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Agricultural Equipment Development Research
for Tropical Rice Cultivation

by

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Introduction

This is the tenth Semiannual Progress Report on agricultural mechanization research being conducted under USAID/IRRI Contract No. AID/csd-834 and Contract No. AID/csd-2541. The latter contract, entitled "Agricultural Equipment Development Research for Tropical Rice Cultivation," is primarily oriented towards the development of power driven equipment for the production and processing of paddy in the tropical countries.

The shortage of suitable agricultural equipment for medium-sized farmholdings (2 to 10 ha) has been a major bottleneck in the mechanization of tropical agriculture. The development of simple power driven equipment for indigenous production in the developing countries would considerably expedite the agricultural mechanization process.

Summary

This program of equipment development gained momentum by the release for commercial production of its first machine -- the drum thresher -- in the Philippines. Four additional machines have been recently released to manufacturers:

(a) Power weeder -- This portable, motorized weeder has three weeding rotors. It uses a lightweight, two-stroke, aircooled engine to drive the three weeding rotors through a shaft and a worm gear transmission. The entire machine weighs 19 kg. When used, the operator supports only half of the machine weight. At the end of the rows, the machine can be lifted off the ground to avoid damaging the paddy plants during turning. The power weeder requires 17 man-hours to weed a hectare as compared with 70 man-hours for a push-type manual weeder and 120 man-hours for hand weeding. The machine offers possibilities also for land preparation in swampy conditions which cannot normally support the lighter two-wheeled tractors. Messrs. Ohtake Nouki Seisakusho Co., Ltd., Nakajima, Ohharu-mura, Amagun, Aichi, Japan, has initiated production of a weeder based on this design. Their machine incorporates a skid which provides complete ground support during operation. Weighing 14 kg, it can be elevated at the end of the rows for easy turning. Several other manufacturers have shown interest in this weeder. Drawings and other information have been forwarded to the interested parties.

(b) Row seeder -- The machine has been designed as a low-cost seeder for pre-germinated paddy. It has a two-step seed metering device which does not damage the roots. One man can seed 1 ha in 5 hours with this seeder which is 20 to 25 times faster than transplanting. No significant yield differences have been found between transplanting and the direct seeding of pre-germinated paddy in rows. Three firms are manufacturing this seeder in the Philippines. Two versions of this seeder, a six-row and an eight-row, are being marketed at a retail price of about US$50. The favorable response received from many Asian countries indicates a widespread need for such a seeder.

(c) Table thresher -- The use of a novel flat threshing surface has permitted a lightweight, simple, low-cost design with fairly high threshing capacity. The thresher has an output of 350 to 400 kg/hr of rough rice with four men feeding it. It is light enough to be manually carried to the paddy fields with no access roads. The machine can thresh wet or high-moisture paddy without clogging. Three manufacturers are about to market this thresher in the Philippines. The selling price, complete with the engine, is expected to be between ₱2400 to ₱2700 (approximately US$400 to $450) in the Philippines. A company in Australia is exploring the possibility of manufacturing it for export to Southeast Asian countries.

(d) Rotary screen grain cleaner -- The grain cleaner combines the operations of mechanical and pneumatic separation in a double-wall rotary screen cylinder. The machine has a cleaning output of over 3 tons/hr. Field demonstrations have indicated a favorable response from millers, drier operators, and large farm owners. Two manufacturers have begun fabrication of this machine in the Philippines. A leading manufacturer of grain cleaners in the United States and a drier manufacturer from Japan are exploring the possibilities of its manufacture for their home markets.

In addition to the above machines, development of a number of other machines for almost all the operations of rice production and processing is underway. The overall research and development program is broadly divided into three areas:

(1) Field Machinery Development involves the complete development of relatively simple field machines to suit the requirements of the 2- to 10-ha farm holdings and the manufacturing capabilities in the tropical areas;

(2) Drying and Processing Research involves the development of economical rice drying and processing equipment for village and farm level operations in the tropics, and

(3) Applied Machinery and Economic Research involves providing assistance to established machinery manufacturers in the development of rice cultivation equipment for the tropics. The evaluation of new machinery concepts and the assistance in field testing and economic evaluation of experimental machines are essential components of this activity.

A paper entitled "Mechanization Research for Tropical Agriculture" which summarized the activities of this program was presented at the annual meeting of the American Society of Agricultural Engineers on July 8, 1970 in Minneapolis, Minnesota.

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The following project personnel were responsible for these projects:

Field Machinery Research

1. Power weeder	N. Navasero and A. U. Khan
2. Row seeder for pre-germinated paddy	N. Navasero
3. Table thresher	A. U. Khan
4. Rotary screen grain cleaner	A. U. Khan
5. Stripper-harvester combine	A. U. Khan
6. Differential cage wheel slip for wetland preparation	P. Cabanos and A. U. Khan
7. Tractor mobility studies	P. Cabanos
8. Tractor PTO-driven thresher	A. U. Khan

Drying and Processing Research

1. Consumer preference tests of heated-sand and flame-dried rice	A. Amilhussin and A. Manalo
2. Heated-sand drier	A. U. Khan
3. Accelerated drying of sorghum	A. Amilhussin and A. U. Khan
4. Drying chemically treated paddy to break seed dormancy	A. Manalo and A. Amilhussin
5. Rice hull furnace	A. Manalo

Applied Machinery and Economic Research

1. Economic aspects of hand tractor ownership	N. Orcino
2. Economics of the row seeder	N. Orcino

Field Machinery Research

ROTARY POWER WEEDER

The development of a three-row and five-row rotary power weeder was included in an earlier report. The machine utilizes a lightweight, aircooled engine to drive three or five weeding rotors through a shaft and worm gear transmission. The weeding rotor assembly consists of three or five specially designed high-flotation rotors which uproot and bury the weeds between the paddy rows. The weeder weighs 19 kg for the three-row and 27 kg for the five row machine. The weeding rotors can be lifted off the ground to permit turning at the end of the rows without disturbing the rice plants.

A machine based on this concept is being produced by Messrs. Ohtake Nouki Seisakusho Co., Nakajima, Ohharu-mura, Amagun, Aichi, Japan (Fig. 1). Their machine weighs 14 kg and is equipped with a sled for ground support. Using the sled, it is possible for the operator to weed without supporting any part of the machine. The weeder is offered in two- and three-row versions. The rotors can be adjusted for different row widths. The price of machine is about US$140 in Japan. Some modifications have been suggested to the manufacturer to improve their rotor design and reduce power requirements. This would permit them to offer a five-row machine with the same engine. Considerable interest has been generated in this type of weeder in Japan, not only for weeding but also for land preparation under swampy soil conditions.

ROW SEEDER FOR PRE-GERMINATED PADDY

The development of a row seeder for lowland rice has been reported earlier. In the last report, reference was made to a field experiment conducted at the Institute to compare the performance of the seeder with transplanting methods. In these experiments, 3 one-fourth hectare plots were puddled and fertilized with 60 kg N by mixing ammonium sulfate with the soil during the final leveling operation and applying 20 kg N at panicle initiation. Each plot was split: one-half was planted with 21-day-old IR8 seedlings 25 cm apart at the rate of 2 to 3 seedlings per hill and the other half was seeded with the eight-row seeder. Standard water management and optimum pest and disease control measures were followed. The amount of seed used, labor requirements, number and weight of tiller, and the yield data are listed in Table 1.

The data taken from the averages of 3 one-eighth hectare plots indicated that 5 man-hr are needed to seed a hectare with the eight-row seeder as compared to 199 man-hr for transplanting. The weight and number of tillers per square meter in the transplanted plots were significantly lower than the seeded plots. The yields of the seeded plots did not differ significantly from those of the transplanted plots.

Field tests and demonstrations of the eight-row seeder were held in two localities in Laguna province. Comments from farmers indicated that improved performance could be attained by reducing the weight of the machine.

The seeder has been subsequently redesigned to reduce its weight and to permit packaging in a compact box. A new six-row seeder weighing 19 kg (compared to 23 kg for the eight-row machine) has also been developed. The reduction in the number of seed tubes has lowered the height of the hopper to 45 in. (12 in. lower than the eight-row unit). The lower center of gravity of the six-row unit has improved handling characteristics and has reduced draft requirements(Fig. 2).

An instruction manual is being prepared to facilitate proper use of the six- and eight-row machines, and to describe the method for germinating seeds.

The designs of the six- and eight-row machines have been released to the following manufacturers in the Philippines:

1. Kalayaan Engineering Co., Inc., Emilia Street, Makati, Rizal
2. Trans-Pacific Steel Industries, Inc., Dongalo, Parañaque, Rizal
3. Far East Industrial & Supply Co., Inc., Del Monte Ave., Quezon City

Satisfactory progress has been made in the manufacture of the eight-row seeder by Messrs. Kalayaan Engineering Co. This company manufactures airconditioning components but is interested in diversifying into the agricultural machinery field. It is well versed in manufacturing techniques and is capable of producing quality precision products. They have recently marketed a few seeders to local farmers and have supplied a number of machines to the Institute which are being shipped to several countries in Asia for evaluation.

Messrs. Trans-Pacific Steel Industries, a custom fabricator and construction equipment manufacturer, is interested in manufacturing agricultural machines. The company has supplied a few six-row seeders which are being evaluated at the Institute.

The retail price of the seeder in the Philippines is ₱300 (approximately US$48) for the six-row unit and ₱350 (approximately US$56) for the eight-row unit.

In response to requests, manufacturing drawings of the seeder have been forwarded to the following companies:

Cervantes Steel, Inc., South SuperHighway, Parañaque, Rizal, Phil.
Karkhana Alat-a-Zari, Bahawalpur, W. Pakistan
Escorts Limited, Faridabad (Haryana), New Delhi, India
Hygrodyn Private Ltd., Mount Road, Madras, India
Yamamoto Mfg. Co., Tendo-city, Yamagata, Japan

Arrangements are being made to ship one seeder to each of the following organizations for test and evaluation purposes:

Rice Department, Ministry of Agriculture, Government of Thailand, Bangkok, Thailand
Mindanao Institute of Technology, Kabacan, Cotabato, Philippines
Agricultural Engineering Department, University of the Philippines, College of Agriculture, College, Laguna, Philippines
International Institute of Rural Reconstruction, Silang, Cavite, Philippines
International Institute of Tropical Agriculture, Ibadan, Nigeria
Agricultural Engineering Department, Central Luzon State University, Muñoz, Nueva Ecija, Philippines
Multiple Cropping Management Project, Thai Government-Ford Foundation, Faculty of Agriculture, Chiengmai University, Chiengmai, Thailand
North Carolina Mission, U.S. Agency for International Development, Lima, Peru
Farm Research Center, San Mateo, Isabela, Philippines
Food and Agriculture Division, U. S. Agency for International Development, Kathmandu, Nepal
East Pakistan Accelerated Rice Research Institute, Dacca, E. Pakistan
The Ford Foundation, Djakarta, Indonesia
Dry Zone Research Station, Maha Illuppallama, Ceylon

A recent issue of The IRRI Reporter, March-April 1970, Vol. 6, No. 2, and the newspaper Hindu, from Madras, India, featured an article on this seeder. Many enquiries have been received from farmers and manufacturers in Asian countries on this seeder.

TABLE THRESHER

The design of a fourth prototype table thresher has been reported earlier. Some problems on grain separation and straw delivery were encountered with this unit. Considerable effort was expended in modifying the machine to improve its performance.

Spiral baffles were mounted on the underside of the cover, just above the screen, to assist in the radial movement of straw. The top cover design and the air intake were substantially modified to permit more compact packaging. The thresher (Fig. 3), complete with the engine, can be packed in a crate of about 45 cu ft. It is felt that compact packaging would encourage export. The machine has a total weight of 174 kg and is equipped with four handles for carrying it into the paddy fields. Two different wheel attachment options are being developed which will facilitate movement of the machine on roads and levees.

Tests conducted at the Institute's farm indicated a threshing output of 350 to 400 kg of rough rice per hour when operated by 4 men. The machine was released to the following three manufacturers in the Philippines:

Oberly & Co., Inc., Mayon St., Sta. Mesa Heights, Quezon City

G. A. Machineries, Inc., Valenzuela, Bulacan
Trans-Pacific Steel Industries, Inc., Dimatimbangan, Dongalo, Parañaque, Rizal

The first prototype machine from Messrs. Oberly & Co. has been received at the Institute and is undergoing tests and modifications. The other two manufacturers are currently fabricating their first units.

