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EQUIPMENT FOR MECHANIZED TROPICAL AGRICULTURE

by

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SUMMARY

Lack of suitable agricultural machines that could be produced by simple fabricating methods has severely hampered the growth of the farm equipment industry in the developing countries. Equipment to provide an intermediate level of mechanization for the 2- to 10-hectare tropical farmer are being developed at The International Rice Research Institute. This paper reviews the progress of this program.

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EQUIPMENT FOR MECHANIZED TROPICAL AGRICULTURE

Amir U. Khan

Recent advances in plant breeding and crop production technology has demonstrated that it is possible to raise crop yields severalfold in tropical areas. These developments have led to significant changes in crop production and many nations that formerly had chronic deficits of rice and other crops now look forward to self-sufficiency. The income of farmers who have adopted new, high-yielding varieties and cultural practices have usually risen sharply and this has provided an impetus for mechanized cultivation.

In rice the short growing period of the new high-yielding, non-photoperiodic varieties provides possibilities for double and triple cropping. To keep his land in near-continuous production, mechanized production methods are of urgent necessity to the tropical farmer.

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.[1/] Many studies have shown that demand for labor in the rural areas of the tropics is highly seasonal. A severe labor shortage occurs during land preparation, transplanting, harvesting and threshing.

Manufacturing Potential

A potential exists in Asian countries for the manufacture of agricultural equipment. A strong desire for industrial development and the shortage of foreign exchange encourage local manufacture of agricultural machinery in these countries. In addition, the long-range socio-economic implications of displacing agricultural labor by imported agricultural machines necessitate the development of a local farm equipment industry along with other agro-business to provide alternate employment. Some progress has been achieved in the manufacture of agricultural machinery in Asia, however, lack of suitable machinery designs that could be produced by simple fabrication methods has severely hampered the growth of the farm equipment industry.

Recognizing this need for development research in Asia, the U. S. Agency for International Development signed a research contract with The International Rice Research Institute. Activities under this contract are oriented towards manufacturers of agricultural equipment in the tropical regions and elsewhere. This approach has been based on certain aspects of machinery research which are typical of the developing countries.

[1/]Equipment for Rice Production, FAO Agricultural Development Paper No. 84, 1966, FAO, Rome.

Machinery Development Bottlenecks

The established manufacturers in the advanced countries have not yet found it attractive to develop specialized equipment for tropical countries. In addition to the relatively higher risks involved, it is difficult for these manufacturers to develop machines for an environment with which their engineering staff is not as closely associated. With a few exceptions, such manufacturers have limited their efforts in tropical countries to marketing studies and testing and evaluation of their existing products. Understandably, these manufacturers prefer to develop equipment for their home market and subsequently attempt to find new markets abroad.

Many Asian countries have publicly supported centers for agricultural mechanization research. Research in such institutions has been directed towards knowledge than application. This research is broadly along the basic and applied research patterns followed by the educational institutions in the industrialized countries. In advanced countries, the machinery manufacturers invest vast resources in utilizing the results of basic and applied research for developing new machinery to mechanize their agriculture It is estimated that the farm equipment industry in the United States spends 3 percent of its total turnover on research and development of new equipment Out of the estimated R & D expenditure of $27.2 billion in the United States during 1970, 14 percent is for basic research, 22 percent for applied research, and 64 percent on development.[1/]

The struggling state of agricultural equipment industry in the developing countries does not permit channeling of any appreciable amount of funds for machine development. Funds for research, however, have been made available to publicly supported organizations in the developing countries. The development of new equipment for tropical countries has therefore received little attention from local governments or from either local or foreign manufacturers. The achievements of mechanization research at the farm level depend to a large extent on the equipment development activity in a country. Relatively few tangible developments are found in the farmers' fields which can be related to the basic and applied machinery research being conducted in the developing countries.

Since the farm equipment industry is in its infancy in the developing countries, it may take a long time before sufficient funds could be diverted for equipment development. Publicly supported research organizations in the developing countries must meet this challenge by diverting their efforts to two areas: one, adaptive research such as testing and modification of available equipment, and, second, the development of new machines for local production.

[1/] National Patterns of R & D Resources, 1953-70. National Science Foundation, Washington, D.C. 20550, U.S.A.

Field Equipment

In Asia, medium-sized landholdings, 2 to 10 hectares, constitute a large segment of the total land under paddy cultivation.[1] As a group, farmers with this amount of land have the potential to support an intermediate level of mechanization. They find that traditional animal or manual equipment is often inadequate for their requirements. Ironically, this large group of farm holdings has the least access to modern power equipment since machinery development research in advanced countries is primarily concerned with equipment for larger holdings.

In Japan, a high price for rice and the rapid industrial growth of the country has resulted in the mechanization of Japanese agriculture with relatively small machines. Japanese equipment is gaining some popularity in tropical Asia. Due to the high degree of design sophistication required by the Japanese market, such equipment is often uneconomical for tropical farmers. There is little doubt that in the long run, larger, more economical equipment will play an increasing 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 are too small for the 30-plus horsepower equipment, require immediate attention from development engineers.

Drying and Processing Equipment

The large rural consumption of rice and the general lack of adequate 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 for drying and processing rice in large quantities is well developed in industrialized countries. This technology is being applied in the establishment of modern, centrally located commercial rice drying and processing plants in Asia. A well developed infrastructure is an essential prerequisite for the establishment of such large processing plants and this has considerably limited their scope in the developing countries.

An estimated 50 to 70 percent of the rice produced in the tropical countries is consumed within the rural areas and does not pass through commercial channels. Rice processed for rural consumption in tropical Asia is of very poor quality. Development research is urgently needed to provide modern village- or community-size drying and processing equipment which could be locally manufactured in the tropical countries.

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[1] Proceedings of an Expert Group Meeting on Agricultural Mechanization, Dec. 12-18, 1967, Vol. 1, Asian Productivity Organization, Tokyo, Japan.

Applied Machinery Research

There is a need for applied machinery research to assist manufacturers outside the tropical regions in the development of new equipment. Such research should emphasize solving specific mechanization problems and not development of machines for production. Assistance in evaluation of new concepts and in field-testing prototype equipment will encourage the development of new equipment for tropical areas.

A number of machinery development and applied research projects are underway at the Institute and the progress made so far is described below:

Tractor Tillage and Mobility in Flooded Soils

Rotary tillers provide a forward pushing action to the tractor during operation. To exploit this action for improving tractor mobility in soft fields, an 85 cm. diameter rotary tiller (Fig. 1) with adjustable tilling blades was designed. The machine was used to study the effect of blade shape, blade angle, tiller diameter and blade velocity on the horizontal component of the soil reaction. A maximum pushing force of 1000 kg was recorded in experiments at the Institute with this experimental rotary tiller.

