9. MACHINERY RESEARCH AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

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Background of research

In the late sixties, scientists at the International Rice Research Institute and elsewhere demonstrated that it was possible to raise rice yields by severalfold in tropical areas. These developments led to significant changes in rice production and many countries that formerly had chronic deficits of rice are now looking forward to self-sufficiency. The income of farmers who have adopted new, high-yielding varieties and practices has usually risen sharply and this has provided an impetus for mechanized cultivation.

The shorter growing period of the new high-yielding varieties has provided possibilities for double and triple cropping. In continuous cropping experiments at the Institute, 3 crops have been harvested each year from the same piece of land for the last 8 years, resulting in a maximum annual production of about 23 metric tons of rice per hectare. If the farmer of the tropics is to keep his land in near-continuous production, suitable power-driven equipment for lowland farming must be made available.

According to the International Rice Commission, the countries of Southeast Asia and the Far East use 5 to 7 hours of labor to produce 20 kg of rice, whereas only 5 to 7 minutes are required to produce this amount of rice in the highly mechanized rice production areas of the world. Many studies have shown that demand for labor in the rural areas of the tropics is highly seasonal. A labor shortage often occurs during land preparation, transplanting, harvesting and threshing.

The U.S. Agency for International Development, recognizing a need for mechanization research in Asia, signed a research contract with the Institute in 1965. Research under this contract has been primarily oriented towards the development and production of new agricultural equipment for rice cultivation. This approach has been based on certain aspects of mechanization research which are typical of the developing countries.

In the past, results of agricultural mechanization research have been slow to reach the Asian farmer. The effectiveness of such research, however, depends on its achievements in the farmers' fields. In industrialized countries, equipment manufacturers generally utilize research results to develop new agricultural machinery. A virtual lack of machinery development capability in the tropical countries has created a serious bottleneck in the flow of research results to the farmers.

This aspect of mechanization research in the tropical countries was recognized in developing this research program. Under the present circumstances, applied machinery research and equipment development projects, rather than research for knowledge, seem to offer more productive possibilities in the developing countries.

In Asia, the medium-sized landholdings, 2 to 10 hectares, constitute a large segment of the total land under paddy cultivation. As a group, farmers with this amount of land have the potential to support an intermediate level of mechanization.

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They find that the traditional animal or manual equipment is often inadequate for their requirements. Ironically, this large group of farm holdings has the least access to suitable power equipment. Except in Japan, machinery development research in advanced countries has been primarily concerned with equipment for larger holdings. However, due to the sophistication desired by the Japanese farmer, such equipment is often uneconomical for tropical farmers. In the long run, larger agricultural equipment will play an increasingly important role in the mechanization of tropical agriculture. Meanwhile, the requirement of the medium-sized tropical farm holdings, which are too large to work economically with animals but too small for the sophisticated 30-plus horsepower equipment, requires immediate engineering attention.

Scope for local manufacture of agricultural equipment exists in many developing countries. The strong desire for industrial development and the shortage of foreign exchange are factors which encourage local production. In addition, the long-range socio-economic implications of displacing field labor by imported agricultural equipment necessitates the development of local machinery industry to provide alternate employment. A lack of acceptable agricultural machinery designs, that could be produced by simple fabrication methods, has hampered the growth of local manufacturers.

In the area of rice drying and processing, the large rural consumption and the inadequate transport facilities in the rural areas of Asia indicate a need for intermediate-scale, modern drying and processing systems for village-level operations. Capital intensive technology to dry and process rice in large quantities is well developed in the industrialized countries and is being applied in the establishment of large-scale, centrally located commercial rice drying and processing plant in many Asian countries. An estimated 50 to 70 percent of the rice produced in the tropical countries, however, is consumed within the rural areas and do not pass through commercial channels. Paddy for rural consumption is sundried and hand-pounded or processed through single-pass husker-polishers located in small towns and villages. The rice processed for rural consumption is generally of very poor quality.

Because of the above considerations, engineering research at the Institute is broadly organized along three lines: field machinery development, drying and processing research, and applied machinery research.

Field machinery development research involves the complete development, from concept to production model, of relatively simple, power-operated, labor-intensive field equipment to suit the capabilities of manufacturers and the requirements of farm holdings of 2 to 10 hectares in tropical areas.

Drying and processing research involves the development of economical rice drying and processing equipment and systems for village-level operations.

Applied machinery research involves providing assistance in the development of improved rice production and processing equipment to manufacturers located outside the tropical regions. Emphasis is placed on applied research to solve specific mechanization problems and not on the design and development of machines for production. The evaluation of new and advanced machinery concepts and assistance in field-testing of experimental and prototype machines is an essential component of this activity.

A number of development and applied research projects undertaken and the progress made so far on some of the projects

Drum thresher

The drum thresher (Figs. 1 and 2) was designed for high-moisture paddy threshing because available threshers do not perform well when the crop is wet or has a high moisture content. The drum thresher has a wire loop threshing drum that is 6 feet long