Interest in the manufacture of this thresher was received from some manufacturers located in the developed countries. An Australian manufacturer, Messrs. National Springs Pty. Ltd., has approached the Institute for exclusive rights to manufacture this machine for export to the Asian countries. Their request is under consideration by USAID/Washington. While it may be difficult to permit exclusive rights for the manufacture of any machine designed under this contract, the Australian company has been informed that they can proceed with the manufacture of the table thresher on a non-exclusive basis. The company is currently evaluating the economics of manufacturing the machine for export.

Additional organizations have sent requests for the engineering drawings of this thresher. In response to their requests, information and engineering drawings were forwarded to the following:

Agricultural Machinery Division, Institute of Agricultural Engineering & Utilization, Office of Rural Development, Suwon, Korea
Department of Agriculture, Maha Illuppallama, Ceylon
International Department, Shin-Norinsha Co., Ltd., Kanda Nishikicho, Chiyodaku, Tokyo, Japan
Ohtake Nouki Seisakusho Co., Ltd., Nakazima, Ohharu-mura, Amagun, A Aichi, Japan
New Maharashtra Engineering, Hadapsar Industrial Estate, Poona, India
University of Missouri-USAID, Orissa, India
Centro Internacional de Agricultura Tropical, Cali, Colombia
Yamamoto Manufacturing Co., Ltd., Tendo-city, Yamagata, Japan
Far East Industrial & Supply Co., Del Monte Ave., Quezon City, Philippines
Crops Division, U. S. Agency for International Development, Saigon, South Vietnam

The May-June 1970, Vol. 6 No. 3 issue of <u>The IRRI Reporter</u> featured an article on this thresher.

ROTARY SCREEN GRAIN CLEANER

The design of a rotary screen grain cleaner utilizing a novel arrangement for screening and winnowing of the grain has been described in previous reports. The development of the first prototype and its problems were included in report No. 9.

A second prototype machine was designed with a separate centrifugal blower and a grain hopper. In the first prototype the hopper and the fan housing were combined in one unit which was difficult to fabricate. The machine was tested at the Institute and at rice mills in Laguna province. An output of up to 3 tons/hr of cleaned grain was attained in the tests. Figure 4 is the schematic drawing of the cleaner. The second prototype machine is illustrated in Fig. 5.

Significant interest in the manufacture of this grain cleaner has been generated. The design has been released to two manufacturers in the Philippines:

G. A. Machineries, Inc., Valenzuela, Bulacan
Oberly & Co., Inc., Mayon St., Sta. Mesa Heights, Quezon City

G. A. Machineries has made substantial progress in the completion of their first prototype cleaner. In addition to marketing the cleaner as a standard and trailer-mounted machine, the company is planning to integrate this rotary cleaner with their continuous-flow paddy drier. Response on the use of the cleaner from the various rice mill owners, drier operators, and larger farm owners has been very encouraging.

Requests for manufacturing drawings have also been received from the following companies in the Philippines:

Ordoveza & Sons, Inc., Bay, Laguna
Trans-Pacific Steel Industries, Inc., Dongalo, Parañaque, Rizal
Far East Industrial & Supply Co., Inc., Del Monte Ave., Quezon City

Substantial interest has been generated in this cleaner in some of the developed countries. Messrs. A. T. Ferrell & Co. of Saginaw, Michigan, U.S.A., makers of the Clipper line of grain cleaning equipment, are exploring the possibilities for its manufacture as a general-purpose farm cleaner for the United States market. Messrs. Yamamoto Manufacturing Co., Ltd., a well known manufacturer of grain drying equipment in Japan, is looking into the possibility of its manufacture for the Japanese market.

Further development and certain modifications are being explored which may substantially increase the cleaning capacity of this machine.

STRIPPER-HARVESTER COMBINE

The design details of a stripper paddy harvester have been reported earlier. Field trials were conducted and certain modifications were carried out to reduce the scattering grain loss. A flexible baffle was mounted inside the gathering mechanism to catch any grain which was thrown out of the machine. Further work is needed to reduce grain scatter. Due to the heavy schedule of other projects in the machine shop, work on the stripper has been temporarily held up. More attention is now being directed to this project.

DIFFERENTIAL CAGE WHEEL SLIP FOR WETLAND PREPARATION

An experimental machine utilizing differential wheel slip for land preparation was described in report No. 9. Briefly, it is a four-wheel riding machine weighing 290 kg with independently driven front and rear wheels. Under soft field conditions, operating the front wheels faster than the rear or vice versa results in a differential slip which accomplishes tillage. In earlier experiments, improved mobility was achieved with this machine in soft paddy fields.

Subsequent tests were conducted to determine the performance of specially designed cage wheels (tilling wheels) for this machine. The design of the tilling wheel was based on the following factors:

(1) The total weight of the machine was not to exceed 290 kg with about 150 kg on the rear wheels. This limited the weight of the tilling wheels to about 55 kg.

(2) The wheel must be able to simultaneously provide good mobility and soil tillage.

Since the special tiller wheels tended to overdrive the front unit, the front engine and drive train of the original machine was replaced by a larger hand tractor with a higher gear ratio. A larger cage wheel was fitted to the front unit for improved mobility (Fig. 6). In this experiment, the rear wheels were operated faster than the front to eliminate any rear wheel tracks on the tilled ground.

Figure 7 shows a tiller wheel with adjustable number and angle of blades. It was hoped that by varying the number of blades and the blade angle, a balance between pushing force wheel, slip and tilling performance could be attained. The toe of the blades was designed with sufficient bearing area for support on harder ground. Tests indicated that tillage could be achieved with this tiller wheel while developing considerable pushing force. Satisfactory tillage was accomplished by using 12 blades per row and a radial blade angle. However, depth of tillage could not be controlled satisfactorily as the tiller readily reached the hardpan. Difficulties were also encountered in soft soils because of clogging of the tiller wheel with mud.

To overcome the above defects, a new hollow drum tiller design (Fig. 8) was fabricated. The size of the drum is such that in static tests it sinks to about 16.25 cm in a well puddled soil when loaded with 150 kg ballast. The hollow drum serves to limit the tilling depth. Blades were welded on the drum for tilling and mobility. Tests have shown encouraging results for mobility and tillage operations. Optimum tillage was achieved at tiller wheel speed of 40 to 50 rpm when the ground travel speed of the machine was 0.6 to 0.9 m/sec.

Although good tillage was achieved with this tiller wheel, it had a tendency to move the soil towards the sides, thus creating a small embankment at the edge of the tilled path. When the machine followed a previously tilled path, difficulty was encountered in getting out of the path. Some design improvement was therefore made in this direction. The angle of the blades with the travel direction was rearranged to reduce the lateral displacement of the soil (Fig. 8). Additional experiments will be conducted with four wheels of the same basic design.

TRACTOR MOBILITY STUDIES

In report No. 9, the rolling resistance of a standard 55-hp tractor was determined under three different fields. The data seemed to indicate a relationship between the tractor rolling resistance and the area under the penetrometer curve (pressure vs depth).

An experiment was conducted to determine a correlation between the rear wheel sinkage of a 55-hp tractor and the area under the penetrometer curve from 0 to 9 in. depths. It was felt that an equation could be established to permit the use of the penetrometer for predicting tractor wheel sinkage. An additional objective was to determine the correlation between tractor wheel sinkage and rolling resistance. The 55-hp tractor with a load cell and strain gage recorder used in the earlier rolling resistance studies was used. Specifications of the tractor are listed in Table 2.

Since accurate field measurement of tractor wheel sinkage is very difficult, a simple method of measuring rear wheel sinkage was developed. This method is based on a comparison between the vertical displacement of the rear axle as the tractor is towed on a concrete floor and over the field. By attaching extensions on the tractor rear axles and placing a beam with a series of deflectable pointers on the ground, as shown in Fig. 9, it was possible to accurately record the vertical movement of the tractor axle. Nine pointers were pivotally bolted to a straight beam and tightened sufficiently so as to retain the deflected position. These beams were positioned, one on each side of the tractor, parallel to the travel path so that the axle extensions contacted the pointers as the tractor was towed (Fig. 9). The height of the axle from the soil surface was calculated by adding the average height of the deflected pointers from the water surface and the average water depth. To obtain axle height at zero sinkage, a similar experiment was done on a concrete floor. The sinkage, z, was computed as follows:

z = average axle height from concrete floor - (average axle
height from water surface + average depth of water)

Four flooded fields with different conditions were used to obtain a wide range of wheel sinkage. Fields F-3 and F-10 were thickly covered with vegetation as both had remained unplanted for over a year. F-1 was the softest as it was often used for testing tillage implements. F-11 had recently been harvested and rice stubbles were still present in the field.

Figure 10 shows a typical curve drawn between penetrometer readings, p, and the depth of penetration, x. Each point is an average of 10 readings.[1/] The curve crosses the x axis at the average soil surface, x_o. From this intercept, 9 in. was measured to the right. The area,

$$A = \int_{x_o}^{x_o + 9} p\,dx$$

was integrated by planimeter.

Figure 11 shows regression lines between area A and sinkage z (data sheet in Table 3). Dot subscripts indicate the fields where observations were made. It was thought that a single line could be drawn for the four fields. The plotting of the data indicated, however, two distinct groupings, which are represented by the two lines. One line was drawn for fields F-1 and F-11 and another for F-3 and F-10. The presence of considerable vegetation on F-3 and F-10 seemed to shift the line downward. The vegetation cover formed a reinforcing mat on the soil surface which had a significant effect in supporting the tractor. This factor was not accounted for in the penetrometer readings as the small size of the cone permitted it to penetrate between the roots.

The regression coefficient for fields F-1 and F-10 is r = 0.945; for F-3 and F-10, r = 0.745. Tests for significance of the slope of both regressions are highly significant at the 1 percent level. There is a strong indication of a linear correlation between the area A as described above and the sinkage z. Ninety-five percent confidence bands were drawn for individual values of z to illustrate the possibility of using the penetrometer as a quantitative instrument for the prediction of tractor wheel sinkage.

Figure 12 shows the regression between sinkage z and rolling resistance of the same tractor. The coefficient of linear regression is 0.88 and the test for significance of the slope shows that it is highly significant at the 1 percent level. It was surmised in report No. 9 that a rolling resistance of about 500 kg (1100 lb) is the critical resistance at which the tractor can propel itself. At the rolling resistance of 1100 lb, the sinkage z, by using Fig. 12, is only about 2.7 in. This sinkage actually is the sinkage relative to the undisturbed soil surface. However, mud is bulldozed in front of the wheel so that in effect, a thicker layer of soil is resisting the movement of the wheel.

TRACTOR PTO-DRIVEN THRESHER

The design of a tractor PTO-driven thresher (Fig. 13) has been reported earlier. The fabrication of the first prototype was started during the period of the report. Problems were encountered with the axial movement of the threshed material through the cylinder and the movement of the wet

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[1/] Ten readings put a 90 percent confidence on the true mean.

grain by the auger located under the concave. The axial movement of the threshed material has been improved by changes in the design of the spiral baffles in the cover. The movement of wet grain through the auger may require the installation of a belt conveyor. Some problems have also been encountered with the movement of straw through the rotary screen cleaner. Work is underway to increase the flow of straw through the rotary screen cleaner.

Preliminary trials are being conducted during the wet season. The performance using wet grain looks very encouraging and it is felt that a machine for production could be developed within the coming year.

Interest in a high-capacity multi-crop thresher is quite substantial in most of the developing countries. Many Asian visitors who have seen the first prototype thresher have commented about the urgency both of completing this project and the need for a machine of this type. Efforts are being made to complete this project at the earliest stage.

This thresher has been oriented principally towards the needs of farmers with large holdings and custom threshing operations. The machine is intended to replace the large, bulky threshers which are used for custom threshing and were originally developed fifty years earlier.

Custom threshing of rice is popular in Ceylon by treading under tractor tires. A high-capacity, PTO-driven thresher could be more efficient for such operations. Substantial demand is foreseen for threshing both wheat and rice in India and Pakistan for this type of machine.