Experiments to determine the coefficient of rolling resistance of a 3257-kg, standard 55-hp tractor with rubber tires (Fig. 2) under soft puddled conditions have been conducted. A unidirectional straingage load transducer was used to measure the horizontal component of the force required to tow the tractor in lowland fields. Rolling resistance ranging from 480 to 1230 kg were recorded from the fields tested at the Institute. The tractor encountered difficulties in propelling itself at 1230 kg of rolling resistance. 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 hardpan are difficult to prepare with conventional tractors due to poor tractor mobility. A project was initiated to study the feasibility of using a small four-wheel riding machine to prepare land by creating a difference in wheel slippage between independently driven front and rear cage wheels. For maximum mobility, 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 faster by inducing a differential wheel slip. To evaluate such a concept, two lightweight hand tractors were coupled with an articulated chassis to form a four-wheel drive riding machine. The experimental tiller (Fig. 3) has good mobility in soft fields even with the hardpan deeper than the wheel radius. The tiller can travel across field levees higher than the wheel diameter without damaging the levees. Tillage is accomplished by increasing the speed of either wheel. However, improved control results with the front wheels operating at a faster speed. The concept looks promising for soft fields and a concept study is

being made on a single engine machine with variable drives to front and rear wheels.

Anhydrous Ammonia Applicator

Anhydrous ammonia is a low-cost source of nitrogen and is available in many developing countries. A lack of suitable application equipment for puddled soils restricts its use to crops other than rice or to large farm holdings. Recent popularity of small walking tractors and tillers for rice cultivation prompted the department to work on an anhydrous ammonia applicator for small tractors. Figure 4 shows the applicator mounted on a 6-hp walking tractor. The applicator is undergoing further development and evaluation.

Row Seeder for Pregerminated Paddy

The traditional practice of transplanting rice has very high labor requirement. In some countries, pregerminated seeds are sown on puddled soils to save labor. Row seeding of pregerminated seed can save labor and facilitate the use of row-crop paddy equipment such as rotary weeders, binders and combine harvesters.

Six- and eight-row machines for seeding pregerminated paddy on puddled soils have been developed (Fig. 5 and 6). A ground driven fluted roller and brush cut-off mechanism gently meter pregerminated paddy into the seed tubes. The machine is equipped with one wheel for transport on field levees and turning between seeded rows. Between 5 to 7 man-hr/ha are required for seeding with this machine as compared to 120 man-hr/ha for transplanting. Three companies in the Philippines have started manufacturing these seeders.

Multipurpose Seeder

Subsequent to the introduction of the six- and the eight-row seeders for pregerminated paddy, numerous inquiries on seeders for upland crops were received. A new seeder has been developed in which component assemblies are made detachable. The basic unit shown in Fig. 7, which consists of hopper, distributor and drive assemblies, is expected to have uses for most grain and vegetable crops. With proper attachments, the basic unit can be used as a manual, animal- or tractor-drawn seeder for both upland and lowland crops. Further development work is underway.

Rotary Power Weeder

A three- and five-row power-driven, portable paddy weeder (Fig. 8a) has been developed for soft field conditions. Since small paddies have no headlands for turning, the machine can be lifted off the ground at the end of the rows. A lightweight 1-hp engine powers the weeding rotors through a worm reduction box. Sheet metal shields keep the rice plants from being

ripped by the weeding rotors. The rotors uproot and bury the weeds under the mud. The operator supports about one-half (about 9 kg) of the machine's weight. The labor requirement for the power weeder is 17 man-hr/ha as compared with 70 man-hr/ha for manual rotary weeders and 120 man-hr/ha for hand weeding. A Japanese company is manufacturing this weeder. Their machine (Fig. 8b) is equipped with a sled to support the engine end of the machine. The operator walks behind the machine without supporting any weight. Their machine weighs 14 kg and can be set for two or three-row operation.

Drum Thresher

The drum thresher (Fig. 9) 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. This thresher has a 6-ft long wire-loop threshing drum and is equipped with a rotary screen cleaner. It is driven by a 4-hp aircooled engine and can thresh 250 kg of paddy per hour. A few locally fabricated units have been exported to Asian countries for evaluation.

Table Thresher

The table thresher (Fig. 10) is light enough to be carried into fields inaccessable by road. A flat circular shape makes a more effective use of the threshing surface than the conventional cylindrical drum. The grain is screened by a flat, rotating screen, concentric with the threshing surface. Radial fan blades on the underside of the threshing surface provide air for winnowing. The machine, complete with a 3-hp air-cooled engine, weighs 175 kg. It has been designed for compact packaging to facilitate export marketing. This thresher has been released to three manufacturers in the Philippines. A few manufacturers in other countries are building prototype units to evaluate the machine and explore its production possibilities.

PTO-Driven Multicrop Thresher

The introduction of combine harvesters in advanced countries has led to a decline in the use of threshers. The acceptance of combines, however, has been slow in the tropics. Consequently, a substantial demand exists for high-output stationary threshers in tropical areas. A three-point linkage-mounted tractor PTO-driven thresher for 30- to 60-hp tractors is being developed to meet this demand. Such a thresher will offer high threshing output, improved mobility, and low down-time. The PTO thresher (Fig. 11) has a spike tooth cylinder with adjustable baffles in the housing to move the threshed material in an axial direction The degree of threshing for different crops and crop conditions can be varied by the adjustable baffles. The machine has a triple-screen rotary separating and cleaning device which is lighter than conventional straw walkers and oscillating screen mechanisms. Initial tests with the first prototype unit have been encouraging. Further development work is underway.

Multicrop Cone Thresher

There is a need for a lightweight thresher for freshly harvested crops which can be conveniently moved in the farmer's field. Conventional threshers do not meet this need because of their unfavorable weight-output relationship. A light thresher design utilizing a slightly conical wire loop cylinder is being developed. Many attempts have been made in the past to develop cone threshers using a one piece perforated concave for both the threshing and separating operations. While a high relative grain and concave velocity is necessary for good threshing, it is undesirable for grain-straw separation at the concave. This cone thresher is being developed with a separate rotary cleaner to achieve more desirable relative velocities between the threshed grain and the screen openings. The base of the threshing cone fits into one end of the cleaner. This configuration permits an in-line mounting of the threshing and cleaning mechanisms and a smooth spiral movement of the threshed material from the conical cylinder to the rotary screen. The rotary cleaner is lighter and better suited for wet crops than the conventional straw-walker type mechanisms. The machine is designed to work both as a hold-on and a throw-in type of thresher. The threshing drum housing has two feed openings, one above and the other below the center line. The lower opening can be closed for throwing operation.

Paddy Stripper-Harvester

Since large volumes of straw must be handled through the machine, conventional combines are quite bulky. The excessive weight of these harvesters creates mobility problems in wet fields. Attempts have been made in the past to develop stripping harvesters to eliminate the handling of straw through the machine. Excessive shattering of grain has been a major problem with these attempts. A review of literature indicates that in the past experimental stripper-harvesters were built to thresh grain from upright crops. Because of the upright plant position, the violent contact between the threshing mechanism and the panicle scatters the grain in front of the machine over a wide pattern.

The stripper under development (Fig. 13) is designed to gently bend the plants into the machine prior to threshing. During operation, panicles are threshed continuously as they slide downward along the inclined threshing belt while the machine moves forward and tramples the threshed plants. The gentle backward deflection of the plants, prior to a violent contact with the threshing belt, directs the threshed grain toward the rear end of the machine which improves grain collection. The machine can harvest all the grain from non-lodged crops. The experimental harvester has been designed to evaluate the stripping concept and is not equipped with crop-lifting devices or grain-cleaning and winnowing components. The harvester is undergoing further development.

