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JULY 1 TO DECEMBER 31, 1969

CONTRACT NO. AID/csd-834
For Research on Farm and Equipment Power
Requirements for the Production of Rice and Associated
Food Crops in the Far East and South Asia

By

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INTRODUCTION

This is the ninth Semi-Annual Substantive Report on Contract No. AID/csd-834 on "Research on Farm and Equipment Power Requirements for the Production of Rice and Associated Food Crops in the Far East and South Asia." This Contract terminated on October 27, 1969 after 52 months.

While the objectives of this contract were broad enough to encompass all aspects of mechanizing rice production, increased emphasis was placed on the design and development of new machinery for rice cultivation in the last two years. A new contract, No. AID/csd-2541 entitled "Agricultural Equipment Development Research for Tropical Rice Cultivation," has been subsequently entered into effective October 28, 1969. The primary objective of the new Contract is the development of new equipment for tropical agriculture.

Machinery research under the new contract will be divided into three categories: (1) Field Application, (2) Design and Development, and (3) Economic Evaluation and Manufacturing Extension. Work initiated during the previous contract on the development of field machinery has been continued and expanded to include equipment for drying and processing paddy. Increased emphasis is to be placed on analyzing the economics of every mechanized operation in the production of rice.

Work on the development of field machinery continued to make satisfactory progress during the period of this report. A lighter table thresher was designed to facilitate manufacture and moving of the machine in the field. An eight-row seeder for pregerminated paddy seed was developed and tested. Test results show that it can seed one hectare in 5 man-hours as compared to 120 man-hours per hectare for transplanting. The project on the development of a stripper-harvester made satisfactory progress. The experimental machine was modified to ensure complete threshing of panicles from the standing plants. Lifting fingers are being developed to enable the harvest of lodged crop.

Research on rice drying and processing was initiated during this period. The drying problem has become increasingly serious due to the introduction of high-yielding varieties. In many Asian countries considerable attention is being devoted towards developing large scale commercial rice drying and processing facilities. Capital intensive technology to dry and process rice in larger quantities is well developed in the industrialized countries. Attempts are being made by governmental, national and international organizations to introduce this know-how in the developing countries.

In the tropical rice-growing countries, approximately 50 to 80 percent of the population lives in the rural areas. It has been estimated that nearly 50 to 70 percent of the rice produced in the tropics is consumed in the rural areas without being handled by the established commercial rice processors. The large rural consumption of rice and the lack of adequate transport facilities in the rural areas indicate a need for intermediate scale drying and processing systems for village level operations. Proper drying and processing of larger quantities of rice at the village level is a difficult problem. In the past relatively little research has been directed to this problem. It was felt that

paddy drying-processing research under the contract should be oriented in this direction.

Two research projects were initiated to develop basic information on accelerated drying of paddy using sand and mechanical agitation to minimize localized grain heating. Preliminary test results indicate that it is possible to rapidly dry high moisture paddy from 35 percent (d.b.) to 18 percent (d.b.) moisture level in 15 seconds. The experimental accelerated drying resulted in increased head rice yields of up to 16 percent due to a parboiling effect. Experimental data gathered to date offer some unusual possibilities for simultaneous drying and parboiling of paddy at economical costs. Research is being pursued to develop equipment for drying paddy at comparable or lower costs than large scale convectional driers.

In addition to the drying research, a project on the development of paddy processing equipment was also initiated during this period. A new rotary screen grain cleaner which combines both the mechanical and pneumatic separation in a single rotating member was fabricated. Grain cleaning output of over one ton per man-hour has been achieved with this machine. The cleaner is fairly simple and can be manufactured in the tropical countries.

The program of providing assistance to established manufacturers on the development of rice production equipment continued to make headway. Engineering teams were sent by the following three manufacturers to IRRI for evaluating their experimental machines under actual field conditions in the Philippines. Assistance was provided by the contract personnel in modifying and testing their machines:

1. Port Implements Division Ralph McKay Limited Blair Athol, S. Australia	1.5 m rotary tiller
2. Rice Mechanization Development Deere and Company Overseas Division Moline, Illinois	60 hp rice tractor
3. Kinetics International Division LTV Aerospace Corporation Tyler, Texas	30 hp Kid tractor

A progress report on the individual projects handled during the reporting period follows.

PROGRESS REPORT

JULY 1 to DECEMBER 31, 1969

The following projects were handled during the reporting period:

Field Machinery Research

1. Table-type power thresher	A. U. Khan
2. Differential Cage Wheel Slip for Wetland Preparation	P. Cabanos
3. Anhydrous ammonia applicator for small tractors	E. O. Casem
4. Comparative performance of threshing cylinders	E. O. Casem
5. Development of a paddy stripper-harvester	A. U. Khan
6. Development of a row seeder for lowland rice	N. Navasero
7. Tractor rolling resistance under lowland conditions	P. Cabanos
8. Development of a tractor PTO-driven thresher	A. U. Khan

Drying and Processing Research

9. Accelerated paddy drying	
(a) Heated sand	A. Amilhussin, A. U. Khan
(b) Mechanical agitation	A. Manalo, A. U. Khan
10. Development of a rotary grain cleaner	A. U. Khan

Economics of Mechanization

11. Analysis of hand tractor ownership	N. Orcino, A. U. Khan
12. Farmers' attitude towards use of tractor for land preparation	N. Orcino

Field Machinery Research

TABLE-TYPE POWER THRESHER

A fourth prototype table thresher was fabricated (Fig. 1). The sheet metal components of this machine are simpler than the former design and the frame has been redesigned to permit dismantling of legs for compact packaging. The machine was designed with a stationary screen cleaner. However, initial trials have indicated problems in grain separation and straw delivery. The machine is now being modified to incorporate a rotating screen cleaner.

DIFFERENTIAL CAGE WHEEL SLIP FOR WETLAND PREPARATION

A major problem of land preparation in wetland conditions is tractor mobility. Soils with deep hard pan are extremely difficult to till with larger conventional tractors. The 6-10 hp lightweight hand tractors with cage wheels are often used for land preparation, but even these tractors encounter serious bogging.

The aim of this project was to study the possibility of using a lightweight four-wheeled riding machine with independent front and rear drive cage wheels to obtain mobility and tillage under difficult conditions. For maximum mobility, front and rear cage wheels could be driven at similar speed. Land preparation could be accomplished through wheel slippage by driving either the front or rear wheels at a faster speed. It was felt that such an arrangement could permit land preparation in very soft conditions without sacrificing mobility.

Since soft wetland soils have low load bearing capacity, weight was a major consideration in the design of such a machine. Two lightweight 6-hp hand tractors were hitched together by an articulated chassis to form an experimental four-wheel riding tiller (Fig. 2). The unit was designed with enough ground clearance to prevent "bellying" and to facilitate moving over dikes. Both engines were equipped with centrifugal clutches for easy control. The speed of each cage wheel was controlled by varying the engine rpm.

The specifications of the experimental tiller are as follows:

Weight distribution	Front axle	Rear axle	Total
without operator	147 kg	117 kg	264 kg
with operator (67 kg)	181 kg	150 kg	331 kg

4 cage wheels	0.50 m dia. x 0.46 m wide 12 blades each 0.6 cm x 5 cm x 46 cm flat bar
Wheelbase	1.64 m
Width	1.28 m

In irrigated fields with relatively shallow hard pan, the experimental tiller can travel with ease, either with equal or different cage wheel speeds. Figures 3(a) and (b) show the mobility of the tiller. On a straight path no difference in stability was noticed while operating the front wheels faster than the rear or vice versa. Good traction was available during turns, however, shorter turning radius and better steering control was achieved when front wheels were made to rotate faster than the rear wheels. With faster rear wheels, the front wheels were pushed forward during turning and this resulted in a jackknifing tendency.

Due to the available traction from both wheels, the machine can cross dikes higher than the wheel diameter (Fig.3a). The mobility of the machine under extremely soft soils with deep hard pan is illustrated in Fig. 3b. In such fields, better tillage was achieved by having the front wheels rotate faster.

Better mobility was obtained when fields were submerged under water. In clay soils where sufficient water was not available, the cage wheels filled with mud resulting in bogging. Alighting from the tiller reduced the load on the machine and improved mobility. The experimental tiller will be further tested under more severe field conditions.

ANHYDROUS AMMONIA APPLICATOR FOR SMALL TRACTORS

The anhydrous ammonia applicator developed at the Institute for single-axle hand tractors was field-tested. On the basis of the field tests, some changes were made in the design. The shanks have been lengthened to allow a 30° back-sweeping angle from the horizontal. A double ammonia tank assembly has been mounted for enlarged capacity. The attachment is still undergoing test and development.

COMPARATIVE PERFORMANCE OF THRESHING CYLINDERS

A study on comparative threshing cylinder performance has been reported in the last semi-annual report. The wire loop cylinder test stand used in this study was equipped with a sheet metal concave housing and rubber flaps to move the grain and straw in an axial direction towards a side opening. Paddy grains and straw that were fed into this test stand rotated a few times before being discharged at the side opening. It was later felt that this created a bias against the peg tooth (Fig. 4a) and rasp bar (Fig. 4b) cylinders. The test stand was, therefore, redesigned with no concave to discharge the threshed material at the bottom of the cylinder like the peg tooth and rasp bar test stands (Fig. 5a). Paddy was fed on the topside of the cylinder in the modified wire loop test stand and was discharged without completely rotating with the cylinder. Generally in wire loop threshers, paddy is either fed on the topside or the underside of the threshing cylinder. A second wire loop test stand was fabricated with a perforated sheet metal concave (3/8-inch round perforations) which was fed on the underside of the cylinder as shown in Fig. 5(b).

Freshly harvested IR20 paddy was used throughout the tests. The mean moisture content of the paddy was 23.5 percent (w.b.). Both the hold-on and throw-in feeding methods were tested. The following cylinder peripheral velo-

cities were used: 900, 1150, 1400, 1650, 1900, 2150, 2400, 2650, 2900, 3150, 3400, 3650, 3900, 4150, 4400 and 4650 fpm.

Visible seed damage was determined by inspection and by the percentage of paddy milled during threshing. Internal seed damage was determined by head rice yield. Germination tests are underway and will be reported later. Discussion of test results with reference to Tables 1, 2 and 3 and Figs. 6(a) to 9(b) is as follows:

Threshing performance

A. Hold-on feeding. The wire loop and rasp bar cylinders exhibited relatively poor performance at the low velocities. At intermediate velocities, performance of the wire loop cylinder with concave and the peg tooth cylinder were slightly better than the wire loop and rasp bar cylinders. At high velocities, all the four performed satisfactorily. The overall performance of the peg tooth cylinder with the hold-on method of feeding was relatively less affected by change in cylinder speed but it did result in slightly more semi-threshed paddy. This peg-tooth cylinder exhibited the best overall performance with this method of feeding. The wire loop cylinder, although poor in performance at the lower velocities, resulted in the least amount of semi-threshed paddy.

B. Throw-in feeding method. The peg tooth cylinder again exhibited the best overall performance. The wire loop and the rasp bar cylinders performed poorly with this method. The wire loop with concave, however, outperformed the peg tooth cylinder at the lower velocities.

All tests indicated an increased threshing performance and decreased amount of unthreshed and semi-threshed paddy at higher cylinder velocities. The relatively poorer performance of the wire loop cylinder with the throw-in feeding method as compared with previously reported tests confirms the suspicion that the previous test stand was causing a bias in the comparative evaluation of the three types of threshing cylinders. Except for the wire loop cylinder with concave, poorer performance was observed with the throw-in than the hold-on feeding method at low cylinder velocities. It has been generally accepted that throw-in type threshers are better suited for high output than the hold-on type of machines. These tests seem to indicate that users of higher output throw-in type threshers are penalized by higher losses.

Grain damage

A. Milled-paddy damage. At velocities of up to 2450 fpm, both the hold-on and throw-in feeding methods did not show any significant milling with the four test stands. The milling of paddy started at 1650 fpm velocity with both the feeding methods. As the velocity increased, the increase in milling with the hold-on method was more than the throw-in method. This seems understandable since for the same peripheral velocity the magnitude of the impact in the hold-on method is generally higher than in the throw-in method because the paddy in the former method is held stationary during threshing.

The rasp bar indicated best overall performance with relatively less milled paddy except at intermediate velocities where the wire loop did a little better. This was perhaps due to greater cushioning effect with a rasp bar cylinder since the serrations on the rasp bar are not large enough like the peg tooth or wire loop to penetrate into the paddy bundle.

B. Head grain yield. As expected, in both the hold-on and throw-in feeding methods, the head grain yield decreased with increased cylinder velocity. The difference among the wire loop, peg tooth, and rasp bar cylinders in both feeding methods were not too significant. The wire loop with concave indicated poorer head grain recovery specially with the throw-in feeding method.

Conclusion

Based on a 2.0 percent maximum unthreshed paddy (percentage of total paddy weight at 14% m.c., w.b.), a 1.0 percent maximum milled paddy and an 85 percent minimum head grain yield (percentage of head grain yield of hand-threshed check), the optimum cylinder peripheral velocities for the four test stands were found to be:

Cylinder type	Hold-on method	Throw-in method
Wire loop without concave, overfed	2650 fpm	3650 fpm[1]
Wire loop with concave, underfed	2150 fpm	2900 fpm
Peg tooth	2150 fpm	2900 fpm
Rasp bar	2650 fpm	3650 fpm

There was a dramatic change in the performance of the wire loop cylinder when a concave was provided for both the hold-on and throw-in feeding methods. In comparing the four test stands, the peg tooth cylinder was outstanding even at relatively lower velocities.

DEVELOPMENT OF A PADDY STRIPPER-HARVESTER

The experimental stripper described in the last report was field-tested and modified to improve the crop gathering mechanism as the machine was not able to satisfactorily thresh the panicles at both ends of the swath. Field trials indicated that the panicles at the end of the swath were not properly deflected on to the threshing belt and were passing between the side walls and the gathering chains. The problem was eliminated by using double wall sides with recessed grooves for the gathering chains.

The machine was originally designed with no grain-straw separating mechanism. A slatted chain separating mechanism was installed for preliminary grain-straw separation. The 6-hp walking tractor on which the stripper is mounted has not been performing well and a new tractor has been ordered.

As soon as the stripper is installed on the new tractor, attention will be directed on minimizing field losses. Hydrostatic transmission and other components for fabricating a self-propelled stripper-harvester have been received. A four-row self-propelled harvester will be designed after some experience has been gained with the present tractor-mounted machine.

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[1] Compromise cylinder peripheral velocity wherein: unthreshed paddy loss - 20.1%; milled paddy at threshing - 0.64%; head grain yield - 78.9%.

DEVELOPMENT OF A ROW SEEDER FOR LOWLAND RICE

Details of an eight-row lowland seeder developed for pre-germinated paddy have been stated in the previous reports. This progress report deals with the design modification and the field evaluation phase of this project.

The modification of the prototype seeder was primarily directed towards design simplification to facilitate fabrication by small shops. The seeder was originally designed with an adjustable seeding rate and had a small hopper for test runs. A larger hopper and a fixed seeding rate was incorporated in the modified design (Fig. 10). Seeding rate, however, can be changed in the modified machine by changing the drive sprocket. The adjustable mechanism for the pivoted handle was difficult to fabricate. It was simplified by using a simple sliding arrangement for changing handle height.

Field experiments are in progress at the Institute to compare the performance of the seeder with transplanting methods. Three one-fourth hectare plots were puddled and fertilized with 60 kg N by mixing $(NH_4)_2SO_4$ during the final leveling operation. Each plot was split; one-half was planted with 21-day-old seedlings and the other half was seeded with the seeder. Standard water management and optimum pest and disease control are being followed. Initial data indicate that about 5 man-hours are needed to seed a hectare. According to an earlier study conducted in the Department, about 120 man-hours per hectare are required for transplanting. The results of the field experiment will be included in the next report.