Drying and Processing Research

CONSUMER PREFERENCE TESTS OF HEATED-SAND AND FLAME-DRIED PADDY

Accelerated drying experiments of high-moisture paddy by heated-sand or flame-exposure methods have been reported. The starch granule in paddy dried by these two methods is gelatinized. The paddy will, henceforth, be referred to as converted rice in this report. Taste preference tests[2] were conducted to find the effect of accelerated drying methods on the eating quality of IR22 rice.

Three rice samples of 2 kg each were dried by (1) the heated-sand method, (2) flame-exposure method, and (3) air-drying method (control). These samples were cooked and tested at the Food Research Laboratory, Home Technology Department, U. P. College of Agriculture. The control sample was dried in an airconditioned room and was artificially aged in a sealed jar at 120°C

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[2] The authors acknowledge the help of Dr. Luz U. Oñate and the staff of the food research laboratory of the Department of Home Technology, University of the Philippines, College of Agriculture, College, Laguna who conducted these tests.

for 2 hours. Cooked rice samples were served to the tasters first, when the rice was freshly cooked and still hot, and second, when it had cooled to room temperature.

The tests were conducted with two separate taste panels: the consumer preference panel and the laboratory taste panel.[3] The consumer preference panel was composed of 50 persons from IRRI Agricultural Engineering and some other departments of the U. P. College of Agriculture. These persons were asked to rank the cooked rice samples according to their preference. Friedman's two-[redacted] way non-parametric analysis of variance was used to determine preference ranking.

A laboratory taste panel of six judges was used to study the differences in one or more attributes such as odor, flavor, tenderness, and cohesiveness of the samples. The judges on the taste panel were selected for their experience in recognizing differences among samples. An F-test was used to test for statistically significant differences among samples.

The consumer preference panel failed to detect any differences in taste among the heated-sand, the flame-exposed, and the control for either the hot and the cold samples (Table 4a and 4(b). The laboratory taste panel, however, detected differences in aroma and color when the rice samples were served hot (Table 5). The converted rice was found to be stronger in aroma than the control. The converted rice was creamy while the control was white.

With the hot samples, however, no significant differences were detected with regard to off-aroma, flavor, tenderness, cohesiveness, and gloss. The judges were able to detect differences in cohesiveness and gloss in addition to aroma and color in the cold samples. The converted rice on cooling was less sticky and more glossy than the control sample.

HEATED-SAND DRIER

Drying of paddy in the wet tropics at village or farm level will require a simple, continuous-flow, adequate-capacity drier. To be well accepted, the drier should be capable of reducing the moisture content of freshly harvested wet paddy in a short period to a safe level in a single pass. Drying with a conventional heated-air drier is limited to a relatively slow rate of drying because of diverse effects on milling recovery or head rice yields.

Previous experiments have indicated the possibility of drying rice in a few seconds by using a heated-sand process. This method imparts a gelatinizing effect on the starch granule in the paddy which improves milling recovery and head rice yields. The effect is similar to parboiling which is

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[3] Oñate, L. U. and A. M. del Mundo, 1966. Consumer and laboratory panel evaluation of seed board rice varieties. Phil. Agr. 50:301-309.

known to improve storage quality and retention of natural vitamins. A project was started on the design of a continuous-flow drier utilizing the heated sand process. The design concepts for two heated-sand driers have have been completed, one for village-level use and the other for farm-level operation. The larger drier has a pre-cleaner and a post-cleaner to permit the cleaning and drying operations in a single pass.

Fabrication of the smaller farm-level drier is underway. It has been designed for fabrication by small machine shops in the developing countries. The machine is essentially a small, hand-cranked drier consisting of a horizontally rotating cylinder placed in a semi-cylindrical pan for sand. The sand is heated with a heat source placed under the pan. The rotary drum is fitted with two sets of scoops and an internal spiral. The scoops transfer the heated sand and the grain from a second pan into the drum. As the drum rotates, the sand-grain mixture is moved in an axial direction by the spiral. After the desired duration of exposure, sand is separated from the grain by a rotary screen which is part of the cylinder. The sand is reheated and recycled into the drum. The first prototype unit is being fabricated and is expected to be completed in the near future.

ACCELERATED DRYING OF SORGHUM

A conduction drying process using heated sand for drying high-moisture paddy was described in the last progress report. Since production of sorghum is gaining popularity in the tropical countries, experiments were conducted to evaluate the heated-sand process for drying sorghum.

Sorghum is usually harvested at 35 to 42 percent (d.b.) moisture level in the tropical countries and needs to be ried to 14 percent m.c. for safe storage. Conventional heated-air driers requiring large investments are not economical for small-scale drying operations. The heated-sand approach seems to offer possibilities for quick, low-cost drying of sorghum.

Experiments on accelerated drying of sorghum were conducted by mixing sorghum with heated sand for period of 15, 30, and 45 seconds. The moisture removed during the sorghum-sand exposure was measured. Sand was heated in an oven to temperatures of 180°, 200°, 220°, and 240°C. A sorghum-sand ratio of 1:20 by weight was used during the entire study.

Two varieties of freshly harvested sorghum samples were carefully cleaned and the initial moisture contents determined by the oven method. The drying tests were conducted by simultaneously pouring 200 grams of sorghum and 4000 grams of heated sand in a flask. The recording of time for sorghum-sand exposure was started after half of the sorghum had been poured into the flask. The flask was shaken vigorously to evenly mix the sorghum and the sand. A glass thermometer was inserted into the flask to measure the temperature of the sorghum-sand mixture.

Table 6 and Fig. 14 indicate that with 15 seconds exposure, there is no significant difference in moisture removal at sand temperatures ranging from 180°to 240°C. Some popping of sorghum was observed at temperatures above 200°C. With the 30 seconds exposure, there was a significant increase in moisture removal with increases in sand temperatures. Above 200°C sand temperatures, increased popping of grain was observed. Exposure of 30 seconds seems satisfactory provided sand temperature of 200°C is not exceeded.

Although the heated-sand method of drying can be used with sorghum, results of the experiment indicated that a lesser degree of moisture removal is possible with sorghum than with paddy when using the heated-sand process.

DRYING CHEMICALLY TREATED PADDY TO BREAK SEED DORMANCY

The breaking of seed dormancy in large quantities is a serious problem. Previous research indicates two possible solutions: (a) heat treatment (holding dry paddy seed in an oven for 4 to 5 days at 50°C)[4/] and (b) chemical treatment (soaking air-dried paddy seed in dilute nitric acid solution [0.1N] for 16 to 24 hours followed by sun-drying for 3 to 7 days)[5/]. Some doubts were encountered as to the applicability of these methods to large-scale operation since they had been tried only for small samples. Although a big oven could be designed, the uniformity of breaking the dormancy when the seeds are placed in sacks is questionable. For the chemical treatment, large quantity sun-drying may not be very practical in the process. The effects of heated-air drying on the acid-treated seed are not well known.

The soaking of freshly harvested moist paddy seed in nitric acid solution followed by heated-air drying would: (a) eliminate the first drying operation common with the two methods, (b)shorten the duration of breaking dormancy by several days by utilizing conventional heated-air driers, and (c) make the process independent of weather conditions.

A study was undertaken to evaluate the effects of various drying treatments on freshly harvested IR22 seed which had been pre-soaked in a nitric acid solution.

Conclusion

(a) The dormancy of IR22 was artificially broken within 4 days after harvest (2 days after drying) by soaking freshly harvested seed in 0.2N nitric acid solution for 24 hours followed by heated-air drying (43 to 46°C) in a batch drier with 30 to 40 cu ft per minute of air for 6 hours.

(b) The dormancy was also broken by soaking freshly harvested seed in 0.1N to 0.2N nitric acid solution for 24 hours followed by sun-drying for 6 hours.

[4/]P. R. Jennings and J. de Jesus Jr., Effect of heat on breaking seed dormancy on rice, Crop Science, Vol. 4, No. 5, pp. 530-533 (1964).

[5/]The IRRI Reporter, Vol. 4, No. 2 (March-April 1968).

(c) Unheated-air drying (ambient air temperature, 29°C) for 48 hours following soaking in nitric acid solution failed to break dormancy when tested 2 days after drying. This indicates the importance of heat in the process.

(d) The drying air temperature for a flat-bed batch type drier should not exceed 46°C (115°F) to maintain the viability of the seed.

About 50 kg of freshly harvested IR22 seeds with an initial germination of 6 to 8 percent was soaked in two concentrations of nitric acid solutions: 25 kg in 0.1N (or 240 ml of concentrated acid in 10 gal of water) and 25 Kg in 0.2N (or 480 ml of concentrated acid in 10 gal of water). For both acid concentrations, the 25 kg seed sample was further subdivided into three parts corresponding to soaking durations of 12, 18 and 24 hours. Four drying methods were used for each soaking duration: sun-drying, drying in the shade, unheated-air drying (29°C), and heated-air drying (43 to 46°C). For sun-drying the paddy was spread 1-in. thick on a concrete floor, stirred every hour, and dried for 6 to 8 hours until moisture content decreased to 14 percent. The same was true for drying in the shade, except the paddy was placed in the shade for 48 hours. For the air-drying methods, a small flat-bed drier with two compartments and a blower was used. One compartment was for unheated-air drying (or ambient air temperature of about 29°C); the other was heated by an electric coil with a variable transformer to control air temperature between 43 to 46°C.

To determine the effect of higher drying-air temperatures on the viability of the seeds, a second experiment was conducted using the same procedure as the first except that three drying methods were used: (a) heated-air drying at 49°C, heated-air drying at 60°C, and (c) sun-drying.

An analysis of the first experiment indicated that any treatment combination giving mean percent germination higher than 85.8 is significantly different from the 80 percent at which level the dormancy is normally considered broken. A total of 16 treatment combinations gave mean percent germination significantly higher than 80 percent as indicated by the underlined means in Table 7; e.g. the dormancy was broken at two days after drying with seeds soaked in 0.1N and 0.2N nitric acid for 24 hours followed by sun-drying, and with seeds soaked in 0.2N for 24 hours followed by heated-air drying (43 to 46°C). The dormancy was not broken, however, with those dried in the shade, and with unheated air.

Higher percentage germination was observed at two weeks after drying as compared to 2 days after drying. The dormancy was broken at the end of two weeks after drying for the following treatments: (a) all the sun-dried treatments, (b) all heated-air treatments except that soaked 12 hours in 0.1N, (c) unheated-air treatments soaked 18 to 24 hours in 0.2N. Dormancy was not broken for those dried in the shade.

For the second experiment (Table 8) any treatment combination giving mean percentage of germination higher than 83.4 percent is significantly different from the 80 percent level. Of all the seeds tested for germination on the third day after drying, only the sun-dried treatment which had been soaked 18 hours in 0.2N showed broken dormancy. Higher percentage of germination was observed 10 days after drying as compared to 3 days after drying. Ten days after drying, the dormancy was found broken with all the sun-dried treatments, with the 49°C drying-air treatments soaked for either 12 hours in 0.1N and 0.2N or soaked 18 hours in 0.2N solution, and with 60°C drying air soaked 18 hours in 0.2N solution.

Heated-air drying at 49°C and 60°C showed a reduction in seed viability at the 24-hours soaking period when tested after 10 days storage. This indicates that the drying-air temperature should be maintained below 49°C to maintain viability of seed.

RICE HULL FURNACE

The construction of a furnace utilizing rice hull as fuel was started. The furnace uses two empty 55-gal oil drums which are connected together by an air duct. Rice hull is fed into and burned on a sloping fire grate in the first drum. The second drum serves as a trap to arrest ash and other combustion products. A centrifugal blower is hooked to the furnace such that it can partially draw the heat of combustion from the furnace and blow it into the grain.

Preliminary test of the furnace with a small blower gave a heat rate of 500 to 2000 BTU/min. Average heating value of rice hull obtained was 5000 BTU/lb. Based on these values the furnace can heat 3000 cu ft/min of ambient air to 120°F. This amount of heated air can dry 1.5 to 2.0 tons of wet paddy (25% m.c.) within 6 hours when placed 1 foot deep in a batch drier and would require 50 kg of rice hull per hour. The tests also indicated that with the help of an aspirator, complete combustion can be achieved, thereby eliminating the need for a heat exchanger. Work on this project is being continued.

