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(For the Period July 1, 1968 to December 31, 1968)

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

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INTRODUCTION

This is the seventh Semi-Annual Substantive Report on Contract AID/csd-834. The contract originally scheduled to terminate on June 27, 1968 was extended for one year. The activities under the contract are broadly divided into two actegories, (1) Agricultural Machinery Research, and (2) General Engineering and Economic Research. The progress report and work plan for these two types of activities are presented separately in this report.

A major highlight of the Agricultural Machinery Research was the release of the drum-type power thresher for regular manufacture in the Philippines. A few commercially produced threshers have been shipped to other tropical countries for test and evaluation purposes. Another important highlight of the Agricultural Machinery Research was the development of the table-type power thresher. Due to its simple design and lower manufacturing costs, this machine offers possibility of wider acceptance than the IRRI drum-type thresher.

Work on the General Engineering and Economic Research continued to make progress. Increased emphasis was placed on two activities, (1) test and evaluation of small and medium-sized commercially available threshers, and (2) cost analyses of both land preparation and threshing equipment. A field experiment was conducted to compare the economics of mechanical weeders with other weed control methods. Work continued on farm management data collection in three areas of the Philippines. The Agricultural Economist, Dr. Stanley S. Johnson, departed after completing a two-year assignment on the contract.

The experimental data collection phase on the rotary tiller and tractor studies at the National Tillage Machinery Laboratory, USDA, Auburn, Alabama was completed. The analyzed data will be presented in the next substantive report.

A number of papers were presented by the contract personnel on the project activities at professional and scientific meetings and seminars. Many distinguished personalities, including the U.S. Secretary of Agriculture, and prominent agricultural engineers visited the Institute's Agricultural Engineering Department and acquainted themselves with the work being done under this contract.

PROGRESS REPORT
AGRICULTURAL MACHINERY RESEARCH
July 1, 1968 to December 31, 1968

SUMMARY

The development of commercially feasible rice cultivation machinery for tropical countries continued to receive major attention in this program. Considerable effort was exerted in testing and evaluating the design of a drum-type power thresher. The machine was released to three manufacturers in November, 1968 for commercial manufacture in the Philippines. One of these manufacturers has started regular manufacture of the thresher in the Philippines. A few commercially produced threshers have been shipped to other tropical countries for test and evaluation purposes.

The major problems encountered earlier with the table-type thresher were solved during this period. A second prototype table thresher was completed and it has exhibited promising performance. Further refinements are being made and it is hoped that the thresher will be ready for commercial production by the end of 1969.

The tractor tillage and mobility study has indicated that specially designed rotary tillers can improve tractor mobility under soft wetland conditions. A second experimental machine has been designed and will be tested in the near future.

The power weeder studies came to a close after the completion of the power weeder design. The performance of this weeder was compared with other weeding methods. Some commercial companies have shown interest in the design of this machine and drawings are being forwarded to the interested parties.

A new project on the development of a paddy stripper combine was initiated during this period. An experimental machine is approaching completion and will be field tested in the 1969 dry season.

The various projects handled by the contract engineering staff during the period of this report were:

1. Drum-type power thresher	A. U. Khan
2. Table-type power thresher	A. U. Khan
3. Tractor tillage and mobility studies	Makoto Hoki, A. U. Khan
4. Use of mechanical power for rotary weeding	N. Navasero, A. U. Khan
5. Application of anhydrous ammonia with small tractors	E. O. Casem, A. U. Khan
6. Physical properties of the rice plant and paddy	E. O. Casem

7. Development of a paddy stripper combine — A. U. Khan

8. Rotary harrow for small tractors — Makoto Hoki

9. Power requirement for wetland rotary tillage — Makoto Hoki

10. Row seeder for lowland rice — N. Navasero

DRUM-TYPE POWER THRESHER

The test and evaluation phase of the drum-type power thresher was successfully completed during the later part of the year. Preliminary test data have been reported earlier in Report No. 6. Performance and comparative data on this machine are included in the economics and general mechanization section of this report.

A number of manufacturers indicated interest in manufacturing this thresher in the Philippines. Quotations were invited for the supply of threshers for field evaluation in other tropical rice-producing countries. The quotations received for the supply of this thresher, exclusive of the engine, varied from ₱1600 ($400) to ₱1850 ($462.50). The OEM price of a 4.5-hp air-cooled gasoline engine in the Philippines is about ₱500 ($125). The design was finally released to the following three manufacturers in the Philippines:

1. G. A. Machineries, Inc. (GAMI)
   Valenzuela, Bulacan, Philippines

2. Clinton (Phil.) Distributing Co., Inc.
   Muelle del Banco Nacional & T. Pinpin Streets
   Manila, Philippines

3. F. Bernabe & Sons
   Km. 15, McArthur Highway
   Valenzuela, Bulacan, Philippines

All the three manufacturers built their own prototype threshers (Figs. 1 to 3) to suit their manufacturing facilities. These prototype machines were pattered after the IRRI thresher but differed in structural details. GAMI has successfully completed the development of this thresher (Fig. 1) and has completed the jigs, dies, and other tooling required for regular manufacture. Ten threshers have been supplied by GAMI for test and evaluation in the Philippines and other tropical countries. The other two manufacturers have completed their first prototype models and are testing and improving their machines. Each manufacturer did submit the first prototype machine for test and evaluation at IRRI. These first machines were tested and recommendations for necessary modification were made. This process of testing the first machine had to be repeated a number of times with each manufacturer to evaluate each subsequent modification. The other two manufacturers are making improvements in their prototype machines.

The GAMI thresher (Fig. 1) is of an all-steel single shell type construction and weighs 500 kg. Their first unit was airshipped in November, 1968 to the ford Foundation IRRI Rice Improvement Adviser, Government of West Pakistan, Lahore. Initial reports on tests from West Pakistan indicate that an output of 500 lbs per hour was achieved. Several manufacturers in Pakistan have shown interest in building this thresher. Arrangements are being made to release the design in West Pakistan. Additional machines are being shipped by IRRI to the following organizations for test and introduction in their respective countries:

1. Ceylon-IRRI Rice Research Project
   Central Agricultural Research Institute
   Peradeniya, Ceylon

2. East Pakistan Accelerated Rice Research Institute
   (EPARRI)
   Dacca, East Pakistan

3. All-India Coordinated Rice Improvement Program
   (AICRIP)
   Hyderabad, India

4. Central Rice Research Institute
   Cuttack, India

The USAID/Manila has ordered five threshers for test and evaluation in the Philippines. The Agricultural Engineer, USAID/Manila, and USAID field personnel are planning an independent program of evaluation and introduction of this thresher. USAID/Vietnam has placed an order for six threshers to evaluate and introduce the machine in Vietnam. The IRRI farm operations department has placed orders for two threshers for their seed multiplication program and general threshing requirements at the Experimental Farm. Information and drawings on this thresher are available and have been forwarded to interested parties in many countries. As soon as satisfactory test results are obtained, attempts will be made to interest local companies in their manufacture within the different tropical countries.

TABLE-TYPE POWER THRESHER

The design of a table-type power thresher was originally described in the Substantive Report No. 5. After a break of nearly six months, further development of this machine was resumed during the second half of 1968. The original machine concept utilized a one-unit flat circular threshing surface with an integral radial fan and a circular comb-like wire screen. Three major problems were encountered with this concept:

1. Long paddy stems were caught in the U-shaped wire loops and tended to clog the flat threshing surface.

2. The wire screen was ineffective in achieving grain-straw separation at the high threshing-surface and screen velocities.

3. Excessive grain was lost from the top of the machine during feeding of the paddy bundles for threshing.

After considerable amount of unsuccessful work, it was decided to scrap the integral thresher-fan-screen approach. A new table thresher was built (Fig. 4) which differed basically in three respects from the original concept:

1. The wire loops were replaced by flat iron pieces, somewhat similar in shape to the loops, to eliminate the paddy stem clogging problem.

2. The threshing surface and the screen were built in separate units and rotated at different speeds. The screen rotated in the same direction but at a slower speed than that of the threshing surface. The threshed material was easier to separate due to the smaller relative velocity between the screen openings and the moving material on top of the screen.

3. A sheet metal cover with four feeding spouts was designed for the machine. The air intake and a control baffle was placed in the center of this cover. This cover reduced the grain scatter by guiding the scattered grain back into the machine.

Fig. 5 shows the schematic drawing of the new thresher. During the threshing operation, the grain and chaff are thrown around the periphery and strike the inside of the top cover walls. The grain and chaff then fall on to the rotating flat circular screen. The grain drops through the screen openings and the straw is radially pushed out by the two spring steel wire prongs mounted on the threshing surface. Radial fan blades are mounted on the underside of the threshing surface to blow a radial air stream just below the screen. The material falling through the screen is winnowed and chaff, dirt, and straw are blown out of the peripheral opening. Clean grain drops on a stationary circular pan where it is swept to the delivery spout by two rubber flaps attached to the underside of the screen.

The new machine concept is simple in design with only two major rotating components. It is a relatively lighter machine and would be cheaper to manufacture than the drum-type thresher. This type of thresher, however, requires more ground area for threshing than the drum-type thresher. This is because of the radial arrangement of the paddy stacks and the radial location of the thresher operators.

Field tests were conducted at the IRRI Experimental Farm in December, 1968. Table 1 shows the preliminary test results on two rice varieties. The output of the machine and the non-recoverable threshing losses were measured during the test. Average output for four operators was 228.80 kg/hr. The non-recoverable threshing loss, which is the grain left unthreshed on the panicles, was 1.18% of the machine output. The average fuel consumption of the table-type thresher was 0.67 liter per hour, which is about two-thirds of the consumption of the drum-type thresher. Since both machines are equipped with identical 4.2-hp engines, the test indicate a lower power consumption for the table-type thresher. Trials with a smaller engine will be conducted to further reduce the cost of this thresher. Additional design work is planned to deliver the chaff and straw at a single location rather than all around the periphery of the machine.

The machine has demonstrated excellent performance during the initial trials and because of the simple design and lower costs it offers possibilities of wider acceptance than the drum-type thresher. Extensive field trials, in the Philippines and other tropical countries, will be undertaken after the satisfactory completion of the final prototype machine. It is hoped that the machine will be released for commercial production by the end of 1969.

TRACTOR TILLAGE AND MOBILITY STUDY

Results of the IRRI experimental rotary tiller tests under relatively hard and soft soil conditions have been reported earlier. The study indicated that slower tiller blade peripheral velocity or higher tractor travel speed decreases the tractor rear wheel slippage under both soft and hard soil conditions. An increase in the tilling pitch (Fig. 6) increases the pushing reaction and results in a decreased tractor wheel slippage.

It is generally known that the sharp tilling blades cut the soil with less soil reaction thus providing less flotation and pushing force to the tractor. The machine used in the earlier tests consisted of six alternate tilling and supporting blades spaced 12 cm apart on the four sections of rotor. In order to increase the horizontal and upward soil reaction, it was decided to remove all the six tilling blades from each section of the IRRI rotary tiller. This doubled the pitch of cut for the same tiller blade velocity and tractor travel speed. The increased spacing between the blades helped to shed the mud out of the rotor and reduced rotor clogging.

The tractor rear wheel slippage was measured at the different combinations of the tractor travel speed and the rotary tiller blade velocities. Four rubber-tipped crown type cage wheels were fitted to the tractor rear wheels as in the case of the tests reported earlier. To simplify the tests, the tractor 2nd travel speed the rotary tiller 2nd gear were skipped during these tests. The machine was tested under extremely soft soil conditions with only six supporting blades in each section of the rotor. The experimental field conditions and the test results are recorded in Table 2 and plotted in Figs. 7 and 8.

The field used in this test was plowed and puddled 40 days prior to the test. The field was flooded to a 5-cm depth at the time of the test. In the previous tests included in the Substantive Report No. 6, the fields were flooded without any prior tillage. The soil conditions during this test were much softer than the previous tests, resulting in increased tractor wheel sinkage and tilling depth. The difference in the soil conditions is shown by the 100% tractor wheel slippage during operation with the trailed rotary tiller although the penetrometer depth did not indicate too much difference from the previous tests.

Fig. 7 shows the relationship between the tractor travel speed and rear wheel slippage at the different operating conditions of the tiller. The slippage on the rear wheels was excessively high throughout the tests and a 100% slippage occurred whenever the PTO was disengaged. One of the reasons seems to be the high rolling resistance of the wheels due to the excessive sinkage in the softer soil conditions. The other reason seems that in spite of the larger pitch of cut the supporting blades did not provide sufficient horizontal pushing force. This may be because the supporting blades make a smaller rake angle, Fig. 6 , with the ground and slip on the soil surface without penetrating the soil like the tilling blades. It seems that relatively larger rake angle of the blades is more effective for improving pushing reaction in the extremely soft soil condition. Fig. 7 also shows an increase of wheel slippage whenever the tractor speed was increased. This result differs from the earlier tests on

this machine. Further tests are necessary to study the reason for this difference.

Fig. 8 shows the relation between the tiller blade velocity and the rear wheel slippage under different tractor travel speeds. The slower blade velocity decreased the wheel slippage whenever the tractor was traveling in the 1st and 3rd speeds. However, when traveling in the high tractor travel speed (4th gear), the tiller blade velocity had no significant effect on the rear wheel slippage. This result shows that under relatively slower tractor travel speeds, increasing pitch of cut by decreasing peripheral blade velocity will improve the pushing force even under very soft soil conditions.

The high wheel slippage in the higher tractor travel speed under the extremely soft soil conditions was a marked departure from the earlier test results. High rolling resistance due to excessive wheel sinkage and cohesion of sticky clay soil may have contributed to the high wheel slippage. The data shown in Fig. 8 indicate that the lower peripheral velocity of the tiller blade becomes effective in pushing the tractor when tractor speeds are slow. This suggests the possibility of further reducing the blade velocity to bring it close to the tractor travel speed in the low gear to achieve maximum mobility characteristics. Further study with the rotary blade velocity close to the tractor travel speed is planned by using a stepless hydraulic drive for the rotary tiller.

Since the blade angle of the rotary tiller was fixed at 45° from the tangent, the effect of blade angle on the pushing force was not studied in this experiment. A new IRRI rotary tiller was fabricated, Fig.9 , with eight adjustable angle blades in five sections. The tiller rotor has a 0.85 m diameter and 1.6 m tilling width, and the machine weighs 450 kg. The blades consist of 12" x 6-1/2" x 1/8" flat steel plates reinforced with 3/4" x 1/8" angle iron on the tilling edges. The angle of the blades can be changed by selecting the proper bolt hole positions, thus permitting four different angle positions of 10°, 30°, 50°, and 70° from the rotor radius. This IRRI rotary tiller with adjustable angle blade will be field tested to find the optimum blade angle and optimum peripheral blade velocity for maximum forward and upward reaction under soft soil conditions.

USE OF MECHANICAL POWER FOR ROTARY WEEDING

The development of a 3-row power weeder has been reported earlier. During preliminary trials, problems were encountered with the plant guide shields. Lighter but rigid guide shields (Fig.10) were developed for the 3-row weeder. The weight of the 3-row weeder with the new guide shields was 19 kg, a reduction of 5 kg from the older design.

A new 5-row power weeder was designed using the new type of plant guide shields. The weight of the 5-row machine was 27 kg. During the preliminary trials, it was found that the machine was too heavy and difficult to operate. Due to the operation problem, test and evaluation work was concentrated on the 3-row machine.

IRRI Power Weeder Test 1968 Dry Season

During the 1968 dry season, the portable 3-row IRRI power weeder (Fig. 10), was tested on rice at different stages of growth. This was done to determine whether the 5 inches rotor axle clearance was sufficient for the plants to bend and pass under the axle without any significant damage.

Table 3 lists the plant age, plant height, rate of weeding, fuel consumption, and the number of hills damaged during one weeding operation. The test indicated that the machine required an average of 15.84 man-hours to weed a hectare and a fuel consumption of 0.70 liter per hour (11.09 liters/ha). The ideal plant age to avoid physical damage during weeding ranges from 22 to 38 days after transplanting.

Comparative Evaluation of IRRI Power Weeder 1968 Wet Season

An experiment was conducted during the 1968 wet season to compare IRRI power weeder performance with the commonly practiced and recommended weeding methods under the lowland conditions. The experiment evaluated the rice yields, weed growth, and the plant damage caused by the weeders. Two varieties, Chianung 242 and IR8-68, were transplanted in a field which was subdivided into plots with a one-meter strip in between for the mechanical weeder application. Plots with herbicide treatments were enclosed with levees to avoid diffusion of chemical to adjacent plots. The field was fertilized during the last harrowing operation with 70 kg of ammonium sulfate. Grass was seeded two days after the fertilizer application. Standard water management and optimum pest control were practiced during the test.

Observations of control plots indicated that only a few grass seeds germinated. It seems that the broadleaf Monochoria Vaginalis (L) Presl. outgrew in competition with grass due to its early stand.

Fig. 11 and 12 show a comparative evaluation of different weeding methods on tiller and weed count at 45 days after transplanting. Highly significant difference of weed population was observed between the control and treated plots. The experiment indicated that the mechanical treatments (1 to 8) had more weeds than the herbicide treatments. Among the mechanical methods of weeding, namely, manual, manual rotary weeding, and power weeding, no significant difference was observed. There was a fairly uniform number of tillers per square meter. This indicates that the number of tillers damaged during weeding was minimal.

Rice yields, weed weights at harvest, and other data are shown in Table 4 . Plots treated with MCPA followed by the IRRI power weeder gave the highest yield. They also gave the highest increase in rough rice net of weeding cost. The most expensive weed control treatments were hand weeding and manual rotary weeding.

