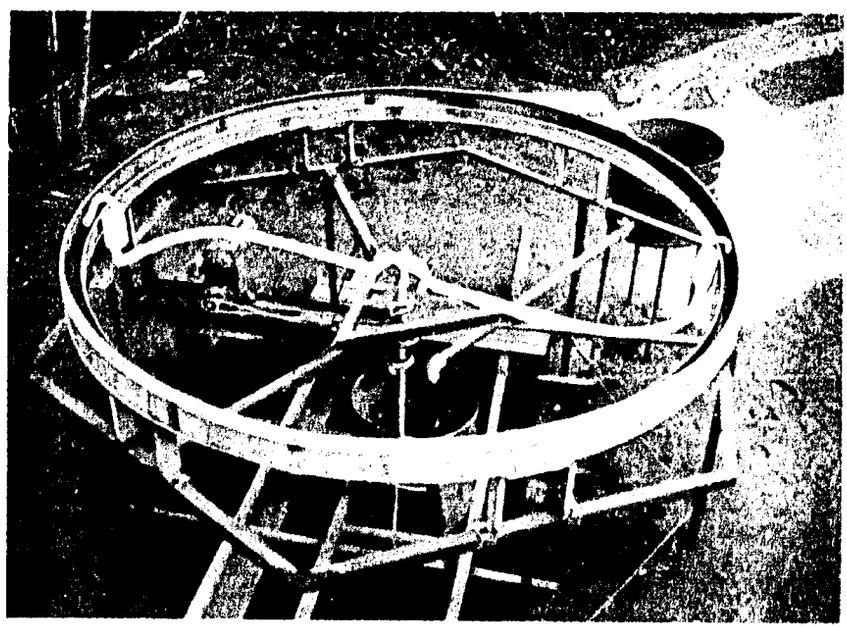


Fig. 33 Tubular pump.

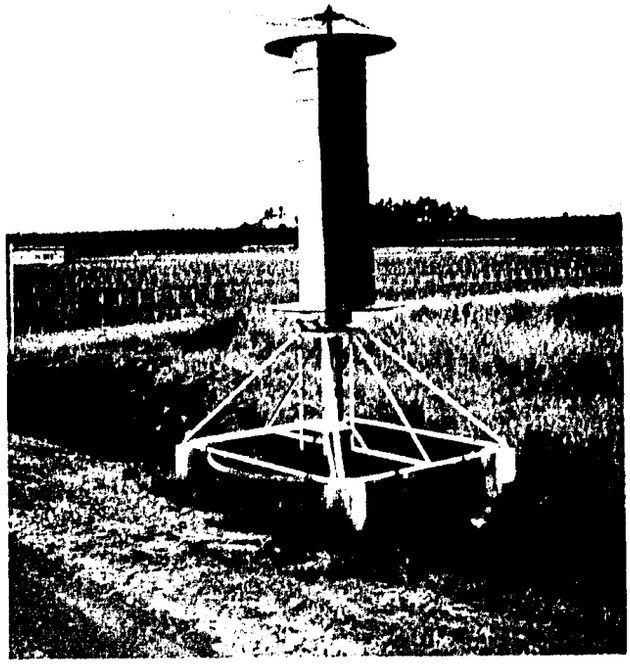


Fig. 34 Vertical-axis windmill.

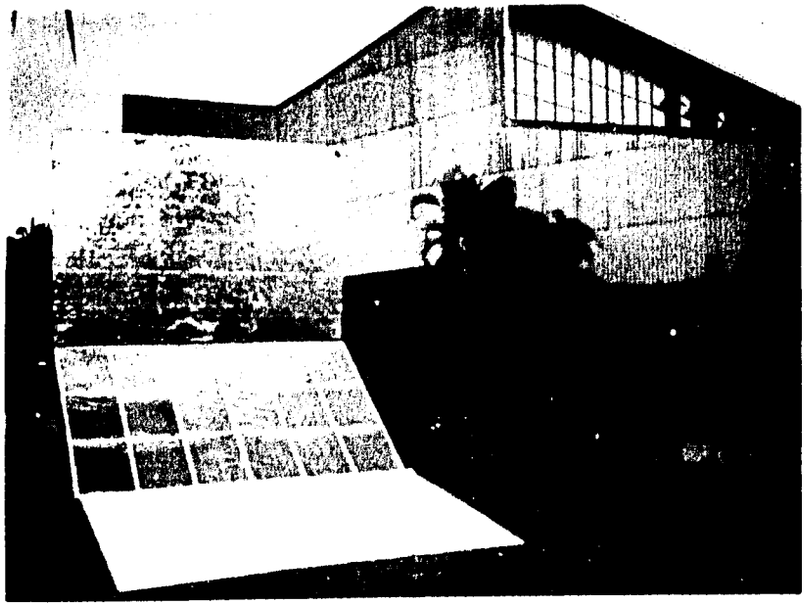


Fig. 35 Solar energy panel collector for batch dryer.

Fig. 36 Marsteel Corporation tiller production.

Fig. 37 Durasteel Industries Corporation production facilities.

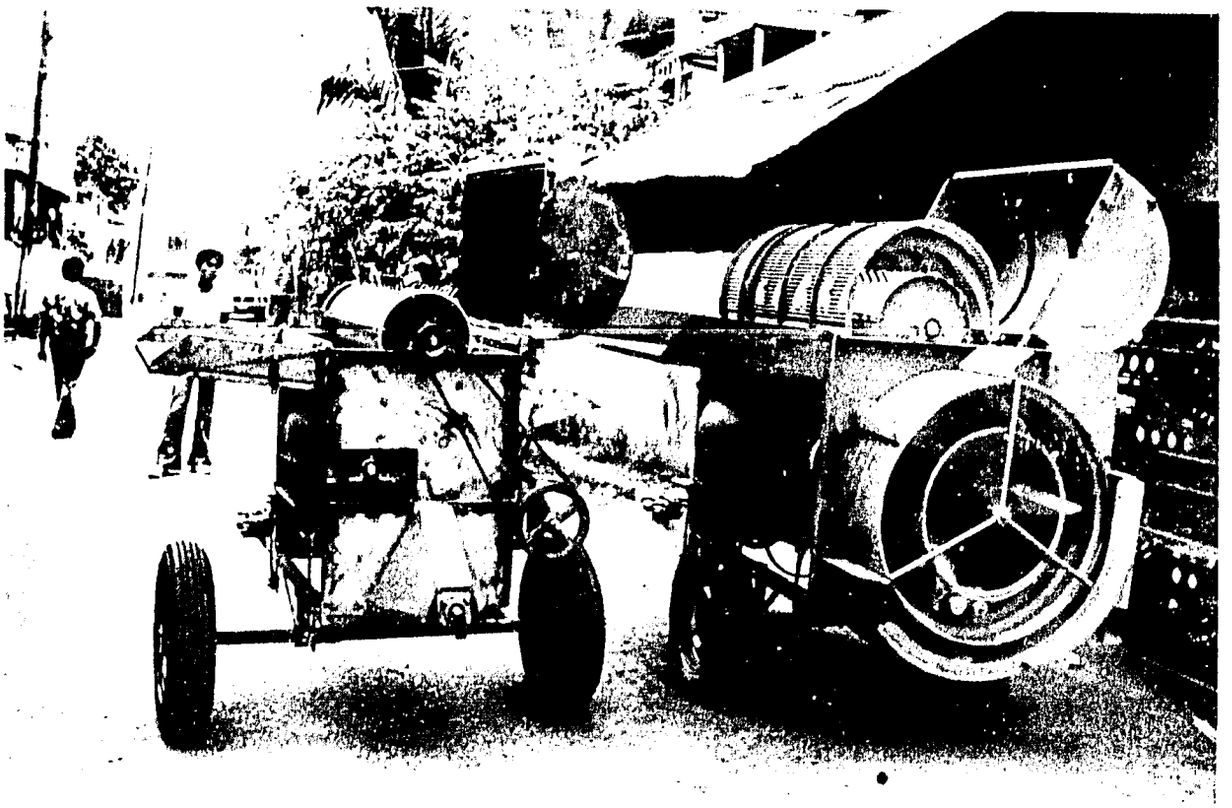


Fig. 38 Oberly & Company axial flow thresher.

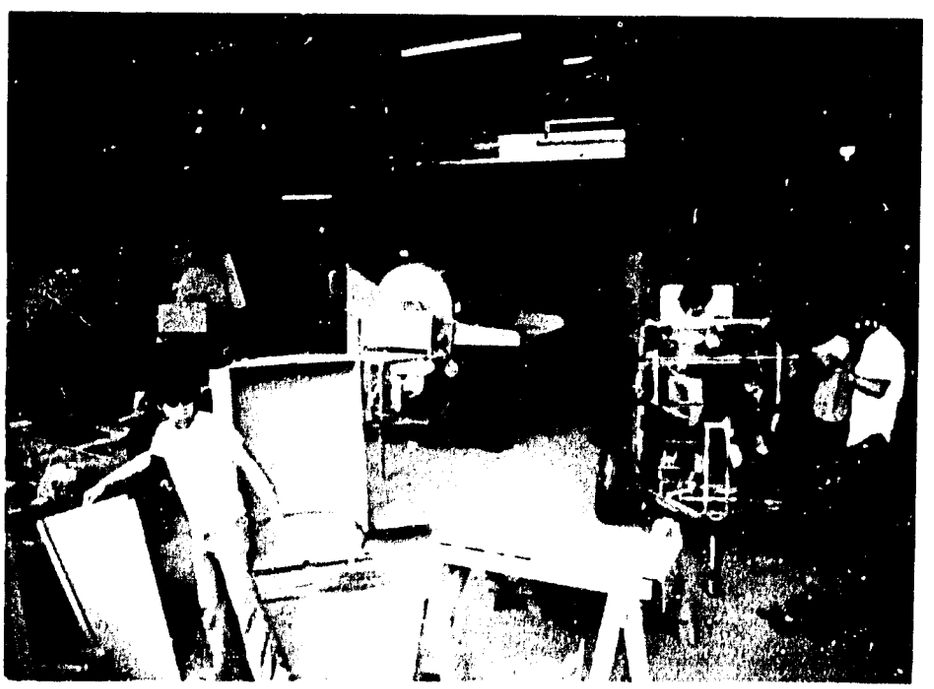


Fig. 39 Kaunlaran Industrial Shop thresher production.

Fig. 40 C&B Crafts thresher production.

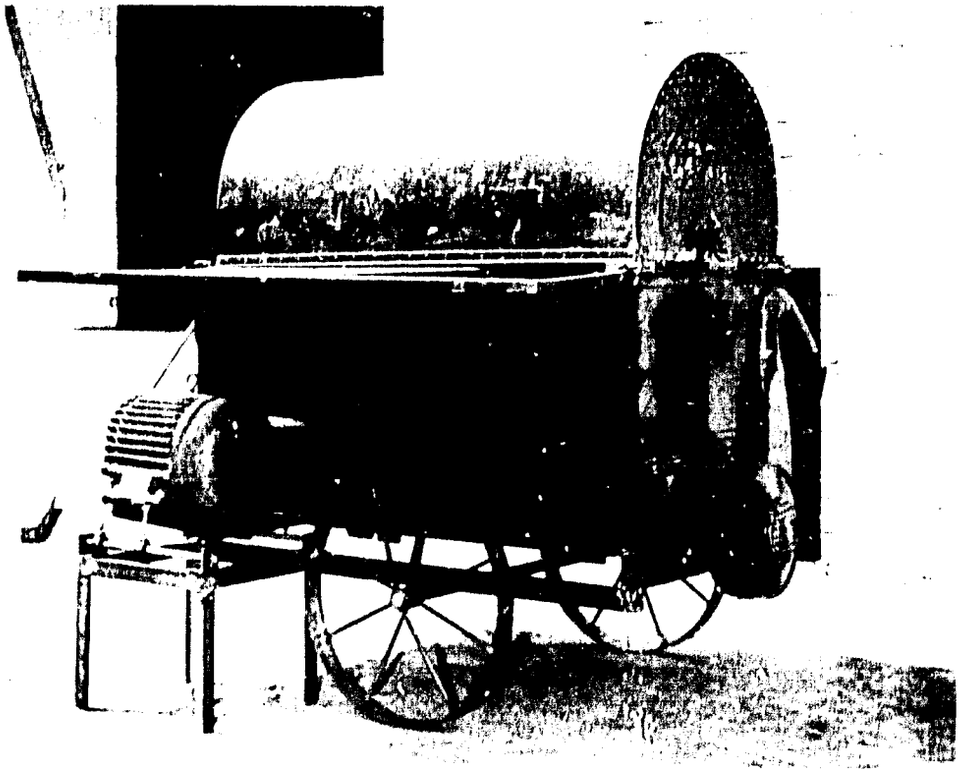


Fig. 41 American Spring & Pressing Works (India) version of **axial flow thresher.**

Appendix I. List of publications:

I. Field Operations, Machinery and Implements

A. Irrigation and irrigation equipment

1. Thongtawee, N. "Measurement of Evapotranspiration and Water Losses in Flooded Fields." Research project conducted under the supervision of Mr. L. Johnson.
2. Johnson, L. 1963. "The Relative Importance of Evaporation, Transpiration, Percolation and Seepage in Flooded Rice Culture." Seminar paper, April 25.
3. Johnson, L. 1965. "Traction Problems on Flooded Rice Soils." Paper presented at the Annual Meeting of the American Society of Agricultural Engineers, University of Georgia, June 20-23.
4. Johnson, L. 1965. "Irrigation of Rice." Saturday seminar paper, August 21.
5. Casem, E. 1966. "Soil Depth Effects on Rice under Lowland Conditions." Paper presented at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, May 6.
6. Johnson, L. 1967. "Water Use and Management." Saturday seminar paper, September 9.
7. Samuel, J., F. Nichols and S. E. Roy. 1974. "Design of a Centrifugal-Jet Pump Combination -- a New Approach for Rice Irrigation and Drainage." Paper presented at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, April.
8. Samuel, J. 1974. "Development of a Jet Flow Pump." Saturday seminar paper, August 24.
9. Samuel, J., G. Salazar and V. Cueno. 1974. "Lift Irrigation for Rice Production." Saturday seminar paper, August 24.
10. Samuel, J. 1974. "The Jet-Flow Pump." Handout sheet.

B. Tillage

1. Johnson, L. 1963. "Report on the Conference on Agricultural Engineering Aspects of Rice Production." International Rice Commission Newsletter. Vol. 7 No. 3, September (reprint).
2. Casem, E. 1965. "Tillage Studies at IRRI." Saturday seminar paper, August 26.
3. Johnson, L. 1967. "Land Preparation." Saturday seminar paper, September 2.
4. Cabanos, P. 1970. "Mobility Studies in Wetland." Saturday seminar paper, August 22.
5. Koike, M. 1970. "Dynamic Analysis of Rotary Tillage." Terminal research report.

6. Gee-Clough, D. 1974. "Characteristics of Single Lugs, Typical of Cage Wheel Lugs, in Wet and Dry Soils." Paper presented at the Annual Convention of the Philippines Society of Agricultural Engineers Manila, April.
7. Orcino, N. and B. Duff. 1974. "Experimental Results from Alternative Systems of Land Preparation." Saturday seminar paper, July 27.
8. Gee-Clough, D. and W. Chancellor. 1974. "Pull and Lift Characteristics of Single Lugs on Rigid Wheels in Wet Rice Soils." Paper presented at the 1974 Winter Meeting of the American Society of Agricultural Engineers, Chicago, December 10-13.

C. Fertilization

1. Manalo, A. 1966. "Anhydrous Ammonia Applications for Lowland Rice." Saturday seminar paper, April 23.
2. Casem, E. 1968. "Fertilizers and Fertilizer Applicators for Lowland Rice." Saturday seminar paper, September 14.
3. Navasero, N. 1974. "Equipment for Application of Agricultural Chemicals." Saturday seminar paper, August 31.
4. Navasero, N. 1975. "Deep-Placement Chemical Applicators for Lowland Rice." Paper presented at the 6th Annual Scientific Meeting of the Crop Science Society of the Philippines, Bacolod City, May 8-10, and at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, May 15-16.
5. Navasero, N. 1975. "Deep-Placement Chemical Applicators for Lowland Rice." Saturday seminar paper, July 19.