Applied Machinery and Economic Research

ECONOMIC ASPECTS OF HAND TRACTOR OWNERSHIP

During the last few years, a substantial increase has occurred in the number of hand tractors on lowland rice farms. The continued adoption of these machines has meant increases in capital investments and operating costs. The primary purpose of this study was to analyze input-output data on the various types of hand tractors and to define the relationship between tractor use and costs by the use of average cost curves.

Information on hand tractors was gathered from the various distributors/dealers of agricultural machinery on the number, type, and owners of hand tractors in Laguna province. Based on this information, a sample of 140 tractor owners which included 47 single-axle tillers (Type I), 68 general tillers (Type II), and 25 double-axle power tillers (Type III), was selected for personal interviews.

The three types of hand tractor are illustrated in Fig. 15 and are briefly described as follows:

(1) Single-axle tillers (Type I) are lightweight, usually with 4 to 6 hp gasoline engines. For tillage operation, rotary tiller blades are directly mounted on the main axle. No separate rotary tiller attachment is available with this tractor. These tractors can be equipped with rubber tires for dryland work or haulage. There is no differential in the axle and no steering clutches.

(2) General tillers (Type II) are usually equipped with aircooled gasoline engines of up to 8 hp. These are equipped with wheels and perform several farm operations by fitting draft-dependent farm implements such as plows, harrows, cultivators, etc. Tractors of this type have provisions for reverse drives and have multi-speed shifting transmissions. The machines are offered with a detachable rotary tiller attachment.

(3) Double-axle power tillers (Type III) have two drive wheels and a separate rotary tilling mechanism which consists of a series of knives attached to a rotating shaft mounted at the rear of the regular wheel axle. Although these tillers are not as versatile as the other two types, they are better suited for tilling in clayey paddy fields due to their sturdier construction and larger-sized engines. Generally, these tractors are equipped with diesel engines with ratings of 8 to 14 hp. The specifications of these types of tractors are shown in Table 9.

Hand Tractor Adoption

A majority (92%) of the tractors were found on irrigated 2-crop farms, and 66 percent of the farmers indicated that the nuisance attendant to the care and maintenance of the carabao was the major reason for buying a hand tractor. A somewhat smaller percentage of the farmers gave a direct economic reason — faster land preparation (Tables 10 and 11). Simplicity and lightness are the major factors behind the selection of Type I tractors. Types II and III tractors, on the other hand, are preferred on the basis of power (Table 12). Procurement and the high cost of spare parts are the major problems confronting the farmers (Table 13).

Establishing Hand Tractor Costs

Performance rates. Reliance was placed on farmer estimates of the performance capacity of the machines, as shown in Table 14. This is a limitation of the study since the operational conditions vary from one farm to another and the data were based on the farmer's memory.

Costing of hand tractors. Table 15 presents the fixed and variable costs of using the three types of hand tractors. Tractor contract costs vary from ₱25 to ₱35 per 8-hour day. The latter is typical of rates in which meals of two men who jointly operate the tractor are not included.

Under these costs, the break-even point in terms of annual use is 230 hours for single-axle tillers and general tillers, and 491 hours for double-axle tillers (Fig. 16). Applying this work load to the average annual use for all types reveals that more than 50 percent of the tractors are used economically.

Except for Type III tractors scale economies (of use) almost disappear at 800 hours of use. After this, there are only marginal cost reductions resulting from the spreading of overhead costs over more hours. Apparently, Type III hand tractors are uneconomical as compared to the other two tractor types for operations of less than 50 ha per year.

Gasoline vs diesel hand tractors. When the gasoline and diesel hand tractors are compared in relation to different wage rates, Fig. 17 is obtained. Any combination of labor cost and annual use to the right and above the line favors the use of diesel tractor. Conversely, gasoline tractors are the less costly alternative for all combinations below the line.

Relative importance of individual cost factors. This portion of the study explored the relative significance of the following cost items: (a) custom rate (pesos/day); (b) wage rate (pesos/day); (c) price of fuel (pesos/liter); (d) price of oil (pesos/liter); (e) interest rate (percent/year). The method used is to compute a ratio of the overhead costs per year to the variable profit per hour of operation.

Results were obtained by varying each factor above and below its baseline value while holding all others constant at their respective average or baseline levels. The net of such changes are shown in Fig. 18 and 19. The horizontal dashed lines represent the baseline levels of the factors considered. Results are read as the net effect of varying one factor, holding others constant, on the hours of annual use needed to break even. A 5-peso increase in the custom rate, for example, reduces the break-even by 43 hours for Type I tractors and 103 hours for Type III tractors.

Hand Tractor Repayments

A substantial number of the farmers interviewed indicated that purchase of their hand tractors was financed from loans extended by Rural Banks under the CB:IBRD Farm Mechanization Program.[6]

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[6] The Central Bank of the Philippines entered into agreement with the World Bank (IBRD) on November 2, 1965 to obtain a credit line of US$5 million to finance medium and long term loans for the acquisition of farm machinery and equipment and small private irrigation pumps and equipment. The loans are extended through the rural banks. Most of the capital, however, was used to finance tractor purchases due to the delay and difficulty in establishing water rights for irrigation pumps.

A "rule of thumb" developed by some product planners states that the gross value of the crop processed per year should be about three times the value of the machine. Using this as a rough guide, budgets were established (Tables 16 through 18) using five different yield levels. The tables show the work load required of each tractor type to achieve a gross income equal to three times their respective values.

The analysis indicates that double-crop irrigated farms of larger-than-average size represent the greatest potential for hand tractor sales.

ECONOMICS OF THE ROW SEEDER

Three firms in the Philippines are marketing the seeder for pre-germinated paddy at a selling price of about ₱350. The economics of owning this seeder are analyzed in this study. It is estimated that the machine can render useful service for 4 years. During this period the replacement costs for parts are estimated to be: (a) fluted roller, ₱5 a year; (b) brush, ₱4.50 a year; (c) paint, ₱5 a year; and (d) skid, ₱80 before the fourth year. Table 19 shows the cost of using the seeder on the basis of the above estimates.

Depreciation was computed by dividing the purchase price by the estimated service life of the machine. Interest on the investment was calculated at 12 percent of the average value of the machine during its life. The operator's labor was estimated to be worth ₱0.50/hr.

Table 20 indicates the average total cost per hectare at varying levels of use. Table 20 indicates that costs decline as annual use is increased. This can be achieved by either hiring the machine or doing contract seeding.

The information contained in Table 20 is plotted in Fig. 20. Superimposed on the graph is the contract cost of transplanting[7] obtained from farmers' interviews in Laguna and Central Luzon. The point x indicates the hectarage at which the cost per hectare by either transplanting or row seeding is equal. The figure indicates that above 2.5 ha of annual use, it is more economical to use the seeder. It would pay a farmer, therefore, with even as small a farm as 1.5 ha, cropped twice a year, to invest in this machine.

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[7] While two different operations are being compared, the seeder has been developed for pre-germinated paddy and is intended to be used as a replacement for transplanting methods.

Work Plan

TABLE THRESHER TESTS

The machine is being fabricated in the Philippines by three manufacturers. Assistance will be provided to these manufacturers by field testing their initial production machines and assisting in further development of their machines.

ROW SEEDER FOR UPLAND CROPS

The lowland row seeder will be adapted to upland operation by replacing the skid with a comb harrow. Response from farmers have indicated a need for such a machine. This seeder will be designed as an animal-drawn unit. If the results are favorable, a large tractor-drawn seeder will be developed.

MECHANIZATION FOR MULTIPLE CROPPING

Multiple cropping is being introduced in many countries. Experiments on mechanizing the various operations by development of a simple drive-wheel attachment to a walking tractor with a variety of new attachments will be undertaken. If successful, the experiments will be followed by the development of a multi-purpose machine with attachments for all the major requirements of multiple cropping.

ROTARY GRAIN CLEANER DEVELOPMENT

Commercial production of the rotary screen grain cleaner is underway. A detailed study of its cleaning performance will be undertaken. Optimum points will be determined for air flow and grain feed, to attain maximum efficiency and cleaning quality. Attempts will be made to further increase the cleaning capacity and quality by the introduction of an additional concentric sheet metal cylinder which will substantially increase the screening area and length of grain travel through the air stream.

STRIPPER-HARVESTER DEVELOPMENT:

Work on the experimental stripper harvester will be continued. Different improvements for reducing grain loss on the ground will be tried. Studies will be carried out to evaluate these losses after the incorporation of the improvements. If these results are encouraging, a four-foot wide stripper attachment will be designed for a tool carrier which will be developed for the tropical rice farmer.

DIFFERENTIAL CAGE WHEEL SLIP FOR WETLAND PREPARATION

A second set of cage wheels will be attached to the axle of a 7.5-hp hand tractor through a fixed ratio drive assembly to convert it into a riding machine. This fixed speed ratio, between the front and rear wheels, will eliminate the over-driving tendency found with the present dual tractor unit. The machine will be skid-steered through the tractor steering clutches and an evaluation of this method of steering in soft wetland will be made.

MULTI-PURPOSE TOOL CARRIER

Design of a multi-purpose basic tool carrier for paddy cultivation has been initiated. The design is based on the All-Terrain Vehicle concept and has six low-pressure tires. This general-purpose machine is being developed to meet three basic needs of the tropical farmer: transportation, land preparation, and harvesting. It is being designed as a lightweight, off-the-road, high-mobility machine for transport work on rough country roads or paddy fields. A rotary tiller attachment and a stripper-harvester will be developed for the basic unit. If the concept proves useful, additional attachments for other agricultural operations will be developed.

COMPARISON BETWEEN CAGE WHEELS, STRAKE WHEELS, AND HALF-TRACKS

Varied claims have been received by the Department as to the best tractor accessory for improving wetland tractor mobility. A study will be initiated to determine the relative performance of cage wheels, strake wheels, half tracks, and eccentric wheel drives. The comparison shall be evaluated in terms of drawbar pull and rolling resistance. The performance of each of these traction aids will also be observed under the difficult conditions often encountered in wetland operation.

PERFORMANCE TESTS OF A SOFT PADDY TILLER

Puddling machines utilizing a sled and a paddy rotor have been used in Thailand and Malaysia for very soft fields. Most of these are machines which have been developed by local blacksmiths and shop owners. A puddling machine with the floating concept will be fabricated. Its performance will also be made to develop a lightweight sled attachment for standard walking tractors to provide extra flotation in soft fields.

DEVELOPMENT OF A HEATED-SAND DRIER

Plans for a manually operated paddy drier using the heated-sand process have been completed. The first prototype unit is being fabricated. The design of this drier is based on the time temperature relationship of sand-grain exposure established in an earlier laboratory study described in report No. 9. The first unit is being developed as a simple farm drier for the tropical farmer. A design concept of a larger village-level drier has been finalized. Detail design of the larger unit will be started after some experience has been gained with the small farm drier.

RICE HULL FURNACE

Test and evaluation of the rice hull furnace and blower will be made by connecting it to a flat-bed batch-type drier. Drying air and grain temperatures will be measured to evaluate the performance of the hull furnace. Heating capacity will be varied by controlling the feed rate of rice hull and the amount of air suction through the furnace. Attempts will be made to develop a hull furnace with an automatic hull feeder to eliminate the problem associated with manual feeding in the present design.

DIRECT-FLAME DRIER

Recent consumer preference tests on converted flame-dried rice have indicated a favorable response. A simple laboratory device which will permit continuous flame-exposure drying will be fabricated. Design data will be obtained from this laboratory model. If the results are found to be favorable, a larger-capacity direct-flame drier will be developed.

TEST AND EVALUATION OF THE CONVECTIONAL DRIER

Two basic types of Japanese driers are being introduced in the Asian countries: batch-type and continuous-flow cycle driers. Performance tests and economic feasibility studies will be conducted on these types of driers.

DEVELOPMENT OF A MANUALLY OPERATED GRAIN CLEANER

The rotary screen concept for a larger-capacity grain cleaner has been quite successful in terms of cleaning capacity. A somewhat similar rotary concept is being explored for the development of a small, manually operated farm cleaner. The machine would have an axially mounted fan and a rotary drum with a series of pockets to pick the grain and tumble it through the air stream. It is anticipated that such a machine could be quite popular with the small farmers of Asia. This concept would offer a higher capacity and better quality cleaning than the simple winnowers widely used by the Asian farmers.