TRACTOR ROLLING RESISTANCE IN LOWLAND CONDITIONS

Bogging of tractors has been a serious problem under lowland conditions. Tests were conducted to determine the rolling resistance of a standard 55-hp rubber-tired tractor by measuring the force required to tow the test tractor with a crawler tractor. This information could be useful in evaluating tractor power requirements and in designing implements for lowland cultivation.

Tests were conducted on three paddy fields, A, B, C, with different degrees of soil penetrating resistance. These fields were submerged in water for over 5 days. In fields B and C, the tractor was able to move on its own power; however, in field A, it could only move about five meters before encountering bogging problems.

The total weight of the test tractor was 3250 kg with a static weight distribution of 885 kg on front and 2365 kg on the rear axles. The test tractor was equipped with 13.6 x 12-38 standard tread rear and 6.00 x 16 front tires. Tread spacings for front and rear wheels were adjusted to the same setting for minimum rolling resistance. No cage wheels or other traction aids were used on the test tractor.

A strain gage tension load cell was used to measure the rolling resistance (Fig. 11). The load cell, installed in a sliding frame with 12 ball bearings, was mounted at the front of the test tractor. The load cell was constrained by the bearings to permit loading in a forward direction only. It was assumed in the study that the friction due to the ball bearings would

be negligible and only the forward component of the pulling force would be indicated by the constrained load cell. The signals from the load cell were recorded by a portable dynograph recorder which was mounted on the test tractor. Figure 12 shows the tractor with the load cell and installed instrumentation.

Field strips with relatively constant firmness were selected for the tests. Twenty random penetrometer readings were taken in the selected strips. Table 4 and Fig. 13(a) indicate the penetration readings in the three fields. Extra-long towing chains were used to ensure that the test tractor wheels would not roll on the tracks made by the crawler tractor. Each test was conducted on a 10-m distance and the time taken to travel this distance was recorded. Due to the slippage of the crawler tractor tracks, the maximum test speed was limited to 4 miles per hour.[a]

Figure 13(b) indicates that the rolling resistance of the tractor does not vary significantly with an increase in speed under the three field conditions. Averaged rolling resistance readings were used for computing the coefficient of rolling resistance in the following formula:

$$\text{Coefficient of rolling resistance } \phi = \frac{\text{Tractor rolling resistance}}{\text{Total tractor weight}}$$

The following values of the coefficient of rolling resistance were found in the test:

$$\text{Field A } \phi = \frac{1231}{3250} = 0.378$$

$$\text{Field B } \phi = \frac{479}{3250} = 0.147$$

$$\text{Field C } \phi = \frac{417}{3250} = 0.128$$

$$\text{On concrete } \phi = \frac{80}{3250} = 0.023$$

The rolling resistance is inversely proportional to the area under the penetrometer curve between the 3 to 12-in. soil depth (Fig. 13a). Additional tests will be conducted to verify these results.

DEVELOPMENT OF A TRACTOR PTO-DRIVEN THRESHER

The drawings on the thresher were completed during the period of the last report. Work on the fabrication of this machine has not yet been initiated due to heavy shop schedule. Some modifications in the drawings were undertaken to incorporate improvements in the rotary cleaner and in the spike tooth cylinder mounting arrangement. Fabrication of the first machine is expected to be initiated in the early part of the coming year.

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[a] SAE J939, "Off-Road Vehicle Mobility Evaluation," recommends rolling resistance measurements at speeds between 2 to 4 mph for soft soil conditions.

Drying and Processing Research

ACCELERATED DRYING OF PADDY

Paddy is generally harvested in the tropics at 20 to 35 percent moisture level and is dried to a 14 percent level for safe storage. Drying of paddy in conventional driers is accomplished by blowing hot air at about 100° to 130° F through a mass of stationary or moving grain. To maintain high total milling recovery and high head rice yields, the rate of moisture removal from paddy with conventional driers is carefully controlled. The extreme care necessary to dry rough rice is indicated by the following quotation from Richey, et al.[3]

> Optimum heated air temperatures for drying rough rice vary somewhat with the quality of the rice as harvested and with the variety. The temperature of the drying air should not exceed a dry-bulb air temperature of 130° F for milling rice and 110° F for seed rice. The temperature of the rice itself should not exceed 110° F as it leaves the dryer, and some evidence indicates that the maximum temperature of the rice should not exceed 100° F for the highest yield of head rice. These temperatures are for column dryers where the rough rice is exposed for 20 to 30 min to the drying air at rates up to 100 cfm per cu ft with a temperature drop of 20 to 30° F across a 6-in. rice column. The moisture loss under these drying conditions should not exceed 2 percentage points. The rice should then be removed from the dryer to a tempering bin for a period not to exceed 12 hr before it is again passed through the dryer. The rice should go through the drying and tempering stage enough times to reduce it to 14 per cent moisture or less. After the last drying, unheated air should be passed through the rice to cool it to storage temperature.

The slow rate of drying requires multipass drying and larger-sized drying equipment involving substantial capital investments. It has not been possible to accelerate the drying process by using conventional dryers because of the adverse effects on milling quality. In order to reduce the cost of artificially drying paddy in the tropics, it is essential that accelerated paddy drying equipment and systems should be developed. The retention of paddy viability during rapid drying is not absolutely essential since approximately 98 percent of the total paddy grown in the tropics is used as food. Paddy for seed can always be dried in conventional dryers to retain seed viability.

The information gathered by some research workers indicate that infrared or conducted heat can raise the temperature of wet grain and cause the moisture to move out rapidly from within the kernel. Efforts have been made with some success at Louisiana State University[4] to accelerate the process of

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[3] C.B. Richey, et al.(ed.), "Agricultural engineers' handbook." (New York: McGraw-Hill Book Co., Inc., 1961), pp. 646-671.

[4] F.T. Wratten and M.D. Faulkner, "A new system for rice drying." LRC Newsletter, 17(1):14-26 (March 1968).

drying paddy by preheating it in an infrared field before drying with a standard fluidized bed drier. It has been possible to dry paddy from an average moisture content of 22.85 percent (d.b.) to 14.22 percent (d.b.) in a matter of 30 minutes with drying intervals of 10 minutes and with drying air temperature of 120°F. The application of this principle requires relatively sophisticated equipment and may be difficult to introduce in the developing countries.

Information on grain drying by conducted heat is scarce and little research has been reported in the engineering journals on the subject. Chancellor's[5] work indicates that it is possible to dry paddy with conducted heat by placing and mechanically stirring wet paddy on a heated surface. Metal surface temperature of up to 200°F were recorded in Thailand with a conducted heat drier utilizing this principle. It was possible to dry about 1000 lbs of paddy with this drier from 24 to 14 percent moisture in about 4 hours. While the drier was quite simple and could be locally fabricated, it is suited to small quantity drying due to the slower rate of moisture removal. Excessive localized heating of individual grains at the point of contact with the steel plate was a major problem. Chancellor suggests the use of a granular medium, such as sand, to reduce excessive localized heating.

Hot sand has been used traditionally for uniformly roasting popped rice, wheat and corn on the Indian subcontinent. Jones[6] reports the ancient practice in India of using hot sand for partial drying of rice during the parboiling process. He states the difficulty of controlling time and temperature as the main problem in this process. Parboiling of rice is a widespread practice in India, Pakistan and Ceylon. It results in increased head yield due to the gelatinization of the starch in the rice kernel and the cementing of internal fissures in the paddy due to sun-checking. The traditional process is time-consuming and involves soaking of paddy in water for 2 to 3 days and steeping it at 140°F for 12 hours followed by sun-drying.

Hall[7] reports some research on drying a single stationary layer of corn on a heated plate at temperatures up to 220°F. He found that the rate of drying was directly proportional to the plate temperature. Natural convection was sufficient in his experiments to carry away the rapidly vaporized moisture from the single layer of corn. His experiments indicate that the conduction method was faster than the convectional method for drying corn to a safe stor-

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[5] W. J. Chancellor, "A simple grain drier using conducted heat." Agricultural Engineering Dept., University of California, Davis, California.

[6] J. W. Jones, "Effect of parboiling and related treatments on the milling, nutritional and cooking quality of rice." USDA Circular No. 752, Washington, D.C., October 1946.

[7] G. E. Hall and C. W. Hall, "Drying shelled corn by conduction heating." Agricultural Engineering, Vol. 42 No. 4, pp. 186-187, April 1961.

age level.

Since basic information on accelerated drying of paddy is not available, studies were initiated to develop background information on accelerated drying of paddy by conducted heat using different possible methods. A few preliminary tests were conducted by rapid introduction of heat into paddy kernels by the following three methods:

1. By submerging wet paddy for a controlled duration in heated oil held at slightly below the rice-popping temperature;

2. By mixing wet paddy in heated sand at temperature slightly below popping temperature; and

3. By placing wet paddy on a shaking screen held over a direct flame.

The oil immersion method was used to evaluate the rate of drying and the absorption of oil by the husk and the rice kernel. It was felt that the oil absorbed by the husk could be utilized for heat generation by using a husk furnace. The test indicated that oil is absorbed not only by the husk but also the kernel and some of it is released during milling. The moisture removal was, however, quite rapid, 15 percent d.b. in 15 seconds.

The hot sand and the direct flame methods did not indicate any adverse results. During these preliminary trials, a few milling tests indicated very high head rice yield. Two experiments were, therefore, initiated to further investigate this unusual phenomenon and the results are discussed below.

ACCELERATED PADDY DRYING WITH HEATED SAND

Accelerated paddy drying experiments were conducted in the laboratory by mixing wet paddy with heated sand for carefully controlled period ranging from 15 to 60 seconds and subsequently measuring the moisture removed from the paddy during the paddy-sand exposure. Sand was heated in an oven on metal trays to temperatures ranging from 374° to 464° F. A glass thermometer was inserted into the sand through the oven wall to measure the sand temperature. A paddy-sand mixture ratio of 1:20 by weight was used during the entire study. Freshly harvested paddy of four varieties, IR-8, IR20, C-4-63, and malagkit, were tested. In order to design equipment for accelerated drying of paddy, it was necessary to establish basic relationships of the following factors with milling recovery and head rice yield: (1) sand temperature, (2) paddy-sand exposure time, (3) initial moisture content of the paddy, and (4) varietal difference.

Wet paddy was carefully cleaned and the initial moisture determined by the oven method. Control paddy samples were dried by spreading on the floor for 24 hours in an airconditioned room and subsequently hulled in a Satake rubber roll sheller and milled in a No. 2 McGill miller. Drying tests were conducted by simultaneously pouring 200 g of wet paddy and 4000 g of heated sand in a flask. The recording of paddy-sand exposure time was started after half the paddy had been poured into the flask. The flask was shaken vigor-

ously to evenly distribute the paddy grain in the heated sand. A glass thermometer inserted into the flask was used to measure the temperature of the paddy-sand mixture.

After the desired time exposure, the paddy-sand mixture was poured on to a shaking sieve for separation of grain and sand. The treated grain was immediately placed in sealed bottles for grain temperature measurement. Then the treated grain was aircooled by spreading in an ambient condition for 10 minutes before determining the final moisture content. The treated samples were then spread on the floor in an airconditioned room for 24 hours to achieve equilibrium moisture level of 15-16% d.b. with the airconditioned room (75-80° F and 60-65% RH). The samples were then milled to determine the amount of head rice and total grain recovery.

Tables 5, 6, 7 and 8 include the data recorded during this experiment. Figures 14(a) and 14(b) show the drying rates and milling recoveries of IR8 and IR20 paddy with a high initial moisture level (32-35% d.b.) at different initial sand temperatures. The maximum reduction in moisture (approximately 15%) occurred during the first 15 seconds of grain-sand exposure. Similar drying performance was observed with other paddy varieties. The head rice yields of IR8 and IR20 paddy varieties increased by about 22 and 18 percent, respectively, during the first 15 seconds of exposure. In appearance, IR20 grains became more translucent and IR8 more glossy with little change in color and less white belly than the control. With higher sand temperature of 425° F and above, the grain changed to a yellowish and finally reddish color depending on exposure time. Slight popping of paddy was observed at 15 seconds exposure at 464° F sand temperature and 30 seconds exposure at 392° F sand temperature.

Exposures of above 15 seconds duration result in a slight decline in milling recovery and head rice yield. Initial sand temperatures ranging from 388° to 396° F seem to indicate a fairly high moisture removal rate coupled with good milling yield and head rice yield from the two varieties. A similar test with the malagkit glutinous variety at a high initial moisture level (31% d.b.) indicated results similar to IR8 and IR20 (Fig. 16). The change in color, however, was more significant with this variety than with IR8 and IR20.

Observation and microscopic examination indicated that the unexpected increase in the head rice yield was due to parboiling of paddy. This observed phenomenon opens possibilities for the development of a rapid parboiling process. From the foregoing results, it may be concluded that the short duration high temperature exposure of paddy with high initial moisture resulted in parboiling and drying. The high initial moisture present in the paddy was sufficient to parboil the paddy. Experiments were conducted on paddy with relatively lower initial moisture to check if similar results could be duplicated. Figures 15(a) and 15(b) indicate the results obtained when IR8 and IR20 paddy varieties with 25 to 26 percent initial moisture levels which were dried under similar time and temperature conditions. Both varieties indicated a decreasing head rice yield with increasing time exposure. The reduction in head yield was more drastic in IR20 than in IR8. These results indicate that it is essential to have sufficient moisture in the paddy rice to obtain higher head rice yields in the sand drying process.

To further test the validity of these results, tests were conducted with the C-4-63 variety at 26 and 30 percent initial moisture levels. Figure 17 con-

firms the necessity for higher initial moisture to obtain increased head rice yields. From the data obtained, it seems that an initial moisture level of at least 27 to 30 percent d.b. is essential to parboil the paddy and increase head yields in this sand process.

Since it would be impractical to always obtain paddy at high enough moisture level for drying and parboiling, similar tests were repeated with presoaked paddy. Figure 18 indicates the results obtained by taking IR22 paddy rice at 22 percent d.b. initial moisture and presoaking for 6, 12 and 24 hours at room temperature. The tests indicate that very high milling recovery and head yield can be obtained by presoaking relatively dry paddy for 6 to 12 hours. Presoaking over 12 hours did not show further improvement in head rice yield.

Conclusion

1. It is possible to simultaneously parboil and dry paddy to about 18 percent m.c. level in a few seconds by exposing paddy with high initial m.c. to heated sand. High total milling yield and head rice yield are obtained by the process due to the gelatinization of the starch granules and cementing of sun check and other fissures in the grain. The limiting conditions of this process, however, are governed by the right combination of sand temperature, paddy-sand exposure time, and initial moisture level of paddy. The process can effectively dry paddy to 18 percent d.b. level and it can be further dried to a safe 16 percent d.b. level by normal aeration.

2. Optimum results were obtained at the 1:20 grain-sand ratio under the following conditions:

Sand temperature	400° F (±10° F)
Grain-sand exposure time	Up to 15 seconds
Initial grain m.c.	30% d.b. or above

3. For grain below the 30 percent d.b. initial moisture level, soaking in water for 6-12 hours can provide sufficient moisture for the process.

CONDUCTED HEAT DRYING OF AGITATED PADDY

Experiments on drying paddy were performed by placing wet paddy on a shaking metal screen held over a flame. The paddy was under constant agitation due to the shaking action of the screen to reduce localized heating. After the completion of the desired drying test duration the paddy samples were removed from the flame and were exposed to ambient air for completion of the drying process.