Power-Operated Rotary Grain Cleaner

There is a need for a high capacity, relatively simple grain cleaner which could be used after threshing, before and after drying, and prior to milling and processing of paddy. The only equipment used in the tropics for grain cleaning are winnowers. A simple rotary screen grain cleaner (Fig. 14) for tropical conditions has been developed. As compared to oscillating screen cleaner, the use of a rotary screen improves performance with wet or high-moisture paddy, reduces mechanical drive problems and improves screening of larger size impurities. The blowing of air through a tumbling mass of grain in the rotary screen which improves the separation of lighter impurities. The machine can clean 3 tons of paddy per hour. This cleaner has been released to two companies in the Philippines for manufacture. Some manufacturer in other countries are exploring its production possibilities.

Manually Operated Rotary Grain Cleaner

A simple manually operated grain cleaner is needed for individual farmers operation in the tropical areas. The traditional wooden winnowers have no screening provisions and cannot effectively separate larger size impurities from the grain. It is also difficult to clean wet or high-moisture grain with these winnowers. A manually operated cleaner with combined screening and winnowing provisions is being developed (Fig. 15) It consists of a grain tumbling cylinder with a co-axial fan. Part of the cylinder has a rotary screen. The grain hopper is supported on the cylinder by a pair of rollers which activate the grain metering mechanism. The metered grain drops externally on the screen portion where it is introduced into the cylinder. Winnowing is accomplished inside the rotary cylinder by repeatedly tumbling the grain in the air stream. The first prototype cleaner is being fabricated.

Accelerated Drying and Parboiling of Paddy

A carefully controlled temperature and a slow rate of drying is necessary to retain seed viability and high head rice (unbroken grains) when drying with conventional driers. But 98 percent of the paddy grain in the tropics is consumed as food and the retention of seed viability is not so essential. Since a more economical method to dry paddy is needed for tropical areas, a project was started to develop basic information on accelerated conduction drying of paddy using heated-sand as a medium.

Experiments (Fig. 16) indicate that paddy can be simultaneously dried and parboiled to a moisture content of about 18 percent in a few seconds (15 to 20 seconds exposure in sand heated to 400°F /F.10°7 temperature) provided sufficient moisture (about 27 to 30%) is initially available in the grain to permit the gelatinization of the starch granules. Otherwise, the paddy can be soaked in water at room temperature for about 6 hours to introduce sufficient moisture (Fig. 17). The gelatinization of the starch granules in paddy improves head rice yields and milling recovery. Parboiling is

known to improve storage quality and retention of natural vitamins. A second set of conduction drying experiments using direct flame exposure combined with mechanical agitation to minimize localized grain heating is also underway. Preliminary tests indicate somewhat similar results as obtained with the heated-sand process.

Heated-Sand Drier

A project has been started to develop a continuous-flow drier using the heated-sand process. A rotary drum type drive drier for farm-level operations in the tropics has been fabricated (Fig. 18). The machine has a horizontally rotating drying cylinder mounted on top of a semi-circular sandpan. The heat source is placed below the sandpan. The present drier uses liquified petroleum gas. However, it can be modified to use other low-grade fuels such as rice husk, wood, coal and kerosene. The drying cylinder has an internal spiral and a set of externally mounted paddles. Two sets of scoops, at one end of the drying cylinder, introduce the heated-sand and wet grain into the drying cylinder. As the drum rotates, sand and grain mix and move axially. After the desired sand-grain exposure, sand is screened out through a screen portion at one end of the cylinder. The sand drops back into the sandpan and is gradually moved by the externally mounted baffles towards the sand scoop for recycling through the drying cylinder. The drier is undergoing tests and further development.

Conclusion

This paper briefly describes the highlights of agricultural machinery research at The International Rice Research Institute. Detailed information on the various projects is available to interested parties. The success of this program depends to a large extent on the cooperation from machinery manufacturers worldwide. A continuing exchange of information with government, industry and other sectors is essential to make this program responsive to the needs of the developing countries. The Institute considers the development of new agricultural machines as one of its important activities during the seventies.

Fig. 1. IRRI adjustable blade rotary tiller.

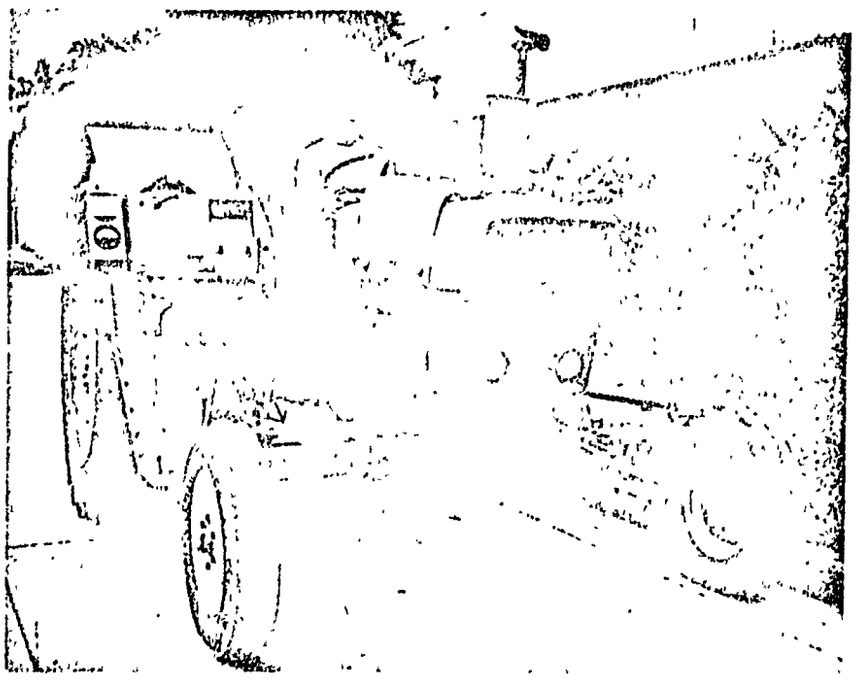


Fig. 2. Tractor with instrumentation for rolling resistance measurement.

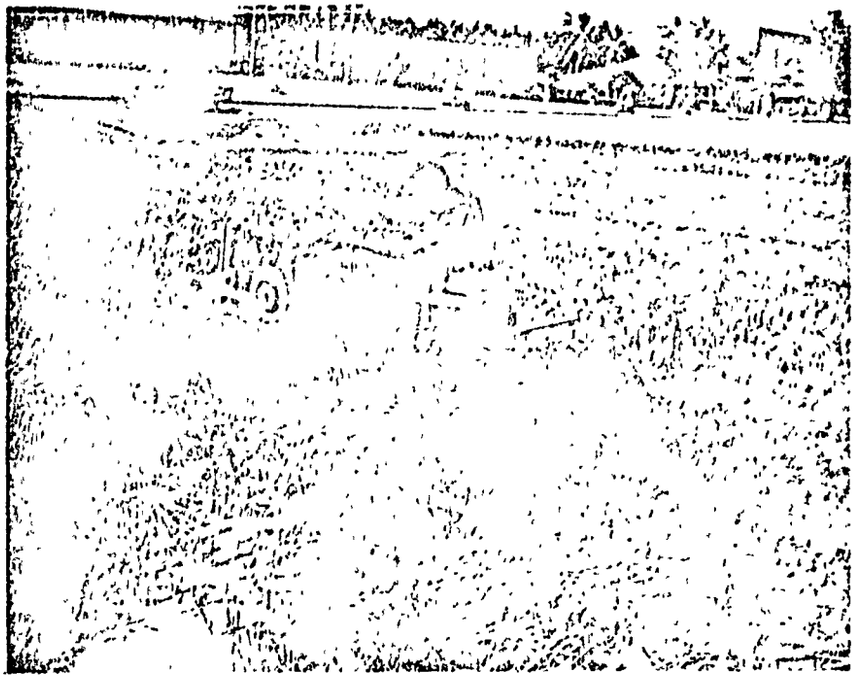


Fig. 3. Differential cage wheel slip tiller.