DEVELOPMENT OF A THRESHER FOR TAIWAN

Request has been received from Taiwan for the development of a thresher for wet paddy. There is a need for a thresher for freshly harvested paddy in Taiwan which would be equipped with power-driven wheels for easy movement in the field. The design of a machine utilizing a wire-loop type threshing drum and a rotary screen cleaner has been started. The rotary screen offers possibilities for improved cleaning of wet paddy. The Taiwanese farmers thresh paddy at very high moisture levels on harvesting. The thresher is being designed to utilize the same engine for either driving the threshing mechanism or the drive wheels for moving the thresher in the fields.

ROW SEEDER FOR PRE-GERMINATED PADDY

The response received from many countries in Asia on the recently developed row seeder has been very encouraging. Some of the comments received on this seeder indicate that a machine which could drop seeds in hills instead of rows would be desirable for certain localities. Hill drop is possible if the metering unit is close to the ground. A lightweight seeder for sowing pre-germinated paddy on puddled soils has been started. The machine will have separate pre-germinated paddy metering device for individual rows. The drive for the individual seed metering units would be taken from a paddle wheel mounted directly on the same shaft as the metering units. It is felt that such a design may be easy to fabricate. Since there will be identical metering devices for each row, mass production methods could be easily applied in its manufacture.

TRANSPLANTER EVALUATION

Considerable interest is being generated in the use of transplanters in Asian countries. A number of companies in Japan are manufacturing a variety of transplanters. These machines are quite popular in Japan but have not proved successful in the Asian countries. A project will be started to evaluate these machines and to study their economic and technical characteristics under tropical conditions. This project will provide some experience in the use of transplanters and would assist in a proposed transplanter development project. A new transplanter concept is being explored which would utilize a high-speed centrifugal device for injecting seedlings into puddled soils.

Personnel and their respective man-months engaged in the project for the past six months, January 1 to June 30, 1970, are presented below:

Position	Name	From January 1/70 To June 30/70
Development Engineer & Project Leader	A. U. Khan[1]	4.5
Evaluation Engineer	Open	0
Agricultural Economist	Open	0
Assistant Design Engineer	E. O. Casem	6
Assistant Design Engineer	P. Cabanos	6
Assistant Design Engineer	A. Manalo	6
Assistant Test Engineer	Open	0
Assistant Test Engineer	Open	0
Research Assistant, Agricultural Economics	N. Orcino	6
Research Assistant, Engineering	N. Navasero	6
Research Assistant, Engineering	A. Amilhussin	6
Research Assistant, Engineering	E. del Rosario	0.25
Draftsman	F. Jalotjot	6
Draftsman	F. Cabrales	6
Secretary	C. Jizmundo	6
Secretary	V. Maraan	4
Secretary	F. Tobias	1
Shop Foreman	S. Gutierrez	6
Machinist	Z. Borja	6
Machinist	A. Dizon	6
Tinsmith	E. Dungo	6
Tinsmith	R. Santos	6
Welder	A. Barot	6
Mechanic-Operator	J. Silos Jr.	6
Shop Mechanic	R. Dignadice	6
Shop Mechanic	M. Macatangay	6
Shop Mechanic	P. de Mesa	6
Shop Mechanic	F. Flores	0.5
Laborer (Shop helper)	M. Castro	6
Laborer (Shop helper)	L. Villegas	6
Laborer (Shop helper)	M. Fabellar	6
Laborer (Student assistant)	B. Ramos	6

[1] Part-time.

Anticipated personnel needs for the next six months, July 1 to December 1970, are presented below:

Position	From July 1 /70 To December 31/70
Development Engineer & Project Leader	6
Evaluation Engineer	6
Agricultural Economist	6
Assistant Design Engineer	6
Assistant Design Engineer	6
Assistant Design Engineer	6
Assistant Test Engineer	6
Assistant Test Engineer	6
Assistant Test Engineer	6
Research Assistant, Economics	6
Research Assistant, Engineering	6
Research Assistant, Engineering	6
Research Assistant, Engineering	6
Draftsman	6
Draftsman	6
Secretary	6
Secretary	6
Shop Foreman	6
Machinist	6
Machinist	6
Tinsmith	6
Tinsmith	6
Welder	6
Mechanic-Operator	6
Shop Mechanic	6
Shop Mechanic	6
Shop Mechanic	6
Shop Mechanic	6
Laborer (Shop helper)	6
Laborer (Shop helper)	6
Laborer (Shop helper)	6
Laborer (Student assistant)	6

TABLE 1. Comparison between manually transplanted and mechanically seeded plots using the eight-row seeder, wet season, 1969.[a]

Method	Seed used (kg/ha)	Labor (man-hr/ hectare)	No. of tillers/ sqm (mean)	Tiller weight (g/sq m)	Yield (mean)
Transplanted in rows[b] (with planting guides)	45	199	249	448	5098
Seeded (with eight-row seeder)	52	4.89[c]	460*	630**	5434

[a] Data based on quarter-hectare plots. Soil condition: Maahas clay loam, shallow hardpan with an average depth of 5 in.

[b] Work done by 8 women: 2 on the planting guide and 6 doing the transplanting. Does not include time in preparing seedling nursery.

[c] Labor required in operating the seeder includes placing of string 1 m away from the levee as guide for straight seeding; also includes refilling of seed hopper with pre-germinated seeds. Does not include time spent in germinating and incubating seed.

* Significant.

** Highly significant.

TABLE 2. Tractor specifications.

Weight distribution (driver and dynograph operator included):	
Left front wheel	475 kg
Right front wheel	480 kg
Left rear wheel	715 kg
Tire pressure:	
Front wheels	24 psi
Rear wheels	18 psi
Wheel base	85 in.
Front and rear wheel tread	53 in.
Front tires	6:00 x 16
Rear tires	13.6/12 x 38

TABLE 3. Tractor rolling resistance.

Plot	Trial No.	Depth[a] of water (inch)	Sinkage[b] z (inch)	Penetrometer reading[c], p, (psi) at depths of 3"	6"	9"	12"	15"	18"	21"	Area, A (in-lb / sq in)	Rolling resistance (lb)
F- 1[d]	1	3.5	5.10	0	13	23	64	171	170	149	232	1708.9
	2	3.15	5.24	.5	16	24	74	127	152	151	228	1653.7
	3	2.36	4.84	8	28	36	144	166	198	120	315	1896.3
	4	1.97	6.03	1	16	29	110	165	154	170	202	1708.9
	5	2.76	4.25	5.5	23	56	168	180	192	180	424	1951.4
	6	2.76	4.85	8	23	36	125	185	148	146	303	2017.5
F- 3[e]	1	1.97	1.69	8	28	36	144	167	198	120	509	1345.0
	2	1.57	1.30	1	16	29	110	165	154	170	545	683.5
	3	1.97	1.49	9	23	56	168	180	192	182	600	926.1
	4	1.59	0.32	7	23	36	125	185	148	146	725	485.1
	5	2.36	0.17	31	72	113	130	140	120	162	795	485.1
F-10[f]	1	2.76	1.97	10	25	60	140	176	148	144	437	441.0
	2	2.76	1.89	27	33	63	164	175	187	200	536	363.8
	3	3.78	0.27	24	37	65	132	181	174	184	608	363.8
	4	3.55	0.59	46	46	91	120	152	158	140	690	463.05
	5	3.25	1.00	26	39	78	178	194	167	180	440	441.0
	6	2.76	1.00	23	35	67	150	136	146	159	523	363.8
F-11[g]	1	3.94	3.16	4	18	82	152	160	174	233	678	1488.4
	2	3.30	3.88	4	20	60	147	173	199	220	490	1389.1
	3	3.86	2.94	5	15	61	154	165	177	222	573	1411.
	4	3.54	2.76	5	13	72	153	158	148	155	573	1345.0
	5	3.54	3.56	2	20	70	151	170	187	186	581	1488.3

[a] Average of 6 readings.

[b] Average of 9 readings.

[c] Average of 10 readings

[d] Flooded, rotavated and harrowed 4 months before test.

[e] Flooded, idle for 1 yr., thick vegetation.

[f] Same condition as in F-3

[g] Flooded, newly harvested field, stubbles present.

TABLE 4(a). Preference scores of the heated-sand and the direct-flame dried rice, served hot.[a]

Taster	Rank			Taster	Rank		
	Sand	Flame	Control		Sand	Flame	Control
1	1	3	2	27	3	2	1
2	3	1	2	28	1	3	2
3	2	1	3	29	2	3	1
4	1	3	2	30	2	3	1
5	2	1	3	31	1	2	3
6	3	2	1	32	3	1	2
7	3	2	1	33	3	2	1
8	2	3	1	34	3	2	1
9	2	3	1	35	2	1	3
10	1	3	2	36	2	3	1
11	1	2	3	37	2	1	3
12	2	3	1	38	3	2	1
13	2	1	3	39	1	2	3
14	1	2	3	40	3	1	2
15	1	3	2	41	2	3	1
16	3	1	2	42	3	2	1
17	1	2	3	43	2.5[b]	2.5[b]	1
18	1	2	3	44	2	3	1
19	3	2	1	45	2	1	3
20	2	3	1	46	2	3	1
21	1	2	3	47	2	1	3
22	2	3	1	48	1	3	2
23	2	1	3	49	3	2	1
24	2	3	1	50	2.5[b]	2.5[b]	1
25	2	3	1				
26	2.5[b]	2.5[b]	1	Rj*	101.50	102.50	96

[a] Rank 1 indicates maximum preference.

[b] Sample obtained equal score.

Rj* — Summation of ranking.

TABLE 4(b). Preference scores of the heated-sand and the direct-flame dried rice served cold.[a]

Taster	Rank			Taster	Rank		
	Sand	Flame	Control		Sand	Flame	Control
1	2.5[b]	2.5[b]	1	24	1	3	2
2	3	1	2	25	2	1	3
3	3	2	1	26	3	2	1
4	1	3	2	27	1	3	2
5	3	2	1	28	2	1	3
6	2	3	1	29	1	3	2
7	3	2	1	30	3	1	2
8	1	2	3	31	3	1	2
9	1	3	2	32	2	1	3
10	2	1	3	33	3	2	1
11	1	3	2	34	2	1	3
12	1	3	2	35	1	2	3
13	2	3	1	36	2	1	3
14	3	1.5[b]	1.5[b]	37	3	2	1
15	1	2	3	38	3	2	1
16	3	2	1	39	1	2	3
17	2	1	3	40	3	2	1
18	2.5[b]	2.5[b]	1	41	3	1	2
19	1	3	2	42	1	2	3
20	2	1	3	43	1	2	3
21	2	1	3	44	2	3	1
22	1	2	3				
23	2.5[a]	2.5[a]	1	Rj*	88.5	89	86.5

[a] Rank 1 indicates maximum preference.

[b] Samples obtained equal scores.

Rj* — Summation of ranking.

TABLE 5. Eating quality mean score for the heated-sand and the direct-flame dried rice as evaluated by a laboratory taste panel.

Characteristics[a]	Sample served hot			Statistical difference[b]	Sample served cold			Statistical difference[b]
	Sand	Flame	Control		Sand	Flame	Control	
Aroma	7.0	7.0	6.0	**	6.0	6.0	5.8	*
Off aroma	1.0	1.0	1.0	ns	1.0	1.0	1.0	ns
Flavor	1.0	1.0	1.0	ns	1.0	1.0	1.0	ns
Tenderness	3.3	3.3	3.5	ns	3.3	3.5	4.3	ns
Cohesiveness	2.3	1.7	2.4	ns	2.7	2.2	3.3	**
Color	2.7	2.5	1.3	*	2.7	2.6	1.0	**
Gloss	3.3	3.3	3.0	ns	3.1	3.1	2.7	**

[a] Quality rating scale:

I AROMA	II OFF AROMA	III FLAVOR	IV OFF FLAVOR	V TENDERNESS	VI COHESIVENESS	VII COLOR	VIII GLOSS
9 Very strong	9 Very strong	9 Very full	9 Very strong	9 Very tender	9 Pasty	9 Brown	9 Very glossy
7 Strong	7 Strong	7 Full	7 Strong	7 Tender	7 Very sticky	7 Light brown	7 Glossy
5 Moderately strong	5 Moderately strong	5 Moderately full	5 Moderately strong	5 Moderately tender	5 Moderately sticky	5 Gray-yellow	5 Moderately glossy
3 Weak	3 Perceptible	3 Perceptible	3 Perceptible	3 Partially tough	3 Partially sticky	3 Cream	3 Dull
1 Very weak	1 None	1 Very weak	1 None	1 Very tough	1 Well separated	1 White	1 Very dull

[b] ns - not significant
* - significant
** - highly significant

TABLE 6. Accelerated drying of sorghum and its effects.