A 4-in. diameter LPG (liquified petroleum gas) stove burner was used to produce a 1½-in. high circular blue flame that directly heated the bottom of the metal screen. The same burner setting was maintained throughout the tests. Heating rate (BTU/hr) was determined by weighing the amount of LPG consumed for one hour burner operation. Based on a heat value of 44,000 BTU/kg of LPG, the burner produced an average of 8800 BTU/hr. A 10x13-in. tray with a sheet metal screen bottom was preheated over the flame to an average temperature of 80° C. Grain exposure time was from 15 to 150 seconds in steps of 15 seconds.

Thirteen 170-g samples of freshly harvested paddy were taken and placed in glass jars. Two 10-g samples from the same paddy were tested for initial moisture contents. Each 170-g sample was poured on the preheated tray which was held 1 in. above the flame. Exposure time was taken by the stop watch at the start of the pouring of the grain. Paddy was constantly agitated by shaking the tray while maintaining a 1-in. distance over the burner.

Paddy was poured back into the jar after the desired flame exposure. A glass thermometer was inserted to measure the paddy temperature. The treated paddy was then spread for 10 minutes over brown paper on the floor. This was done to permit evaporation of additional moisture from the paddy and to cool it to the ambient temperature (27-30°C and 75-85% RH). The cooled paddy was poured and sealed in the jar.

On completion of the tests, 10-g samples were taken from each jar for moisture determination by the oven method. The difference between the original and the final moisture content was the reduction in the moisture content due to the flame exposure. The paddy from each test along with a control sample was spread in an airconditioned room for 24 hours to achieve moisture equilibrium of about 15 percent d.b. Paddy samples of 125 g were taken from each test and control sample for total milling recovery and head rice tests. The samples were husked with a Type THU Satake husker and milled in a No. 2 McGill miller.

Figure 19(a) is a plot of the exposure time versus moisture content for three paddy samples with different initial moisture contents, 36, 34, 22 percent d.b. The curves indicate that the rate of moisture removal is higher in the early stages of exposure and is gradually reduced with longer exposure time. The curves do not indicate any sudden change in slope between 20 to 150 seconds exposure.

The average grain temperature after exposure is indicated by the radial lines. These lines indicate that to attain the same grain temperature after exposure, paddy with higher initial moisture content can be exposed to the flame for a longer time than paddy with lower initial moisture content.

The color of the milled rice did not show any change from the control up to 185°F grain temperature and in some cases the appearance of the grain was improved due to more transluscency. Beyond 185°F, some degree of yellowing was observed and this intensified with exposure time.

Figure 19(b) is a plot of the head rice yield for the three paddy samples with different initial moisture contents. The initial moisture content played a significant part in the head rice yield of the three samples. For the high initial moisture paddy (34 and 36%), the head yield was higher than the control for the whole range of exposure time. The increase in the 36 percent moisture content paddy was much higher (36% more than the control) than the 34 percent initial moisture paddy (24% more than the control) in the shorter exposure time. A low initial moisture paddy, 22 percent m.c., resulted in considerably lower head yield than the control sample. An examination of the higher initial moisture paddy indicated a parboiling effect and the grain was more transluscent.

A comparison of the two accelerated drying experiments seems to indicate that the moisture removal is faster in the sand process than the flame exposure. The change in appearance of the grain due to parboiling and scorching at the higher temperature and longer exposure are factors which need careful study. Both methods prove that rapid parboiling of paddy is possible provided sufficient moisture is initially present in the grain. Tests with the sand process indicate that artificially introducing moisture by presoaking can also provide sufficient moisture for rapid drying and parboiling. The data reported here are results of a preliminary study and further tests are planned to investigate in more detail the effects of accelerated drying and parboiling on paddy quality, and under mechanical agitation on a non-perforated heated surface.

DEVELOPMENT OF A ROTARY SCREEN GRAIN CLEANER

A prototype rotary screen grain cleaner, as described in the last semi-annual report, was fabricated. The machine was designed to clean the grain by a mechanical screening process, followed by a winnowing operation. Figure 20 is the schematic drawing of the modified prototype cleaner which shows its principle of operation. The cleaner is powered by a 2½-hp aircooled engine and is equipped with wheels to facilitate transport.

Initial tests with the first prototype machine, utilizing a gravity feed arrangement, indicated an irregular feeding rate due to bridging of grain in the hopper. A variable speed auger-feed was later installed which resulted in a uniform delivery of grain at any desired rate from the hopper. The use of an axial fan resulted in a non-uniform swirling air flow between the two cylindrical screens. Deflecting air baffles were later installed in the fan housing to reduce this swirling action and to direct the air flow on to the point of grain delivery from the inner screen.

The axial movement of grain and the degree of tumbling inside the outer cylindrical screen are critical factors in achieving satisfactory pneumatic separation. Too fast an axial grain movement or less tumbling of grain in the outer cylinder reduces the separation of light empty grain from full grain. Two kinds of sheet metal baffles were installed inside the outer cylinder, one for lifting the grain for tumbling, and the other for sliding the grain against the air movement. Considerable experimentation with the baffle arrangement was needed to achieve optimum balance between the tumbling and sliding action of the grain.

Initial tests indicated that at the maximum setting of the machine it was difficult for one man to empty the paddy sacks into the hopper and to fill the grain discharged into sacks. The cleaner has now been equipped with a bagging attachment. The modified machine is illustrated in Fig. 21. It is now possible for only one person to operate the machine. A test was conducted to determine cleaning output and cleaning quality with different rice varieties and moisture levels. Table 9 includes the results of this test. Output of over a ton per hour of paddy at 420 feed-auger rpm was obtained for the malagkit variety (Fig. 22). Generally the output decreased with an increase in grain moisture. Some bridging of paddy was observed with excessively dirty samples. The machine was able to remove all the straw and chaff and a major portion of the empty grains. A small quantity of light immature grains, ranging from 0.15 to 0.75 percent of the clean grain output, is blown out of the impurity outlet.

The degree of cleanliness and the grain delivered through the impurity outlet are interrelated and are affected by the air flow rate in the annular space between the two screens. Comparison of test No.10 (airflow fully open) and No.13 (airflow partially closed) indicates a reduction in the grain delivered with impurities from 2 to 1%, whereas the impurities increased in the cleaned grain grom 1 to 5%, respectively. A similar trend is observed in test No. 15 and 16.

A second test was conducted to compare the cleaning capacity and quality with a native motorized winnower. Table 10 includes the results of the comparative test. The grain output of the experimental rotary grain cleaner (1274 kg/hr) was about six times that of the native winnower (215 kg/hr) with similar cleaning quality.

Work has now been initiated on a second prototype machine which would be simpler and cheaper to manufacture. Interest has been generated in manufacturing this machine in the Philippines and some owners of rice mills and paddy driers have indicated a desire to obtain it for their use. On the completion of the second prototype cleaner, trial production will be undertaken through a local manufacturer.

Economics of Mechanization

ANALYSIS OF HAND TRACTOR OWNERSHIP

A survey of hand tractor owners in Laguna Province of the Philippines has been initiated. The increase in the number of hand tractors in the tropical countries, in spite of widespread controversy on their introduction, necessitated a detailed study of the farmers' experience in using these machines.

One of the objectives of the study is to formulate specifications on hand tractors for tropical farmers and to evaluate the desirable and undesirable features of existing machines. Farmers' experience and opinion on tractors can provide valuable information for design improvement and would shed light on the costs of owning and operating these tractors. The costs will be compared with that of the larger standard four-wheel tractors. The study will provide useful information for evaluating (1) owner profile, (2) design suitability, (3) economic returns, (4) financing source, (5) servicing and maintenance data, and (6) average hours of tractor use, etc.

The province of Laguna has been chosen as the area of study because of its large hand tractor population and because it was one of the first provinces to adopt these machines. A survey made in 1967 indicated that prior to 1960 only three hand tractors were sold in the province. It is estimated that in 1969 there are 1500 hand tractors in Laguna. A random sample of 140 farmers was selected for a detailed interview from a list of over 1000 tractor owners compiled from the sales records of the tractor dealers in Laguna province.

The data gathered to date indicate that the price of the tractor was not too significant to the farmers in selecting a specific tractor brand name, however, it was important in the selection of a proper horsepower tractor from the preferred make. Although the majority of the farmers interviewed were first-time tractor owners, they had operated a tractor of the same make before purchasing it. This personal operating experience, the observation of other tractors operating in the area, and suggestions of other farmers were major factors in the selection of a particular tractor brand name. Perhaps this is one of the reasons why one make of tractor is often concentrated in one neighborhood.

A majority of the tractor owners indicate that they are satisfied with their machines. The high price and difficulty of obtaining parts are their major problems. It is expected that data collection will be completed by the early part of next year and the findings will be reported in the next semi-annual report.

FARMERS' ATTITUDE TOWARDS USE OF TRACTORS FOR LAND PREPARATION

The farm operators in the previously reported survey areas of Central Luzon, Isabela, Midsayap and Tacurong were asked to indicate their opinion about hiring a tractor for land preparation. Out of the 307 farmers interviewed 230 (75%) indicated a desire to hire tractors, whereas 12 percent did not want to hire tractors. The remaining 13 percent did not give any answer (Table 11). Timely operation was the major reason given for tractor hiring by the farmers. This observation is interesting since approximately one-third of the pre-harvest labor is associated with the task of plowing and harrowing and it would seem normal that a reduction in the labor requirement would be a significant reason for mechanizing land preparation. The labor required per hectare for land preparation with hand tractors is about one-half of that for carabaos, whereas the total time required is about one-third to one-fourth. It must be noted that two men are normally required to operate a hand tractor.

A number of other reasons to hire tractors for plowing and harrowing were also advanced by the farmers. Some indicated that they simply had no carabaos or that it was too tedious to use them. Others felt that it was easier to control weeds when tractors are used for land preparation due to better incorporation of weeds in the soil.

The farmers who did not want to hire a tractor for land preparation advanced the following reasons: (1) still own carabaos; (2) sufficient supply of family and exchange labor; (3) too small a farm; (4) hard and stony field conditions; and (5) lack of cash resources to pay for custom service. A related response to the last reason, and perhaps more significant than the rest, was the feeling that the custom rates for land preparation were too high to be profitable for the farmers. If the tractor custom service is to gain acceptance, it seems essential that the rates must be kept in line with that of hiring a carabao to accomplish similar work. The information gathered in the study indicate that a good potential demand for tractor custom operation is present in the survey areas.

Table 12 shows the custom rates for plowing and harrowing. It can be noted that, on the average, the rates charged for both plowing and harrowing are higher in Luzon than in Mindanao. This could be because most of the figures for the Midsayap and Tacurong areas are for standard large four-wheel tractors whereas the figures for Luzon also include rates for hiring small walking tractors.

WORK PLAN

JANUARY 1 TO DECEMBER 31, 1970

Field Machinery Research

1. Drum-Type Power Thresher

Some of the threshers marketed in the Philippines have been in use for some time. A study is planned to evaluate their performance and collect information on their owners' reaction. A service man is being sent with a detailed check list and tools to assist in their maintenance. It is felt that this study would provide information not only on the performance of the drum thresher but would also provide some guide lines for future machinery design.

2. Table-Type Power Thresher

A fourth prototype is nearing completion. It is lighter than the previous machine and will be easy to fabricate. If the machine is found satisfactory, the design will be released to local manufacturers for limited production. Experience with the drum thresher indicates that it is desirable to initially manufacture a limited number of machines for field evaluation before going into regular production.

3. Tractor Tillage and Mobility Studies

The hydrostatic drive component for the large diameter experimental tiller has been received. A PTO-driven hydrostatic power transmission system is being designed for operating the experimental tiller with a 57-hp tractor. The tiller rotor speeds could be changed in the field without stopping the tractor. This will provide operational flexibility and permit a more precise evaluation of pushing reactions due to blade velocities.

4. Power Requirement for Wetland Rotary Tillage

Studies of the power distribution under soft wetland conditions between tractor drive wheels and rotary tiller will be resumed. Strain gage tractor wheel torque transducers are now being fabricated to fit a standard 60-hp tractor with a conventional mechanical transmission. The results from this study will be useful in the design of tractors and rotary tillers for wetland operation.

5. Cage Wheel Studies

Studies to determine the desirable design parameters of cage wheels by tests of adjustable blade cage wheels will be continued. Cage wheel designs, based on the results of this study, will be developed for standard tractors.

6. Tractor Rolling Resistance in Lowland Conditions

The experiments reported here on rolling resistance of tractors indicate that there is a relation between the rolling resistance and the area under

the penetrometer curve between 3 and 12-in. soil depths. Tests will be conducted to substantiate this indication and to define the relationship. Devices for accurate determination of wheel sinkage will be fabricated to facilitate these tests.

7. Anhydrous Ammonia Applicator for Small Tractors

Some design modifications on the ammonia applicator have been completed. Attempts will be made in the near future to evaluate the loss of anhydrous ammonia at different depths in mud slurry.

8. Physical Properties of the Rice Plant and Paddy

Mechanical properties of paddy grain such as impact strength, shear resistance, and compressive strength are important in the design of paddy equipment. Data are needed to study grain resistance to cracking during harvesting and drying.

9. Row Seeder for Lowland Rice

A simpler lightweight seeder which is easier to fabricate has been completed. Field tests and economic evaluation will be undertaken to compare it with other methods of planting. The final design will be released to interested manufacturers.

10. Paddy Stripper-Harvester

Changes on the stripper mechanism are being made. A 6-hp tractor is being acquired for the stripper. The machine will have to be modified for installation on the new tractor. After more experience has been gained with the present machine, a self-propelled machine will be fabricated. This machine will have mechanisms for lifting lodged crops, grain-straw separation, and pneumatic grain cleaning. The self-propelled stripping harvester would be designed for harvesting four rows of paddy. The machine will be equipped with a hydrostatic transmission for precise speed control for optimum grain stripping.

11. Equipment for Multiple Cropping

The Multiple Cropping Department at the Institute has developed a system of intensive cultivation which combines the cropping practices of dry and wet land farming. Substantial increase in economic returns has been demonstrated by their studies. Mechanization of the multiple cropping system would facilitate its introduction in the tropics. A basic tractive machine with attachments for rotavating, plowing, harrowing, harvesting, planting, weeding and spraying is needed. A design for such a machine is being developed in cooperation with the Multiple Cropping Department.

12. Tractor PTO-Driven Thresher

The objectives and a description of the tractor PTO-driven thresher have been mentioned in the last report. Engineering drawings have been prepared and fabrication of a prototype will be undertaken as soon as shop sche-

dules will permit. The first machine will be field-tested at IRRI and development work will be continued until satisfactory performance is obtained. A final prototype will be fabricated and the design will be released for field evaluation in the Philippines.

13. Differential Cage Wheel Slip for Wetland Preparation

The fabrication of a machine using two hand tractors coupled by an articulated chassis and some preliminary observations on its performance have been reported. Tests will be conducted to determine under more severe conditions the front and rear wheel speed relationship for optimum mobility and tillage. If encouraging results are obtained, a second machine will be fabricated with a single engine and separate variable speed transmission to the front and rear wheels.

Drying and Processing Research

14. Accelerated Paddy Drying

Basic data on accelerated drying of paddy have been furnished in this report. Experiments on conduction drying by mixing grain with heated sand have shown encouraging results. The design of an experimental continuous flow drier using the sand technique for drying has been initiated. It is felt that such a machine will be more economical than the conventional driers and would be better suited for small scale drying and parboiling operations.

15. Test and Evaluation of Paddy Driers

It has been estimated that due to the high percentage of rural population in the tropics, nearly 50 to 75 percent of the paddy rice crop is consumed without reaching the commercial grain market. This paddy rice is generally sun-dried. Numerous attempts are being made in the tropical countries to improve and upgrade large commercial grain drying and handling facilities.