D. Planting

1. Reyes, R. 1966. "Plant Spacing in Direct Row-Seeded and Square-Hill Transplanted Rice." Paper presented at the Convention of the Philippine Society of Agricultural Engineers, Manila, May 6.
2. Navasero, N. 1969. "A Row Seeder for Lowland Rice Soils." Saturday seminar paper, September 6.
3. IRRI. 1970. "Fast Seeder." The IRRI Reporter, Vol. 6 No. 2.
4. Wikramanayake, V.E.A. 1971. "Direct Seeding and Transplanting of Rice." Paper presented at the International Rice Research Conference, IRRI, April 19-20.
5. Agricultural Engineering Dept. 1971. Row Seeder Manual.
6. Padolina, C. and F. Nichols. 1972. "Methods of Seeding and Transplanting of Rice." Saturday seminar paper, August 19.

E. Pest control.

1. Takenaga, T. 1971. "Technical Problems in Mechanization of Pest Control." Institute of Agricultural Machinery, Omiya, Japan (reprint).

F. Weeding

1. Navasero, N. 1968. "Mechanized Weeding in Wetland." Paper presented at a joint UPCA-IRRI seminar, September 30.
2. Navasero, N. and A. U. Khan. 1969. "Use of Mechanical Power for Rotary Weeding." Paper presented at the Convention of the Philippine Society of Agricultural Engineers, IRRI.
3. Navasero, N. and A. U. Khan. 1970. "Use of Mechanical Power for Rotary Weeding." PANS. Vol. 16 No. 1 (Reprint).
4. IRRI. 1970. "Power Weeder for Paddies." The IRRI Reporter, Vol. 6 No.2.

II. POST-HARVEST OPERATIONS

A. Harvesting and threshing

1. Casem, E. 1967. "Harvesting and Threshing." Saturday seminar paper, September 9.
2. IRRI. 1967. "Lightweight Paddy Thresher." The IRRI Reporter. Vol.6 No.3.
3. Casem, E. and A.U. Khan. 1969. "Physical Properties of the Rice Plant and Paddy." Saturday seminar paper, August 23.
4. Khan, A.U. 1971. "Harvesting and Threshing of Paddy." Paper presented at the International Rice Research Conference, IRRI, April 19-21. Paper No. 71-05.
5. Agricultural Engineering Dept. 1971. Table Thresher Manual.
6. Khan, A.U. 1972. "New Harvesting and Threshing Equipment for Small Tropical Farms." Paper presented at the IAMFE Third International Conference on the Mechanization of Field Experiments, Brno, Czechoslovakia, July 10-15.
7. Ramos, B., J. Policarpio and F. Michols. 1973. "Harvesting and Threshing Equipment Development at IRRI." Saturday seminar paper, June 23.
8. Samson, B. and B. Duff. 1973. "The Pattern and Magnitude of Field Grain Losses in Paddy Production." Saturday seminar paper, July 7.
9. Agricultural Engineering Dept. 1975. Axial Flow Thresher Manual.

B. General papers on rice milling and processing

1. Khan, A.U. and V.E.A. Wikramanayake. 1971. "A Laboratory Test Tube Rice Miller." Agricultural Engineering Dept. Paper No. 71-08.
2. Van Rulten, Harry. 1971. "Recent Developments in the Rice Milling Industry of the Philippines." Paper presented at the International Rice Research Conference, IRRI, April 19-21. Agricultural Engineering Dept. Paper No. 71-09.
3. Khan, A.U. 1971. "Rotary Grain Cleaner for Tropical Countries." Handout sheet.
4. Wimberly, J. 1972. "Review of Storage and Processing of Rice in Asia." Agricultural Engineering Paper No. 72-01.

5. Khan, A. U. 1972. "Rice Drying and Processing Equipment for Southeast Asia." Paper presented at the ASAE Summer Meeting; Hot Springs, Arkansas, June 27-30. ASAE Paper No. 72-339.
6. Agricultural Engineering Department 1972. Grain Cleaner Manual.
7. Agricultural Engineering Dept. 1972. Bibliography of Drying and Processing Studies in Southeast Asia.
8. Duff, B. and I. Estioko. 1972. "Establishing Design Criteria for Improved Rice Milling Technologies." Saturday Seminar Paper, August 26.
9. Duff, B. 1972. "A Note on Economies of Size in Rice Milling Systems." Paper prepared for the UPCA/UNDP/FAO Seminar Workshop of the Philippine Grain Centrals Association. UPCA/UNDP Project on Training of Technicians for the Grain Industries, Manila, August.
10. Agricultural Engineering Dept. 1972. References on Grain Loss Studies.
11. Z. Toquero, B. Duff, T. Anden and Y. Hayami. 1975. "Estimating the Elasticities of Home Consumption and Marketable Surplus for a Subsistence Crop: Rice in the Philippines." Agricultural Engineering Dept. Paper No. 75-02.
12. Arboleda, J. 1975. "Improvement of the Kiskisan Rice Mill." Saturday Seminar Paper, July 5.
13. Ramos, B. 1975. "Manufacture and Performance of Paddy Threshers in the Philippines." Saturday Seminar Paper, July 12.
14. Toquero, Z. and B. Duff. 1975. "Technical and Economic Factors Affecting the Efficiency of Mechanization in Rice Post-Production Systems." Saturday Seminar Paper, July 26.

C. Drying

*1. Amilhussin, A., A. Manalo and A. U. Khan. 1970. "Accelerated Drying of Paddy." Saturday Seminar Paper, September 5.
2. IRRI. 1970. "Drying Paradox: Wet is Better." The IRRI Reporter, Vol. 6 No. 2.
*3. Manalo, A., A. Amilhussin and A. U. Khan. 1970. "Drying Chemically Treated Paddy to Break Dormancy." Saturday Seminar Paper, Sept. 5.
4. Manalo, A. 1970. "Design Data on Counterflow Drying of Rice." Paper presented at the Seminar-Workshop on Grain Processing. University of the Philippines College of Agriculture, December 7-10.
*5. Manalo, A. 1970. "Paddy Drying Research at IRRI." Paper

presented at the Annual Convention of the Philippine Society of Agricultural Engineers, UPCA, December 11-12.

6. Manalo, A. 1971. "Rice Hulls as Fuel for Drying Paddy." Saturday Seminar Paper, September 11.
7. Manalo, A., J. Arboleda and A.U. Khan. 1972. "Drying and Processing Research at IRRI." Saturday Seminar Paper, August 12.
8. Manalo, A. 1973. "A Low-Cost Grain Dryer." Paper presented at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, January 25-26.
9. Arboleda, J. 1973. "Accelerated Conduction Drying of Paddy." Paper presented at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, January 25-26.
10. Arboleda, J. and A. Manalo. 1973. "Paddy Drying." Handout sheet for the Agricultural Engineering Session of the Rice Production Training and Research Program, IRRI.
11. Khan, A., A. Amilhussin, J. Arboleda, A. Manalo and W. Chancellor. 1973. "Accelerated Drying of Rice Using Heat Conduction Media." Paper presented at the Annual Meeting of the American Society of Agricultural Engineers, Lexington, Kentucky, June 17-20.
12. Arboleda, J., A. Manalo, A. Khan. 1973. "Accelerated Drying of Paddy." International Symposium on Preservation of Wet Harvested Grains, Institute National de la Recherche Agronomique, Paris, March 5-10.

III. MACHINE TESTING AND EVALUATION

1. Nichols, F. 1971. "The Role of Preventive Maintenance in Agricultural Equipment Development." Saturday Seminar Paper, August 28.

IV. MECHANIZATION IN AGRICULTURE AND ECONOMIC DEVELOPMENT

1. Johnson, L. 1963. "Power Requirements in Rice Production." Paper presented at the Conference on Agricultural Engineering Aspects of Rice Production, August 11-17.
2. Johnson, L. 1964. "Mechanization of Philippine Farms." Paper presented at the Second Irrigation Institute Conference, May 29.
3. Johnson, L. 1964. "Mechanization to Improve the Standard of Living in Tropical Rice-Growing Areas." Presented at the ASAE Winter Meeting, New Orleans, Louisiana, December 8-11.
4. Johnson, L. 1965. "Mechanization to Improve the Agriculture of Developing Countries." Presented at the Annual Meeting of the Indian Society of Agricultural Engineers, New Delhi, November 11.
5. Johnson, L. 1966. "Is Mechanization Possible Where Rice is King?" Agricultural Engineering, Vol. 37, No. 3
6. IRRI. 1966. "Labor and Procedure for the Pedal Thresher."

Technical Paper No. 2, September.

7. Casem, E. O. and E. Ruiz, 1967. "An Analysis of Rice Farm Operations in Central Luzon " Presented at the Annual Convention of the Philippine Society of Agricultural Engineers, May.

*8. Johnson, L. 1967. "Mechanization of Rice in Tropical Areas." Thursday Seminar Paper, May 25.

*9. Khan, A. U. 1968. "Agricultural Machinery Research and Development at the International Rice Research Institute." Paper presented at the meeting of the Japanese Society of Agricultural Machinery, Kyoto, Japan, April 6-8.

*10. Khan, A. U. 1968. "Agricultural Machinery Research and Development at the International Rice Research Institute." Paper presented at the Fifth Session of the International Rice Commission Working Party on the Agricultural Engineering Aspects of Rice Production, Storage and Processing, Kandy, Ceylon, September 5-9.

*11. Khan, A. U. 1969. "Agricultural Machinery Development Program at the International Rice Research Institute." Paper presented at the VII International Congress of Agricultural Engineers, Baden-Baden, West Germany, October 6-12.

12. Khan, A. U. 1969. "Position Paper on Agricultural Engineering Research in the Philippines." Presented at the Advisory Committee on Agricultural Research Meeting, National Science Development Board, Manila, August 28.

*13. Khan, A. U. 1970. "Mechanization Research for Tropical Agriculture." Paper presented at the Annual Meeting of the American Society of Agricultural Engineers, Minneapolis, July 8-10. ASAE Paper no. 70-114.

14. Khan, A. U. 1970. "Mechanizing the Tropical Farm." Agricultural Engineering. Vol. 51 , No. 11 (Reprint).

*15. Khan, A. U. 1971. "Equipment for Mechanized Tropical Agriculture." Paper presented at the seminar on the Mechanization of Agriculture in West Africa, Bambey, Senegal, January 25-29. Agricultural Engineering Department Paper No. 71-02.

16. Khan, A. U. 1971. "Agricultural Machinery Development at the International Rice Research Institute." Paper presented at the seminar on Mechanization of Rice Production and Processing, Paramaribo, Surinam, September 27-October 2. Agricultural Engineering Department Paper No. 71-07.

17. Khan, A. U. 1971. "Present and Future Development of the Mechanization of Rice Production." Paper presented at the seminar on Mechanization of Rice Production and Processing Paramaribo, Surinam, September 27-October 2. Agricultural Engineering Department Paper No. 71-06.

*18. Khan, A. U. 1971. "Machinery Development for Tropical Agriculture." Agricultural Mechanization in South East Asia. Spring.

*19. Khan, A. U. 1972. " Agricultural Mechanization: The Tropical Farmer's Dilemma." World Crops. Vol. 24

20. Duff, B. 1972. "Design, Development and Extension of Small-Scale Agricultural Equipment." Paper presented at the Seminar on Farm Mechanization in Southeast Asia, November 27-December 2, A/D/C and MADA, Penang, Malaysia.

*21. Khan, A. U. 1972. "New Agricultural Equipment from The International Rice Research Institute." Agricultural Mechanization in Asia. Vol. 3.

*22. Khan, A. U. 1972. New Machinery for Tropical Agriculture." Paper presented at the International Conference on Tropical and Sub-Tropical Agriculture, Honolulu, American Society of Agricultural Engineers, April 11-13.

23. Khan, A. U. and B. Duff. 1972. "Agricultural Mechanization Technology Development at The International Rice Research Institute." Paper presented at the seminar on Priorities for Research on Innovating and Adapting Technologies for Asian Development, Woodrow Wilson School, Princeton University, New Jersey, September 20-23, and at the conference on Technology, Employment and Development, CAMS, Penang, Malaysia, January 3-5, 1973.

24. Khan, A. U. and J. Policarpio. 1972. "Mechanization Technology for Small Tropical Farms." Saturday Seminar Paper, September 2.

25. Policarpio, J. 1973. "Power Tiller and Tractor Development at IRRI." Paper presented at the Annual Convention of the Philippine Society of Agricultural Engineers, Manila, January 25-26.

26. Khan, A. U. 1973. "Appropriate Technologies: Do We Transfer, Adapt, or Develop?" Paper presented at the Ford Foundation Seminar on Technology and Employment, New Delhi, India, March 21-24.

27. Khan, A. U. 1974. "Appropriate Mechanical Technology for Developing Countries." Paper presented at the AAAS Symposium on "How Can Technology in the United States and Developed Countries be directed towards Helping Developing Technologies in the Less Developed Countries?", San Francisco, March.

28. Khan, A. U. 1974. "Mechanization Technology for Tropical Agriculture." Paper presented to the Study Group on Low-Cost Technology and Rural Industrialization, OECD, Paris, September 17-20.

29. Khan, A. U. 1975. "University Research and Industrial Research in the LDC." Paper presented at the 1975 Annual Meeting of the American Society of Engineering Education, Fort Collins, Colorado, June 16-19.

V. ECONOMICS OF MECHANIZATION

A. Mechanization and Employment

*1. Johnson, L. 1963. "More Farm Power for More Days of Farm Production per Year." Paper presented at the First National Convention of Pump Irrigators sponsored by the National Federation of Pump Irrigation Associations, Manila Hotel, January 23.

*2. Johnson, S., E. U. Quintana and L. Johnson. 1967. "Mechanization of Rice Production." Paper presented at the Seminar Workshop on the Economics of Rice Production. IRRI, December 8-9.

3. Johnson, S. 1968. "Performance and Economics of Use of Small Equipment in Tropical Monsoon Countries: The Case of the Philippines." Paper presented at the Annual Meeting of the Japanese Society of Agricultural Machinery, Kyoto, Japan, April 6-8

*4. Orcino, N. 1970. "Economic Aspects of Hand Tractor Ownership and Operation." Saturday Seminar Paper, September 22.

*5. Duff, B. 1971. "The Impact of Improved Varieties and Agricultural Mechanization on the Labor Force Absorption Problem in West Pakistan." Tables and charts. Thursday Seminar Paper, February 25

*6. Duff, B. and N. Orcino. 1971. "Economic Research in the Department of Agricultural Engineering." Saturday Seminar Paper, August 21.

*7. Crisostomo, C., W. H. Myers, T. Paris, B. Duff and R. Barker. 1971. "The New Rice Technology and Labor Absorption in Philippine Agriculture." The Malayan Economic Review. Vol. XVI (Reprint).

*8. Duff, B. 1971. "Economics of Mechanizing Large versus Small Farms in West Pakistan." Paper presented at the International Rice Conference, IRRI, April 19-21.

9. Barker, R., W. H. Myers, C. M. Crisostomo and B. Duff 1972. "Employment and Technological Change in Philippine Agriculture." International Labour Review. Vol. 106.

*10. Duff, B. 1972. "Mechanization and Employment in Philippine Agriculture: Some Empircal Evidence." Paper presented at the Seventh Session of the IRC Working Party on Agricultural

Engineering Aspects of Rice Production, Processing and Storage, November 3-6, Bangkok.

11. Estioko, I. 1972. "CB:IBRD Farm Mechanization Credit Program: Philippines." Paper presented at the Seminar on Farm Mechanization in Southeast Asia, November 27-December 2, A/D/C and MADA, Penang, Malaysia.

12. Orcino, N. 1972. "Economic Aspects of Hand Tractor Ownership and Operation." Paper presented at the Seminar on Farm Mechanization in Southeast Asia, November 27-December 2, A/D/C and MADA, Penang, Malaysia.