APPLICATION OF ANHYDROUS AMMONIA WITH SMALL TRACTORS

The development of an anhydrous ammonia applicator for small tractors

was reported in the last progress report. Except for some applicator shank modifications, no major design change was made during this period. The applicator has been calibrated and is in readiness for use in experimental work by the IRRI Agronomy Department during the 1969 dry season. The contract engineering personnel will study the machine performance during this period and make necessary design improvements.

PHYSICAL PROPERTIES OF THE RICE PLANT AND PADDY

The department is engaged in the development of harvesting and threshing equipment for use in the tropical countries. Basic information on the physical properties of paddy and the rice plants is needed for the development of such equipment. The lack of information in this area prompted the initiation of a study on the forces required to: (a) separate paddy from the panicle, (b) separate the panicles from the stalk, (c) pull the individual tillers from the ground, and (d) pull the whole plant from the ground.

Eight varieties of rice (IR8, Bluebonnet 50, C_4-63, T(N)1, 81B-25, IR5, BPI-76, and ADT-27) were transplanted at staggered dates in June and July, 1968 to mature simultaneously on October 7, 1968. Variety ADT-27 matured much earlier than the others and was not included in the test. Tests were conducted at seven different dates, September 26, 30, October 3, 7, 11, 14, and 19, 1968 to assess the effect of plant maturity and moisture content on the required forces.

Experimental Equipment and Procedures

A. Separation of Paddy from Panicle

Detachment of the paddy from the panicle occurs when the applied force exceeds the restraining force. This detaching force was applied by rapidly accelerating the panicle following a definite radial path.

An experimental non-impulsive centrifugal threshing device was built to thresh 10 panicles at a time (Fig. 13). The device consisted of a circular metal disc, mounted horizontally on a vertical shaft. The circular disc was fitted with 10 clamps for holding individual panicles. The shaft and the disc was driven by a 1-HP electric motor through a variable speed drive. The rotation of the disc could be varied from 1000 to 3500 rpm. A circular flexible plastic shroud was hung around the disc to catch the paddy which was detached and thrown from the panicle. An inclined sheet metal pan was fitted below the shroud to enable the continuous collection of threshed paddy during the test.

Ten panicles of each variety were clamped to the rotary disc by hand for each test. The panicles extended to an average radii (mts.) of 0.31785 (IR8), 0.35335 (Bluebonnet 50), 0.31620 (C_4-63), 0.31905 (T(N)1), 0.33150 (81B-25), 0.31810 (IR5), and 0.32690 (BPI-76). The samples were rotated at speeds of 1000, 1500, 2000, 2500, 3000, and 3500 rpm, subjecting the paddy grains to accelerations of 364, 820, 1458, 2278, 3281, and 4466 g, respectively.

The grain threshed at each speed increment was collected and the following data was recorded:

1. Total weight of threshed paddy;
2. Number of individual paddy grain;
3. Moisture content of paddy as determined by oven drying.

The weight of threshed paddy at any speed increment was divided by the total paddy in the sample to determine the percent of paddy threshed at each speed increment.

The threshing force was determined with the use of the equation,

$$F = 3.99433\ WgRN_c^2$$

a metric equivalent of the one developed by B. J. Lamp, Jr. and W. F. Buchele[1/],

where:

F = threshing force
Wg = grain weight, kg
R = average radius of panicle, mts
N_c = revolutions of disc per second.

B. Panicle, Tiller, and Plant Strength

A simple, tripod-mounted crank and pulley device with a spring scale fitted flexible wire (Fig. 14) was used to pull the individual panicles, tillers and whole plants. A piece of string (or rope) with a noose was attached to the scale to firmly hold the panicle, tiller, or the whole plant. The crank was manually turned at a steady rate during the tests.

Normal panicles and corresponding tillers from ten plants and ten additional whole plants from each variety were pulled at the rate of 0.45 m/sec. This rate of pulling was used because it would be the approximate forward speed of a stripper harvester combine being developed in the Department. Individual values and their corresponding averages were recorded.

Results and Conclusions

A. Separation of Paddy from Panicle

1. Figs. 15, 16, 17, 18, 19, 20, and 21 show the relationship of threshing force versus paddy threshed for the different varieties tested at seven different stages of maturity and moisture levels. As expected within a variety, the higher moisture content paddy required a larger threshing force. The upper moisture limits and the force required to thresh 98% of paddy for the tested varieties are shown in Table 5.

There is a marked difference in threshability among the many varieties tested in this study, the order being -

81B-25 > Bluebonnet 50 > IR8 > C_4-63 > T(N)1 > BPI-76 > IR5

[1/] Lamp, B. J. and W. F. Buchele. "Centrifugal Threshing of Small Grains." Transaction of the ASAE, Vol. 3, No. 2. 1960.

Even at approximately the same grain moisture levels, the forces required for threshing vary among varieties. There was prevalent breakage of the panicle with the variety T(N)1, indicating a relatively weak straw.

A force of 0.075 kg is sufficient to thresh 98 percent of paddy under all typical harvesting conditions for these varieties.

There is evidence of paddy selection by weight in a centrifugal threshing device. The heavier (apparently more mature) kernels were threshed at the lower speeds, i. e., lesser forces. In a germination test conducted with the IR8 variety, the heavier kernels threshed at lesser forces exhibited higher viability as compared to the lighter kernels which were threshed at higher forces and the hand-threshed control sample. Table 6 and Fig. 22 show the relationship between grain weight and germination. This observation indicates that a centrifugal threshing device may be more useful for seed threshing purposes than the conventional machines.

B. Panicle, Tiller, and Plant Strength

Straw with extreme moisture levels were more susceptible to breakage as evident in Tables 7, 8, and 9. There are varietal differences with respect to straw strength. The varieties are in the following order as regards to:

Panicle Strength

BPI-76 > B'bonnet 50 > C_4-63 > 81B-25 > IR8 > IR5 > T(N)1

Tiller Strength

B'bonnet 50 > 81B-25 > IR5 > BPI-76 > IR8 > C_4-63 > T(N)1

Whole Plant Uprooting Force

B'bonnet 50 > 81B-25 > BPI-76 > IR5 > IR8 > C_4-63 > T(N)1

Irrespective of variety, nearly 50% of the plants pulled on September 26 were completely uprooted without severing the root from the plant. However of the plants pulled on October 19, nearly 10 percent were uprooted and the rest were severed at the base leaving the stumps in the ground. The progressive hardening of the soil and the change in the straw strength due to late rest seems to have contributed to this difference.

Pulling force was at a maximum for panicle, tiller, and whole plant at the same date, October 7, 1968. Thus the maximum panicle, tiller, and whole plant pulling force was recorded on the 107th day for Bluebonnet 50; the 112th day for T(N)1; the 116th day for IR8; the 122nd day for BPI-76 and C_4-63; and the 129th day for IR5 and 81B-25.

DEVELOPMENT OF A PADDY STRIPPER COMBINE

The design and development of a stripper combine for paddy was initiated during the year. Efficient handling of paddy from the field to the storage has always intrigued engineers. It was felt that the current practice of harvesting and then threshing creates many difficulties to the tropical farmer and results in excessive grain losses.

The use of conventional combine harvesters have not found widespread acceptance in the tropical areas. The large conventional combines are too expensive for the small farmers in the tropics and the weight of such machines creates severe mobility problems in the wet paddy fields. Japanese manufacturers have introduced smaller conventional type combines but these machines also encounter similar problem in the tropical countries.

A conventional combine consists of four different sections, namely, a cutterbar, an elevator mechanism, a threshing cylinder, and a grain-straw separating section. A stripper combine, which would thresh directly from standing crop, could dispense with the cutterbar and the elevator mechanism of a conventional combine. Such a design will permit light-weight, low-cost machines which could be better suited for harvesting rice in the wet tropical countries.

Attempts have been made in many countries, notably the United States, the United Kingdom, Australia, Japan, and Taiwan, to design stripper harvesters for rice and other crops. Serious field scattering losses have been one of the major problems being encountered in these experiments. The concept being used in the design and development of a stripper harvester combine at the International Rice Research Institute is specially directed towards solving this major problem of excessive grain loss.

The first experimental machine (Fig. 23) will be offset-mounted on a 6-hp walking tractor. Fig. 24 shows the schematic drawing of the stripper in action. The experimental machine is designed to first bend the rice plants backward for stripping the grain on a threshing belt. During the forward motion of the machine, the plants would continually unwrap out of the machine after the stripping action.

The machine basically differs from other stripper harvester designs in gently bending the plant prior to the threshing action. This feature can improve the collection of threshed grain and could reduce the problem of grain scatter loss encountered with other stripper designs. The first experimental machine is designed without a straw-grain cleaning system. A rotary screen cleaner will be added to the machine after the stripping mechanism has been developed. A self-propelled stripper harvester combine, using its own engine and transmission, will be eventually developed to offer a practical

field machine. There is widespread interest in a stripper combine for not only rice but other crops among the manufacturers in the industrialized countries. If a successful stripper harvester combine could be developed for rice, the techniques learned could be applied in the development of combine harvesters for other crops. A successful development of a stripper combine can be useful not only for the developing countries but also for the advanced countries.

ROTARY HARROW FOR SMALL TRACTORS

The use of small walking tractors with comb harrow (Fig. 25) is gaining popularity among the rice-growing farmers in the tropics. A comb harrow, however, results in excessive resistance to tractor movement in the field due to the collection of vegetative matter on the spikes of the harrow. It has also been observed that the comb harrow can only produce a scratching-type action without sufficient burying effect.

A project was initiated to study the use of a rotary harrow in place of a comb harrow for faster harrowing and better incorporation of vegetative matter into the soil. An experimental rotary harrow (Fig. 26) which can be attached to a small walking tractor was fabricated to evaluate this possibility. The construction of the rotary harrow was similar to a conventional cage wheel used with small tractors. It had 12 flat steel bars, 15 cm wide and 0.4 cm thick, welded to three circular structural members at a 45° angle from the tangent. The total weight of the rotary harrow was 38 kg as compared to 11 kg of a conventional comb harrow.

In the preliminary field trials, the rotary harrow could puddle and bury the weeds well in the flooded fields. The field was puddled about two weeks prior to this test. The average WES cone penetrometer[2/] readings were 20 cm at 35 psi and 25 cm at 70 psi. Table 10 shows the results of comparison tests of the rotary harrow and the conventional comb harrow. While the time required to till a certain land area was not significantly different, the fuel consumption for the rotary harrow was less than that for the comb harrow.

In trials under softer soil conditions, where the average WES cone penetrometer readings were 40 cm at 35 psi and 50 cm at 70 psi, the rotary harrow was not successful due to excessive bogging.

[2/] A 30° angle cone with 3.2 cm^2 of base area.

It was felt that a rotary harrow with a hollow drum would increase flotation and reduce the bogging problem. A 110-cm long, 33-cm diameter hollow sheet metal drum with 94.1 liter volume was placed inside the rotary harrow. This added a total of 18 kg to the weight of the rotary harrow. This rotary harrow with drum was tried in a puddled field with 10 cm water and the harrow exhibited adequate flotation to keep the tractor from bogging.

The rotary harrow with drum was compared with the conventional comb harrow in two 1/8 ha plots (25 m x 50 m rectangular plots) and the results are recorded in Table 11. The harrowing depth was 10 cm for both implements. Four passes were needed to achieve adequate soil condition for transplanting with both the harrows. The fuel consumption and time required for the rotary harrow with drum was more than the comb harrow in this test. It was, however, observed that with the rotary harrow with drum, the downward pushing effect of the rotating blades buried the weeds better than the comb harrow. The comb harrow indicated better soil breaking than the rotary harrow with drum due to the scratching operation from the spikes. Under a uniform soil condition the operation of the rotary harrow with drum was easier than the comb harrow since the operator did not support the handles to counteract the axle torque reaction.

While in certain field conditions the rotary harrows exhibited some advantages, the economy and performance did not clearly justify the higher cost of the rotary harrow. More tests and further design modifications may have to be done to evaluate the advantages ofthe rotary harrow under different conditions.

POWER REQUIREMENT FOR WETLAND ROTARY TILLAGE

The 30-60 HP tractor PTO driven rotary tillers are gaining popularity in the tropical countries for wetland preparation on larger holdings. These machines offer several advantages for wetland operation. Since most of the power is transmitted directly to the soil through the tractor PTO rather than the drawbar, power loss due to poor traction efficiency is minimized. The rotary tiller operation produces excellent soil breakage and puddling effect in clayey soils and results in less number of passes during land preparation. Frequently tractor PTO shaft failures have been encountered during the rotary tiller operations in the rice paddies. A good knowledge of the power transmitted through the tractor PTO shaft, during rotary tiller operations under tropical conditions, is essential to tractor design engineers.

A study was therefore initiated to study the power requirement for land preparation with rotary tillers under dry and wet field condtions at IRRI This project was also undertaken to study the relative power distribution between soil tillage and tractor mobility by measuring simultaneously the power transmitted through the PTO to the rotary tiller and through the tractor rear axles. This information could be useful for proper selection and design of tractors and rotary tillers for paddy cultivation.

A 2.8 m wide rotary tiller, fabricated at IRRI with Japanese-type rotary

tiller blade, was used during this study. The rotary tiller was mounted on a 55-HP conventional tractor equipped with a hydrostatic transmission to the rear wheels. The first portion of the test was conducted on upland field conditions to establish the PTO torque at the most severe operative condition. The soil was so hard and dry that the WES cone penetrometer did not penetrate at all at 70 psi. The PTO torque and tractor rear axle torque were recorded simultaneously by a two-channel strip recorder (Fig. 27(a)) mounted on the tractor. Biaxial strain gages (90°) were mounted on the female portion of the PTO shaft for sensing the torque. The signal was transmitted to the recorder through a slip ring assembly (Fig. 27(b)).

A strain gage pressure transducer was used to record the input-output differential pressure of the hydraulic motor powering the tractor rear wheels. Calibration curve was drawn from tests conducted to establish torque pressure relationship. The pressure was converted into rear wheel torque by the calibration curve. The PTO rpm was calculated from the indicated rpm on the engine speed indicator. During the field tests, the three-point linkage mounted rotary tiller was gradually lowered into the ground only after the tractor forward travel speed had stabilized. Attempts were made to maintain tilling depths of 12 cm to 15 cm by controlling the hydraulic lift lever. It was found that the tilling depths had to be reduced in the very hard portions of the fields due to the power limitations of the engine.

Fig. 28 shows a typical recorder chart. The upper line indicates the rear axle drive pressure and the lower line the PTO torque for driving the rotary tiller. The recording chart speed was 5 mm/sec. Prior to the start of the tilling operation, the chart indicated some torque on the rear axles which was consumed in moving the tractor across the field and no torque on the rotary tiller. When the rotary tiller was lowered and it engaged the soil, the rear axle torque was reduced while the PTO torque increased abruptly. It was seen that the fluctuation of torque occurring on the PTO shaft was of relatively high frequency.

The torque and power requirement for tilling and traveling are shown in Table 12 under several (test) operating conditions. The average torque of the PTO shaft varied from 43.8 kg m to 62.3 kg m depending on the tilling condition. The highest PTO torque of 62.3 kg.m. and power requirement of 47.0 HP was recorded at the highest tractor travel speed and at 540 PTO rpm. At the slowest tractor speed and high PTO speed (540 rpm), the lowest PTO torque was observed. For the same PTO speed of 540 rpm, a change in the tractor forward travel speed of 177% resulted in 139% change in power requirement at the PTO, indicating that faster tractor travel speeds or increased tilling pitch reduced power requirement. It was also noted that for the same tractor speed (treatment Nos. 1 and 2) the PTO torque was higher when the rotary tiller speed was slow, even though the depth of tilling was less by 1 cm in treatment No. 2. This shows that torque was increased by an increase in the pitch of cut.

The large tilling pitch increased the soil reaction on the machine, resulting in an increased torque, whereas power requirement was reduced by an increase in the pitch of cut. These phenomena indicate that an increased pitch of cut results in higher torque but lower power consumption. The rear axle

torque for tractor travel without using the rotary tiller varied from 330 kg-m to 460 kg-m, and power requirement was 2.5 hp to 5.1 hp. Whenever the rotary tiller was tilling in hard soil conditions, the torque on the tractor rear axles was reduced to a range of 0.6 hp to 1.4 hp due to the pushing effect of the rotary tiller. The following items can be summarized from the preliminary experiment:

1. During the rotary tiller operation under hard soil conditions, most of the tractor engine power was transmitted through the PTO shaft and a small torque appeared on the tractor rear axle.

2. Considerably high torque appeared on the PTO shaft during tilling operation. Generally increased tilling pitch results in high torque and lower power consumption but it also produces coarser tillage.

Further tests under soft soil conditions will be made in the future.

ROW SEEDER FOR LOWLAND RICE

Paddy transplanting is widely practiced in most tropical countries. However, in countries with larger farm holdings and high labor costs, direct seeding of paddy in rows would be preferable over the present transplanting methods. Direct seeding in rows reduces the cost of planting lowland rice by eliminating the costs involved in growing, pulling and transplanting the seedlings. Generally, direct seeded rice matures 7 to 10 days earlier than transplanted rice. Equipment for direct seeding of paddy in rows under lowland conditions is not available. A study was, therefore, initiated to investigate the possibility of developing suitable direct seeding equipment for lowland paddy cultivation.

A major problem with direct seeded rice is that it does not have enough of a headstart to outgrow the weeds like the transplanted rice. To overcome this problem, pre-germinated rice is seeded by hand broadcast methods in some tropical rice growing regions. It was, therefore, decided to develop a mechanical row seeder for pre-germinated paddy under lowland conditions.