Relatively little attention is being directed, however, towards the problems of on-the-farm or village level drying of paddy rice in the tropics. In Japan, nearly a million and a half small-batch or continuous flow driers are used for drying paddy rice by individual or small-group farmers. A project will be initiated to evaluate the performance of such small driers and to study their economic feasibility under tropical conditions.

16. An Experimental Drying Furnace Using Rice Hull

Rice hull is a good source of heat energy for drying paddy rice crop. The disposal of rice hull at the rice mill is a serious problem. With the interest directed towards the development of small-sized driers, the use of rice hull as fuel looks promising. Design and fabrication of a small furnace using rice hull as fuel will be initiated.

17. Rotary Screen Grain Cleaner

Fabrication of the second prototype rotary screen grain cleaner is in progress. The second prototype will have a capacity of about 1320 kg/hr. The feeding hopper and auger have been enlarged and a slightly larger diameter, axially-supported screen cylinder has been designed for the new machine. The air flow control is expected to improve due to the centrifugal blower. It is felt that besides the increased capacity, it will result in better cleaning quality than the first prototype. Interest in its manufacture has been quite encouraging and it is hoped that trial commercial production can be achieved during the next report period.

Economics of Mechanization

18. Analysis of Hand Tractor Ownership

A preliminary survey on the economics and performance of hand tractors has been included in this report. The survey is still in progress and the completed results will be reported in the next semi-annual report.

PROJECT PERSONNEL*

Personnel and their respective man-months engaged in the project for the past six months, July 1 to December 31, 1969, are presented below. Anticipated personnel needs for the coming year are presented in the last two columns.

Category	Name	Fr: 7- 1-69 To:12-31-69	Fr:1- 1-70 To:6-30-70	Fr: 7- 1-70 To:12-31-70
Machinery Development Eng.	A. U. Khan[3/]	4.5	4.5	4.5
Machinery Field Application Engineer	Open	0	0	6
Agricultural Economist/ Economic Consultant	Open	0	0	3
Asst. Design Engineer	E. O. Casem	6	6	6
Asst. Design Engineer	P. Cabanos	6	6	6
Asst. Design Engineer	A. Manalo	4	6	6
Asst. Test Engineer	Open	0	6	6
Asst. Test Engineer	Open	0	6	6
Research Assistant, Agr. Economics	N. Orcino	6	6	6
Research Assistant, Engineering	N. Navasero	6	6	6
Research Assistant, Engineering	Open	0	6	6
Research Aide, Engineering	A. Amilhussin	6	6	6
Draftsman	F. Jalotjot	6	6	6
Draftsman	F. Cabrales	6	6	6
Secretary	C. Jizmundo	6	6	6
Secretary	Open	0	6	6
Shop Foreman	S. Gutierrez	6	6	6
Machinist	Z. Borja	6	6	6
Machinist	A. Dizon	6	6	6
Tinsmith	E. Dungo	6	6	6
Tinsmith	R. Santos	6	6	6
Welder	A. Barot	6	6	6
Mechanic-Operator	J. Silos, Jr.	6	6	6
Shop Mechanic	R. Dignadice	6	6	6
Shop Mechanic	M. Macatangay	1	6	6
Shop Mechanic	P. de Mesa	0.5	6	6
Shop Mechanic	Open	0	6	6
Laborer	M. Castro	6	6	6
Laborer	L. Villegas	6	6	6
Laborer	M. Fabellar	6	6	6
Laborer	J. Reyno	6	6	6
Student Assistant[3/]	B. Ramos	2	2	2

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* Personnel list based on Contract No. AID/csd-2541.

[3/] Part-time.

TABLE 1. Comparative threshing efficiency of threshing cylinders with hold-on and throw-in feeding methods. Paddy moisture at 14% wet basis.

Threshing cylinder peripheral velocity ft/min	Total paddy weight (grams)								Threshed paddy % of total paddy weight							
	Wire loop		Wire loop with concave		Peg tooth		Rasp bar		Wire loop		Wire loop with concave		Peg tooth		Rasp bar	
	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in
900	1887.1	1875.4	1693.8	1681.8	2010.4	1988.9	2010.0	2050.6	80.8	38.7	83.0	84.5	83.0	86.3	84.6	62.7
1150	1769.1	1946.7	1726.5	1702.6	1962.0	1991.7	1985.2	1953.5	84.0	40.6	85.1	86.3	85.2	87.0	85.0	64.3
1400	1713.1	1918.0	1702.3	1754.2	2196.1	2008.9	1942.2	2010.7	87.3	42.0	87.3	88.5	87.7	89.4	85.9	67.9
1650	1861.3	1927.4	1728.8	1680.4	1916.8	1971.2	1998.7	1824.5	89.0	45.1	89.8	89.6	89.6	89.7	86.3	69.4
1900	1864.7	1889.8	1769.9	1776.1	1959.0	1948.5	2037.1	2021.1	91.6	48.4	91.7	90.0	90.4	89.9	87.7	72.9
2150	1929.9	1847.3	1799.8	1761.3	1850.8	1960.5	2034.7	2007.7	94.5	50.8	92.8	91.3	91.9	91.7	89.4	75.8
2400	1926.9	1924.8	1767.3	1744.3	1892.4	1855.8	2065.9	1973.8	95.2	52.6	93.2	93.3	93.7	93.0	90.3	77.3
2650	1994.6	1922.0	1708.4	1716.6	1929.3	1916.7	2049.4	2054.9	96.6	55.0	94.1	94.1	94.2	94.1	92.0	79.6
2900	1705.1	1910.7	1693.0	1773.8	1972.0	1955.7	2006.0	1949.3	97.0	59.0	94.8	94.7	95.6	95.6	94.9	82.7
3150	1996.9	1872.2	1833.1	1749.6	1879.8	1908.7	2000.0	2013.1	97.7	62.2	95.2	95.2	96.0	96.1	96.5	85.2
3400	1979.2	1914.8	1780.3	1800.5	1938.0	1944.0	2041.0	1947.3	98.1	65.3	96.4	96.5	97.3	97.3	97.5	89.6
3650	1941.1	1917.9	1767.7	1733.1	1956.8	1928.7	2024.2	2019.6	98.4	67.5	98.2	96.7	98.0	97.7	98.1	93.5
3900	1832.6	1926.2	1764.3	1793.2	1916.1	2000.4	1915.1	1999.5	98.7	70.8	99.0	96.9	98.2	97.7	98.8	96.4
4150	1970.2	1862.9	1653.0	1653.3	1814.1	1928.0	1913.0	1975.4	99.5	73.6	99.5	97.2	98.7	98.0	99.0	98.1
4400	1993.1	1920.0	1768.1	1826.5	1921.5	1886.5	2001.8	1903.5	99.5	74.4	99.6	97.4	99.0	98.4	99.4	99.0
4650	2038.0	1849.2	1671.9	1742.9	1838.2	1957.7	1948.0	1950.2	99.6	77.2	99.7	97.8	99.1	98.5	99.6	99.1

Threshing cylinder peripheral velocity ft/min	Semi-threshed paddy % of total paddy weight								Unthreshed paddy % of total paddy weight							
	Wire loop		Wire loop with concave		Peg tooth		Rasp bar		Wire loop		Wire loop with concave		Peg tooth		Rasp bar	
	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in
900	5.9	25.6	11.2	11.4	10.1	7.0	9.4	16.2	13.3	35.7	5.8	4.1	6.9	6.7	6.0	21.1
1150	5.4	24.0	10.0	10.7	10.0	7.0	9.2	15.5	10.6	35.4	3.9	3.0	4.8	6.0	5.8	20.2
1400	4.8	22.8	9.1	9.2	9.8	6.5	8.7	14.8	7.9	35.2	3.6	2.3	2.5	4.1	5.4	17.3
1650	4.2	21.1	7.2	8.5	8.3	6.1	8.2	13.3	6.8	33.8	2.7	2.2	2.1	4.2	5.5	17.3
1900	3.9	20.4	6.1	8.0	7.8	5.5	7.9	11.7	4.5	31.2	2.2	2.0	1.0	4.6	4.4	15.4
2150	3.4	18.7	5.5	6.4	7.7	5.1	7.5	9.9	2.1	31.1	1.7	1.9	1.6	3.2	3.1	14.3
2400	3.1	17.1	5.3	5.0	5.1	4.5	7.1	8.6	1.7	30.3	1.5	1.7	1.2	2.5	2.6	14.1
2650	2.7	15.9	4.5	4.1	4.7	4.2	6.4	7.2	0.7	29.1	1.4	1.8	1.1	1.7	1.6	13.2
2900	2.2	14.3	3.9	3.6	3.7	3.3	3.9	6.0	0.8	26.7	1.3	1.7	0.7	1.1	1.2	11.3
3150	1.7	13.3	3.8	3.0	2.3	3.1	2.6	4.5	0.6	24.5	1.0	1.8	0.7	0.8	0.9	10.3
3400	1.4	12.8	1.9	1.9	2.2	2.0	1.7	3.3	0.5	21.9	0.7	1.6	0.5	0.7	0.8	7.1
3650	1.0	12.4	1.3	1.8	1.6	1.7	1.2	2.1	0.6	20.1	0.5	1.5	0.4	0.6	0.7	4.4
3900	0.9	11.7	0.6	1.7	1.5	1.7	0.7	1.7	0.4	17.5	0.4	1.4	0.3	0.6	0.5	1.9
4150	0.3	10.0	0.2	1.6	1.0	1.6	0.5	1.0	0.2	16.4	0.3	1.2	0.3	0.4	0.5	0.9
4400	0.2	9.8	0.2	1.5	0.7	1.3	0.4	0.4	0.3	15.8	0.2	1.1	0.3	0.3	0.2	0.6
4650	0.2	7.5	0.2	1.2	0.7	1.3	0.2	0.4	0.2	15.3	0.1	1.0	0.2	0.2	0.2	0.5

TABLE 2. Milled paddy during threshing.

Threshing cylinder peripheral velocity	Percentage of milled paddy during threshing							
	Wire loop		Wire loop with concave		Peg tooth		Rasp bar	
ft/min	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in
900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1650	0.00	0.00	0.07	0.09	0.05	0.00	0.02	0.00
1900	0.00	0.00	0.11	0.12	0.07	0.06	0.00	0.00
2150	0.08	0.05	0.22	0.15	0.13	0.09	0.06	0.00
2400	0.00	0.15	0.32	0.21	0.17	0.10	0.09	0.05
2650	0.11	0.20	0.45	0.28	0.28	0.16	0.17	0.09
2900	0.22	0.24	0.64	0.38	0.36	0.30	0.28	0.11
3150	0.33	0.30	1.02	0.39	0.66	0.43	0.39	0.18
3400	0.49	0.51	1.44	0.66	0.95	0.57	0.43	0.22
3[illegible]	0.64	0.63	1.79	0.82	1.26	0.74	0.70	0.43
3900	1.05	0.82	2.20	0.91	1.66	1.06	0.94	0.54
4150	1.40	1.10	3.20	1.38	1.97	1.38	1.30	0.80
4400	1.98	1.62	2.75	2.00	2.89	1.90	1.90	1.30
4650	3.00	1.88	3.80	2.70	4.00	3.17	2.60	1.88

TABLE 3. Head grain yield of mechanically threshed IR20 paddy compared with hand-threshed check samples (125 grams per sample at 14% m.c., w.b.).

Threshing cylinder peripheral velocity	Head grain, percentage of total milled grain at 14% m.c., w.b.								Head grain, percentage of check at 14% m.c., w.b.							
	Wire loop		Wire loop with concave		Peg tooth		Rasp bar		Wire loop		Wire loop with concave		Peg tooth		Rasp bar	
ft/min	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in	Hold-on	Throw-in
900	87.7	87.7	84.3	83.9	86.9	86.6	86.5	85.7	100.4	99.7	98.8	98.4	99.5	99.2	99.8	98.9
1150	87.7	87.0	83.8	83.8	86.5	85.4	86.4	85.7	100.4	99.6	98.3	98.2	99.1	97.8	99.6	98.9
1400	87.5	86.8	83.8	83.3	86.7	86.0	85.8	85.2	100.1	99.3	98.3	97.7	99.3	98.5	99.0	98.3
1650	87.4	86.5	82.7	82.2	85.9	85.5	85.8	85.3	100.0	99.0	96.9	96.4	98.4	97.9	99.0	98.4
1900	87.0	86.3	82.8	81.5	86.5	84.5	85.1	84.9	99.5	98.7	97.1	95.5	99.1	96.8	98.2	97.9
2150	86.2	86.1	81.9	79.5	85.4	83.9	85.1	82.6	98.6	98.5	96.0	93.2	97.8	96.1	98.2	95.3
2400	85.4	85.1	81.1	78.5	84.4	82.9	83.9	82.8	97.7	97.4	95.1	92.0	96.7	95.0	96.8	95.5
2650	84.9	83.3	79.9	77.3	83.8	82.2	82.4	80.6	97.2	95.3	93.7	90.6	96.0	94.2	95.0	93.0
2900	83.9	83.4	78.7	73.4	82.6	81.5	80.5	78.6	96.0	95.4	92.3	86.1	94.6	93.3	92.9	90.6
3150	82.6	81.7	77.5	69.5	81.5	80.1	79.6	77.9	94.5	93.5	90.8	81.5	93.3	91.8	91.8	89.9
3400	80.7	79.8	75.1	66.1	79.9	77.5	77.0	76.1	92.3	91.3	88.0	77.5	91.5	88.8	88.8	87.8
3650	79.0	76.9	72.5	65.6	77.7	72.2	73.0	73.7	90.4	88.0	85.0	76.9	89.0	82.7	84.2	85.0
3900	76.9	71.1	69.5	59.0	75.2	70.4	70.0	68.7	88.0	81.4	81.5	69.2	86.1	80.6	80.7	79.2
4150	74.9	69.0	62.9	53.7	71.8	66.9	64.2	64.0	85.7	79.0	73.7	63.0	82.2	76.6	74.0	73.8
4400	71.8	64.7	58.0	50.7	65.3	64.2	61.7	60.7	82.1	74.0	68.0	59.4	74.8	73.5	71.2	70.0
4650	63.1	57.8	52.9	48.5	59.3	54.7	59.0	55.3	72.2	66.1	62.0	56.8	67.9	62.7	68.0	63.8
Hand-threshed check	87.4	87.4	85.3	85.3	87.3	87.3	86.7	86.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4. Cone penetrometer resistance readings in Fields A, B and C during rolling resistance test.