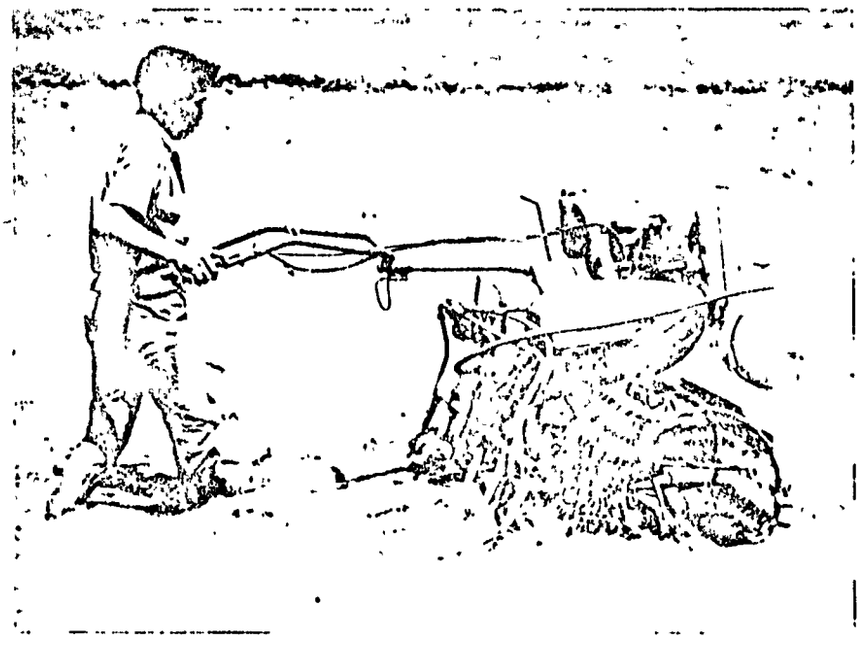


Fig. 4. Anhydrous ammonia applicator for walking tractors.

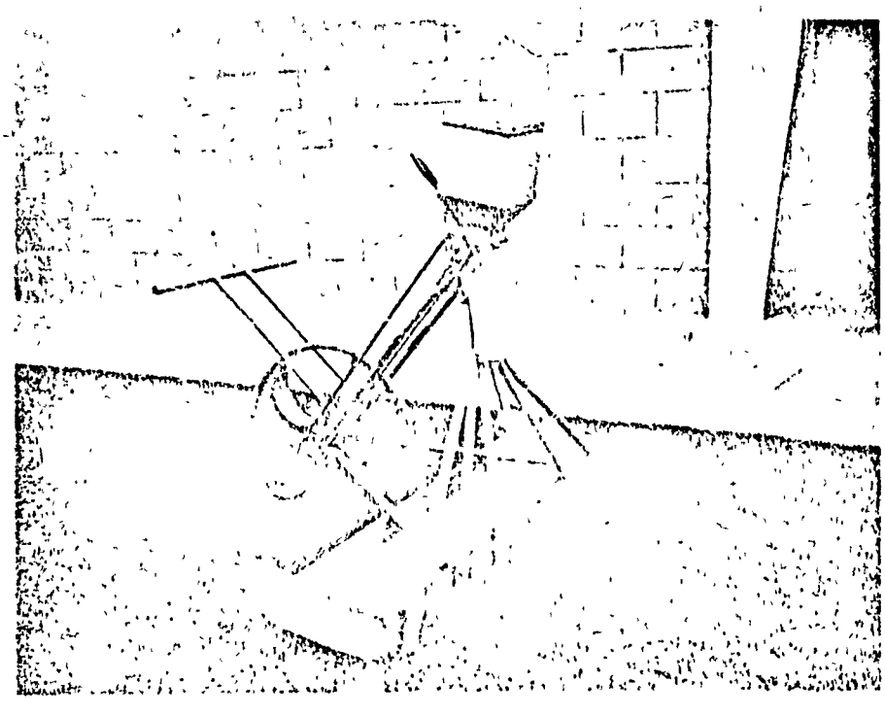


Fig. 5. Six-row seeder for pre-germinated paddy.

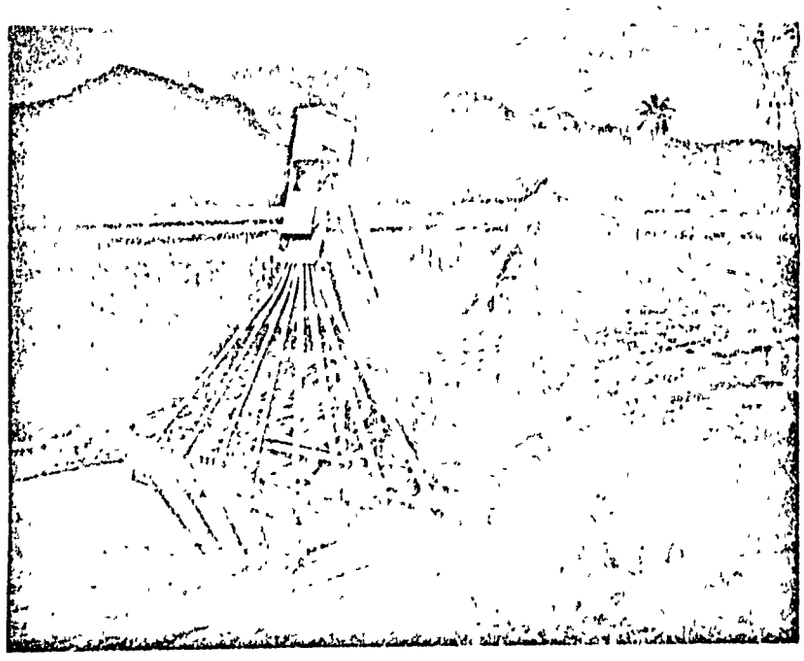


Fig. 6. Eight-row seeder for pre-germinated paddy.