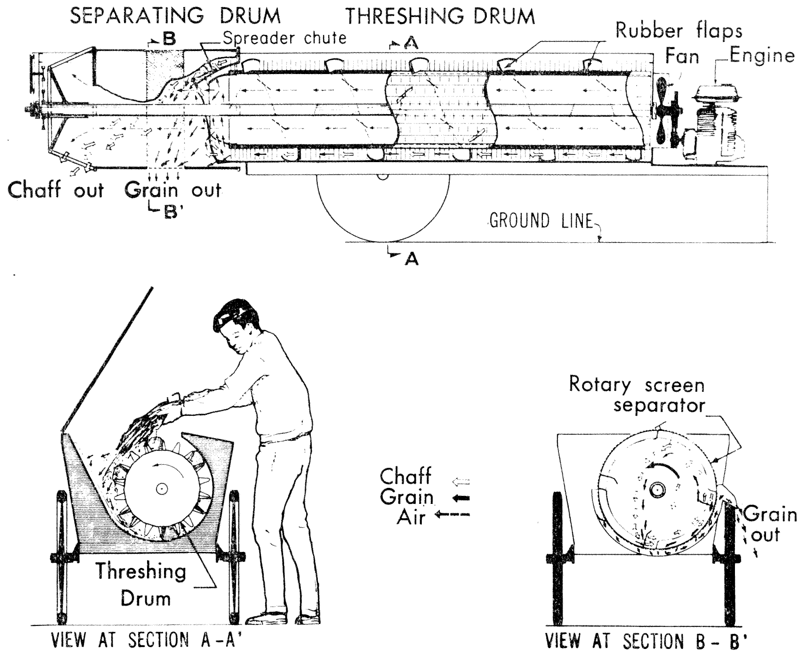

Fig. 1. Schematic drawing of the drum-type thresher.

Fig. 2. Commercially manufactured drum-type thresher in the Philippines.

and a rotary screen cleaner. It is driven by a 4-hp aircooled engine and can thresh 250 kg of paddy per hour. The thresher is being manufactured in the Philippines and some units have been exported to other Asian countries for evaluation.

Table thresher

The table thresher (Figs. 3 and 4) is light enough to be hand-carried into fields with no access roads. A flat, circular threshing surface gives this design more effective use of the threshing surface than cylindrical drum threshers. The screening of grain

Fig. 3. Schematic drawing of the table-type paddy thresher.

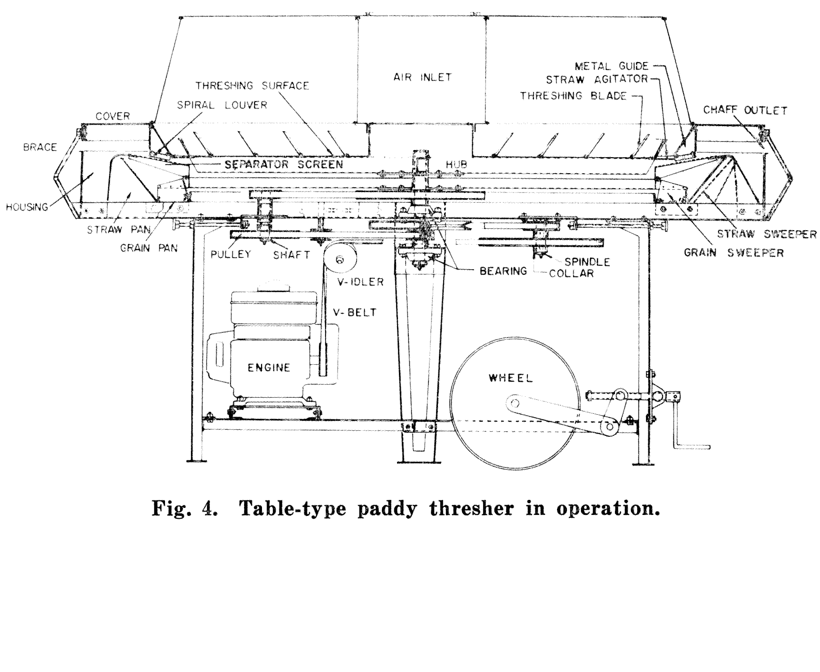

Fig. 4. Table-type paddy thresher in operation.

is done by a flat, circular, rotating screen. A radial fan built on the underside of the threshing surface provides air to winnow the threshed grain. The machine, complete with a 2.5-hp aircooled engine, weighs 170 kg. The thresher has been designed for compact packaging to facilitate export to other countries. Manufacturing arrangements are being made for the production of this thresher in the Philippines and Australia.

Rotary power weeder

While low-cost herbicides for weed control are now available, manual weeding in wetland paddy is still widely practiced in Asia. A portable, power-driven weeder (Fig. 5) for weeding three or five rows of paddy under soft field conditions has been

Fig. 5. Experimental three-row power weeder.

developed. For turns, the machine can be lifted from the field at the end of the rows since small paddies have no headlands. A lightweight 1-hp engine powers the weeding rotors through a worm reduction box. Shields made of light metal keep the plants from being ripped by the weeding rotors. The rotors uproot and bury the weeds under the mud. During operation, the operator supports only about one-half of the machine's weight. The quality of weeding is comparable to manual rotary weeders which are quite popular in the tropics. The power weeder requires only 17 man-hrs/ha as compared with 70 man-hrs/ha for manual rotary weeders and 120 man-hrs/ha for hand-weeding. Manufacturers from the Philippines and Japan have shown considerable interest in this machine. A Japanese manufacturer has started the production of a weeder based on this concept.