Test no.	Variety	Moisture content (%, d.b.) Before drying	After drying	Heated sand temperature (°C) Before drying	After drying	Grain temperature just after drying (°C)	Time of drying (sec)	Remarks
1	NKX 3009	39.40	30.70	240	210	89	15	Grain popped
2	NKX 3009	39.40	26.77	240	214	92	30	"
3	NKX 3009	39.40	30.60	220	178	87	15	"
4	NKX 3009	39.40	28.57	220	180	87	30	"
5	NKX 3009	39.40	31.51	200	173	82	15	No popping
6	NKX 3009	39.40	30.70	200	180	82	30	"
7	NKX 3009	39.40	28.90	200	169	87	45	"
8	Pay Master R109	41.60	30.62	220		80	15	Grain popped
9	PM R109	41.60	26.28	220		90	30	"
10	PM R109	41.60	33.40	200		75	15	No popping
11	PM R109	41.60	28.20	200		87	30	"
12	PM R109	41.60	27.30	200		77	45	"
13	PM R109	41.60	32.40	180		73	30	"
14	PM R109	41.60	30.43	180		74	45	"

TABLE 7. Mean percentage of germination of IR22 seeds soaked in nitric acid solution followed by different drying methods.

Drying methods	Concentration of solution, N	2 days after drying: Soaking duration, hr 12	18	24	2 weeks after drying: Soaking duration, hr 12	18	24
Sun drying	0.1	61.0	75.0	86.0	88.0	91.0	94.5
	0.2	73.0	85.0	91.0	93.0	95.0	95.0
Heated-air drying, 43-46°C	0.1	39.0	64.0	78.5	77.0	87.5	91.5
	0.2	55.5	76.5	87.5	86.5	92.0	96.5
Unheated-air drying, 29°C	0.1	15.5	34.5	43.0	59.5	73.0	74.5
	0.2	22.0	63.5	62.0	71.5	88.0	88.5
Shade drying	0.1	26.5	35.0	45.5	63.5	67.5	79.0
	0.2	29.5	41.0	64.0	75.5	78.5	84.0

Note: (a) The underlined means are significantly higher than 80%.

(b) Percentage of germination after soaking — without drying treatment:

N	Soaking duration, hr 12	18	24
0.1	17	23	54
0.2	25	51	78

TABLE 8. Mean percentage of germination of IR22 seeds soaked in nitric acid solution followed by heated-air and sun-drying methods.

Drying methods	Concentration of solution, N	3 days after drying: Soaking duration, hr 12	18	24	10 days after drying: Soaking duration, hr 12	18	24
Heated-air drying at 49°C (120°F)	0.1	65.0	58.0	74.0	86.0	80.5	79.0
	0.2	72.5	72.0	78.0	88.0	87.5	79.0
Heated-air drying at 60°C (140°F)	0.1	62.5	62.5	67.0	73.0	82.5	73.5
	0.2	75.0	70.5	63.0	83.0	85.5	60.0
Sun drying	0.1	78.5	68.0	83.0	93.5	90.5	90.0
	0.2	81.0	85.0	81.5	90.5	92.5	88.5

Note: (a) The underlined means are significantly higher than 80%.

(b) Percentage of germination after soaking — without drying treatment:

N	Soaking duration, hr 12	18	24
0.1	39	34	46
0.2	35	51	56

TABLE 9. General specifications of hand tractors.

Item	Type I	Type II	Type III
Rated hp	6	7.5	14
Engine	gasoline; aircooled	gasoline; aircooled	diesel
Weight average (kg)	80	135	300
Tilling attachment	(tiller on axle) moldboard plow comb harrow	moldboard plow comb harrow	rotary tiller
Steering clutch	none	has	has
Speed control	belt-pulley change & throttling	gear shift & throttling	gear shift & throttling
Reverse drive	none	has	has

TABLE 10. Hand tractor owners' profile, Laguna, Philippines, 1969.

Item	Hand tractor type			All
	I	II	III	types
No. of observations	47	68	25	140
Tenure: share tenant	27 (57)*	35 (51)	5 (20)	67 (48)
lessee	14 (30)	21 (31)	3 (12)	38 (27)
part-owner	2 (4)	6 (9)	1 (4)	9 (6)
owner-operator	4 (9)	6 (9)	16 (64)	26 (19)
Farm type: rainfed	- -	2 (3)	1 (4)	3 (2)
irrigated 1-crop	1 (2)	4 (6)	3 (12)	8 (6)
irrigated 2-crop	46 (98)	62 (91)	21 (84)	129 (92)
Average farm size (ha)	4.04	4.35	4.82	4.33

* Numbers in parentheses are percentages.

TABLE 11. Reasons for buying a hand tractor, 140 farmers, Laguna, Philippines, 1969.

Reason	Number reporting	
	Number	Percent
Rampant carabao rustling	80	57
Faster land preparation	91	65
Easier to maintain than carabao	92	66
Deep mud	19	14
Better puddling	6	4
To keep pace with other farmers	7	5
Income from custom work	4	3
Custom service not available when needed	4	3
T o t a l	302	216

TABLE 12. Criteria for choice of hand tractor type.

Item	Type I	Type II	Type III
No. of respondents	47	68	25
	Number reporting		
Initial cost	4 (9)	12 (18)	----
Weight	31 (66)	12 (18)	2 (8)
Simplicity	25 (53)	----	----
Durability	10 (21)	11 (16)	8 (32)
Popularity	9 (19)	10 (15)	----
Power	----	20 (29)	15 (60)
Demonstration	3 (6)	11 (16)	----
Fuel type	----	----	7 (28)
Experience with type	----	13 (19)	----
Other farmers' advice	3 (6)	13 (19)	5 (20)
All items	85 (180)	102 (150)	37 (148)

Note: Numbers in parentheses are percentages.

TABLE 13. Problems of ownership and maintenance of hand tractor, Laguna, Philippines, 1969.

Item	Hand tractor type I	Hand tractor type II	Hand tractor type III	All types
	Number reporting			
High initial cost	13 (28)*	26 (38)	6 (24)	45 (32)
Spare parts procurement	28 (60)	36 (53)	5 (20)	69 (49)
Costly spare parts	13 (28)	16 (24)	3 (12)	32 (23)
Frequent breakdown	1 (2)	5 (7)	4 (16)	10 (7)
Weak axle	- -	12 (18)	2 (8)	14 (10)
No ready cash with which to buy spares	1 (2)	5 (7)	- -	6 (4)
No problem	21 (45)	19 (28)	13 (52)	53 (38)
T o t a l	77 (165)	119 (175)	33 (132)	229 (163)

* Numbers in parentheses are percentages.

TABLE 14. Labor requirements and machine performance (plowing + harrowing*).

Item	Hand tractor type I	Hand tractor type II	Hand tractor type III[a]	All types
No. of observations	47	68	25	140
No. of operators	2	2	2	2
Total man-hr/ha	88.20	88.38	63.10	83.80
Machine-hr/ha	44.10	44.19	31.55	41.90
Average tractor hp	5.34	5.53	7.46	5.81
Rhp-hr/ha	235.49	244.37	235.36	243.44
Fuel consumption (lit/hr)	1.18	1.18	1.06	1.16
Lubricants (lit/hr)	0.06	0.07	0.07	0.07

* Each harrowing requires 2 passes of the comb harrow.

[a] Two passes of the rotavator only.

TABLE 15. Average costs of ownership and operation, Laguna, Philippines, 1969.

Item		Hand tractor type I	II	III	All types
Estimated service life (yr)		8	8	10	8
Average annual use (hr)		486	442	641	492
No. of observations		47	68	25	140
			Pesos*		
Average purchase price		3367.35	3419.54	7318.80	4098.32
Overheads:	Depreciation[a/]	378.83	384.70	658.69	461.06
	Interest[b/]	222.24	225.69	483.04	270.49
	Total	601.07	610.39	1141.73	731.55
Variable costs/hr:	Fuel	0.32	0.32	0.18	0.29
	Lubricants	0.09	0.11	0.11	0.10
	Repairs	0.35	0.29	0.76	0.39
	Labor	1.00	1.00	1.00	1.00
	Total	1.76	1.72	2.05	1.78

* US$1 = ₱3.90

a/ Straight-line; salvage value = 10% of purchase price.

b/ 12% per annum.

TABLE 16. Alternative means of achieving income capacity needed to maintain a Type I tractor valued at ₱3400 on a 4-hectare double-cropped farm.[a]

Item	Yield per hectare per year (tons)				
	4.4	5.3	6.2	7.0	7.9
Effective crop area	8	8	8	8	8
Yield (kg)	4,400	5,280	6,160	7,040	7,920
Custom hectare	19.7	13.1	6.4	0	0
Total hectare[b]	27.7	21.1	14.4	8	8
Hours/tractor[c]	1,221.5	930.5	635.0	352.8	352.8
Gross farm income[d]	6,400	7,680	8,960	10,240	11,520
Gross custom income[e]	3,800	2,520	1,240	0	0
Total gross income[f]	10,200	10,200	10,200	10,200	10,200

[a] Based on the "rule of thumb" that gross income should be three times the value of the tractor.

[b] Hectares plowed and harrowed for wet and dry seasons.

[c] 44.10 hrs/ha.

[d] Based on the price of paddy of ₱0.36/kg.

[e] Based on ₱35/day.

[f] US$1 = ₱3.90

TABLE 17. Alternative means of achieving income capacity needed to maintain a Type II tractor valued at ₱3420 on a 4.35-hectare double-cropped farm.[a]

Item	Yield per hectare per year (tons)				
	4.4	5.3	6.2	7.0	7.9
Effective crop area	8.7	8.7	8.7	8.7	8.7
Yield (kg)	4,400	5,280	6,160	7,040	7,920
Custom hectare	17.1	9.9	2.7	0	0
Total hectare[b]	25.8	18.6	11.4	8.7	8.7
Hours/tractor[c]	1,140.1	821.9	503.8	384.4	384.4
Gross farm income[d]	6,960	8,352	9,744	11,136	12,528
Gross custom income[e]	3,300	1,908	516	0	0
Total gross income[f]	10,260	10,260	10,260	10,260	10,260

[a] Based on the "rule of thumb" that gross income should be three times the value of the tractor.

[b] Hectares plowed and harrowed for wet and dry seasons.

[c] 44.19 hr/ha.

[d] Based on the price of paddy of ₱0.36/kg.

[e] Based on ₱35/day.

[f] US$1 = ₱3.90.

TABLE 18. Alternative means of achieving income capacity needed to maintain a Type III tractor valued at ₱7300 on a 4.8-hectare double-cropped farm.[a/]

Item	Yield per hectare per year (tons)				
	4.4	5.3	6.2	7.0	7.9
Effective crop area	9.6	9.6	9.6	9.6	9.6
Yield (kg)	4,400	5,280	6,160	7,040	7,920
Custom hectare	101.9	91.0	80.0	69.0	58.1
Total hectare[b/]	111.5	100.6	89.6	78.6	67.7
Hours/tractor[c/]	3,214.9	2,871.0	2,524.0	2,177.0	1,833.0
Gross farm income[d/]	7,680	9,216	10,752	12,288	13,824
Gross custom income	14,276	12,740	11,204	9,668	8,132
Total gross income	21,956	21,956	21,956	21,956	21,956

[a/]Based on the "rule of thumb" that gross income should be three times the value of the tractor.

[b/]Hectares rotavated for wet and dry seasons.

[c/]31.55 hr/ha.

[d/]Based on the price of paddy of ₱0.36/kg.

[e/]Based on ₱35/day.

[f/]US$1 = ₱3.90.

TABLE 19. Annual costs of the eight-row seeder.