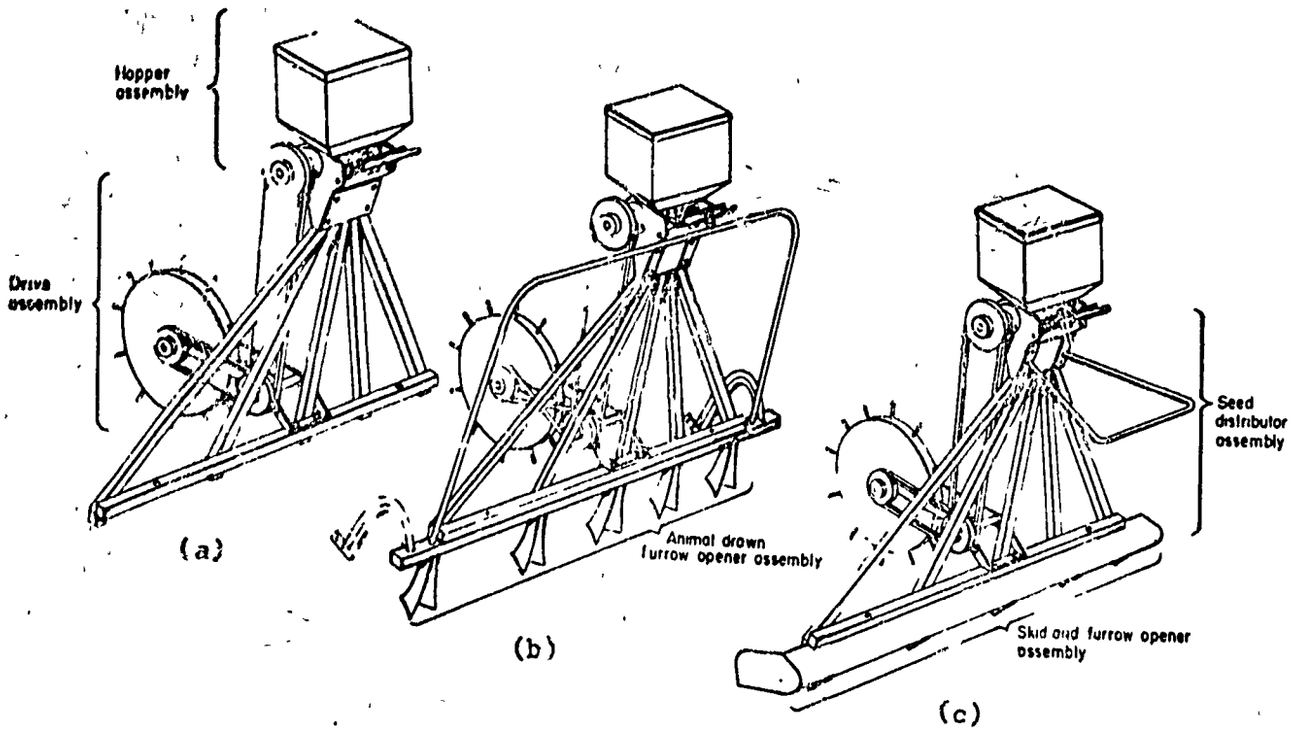
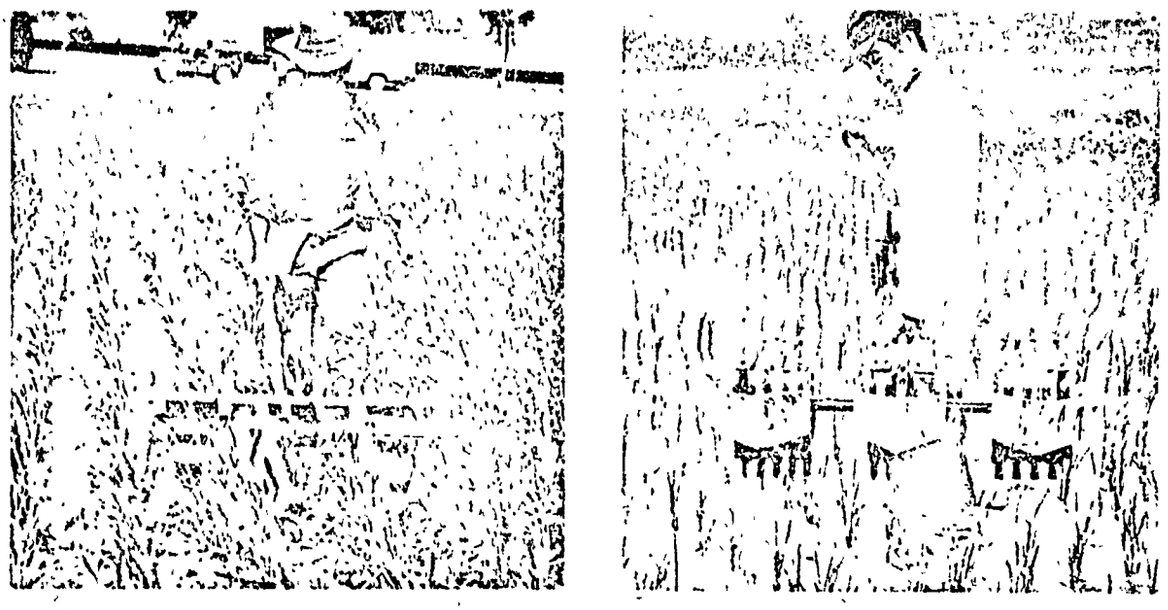
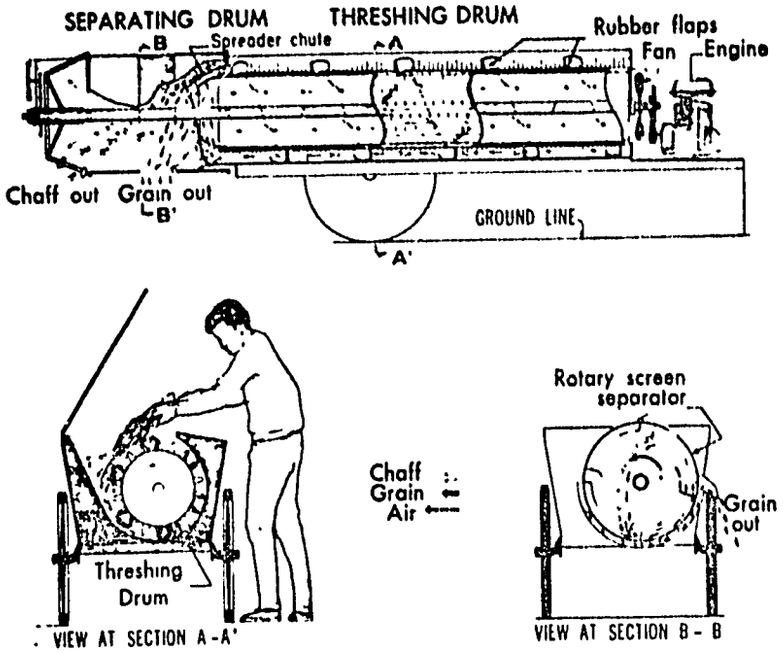


Fig. 7. Multi-purpose seeder (a) basic unit (b) for dryland (c) for wetland.



(a) (b)

Fig. 8. Three-row portable power weeder for paddy. (a) prototype (b) commercially produced machine.