Anhydrous ammonia applicator

Asian rice farmers do not apply anhydrous ammonia, a low-cost source of nitrogen, to paddies because suitable application equipment for puddled soils is not available. The recent popularity of small walking tractors and power tillers for tropical rice cultivation prompted the Department to develop an anhydrous ammonia applicator for small

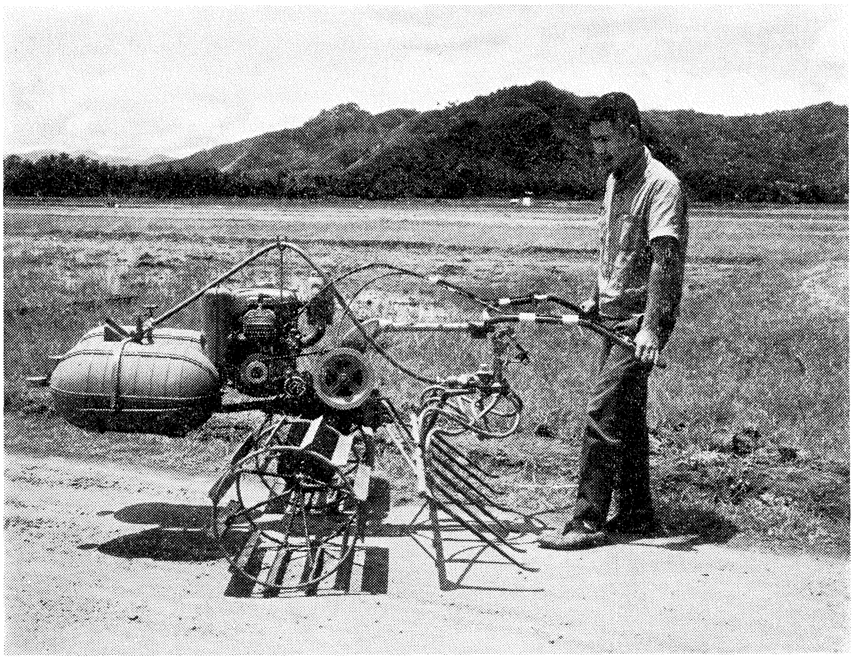

Fig. 6. Anhydrous ammonia applicator for small hand tractors.

tractors. Figure 6 shows the applicator mounted on a 6-hp walking tractor. Further development work is in progress.

Tractor tillage and mobility in flooded soils

Since it is difficult to develop adequate traction under soft wetland conditions, land preparation has been limited to implements, such as rotary tillers, that do not depend on traction. Rotary tillers, however, develop some forward pushing reaction on the tractor during tilling. To exploit this reaction and improve tractor mobility in soft soils, a large-diameter rotary tiller (Fig. 7) with adjustable tilling blades was designed. The machine is being used to study the effect of blade shape, blade angle, and tiller diameter on horizontal soil reaction. Experiments have shown that a rotary tiller with a diameter of 85 cm which is attached to a 55-hp tractor can develop up to 1,000 kg of pushing force, thereby improving tractor mobility.

Experiments to determine the coefficient of rolling resistance of a 3,257 kg, standard 55-hp tractor with rubber tires (Fig. 8) under soft puddled conditions were also conducted. A strain-gage transducer designed to measure only the horizontal component of the tractor towing force was used in the tests. Rolling resistance readings ranging from 480 to 1,230 kg were recorded from the fields tested at the Institute. It was obserevd that the tractor encountered difficulty in propelling itself in fields where 1,230 kg of rolling resistance was indicated. The coefficient of rolling resistance for the test tractor varied from 0.147 to 0.378 in the lowland paddy fields at the Institute.

Differential slip for wetland preparation

Flooded soils with deep hardpans are very difficult to prepare with conventional tractors due to poor tractor mobility and bogging problems. Under such conditions, conventional tillage implements do not work satisfactorily. Often tractors have to be

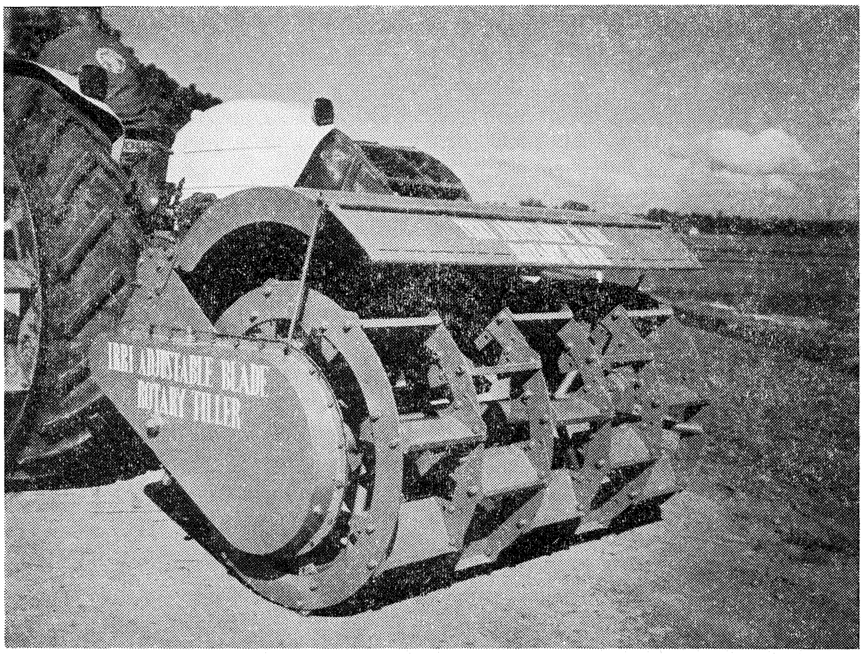

Fig. 7. Experimental wetland rotary tiller with adjustable blades.