*13. Orcino, N. and B. Duff. 1973. "Technical and Economic Characteristics of Tractor Contract Operations in Central Luzon." Saturday Seminar Paper, June 30.

B. Comparative Economic Studies of Rice Production and Processing

*1. Alicbusan, L. C. 1964. "The Rate of Substitution of Man-Hours by Animal or Machine Horsepower Hours in Rice Production." August.

2. Barker, R., S. Johnson, N. Alviar and N. Orcino. 1969. "Comparative Economic Analysis of Farm Data on the Use of Carabao and Tractor in Lowland Rice Farming." Paper presented at the Farm Management Seminar with Focus on Mechanization, U. P. Institute of Small-Scale Industries, Manila, February 24-March 1.

3. Johnson, S. 1969. "Terminal Report on the General Engineering and Economic Research Portion of Contract No. AID/csd-834."

4. Toquero, Z. and B. Duff. 1974. "Survey of Post-Production Practices among Rice Farmers in Central Luzon." Saturday Seminar Paper, September 7.

C. Economic Aspects of Machinery Manufacturing and Marketing

1. Johnson, L. 1967. "Comments, Definitions, and Personal Opinions to Explain the Tropical Rice Producers' Conditions and Problems of Machinery Manufacture." Project Committee Meeting of Contract No. AID/csd-834.

2. Cabanos, P. 1971. "Jeepney Manufacturing in the Philippines, A Model for Developing the Agricultural Machinery Industry." Agricultural Mechanization in South East Asia, Vol. 2 (reprint).

VI. SEMIANNUAL PROGRESS REPORTS

In addition to materials prepared for meetings and publications, the Department submits a regular semiannual progress report describing the status of individual research and development projects conducted under a joint IRRI-AID contract. These reports are listed below:

*Semiannual	Progress	Report	No. 1	by	L. Johnson			
* "	"	"	2	"	"			
* "	"	"	3	"	"	and S. Johnson		
* "	"	"	4	"	"		"	
"	"	"	5	"	A. U. Khan	"	"	
"	"	"	6	"	"	"	"	
"	"	"	7	"	"	"	"	
"	"	"	8	"	"			
"	"	"	9	"	"			
"	"	"	10	"	"			
"	"	"	11	"	"	, F. Nichols, B. Duff		
"	"	"	12	"	"	"	"	
"	"	"	13	"	"	"	"	
"	"	"	14	"	"	"	"	
"	"	"	15	"	"	"	"	
"	"	"	16	"	"	"	"	
"	"	"	17	"	F. Nichols, B. Duff, J. Campbell			
"	"	"	18	"	"	"	"	
					C. Lee			
"	"	"	19	"	A.U. Khan, B. Duff, C. Lee			

VII. MISCELLANEOUS

1. Johnson, L. 1966. "Mathematics, Engineering and Agriculture," Thursday Seminar Paper, February 17.

Appendix II. List of personnel:

Johnson, L.	Agricultural Engineer	7/66- 6/67
Khan, A.U.	Development Engineer & Project Leader	7/67-12/74
Johnson, S.	Agricultural Economist	7/66-10/68
Duff, B.	Agricultural Economist	10/70-12/74
Nichols, F.	Evaluation Engineer	11/70- 4/74
Campbell, J.	Assoc. Agricultural Engineer	8/73- 7/74
Lee, C.C.	Visiting Assoc. Agricultural Engineer	4/74- 5/75
Casem, E.	Asst. Agricultural Engineer	5/66-11/71
Manalo, A.	Asst. Agricultural Engineer	9/69-12/73
Cabanos, P.	Asst. Design Engineer	5/69- 2/72
Policarpio, J.	Asst. Design Engineer	11/71- 8/73
Navasero, N.	Senior Research Assistant	11/67-12/74
Arboleda, J.	Senior Research Assistant	11/71-12/74
Padolina, C.	Senior Research Assistant	5/71-12/74
Toquero, Z.	Senior Research Assistant	1/73-12/74
Rosario, E. del	Research Assistant	6/70- 3/73
Gutierrez, S.	Shop Foreman-Sr. Research Assistant	6/69-12/74
Espiritu, G.	Research Assistant	11/73-12/74
Ramos, B.	Student Assistant-Research Assistant	12/68-12/74
Orcino, N.	Research Assistant	7/68-12/73
Amilhussin, A.	Research Aide	9/68- 8/71
Estioko, I.	Research Aide	7/71- 6/73
Samson, B.	Research Aide	7/71-12/73
Lumang, L.	Student Assistant-Research Aide	7/70- 2/74
Aguila, B.	Junior Technician	3/66- 4/68
Ruiz, E.	Junior Technician	3/66- 6/68
Jalotjot, F.	Draftsman	1/67-12/71
Cabrales, F.	Draftsman	7/68- 6/74
Buan, B.	Draftsman	10/71-12/74
Jizmundo, C.	Secretary	3/67-12/74
Manalo, E.	Secretary	5/73-12/74
Maraan, V.	Secretary	3/70- 3/73
Go, V.	Clerk-Typist	1/67- 6/69
Dungo, E.	Tinsmith-Shop Foreman	6/68-12/74
Malabonga, P.	Shop Foreman	7/67- 6/68
Borja, Z.	Machinist	9/68-12/74
Dizon, A.	Machinist	7/69-12/74
Dignadice, R.	Shop Mechanic	12/68-12/74

Macatangay, M.	Shop Mechanic	12/69-12/74
Mesa, P. de	Shop Mechanic	12/69-12/74
Camacho, A.	Shop Mechanic	4/74-12/74
Flores, F.	Shop Mechanic	6/70- 8/72
Silos, J.	Mechanic-Operator	6/68- 6/72
Lescano, M.	Mechanic-Operator	1/67-12/67
Tamisin, B.	Mechanic-Demonstrator	6/67- 3/68
Santos, R.	Tinsmith	6/68-12/74
Flojo, C.	Tinsmith	2/74-12/74
Mangahis, A.	Tinsmith	7/67- 2/68
Barot, A.	Welder	12/68-12/74
Tamisin, R.	Welder	6/67- 6/68
Macatangay, E.	Laborer	1/71-12/74
Castro, M.	Laborer	5/68-12/74
Fabellar, M.	Laborer	9/66- 6/71
Villegas, L.	Laborer	7/69- 6/71
Reyno, J.	Laborer	8/66-11/69

Consultants:

Suter, D.	Agricultural Engineer	1967
Chancellor, W.	Agricultural Engineer	1967
Shepardson, S.	Agricultural Engineer	1970
Wimberly, J.	Agricultural Engineer	1971
Davis, D.E.	Agricultural Engineer	1972
Harper, J.	Agricultural Engineer	
and		
Davis, D.E.	Agricultural Engineer	1973
Wijewardene, R.	Agricultural Engineer	1973
Merrill, W.	Agricultural Engineer	1974

Appendix III. List of cooperating subcontractor organizations

India

All-India Coordinated Rice Improvement Project
Rajendranagar, Hyderabad
Krishi Engines Pvt. Ltd.
Sanatnagar, Hyderabad
G. B. Pant University of Agriculture & Technology
Pantnagar, (Distt. Nainital)

Indonesia

Directorate of Agricultural Technique
Pasarminggu, Jakarta

Korea

Institute of Agricultural Engineering & Utilization
Suwon

Malaysia

Malaysian Agricultural Research & Development Institute
Kuala Lumpur

Pakistan

Lahore Engineering & Foundry Limited
Lahore

Philippines

Nueva Ecija Land Reform Integrated Development Project
Bitas, Cabanatuan

Sri Lanka

Browns Group Industries Limited
Colombo

Farm Machinery Research Center
Maha-Illuppallma

Taiwan

Joint Commission on Rural Reconstruction/Taiwan Agricultural Research Institute
Taipei

Thailand

Engineering Division
Department of Agriculture
Ministry of Agriculture & Cooperatives
Bangkhen, Bangkok

Vietnam

Vietnam Agricultural Machinery Co.
Saigon

Appendix IV. List of engineers-trainees

India

B. C. Babu
All-India Coordinated Rice Improvement Project
Hyderabad, A.P.

S. F. Qader
All-India Coordinated Rice Improvement Project
Hyderabad

Indonesia

A. Hamid
Directorate of Agricultural Technique
Pasarminggu, Djakarta

A. Anwar
P. T. Pupuk Sriwidjaja (PUSRI)
Jakarta

J. Helmi
P. T. Pupuk Sriwidjaja (PUSRI)
Palembang

R. Hitijahubessy
P. T. Purna Sadhana (PINDAD)
Bandung

K. Sudjana
P. T. Pupuk Sriwidjaja (PUSRI)
Palembang

R. D. Tarmana
Directorate of Agricultural Technique
Pasarminggu, Jakarta

J. Yuwono
P. T. Purna Sadhana (PINDAD)
Bandung

Korea

Mr. Soung Rai Kim
Institute of Agricultural Engineering & Utilization
Office of Rural Development
Suwon

Pakistan

M. A. Farooq
Lahore Engineering & Foundry Ltd.
Lahore

Philippines

. Arenas
Philippine American Timber Co.
Negros Oriental

Sri Lanka

S. Kathirkamathamby
Engineering Division, Department of Agriculture
Peradeniya

T. Jinasena
Jinasena Limited
Colombo

Taiwan

C. P. Wu
Taiwan Agricultural Research Institute
Taipei

Thailand

P. Laknanurak
Engineering Division, Department of Agriculture
Bangkhen, Bangkok

N. Thunyaprasat
Engineering Division, Department of Agriculture
Bangkhen, Bangkok

Vietnam

P. H. Hien
Vietnam Agricultural Machinery Co.
Saigon

Bangladesh

A. Haq
Bangladesh Rice Research Institute
Joydevpur, Dacca

A. R. Bose
Jhowtala, Comilla

Appendix V. List of cooperating Philippine manufacturers.
(Numbers in parentheses refer to the companies listed below)

MULTIHOPPER SEEDER, 6-ROW

(1) (14) (18)

5-7 HP POWER TILLER

(1) (3) (4) (6) (7) (8) (9) (11) (13) (15) (17) (18)

BATCH DRYER, 1-ton capacity, with either kerosene burner or rice hull furnace and blower

(1) (2) (5) (12) (15) (16)

POWER GRAIN CLEANER

(1) (15)

BELLOWS PUMP

(1) (18)

MULTICROP AXIAL FLOW THRESHER

(1) (2) (3) (4) (6) (7) (10) (12) (13) (15) (16) (17)

CONTACT HERBICIDE APPLICATOR

(1)

DEEP-PLACEMENT GRANULE APPLICATOR

(1) (7)

---

(1) Kalayaan Engineering Co., Inc.
4255 Emilia St., Makati, Rizal
(P.O. Box 665, MCC, Makati)

(2) Kaunlaran Industrial Shop
Osmeña St., SPC Subdivision
San Pablo City

(3) Marsteel Corporation
666 T.M. Kalaw, Manila
(P.O. Box 834, Manila)

(4) Oberly & Co., Inc.
253 Mayon St., Sta. Mesa Heights, Quezon City

(5) A.P. Rodriguez Agro-Industrial Machineries
Bitas, Cabanatuan City

(6) IGRI Industrial Sales Corp.
484 Araneta Blvd., Quezon City
(P.O. Box 34, Manila

(7) Durasteel Industries
380 Dasmariñas St., Manila

(8) Radiowealth Trading, Inc.
498 Shaw Blvd., Mandaluyong
Rizal
(P.O. Box 3130, Manila)

(9) REB Industries
Jones Street Ext., Tacloban
N. Leyte

(10) C&B Crafts
Cruz-na-daan, San Rafael
Bulacan

(11) Mindanao Machine Shop, Inc.
Sta. Ana Ave.-Lizada
Davao City

(12) Mariñas Mfg. Co., Inc.
Rizal Street, Pila, Laguna

(13) F.E. Zuellig (M) Inc.
IMAG Mfg. Division
64 Kitanlad St., Quezon City
(P.O. Box 604, Manila)

(14) Quinzy-Pacific
P. Tamo, Makati, Rizal

(15) Philip Eng. & Steel Industries
ADCOM, Philippines
811 Sikatuna Bldg., Ayala Avenue
Makati, Rizal

(16) D&O Concrete & Allied Industries
Kabacan, Cotabato

(17) Jamandre Industries, Inc.
345 Huervana St., La Paz
Iloilo

(18) D.H. Farm Implements
Km 1, National Highway
Roxas City

Appendix VI. List of cooperating manufacturers outside the Philippines.

5-7 HP POWER TILLER

(3) (8) (10) (11) (13) (14) (17)

POWER WEEDER

(6)

GRAIN CLEANER

(5)

AXIAL FLOW THRESHER

(1) (2) (4) (5) (9) (14) (15) (16) (18)

BATCH-TYPE DRYER, 1-ton capacity, with either kerosene burner or rice hull furnace and blower

(1) (7) (12)

---

(1) Attah Farm Equipment Supplies
P.O. Box 100, Akosombo, Ghana

(2) American Spring & Pressing Works
P.O.Box 7602, Malad, Bombay
India

(3) IKABI Primkopad Bengpusmat II
Divisi Produksi Mesin dan Engineering
P.O. Box 999, Bandung
Indonesia

(4) PINDAD (Perindustrian Angkatan Darat)
P.O. Box 8, Bandung, Indonesia

( ) P.T. Purna Sadhana
P.O. Box 192, Jakarta, Indonesia

(6) Ohtake Nouki Seisakusho Co.
Nakajima, Oharu-mura, Amagun
Aichi, Japan

(7) Hyup Sin Industrial Corp.
46-1 Yongdu-dong, Dongdaemungu
Seoul, Korea

(8) Wuon Poong Co., Ltd.
21-2-ka Dang San-dong, Young Dongpo-ku, Seoul, Korea

(9) Habib Industries, Ltd.
4th Floor, Commerce Bank Bldg.
I.I. Chundrigar Road
Karachi 2, Pakistan

(10) Browns Group Industries Ltd.
481 Darley Road, Colombo, Sri Lanka

(11) Somasiri Huller Manufactory
18 Parakrama Ave., Kohuwela
Nugegoda, Sri Lanka

(12) Kuo Hua Agr. Engine Works Co.
1, Lane 104, Chung Hsiao Road
Taichung, Taiwan

(13) J-Charoen Chai
J. 55-57 Utong Road, Ayudhaya
Thailand

(14) Anusarn Co., Ltd.
94-120 Charoen Rd., Chiang Mai
Thailand

(15) Kaset Thai Ltd.
27, Panitkom, Cholburi, Thailand

(16) Pramual Kolakij, Ltd.
53 Soi Nugoonton Nganwongvan Rd.

(17) Than N ng Cong Ty
40-E Ngo Duc Ke
Saigon, Vietnam

(18) Vietnam Agricultural Machinery Co. (VIKYNO)
422 Tran Hung Dao
Saigon, Vietnam

Appendix VII. List of patents and awards

	Number of Patent Issued and Date of Issue		
	Philippines	United States	Patentee
Drum thresher	UM-711 May 14/70	None	A. U. Khan
Table thresher	6428 Jan 27/72	3,763,868 Oct. 9/73	A. U. Khan
Row seeder	UM-762 Feb. 25/71	3,763,797 Oct. 9/73	N. Navasero
Grain cleaner	6430 Jan. 27/72	3,756,406 Sept. 4/73	A. U. Khan
Method for parboiling and drying of paddy	7275 Feb. 6/73	None	A. U. Khan W. Chancellor, A. Amilhussin
Sand dryer	6806 July 26/72	3,739,448 June 19/73	A. U. Khan
Combination threshing and separating machine	7757 Sept. 7/73	3,776,242 Dec. 4/73	A. U. Khan
Low-lift bellows pump	7253 Jan. 31/73	None	N. Navasero
Liquid herbicide applicator	UM-1222 May 22/73	None	N. Navasero
Axial flow thresher	UM-1379 Jan. 29/74	None	A. U. Khan
Power tiller	UM-2338 April 22/75	None	P. Cabanos
Portable rice hull furnace	UM-1519 June 6/74	None	A. Manalo
Burner fuel control device	UM-1502 May 22/74	None	A. Manalo

Awards:

1974 Ferdinand E. Marcos Presidential Gold Medal, Philippine Inventors Commission, to A. U. Khan for the axial flow thresher.