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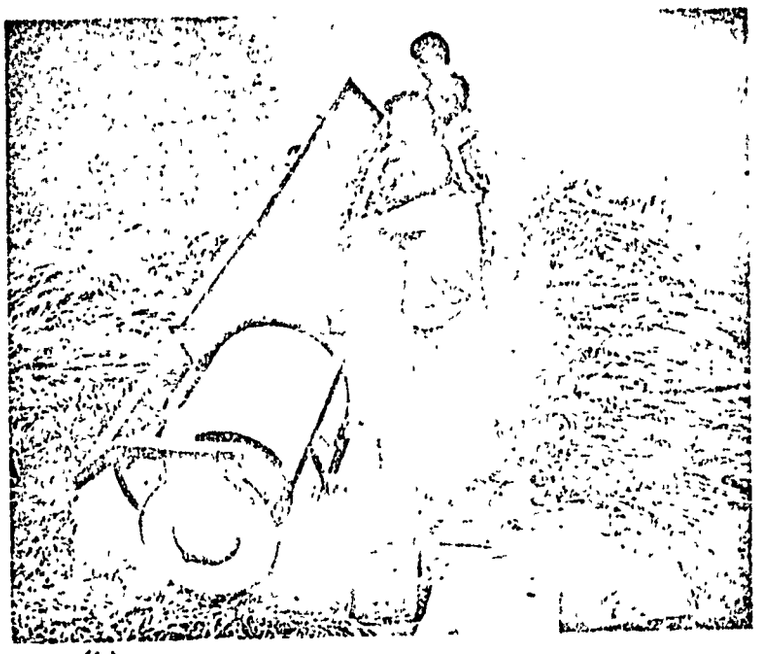
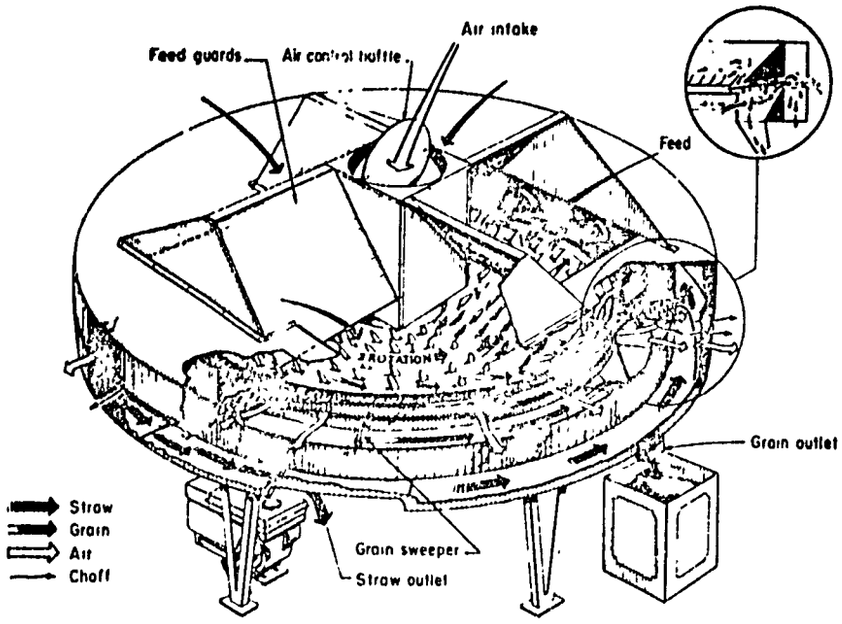


(b)

Fig. 9. Drum thresher (a) schematic drawing (b) in operation.



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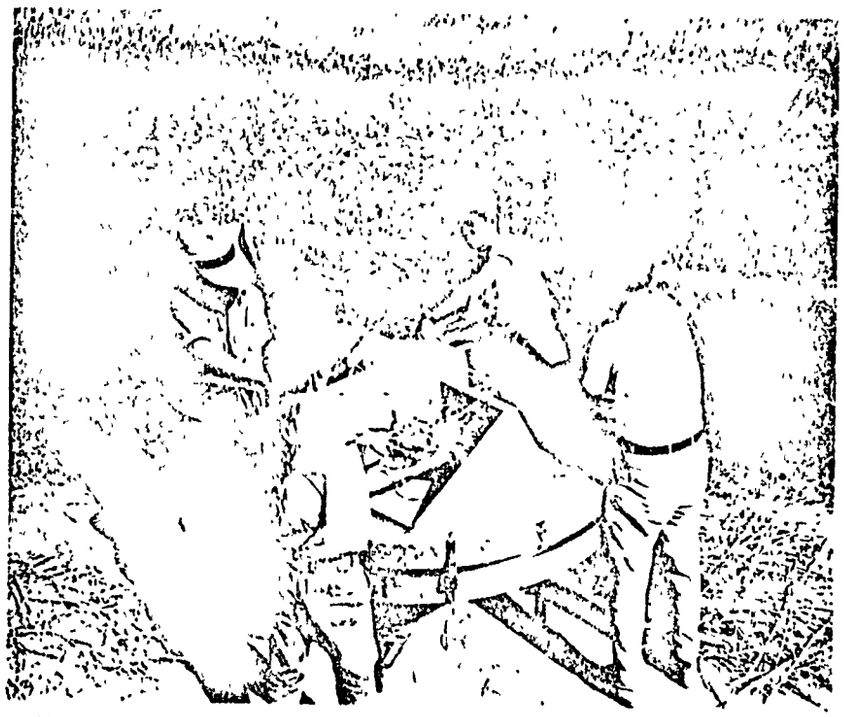
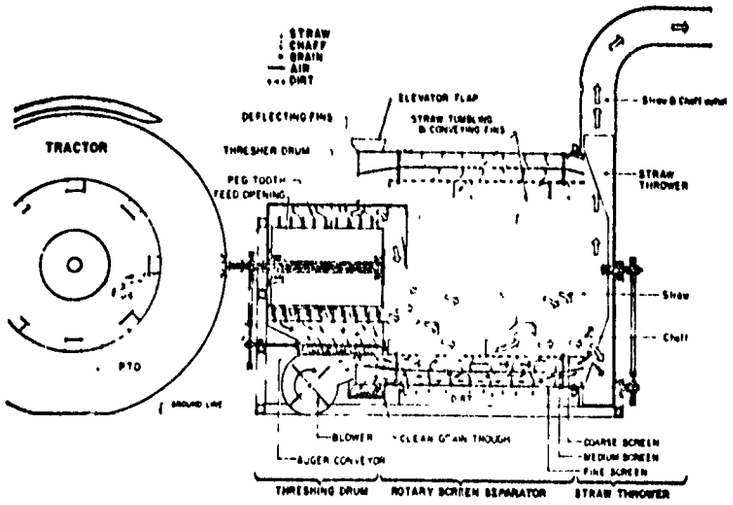


(b)

Fig. 10. Table thresher (a) schematic drawing (b) in operation.



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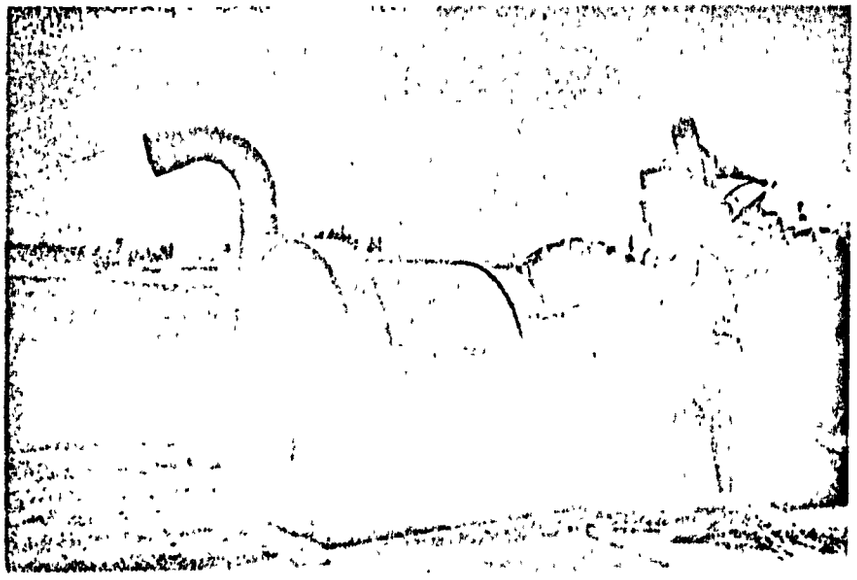


(b)

Fig. 11. Tractor PTO-driven multi-crop thresher (a) schematic drawing (b) in operation.