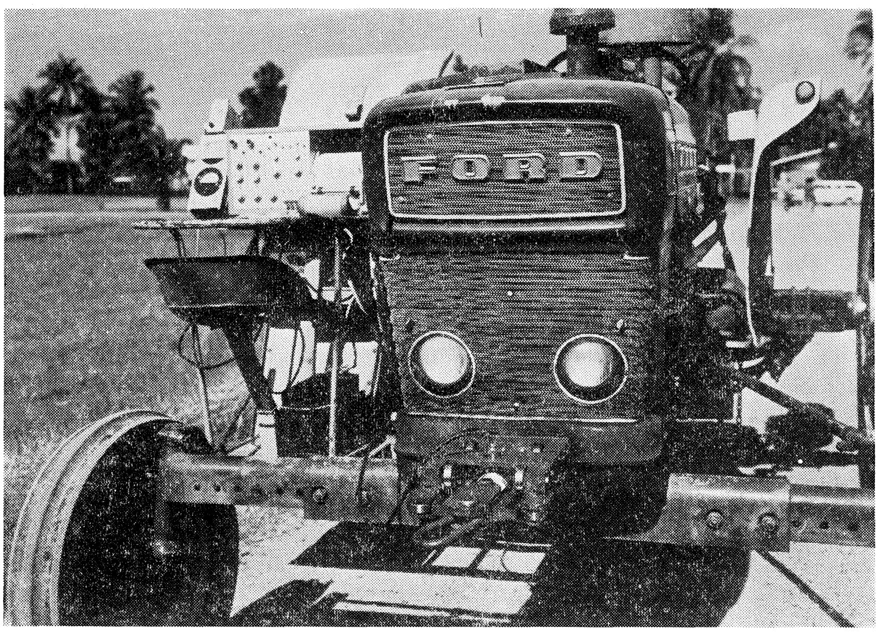

Fig. 8. Tractor with instrumentation for rolling resistance measurement.

used with cage wheels alone to prepare the land. A project was initiated to study feasibility of using a small four-wheel riding machine to prepare land by a difference in slippage between independently driven front and rear cage wheels. For maximum mobility on soft ground, the front and rear cage wheels could be driven at the same speed. For land preparation, the front or the rear cage wheel could be driven at a faster speed, thus deliberately inducing some difference in wheel slip between front and rear wheels.

To evaluate this possibility, two lightweight hand tractors were coupled with an articulated chassis to form a four-wheel-drive riding tiller. The experimental tiller (Fig. 9) had excellent mobility in soft fields even when the hardpan was deeper than

Fig. 9. Experimental four-wheel tiller in soft soil with deep hard pan.

the wheel radius. Due to its light weight, the tiller could travel across dikes without damaging the dikes. Tillage was accomplished by increasing the speed of either wheel. The concept looks promising for soft soils and a new machine is being designed with a single engine and variable drive to front and rear wheels.

PTO-driven multicrop thresher

The introduction of combine harvesters in countries with mechanized agriculture has led to a decline in the use of threshers. The acceptance of combines, however, for harvesting rice and other crops has been slow in the tropics. Consequently, a substantial demand exists for high-output, stationary threshers. The development of a three-point linkage, tractor-mounted PTO-driven thresher for 30- to 60-hp tractors was started to meet this demand. Such a thresher would offer improved mobility, high threshing output, and minimum down time.

The PTO thresher (Fig. 10) being developed at the Institute has a conventional spike tooth cylinder with adjustable deflecting baffles in the drum housing to move the threshed material in an axial direction along the cylinder. The adjustment on the deflect-

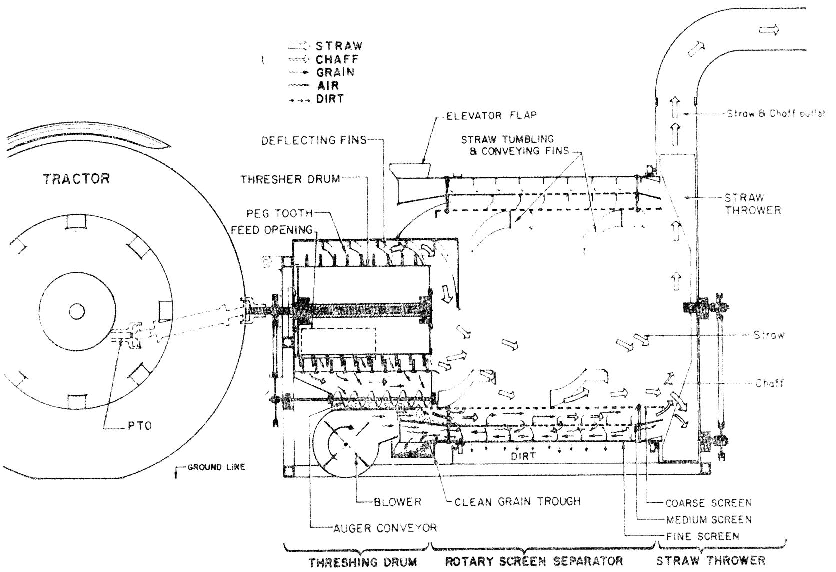

Fig. 10. PTO-driven paddy thresher with rotary screen separator.

ing baffles controls the degree of threshing for different crops and varying crop conditions.

The machine has a three-screen rotary separating and cleaning mechanism which is lighter than the straw walkers and oscillating screens used in conventional threshers. Fabrication of the first prototype machine has been completed. Further development and evaluation are under way.

Paddy combine stripper-harvester

Conventional combines are bulky machines since they are designed to handle large volumes of straw during harvesting. The weight of these combines creates serious mobility problems under wet tropical field conditions. Attempts have been made in the past to develop stripping harvesters to eliminate handling of straw through the machine. Excessive grain shattering, however, has been one of the major problems.

Most of the stripper-harvesters built experimentally have been designed to thresh grain from upright crops. Because the plant is upright, the violent contact during threshing scatters the grain over a wide pattern. The stripper under development at the Institute (Figs. 11 and 12) is designed to bend the plants gently into the machine prior to threshing. The plants are pressed against the upper portion of an inclined threshing belt. During operation, panicles continuously slide down along the threshing belt as the machine moves forward and tramples the threshed plants. During the forward movement of the machine, more plants are gently deflected against the top portion of the threshing belt and are subsequently threshed and trampled under the machine. The gentle backward deflection of the plants, just before they contact the threshing belt, directs the threshed grain toward the rear of the machine and this facilitates grain collection and reduces grain scatter.