1973 Certificate of Appreciation, Agency for International Development, Department of State, Washington, D.C. to A. U. Khan.

1973 Ferdinand E. Marcos Presidential Gold Medal, Philippine Inventors Commission, Manila, to N. Navasero for the bellows pump.

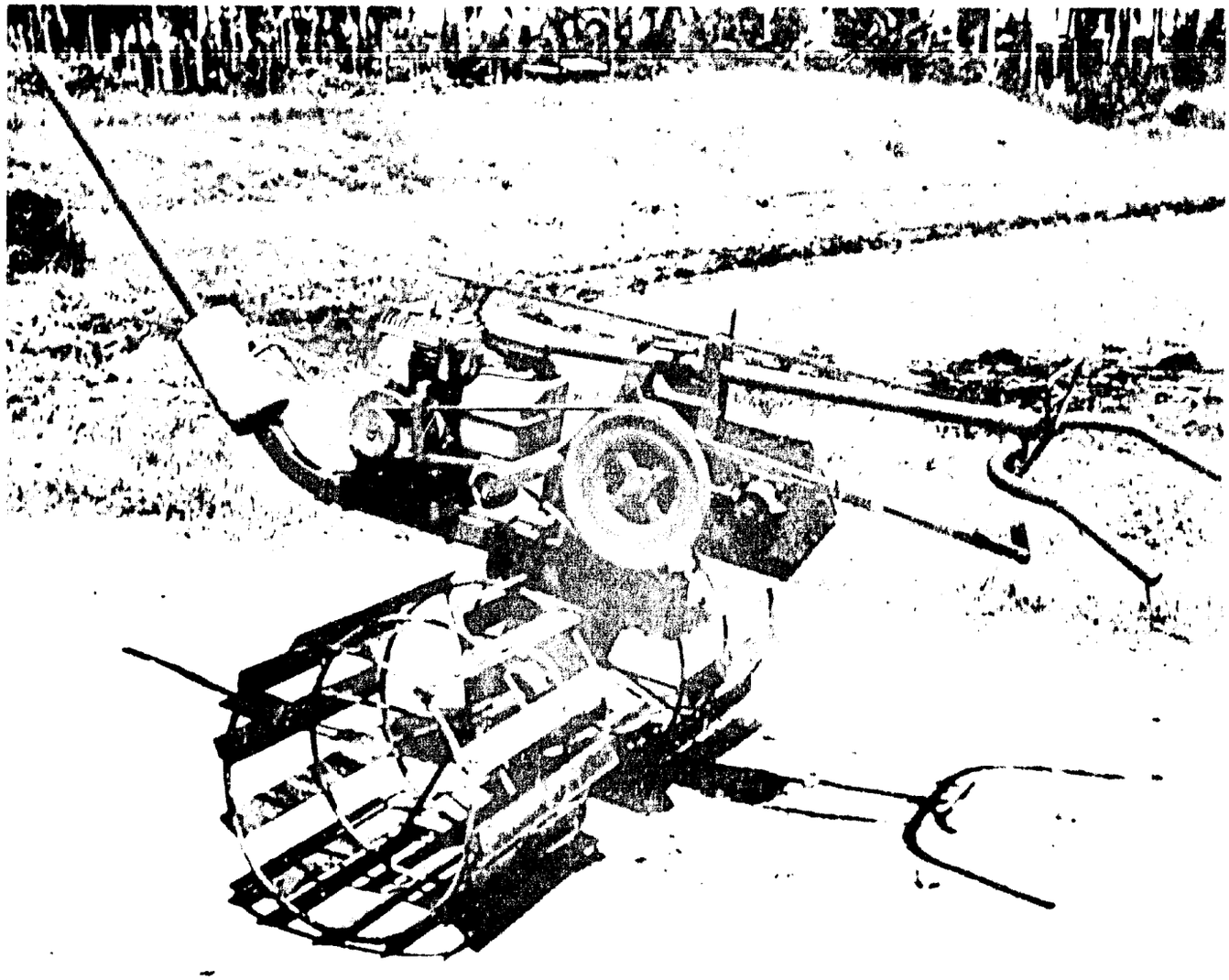
1972 Ferdinand E. Marcos Presidential Gold Medal, Philippine Inventors Commission, Manila, to A. U. Khan for the table thresher.

1972 Silver Medal, Philippine Inventors Commission, Manila, to A. U. Khan for the power grain cleaner.

1971 Ferdinand E. Marcos Presidential Gold Medal, Philippine Inventors Commission, Manila, to N. Navasero for the single-hopper pregerminated paddy seeder.

1971 "Golden Star" Award, National Farm Guide Council of Pakistan, Lahore, to N. Navasero for the single-hopper seeder.

IRRI single axle tractor
designed and priced for small farmers



The tiller offers dependability, versatility, and easy operation for a wide range of farming operations. Built primarily of locally available materials, it costs less than half the price of comparable imported tillers. Initial investment, operating cost, and maintenance costs are low, making this an ideal tiller for the small farmer.

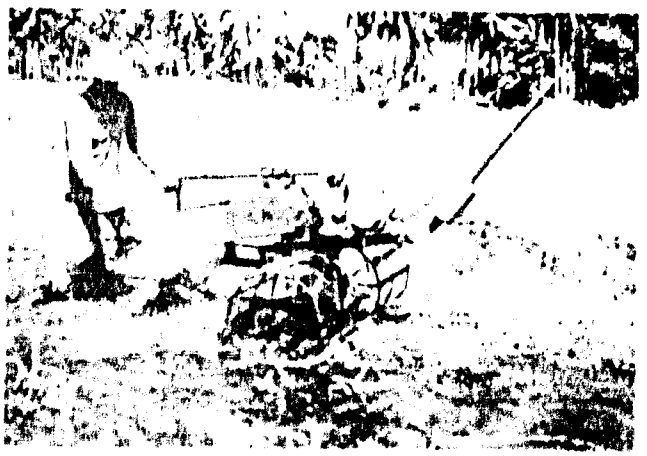
Important features

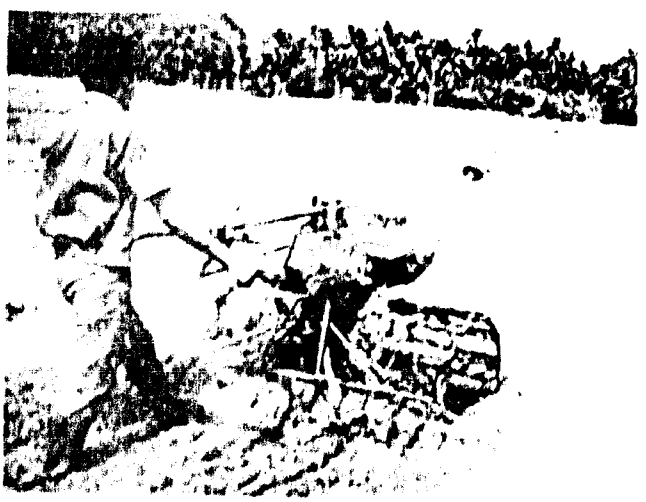
SIMPLE CONSTRUCTION The tiller is constructed from standard drive components and simple structural sections. There are only four main parts: main frame, transmission, handlebar, and engine.

LIGHTWEIGHT For mobility the weight of the tiller is low (112 kg). If the tiller bogs down, three men can easily lift it out. The high power-to-weight ratio gives the tiller more power for useful work.

DURABLE Simple components designed for hard use provide long life. Repair and replacement of the components is fast, and at minimum cost.

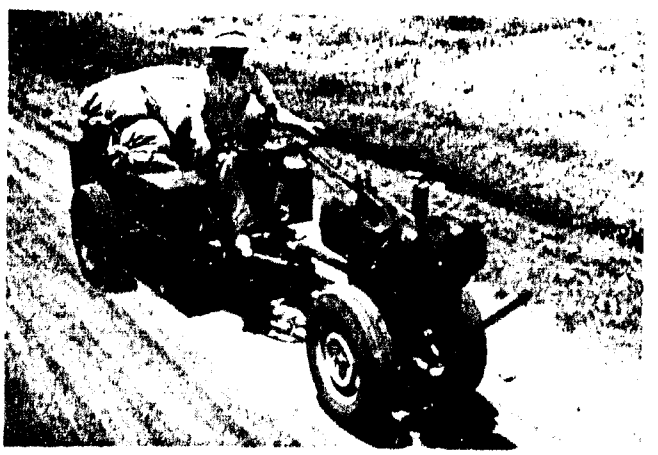
VERSATILE The tiller can perform farm operations such as plowing, puddling, cultivation, and hauling. Attachments can be changed in seconds without the use of tools. The handlebar adjusts forward and back to permit operation with towed implements. The tiller's high ground clearance makes it well suited for wet, muddy fields.





EASY TO OPERATE Operation of the tiller is easy to learn. To change from field speed to transport speed or vice-versa, the operator simply slips a V-belt from one set of pulleys to another. A single lever on the handlebars engages the drive.

LOW MAINTENANCE Sturdy construction plus sealed bearings and chaincase gives the tiller low maintenance needs. Oil in the chaincase lubricates all moving parts. Daily engine maintenance is required as directed by engine manufacturer's specifications.



TRANSPORT

Machine specifications

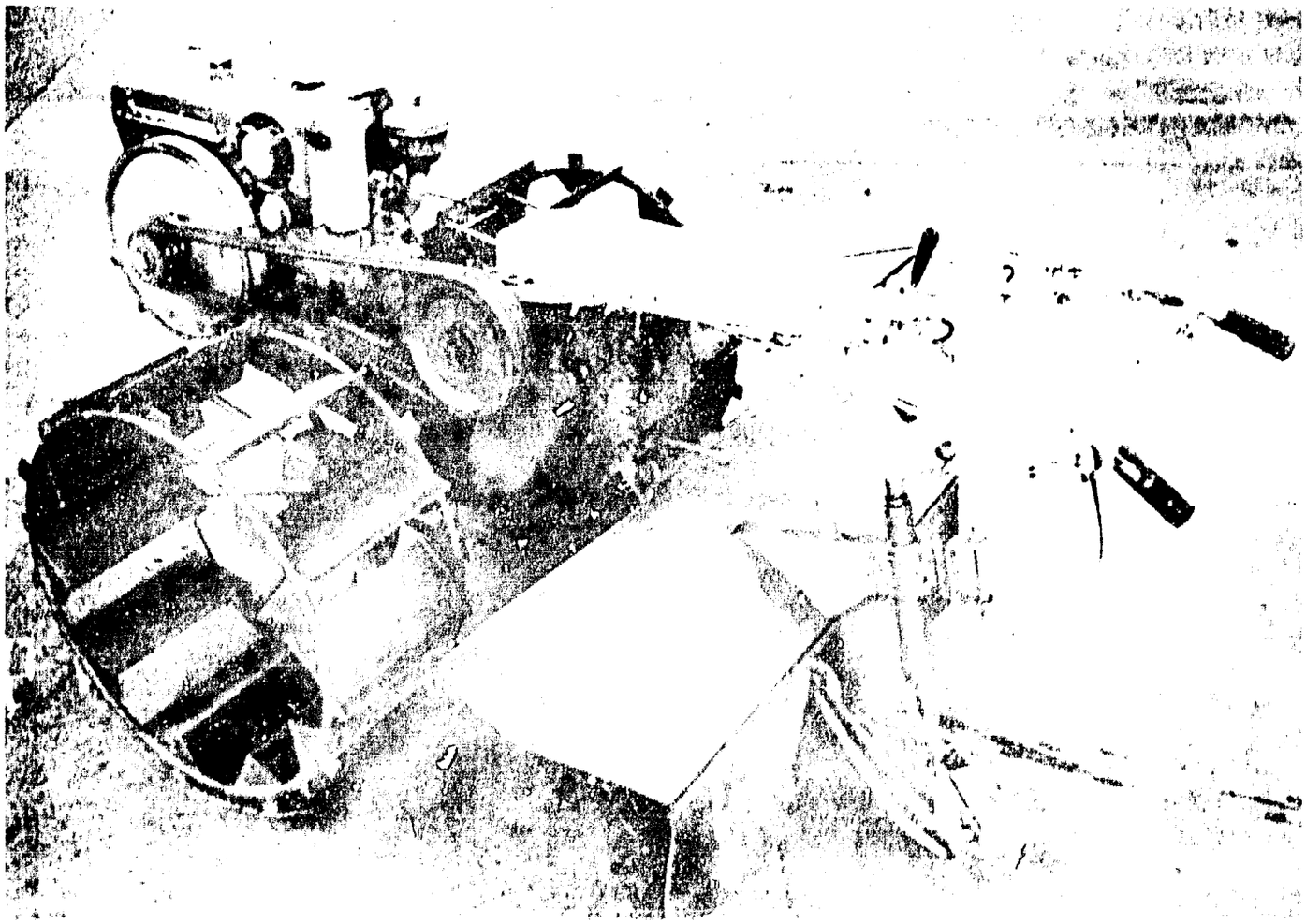
POWER	5 to 7 hp gasoline engine
WEIGHT (with engine)	112 kg
LENGTH	200 cm
WIDTH	120 cm
HEIGHT	96 cm
SPEED (max.) Two forward	
Field position	1.3 kph
Road position	11.5 kph
POWER TRANSMISSION	V-belt to chain and sprockets
FUEL CONSUMPTION	5 hp = 2 liters/hr
	7 hp = 4 liters/hr
FIELD CAPACITY	
Plowing wet soil (one pass)	0.5-0.5 ha/8 hr-day
Harrowing flooded soil (one pass	1.0 ha/8 hr-day

Prepared at the International Rice Research Institute under a research contract with United States Agency for International Development

For further particulars write International Rice Research Institute, P.O. Box 933 Manila, Philippines • Cable: RICEFOUND, MANILA

IRRI Power tiller
8 to 12 hp

Features designed specially for developing countries



The heavy duty power tiller offers almost all of the features of the latest power tillers produced in the industrialized countries, yet it can be easily fabricated in the developing nations at a fraction of the cost.

FEATURES

The machine is well balanced and requires less effort to operate than most smaller power tillers. The tiller is equipped with steering clutches so it can be turned easily. The cam-operated dogs of the steering clutches permit smooth disengagement when turning. Speeds can be shifted using a simple main clutch control and gear shifting lever. Belts do not have to be shifted to change speeds.

VERSATILE

The tiller can be used for cultivation on upland and lowland conditions and for transport with a trailer. A range of implements are available for many agricultural operations. The multistage gear transmission permits operation over a wide range of farming conditions. The tiller has four forward and two reverse speeds. The tiller can prepare 1.2-1.5 ha of land per (8 hr) day. It can transport 600 kg on country roads.

DURABLE

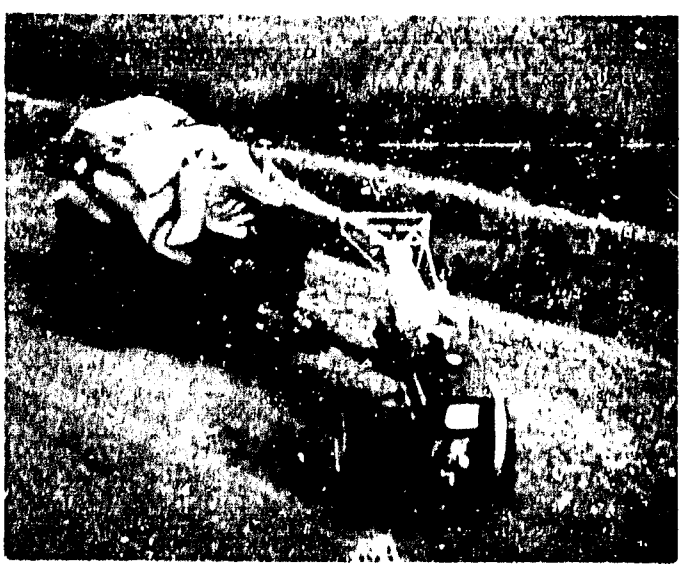
The design is simple with rigid heavy-duty construction. A friction disc-type main clutch transfers the engine power to the transmission, providing more durable and trouble-free clutching than the idler belt clutches used in most power tillers. The tiller is equipped with a water-cooled, horizontal-stroke 8 to 12 hp diesel engine. Three B-section V-belts are used to transmit power from the heavy-duty engine to provide longer belt life and trouble-free operation.