Item		Cost (Pesos)*
Purchase price		₱ 350.00
Estimated service life (yr)		4
Overheads:	Depreciation	87.50
	Interest	21.00
	Total	108.50
Variable costs:		
	Repairs/replacements	30.88
	Labor (per hour)	0.50

*US$1 = ₱6.10 (approx.)

TABLE 20. Average total cost per hectare, 8-row seeder.

Annual use (ha)	Cost/ha (Pesos)*
1	₱ 143.38
3	50.46
5	31.88
7	23.91

*US$1 = ₱6.10 (approx.)

Fig. 1 Power weeder manufactured in Japan by Ohtake Nouki Seisakusho Co., Ltd. based on the IRRI concept.

Fig. 2 Six-row seeder for pre-germinated paddy.

Fig. 3 Fourth prototype table thresher.

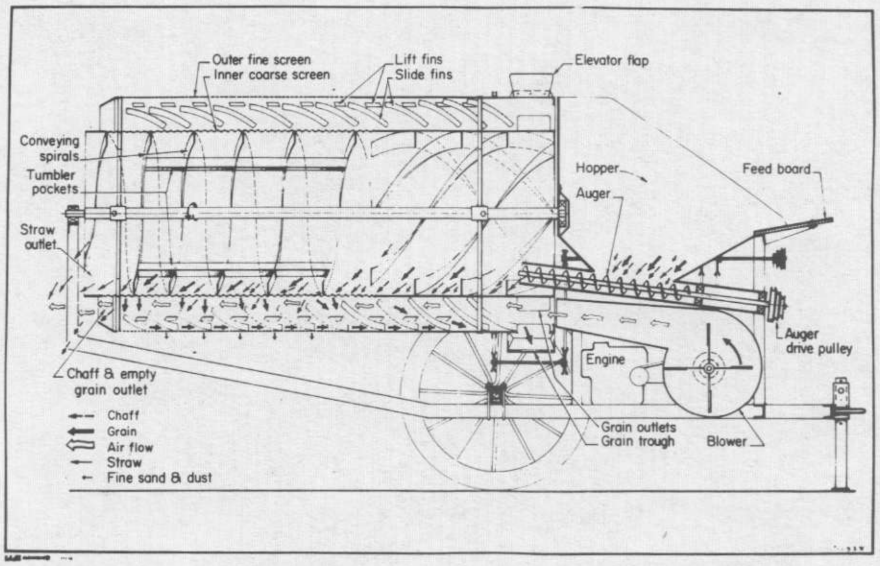

Fig. 4 Schematic drawing of the rotary grain cleaner.

Fig. 5 Second prototype rotary grain cleaner.

Fig. 6 Dual tractor set-up for tiller wheel tests.

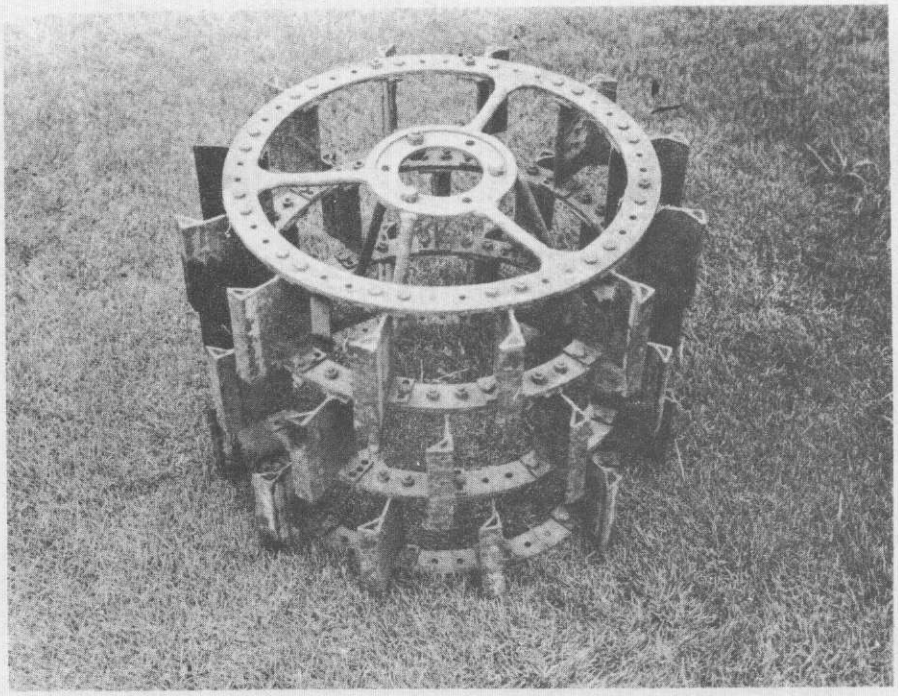

Fig. 7. Tiller wheel with adjustable number and angle of blades.

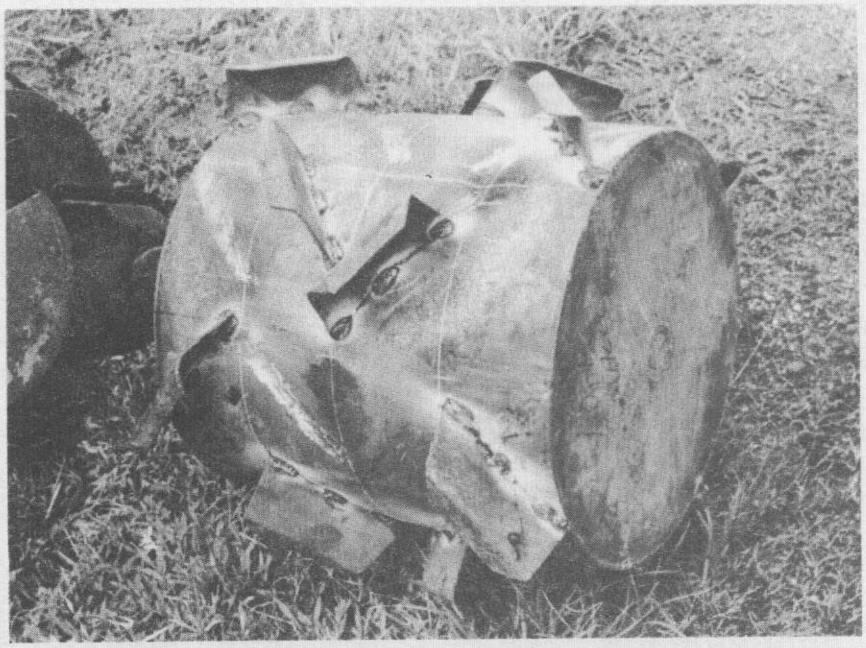

Fig. 8 Drum tiller wheel.

Fig. 9 Set-up of depth measuring device for tractor mobility studies.

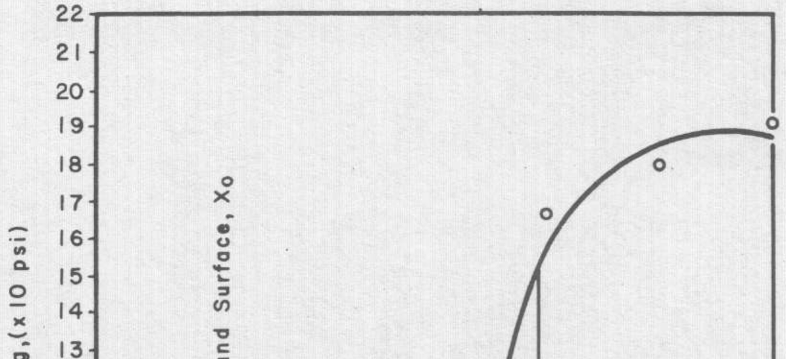

Fig. 10 A typical cone diagram of a test field.

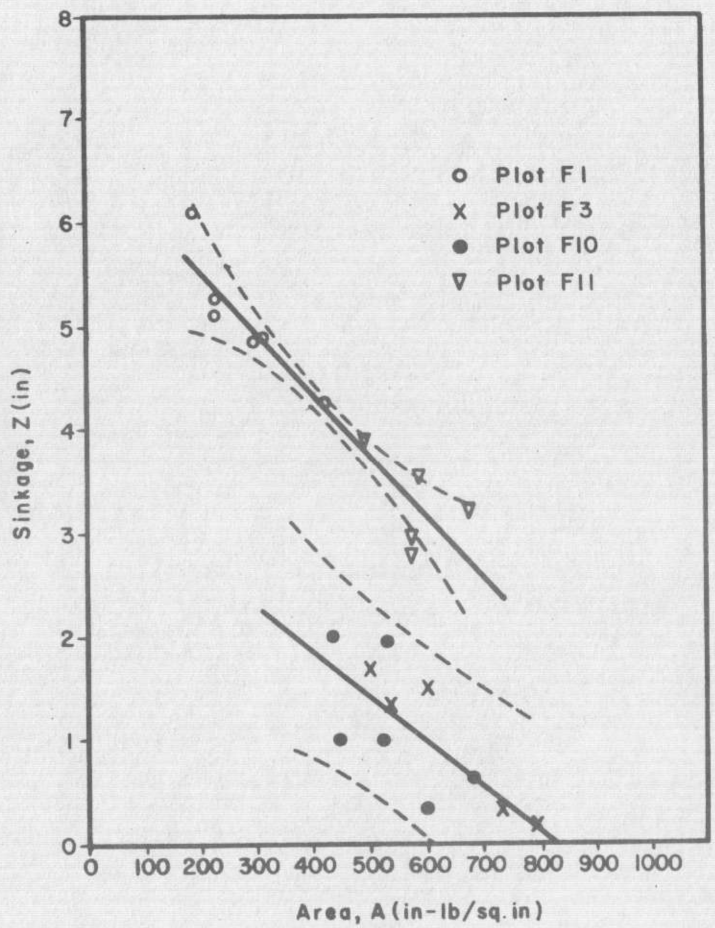

Fig. 11 Sinkage z vs area A.

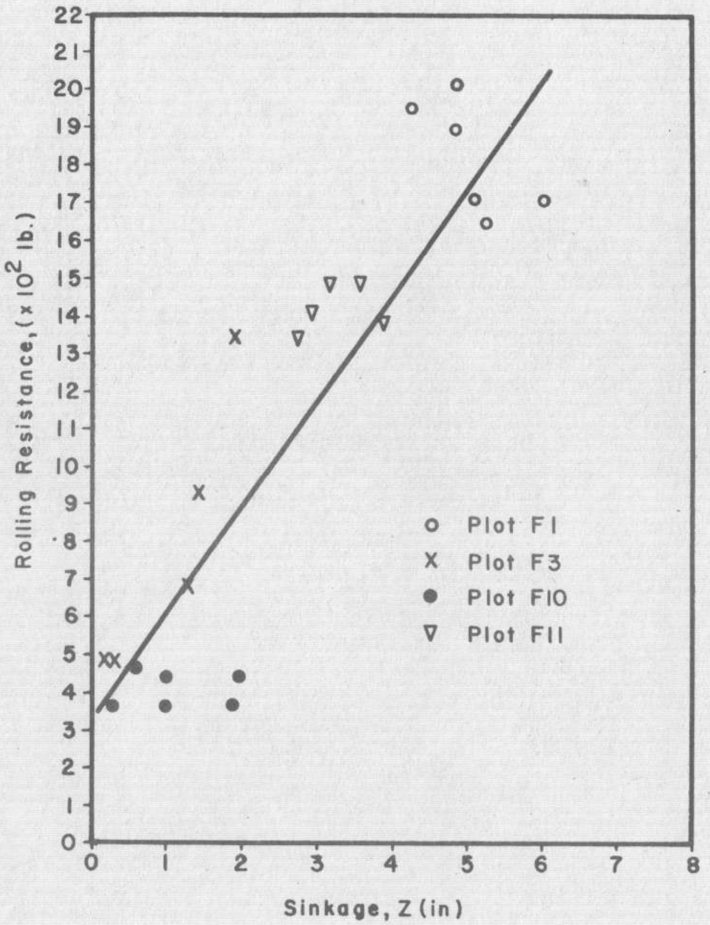

Fig. 12 Rolling resistance vs sinkage.