The experimental machine is capable of harvesting all grain from non-lodged crops. The first experimental unit was primarily designed to evaluate the new stripping concept and was not equipped with croplifting components. This concept offers possibilities

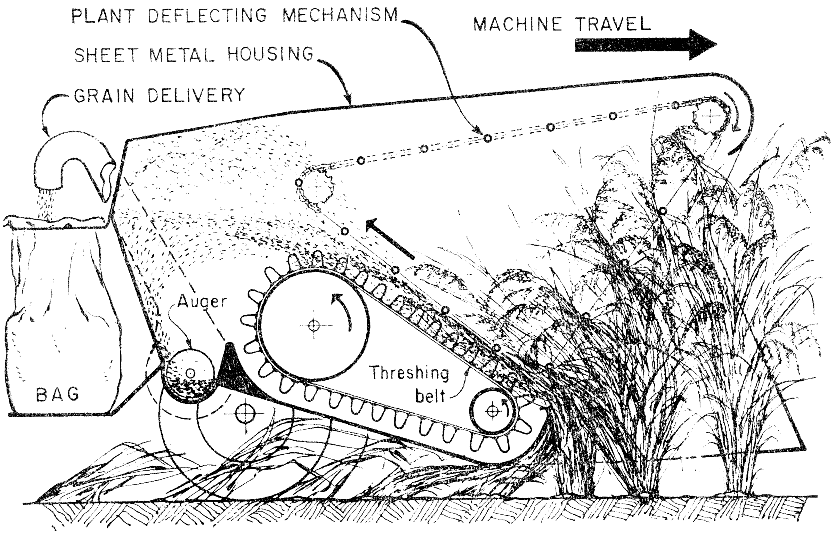

Fig. 11. Schematic drawing of the paddy stripper combine.

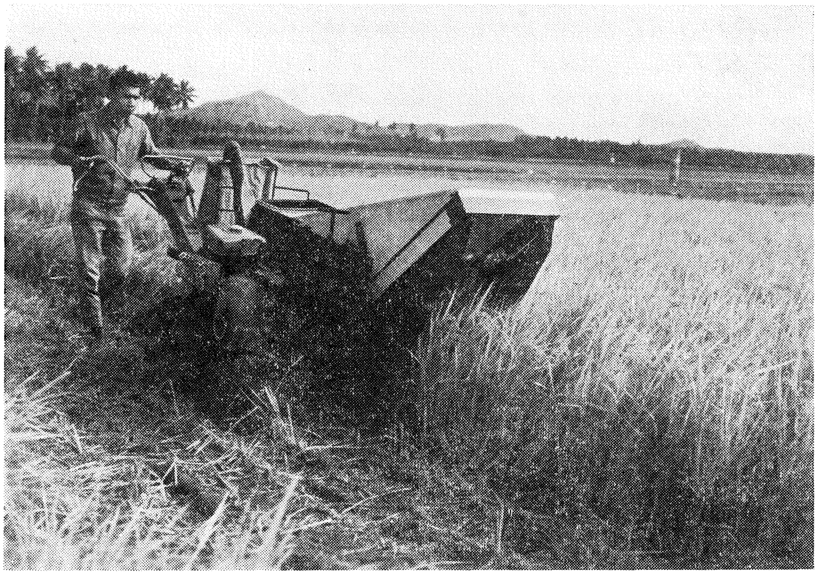

Fig. 12. Experimental paddy stripper combine harvester.

for harvesting not only paddy crop but also other grain crops.

Row seeder for pre-germinated paddy

The traditional practice of transplanting rice has high labor requirement. In some countries, pre-germinated seeds are broadcast manually on puddled soils to save labor. Row seeding of pre-germinated seed would not only save labor but would also permit the use of all row-crop paddy equipment such as rotary weeders, binders, and combine harvesters.

An eight-row portable seeder has been developed (Fig. 13). The ground-driven

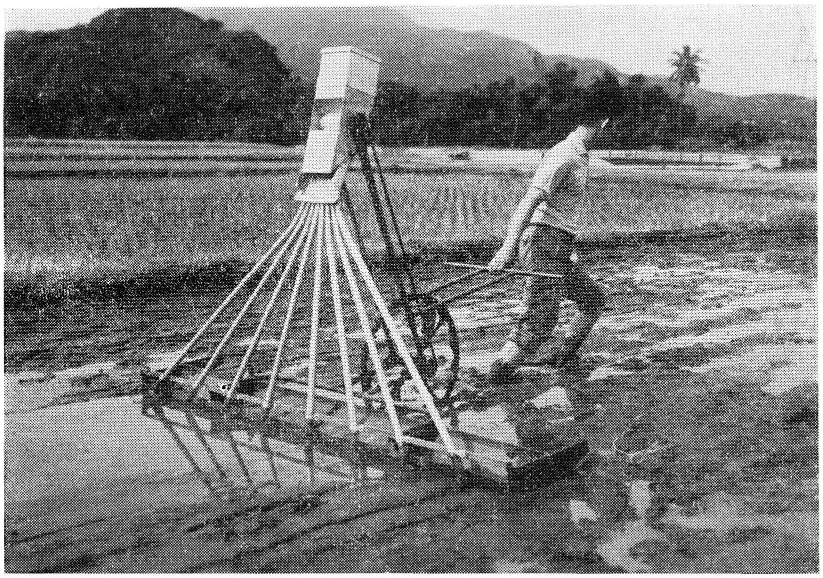

Fig. 13. Eight-row seeder for pre-germinated paddy.