LOW MAINTENANCE COST

Most parts can be easily repaired in small machine shops. Many machine elements are readily available at fairly low cost in developing nations. Flexible control cables are a problem in most power tillers. The IRRI tiller uses rigid rods in the clutch control for trouble-free operation.

SIMPLE TO MANUFACTURE

The power tiller has five major assemblies: engine, transfer case, multi-speed gear transmission, handle bars and rotary tiller. All components, except the engine, can be easily fabricated in developing nations. The transmission is of a simple design, with spur gears. Most components are designed so that special production dies and tooling are not necessary for manufacture. Consequently, production can be economical even with low market demand. Manufacturers do not have to carry a large component inventory because the imported machine elements used in the tiller are commonly used for many other machines in the developing countries.



TRANSPORT

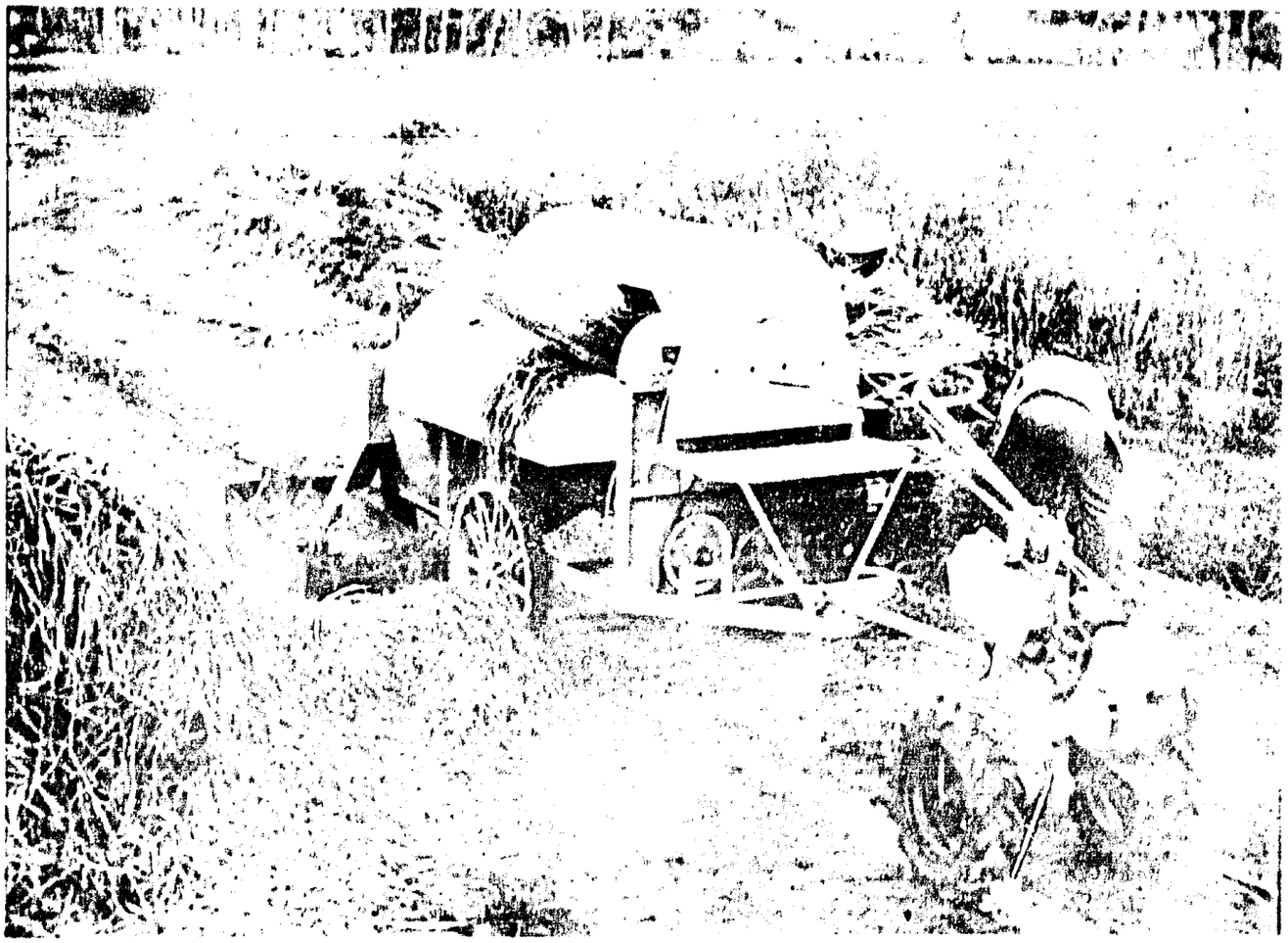
FIELD OPERATION

SPECIFICATIONS

Model	IRRI-PT2		
Dimensions	2300(L)x610(W)x1100(H)		
Weight without engine	215 kg		
Wheels dia.:			
Rubber type	550 mm		
Cage wheel	760 mm		
Operating handle	Y-shaped, adjustable		
Main clutch	Friction disc (dry)		
Steering clutches	Dog-type		
Transmission	Engine to input shaft • triple V-belts B-section 4 forward and 2 reverse speed spur gear box		
Travel speed at 1800 engine rpm	Gear settings		Kph
	Low	1st gear	1.6
		2nd gear	2.7
		Reverse	2.1
	High	3rd gear	4.2
		4th gear	6.8
		Reverse	5.6
Rotovator	Enclosed center chain drive from tiller PTO		
	No. of tines • 16		
	Tiller dia. = 330 mm		
	Tiller width = 700-800 mm		
Engine	8-12 hp diesel		
	Max. engine rpm • 1800		

Developed by the Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines, under a research contract with the U. S. Agency for International Development, Washington, D.C. Manufacturers may incorporate modifications resulting in slight deviations from the basic design.

IRRI multicrop axial flow thresher



THRESHES PADDY, SORGHUM, SOYBEANS, AND OTHER SMALL GRAIN CROPS

Features

HIGH OUTPUT: One ton per hour when threshing paddy

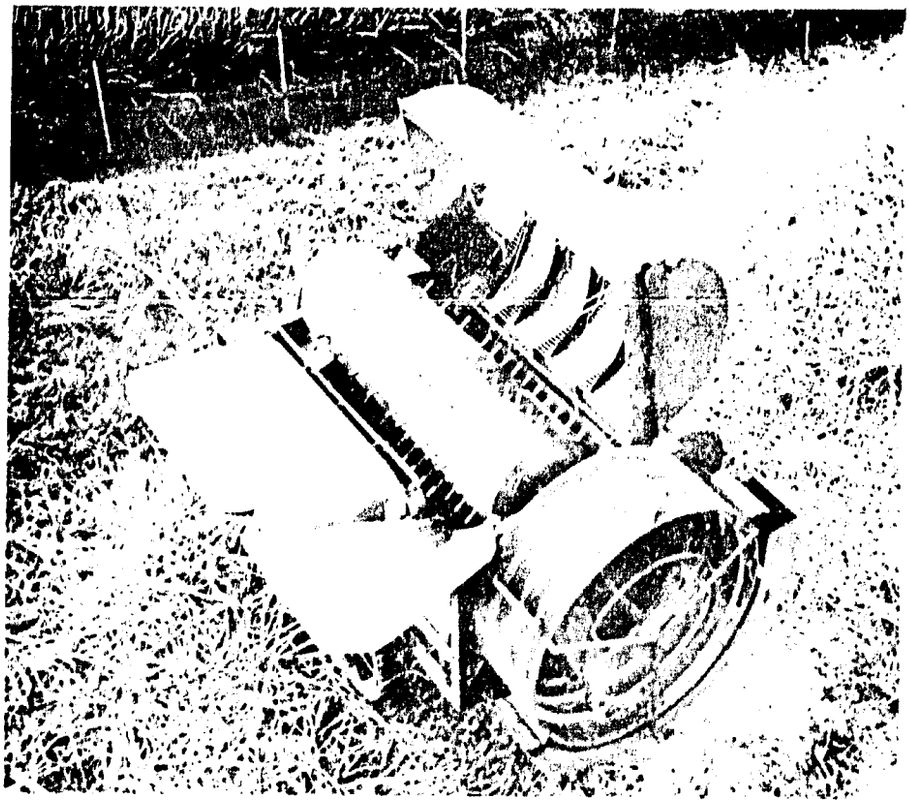
LOW HORSEPOWER REQUIREMENT: 7 hp engine

LOW LABOR REQUIREMENT: Three men to feed, thresh, and bag grain

EASE OF OPERATION: Simplicity of design reduces operation and maintenance problems

THRESHING AND WINNOWING COMBINED: Throw-in threshing combined with air and screen cleaning mechanisms

HIGHLY MOBILE: Can be moved behind small hand tractor, jeep or truck



Threshing cylinder and upper concave exposed

Machine specifications

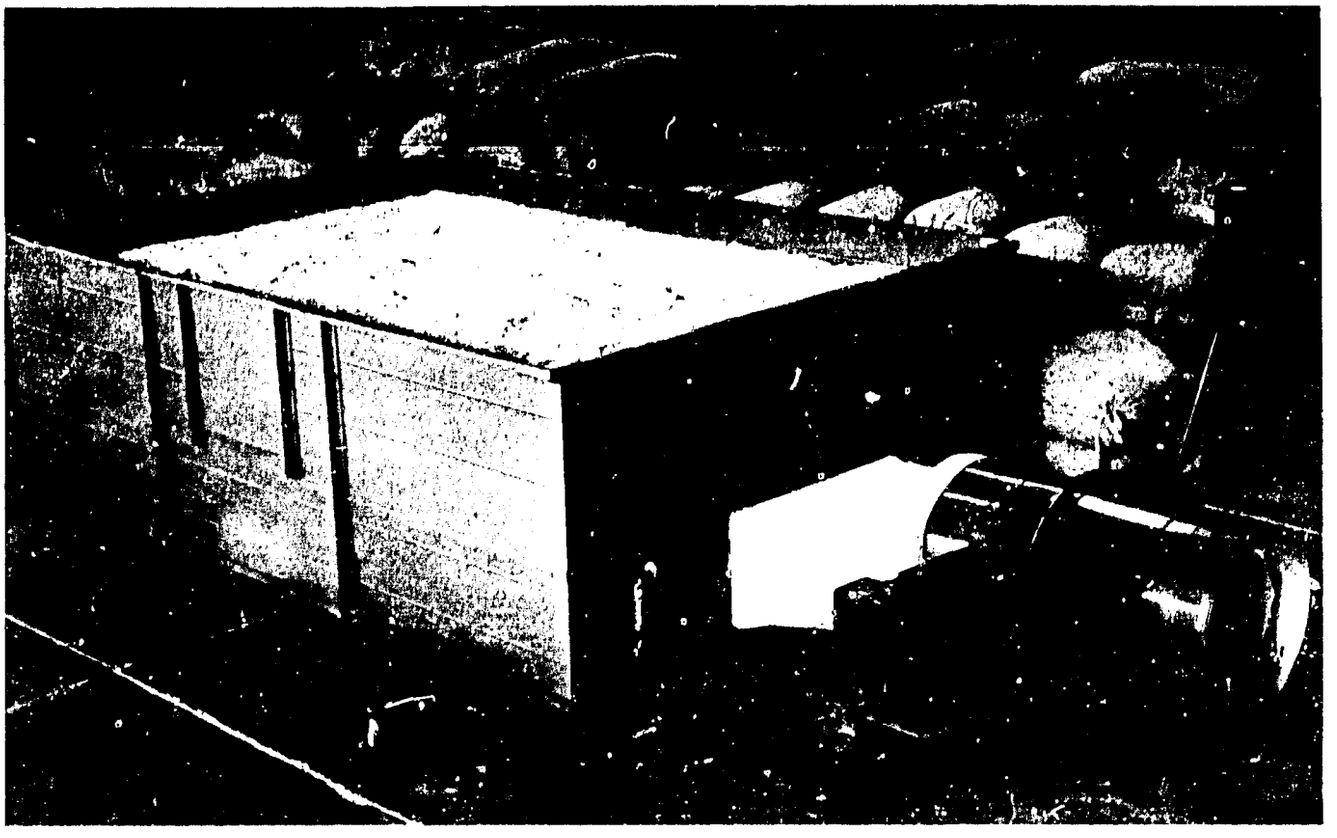
POWER	7 hp engine
WEIGHT (with engine)	480 kg
LENGTH	227.0 cm
WIDTH	179.8 cm
HEIGHT	
With wheel	161.2 cm
Without wheel	119.2 cm
CAPACITY	1 t/h (rough rice)
SEPARATION RECOVERY	98% (weight basis)
CYLINDER	Spiketooth, 39.8 cm O.D. × 122.0 cm length
CONCAVE	0.6 cm dia. steel rods with 16 mm spacing
CONSTRUCTION	All steel
COMPONENT SPEEDS	
Cylinder	500-530 rpm
Fan	1030 rpm
Auger	171 rpm
Screen	17 rpm
ADJUSTMENTS	Angle of air deflector and engine speed
LABOR REQUIREMENTS	3 men

Throw in design results in high output

Developed at the International Rice Research Institute under a research contract with United States Agency for International Development

For further particulars write: International Rice Research Institute, P.O. Box 933, Manila, Philippines • Cable: RICEFOUND, MANILA

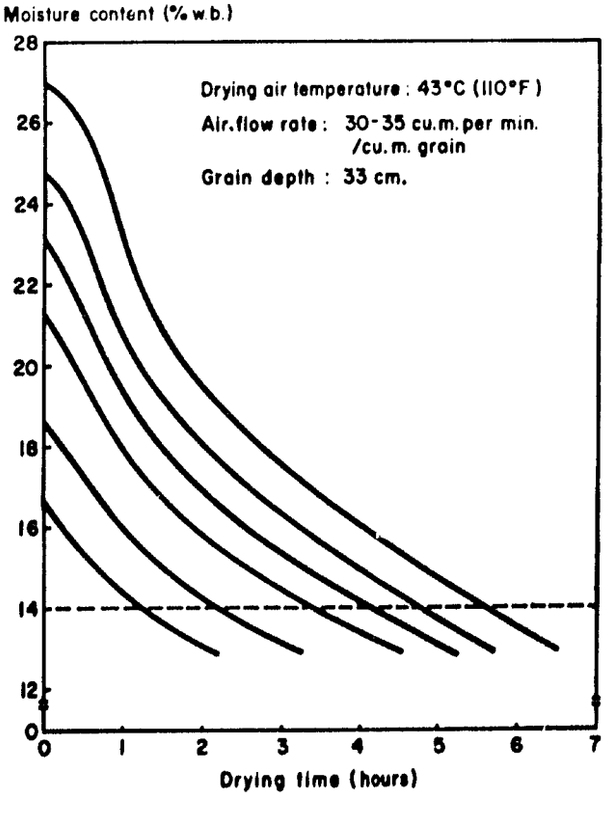
IRRI batch dryer



FEATURES

- has low cost
- uses locally available materials
- uses engine as supplementary heat source
- is compact and portable
- needs little maintenance and is easy to operate
- drys 1 metric ton of paddy in 4 to 6 hours
- gives uniform final moisture content
- has automatic safety feature to shut off burner assembly
- bin designed for wood or steel construction