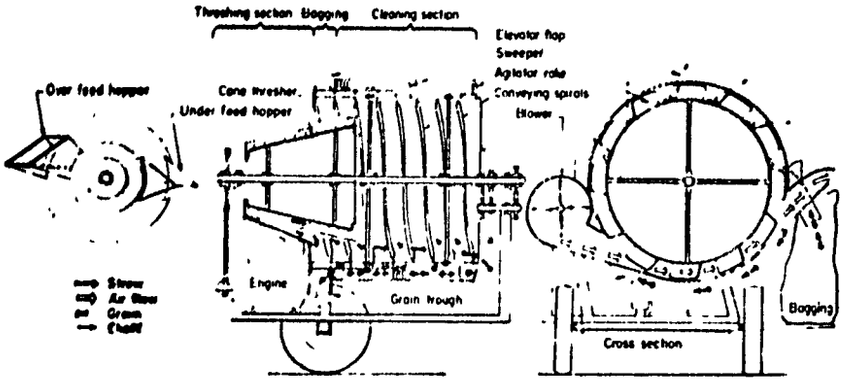
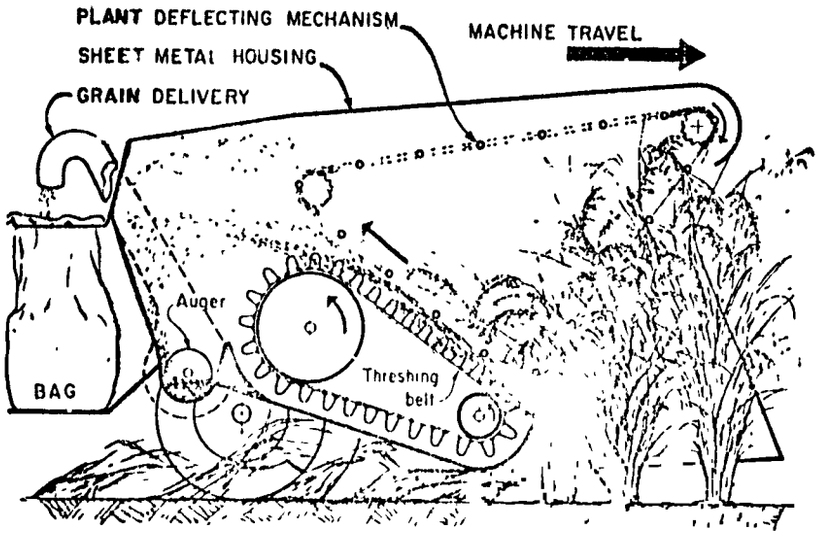


Fig. 12. Multi-crop cone thresher.



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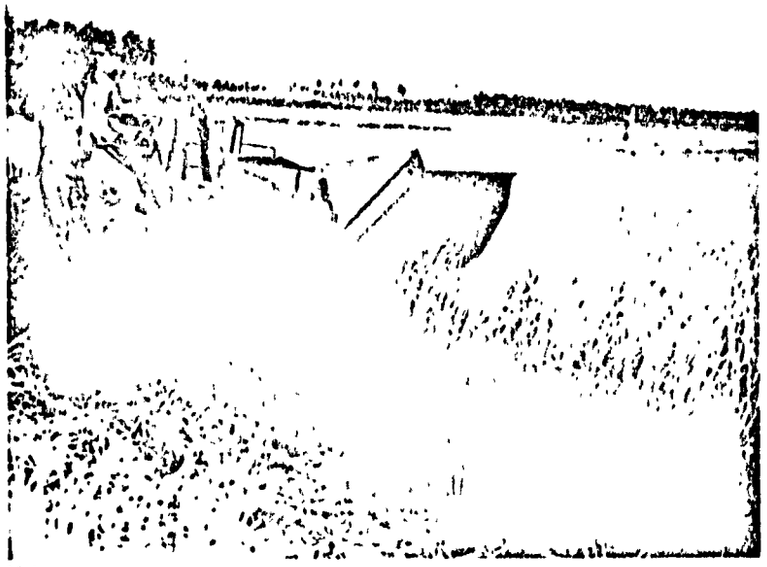


(b)

Fig. 13. Experimental paddy stripper harvester
(a) schematic drawing (b) in operation.

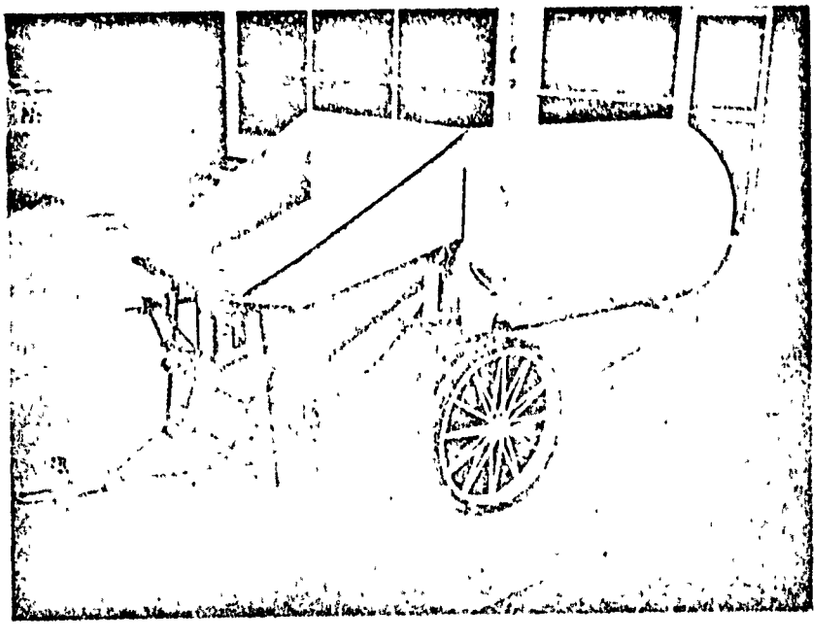


Fig. 14. Rotary grain cleaner.