metering mechanism (Fig. 14) is designed to meter pre-germinated paddy seeds that have sprouted up to one-half inch. The machine is equipped with a single wheel which allows it to be transported on field levees and between dropped seeds when turning at the end of the rows. Planting with the machine requires 5 man-hrs/ha as compared

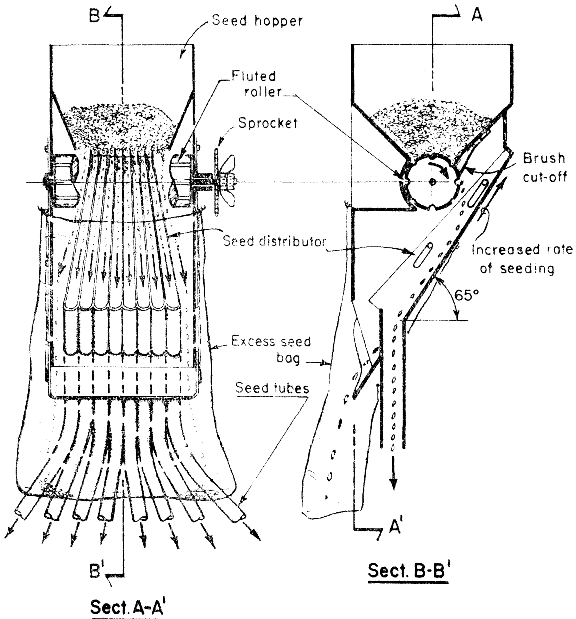

Fig. 14. Schematic drawing of the metering mechanism for pre-germinated seeds.

with 120 man-hrs/ha for transplanting. Three companies have started the production of this seeder in the Philippines.

Rotary screen grain cleaner

There is a need for a simple grain cleaner which could be used during threshing, before and after drying, and prior to milling and processing of paddy. The only equipment used in the tropics for seed cleaning are simple winnowers. Seed cleaners that are popular in the advanced countries use oscillating screens in conjunction with a high-velocity air stream. The oscillating screens are a source of mechanical problems and do not perform well when excessive amounts of larger impurities are present in the grain. Also, the grain is exposed to the air stream too briefly to satisfactorily separate the empty kernels from the mature paddy grain.

The design of a simple grain cleaner (Figs. 15 and 16) for tropical conditions was initiated. The use of a rotary screen reduces mechanical drive problems, improves the screening of grain with excessive amount of larger impurities, and can perform on a wet or high-moisture paddy. The flow of a relatively low velocity air for a longer duration through the tumbling grain improves the separation of light impurities. A cleaning output of over 3 tons per hour has been obtained with the machine. Arrangements for manufacture of the machine in the Philippines have been recently completed with two manufacturers.

Accelerated drying of paddy

A carefully controlled temperature of 100°–120°F and a slow rate of drying is necessary to retain paddy seed viability and high head rice (unbroken grains) yields during drying. For rice to be consumed as food, seed viability is not essential and a much higher temperature and faster drying rate are permissible. Since a more economical and rapid method to dry paddy is necessary for tropical areas, two research projects have been started to develop basic information on conduction drying of paddy using heated-sand and direct-flame exposure with mechanical agitation to minimize localized heating paddy grain.

The experiments using heated-sand (Figs. 17a to 18b) indicate that paddy can be simultaneously dried to a moisture content of about 18 percent and parboiled in a few seconds (15 to 20 seconds exposure in sand heated to 400°F [±10°] temperature) provided sufficient moisture (about 30%) is initially present in the grain to permit the gelatinization of the starch granules. Otherwise, the paddy can be soaked in water at room temperature for 6 hours to introduce sufficient moisture (Fig. 19). Work is under way on the development of a continuous-flow, heated-sand, conduction drier. The concept used in the drier under development is simple and shows possibilities for more economical drying and parboiling of paddy than conventional methods. Such a drier could be very useful for countries where parboiled rice is popular.

A second set of conduction drying experiments using mechanical agitation to minimize localized heating of grain is also under way and preliminary results indicate somewhat similar results as obtained with the sand process.

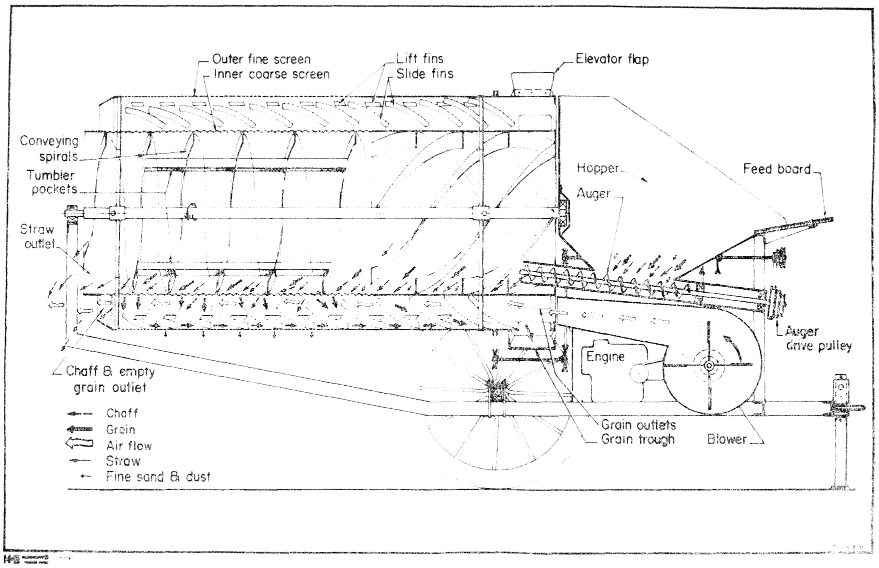

Fig. 15. Schematic drawing of rotary screen grain cleaner.