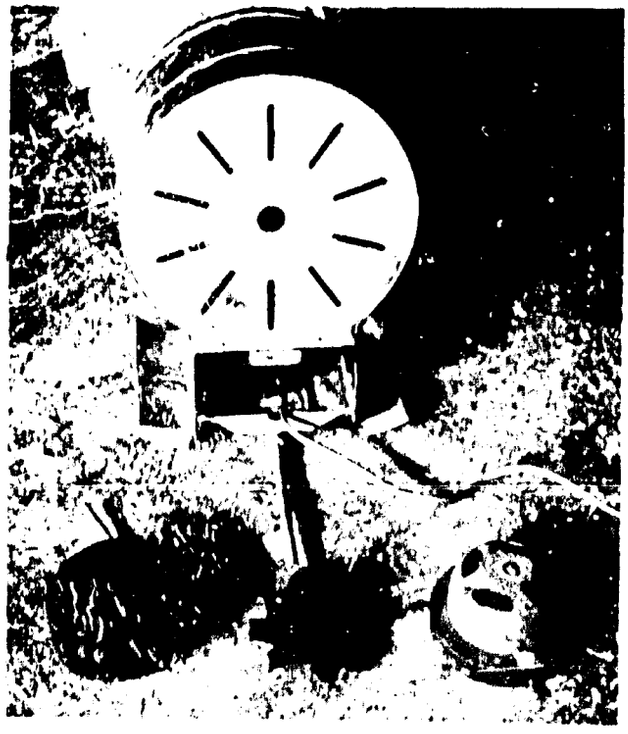
Drying rate



Choice of heat units

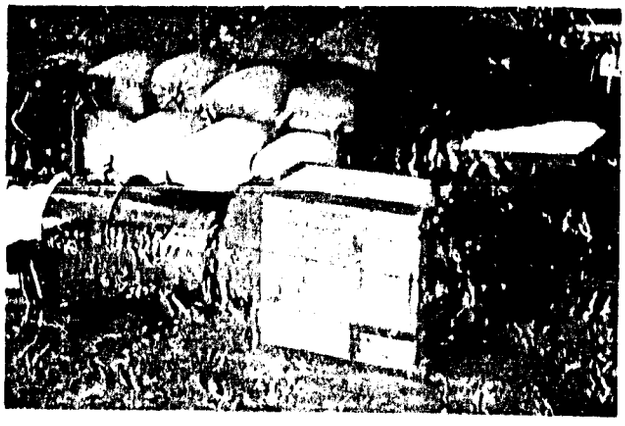
KEROSENE →

Close up of kerosene burner

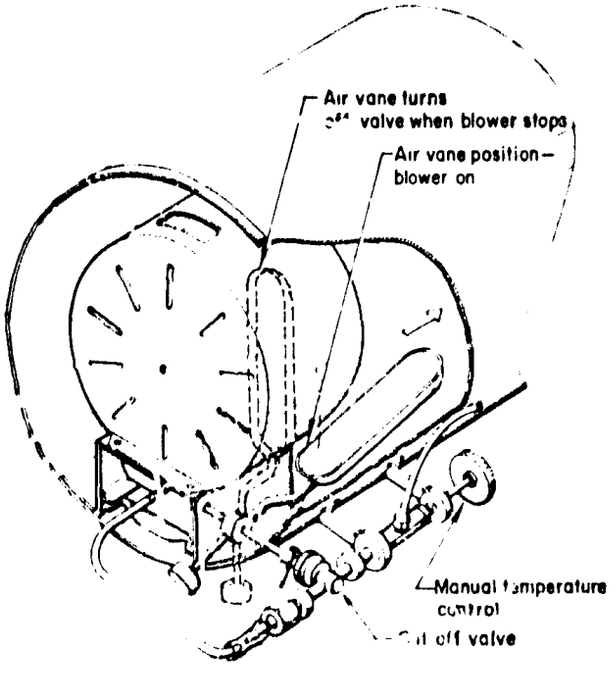


RICE HULLS

Hull furnace attached to blower



Built-in safety



Close up of automatic cut off valve and control

Specifications

POWER: 3 hp gasoline engine or 2 hp electric motor

WEIGHT: Fan and kerosene burner (without engine) 40 kg

Drying bin

Steel 220 kg

Wood 200 kg

Rice hull furnace* 290 kg

	Fan and burner	Drying bin Steel	Drying bin Wood*
LENGTH, cm	90	277	254
WIDTH, cm	110	190	254
HEIGHT, cm	60	92	109
GRAIN DEPTH, cm		33-46	33-46

GRAIN FLOOR: 2.38 mm dia. perforated steel sheet 0.76 mm thick, or 7.9 mm mesh expanded steel sheet 0.61 mm thick

FAN: 47 cm diameter vane-axial type

AIRFLOW: 1650 cfm operating at 2200 rpm, a static pressure of 0.8 cm water and temperature of 43°C

DRYING AIR TEMPERATURE: 43°C

DRYING RATE: 23% moisture (w.b.) palay to 14% in 5 to 6 hours

FUEL CONSUMPTION: 0.75 liter gasoline/hr
2.0 liter/kerosene/hr
3-4 kg rice hull/hr**

*May be used as alternatives to kerosene burner and steel bin design.

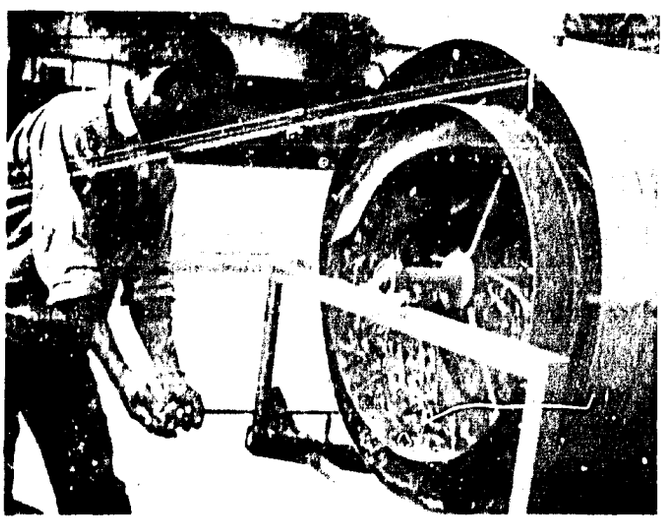
**One ton of paddy contains approximately 200 kg of rice hull.

Developed at the Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines under a research contract with U.S. Agency for International Development, Washington, D.C.

IRRI power grain cleaner

removes large and small impurities in one operation

For cleaning rice, wheat, sorghum, barley, and other grain crops.

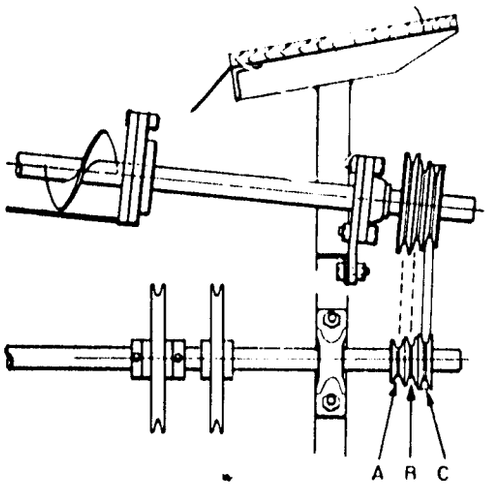


The power grain cleaner uses rotary screens in conjunction with an air blast. This combination simplifies the design and permits extended exposure of a tumbling mass of grain to air to give improved cleaning.

It is ideally suited for tropical countries and designed particularly for rice mills, farms, warehouses, and experiment stations.

FEATURES

Two concentric cylindrical screens permit extended exposure of grain to air resulting in improved cleaning. The inner screen retains large impurities, and lets the grain through. Smaller impurities like sand, dust, and weed seeds pass through the outer screen.



Adjustable feeding rate. The three pulley settings (A, B, C) result in approximate cleaning capacities of 1.6, 2.0, and 2.5 metric tons per hour.

Double spouted shute for direct and easy bagging. Clean grain is delivered into a trough where it is lifted by rubber flaps to the bagging attachment. The "cut-off" enables you to switch the flow of grain from one spout to the other.

Adjustable air opening for quality cleaning. The air intake opening can be easily varied to meet different degrees of output quality. For improved cleaning quality use a high air setting and a slow auger feed rate.

Machine specifications

POWER: 3 hp gasoline engine or 1 hp electric motor

WEIGHT (without engine):	340 kg
LENGTH	355 cm
WIDTH:	143 cm
HEIGHT:	148 cm
CAPACITY:	1.5-2.5 tons/hr
FUEL CONSUMPTION (gasoline):	0.8 liter/hr

INNER SCREEN: 8.0 mm (5/16 in.) or 9.0 mm (3/8 in.) dia. perforated steel sheet

OUTER SCREEN: 1.6 mm (1/16 in.) dia. perforated steel sheet

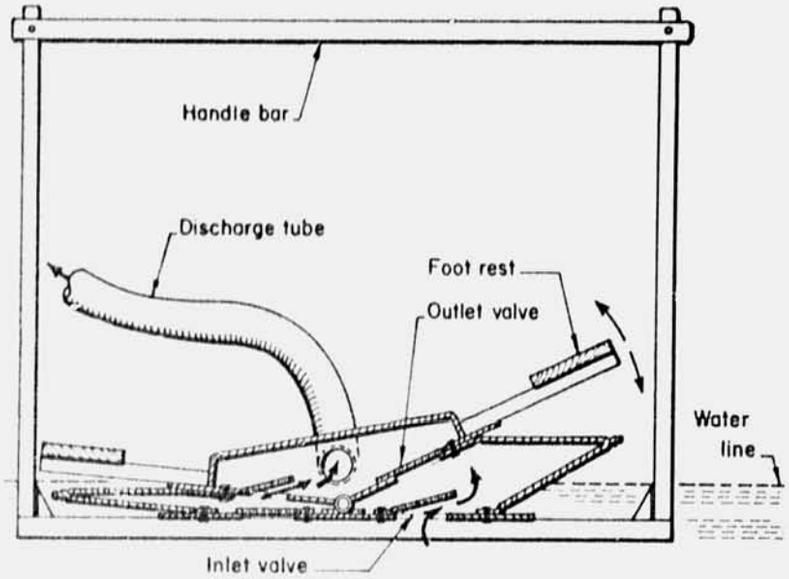
ADJUSTMENTS: Air control and feed auger control (3 settings)

The rotary grain cleaner is protected by Phil. Pat. No. 16430.

Developed at the International Rice Research Institute under a research contract with United States Agency for International Development

IRRI bellows pump
a simple way to pump water

For irrigation, drainage, and other low lift applications



The pump

The foot pump is made of two canvas bellows reinforced with metal inserts. The entire unit, equipped with a handle for convenient carrying, weighs 20 kg. The design is rugged for long service and easy repair yet simple enough to be manufactured by small machine shops.

How it works

The operator stands on the two foot rests and shifts his weight from one foot to the other. This compresses a bellows, forcing water from the outlet valve. By alternately shifting his weight in a rhytmic manner, the operator pumps a continuous flow of water.

What it does

This low-cost pump can lift 50 to 60 gallons of water per minute to a height of 1 to 2 meters.

The IRRI bellows pump is well suited for pumping water from irrigation ditches, open channels, river banks, and shallow wells. Unlike most pumps, it can handle muddy water with small stones or other solid impurities.

Machine specifications

POWER: 1 man

WEIGHT: 20 kg

LENGTH: 105 cm

WIDTH: 50 cm

HEIGHT: 92 cm

CAPACITY: 150 liters/min at 0.5 m head
120 liters/min at 1.0 m head
90 liters/min at 1.5 m head

CONSTRUCTION: Wood and steel frame, canvas bellows

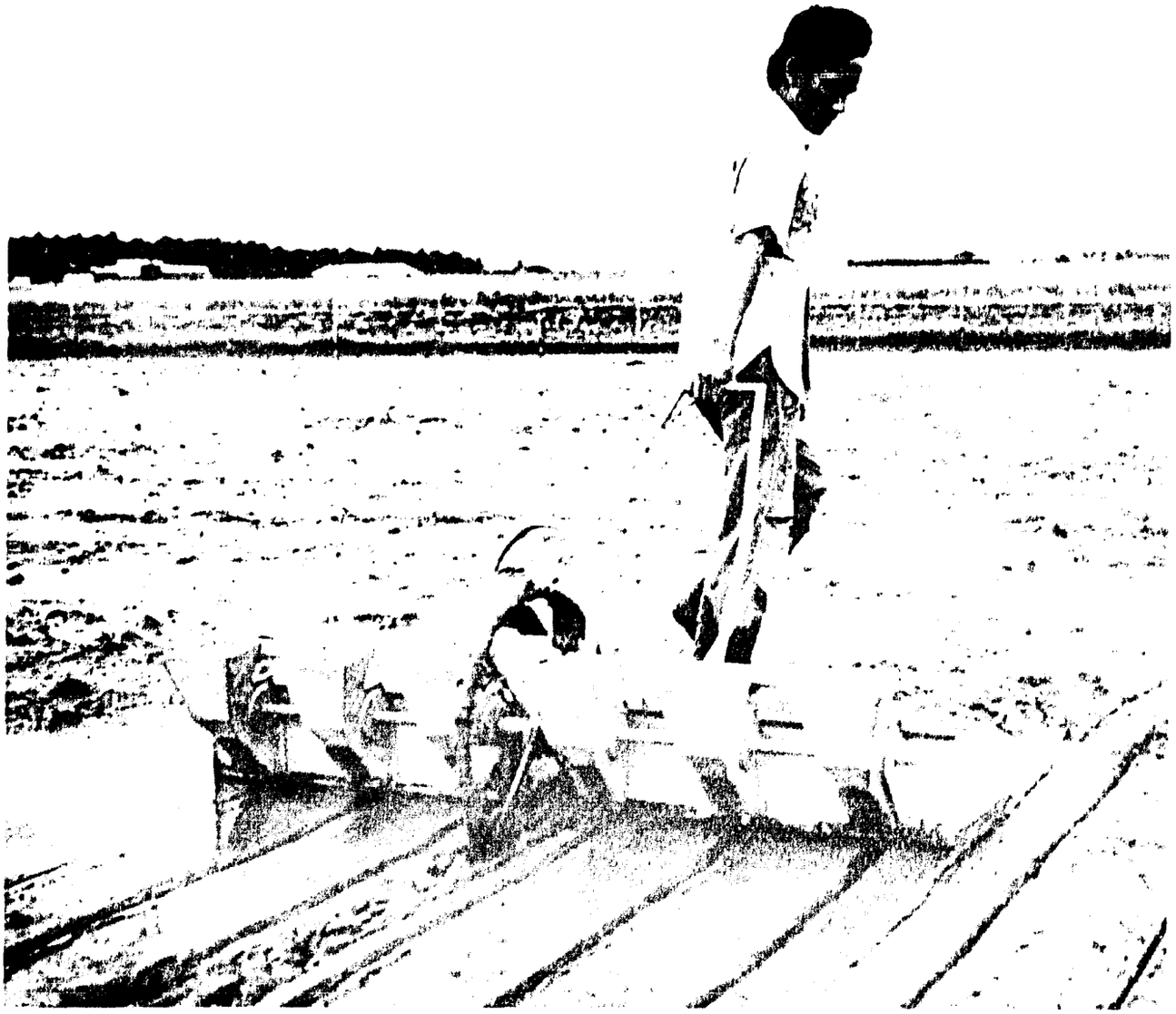
NOTE: Canvas bellows may require repair after 175 hours of use.

Protected by Phil. Pat. No. 17253.

Developed at the International Rice Research Institute under a research contract with United States Agency for International Development
For further particulars write
International Rice Research Institute, P.O. Box 933, Manila, Philippines Cable RICEFOUND, MANILA

IRRI multihopper seeder

for fast, accurate placement of pre-germinated seeds



The IRRI multi-hopper seeder is lightweight and compact with a low center of gravity for easy handling. The six-row seeder is built entirely of local materials. Initial investment, maintenance, and operating costs are low, making it ideal for small farmers.