Trials	WES cone index for Field A Depth, in inches						WES cone index for Field B Depth, in inches						WES cone index for Field C Depth, in inches					
	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9	12	15	18
1	3	7	40	130	135	140	10	20	30	100	200	280	10	70	120	180	220	
2	5	5	17	120	170	200	20	25	80	180	220		5	40	100	120	160	
3	5	10	40	135	155	170	10	20	120	150	160	180	0	60	80	100	100	180
4	5	10	10	140	140	180	10	45	120	200			10	40	80	100	160	180
5	5	10	30	120	170		40	60	140	180	180		0	60	80	120	160	180
6	4	10	30	120	220	220	60	60	120	160	220		10	60	100	120	160	
7	5	5	40	160	190		40	40	90	160	120	140	0	80	100	140	220	
8	5	7	40	140	200	200	40	40	60	220			0	40	100	140	220	
9	5	15	40	100	160	190	40	40	180	180	220		10	60	80	220		
10	5	10	60	120	200	220	40	40	90	120	140		5	80	60	140	140	
11	10	10	40	120	170	240	30	60	80	100	180	180	5	20	120	120	200	
12	10	15	80	140	260		60	40	100	200			10	40	80	100	140	
13	5	50	160	190	200		50	60	120	200	200	200	20	60	160	140	140	140
14	10	40	90	160	260		40	50	120	220			10	40	160	200		
15		30	160	180	220		40	70	100	140	140	120	10	100	120	120	120	
16	15	40	170	180	250		40	70	100	140	140	120	10	60	120	140	100	100
17	10	20	40	160	220		40	40	160	140	200		30	60	80	120	150	150
18	10	15	60	180	180	200	40	40	160	140	200		20	40	80	140	120	140
19	5	10	60	200	180		40	40	90	120	160	140	30	80	80	160	120	180
20							30	40	120	140	160	200						
Total	129	329	1207	2795	3680	1960	710	870	2940	3230	2700		195	1090	1900	2620	2630	
Average	6.8	17.3	63.5	147	194	196	35.5	43.5	147	161	180		10	57	100	155		

Note: Field condition: clay loam soil thickly covered with vegetation, submerged in 5 cm of water for more than 5 days.

*WES cone penetrometer with 30° cone, 1/2 sq. inch cone base area.

TABLE 5. Accelerated drying of paddy and its effect on milling recovery, IR20.

Test No.	Moisture content (%, d.b.)		Temperature of heated sand (°F)	Temperature[a] of grain just after drying (°F)	Time[b] of drying (sec)	Milling recovery (percentage of control)					
	Before drying	After drying				Brown rice		Milled rice		Head rice	
1	33.82	19.50	464	195	15	98.09	(79.76)	104.88	(69.40)	124.08	(56.02)
2	33.82	18.69	428	201	15	99.10	"	105.36	"	122.40	"
3	33.82	19.28	392	201	15	100.30	"	106.58	"	123.51	"
4	33.82	19.81	392	201	30	100.30	"	105.78	"	125.08	"
5	33.82	20.31	392	187	45	100.20	"	106.73	"	125.61	"
6	33.82	18.23	464	195	30	97.19	"	103.82	"	120.44	"
7	33.82	18.60	428	190	30	97.79	"	104.31	"	121.87	"
8	33.82	19.48	392	183	60	99.50	"	106.12	"	122.76	"
9	33.82	20.47	374	185	30	100.10	"	106.68	"	126.74	"
10	33.82	20.34	374	182	45	99.60	"	106.94	"	125.19	"
11	33.82	18.58	374	180	60	99.50	"	104.36	"	104.69	"
12	33.82	20.28	374	165	90	100.00	"	105.09	"	136.02	"
13	33.84	22.56	446	195	15	100.20	(77.28)	105.13	(68.26)	115.81	(59.82)
14	33.34	20.15	446	198.60	30	99.69	"	104.69	"	115.31	"
15	33.34	21.06	410	203	15	100.20	"	104.12	"	114.84	"
16	33.34	20.01	410	195.80	30	98.45	"	103.57	"	114.83	"
17	33.34	23.15	374	192.20	15	98.96	"	104.77	"	114.86	"
18	33.34	19.97	374	197.60	30	100.41	"	104.98	"	115.35	"
19	33.34	19.41	374	197.60	45	99.79	"	104.29	"	113.37	"
20	29.88	16.31	455	199.40	15	97.02	(78.00)	103.79	(66.27)	127.63	(53.89)
21	29.88	15.08	455	201.20	30	98.15	"	102.72	"	126.31	"
22	29.88	19.10	392	190.40	15	100.72	"	118.54	"	130.64	"
23	29.88	16.73	392	199.40	30	99.59	"	105.10	"	129.24	"
24	29.88	18.69	374	172.40	30	100.82	"	105.70	"	129.99	"
25	29.88	18.43	374	192.80	45	100.41	"	104.50	"	128.50	"
26	29.88	16.45	392	197.40	45	100.00	"	102.64	"	126.22	"
27	26.29	10.53	329	171	300	92.23	(79.09)	85.43	(65.06)	37.75	(54.68)
28	26.29	8.79	329	165	600	92.99	"	79.77	"	23.97	"
29	26.29	7.76	329	131	1200	94.09	"	85.23	"	15.54	"
30	26.29	18.67	329	133	120	97.03	"	93.24	"	52.54	"
31	26.09	17.91	455	192	15	97.04	(78.48)	97.46	(70.79)	100.24	(62.57)
32	26.09	15.66	455	163	30	97.96	"	98.33	"	73.45	"
33	26.09	16.78	455	183	45	98.06	"	98.71	"	82.45	"
34	26.09	18.00	392	195	15	99.69	"	100.39	"	101.68	"
35	26.09	17.14	392	195	30	99.90	"	100.47	"	81.35	"
36	26.09	17.77	392	187	45	99.90	"	99.66	"	79.22	"
37	26.09	17.53	392	184	60	100.00	"	98.29	"	80.18	"
38	25.82	14.71	410	195	15	99.58	(77.12)	100.07	(70.72)	63.78	(59.74)
39	25.82	14.36	392	174	15	100.73	"	98.56	"	57.48	"
40	25.82	12.24	410	167	45	97.61	"	93.35	"	64.39	"
41	25.82	13.16	392	187	45	97.30	"	96.58	"	57.06	"
42	25.82	14.82	392	200	30	98.55	"	95.90	"	65.47	"
43	25.82	17.00	392	203	15	99.69	"	85.07	"	52.16	"

a/Temperature measured just after separation of grain from sand.

b/Time of grain exposure to heated sand in the jars. Grain-sand separation was done with 1/16" screen.-

Note: Numbers in parentheses refer to percentage of control, which is based on rough rice. All treated samples were equalized in an air-conditioned room for 24 hours before milling.

TABLE 6. Accelerated drying of paddy and its effect on milling recovery, IR8-68 variety.

Test No.	Moisture content (%, d.b.) Before drying	After drying	Temperature of heated sand (°F)	Temperature[a] of grain just after drying (°F)	Time[b] of drying (sec)	Milling recovery (percentage of control) Brown rice		Milled rice		Head rice	
1	35.67	20.35	455	165	30	96.70	(77.60)	102.83	(67.21)	122.40	(50.50)
2	35.67	20.38	455	176	15	94.23	"	107.45	"	133.42	"
3	35.67	21.95	428	176	15	100.82	"	108.32	"	134.85	"
4	35.67	20.95	428	185	30	100.52	"	107.84	"	132.08	"
5	35.67	23.52	392	176	30	125.39	"	108.33	"	135.35	"
6	35.67	21.99	392	183	15	125.39	"	108.13	"	133.70	"
7	35.67	18.36	392	174	60	122.81	"	104.61	"	113.86	"
8	35.67	20.50	383	165	60	124.23	"	106.05	"	124.51	"
9	35.67	21.85	383	176	45	126.42	"	108.17	"	129.11	"
10	35.67	24.95	383	149	30	126.03	"	107.19	"	129.94	"
11	33.57	19.72	455	175	15	99.90	(78.40)	111.59	(64.36)	147.17	(45.47)
12	33.57	18.42	428	176	15	100.00	"	111.93	"	145.85	"
13	33.57	20.73	392	184	15	100.51	"	112.63	"	149.79	"
14	33.57	20.89	392	150	30	100.92	"	122.93	"	151.18	"
15	33.57	20.27	455	175	45	100.31	"	112.48	"	147.02	"
16	33.57	17.41	428	166	30	99.80	"	109.62	"	135.69	"
17	33.57	19.50	464	165	30	100.92	"	112.30	"	138.96	"
18	32.47	19.50	464	195	15	100.42	(76.80)	110.16	(64.48)	165.17	(40.60)
19	32.47	18.26	464	190	30	97.92	"	106.70	"	151.85	"
20	32.47	20.24	410	161	15	102.08	"	110.59	"	162.31	"
21	32.47	19.92	410	185	30	101.04	"	110.37	"	156.72	"
22	32.47	20.94	374	189	15	101.25	"	110.72	"	164.06	"
23	32.47	19.00	374	192	30	101.04	"	110.36	"	155.66	"
24	32.47	19.74	374	183	45	100.83	"	109.71	"	151.13	"
25	30.20	19.73	455	192	15	100.00	(77.44)	106.29	(66.93)	128.05	(51.23)
26	30.20	16.94	455	153	30	98.65	"	103.81	"	104.98	"
27	30.20	18.67	428	185	15	99.48	"	105.45	"	121.31	"
28	30.20	19.97	428	181	30	99.48	"	105.15	"	112.86	"
29	30.20	19.60	392	183	15	100.21	"	105.90	"	118.35	"
30	30.20	19.84	392	163	30	100.21	"	104.90	"	113.94	"
31	30.20	19.17	392	174	45	99.69	"	105.17	"	117.02	"
32	25.76	15.64	455	205	15	100.41	(77.44)	104.54	(68.06)	105.98	(54.68)
33	25.76	13.79	455	208	30	95.25	"	70.72	"	81.44	"
34	25.76	16.67	392	203	15	100.21	"	103.57	"	100.35	"
35	25.76	15.56	392	203	30	98.97	"	101.19	"	80.01	"
36	25.76	17.49	392	187	45	100.00	"	102.36	"	91.28	"
37	25.76	16.40	428	201	15	99.10	"	101.79	"	98.43	"
38	25.76	15.03	428	203	30	98.35	"	100.73	"	81.60	"

[a] Temperature measured just after separation of grain from sand.

[b] Time of grain exposure to heated sand in the jars. Grain-sand separation was done with 1/16" screen.

Note: Numbers in parentheses refer to percentage of control, which is based on rough rice. All treated samples were equalized in an air-conditioned room for 24 hours before milling.

TABLE 7. Rate of drying and its effect on milling recovery, C-4-63 and malagkit (glutinous) varieties.

Test no.	Moisture content (%, d.b.) Before drying	After drying	Temperature of heated sand (°F)	Temperature[a] of grain just after drying (°F)	Time[b] of drying (sec)	Milling recovery (percentage of control) Brown rice		Milled rice		Head rice	
					C-4-63						
1	29.86	21.78	392	199.40	15	100.41	(78.40)	104.79	(70.53)	118.52	(60.75)
2	29.86	20.87	392	203.00	30	100.10	"	106.88	"	118.06	"
3	29.86	21.95	392	203.00	45	100.10	"	104.61	"	114.93	"
4	26.00	15.18	464	195.80	15	94.84	(77.60)	95.77	(70.86)	89.32	(64.70)
5	26.00	16.32	464	201.20	30	96.91	"	97.70	"	84.88	"
6	26.00	18.25	428	190.40	15	99.48	"	101.66	"	94.00	"
7	26.00	17.73	428	199.40	30	96.91	"	96.92	"	82.21	"
8	26.00	18.94	392	192.20	15	100.10	"	101.40	"	91.53	"
9	26.00	18.03	392	197.60	30	99.90	"	101.17	"	84.59	"
10	26.00	18.25	392	188.60	45	98.35	"	98.09	"	74.90	"
					Malagkit (Glutinous) Variety						
11	30.97	21.64	464	217.20	15	99.39	(79.04)	97.63	(84.08)	107.21	(64.31)
12	30.97	18.70	464	217.20	30	92.10	"	91.01	"	99.36	"
13	30.97	20.95	419	213.00	15	98.99	"	98.35	"	105.80	"
14	30.97	19.17	419	201.20	30	97.97	"	100.05	"	100.11	"
15	30.97	22.00	392	172.40	15	100.40	"	99.89	"	107.29	"
16	30.97	18.71	392	195.80	30	92.71	"	93.07	"	97.95	"
17	30.97	22.77	392	199.40	45	100.00	"	99.81	"	105.97	"

[a] Temperature measured just after separation of grain from sand.

[b] Time of grain exposure to heated sand. Time of grain-sand separation of about 60 seconds was not included.

Note: Numbers in parentheses refer to percentage of control, which is based on rough rice. All treated samples were equalized in an air-conditioned room for 24 hours before milling.

TABLE 8. Effect of soaking period on milling recovery, IR22.

Test No.	Moisture content (%, d.b.)		Soaking time (hr)	Temperature of heated sand (°F)	Temperature[a] of grain just after drying (°F)	Time[b] of drying (sec)	Milling recovery (percentage of control)		
	Before drying	After drying					Brown rice	Milled rice	Head rice
1	22.12	12.62	Unsoaked	455	190.40	15	90.90 (75.60)	89.42 (68.43)	64.08 (55.51)
2	22.12	11.73	"	455	199.40	30	84.44 "	83.03 "	60.24 "
3	22.12	14.24	"	418	199.40	15	94.07 "	94.75 "	70.51 "
4	22.12	13.74	"	401	201.20	15	94.28 "	92.68 "	66.13 "
5	22.12	13.83	"	401	194.00	30	94.18 "	92.02 "	62.04 "
6	22.12	14.43	"	401	201.20	45	96.40 "	94.55 "	56.89 "
7	22.12	13.70	"	418	203.00	30	87.94 "	92.47 "	61.83 "
8	29.73	16.32	6	418	201.20	15	100.32 "	104.64 "	122.75 "
9	29.73	16.34	6	418	201.20	30	99.26 "	102.99 "	119.47 "
10	29.73	19.86	6	374	194.00	15	105.61 "	110.78 "	131.85 "
11	29.73	19.14	6	374	190.40	30	105.71 "	110.93 "	129.22 "
12	29.73	18.51	6	374	190.40	45	105.71 "	110.58 "	123.81 "
13	34.20	23.17	12	374	192.20	15	105.82 "	111.11 "	135.47 "
14	34.20	21.00	12	374	197.60	30	105.82 "	111.34 "	133.63 "
15	34.20	23.01	12	374	188.60	45	105.82 "	111.25 "	134.98 "
16	34.20	21.63	12	374	197.60	60	105.82 "	111.08 "	133.63 "
17	34.20	20.98	12	418	213.00	15	105.82 "	111.34 "	135.94 "
18	34.20	20.97	12	418	201.20	30	105.82 "	111.93 "	135.63 "
19	31.87	23.66	24	374	172.40	15	106.03 "	110.92 "	134.34 "
20	31.87	21.24	24	374	195.80	30	106.24 "	109.40 "	134.06 "
21	31.87	21.64	24	374	197.60	45	106.03 "	110.64 "	133.16 "
22	31.87	17.72	24	374	199.40	60	105.82 "	110.61 "	131.69 "
23	31.87	18.88	24	418	217.20	15	105.61 "	104.87 "	126.26 "
24	31.87	19.66	24	418	217.20	30	105.29 "	110.07 "	131.76 "

[a] Temperature measured just after separation of grain from sand.

[b] Time of grain exposure to heated sand in the jars. Grain-sand separation was done with 1/16" screen.

Note: Numbers in parentheses refer to percentage of control, which is based on rough rice. All treated samples were equalized in an air-conditioned room for 24 hours before milling.

TABLE 9. Performance data of the experimental rotary grain cleaner on wet paddy.