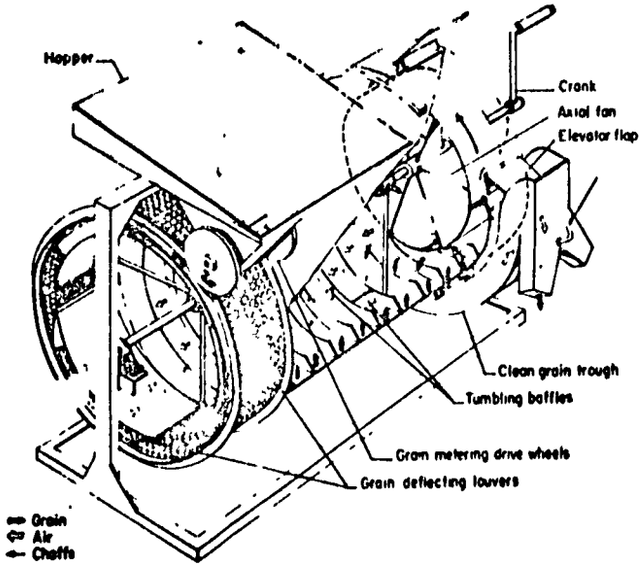
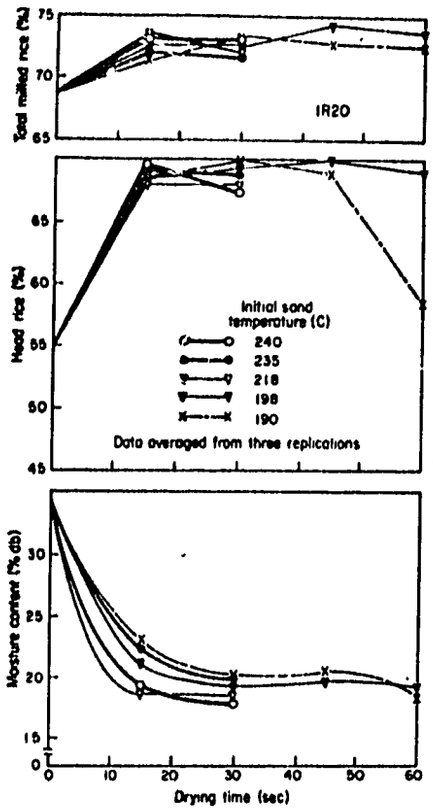
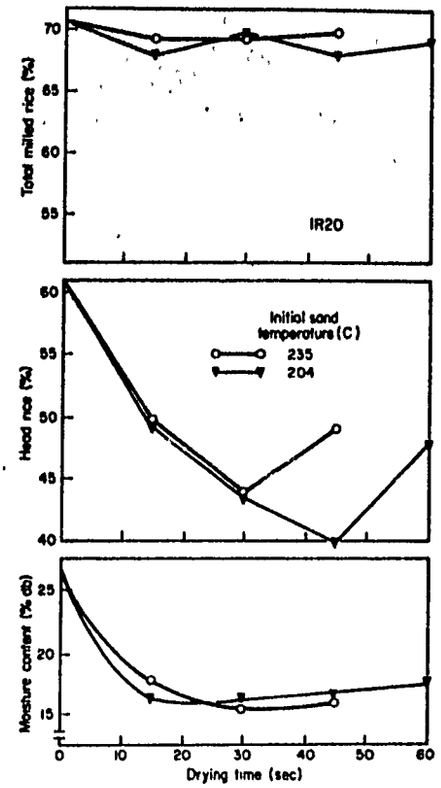


Fig. 15. Schematic drawing of the manually operated grain cleaner.





(b)

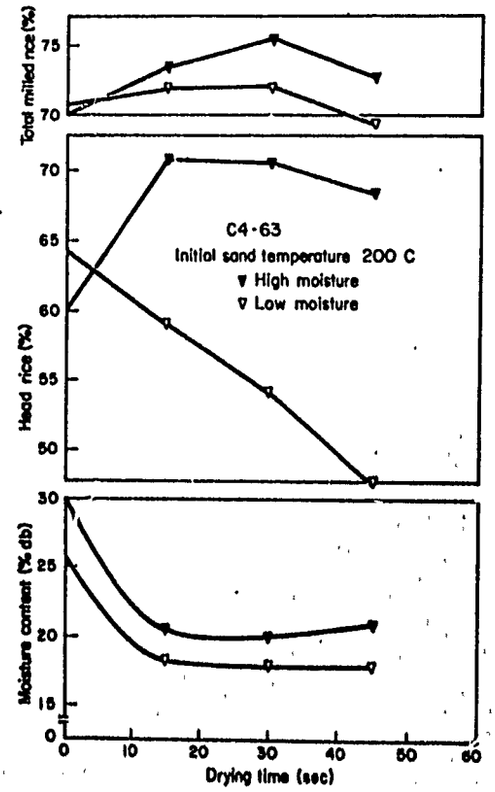


Fig. 16. Effect of accelerated drying rate on milling recovery of paddy

(a) high initial moisture content

(b) relatively low initial moisture content

(c) high and low initial moisture content

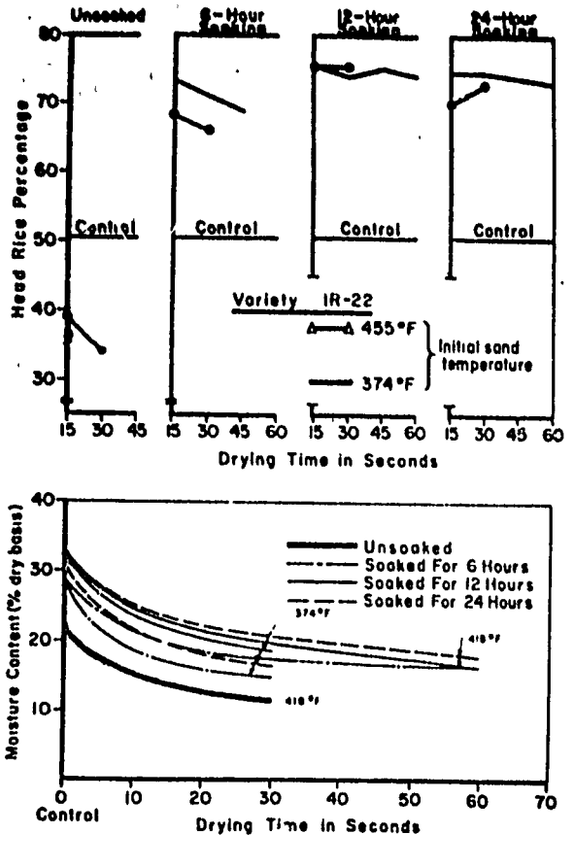


Fig. 17. Effect of pre-soaking on head rice yield.

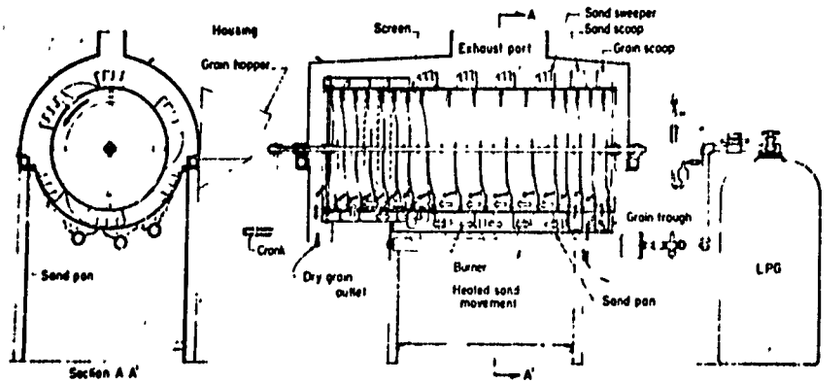


Fig. 18. Schematic drawing of the continuous-flow heated-sand drying and parboiling equipment.