A seeder has two basic functions. First, metering of the seed from a bulk supply, and second, conveying and placing the metered seed at a desirable location in the soil. The metering of pre-germinated paddy seeds poses considerable problems due to the mechanical damage susceptibility of pre-germinated seeds. Excessive agitation and high seed pressure in the hopper can destroy the growing embryo of the pre-germinated seed. The seed hopper should have a minimum of moving parts to provide only the minimum agitation for continuous flow of the seeds. The size of the hopper should not be too large to build up excessive pressure between the seeds and the hopper walls. The metering mechanism should be adjustable for the different seeding rates and should distribute the seeds evenly into the individual seed tubes. Present seed metering mechanisms for non-germinated seeds do not meet the special requirements of pre-germinated seeds.

The placement of seeds under lowland conditions also poses a number of

challenging problems. In order to avoid seed damage from pre- emergence herbicide application, rats, birds, algae and other pests, it is desirable to embed the seed in the mud just below the surface. The clogging of seed tubes under lowland condition and the covering of the seed after placement are both severe problems which need special attention. A large conventional tractor mounted seeder will create problems of uneven seedbed due to wheel tracks and uneven rows due to wave action. It would also require headland for turning at the end of the fields. For these reasons it was decided that initial work should be done on a portable row seeder which will simplify many of the placement problems of tractor mounted seeder.

An eight-row portable seeder was built to study the problem of seeding rice in lowland. The manually operated metering device was used and it showed little difference in seed distribution within a row and in between rows. The rate of seeding ranged from 30 to 40 kg/ha (Tables 13 and 14) and it required 40 to 45 manhours/ha when sowing in 25-cm row spacing with a hill spacing of 25 cm.

A second seeder with additional features for better accuracy in seed metering and adjustable row spacing is being developed.

WORK PLAN
AGRICULTURAL MACHINERY RESEARCH
January 1, 1969 to December 31, 1969

The contract is due to terminate in June, 1969. Negotiation for a new contract on machinery development is underway. This work plan is based on the assumption that work on the development of rice machinery will continue beyond June, 1969. The following developments are proposed for this coming year:

1. Development of the Drum Thresher

Work will be continued on improving the models of threshers being manufactured in the Philippines. Quite a few of these threshers have been shipped, or are in the process of being shipped, to other tropical countries. The contract personnel will have to study the test reports on these threshers and may have to recommend design modifications to suit the local conditions in these countries. On a satisfactory completion of these trials in various tropical countries, local manufacturing will be encouraged. The different levels of manufacturing know-how in each tropical country may require some design modifications to suit each country's manufacturing requirements. The contract engineering personnel may have to spend some time in each country to provide technical assistance in the early stages of local manufacture. An operation and service manual will be prepared on this machine.

2. Development of the Table Thresher

In the second prototype table thresher, the chaff and straw are delivered all around its periphery. It would be desirable to deliver the chaff and straw to one convenient location. A third prototype thresher will be built to improve the chaff delivery. The drawings of this third prototype machine are ready but work has been held up due to heavy shop schedule. The third prototype would be completed and tested during this period. On a satisfactory completion of the third prototype, extensive field evaluation would be undertaken in the Philippines. Additional machines would be acquired from interested local manufacturers for evaluation in the Philippines and other tropical countries.

3. Tractor Tillage and Mobility Studies

A second IRRI experimental wetland rotary tiller with adjustable angle blades has been fabricated. This tiller will be tested under soft soil conditions to study the effect of blade angle and blade velocity on the upward and horizontal soil reaction. A strain gage transducer will be used for measuring the pushing reaction and the power requirement of this rotary tiller.

A hydrostatic transmission has been ordered for driving the rotary tiller from the tractor. This would provide stepless variable tiller speeds. With this transmission, it would be possible to reduce the tiller blade velocity to approximately equal the tractor travel speed for maximum mobility characteristics or to increase it to approach a conventional rotary tiller blade velocity for optimum tillage characteristics. It would also permit an on-the-go change in the tiller blade velocity, thus enabling the tractor operator to select the

best speed for each field condition while operating the machine.

4. Application of Anhydrous Ammonia with Small Tractors

The applicator attachment has been calibrated in readiness for use in experimental work by the IRRI Agronomy Department. Attempts will be made to use a larger capacity tank to permit use of this applicator on larger rice fields and to reduce the down time. A simpler discharge control valve will be used with this applicator. Extensive field tests are planned and improvements on the applicator as shortcomings appear during field operation.

5. Physical Properties of the Rice Plant and Paddy

There are three main types of threshing cylinders used for threshing different crops: (a) spike tooth, (b) rasp bar, and (c) wire loop. A study is required to evaluate the quality of threshing and the effect on the physical properties of paddy when using each kind of threshing drum. The three threshing devices primarily depend on impact for threshing; however, the degree and type of impact vary in each drum. The study will involve the construction of three experimental drums and a controlled study on threshing of paddy by the three drums at different speeds. The various physical effects will be evaluated to give a comparative performance evaluation.

6. Development of a Paddy Stripper Combine

This is a major project on harvesting-threshing and would demand considerable attention from the contract personnel over an extended period. The machine in its final form would be developed as a small self-propelled combine. The project would involve the development of machine components for four major functions: machine locomotion, grain stripping, grain-straw separation, and winnowing. The first experimental machine is intended to study and find solutions for the grain stripping problems. Once the stripping component of this machine is developed, attention would be directed to the other components. The grain stripping component would require some new solutions; however, the problems of machine locomotion, grain-straw separation, and winnowing may be solved by the application and adaptation of popular conventional methods. On a satisfactory completion of a stripper combine, extensive field evaluation would be undertaken in the Philippines.

7. Rotary Harrow for Small Tractors

The previous tests conducted on the rotary harrow did not conclusively establish the advantage or disadvantage of the rotary harrow over the comb harrow for small tractors. Further tests will be conducted to clarify the relative performance between the rotary and the comb harrow. If the rotary harrow is found to be superior in performance, then efforts will be directed to finding the optimum diameter of the rotor and the suitable blade shapes and spacings for optimum performance. Finally, a rotary harrow will be designed as a riding harrow attachment for small walking tractors.

8. Power Requirement for Wetland Rotary Tillage

Rotary tillers have gained popularity in recent years for wetland tillage. Little is known about the power requirements for rotary tillage under such conditions. Tractor manufacturers find it difficult to recommend properly matched rotary tillers for the different sizes of tractors. Power-take-off mounted strain gage type torque transducer will be used to record the PTO torques at different tractor travel speeds, tillage depths, and field conditions. Power requirements under these varying conditions will be calculated to enable a more precise matching of tractor sizes to rotary tiller widths.

Power distribution between tractor rear axle and tractor PTO during rotary tiller operation under hard upland condition has been reported in this report. A similar study for measuring tractor rear axle and rotary tiller power distribution will be conducted under the soft wetland conditions. It is felt that considerably high torque thrust and bending loads act on the tractor PTO shaft during rotary tilling operation. These forces will be measured by strain gage transducer to assist in the design of tractors for rice cultivation.

9. Row Seeder for Lowland Rice

Row seeding on flooded puddled soil has been a major problem. Equipment for seeding under such conditions is not available. It is felt that if a successful wetland seeder for pre-germinated seeds could be developed, it may perhaps replace the costly operation of transplanting. A portable 8-row seeder for pre-germinated seeds is being developed. This seeder will be tested during this planting season and attempts would be made to develop a tractor-mounted seeder using some of the features from the portable seeder.

10. Cage Wheel Studies

Tractor wheels have become a necessary equipment for wetland cultivation. A large variety of cage wheel designs have evolved in all rice-producing countries. Almost all these designs are built on a cut-and-try method. There are many basic questions which need to be studied to understand the proper actions of a cage wheel. This study is planned to investigate the optimum blade angle and the cage wheel-tire diameter relationship for improved traction under varying sinkage and soil conditions. An experimental cage wheel with adjustable blade angle has been built. The tractor rear wheel slippage at different speeds will be used as an indication of the cage wheel performance under soft wetland conditions.

PROGRESS REPORT
GENERAL ENGINEERING AND ECONOMIC RESEARCH
July 1, 1968 to December 31, 1968
SUMMARY

Research efforts in general engineering and economics were as follows:

(1) The program of thresher evaluation received primary attention; commercial models of the IRRI-developed drum paddy thresher were tested, along with as many other types of threshers as could be found. A prime consideration was to test each machine under conditions of high grain moisture content;

(2) A field experiment was initiated to compare alternative methods of weed control in paddies; preliminary data are presented on mid-season rice growth and weed conditions by type of weed control method;

(3) Data collection and analysis continued on rice farms in three large rice-producing areas in the Philippines; special emphasis was placed on seasonal farm labor use, and labor use by categories of farm workers: operator and family labor, exchange labor, and hired labor. Data was compiled on the differential impact of use of animal or machine power for land preparation.

The agricultural economist departed IRRI on November 3, 1968; he will return for a short period in 1969 to complete the terminal report of the project to date. Meanwhile, the economic research is being performed by Mr. Norberto Orcino, research assistant, under the supervision of the Institute agricultural economist and the agricultural engineer.

PRELIMINARY RESULTS FROM RICE THRESHER TESTS

The purpose of these tests is to check the capabilities of the various threshers to thresh and separate wet straw and grain, and to field test commercial models of the newly-introduced IRRI drum paddy thresher.

In general, it was found that not all threshers can thresh wet rough rice without grinding and milling the kernels, and that common dry straw separating techniques are not satisfactory when the straw is wet. And there seems to be a point (somewhere beyond 30 percent moisture content) at which no machine tested could perform.

The threshing practices in the Philippines are commonly of two kinds: one, where there are large areas of rice and where the rice matures at the end of the rainy season, the large tractor-drawn McCormick type threshing machine is used; two, threshing otherwise is accomplished by hand methods.

The sequence of operations with threshing machines ordinarily involves some delay for drying between harvesting and threshing. For wet conditions, a machine is needed that can thresh the rice immediately after harvesting so as to avoid large losses caused by the subsequent poor condition of the grain.

And in these areas where capital is short and labor relatively plentiful and low-cost, the requirements for a machine are economy of cost, simplicity of design, adaptability to local conditions, and, perhaps, local fabrication, and at least a medium output per man-hour.

The following threshers were tested:

1. IRRI drum-type paddy thresher powered by a 4.2-hp gasoline engine
2. IRRI table-type paddy thresher powered by a 4.2-hp gasoline engine
3. Japanese automatic thresher powered by a 4.2-hp gasoline engine
4. Locally made thresher Make A powered by a 10-hp diesel engine
5. Locally made thresher Make B powered by a 4.0-hp gasoline engine
6. TURNER "Economy" thresher powered by a 10-hp gasoline engine
7. Vogel thresher powered by a 10-hp gasoline engine
8. GARVIE Type DA thresher powered by a 12-hp diesel engine
9. Pedal thresher, manually operated.

The detailed specifications of the threshers are listed in Table 15. The IRRI drum thresher was simultaneously tested with the other makes of threshers in the same field and with the same paddy variety. The paddy used in the tests were freshly harvested with a grain moisture content varying from 18 percent to above 30 percent. The method of feeding differed in each machine. In the case of the IRRI drum-type paddy thresher, the 4-men pick-thresh method was employed. As in the earlier tests with this machine, good results were obtained by this method. The method of feeding for each machine is shown in Table 16.

The tests were conducted around Laguna and Isabela provinces located in the southern and the northern parts of Luzon Island in the Philippines. The duration of the tests ranged from 15 minutes to 1 hour for every trial. The data were analyzed in three categories: (1) low output when threshing very wet grain; (2) average output; and (3) high output when feeding was at the maximum possible rate. The data shown in Table 16, particularly thresher output, grain m.c., and fuel consumption, are the average results of 5 to 10 tests. The thresher output (kg/hr) is adjusted to 14 percent m.c. level.

The data in tables 16 and 17 present some preliminary results. These data refer to the more conventional statistics on output, but moisture conditions (as a percentage figure) accompany the output figures in TAble 16. These figures are not necessarily indicative of output of the machines in very dry conditions or of output obtained by very skilled operators. Further, Table 16 refers to more specific tests and is limited in scope since not all the test data were available in acceptable form for inclusion in this report. Company names have not been included. The criterion was to obtain as much field test data as possible under varying local conditions with emphasis on wet rice.

The next table (Table 17) presents some average results of these threshers in a different format under the headings of machine, power and labor performance*. These data are still tentative. The complete evaluation of equipment to date will be presented in the next report.

ECONOMICS OF USE OF DIFFERENT THRESHERS

Mechanically powered threshers are gaining popularity in the tropical rice-growing regions. Because their cost is an important item in producing farm products, farmers are often faced with the choice between buying or hiring a threshing machine. While the shortage of labor during the harvest season may induce some farmers to purchase power threshers, most farmers would be interested in the relative cost of threshing by alternate methods (like hand threshing, using pedal thresher, trampling by animals, etc.) before purchasing a thresher. They would like to know the number of hectares or hours of use needed to make the machine pay. The various types of threshers available in the market and the availability of custom threshing make it increasingly difficult to pick the best machine and method of threshing.

This study was undertaken to derive the average costs of owning and operating some of the threshers currently available in the Philippines. Such information would be helpful to farmers in thresher selection and to thresher designers in developing new threshing machines. The following analysis is primarily based onthe data gathered at IRRI from performance tests conducted on a number of threshers. The following output for the threshers was found in the tests at IRRI:

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*Format suggested by G.W. Giles, Consultant in Agricultural Engineering, College of Agricultural Engineering, Punjab Agricultural University, Ludhiana, Punjab, India.

Make of thresher	Output/hour	
	cavans	kilograms
1. IRRI drum-type paddy thresher		
Feeding method:		
a. 4-man method (2 men pick-transfer and 2 men thresh)	4.02	176.88
b. 5-man method (2 men pick-transfer and 4 men thresh)	5.70	250.80
c. 6-man method (2 men pick-transfer and 4 men thresh)	7.15	314.60
2. Japanese automatic thresher (3 men)	4.40	193.60
3. Locally made threshers, Make A (4 men)	2.66	117.04
Make B (3 men)	3.60	158.40

Thresher Costs

There are two groups of factors that affect the cost of using a thresher: (1) factors related to machine ownership, and (2) factors related to machine operation. Costs associated with the first group of factors are referred to as fixed costs and costs associated with the latter are called variable costs.

Fixed costs result from mere ownership and will be incurred whether the thresher is used or not. In determining the fixed cost associated with the thresher ownership, only the depreciation and interest on investment were considered.

Depreciation is a typical cost item. It consists of: (1) depreciation due to use, i.e., loss of service capacity due to war, and (2) time depreciation, which is independent of use and is usually due to obsolescence, rust, decay, and other factors. Depreciation can be due to time and due to use. The common practice is to handle all depreciation as a fixed cost. In our analyses, the straight-line method of computing depreciation was used. In this method, the service life of the machine is assumed, thus the yearly depreciation is:

$$\text{Depreciation} = \frac{\text{Original cost} - \text{Trade-in value}}{\text{Expected life}}$$

Annual interest costs were computed on average investment at the rate of 12 percent per annum. Average investment is half the sum of the purchase price and the resale value. Thus, the interest cost for any year is:

$$\text{Interest cost} = \frac{\left(\begin{matrix}\text{(Value of machine for)}\\ \text{(the year in question)}\end{matrix}\right) + \text{(Trade-in value)}}{2} \times 0.12$$

As stated earlier, the fixed ownership costs are based on the investment in the machine and would vary with its price.

Variable cost is directly related to machine use and includes maintenance, repairs, fuel, lubricants, and labor. No wage data for threshing operations are available because the common practice in the Philippines is to pay for threshing in kind on the basis of the weight of the paddy threshed during the the day. Therefore, the institutional agricultural wage rate of P3.50 per man-day was used in estimating labor cost. It was found that the labor

cost for the IRRI drum-type paddy thresher for the four-man, five-man, and the six-man method of feeding would be ₱1.75, ₱2.19, and ₱2.62 per hour, respectively (Table 18). Table 18 also shows the hourly operating cost of the other threshers.

Total costs were calculated for assumed number of hours of use over the estimated life of the machines. The fixed, variable, and total costs for the threshers are shown in Table 19. The hourly operating costs are shown in Table 20 for a wide range of hours of use.

To establish the economic feasibility of use of each machine, the break-even point for the number of hours of operation was calculated by the following formula:

$$B/E = \frac{FC}{TR-TVC}$$

where:

B/E = number of hours of operation to break even with current threshing practices

FC = fixed cost

TR = total returns ("custom rate" which is 5% of output times price per cavan)

TVC = total variable cost (hourly operating cost)

The results are given below:

Machine	Break-even (hours)
A. IRRI Paddy Thresher	
1. Four-man method	2062
2. Five-man method	1612
3. Six-man method	1104
B. Japanese Automatic Thresher	3445

The break-even point computations show that on the average, the choice of thresher will greatly depend upon utilization. To elucidate this point, let us turn to the IRRI drum-type paddy thresher. The average total cost per hour curves on the IRRI drum-type thresher are shown in Fig.29 . On the assumption that the custom rate for threshing is 5 percent of the threshing output (which is a typical threshing rate in the Philippines), the break-even point for the four-man, five-man, and six-man feeding method would be about 2062, 1612, and 1104 hours, respectively. This is based on a ₱17 per cavan (44 kg) price of paddy (rough rice). The price of paddy would have a marked influence on the break-even point and it may be attained earlier or later depending upon the direction of change in the price of paddy. Although the cost per hour increases considerably with the number of men used for feeding, the increase is sufficiently justified by the higher returns.