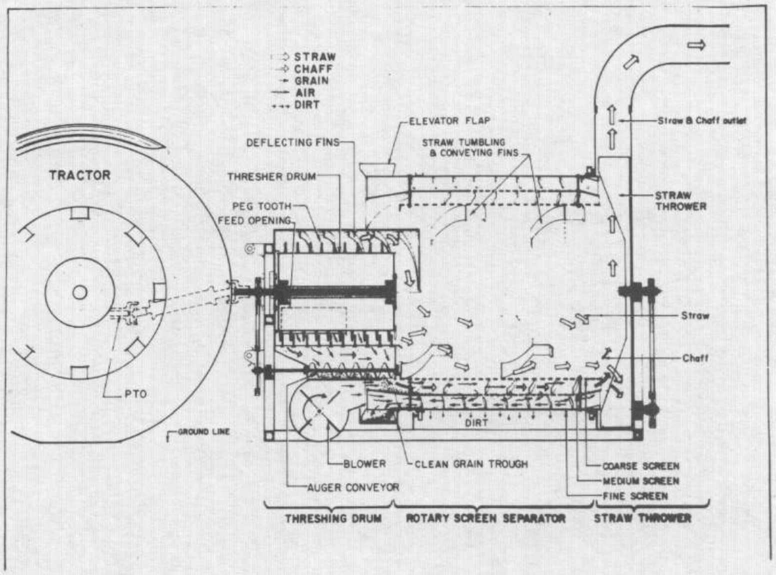

Fig. 13 Schematic drawing of the tractor PTO-driven multi-crop thresher.

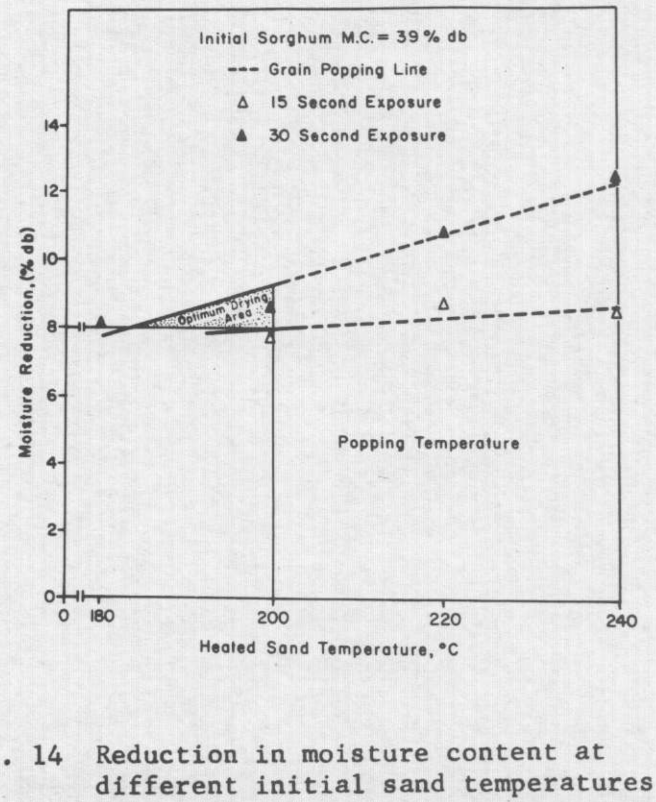

Fig. 14 Reduction in moisture content at different initial sand temperatures.

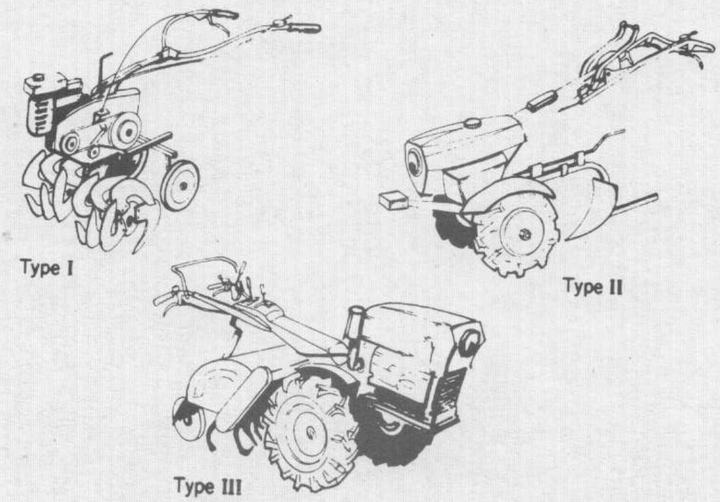

Fig. 15 Three types of hand tractor.

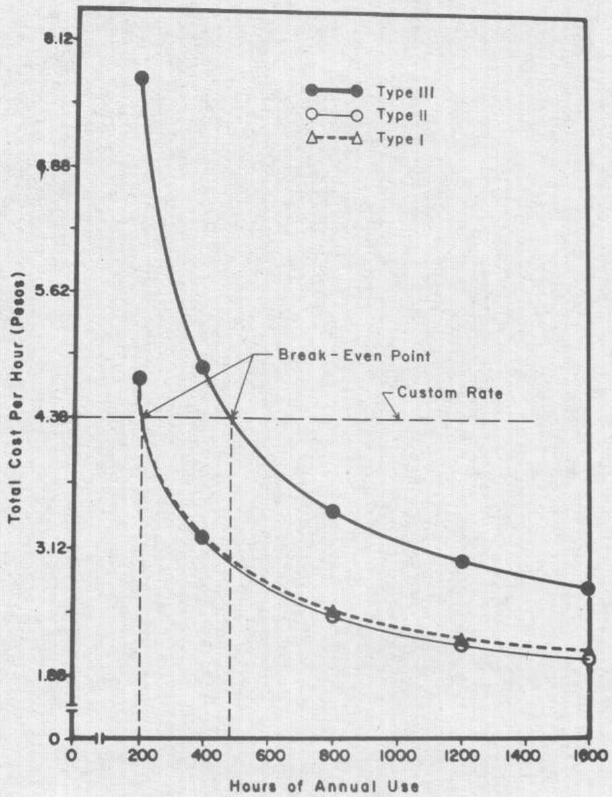

Fig. 16 Relationship between annual use and cost.

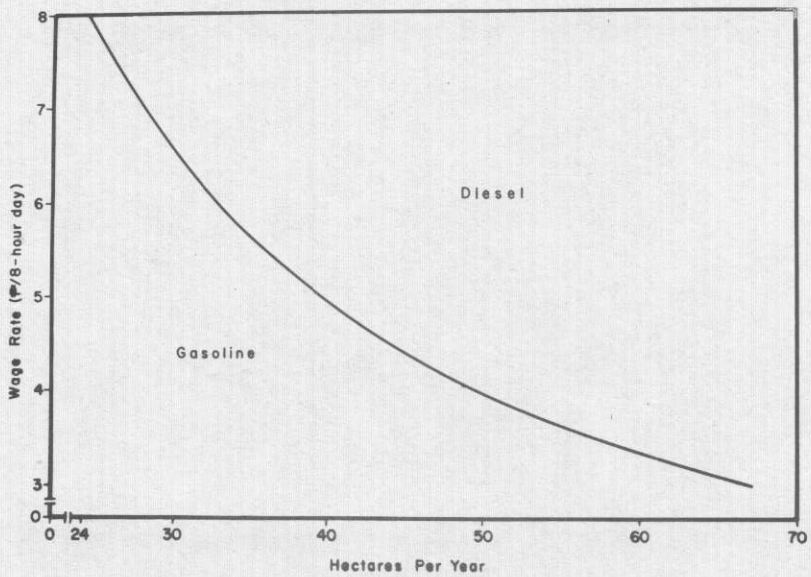

Fig. 17 Zones of cost advantage: gasoline vs diesel hand tractors.

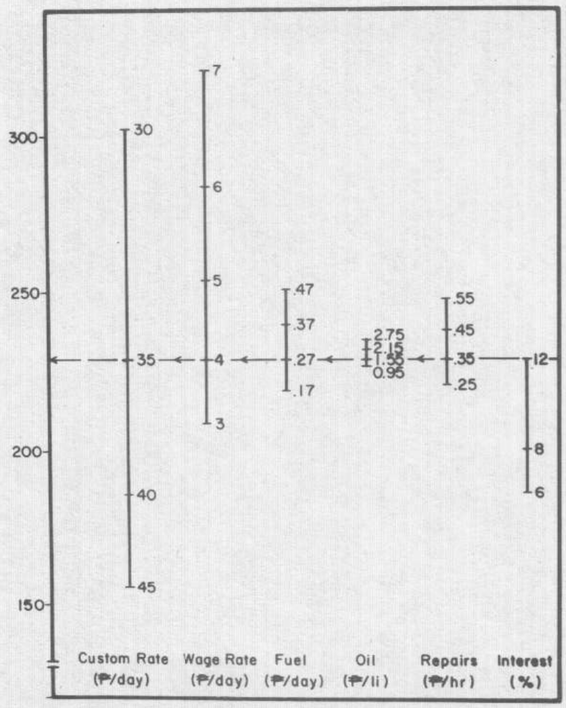

Fig. 18 Relative importance of cost factors, Type I tractors.

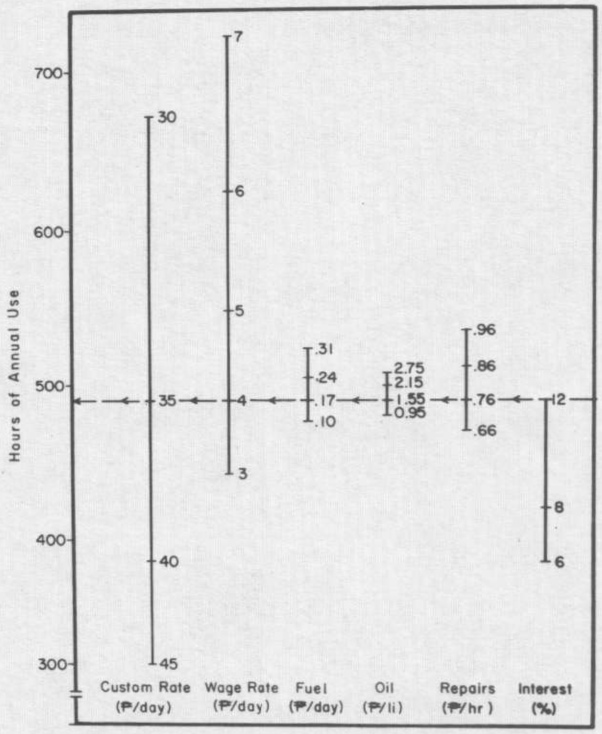

Fig. 19 Relative importance of cost factors, Type III tractors.

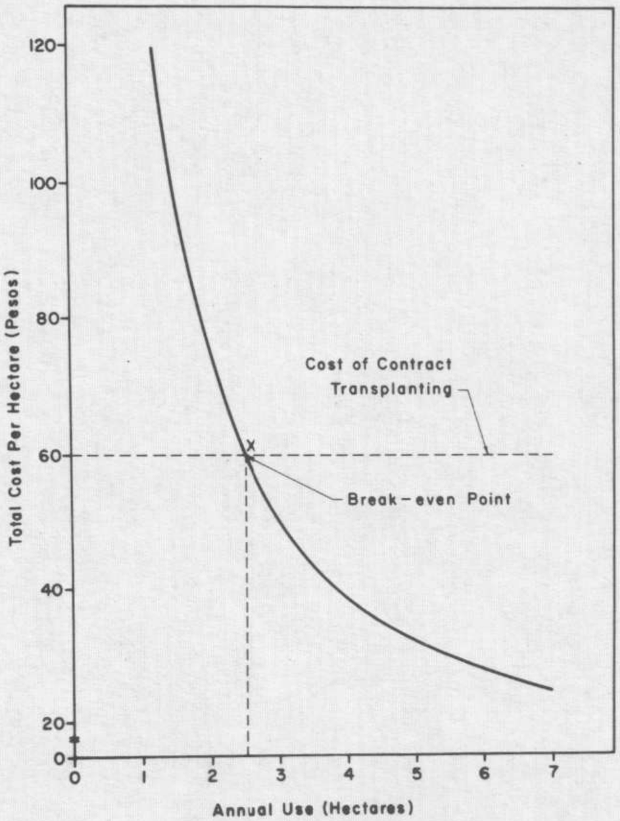

Fig. 20 Average total cost per hectare of the eight-row seeder.