Test No.	Test duration min	Rpm			Clean grain output		Composition of feed material, percentage by weight		Percentage of chaff and empty grains removed in one pass	Percentage of empty grains with clean grain output	Grain that goes with chaff kg/min	Rice variety and moisture content, w.b.	
		Engine	Auger	Screening drum	kg/min	Computed kg/hr	Grain	Chaff and empty grains					
1	1	2325	325	18	13.55	813	96	4	4	0	.15	Malagkit,	23%
2	1	2490	350	20	14.60	876	96	4	3	1	.20	"	"
3	1	2687	378	21.5	15.30	918	96	4	3	1	.40	"	"
4	1	2800	395	22	16.50	990	96	4	4	0	.55	"	"
5	1	2350	362	18.5	16.05	963	96	4	3	1	.17	"	"
6	1	2590	390	21	16.95	1017	96	4	4	0	.30	"	"
7	1	2760	420	22	16.90	1014	96	4	2	2	.45	"	"
8	1	2300	380	18	14.65	879	91	9	8	1	.16	"	30%
9+	1	2580	430	21	13.65	819	91	9	9	0	.35	"	"
10	1	2580	430	21	17.30	1038	91	9	8	1	.30	"	"
11+	1	2780	475	22	14.15	849	91	9	--No data taken---		.45	"	"
12+	1	2780	475	22	16.95	1017	91	9	9	0	.54	"	"
13*	1	2580	440	21	18.65	1119	91	9	4	5	.15	"	"
14*	11	2760	389	22	13.02	781	89	11	10	1	.26	C-4	30%
15*	10	2750	435	22	15.17	910	89	11	9	2	.40	"	"
16	8	2750	435	22	14.54	873	89	11	10	1	.73	"	"

+Bridging of wet paddy occurred at auger intake.

*Air control partially closed (2.5 inches from the rim's top). The other tests (Nos. 1-12 and 16 with air control fully open.

TABLE 10. Comparative performance of the native winnower and the experimental rotary grain cleaner on dry paddy seeds.

Grain cleaner	Test duration min	Grain output kg/hr	Chaff and empty grains, %[c]		Empty grains at cleaner grain outlet, %	Grain collected at impurities outlet %[e]	Variety and moisture content, % w.b.
			Before cleaning	Removed by cleaner[d]			
Native winnower (hunkuyan)[a]	60	215	7	5	2	1.7	IR-662-2-7-2-2, 12%
Experimental rotary grain cleaner[b]	12	1274	7	5	2	1.3	" "

[a] Motorized native wooden winnower being used by Experimental Farm, IRRI, for cleaning seeds.

[b] With fan gate full open, engine rpm 2750, auger rpm 430.

[c] Percentage by weight of feed material.

[d] Both machines removed all the chaff; however, some empty grains were not separated from the full grain.

[e] Percentage by weight of clean grain input to the cleaner. Most of the grains collected here were light-weight grains (47 - 48 kg/hectoliter) compared to the full-size grains (51 - 52 kg/hl) obtained at the grain outlet. This light portion is usually discarded in seed cleaning.

TABLE 11. Farmers' response to hire tractors for plowing and harrowing in four areas of the Philippines.

Area	Total number of farmers	Will hire		Will not hire		No answer	
		No. of farmers	Percent of total	No. of farmers	Percent of total	No. of farmers	Percent of total
Central Luzon	75	63	84	5	7	7	9
Isabela	124	80	64	28	23	16	13
Midsayap	45	35	78	3	7	7	15
Tacurong	63	52	82	1	2	10	16
All areas	307	230	75	37	12	40	13

TABLE 12. Tractor custom rates for plowing and harrowing, for four areas of the Philippines.

Item	Central Luzon	Isabela	Midsayap	Tacurong	Total
	Number of observations				
Plowing, per hectare					
< ₱30	2	1	7	18	28
₱30 - ₱40	17	36	5	2	60
₱41 - ₱50	4	14	12	-	30
₱51 - ₱60	18	7	3	-	28
₱61 - ₱70	3	9	-	-	12
> ₱70	4	1	-	-	5
No answer	-	56	18	43	117
Harrowing, per hectare					
< ₱30	3	4	1	43	51
₱30 - ₱40	11	16	1	4	32
₱41 - ₱50	-	7	-	1	8
₱51 - ₱60	8	12	-	-	20
₱61 - ₱70	-	16	-	-	16
> ₱70	-	4	-	-	4
No answer	-	65	43	15	123

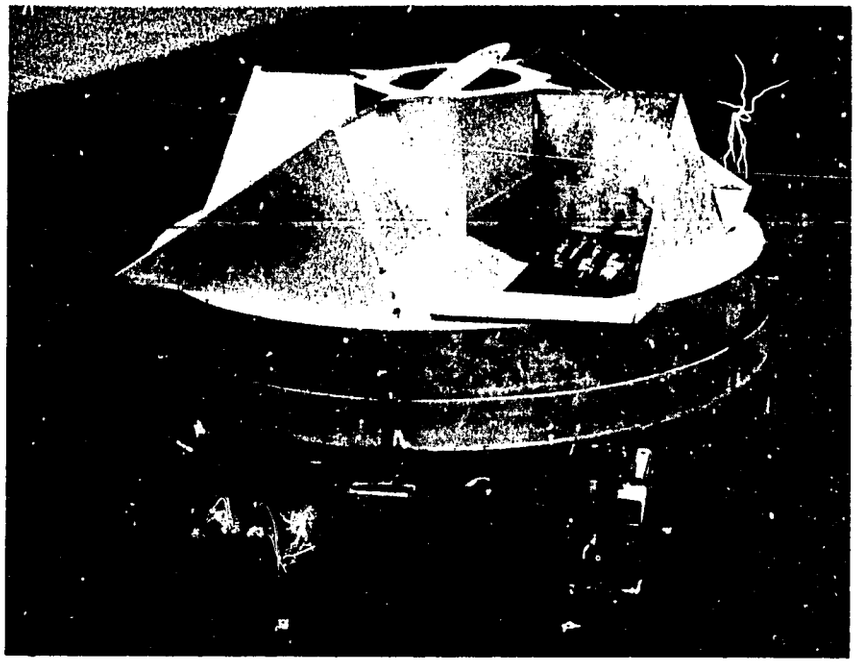

Fig. 1 Fourth prototype table-type thresher.

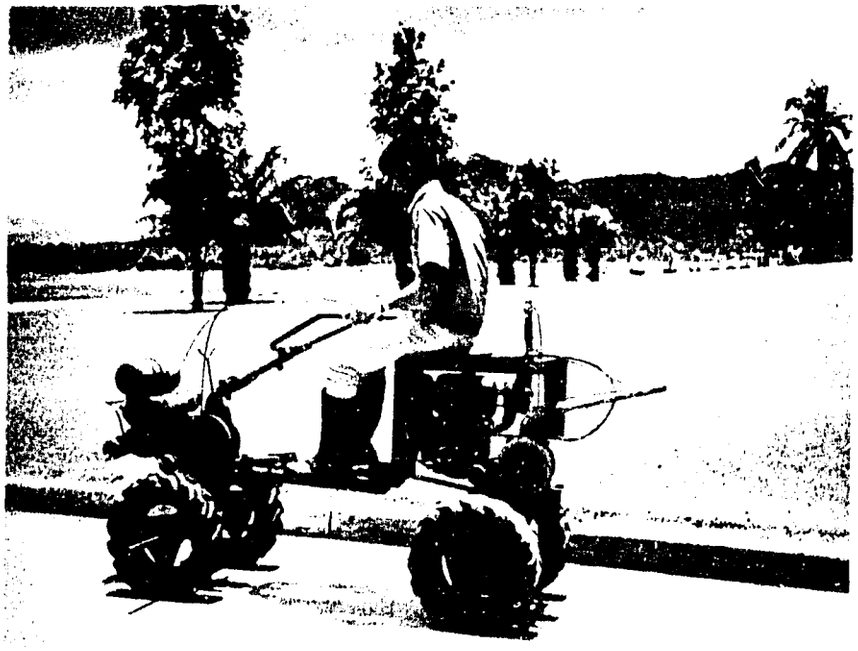

Fig. 2 Experimental four-wheel riding tiller.

Fig. 3(a) Experimental four-wheel tiller crossing a dike.

Fig. 3(b) Experimental four-wheel tiller in soft soil with deep hard pan.

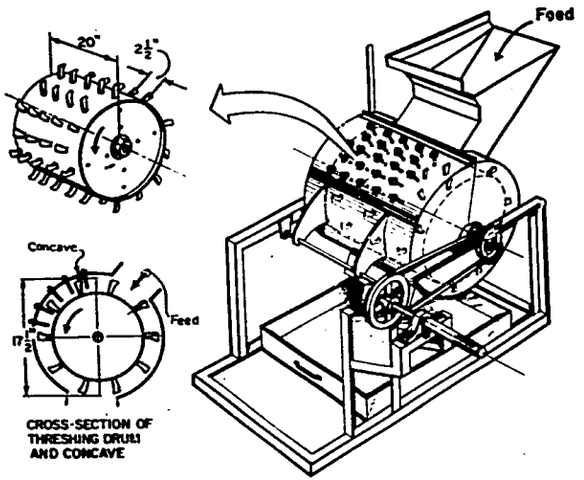

Fig. 4(a) Peg tooth threshing cylinder test stand.

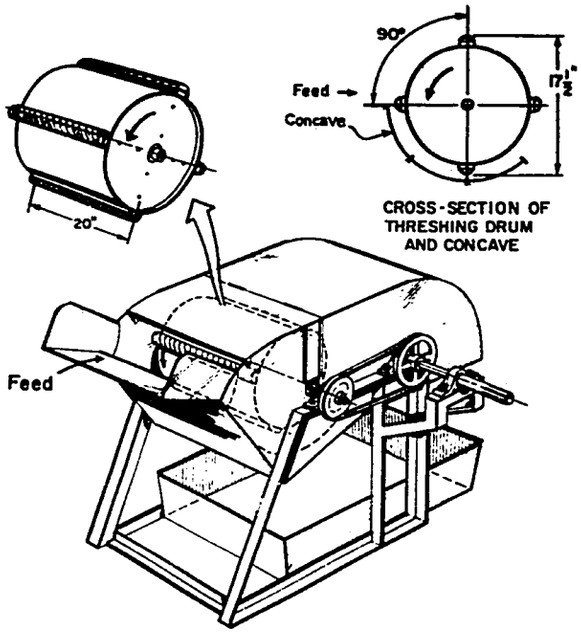

Fig. 4 (b) Rasp bar threshing cylinder test stand.

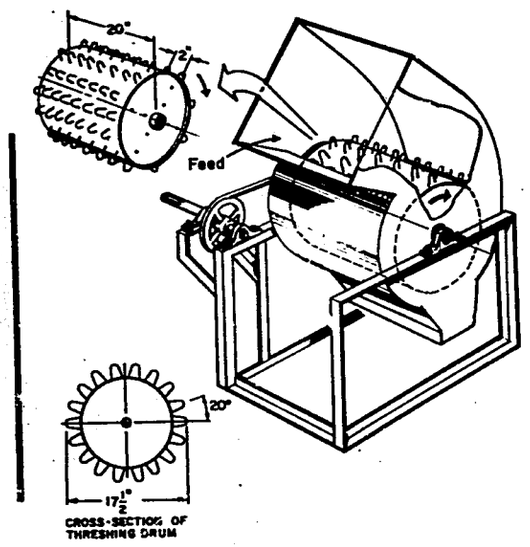

Fig. 5(a) Wire loop threshing cylinder test stand without concave.

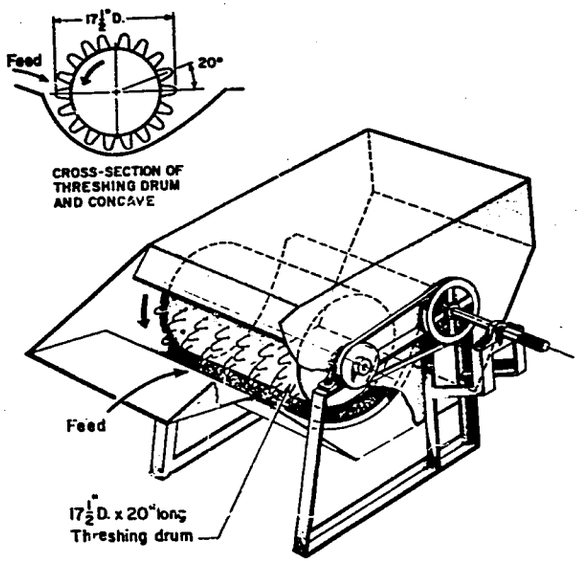

Fig. 5(b) Wire loop threshing cylinder test stand with perforated concave.

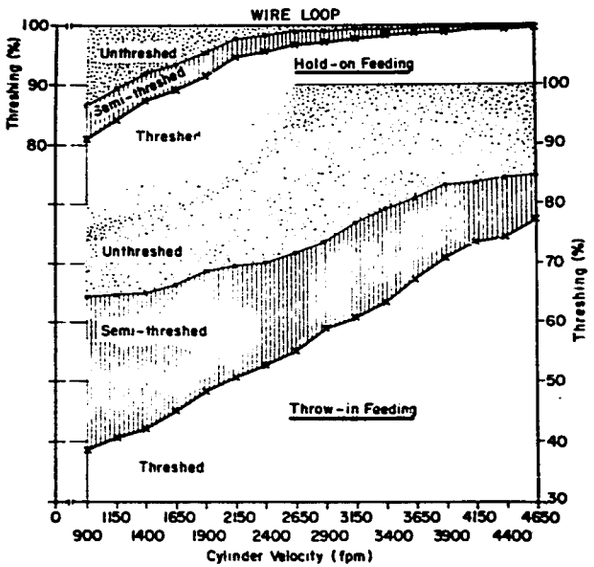

Fig. 6(a) Threshing performance of the wire loop threshing cylinder without concave.

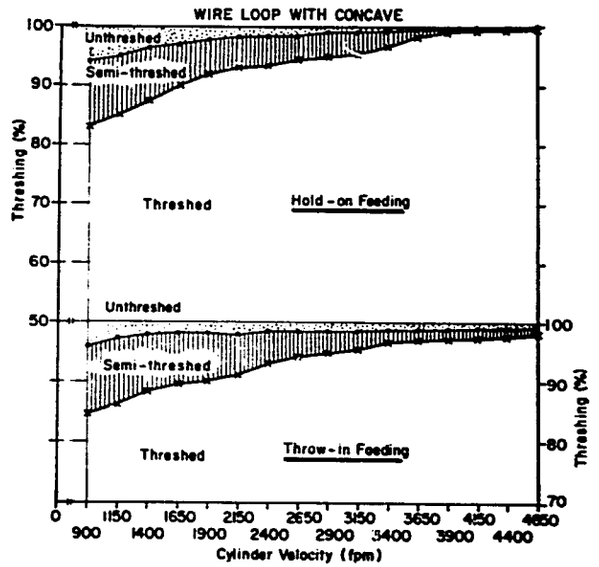

Fig. 6(b) Threshing performance of the wire loop threshing cylinder with concave.

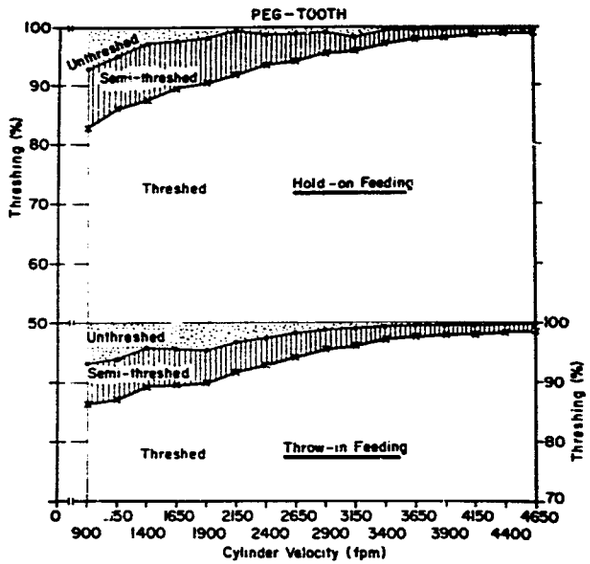

Fig. 7(a) Threshing performance of the peg tooth threshing cylinder.