A wage rate of P3.50 per man-day has been assumed, however, wages may be lower in some areas than others. Figure 29 illustrates this possibility. With a custom threshing rate of P4.84 per hour, the break-even point for the five-man method is about 1612 hours. In other words, at this number of hours of use the threshing cost is the same by either method - owning the paddy thresher or custom threshing. Thus, with the five-man method, the least cost alternative is custom threshing up to 1612 hours. To generalize the analysis, various wage rates were substituted into the equation,

$$C = F/A + V + L$$

where:

C = custom rate per hour
F = fixed cost
A = break-even point in hours
V = operating costs per hour
L = labor cost per hour

Figure 30 shows the various combinations of labor wage and hours of use for the five-man feeding method. The curve separates the zones for which it costs less to custom hire or to own the paddy thresher. For all combinations of labor cost and hours of use to the right and below the line, it costs less to own the paddy thresher. The competitive position of custom hiring is, therefore, greater at higher wage rates and more hours of use are required to justify ownership of the machine.

ECONOMIC EVALUATION OF ALTERNATE WEEDING METHODS

Straight-row planting has made possible the development of mechanical weeders. A push-type one-row rotary weeder developed in Japan is already in use in many tropical countries. As described in Reports 5 and 6, three- and five-row portable power weeders were developed at IRRI, utilizing light air-cooled gasoline engines. In order to test the IRRI machines and make comparisons with the other weed control methods, a weeding experiment was conducted. The plot layout for the experiment is presented in Fig. 31. Two varieties of rice were planted in three replications. The treatments consist of the following weed control methods: (1) hand weeding, (2) push-type one-row rotary weeder, (3) IRRI portable portable power weeder, (4) herbicides MCPA, EPTC + MCPA, Trifluralin + MCPA, and Nitrofen + 2-4D, and (5) control (no weeding).

The partial budgeting technique was used to evaluate some of the weed control methods employed in this experiment. This method focused attention only on those variables which were expected to change during the particular period and involved the estimation of the possible changes in costs and returns during the specified period. It must be emphasized, however, that the budget examples, presented in Table 21, are suggestive rather than definitive. For one thing, cropping pattern, season, weather conditions, etc. are expected to affect the time for weeding.

An economic analysis of the experimental results served two major purposes. First, it enabled the selection from among several trials of those which should be tested further. Second, it resulted in a preliminary evaluation of results which should be made available to extension workers for transmitting new practices to farmers.

SURVEY DATA COLLECTION

Data collection was continued in three large rice areas of the Philippines. Crop management data were collected on a weekly basis and interviews were conducted with farm operators. However, at the time of the departure of the agricultural economist, much of the data had not been collected and analyzed. These data will be presented in the next report.

Differential effect of the use of the small 4- to 6-hp hand tractor and the carabao for land preparation

Data from the Central Luzon-Laguna Province surveys are presented in Table 25. The 115 farms included in the surveys are grouped into categories of rainfall-dependent and irrigated two-crop farms. Each type of farm is analyzed according to land preparation power source: carabao, hand tractor, or a combination of use of the two.

The farms using only carabao were not only rainfed but smaller, on the average being 2.4 hectares, while the two-crop farms were 41 hectares. The difference between sizes of farms using machines and carabaos on irrigated farms, however, was not great.

The expectation that farmers use either animals or tractors exclusively was not borne out on irrigated farms. The largest category was a combination of machines and animals. Thus farms using tractors have not discarded the animal. The most common practice is to use both, as the animal is useful in preparing land up against the levees, corners, and in odd-shaped fields.

As expected, the number of man-hours for land preparation was greatest on farms using only animals. However, the range in man-hours is not as great as that of the experimental data. The experimental data obtained from fields at IRRI were based on the premise that the fields were to be prepared at the same level of "finish" as that required by a farmer in the province. The data in Report 5 lis 11-20 animal-days (8-hour basis) and 2.8-4.0 tractor-days total per hectare. Thus, while animal use is within the range of experimental time, the number of days of tractor use was twice that considered necessary.

The typical frequency of operations is one plowing followed by three harrowings. Note that it is customary to make two passes over the field with each harrowing. There is a further pattern in irrigated farms to plow twice and harrow twice. This is noteworthy since the hand tractor has the greatest advantage over the animal in harrowing rather than in plowing.

Yields as reported by farmers for their total farms are listed. The varieties have been divided into three categories: improved varieties such as IR8, local varieties that are common in Central Luzon such as Intan, and all other varieties. Some of the yields were omitted when the number of fields in that class of varieties was too small to be indicative of any average.

Two comments should be made about the varieties. First, notice that no rainfall-dependent farm had grown an improved variety. All of the improved varieties listed are on irrigated farms. Perhaps this sample is too small to be indicative of any wide trend, but the next report will pursue this possible trend further. If there is a general tendency for rainfall-dependent farms to stay with traditional varieties, then this is an important factor to study in predicting the spread of innovations. The second comment is that there is a large difference in reported yields between improved and other varieties.

WORK PLAN
January 1, 1969 to June 28, 1969
GENERAL ENGINEERING AND ECONOMIC RESEARCH

The agricultural economist departed IRRI on November 3, 1968 to return to his previous position. He will return in May 1969 to complete the terminal report of the AID Contract csd-834, due to terminate June 28, 1969.

The terminal report will include complete reports on:

(1) Performance and economics of use of harvesting-threshing equipment in Southeast Asia;

(2) Performance and economics of use of power units in Southeast Asia;

(3) Economics of use of mechanical and chemical methods of weed control;

(4) Machinery cost and the cost of producing rice;

(5) Analysis of farm management surveys in three rice areas of the Philippines, 1966-1968; and

(6) Impact of mechanization on traditional agriculture: cost of production, size of farm, capital structure, labor force adjustments, and the movement from subsistence-type to commercial farming.

Further plans for general engineering and economic research after this date will be presented in the next (terminal) report, or in a separate report.

PROJECT PERSONNEL

Personnel and their respective man-months engaged in the project for the past six months, July 1 to December 31, 1968, are presented below. Anticipated personnel needs for the coming year are presented in the last two columns in man-months.

Name	Category	Actual July 1 to Dec. 31, 1968	Projected Jan. 1 to June 30/69	Projected July 1 to Dec. 31/69
		(man-months)		
1 Amir U. Khan	Agr. Engineer	6	4.5	4.5
2 Stanley S. Johnson	Agr. Economist	4	3	0
3 Emilio O. Casem[1/]	Asst. Agr. Engineer	2	0	0
4 Makoto Hoki	Visiting Asst. Design Engineer	6	4	0
5 Nestor Navasero	Research Assistant	6	6	6
6 Norberto Orcino	Research Assistant	6	6	6
7 Abdul Amilhussin	Research Aide	4	3	6
8 F. C. Jalotjot[1/]	Draftsman	2	0	0
9 F. Cabrales	Draftsman	6	6	6
10 C. Ll. Jizmundo	Secretary	6	6	6
11 Videlia L. Go	Clerk-Typist	6	6	6
12 Priscilo Oteyza	Shop Foreman	2.5	6	6
13 Edison Dungo	Tinsmith	6	6	6
14 Jose Silos, Jr.	Mechanic-Operator	6	6	6
15 Rolando Santos	Tinsmith	6	6	6
16 Zoilo Borja	Machinist	4	6	6
17 Anatalio Barot	Welder	1	6	6
18 R. Dignadice	Mechanic	1	6	6
19 Juan P. Reyno[1/]	Laborer	2	0	0
20 Miguel Fabellan[1/]	Laborer	2	0	0
21 Marcelino Castro	Laborer	6	6	6
22 Josue Munar[2/]	Field Assistant	1	0	0
23 Francisco Babac[2/]	Field Assistant	1	1	0
24 Felix de la Cruz[2/]	Field Assistant	1	1	0
25 Bibiano Ramos[2/]	Student Assistant	0.5	2	2
26 Cielo Sumayao[2/]	Student Assistant	0.5	2	2
27 Dwayne Suter[2/]	Consultant	1	0	0

[1/] Transferred to Agricultural Engineering Staff.

[2/] Part-time

TABLE 1. Output and loss test of IRRI cable-type paddy thresher powered by a 4.2-hp (gasoline) engine.

	Output Test					Loss Test			Average
	60 minutes	27.5 minutes	15 minutes	15 minutes	17.5 minutes	5 minutes	5 minutes	5 minutes	
Weight of threshed grain at threshing, kg	228.90	131.65	68.97	56.56	84.04	18.35	16.70	29.10	
Average M.C. (%) at threshing	32	32	19.3	19.3	19.3	20.5	20.5	20.5	
Weight of threshed grain at 14% M.C.	181.78	104.96	63.91	52.41	77.88	16.96	15.44	26.90	
Thresher output, kg/hr	181.78	229.08	255.64	209.64	267.00	203.52	185.28	322.80	231.84
Fuel consumption, liter/hr	0.54	0.488	0.97						0.67
Method of feeding	- - - - - - - - - - - - - - - - - - 4 men pick thresh - - - - - - - - - - - - - - - - - -								
Variety, grain yield, kg/ha	(- - - - - - - - - - IR5 - - - - - - - - -)					(- - - - - - - - - - IR8 - - - - - - - -)			
	(- - - - 5456 kg or 124 cavans - - - -)					(- - - - - - - - unknown - - - - - - - -)			
Grain loss:									
a. Threshing loss, (unthreshed grain on panicles after threshing)						1.164	3.128	4.27	2.85
Threshing loss, %						0.567	1.660	1.305	1.18
Threshing efficiency, %						99.43	98.31	98.68	98.81
b. Cleaning efficiency, %									
Chaff and empty grains that go with the threshed grain (percentage by weight of the total grain threshed)						6.27	2.99	4.81	4.6

TABLE 2. IRRI experimental wetland rotary tiller test under extremely soft soil conditions.

Tractor used: Ford 4000 (55 hp) equipped with rubber-tipped crown-type lug wheels

Implement used: 1.6 m length, 1 m diameter IRRI Experimental Wetland Rotary Tiller with supporting blades only.

Tractor engine speed: 1800 rpm

No-slip travel distance of tractor rear wheel per 2 revolutions on concrete: 9.22 m

Field condition: Loamy soil puddled 40 days before the test, flooded to 5 cm for 1 week, covered with heavy weeds

Average depth of cone penetrometer: 22.5 cm at 35 psi
30.2 cm at 70 psi

Test No.	Tractor travel speed based on zero slippage m/s	speed	Peripheral tiller blade velocity m/s	gear	Tilling depth[1] cm	Rear wheel travel distance per 2 revs[2] m	Cone penetrometer depths[3] at 35 psi cm	at 70 psi cm	Slippage of rear wheels %
1	0.48	1st	2.10	1st	29.3	3.55	22.8	27.6	61.5
2	1.27	3rd	2.10	1st	28.7	2.85	22.0	29.8	69.1
3	1.73	4th	2.10	1st	30.0	1.15	21.4	30.8	87.5
4	0.48	1st	3.00	3rd	29.0	1.80	20.6	31.6	80.5
5	1.27	3rd	3.00	3rd	30.8	1.57	19.4	28.6	83.0
6	1.73	4th	3.00	3rd	30.7	1.36	20.5	36.0	85.2
7	0.48	1st	3.77	4th	27.7	1.39	23.7	29.3	84.9
8	1.27	3rd	3.77	4th	32.7	1.39	25.4	29.5	84.9
9	1.73	4th	3.77	4th	27.5	1.08	23.0	29.8	88.3
10	0.48	1st)	With rotary tiller			0	23.0	29.8	100.0
11	1.27	3rd)	trailed PTO			0	23.0	29.8	100.0
12	1.73	4th)	disengaged			0	23.0	29.8	100.0
13	0.48	1st)	Without rotary tiller, tractor only			0.75	23.4	30.2	91.9
14	1.27	3rd)				0	23.4	30.2	100.0
15	1.73	4th)				0	23.4	30.2	100.0

[1] Average of 3 readings.

[2] Average of both rear wheels.

[3] Average of 5 readings.

TABLE 3. Performance test of IRRI power weeder on different plant height.*

Plot	Plant age (DAT)1/	Plant height (cm)	Rate of machine (man-hr/ha)	Fuel consumption (lit/hr)	Hills damaged per ha	Remarks
1	18	10-20	18.5	0.72	666	Hills buried in soft mud which did not recover as as inspected 10 days after weeding.
	18	10-20	20.8	0.71	832	
2	22	20-25	16.4	0.74	0	Fairly good performance: damaged hills were mostl those not in a straight row.
	22	20-25	13.9	0.75	56	
3	24	25-30	13.8	0.70	83	
	24	25-30	12.4	0.66	50	
4	26	30-35	16.7	0.69	33	
5	38	41-50	12.0	0.66	0	Plants that had been bent during weeding were found to have recovered, as inspected 10 days after weeding.
	38	41-50	13.9	0.62	0	
6	50	60+	20.0	0.75	400	Bent and broken tillers; sprouts seen growing as inspected 10 days after weeding.
		Average	15.84	0.70		

*Data taken from results of 30-minute trials.

1/ Days after transplanting.

TABLE 4. A comparative evaluation of weeding methods in flooded rice, IRRI, 1968 wet season.

	IR8		Chianung 242		Yield	Labor	Evaluation of Weeding Returns (kg rough rice/ha)			
	Weeds at 45 DAT[1] per m²	Weed weight at harvest (gm/m²)	Weeds at 45 DAT per m²	Weed weight at harvest (gm/m²)	means[2] (kg/ha)	(man-hrs per ha)	Rice earned per man-hr	Cost of labor[3]	Cost of chemical and gasoline[4]	Yield increase (net of weeding cost)
1 Rotary weeding 2x	84	56.33	196	320.00	2416[b]	200	6	350	0	862
2 Hand weeding 2x	58	24.67	122	110.00	2966[ab]	500	4	875	0	887
3 IRRI power weeder 2x	106	23.33	177	133.67	2939[ab]	50	35	88	85	1562
4 Rotary weeding fb hand weeding	149	13.33	120	35.33	2827[ab]	310	5	542	0	1081
5 IRRI power weeder fb hand weeding	93	7.33	133	150.67	2779[ab]	320	5	560	37	978
6 Rotary weeding 1x	96	139.33	214	242.33	2426[b]	90	14	158	0	1064
7 Hand weeding 1x	44	26.33	117	202.00	3604[a]	240	10	420	0	1980
8 IRRI power weeder 1x	94	129.00	145	340.67	2328[b]	25	45	44	42	1038
9 MCPA fb rotary weeding	18	20.33	57	32.33	3180[ab]	104	19	182	35	2193
10 MCPA fb hand weeding	2	2.67	9	25.00	3084[ab]	260	7	455	35	1390
11 MCPA fb IRRI power weeder	9	0	10	38.33	3657[a]	36	68	63	73	2317
12 Trifluralin + MCPA (G)	6	7.67	8	16.33	3546[a]	8	293	14	256	2072
13 Nitrofen + 2,4D IPE (G)	0	0	0	8.67	3285[ab]	11	189	19	266	1796
14 EPTC + MCPA (G)	0	0	1	12.33	2777[ab]	8	197	14	266	1293
15 No weeding (control)	385	214.67	339	550.00	1204[c]		CV(b) = 24.6%			

[1] Days after transplanting.

[2] Any 2 means followed by the same letter are not significantly different at 5% level by the Duncan multiple range test.

[3] Cost of labor - P0.50/man-hr = 1.75 kg rough rice.

[4] Cost of (a) chemical: Trifluralin + MCPA (.7 + .4 kg active ingredient/ha) = P73.
Nitrofen + 2,4D IPE (G) (2.0 + .8 kg active ingredient/ha) = P76.
EPTC + MCPA (1.75 + .7 kg active ingredient/ha) = P76.
MCPA (0.8 kg active ingredient/ha) P10.

(b) gasoline consumption/ha = P12.

TABLE 5. Maximum permissible paddy moisture levels with corresponding minimum force required to thresh 98 percent of paddy for seven rice varieties.

Variety	Maximum permissible paddy moisture content (% d.b.)	Minimum threshing force (kg)
IR8	32.5	0.058
Bluebonnet 50	34.6	0.052
C_4-63	28.4	0.062
T(N)1	31.5	0.069
81B-25	30.1	0.049
IR5	31.8	0.075
BPI-76	29.6	0.073

TABLE 6. Germination of centrifugally-threshed IR8 paddy compared with hand-threshed check samples at seven levels of maturity (10 panicles per test).

Plant Age (days from seedling)		Hand-Threshed Paddy	Centrifugally-threshed Paddy							
			1000 rpm	1500 rpm	2000 rpm	2500 rpm	3000 rpm	3500 rpm	Paddy left on panicle	Total paddy
105	a	.0290	.0310	.0303	.0294	.0288	.0275	.0270	.0268	.0291
	b	86	95	92	87	70	39	21	5	85
109	a	.0287	.0309	.0301	.0294	.0287	.0279	.0269	.0266	.0286
	b	92	96	94	90	70	47	30	8	90
112	a	.0286	.0306	.0298	.0290	.0285	.0277	.0269	.0264	.0285
	b	92	98	95	88	67	46	33	4	91
116	a	.0284	.0301	.0296	.0289	.0282	.0275	.0268	-	.0284
	b	89	97	96	88	66	47	29	-	90
120	a	.0283	.0297	.0292	.0284	.0276	.0273	-	-	.0281
	b	85	96	94	76	59	38	-	-	83
123	a	.0281	.0294	.0286	.0281	.0274	-	-	-	.0280
	b	83	92	86	71	59	-	-	-	82
128	a	.0279	.0290	.0282	.0275	-	-	-	-	.0278
	b	78	82	78	66	-	-	-	-	78

Note: a = Average paddy weight (grams).

b = Germination percentage (%).