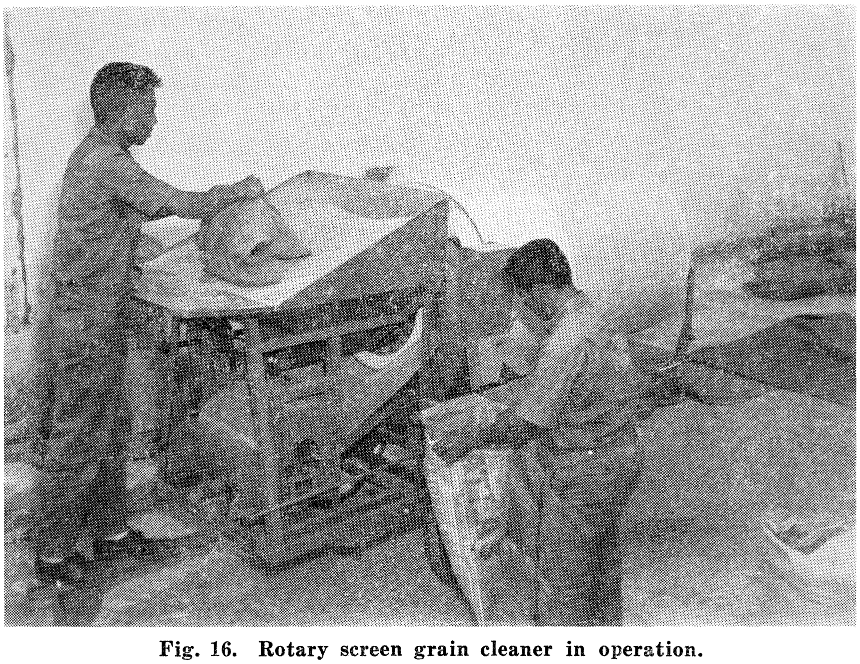

Fig. 16. Rotary screen grain cleaner in operation.

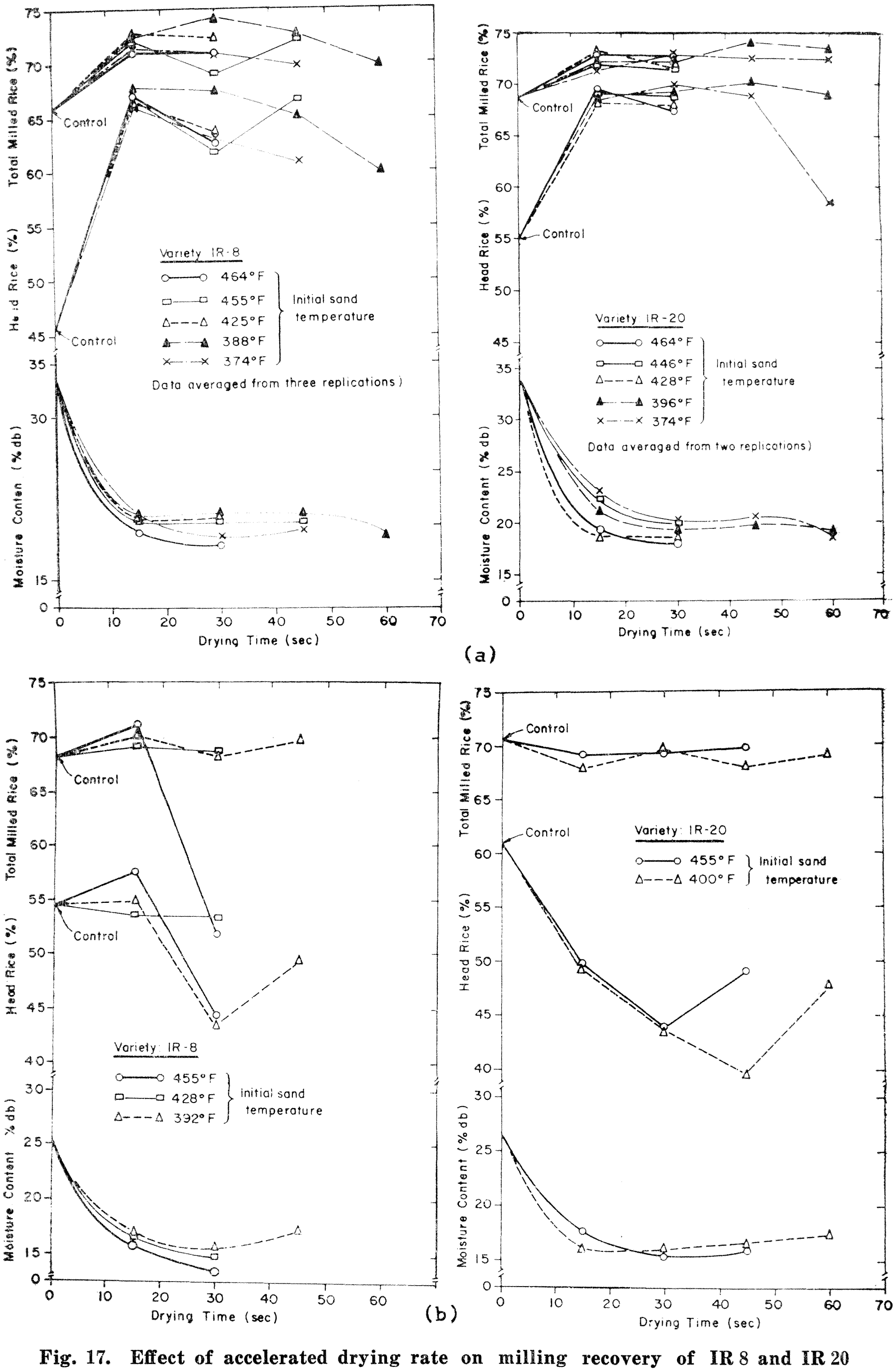

Fig. 17. Effect of accelerated drying rate on milling recovery of IR 8 and IR 20 paddy with (a) high and (b) low initial moisture contents.