Developed at the International Rice Research Institute under a research contract with United States Agency for International Development

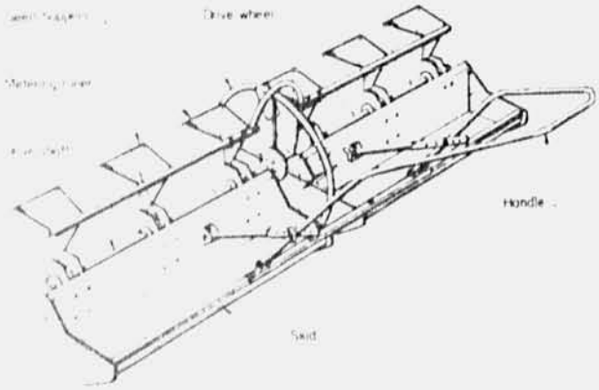
FEATURES

Optimal seed/gear combination

Efficient [illegible]

Simple construction

The seeder consists of six basic parts: handle, skid, seed hoppers, metering rollers, drive shaft, and drive wheel. The skid is in two sections divided by the drive wheel. The wheel turns the drive shaft, which operates the seed meter.



Specifications

POWER: Pulled by operator. Ground wheel drives meter-[illegible]

WEIGHT ([illegible] complete)	17 kg
[illegible]	110 cm
Wheel	150 cm
[illegible]	60 cm
ROW SPACING	25 cm
SEEDER CAPACITY (11 min. paddy)	3 kg (500 g/hopper)
[illegible] RATE	35–50 kg/ha
[illegible] CAPACITY	7 man-hr/ha

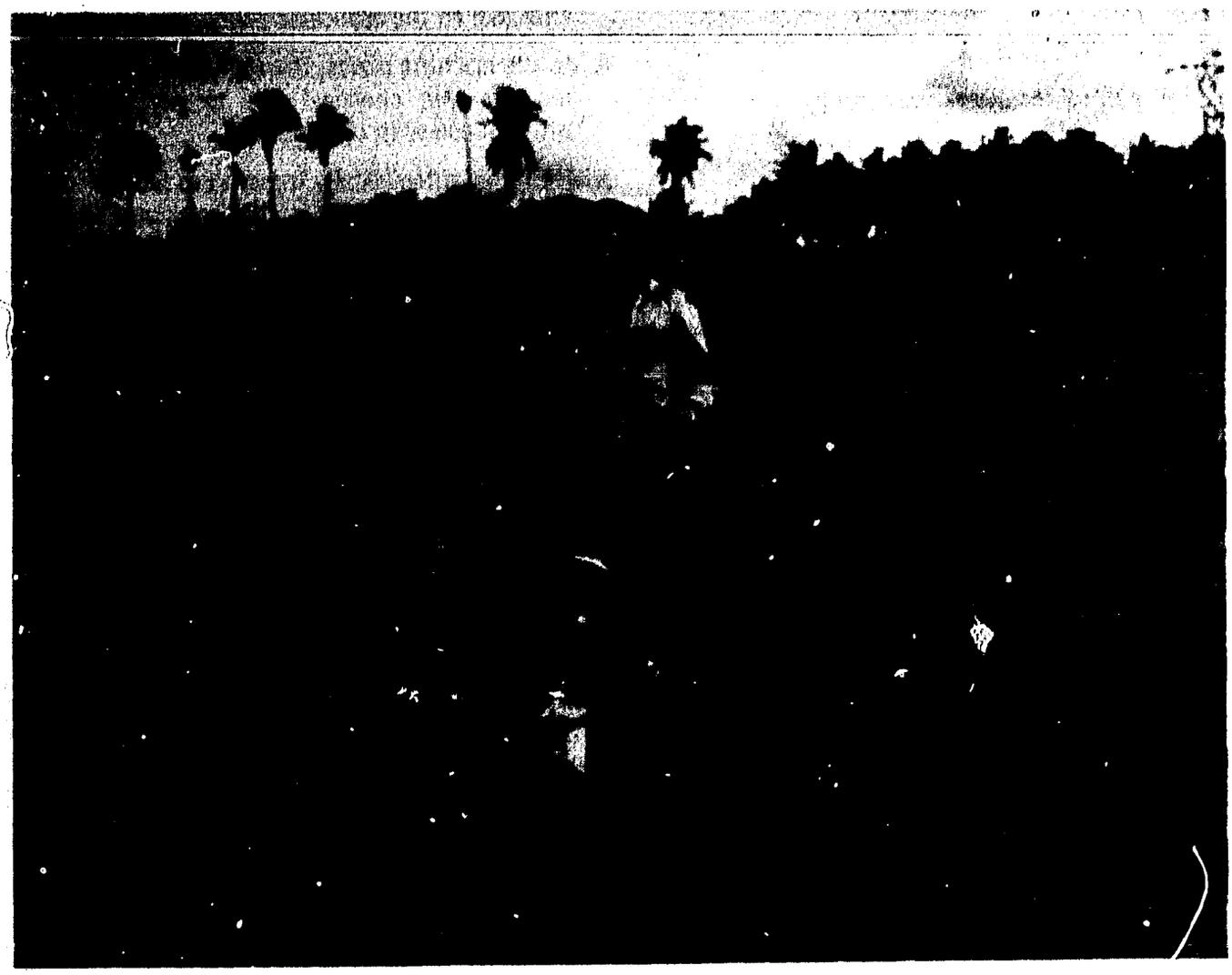
SOCIAL REQUIREMENTS

- [illegible] germinated seed.
- Good water control at planting time.
- Good land preparation.

[illegible] Cable: RICEFOUND MANILA

IRRI Contact herbicide applicator

a safe way to apply non-selective weed killers on upland crops



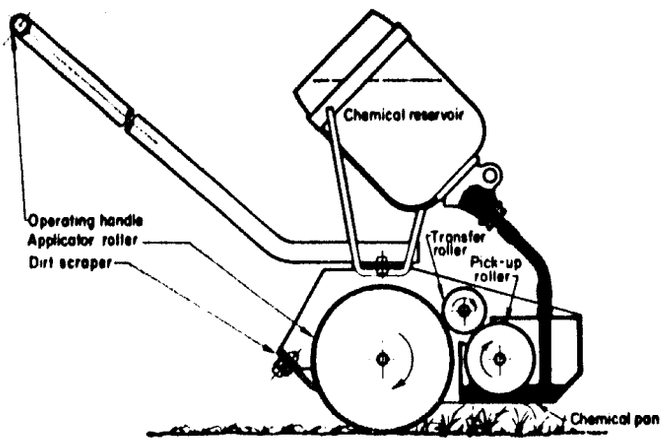
A simple substitute for handweeding in upland row crops

Non-selective herbicides are highly toxic to row crops. Applying them uniformly between rows is a problem with spray-type applicators. Spray patterns do not always conform to the space between the rows, so the herbicide often damages crops, particularly on windy days. Protective shields can be used to control the spray pattern, but the chemical often accumulates on the shields and is wasted by dripping. Because the chemical deposition patterns of sprayers are not often uniform, herbicide application may be concentrated at the center. In addition, pressure-generating devices on sprayers are costly and subject to service problems.

The contact applicator was developed at the International Rice Research Institute to overcome these problems. The applicator concept is based on the ink-dispersing principle that is widely used in printing presses. Its design is simpler and more trouble-free than those of other herbicide applicators.

FEATURES

- Automatic feeding
- Applies uniform quantity of weed killer to any surface contacted by the roller
- Uses 200 to 300 liters of solution per hectare
- No chemical drip
- No chemical drift in wind
- Accurate control for inter-row weeding
- Ground-driven
- Manually operated



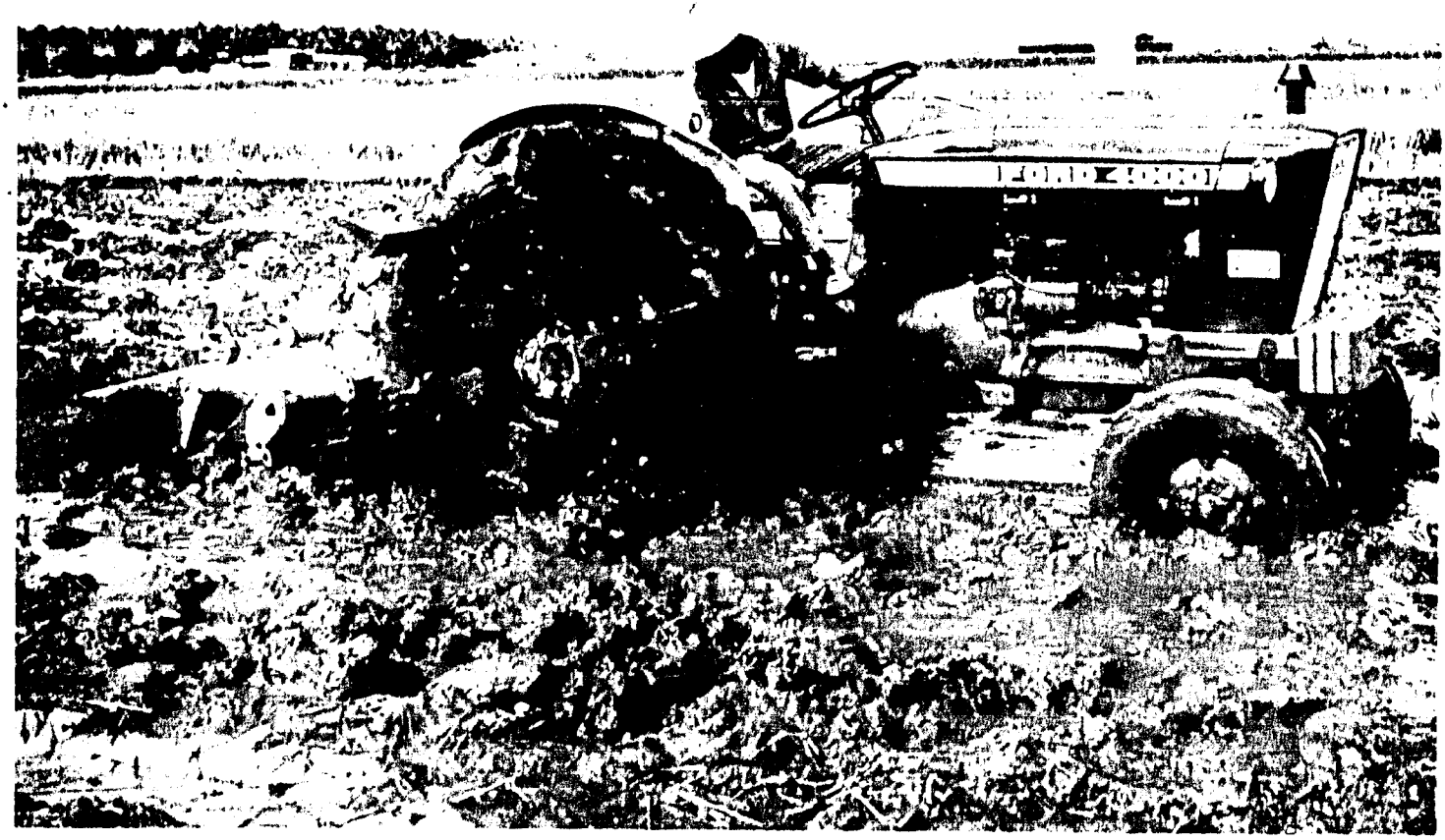
Contact Applicator for non-selective herbicides
(Capacity 200 to 350 liters per hectare)

HOW IT WORKS

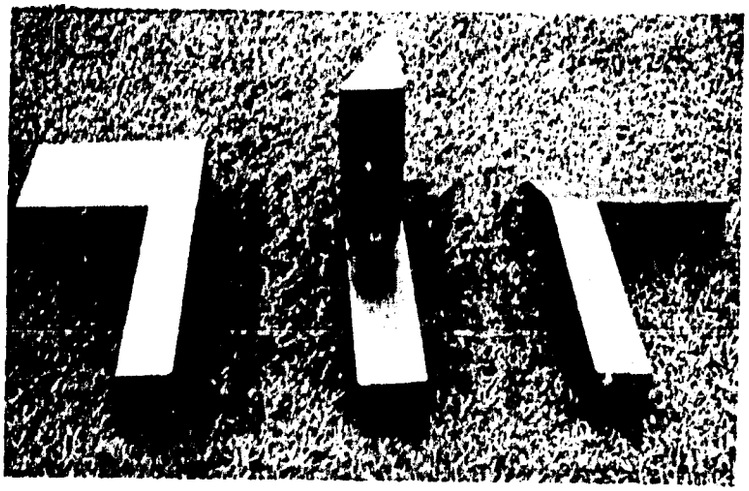
1. The bottle reservoir is filled with the desired mixture of weed killer and water.
2. The pick-up roller picks the chemical from the pan and spreads it on the transfer roller.
3. The transfer roller imparts a thin layer of the chemical on the applicator roller.
4. As the machine moves, the applicator roller transfers the thin chemical film to any weeds with which it comes in contact.
5. Liquid is automatically transferred from the bottle reservoir as chemical is consumed and the level in the pan drops. This provision ensures a uniform thickness of chemical film on the applicator roller.
6. A scraper removes any dirt or trash that may be picked up by the applicator roller.

Developed by the Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines, under a research contract with the U. S. Agency for International Development, Washington, D.C. Manufacturers may incorporate modifications resulting in slight deviations from the basic design.

Extendible lug wheel



Developed by the Agricultural Engineering Department, The International Rice Research Institute, Los Baños, Laguna, Philippines, under a research contract with the Technical Assistance Bureau, U.S. Agency for International Development, Washington, D.C.