TABLE 7. Average panicle pulling force in kilograms at a constant pulling speed of 0.45 meter per second.

Test Date	Variety						
	IR8	Bbt. 50	C_4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	2.91	3.08	3.20	2.05	3.14	2.57	4.01
9-30-68	2.94	3.42	3.28	2.10	3.18	2.59	4.11
10-03-68	2.99	3.49	3.27	2.07	3.19	2.60	4.10
10-07-68	3.05	3.56	3.30	2.09	3.20	2.61	4.22
10-11-68	3.02	3.48	3.25	2.06	3.20	2.61	4.10
10-14-68	2.97	3.37	3.19	2.05	3.17	2.59	3.95
10-19-68	2.93	3.20	3.18	2.07	3.18	2.53	3.98

TABLE 8. Average tiller pulling force in kilograms at a constant pulling speed of 0.45 meter per second.

Test Date	Variety						
	IR8	Bbt. 50	C_4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	6.00	8.41	5.09	3.79	6.95	7.20	6.29
9-30-68	6.12	8.57	5.60	3.92	7.19	7.69	6.38
10-03-68	6.12	8.60	5.60	3.97	7.35	7.67	6.38
10-07-68	6.15	8.66	5.62	3.97	7.37	7.70	6.40
10-11-68	6.13	8.58	5.61	3.95	7.36	6.71	6.34
10-14-68	6.10	8.56	5.56	3.88	7.31	7.60	6.35
10-19-68	6.03	8.37	5.12	3.84	7.08	7.20	6.31

TABLE 9. Average plant pulling force in kilograms at a pulling speed of 0.45 meter per second.

Test Date	Variety						
	IR8	Bbt. 50	C_4-63	T(N)1	81B-25	IR5	BPI-76
9-26-68	41.6	52.9	43.3	19.8	63.9	56.2	54.2
9-30-68	43.3	61.5	42.6	20.4	65.6	55.3	50.7
10-03-68	45.2	58.1	43.5	22.7	64.9	54.7	56.8
10-07-68	45.6	60.1	44.9	22.8	65.6	55.4	56.6
10-11-68	43.5	57.7	41.7	20.6	63.3	56.3	55.5
10-14-68	44.7	57.3	40.5	18.1	60.4	53.9	52.2
10-19-68	39.3	51.6	38.8	17.5	57.2	51.8	49.3

TABLE 10. Performance test of rotary and conventional comb harrow.

Tractor used: 6-hp walking tractor
Implement used: 127-cm wide rotary harrow, and 127-cm wide comb harrow
Field condition: Loamy soil flooded to 5 cm, harrowed 2 weeks before this test, covered with vegetation.

Test No.	Penetrometer depth* at 35 psi (cm)	Penetrometer depth* at 70 psi (cm)	Vegetative condition	Implement used	Time requirement per 1/16 ha 1st pass (min)	Time requirement per 1/16 ha 2nd pass (min)	Fuel consumption per 1/16 ha 1st pass (ml)	Fuel consumption per 1/16 ha 2nd pass (ml)
1	20.4	25.0	Slight	Comb harrow	15.5	12.5	306	238
2	17.4	23.0	Heavy	Comb harrow	14.0	12.5	405	442
3	18.2	24.6	Slight	Rotary harrow	16.5	15.5	216	268
4	19.6	26.4	Heavy	Rotary harrow	13.5	14.5	228	162

*Average of five readings.

TABLE 11. Performance test of rotary harrow with drum and conventional comb harrow.

Tractor used: 6-hp walking tractor
Implement used: 127-cm wide rotary harrow with drum and 127-cm wide comb harrow
Field condition: Loamy soil with 10 cm rice stubble, plowed 3 weeks before the test, and flooded to 5 cm 3 days before the test.

Test No.	Implement used	No. of passes needed for transplanting	Time requirement per 1/8 ha in)	Fuel consumption per 1/8 ha (ml)	Harrowing depth (cm)
1	Rotary harrow with drum	4	82	2167	10.8
2	Comb harrow	4	79	1547	9.0
3	Rotary harrow with drum	4	102	1490	9.0
4	Comb harrow	4	96	1518	11.2

TABLE 12. Power distribution between tractor axle and P.T.O. during rotary tiller operation.

Tractor used: International Harvester Farmall 656 Hydrostatic Drive Tractor (65 B.H.P.)
Rotary tiller: IRRI-designed 2.8-meter wide rotary tiller with conventional blades
Field condition: Dry sandy loam covered with heavy vegetation.

Treat-ment No.	Tractor Travel Speed		Rotary Tiller Condition	PTO Speed rpm	Rotary Tiller Speed rpm	Tilling Depth cm	Tilling Degree	Average Torque		Power Requirement	
	m/s	Rear wheel rpm						PTO kg m	Rear axle kg m	Rotary tiller hp	Rear axle hp
1	0.44	5.46	raised	540	196	-	-	negligible	330	-	2.5
	0.44	5.46	tilling	540	196	14.3	fine	43.8	120	33.8	0.9
2	0.44	5.46	raised	364	132	-	-	negligible	380	-	2.9
	0.44	5.46	tilling	364	132	13.6	medium	54.0	85	27.4	0.6
3	0.53	6.56	raised	270	98	-	-	negligible	460	-	4.2
	0.53	6.56	tilling	270	98	8.9	coarse	60.4	120	22.8	1.1
4	0.67	8.20	raised	364	132	-	-	negligible	410	-	4.7
	0.67	8.20	tilling	364	132	13.0	coarse	50.6	125	25.7	1.4
5	0.78	9.56	raised	540	196	-	-	negligible	380	-	5.1
	0.78	9.56	tilling	540	196	7.0	medium	62.3	70	47.0	0.9

TABLE 13. Dry-run test of 8-row portable seeder.

Range of seeds dropped per hill	Rows							
	1st	2nd	3rd	4th	5th	6th	7th	8th
0 - 1	0	0	0	0	0	0	0	0
2 - 3	4	2	3	5	3	5	4	2
4 - 5	14	17	10	12	12	11	20	14
6 - 7	14	20	15	18	18	18	19	16
8 - 9	14	7	12	14	9	14	7	11
10 - 11	5	6	12	5	13	6	6	6
12 - 13	3	4	4	4	4	5	4	4
14 - 15	4	2	3	2	0	1	0	4
16 - 17	0	1	1	0	1	0	0	1
18 - 19	1	0	1	0	0	0	0	2
20	1	1	0	0	0	0	0	0
Total	470.00	454.00	506.5	434.0	458.0	438.0	596.0	490.0
Mean	7.83	7.57	8.44	7.23	7.63	7.30	6.60	8.17

Duncan's Test at 5% level:

Rows	3rd	8th	1st	5th	2nd	6th	4th	7th
Means	8.44	8.17	7.83	7.63	7.57	7.30	7.23	6.60

Note: All the means are not statistically different at 5% level.

TABLE 14. Rate of seeding based on "Stand Establishment Applied Research Trial," Applied Research, IRRI, 1968.

Rate of Seeding kg/ha	IR8		IR5	
	Broadcast seeds/m^2	Planted seeds/hill*	Broadcast seeds/m^2	Planted seeds/hill*
30	117.0	7.3	106.0	6.6
45	175.5	11.0	159.0	9.9
60	234.0	14.6	212.0	13.2
75	292.5	18.3	265.0	16.6
90	351.0	21.9	318.0	19.9
105	409.5	25.6	371.0	23.2
120	468.0	29.2	424.0	26.5

*25 x 25 cm spacing.

TABLE 15. Specifications of different threshers.

Thresher Model	Dimensions			Cylinder		Type of Threshing Cylinder	Engine		Weight of Machine including Engine (kg)
	Length (mm)	Width (mm)	Height (mm)	Width x dia. (mm)	RPM		Make	HP	
IRRI drum-type	3570	830	870	500 x 2270	300	U-shaped wire loop	Honda	4.2	500
IRRI table-type	1550	1550	1080	1117*	130	U-shaped wire loop	Honda	4.2	175
Japanese Automatic Model D2L	1100	530	1020	500 x 460	450	U-shaped wire loop	Honda	4.2	150
Locally made Thresher I				560 x 485	750	U-shaped wire loop	Ditter	10.0[1]	975
Locally made Thresher II				925 x 400	500	U-shaped wire loop	Kawasaki	4.0	
TURNER "Economy"	3400	765	1560	705 x 330	680	Rasp bar	Wisconsin	10.0	820
GARVIE Type DA	3962	1575	2083	470 x 508	1450	Rasp bar	Hosch	12.0[1]	545
Vogel	1820	754	1830	504 x 300	800	Spike tooth	Wisconsin	10.0	

*Diameter of the thresher table.

[1]Diesel engine.

TABLE 16. Comparative output of different threshers.

Thresher Model	Thresher Output, 14% M.C. Low (kg/hr)	M.C.* %	Average (kg/hr)	M.C.* %	High (kg/hr)	M.C.* %	Fuel (Gas) Consumption (liter/hr)	Method** of Feeding	Grain Yield (kg/hr)	Variety
IRRI drum-type	46.48	32.0	127.53	24.9	326.16	18.0	1.09	1	2640	Mixed
IRRI drum-type (Clinton)	80.76	25.4	147.0	21.80	249.80	26.0	1.47	1	3300	Mixed
IRRI drum-type (GAMI)	160.76	18.20	212.68	18.20	252.16	18.6	1.39	1	2772	Mixed
IRRI table-type	181.78	32.0	228.86	24.38	267.0	19.3	0.67	1	5280	IR5
Japanese Automatic D2L	86.64	31.0	89.73	30.37	95.28	30.0	0.87	4	3300	IR8
Japanese Automatic TF50	123.92	26.0	195.52	21.80	261.60	19.6	1.81	4	5280	IR5
Locally made Thresher I	27.56	24.0	117.13	20.77	186.28	19.5	1.67***	3	2200	C-4
Locally made Thresher II	131.54	18.50	158.50	18.0	181.65	17.0	2.45	2	Unknown	Mixed
TURNER "Economy"	163.68	32.0	171.14	31.30	180.72	30.0	1.74	3	3080	C-4
GARVIE Type DA	143.92	32.0	163.28	32.0	204.0	32.0	1.43***	3	5280	IR5
Vogel	103.0	32.0	118.76	32.0	130.0	32.0	1.93	4	Unknown	Mixed
Pedal	61.35	19.8	89.19	19.8	117.04	19.8	-	2	Unknown	IR5

*Grain moisture content during threshing.
**Method of feeding: (1) 4 men pick-thresh, (2) 2 men pick-thresh, (3) 2 men pick-transfer and 1 man thresh, and (4) 1 man pick-transfer and 1 man thresh.
***Diesel fuel.

TABLE 17. Comparative performance of selected rice threshers.

Thresher model	Machine Performance			Power Perform'ce			Labor Performance				Economic Performance		
	kg/hr	ha/hr*	Rating	Engine hp	Hp-hr/ 44 kg	Rating	No. of men**	Man-hr/ ha*	Grain output/ man-hr kg	Rating	Machine cost ₱	Threshing cost/ 44 kg ₱	Rating
IRRI drum-type													
Low feed	160.60	0.0365		4.2	1.095		5	136.98	32.12		2500	1.392	
Average feed	216.04	0.0491	2	4.2	0.855	2	5	101.83	43.21	4	2500	1.035	4
High feed	252.12	0.05373		4.2	0.695		5	87.26	50.42		2500	0.887	
IRRI table-type	228.80	0.0520	1	4.2	0.807	1	5	96.17	45.76	3	1800	0.657	1
Japanese automatic	195.36	0.0444	3	4.2	0.946	3	3	67.56	65.12	1	3500	0.765	2
Locally made thresher I	117.04	0.0266	8	12.5	4.700	7	4	172.94	29.26	9	6750	1.512	5
Locally made thresher II	158.40	0.0360	5	4.0	1.333	4	3	83.33	52.80	2	2464	0.930	3
TURNER "Economy"	170.72	0.0388	4	10.0	2.577	5	4	120.00	39.60	6			
GARVIE Type DA	163.24	0.0371	6	17.5	4.717	8	4	107.85	40.79	5			
Vogel Nursery	126.72	0.0288	7	10.0	3.473	6	4	138.81	31.68	8			
Pedal	68.64	0.0156	9				2	128.20	34.32	7			

* Based on 4400 kg per ha yield.

**Number of men includes one man who collects and sacks the grain.

TABLE 18. Hourly operating cost of different threshers.

Item	IRRI paddy power thresher			Japanese automatic thresher	Locally-made thresher	
					Make I	Make II
	4 men	5 men	6 men	3 men	4 men	3 men
	Pesos per hour					
Labor	1.75	2.19	2.62	1.31	1.75	1.31
Fuel	0.43	0.43	0.43	0.51	0.45	0.70
Oil	0.009	0.009	0.009	0.012	0.015	0.009
Repairs	0.47	0.47	0.47	0.66	0.63	0.46
Total	2.66	3.10	3.53	2.60	2.98	2.48

TABLE 19. Total cost of using different threshers.

Item	IRRI drum-type paddy thresher	Japanese automatic thresher	Locally-made thresher Make I	Locally-made thresher Make II
	pesos			
Initial cost	2,500.00	3,500.00	6,750	2,464
Estimated service life*	3,200 hrs (5 yrs)	3,200 hrs (5 yrs)	6,400 hrs (10 yrs)	3,200 hrs (5 yrs)
Fixed cost (cost of ownership)				
Depreciation (assuming a trade-in value 10% of initial cost)	2,250	3,150	6,075	2,217.60
Interest (12% a year)	555	777	2,814.75	547
Total	2,805	3,927	8,889.75	2,764.60
Variable cost (cost of operation)				
Repairs (60% of initial cost)	1 500	2,100	4,050	1,478.40
Fuels (₱0.286/liter)	1,372.80	1,625.57	2,928.64	2,242.24
Oil (₱1.50/liter)	30	40	100	30
Labor (₱3.50/man-day)				
3 men		4,200		4,200
4 men	5,600		11,200	
5 men	7,000			
6 men	8,400			
Total				
3 men		7,965.57		7,950.64
4 men	8,502.80		18,278.64	
5 men	9,902.80			
6 men	11,302.80			
Total Cost				
3 men		11,892.57		10,715.24
4 men	11,307.80			
5 men	12,707.80			
6 men	14,107.80			

*Except for the locally-made thresher (Make I), an estimated service life of 3200 hours (5 years) was assumed for all the threshers studied. This, therefore, becomes one of the limitations of the analysis because, certainly, the service capacity of the threshers are not the same; much less their make and the materials they are made of. Thus, caution should be exercised in using these data.

TABLE 20. Average cost of using different threshers.

Working hours	IRRI paddy power thresher			Japanese automatic thresher	Locally-made thresher	
					Make I	Make II
	4 men	5 men	6 men	3 men	4 men	3 men
	Pesos per hour					
500	8.27	8.71	9.14	10.34		8.01
1000	5.46	5.90	6.33	6.42	11.73	5.24
1500	4.53	4.97	5.40	5.11		4.32
2000	4.06	4.50	4.93	4.46	7.29	3.86
2500	3.78	4.22	4.65	4.06		3.58
3000	3.59	4.03	4.46	3.80	5.81	3.40
3200	3.54	3.98	4.40	3.72		3.34
4000					5.07	
5000					4.62	
6000					4.33	

TABLE 21. Partial budgeting of costs and returns from changes in weed control methods, IRRI.

Items	Weeding method							
	Case I		Case II		Case III		Case IV	
	a	b	a	b	a	b	a	b
	pesos per hectare							
a. Added costs								
Materials[1]		-		76.00		76.00		-
Weeding labor[2]	300	120.00	300	-	120	-	300	60.00
Application labor[3]		-		6.60		6.60		-
Equipment charge[4]		1.00		1.00	1			35.00
b. Reduced returns								
Change in paddy produced[5]		-		-		-		-
SUBTOTAL A	300	121.00	300	83.60	121	82.60	300	95.00
c. Added returns								
Change in paddy produced[5]		-		-		-		-
d. Reduced costs								
Weeding labor[2]		180.00		293.40		113.40		270.00
Interest[6]		2.95		8.39		1.23		7.00
SUBTOTAL B		182.95		301.79		114.63		277.00
ESTIMATED CHANGE (A - B)		61.95		218.19		32.03		182.00

Note: Case I = change from (a) handweeding (2x) to (b) manual rotary weeding (2x).
Case II = " " (a) handweeding (2x) to (b) chemical weeding.
Case III = " " (a) rotary weeding (2x) to chemical weeding.
Case IV = " " (a) handweeding (2x) to power weeding (2x).

1/ 2.0 + 0.8 kg a.i. [NITROFEN + 2, 4D IPE(G)].

2/ Case I = total time for weeding is reduced from 500 hrs to 200 hrs.
Case II = " " " " " " " 500 hrs to 11 hrs.
Case III = " " " " " " " 200 hrs to 11 hrs.
Case IV = " " " " " " " 500 hrs to 50 hrs.

3/ Spraying.

4/ Arbitrary change for use of: Case I = manual rotary weeder.
Case II = sprayer.
Case III = power weeder.

5/ No statistically significant change in yield.

6/ Savings in other costs at 1% per month for 4 months.

TABLE 22. Type of farm, use of hand tractor, and yield relationships, 115 farms, Laguna and Central Luzon, 1966-1968.