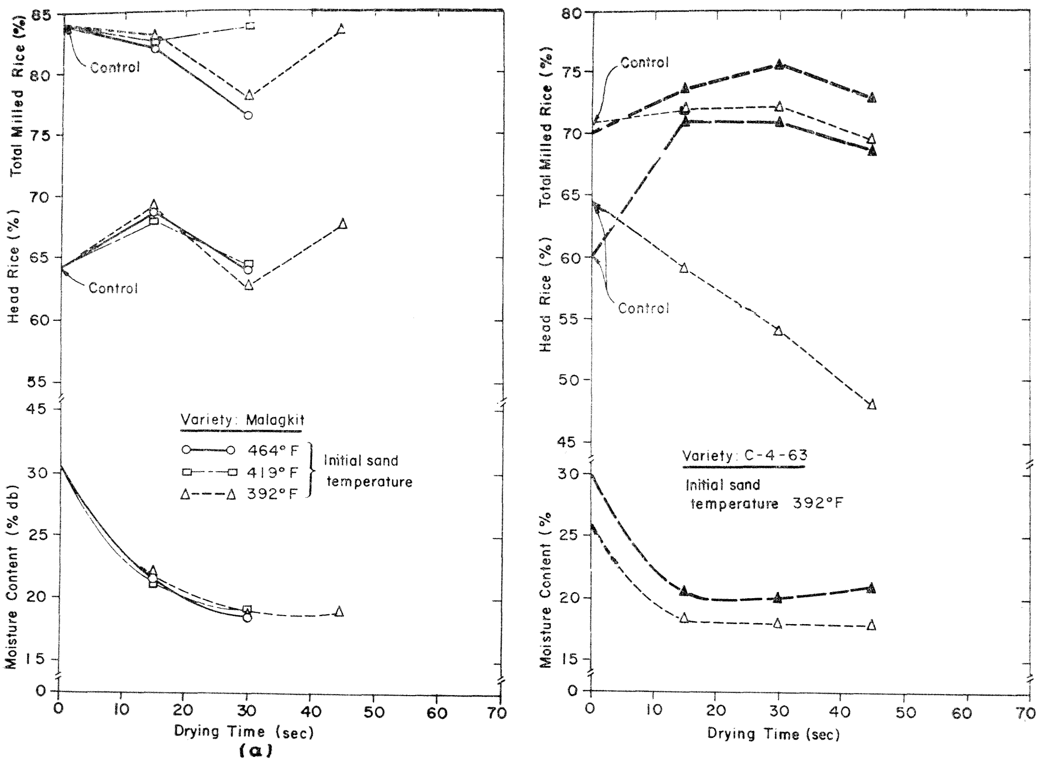

Fig. 18. Effect of drying rate on milling recovery of (a) Malagkit paddy with high initial moisture content and (b) C-4-63 with high and low initial moisture contents.

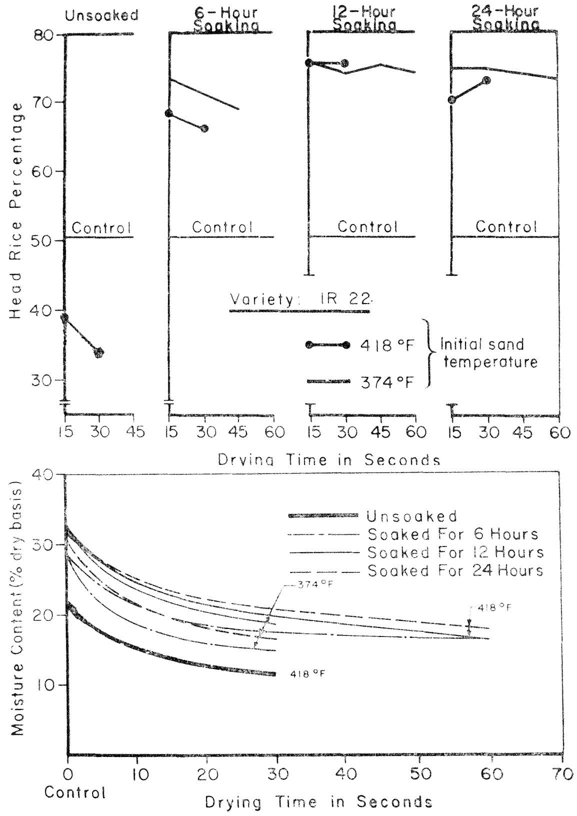

Fig. 19. Effect of presoaking on head rice yield during accelerated drying of IR 22 paddy.

Conclusion

This paper briefly describes some of the highlights of agricultural machinery research at the Institute. Detailed information on the research projects is available to interested manufacturers and research workers. The Institute considers the machinery research program as one of its important activities during the seventies. The success of this program, however, will depend largely on the cooperation from agricultural machinery manufacturers all over the world. A continuing exchange of information with industry and research workers is necessary to make this program more responsive to the needs of the developing countries.