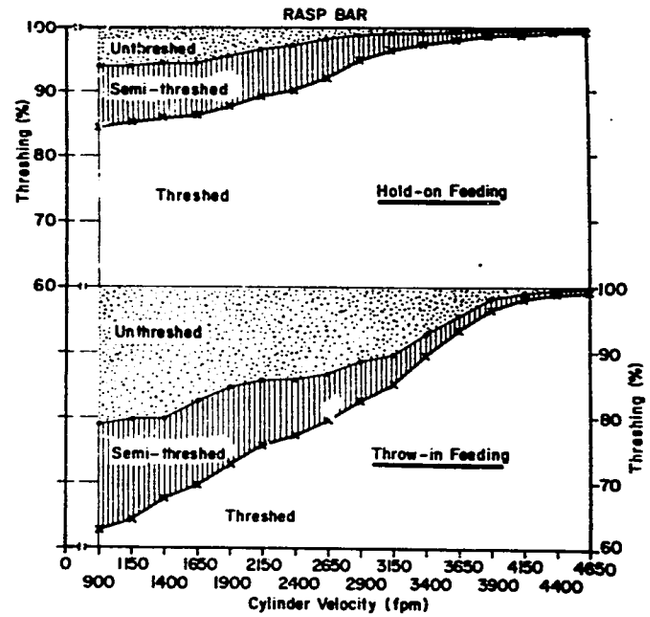

Fig. 7(b) Threshing performance of the rasp bar threshing cylinder.

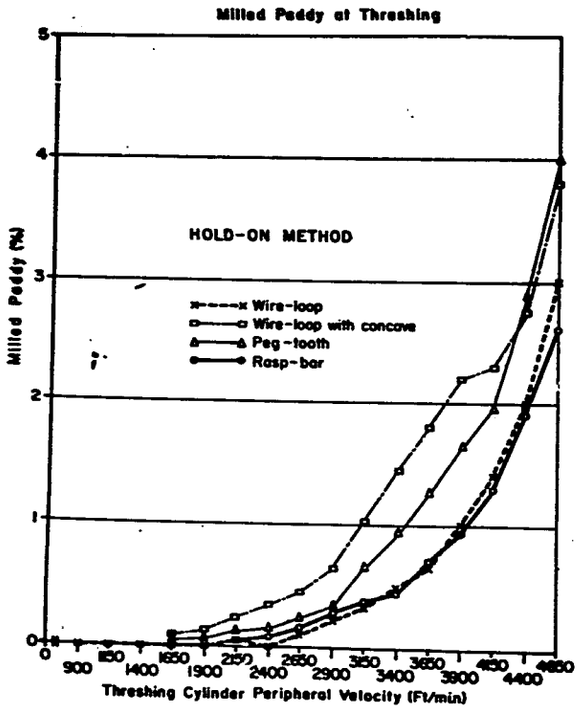

Fig. 8(a) Milled-paddy damage during threshing with the hold-on feeding method.

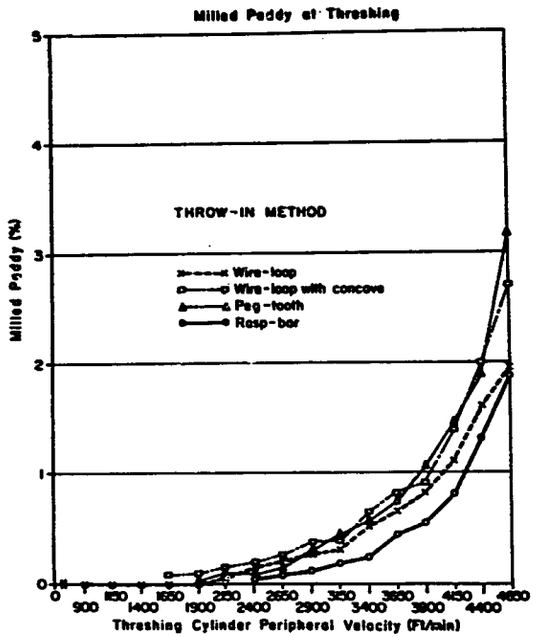

Fig. 8(b) Milled-paddy damage during threshing with the throw-in feeding method.

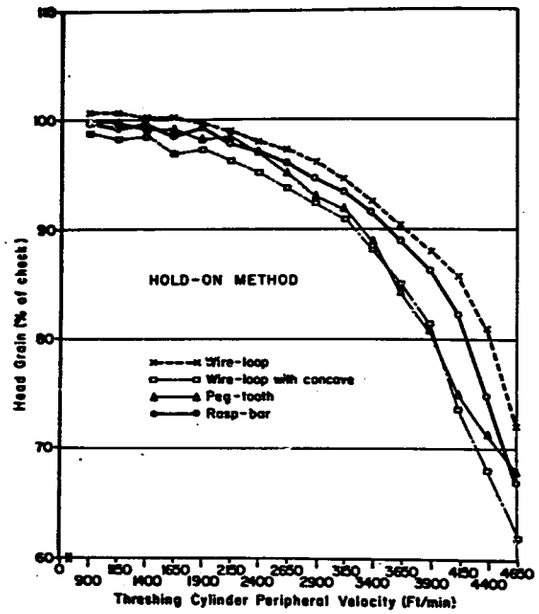

Fig. 9(a) Head grain yield in threshing with the hold-on feeding method.

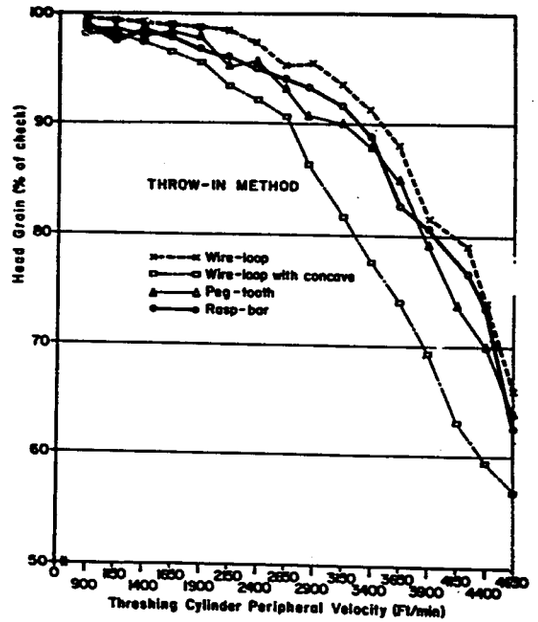

Fig. 9(b) Head grain yield in threshing with the throw-in feeding method.

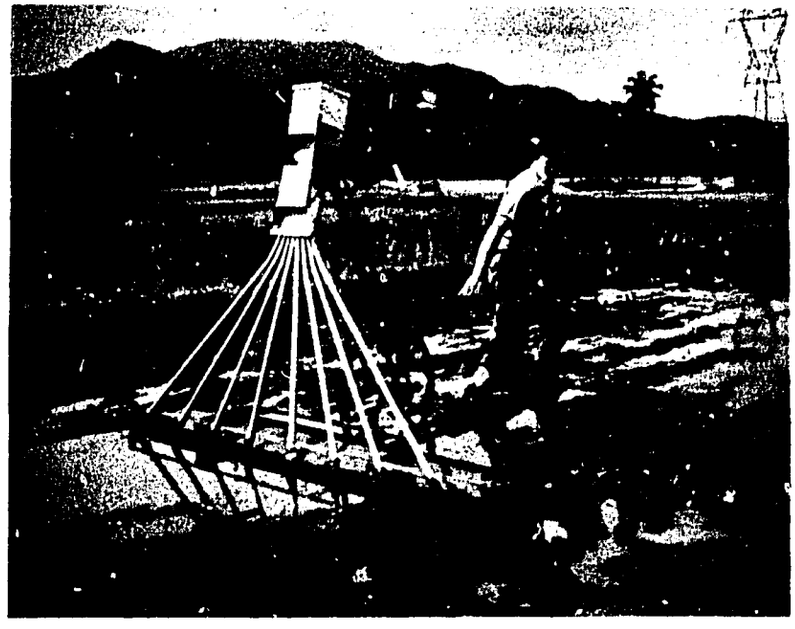

Fig. 10 Modified row seeder for lowland rice.

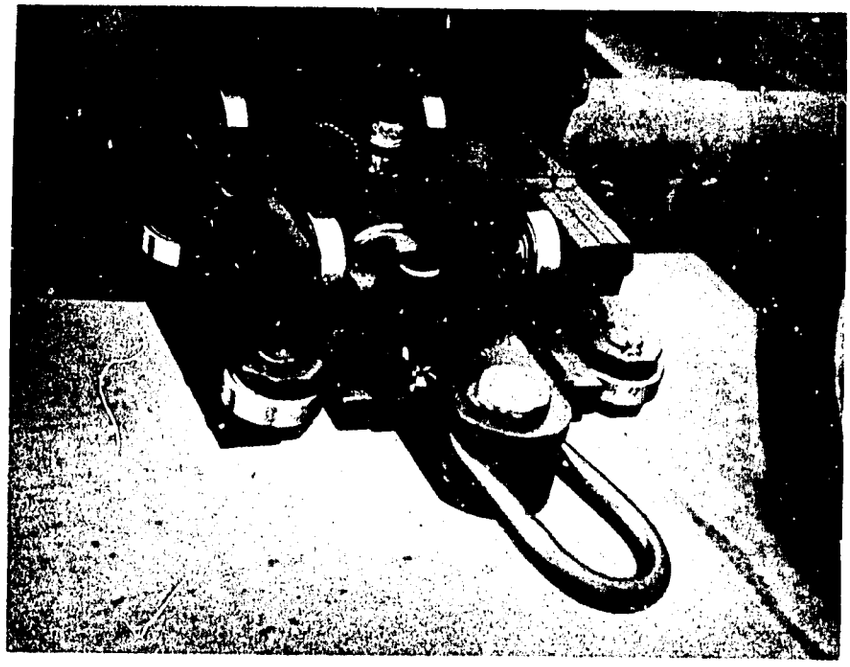

Fig. 11. Load cell for uni-directional measurement.

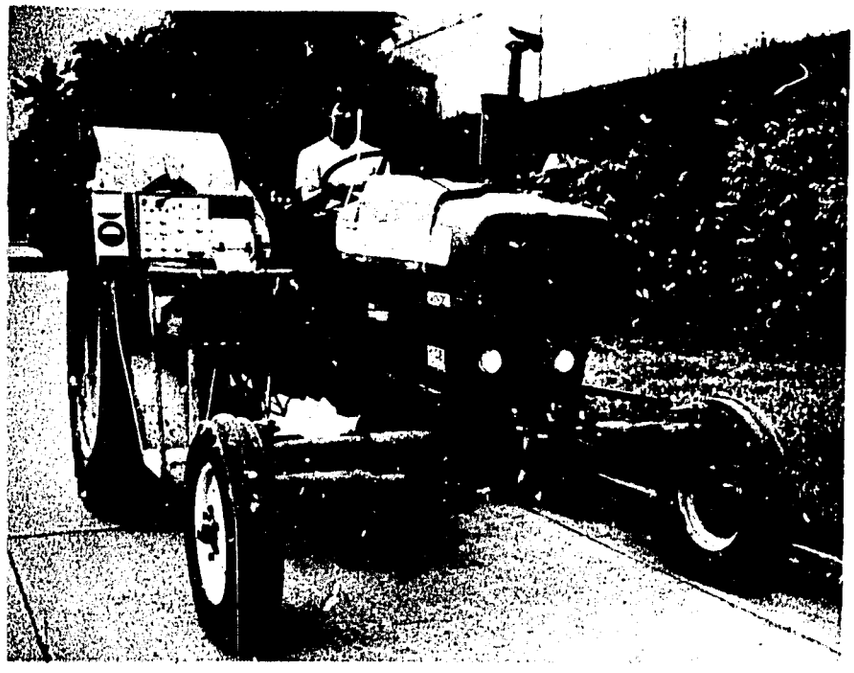

Fig. 12. Rolling resistance test tractor with instrumentation.

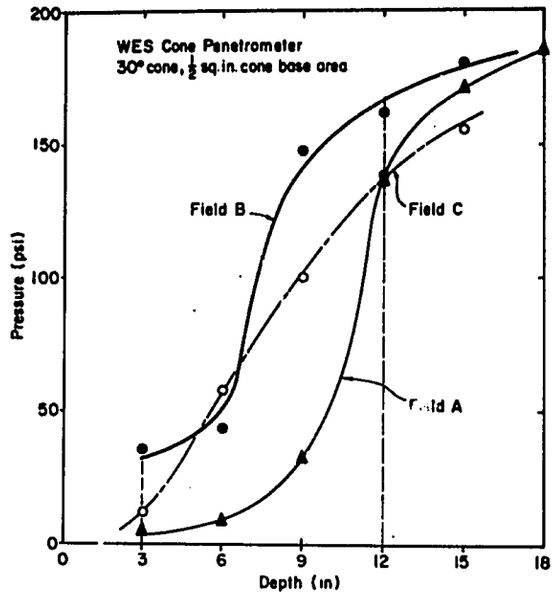

Fig. 13(a). WES cone penetrometer readings in three selected fields.

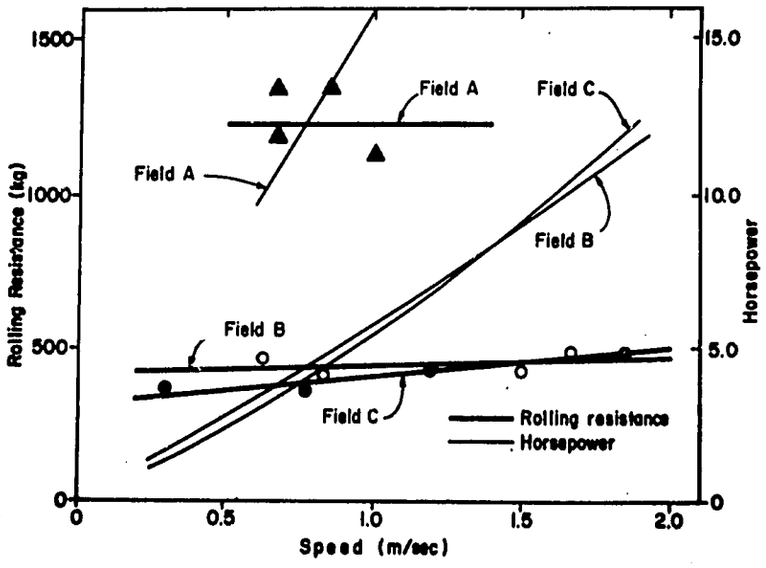

Fig. 13(b). Rolling resistance and towing horsepower requirement of the test tractor in the three selected fields.

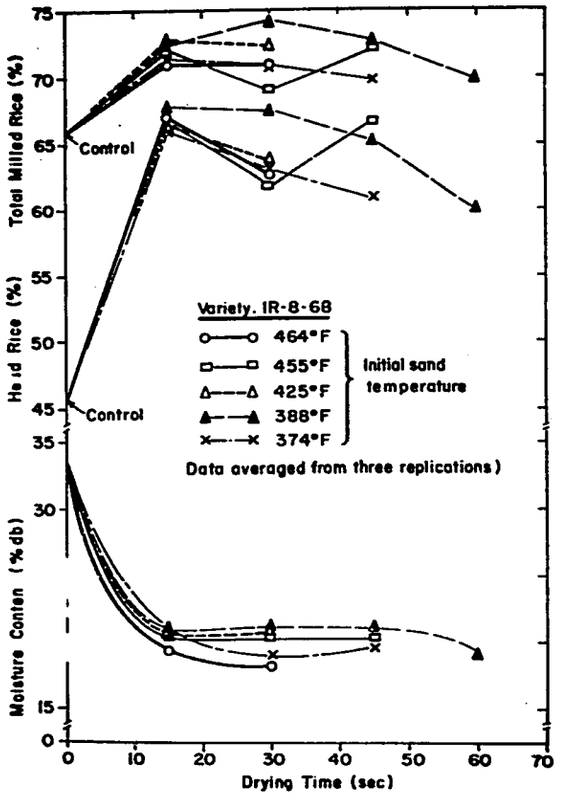

Fig. 14(a). Effect of accelerated drying rate on milling recovery of IR8 paddy with high initial moisture content.