Item	Type of farm							
	Rainfed				Irrigated, growing 2 rice crops			
	a	b	c	All rain-fed farms	a	b	c	All irrigated 2-crop farms
1. Number of farms	24	7	-	31	17	44	15	76
2. Average size of farm (ECA)	2.4	7.2	-	3.5	4.1	4.9	5.4	4.8
3. Labor input (man-days/ha)								
plowing	5.8	3.4	-	5.3	6.5	3.5	3.1	4.1
harrowing	9.4	6.1	-	8.7	11.2	6.4	4.8	7.1
plowing + harrowing	15.2	9.5	-	14.0	17.7	9.9	7.9	11.2
4. Operation(frequency)								
1 plow, 1 harrow	-	1	-	1	-	1	3	4
2 plow, 2 harrow	6	3	-	9	2	18	6	26
1 plow, 3 harrow	16	2	-	18	15	20	5	40
2 plow, 1 harrow	-	-	-	-	-	1	-	1
2 plow, 2 harrow	-	-	-	-	-	2	-	2
2 plow, 3 harrow	2	1	-	3	-	2	1	3
For farms using tractor and carabao:								
No. of farms using:								
carabao for plowing, tractor for harrowing		-				4		
tractor for plowing, carabao for harrowing		4				11		
tractor and carabao for plowing and harrowing		3				29		
5. Yield (cavans/ha)*								
improved varieties[1/]	-	-	-	-	-	79.2	70.6	74.5
local varieties[2/]	55.9	57.1	-	56.0	59.7	54.5	62.1	56.5
other varieties[3/]	51.0	59.0	-	54.6	-	-	-	-
all varieties	54.7	58.4	-	55.5	62.3	67.5	69.4	66.7
6. Cavans per man-day[4/]	4.4	5.5	-	4.7	4'3	11'5	12'2	10.0

*From interview data; 1 cav= 44 kg.
[1/] IR-8, IR-5, C_4-63, BPI-76.
[2/] Intan, Binato, Wagwa.
[3/] Varieties other than 1 & 2.
[4/] Cavans/man-day of plowing and harrowing.

a = Farms using carabao.
b = Farms using carabao and tractor.
c = Farms using tractor.

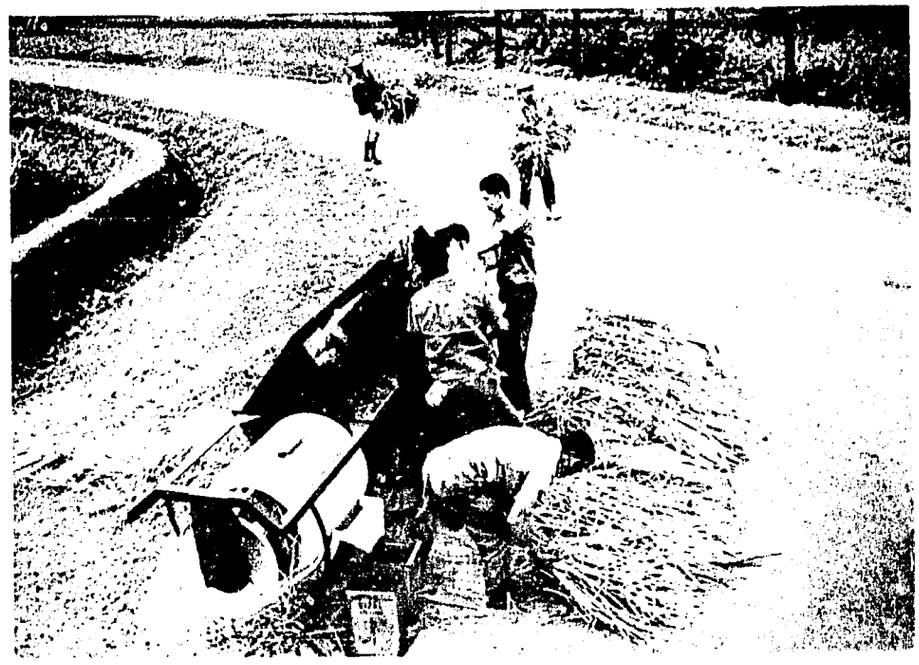


Fig. 1. Commercially produced drum-type thresher by G. A. Machineries, Inc.

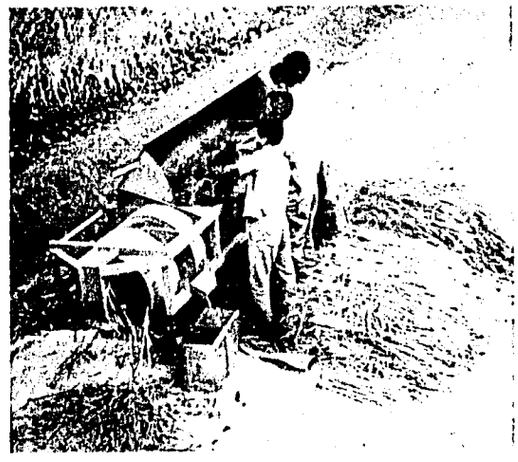


Fig. 2. Commercial prototype drum-type thresher by Clinton (Philippines), Inc.

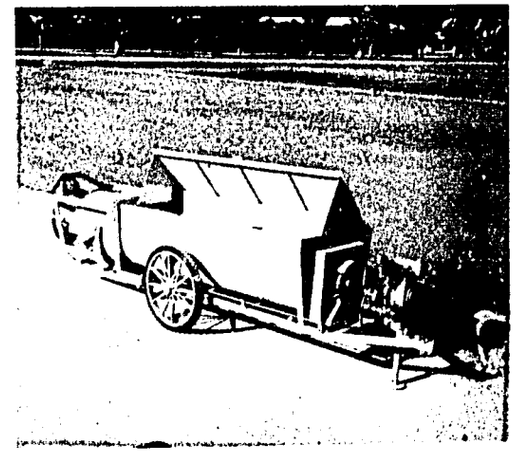


Fig. 3. Commercial prototype drum-type thresher by F. Bernabe and Sons.

Fig. 4. Second prototype table-type paddy thresher in operation.

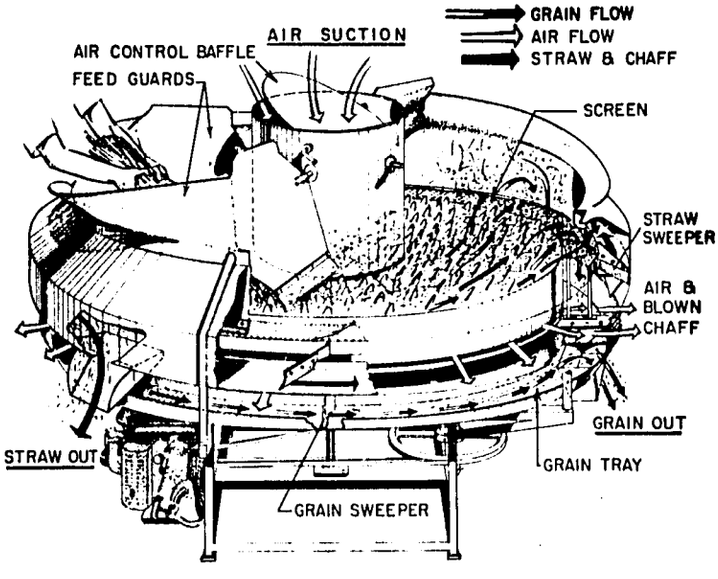


Fig. 5. Schematic drawing of second prototype table-type paddy thresher.

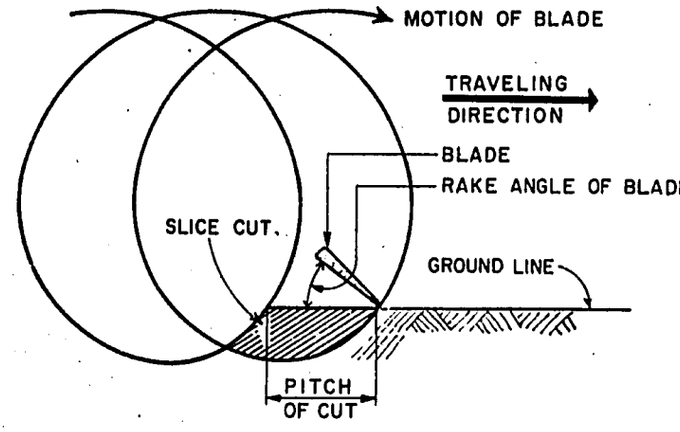


Fig. 6. Schematic drawing of rotary tiller blade motion.

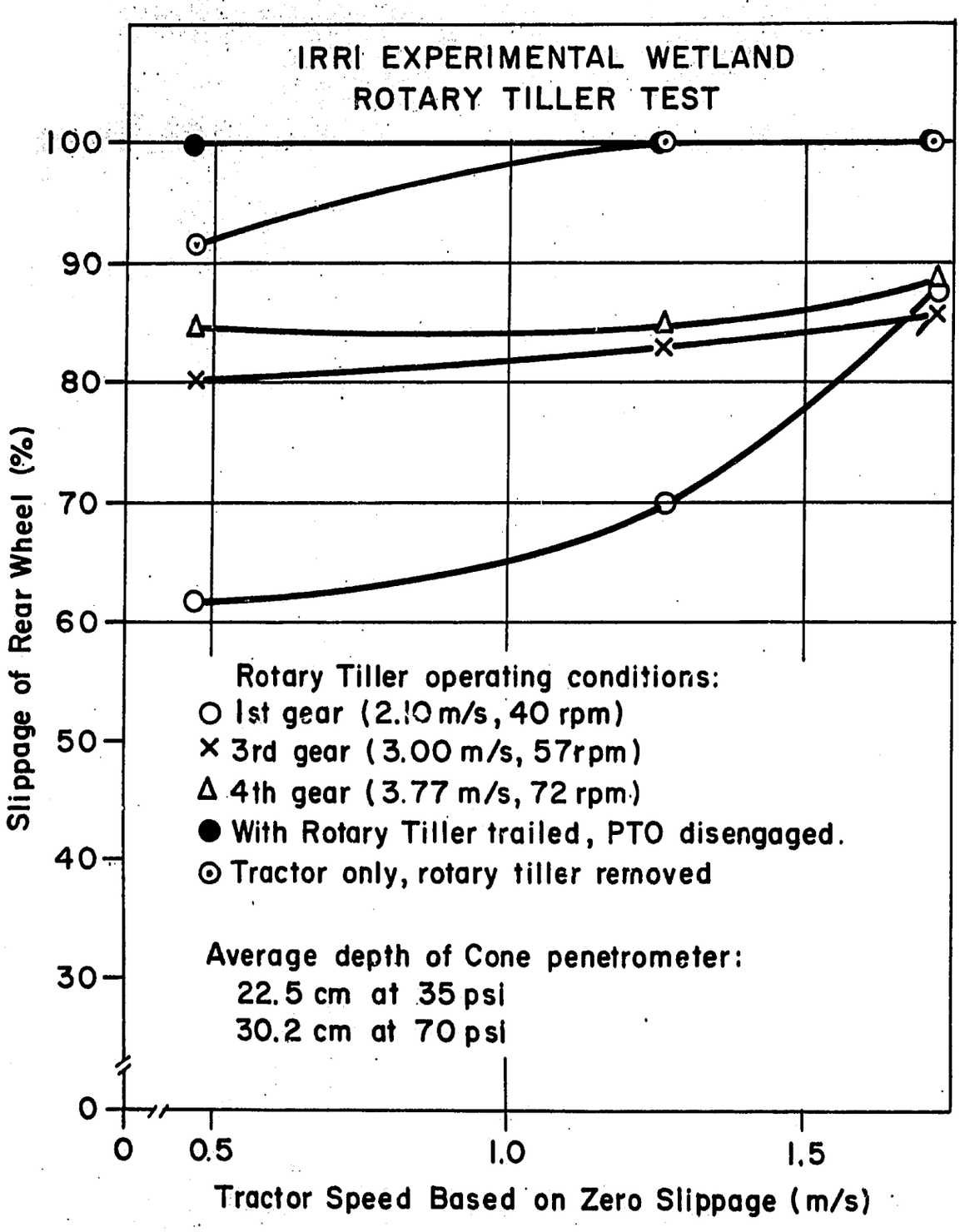


Fig.7. Tractor rear wheel slippage at different tractor forward travel speeds and different IRRI rotary tiller drive condition under very soft wetland condition. Tiller with support blades only.

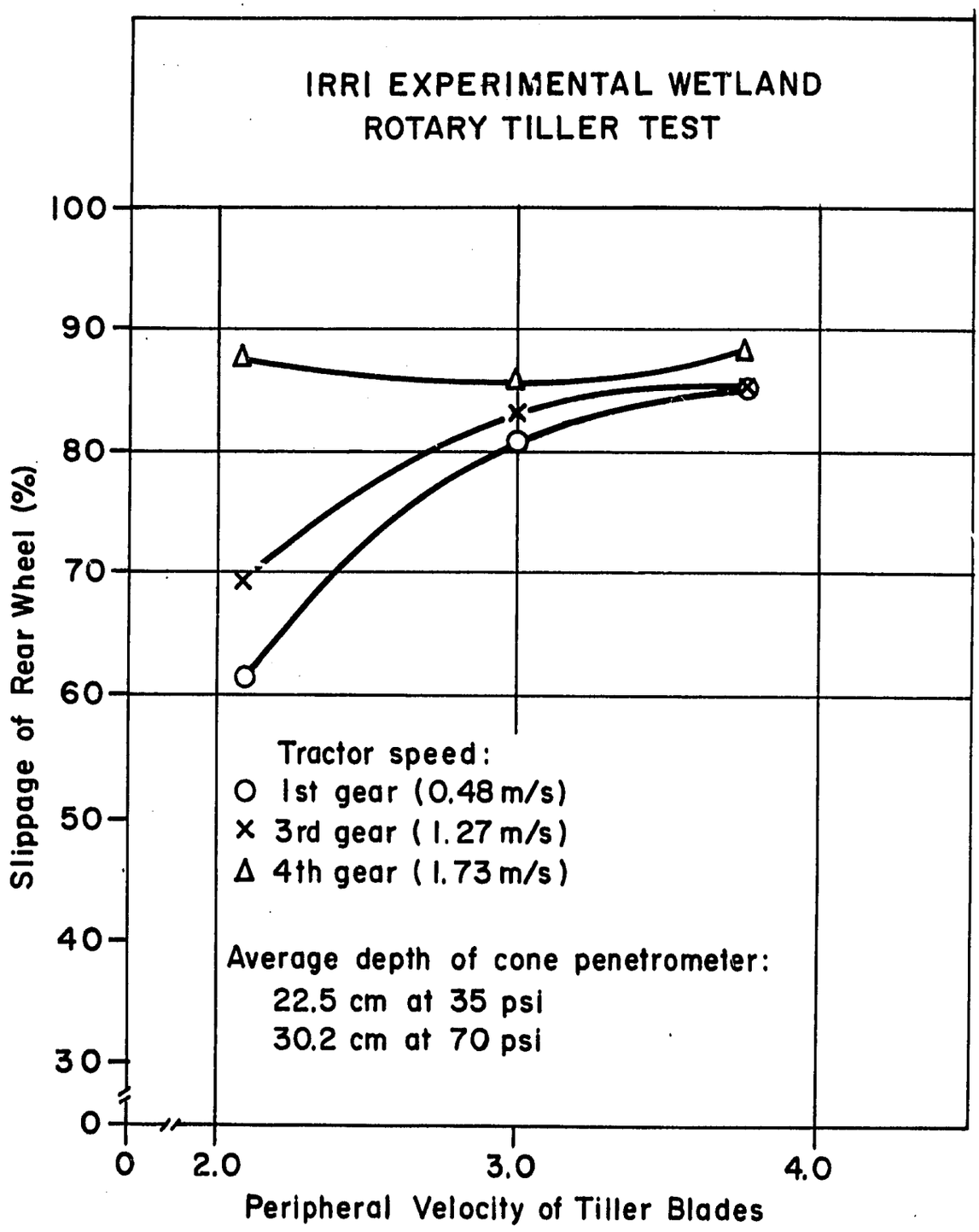


Fig. 8. Tractor rear wheel slippage at three constant tractor travel speed and changing IRRI rotary tiller blade velocity. Rotary tiller with support blade only.

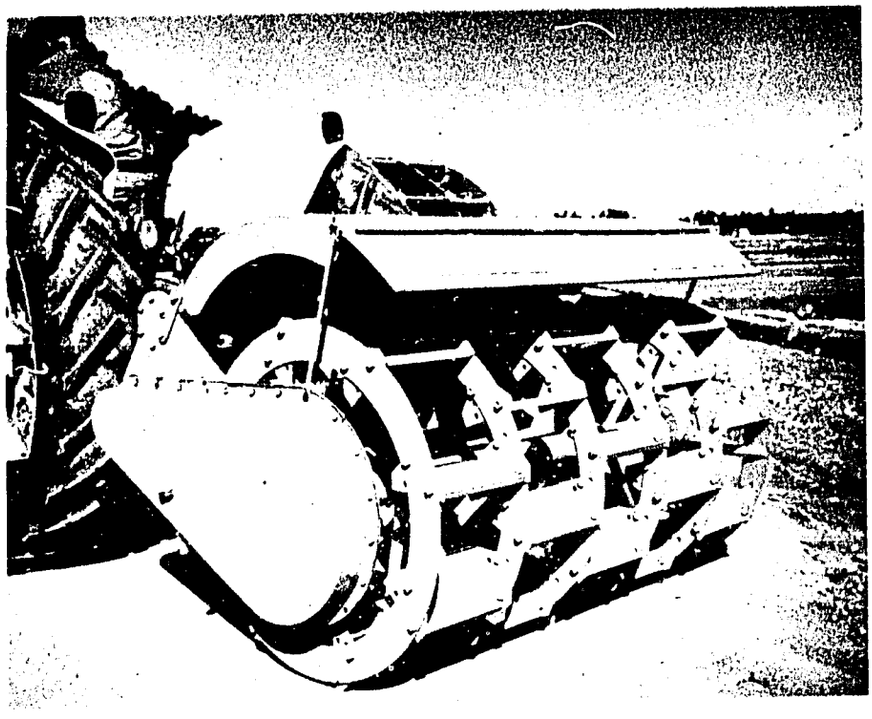


Fig. 9. Second experimental wetland rotary tiller with adjustable blades.