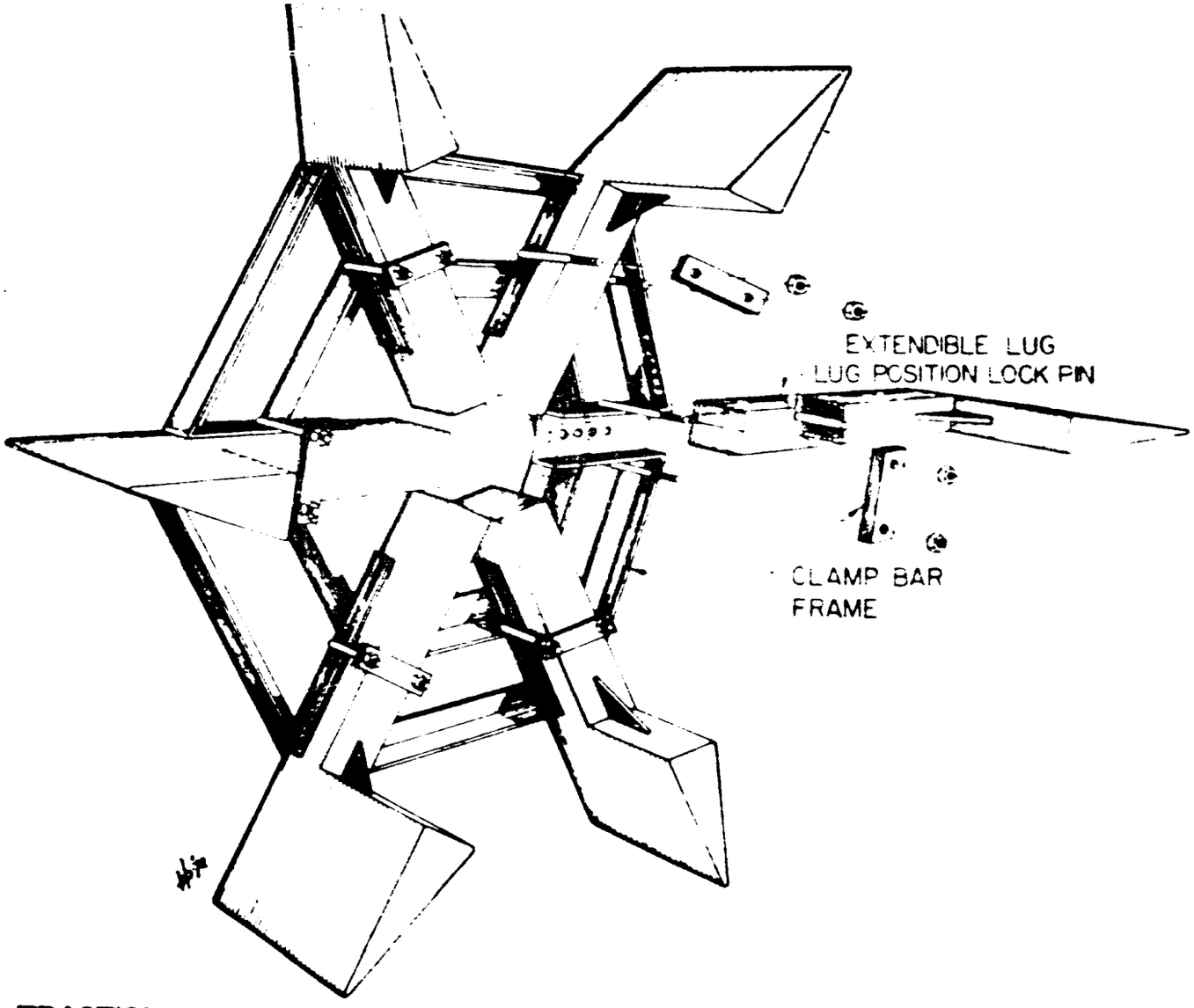


Extendible lug wheel

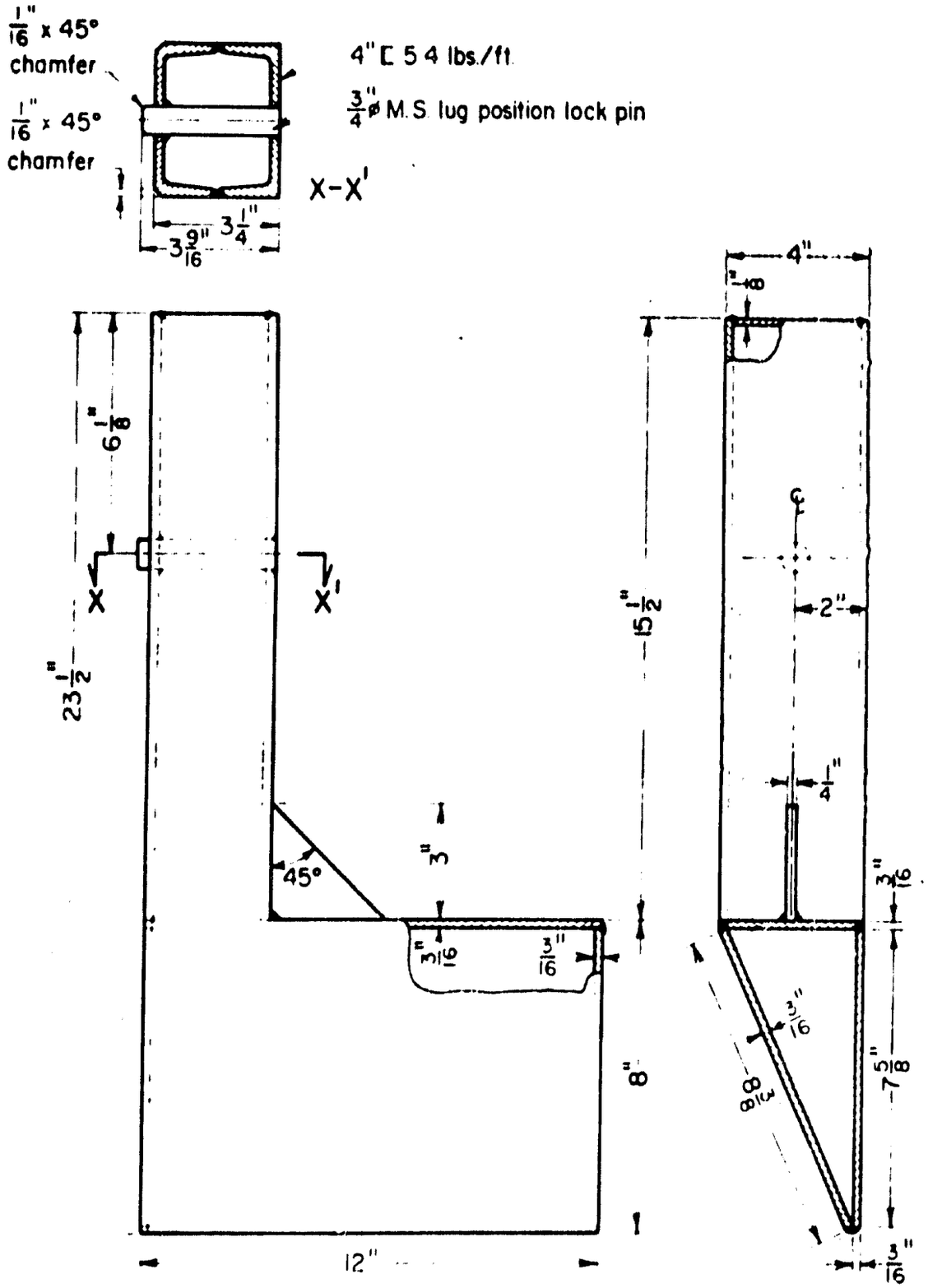
Summary: An extendible lug wheel has been designed at the International Rice Research Institute to improve the traction of tractors in muddy fields. Small metal fabricating shops can construct the wheel. Plans are shown.

Because rubber-tired tractors often bog down (become stuck) in muddy fields, such as rice paddies, several devices are available to improve traction. Fixed lug wheels are quite popular in tropical rice areas. A major drawback of the fixed lug wheel is that traction assistance is directly related to how deep the tire sinks in the soil. The depth of sinkage cannot be adjusted to suit varying soil conditions. A simple strake wheel that has gained popularity in Malaysia consists of five or six 10 x 10 cm wooden strakes mounted radially on a metal frame. The strakes can be extended and locked in position to provide the desired degree of traction assistance. Wooden strake wheels have several shortcomings: the strake ends have a large "footprint" area so when the strakes are extended beyond the tire periphery, the tractor tends to move with a rocking motion; the strakes are not wide enough to develop adequate traction; and the strakes are difficult to adjust because the wood swells when wet.

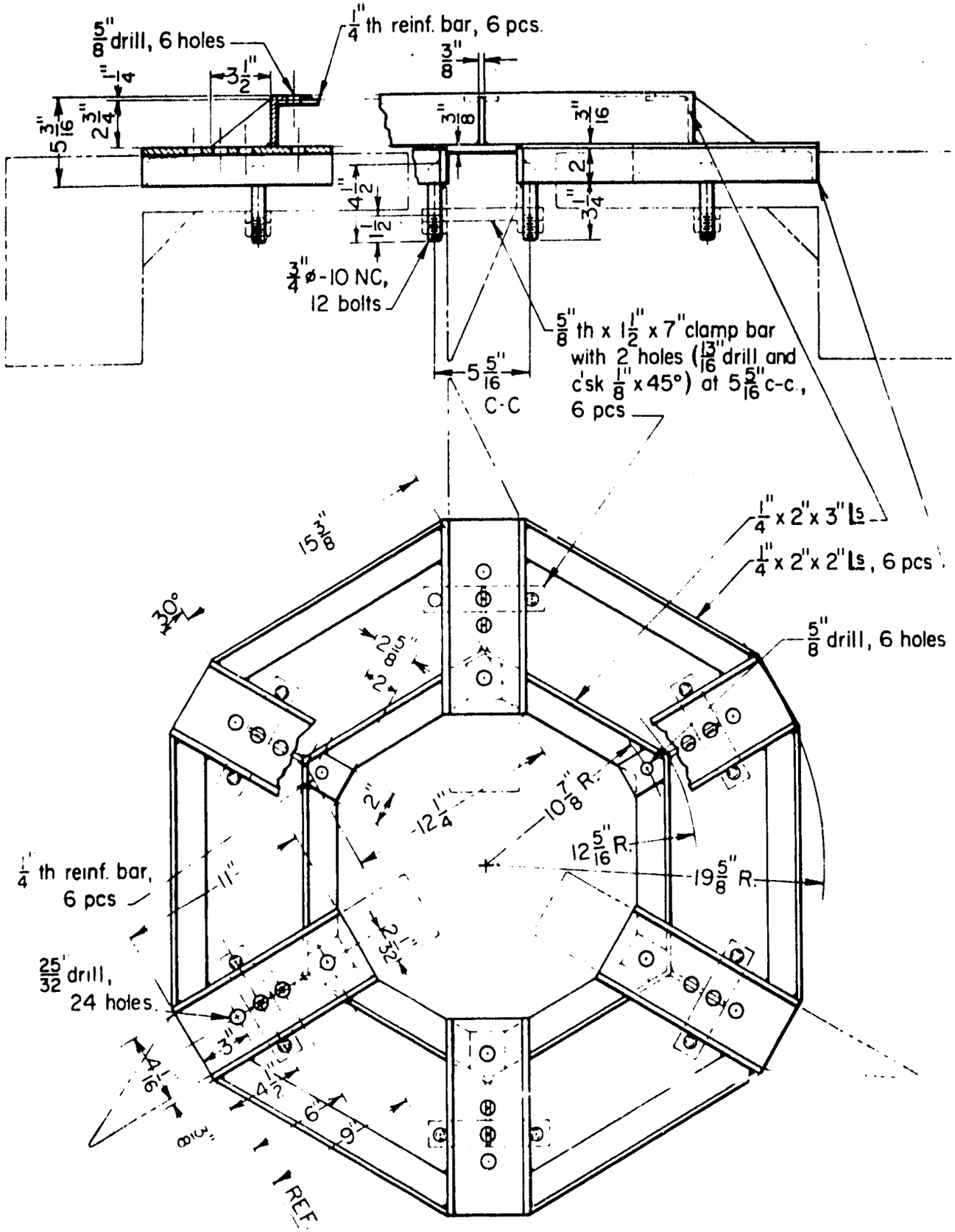
We attempted to combine the desirable features of the fixed lug wheel and the strake wheel in an extendible steel blade wheel. An experimental wheel was designed which could accept five or six blades with equal spacing. Two blade face angles were tested, one 25° with the radial line and the other along the radial line. The blade lugs could be locked at -5.0, -1.5, +2.5, +6.5, and +10.0 cm from the periphery of the tire. The two different face angles of the blade produced no appreciable difference in traction. Nor was traction at the -1.5 cm and -5.0 settings significantly different, but the -5.0 cm position was more convenient for travel on hard ground. With six lugs, maximum drawbar pull was obtained at about 50 percent wheel slip while with five lugs, maximum drawbar pull occurred at 85 percent slip. To obtain high traction efficiency at low wheel slippage, we recommend six lugs with the following positions: -5.0, +2.5, +6.5, and +10.0 cm.



TRACTION ASSISTING EXTENDIBLE LUG WHEEL FOR RUBBER TYRED WHEEL

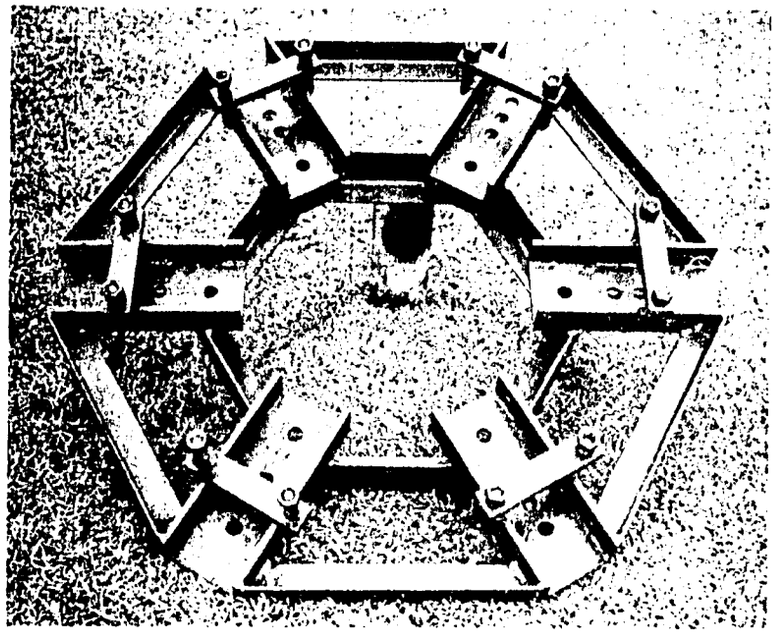


DETAILS OF EXTENDIBLE LUG



DETAILS OF FRAME

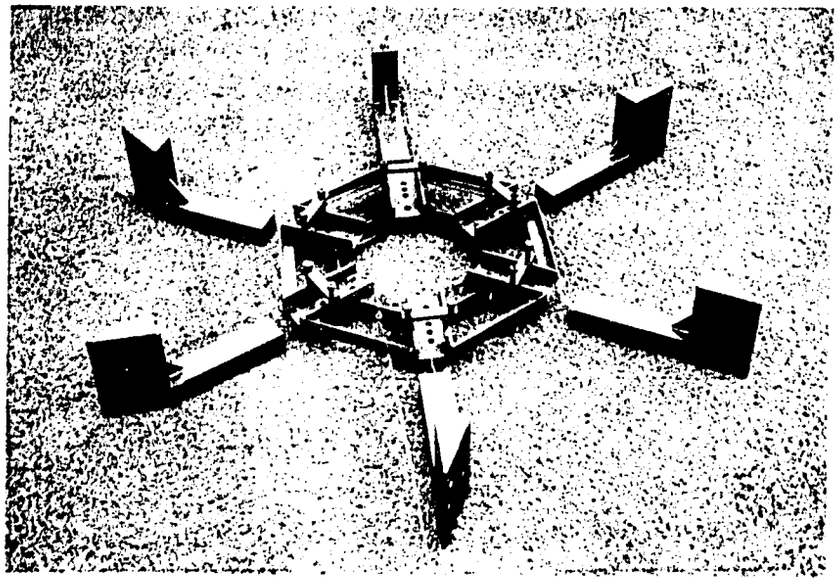
Based on these results, we designed an extendible lug wheel for commercial production. In this wheel, the blade position is easily adjusted. A single wrench is required to loosen the two clamping nuts sufficiently to free the locating pin. Slide the lug to the new position, engage the locating pin, and re-tighten the clamping nuts. The extendible lug wheels can be manufactured by most small metal fabricating shops. Standard steel sections (i.e., angles, channels, and plate) are used throughout its design. Simple fabrication methods are used which require a minimum of production tools.



LUG WHEEL FRAME

Operating procedure

Position the blades in the -5 cm locating hole when traveling on the road. This position should also be used if the field is not too wet and traction assistance is not required on a continuous basis. In wetland conditions, adjust the blades to the +2.5 cm position for normal operation. In very soft fields, use the +6.5-cm setting. Watch the amount of the wheel slippage closely. If the wheels slip too much, the tractor will bog down (become stuck in the mud). To reduce wheel slippage, slow down. If the wheels continue to slip too much, stop the tractor immediately. Then extend every second blade to the +10 cm setting and very slowly back the tractor out. By backing out you avoid the danger of overturning. If the tractor is severely bogged down extend all the blades to the +10-cm setting and back the tractor out slowly. Keep the wheels from slipping, otherwise they will dig a bigger hole.



FRAME AND LUGS

The design illustrated fits the standard wheel rim of a FORD 4000 tractor which has 13.6 X 12-38 tires. Slight modifications of the center mounting ring may be necessary to adapt the extendible lug wheel to other rims.

Specifications

WEIGHT (per pair):	274 kg
MATERIAL:	Steel
EXTENDIBLE LUGS PER WHEEL:	6
LUG WIDTH:	30.5 cm

LUG POSITIONS: -5 cm (for highway), +2.5, +6.5, +10.0 cm

ADJUSTMENT: Lug position is manually adjusted by a locating pin and a U-bolt securing each lug.

Basic design fits standard rear wheel rim of a Ford 4000 tractor. Modification of the center mounting rim may be necessary to adapt the extendible wheel strakes to other rims.