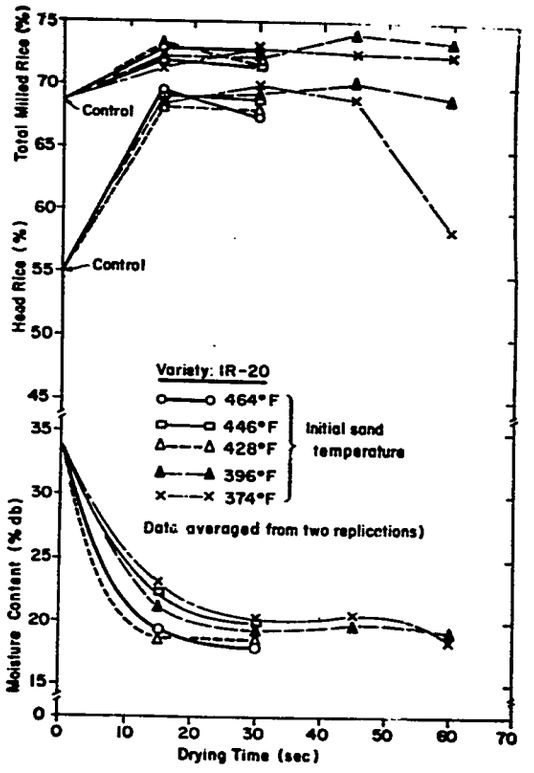

Fig. 14(b). Effect of accelerated drying rate on milling recovery of IR20 paddy with high initial moisture content.

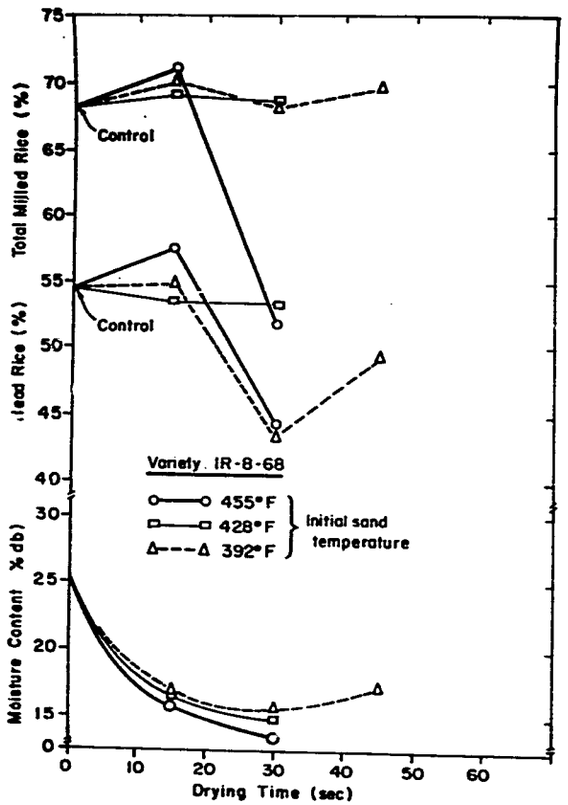

Fig. 15(a). Effect of accelerated drying rate on milling recovery of IR8 paddy with low initial moisture content.

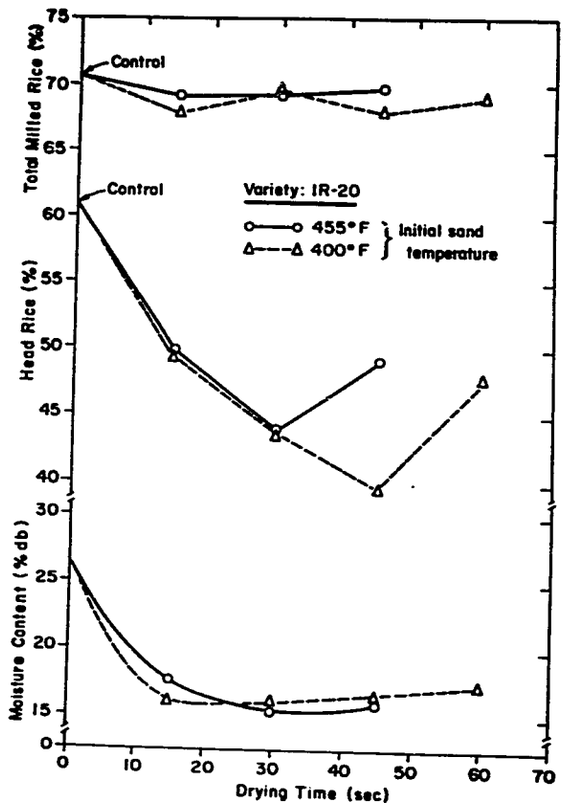

Fig. 15(b). Effect of accelerated drying rate on milling recovery of IR20 paddy with low initial moisture content.

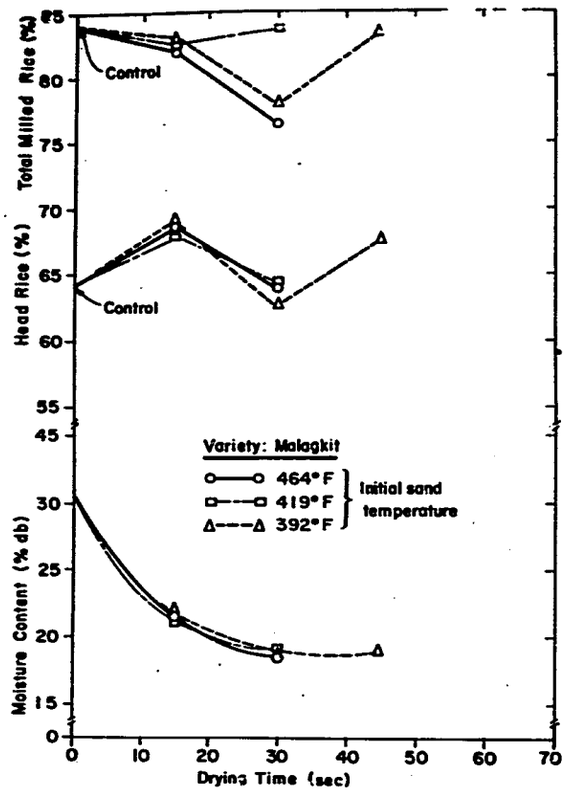

Fig. 16. Effect of accelerated drying rate on milling recovery of Malagkit paddy with high initial moisture content.

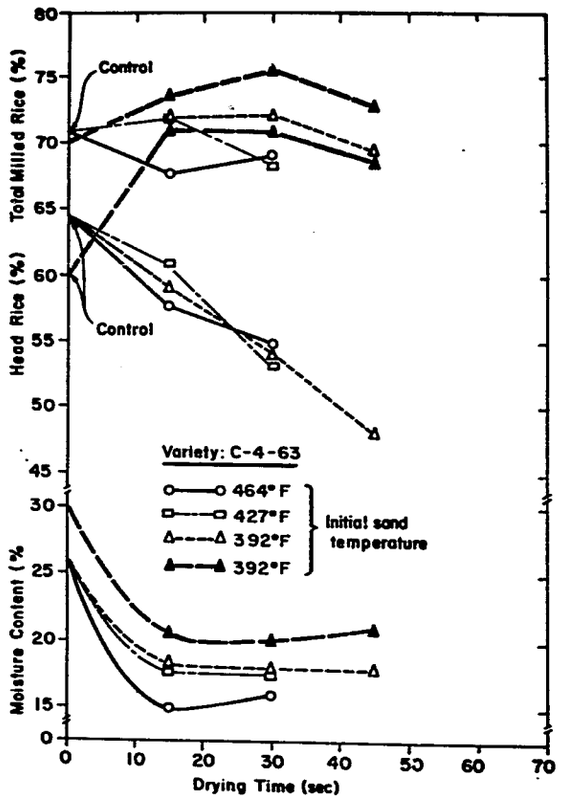

Fig. 17. Effect of accelerated drying rate on milling recovery of C-4-63 paddy with high and low initial moisture content.

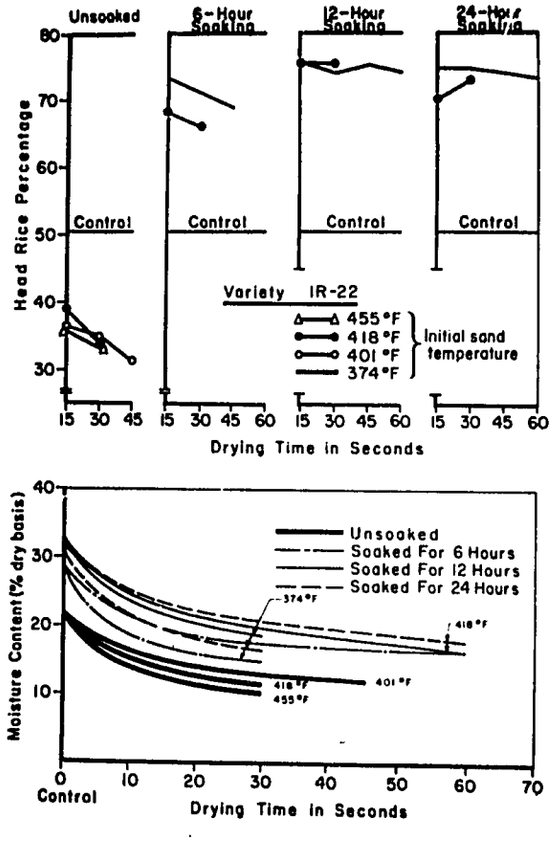

Fig. 18. Effect of presoaking on head rice yield during accelerated drying of IR22 paddy.

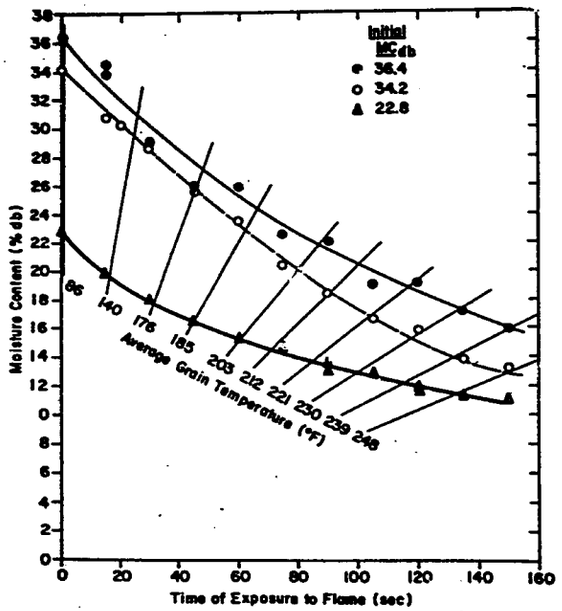

Fig. 19(a). Exposure time versus moisture content for three paddy samples with different initial moisture contents in conducted heat drying of agitated paddy.

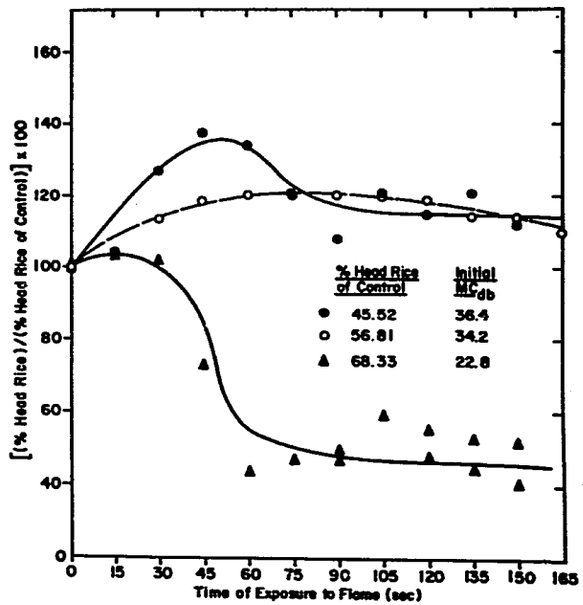

Fig. 19(b). Head rice yield for three paddy samples with different initial moisture contents in conducted heat drying of agitated paddy.

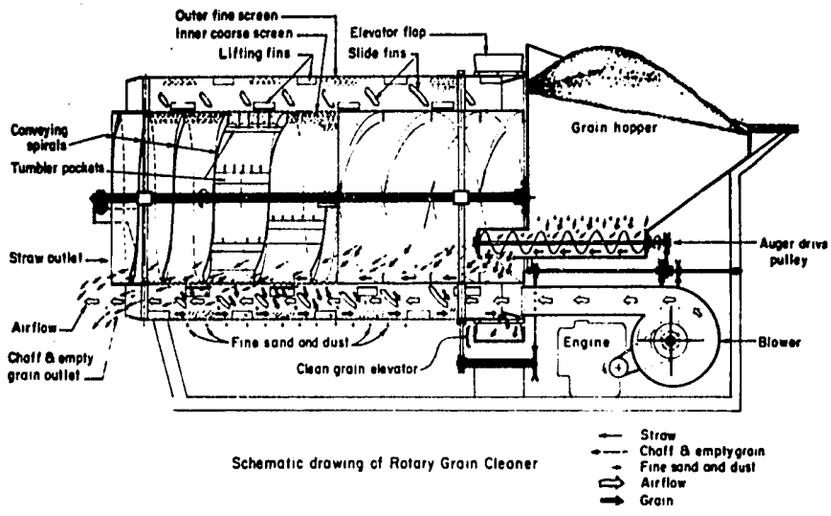

Fig. 20. Schematic drawing of the second experimental rotary screen grain cleaner.

Fig. 21. First prototype rotary screen grain cleaner.

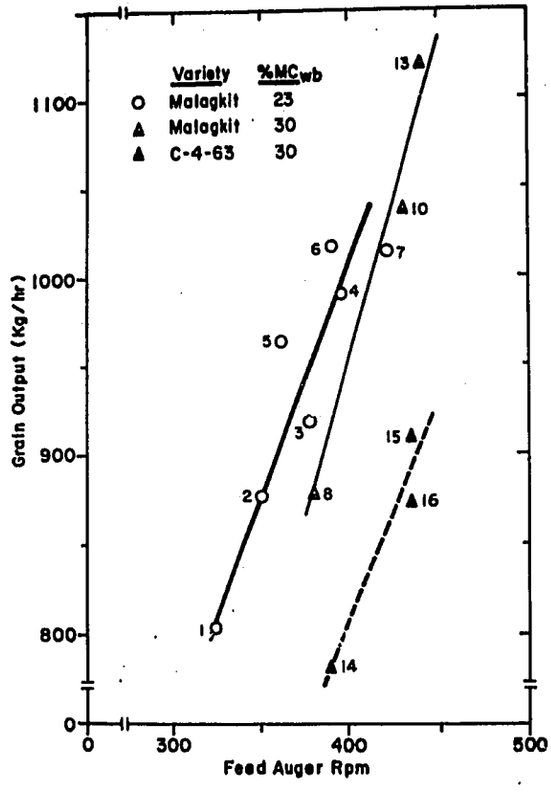

Fig. 22. Grain output versus feed auger rpm of the experimental grain cleaner.