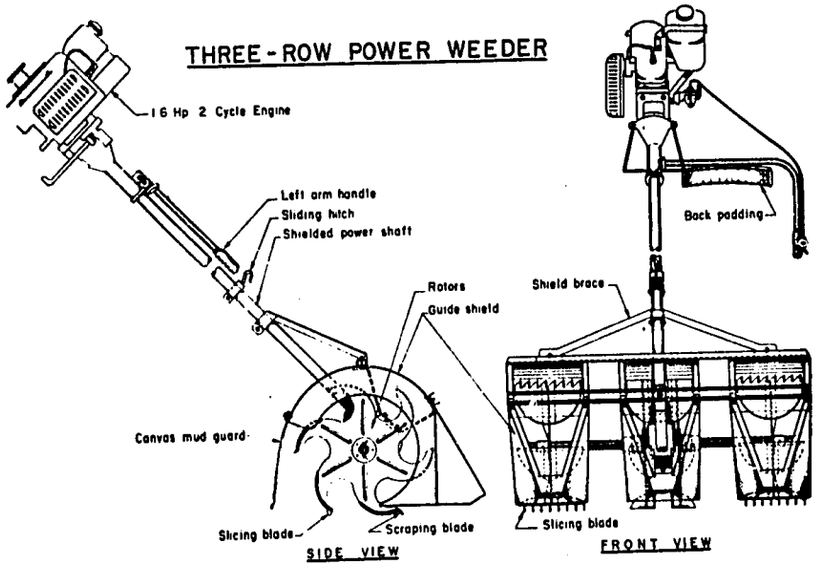


Fig. 10. Three row experimental power weeder with improved shield for guiding plants in rows.

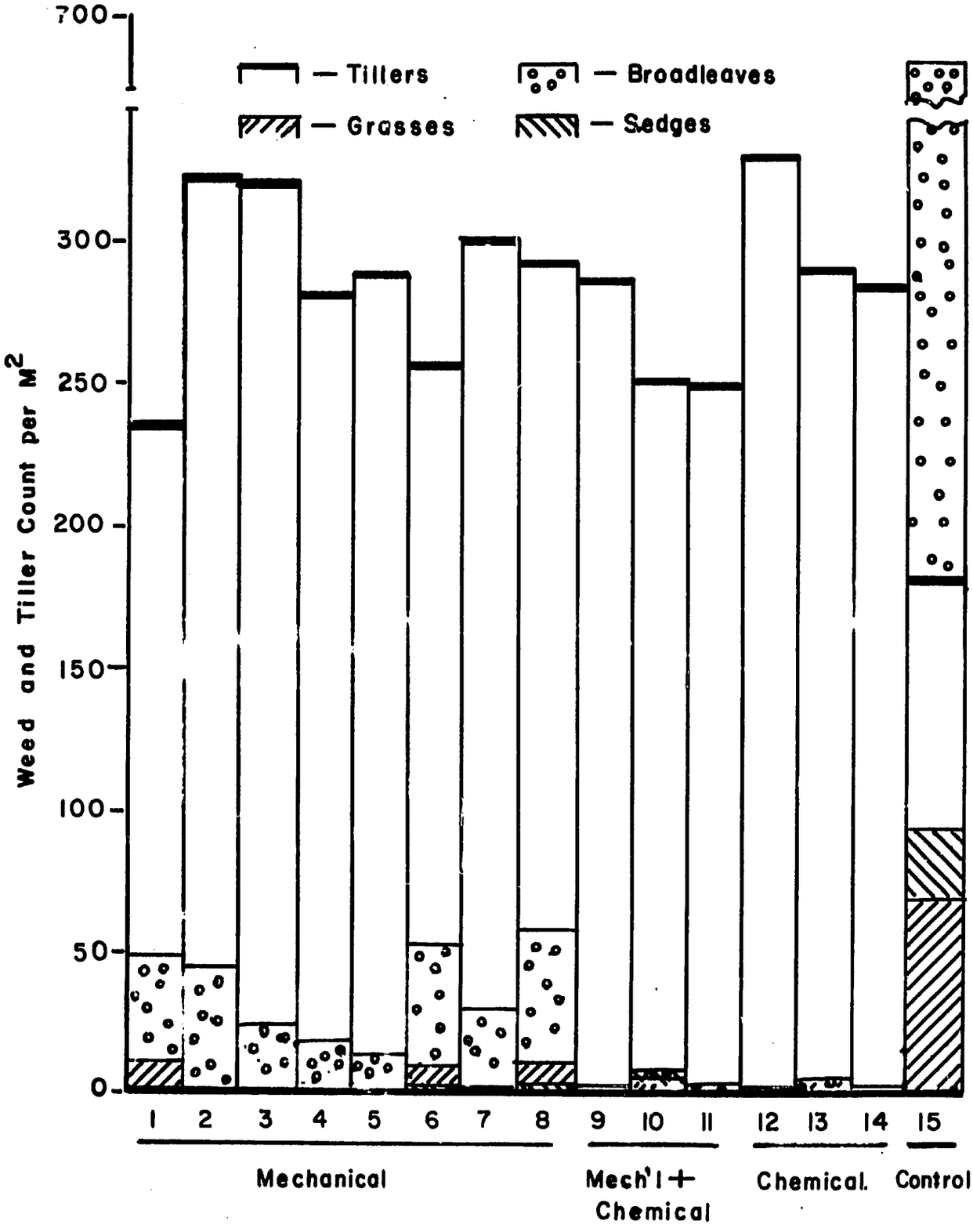


Fig.11. Effect of different weeding methods on weed population and tillers per square meter of IR8-68 at 45 days after transplanting, IRRI wet season, 1968.

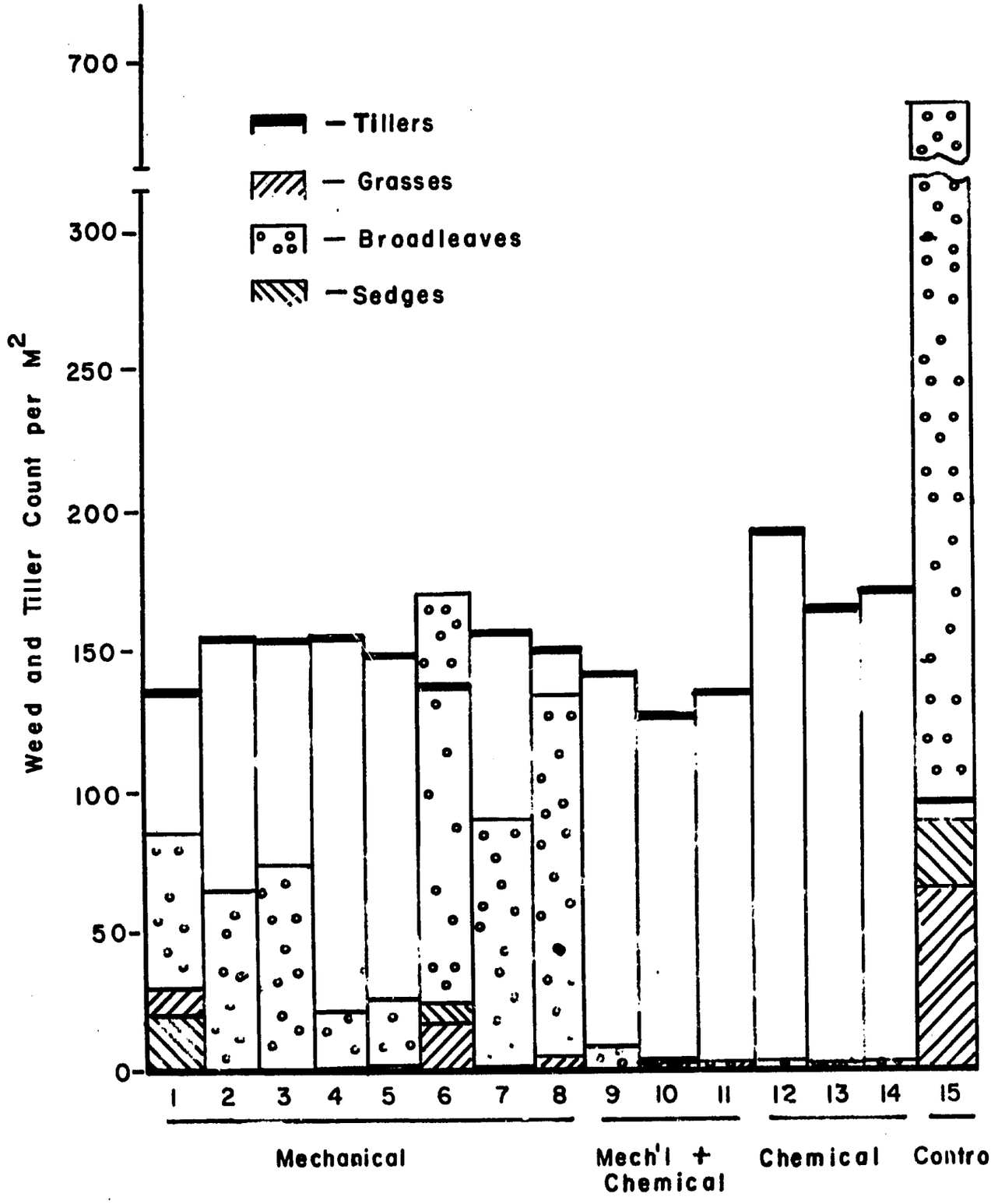


Fig.12. Effect of different weeding methods on weed population and tillers per square meter of Chianung 242 at 45 days after transplanting, IRRI wet season, 1968.

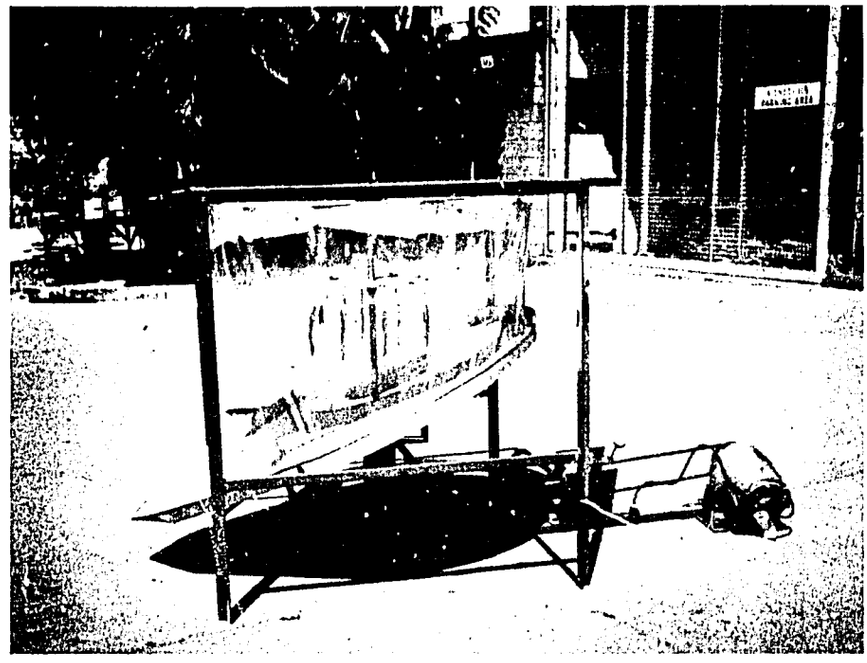


Fig. 13. Experimental non-impulsive centrifugal threshing device.

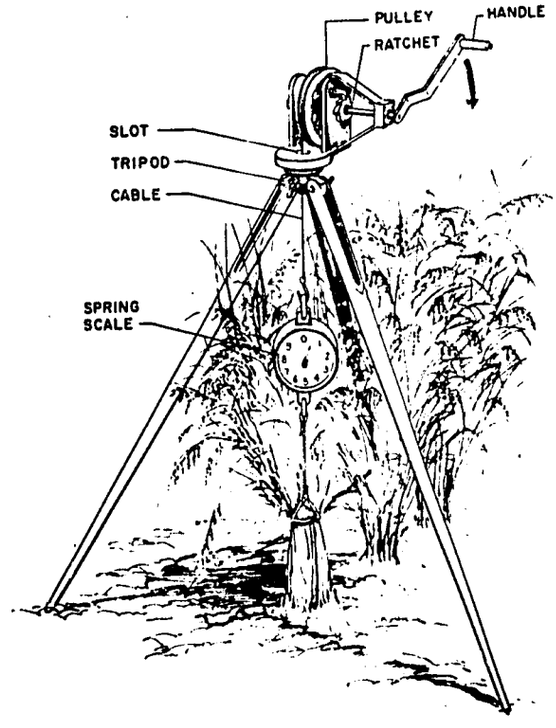


Fig. 14. Tripod-mounted riceplant pulling device.

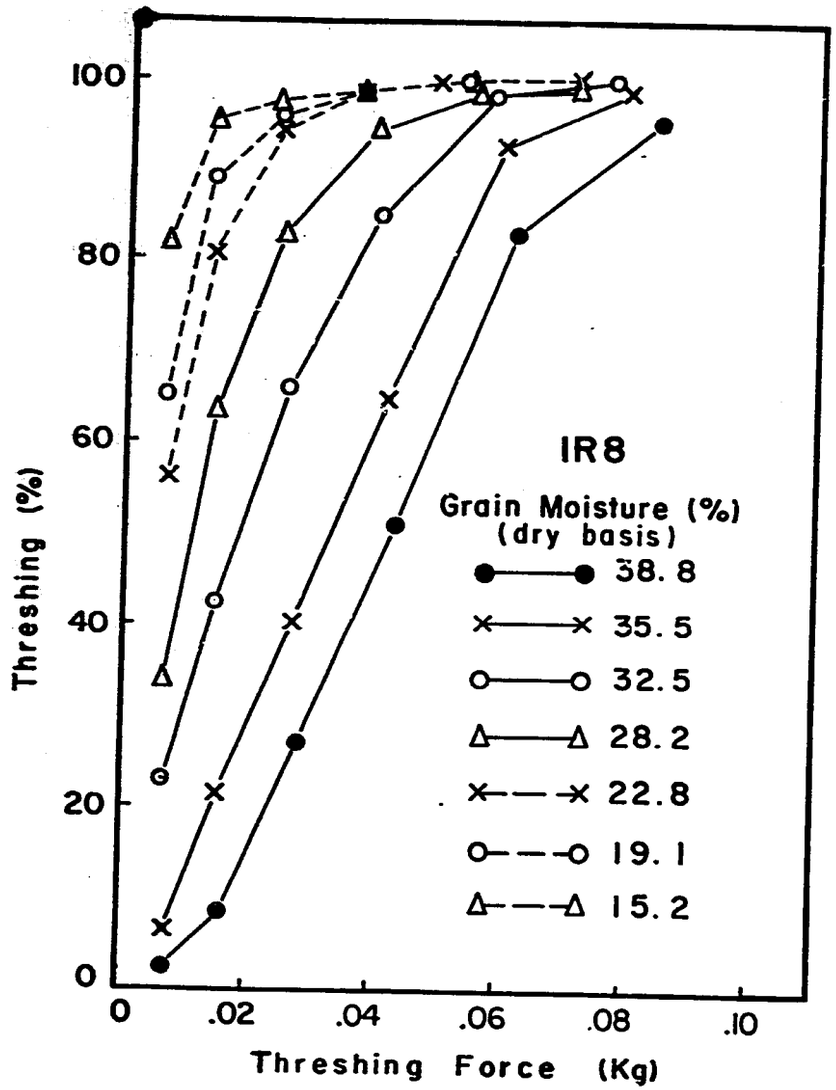


FIG. 15. Relation between threshing force and threshing for IR8 at seven grain moisture levels.

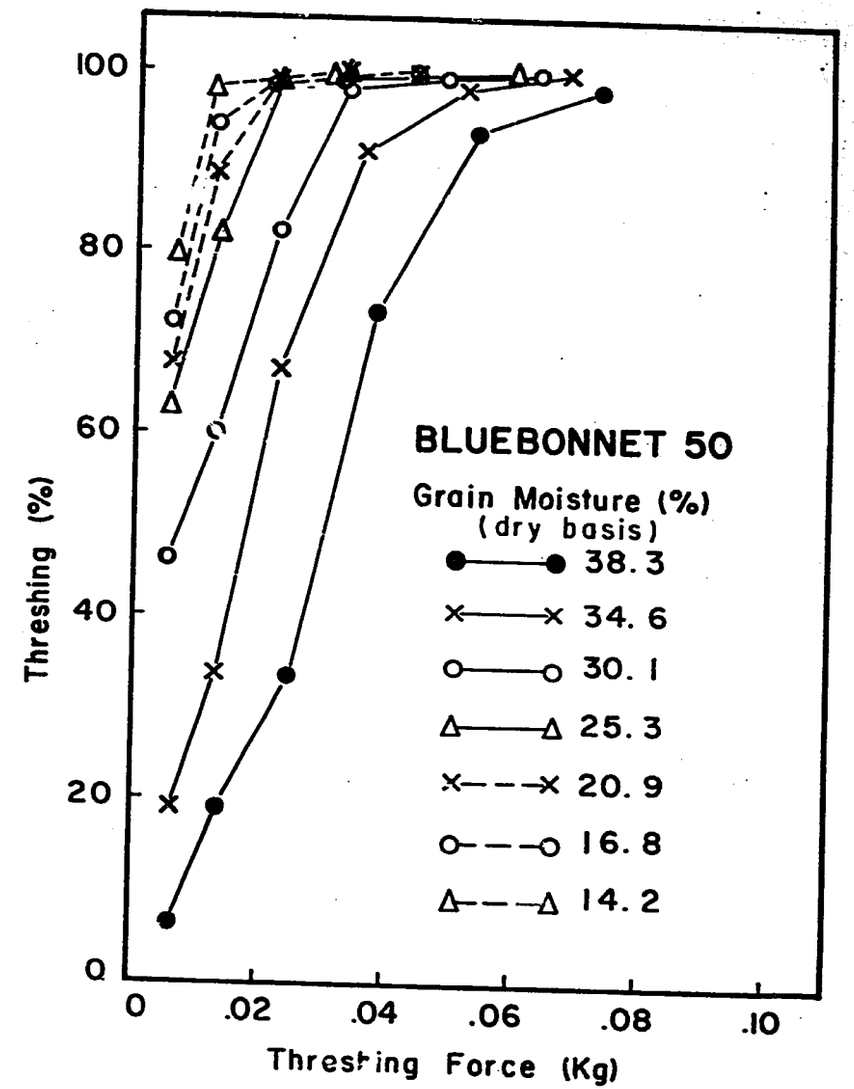


FIG. 16. Relation between threshing force and threshing for Bluebonnet 50 at seven grain moisture levels.

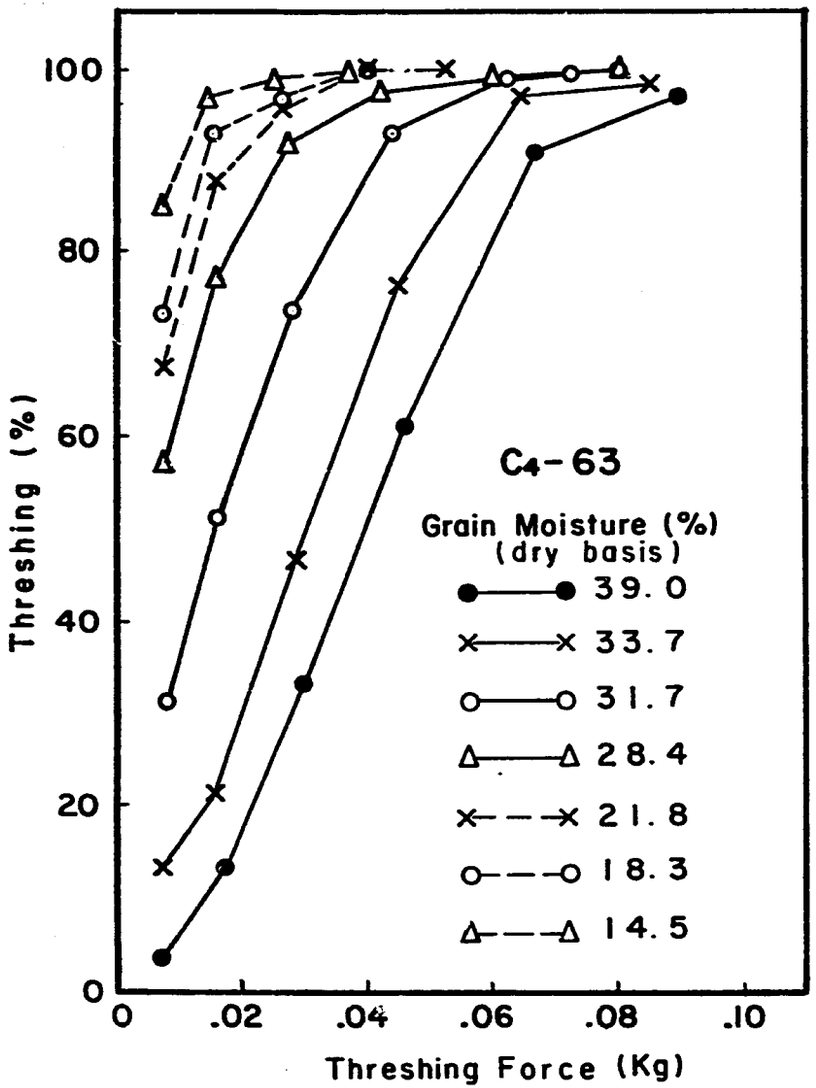


FIG.17. Relation between threshing force and threshing for C_4-63 at seven grain moisture levels.

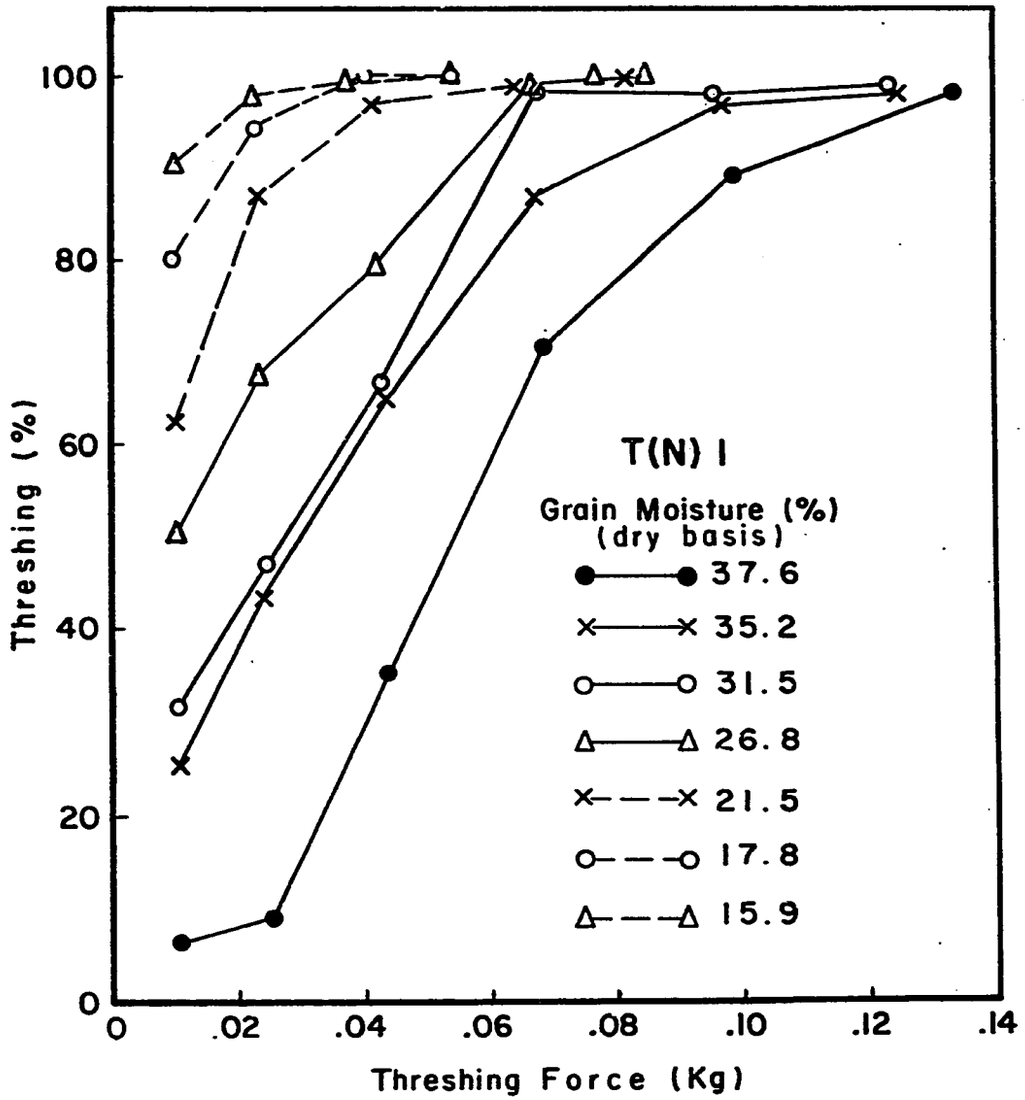


FIG.18. Relation between threshing force and threshing for T(N)1 at seven grain moisture levels.

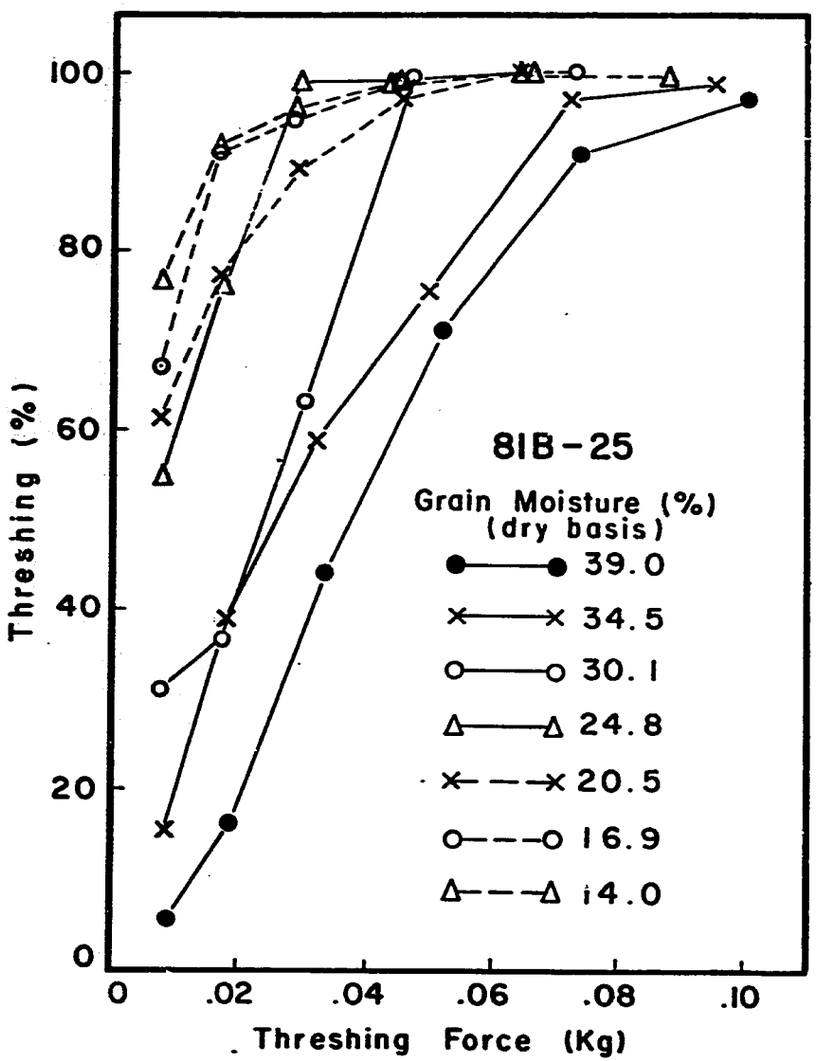


FIG. 19. Relation between threshing force and threshing for 81B-25 at seven grain moisture levels.

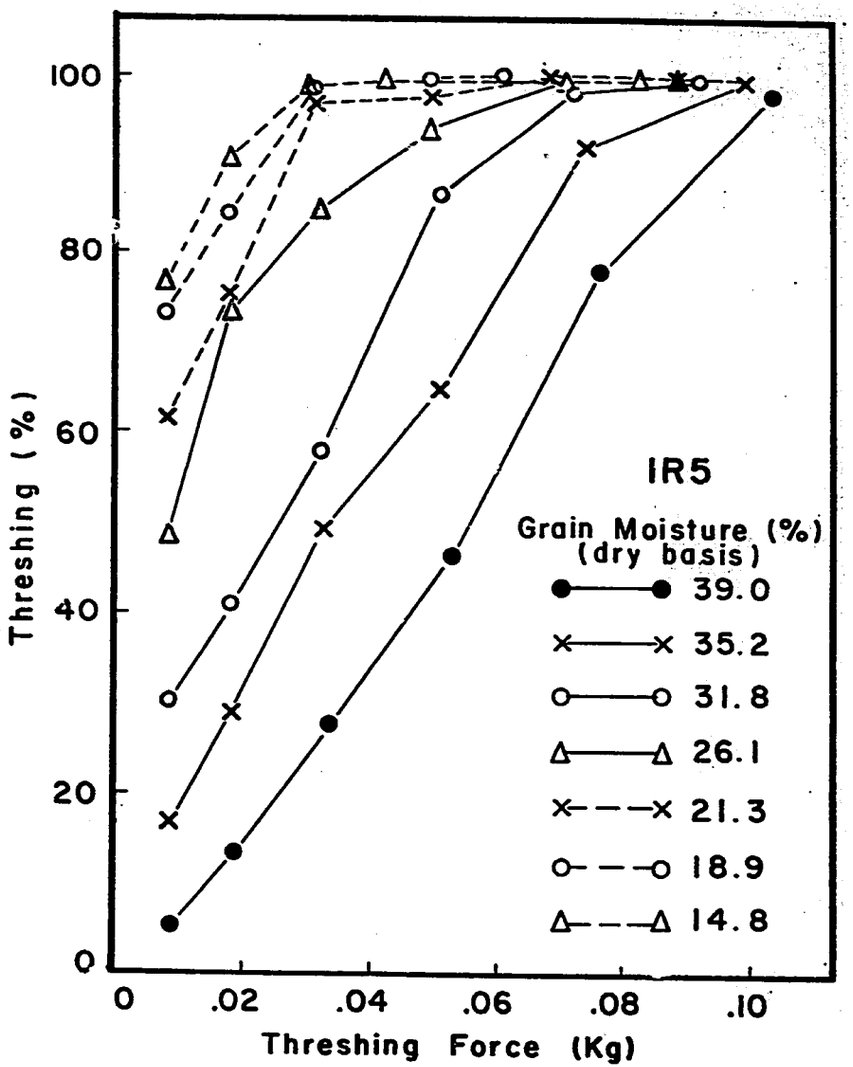


FIG. 20. Relation between threshing force and threshing for IR5 at seven grain moisture levels.

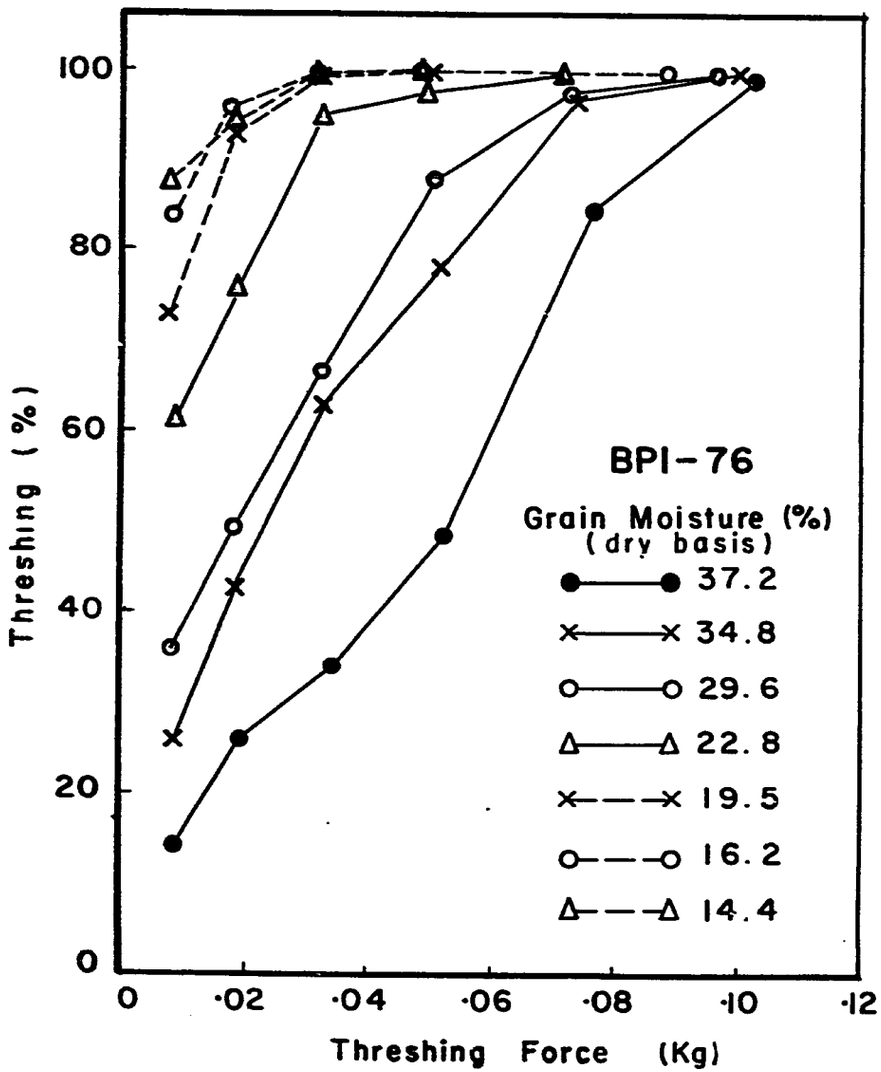


FIG. 21. Relation between threshing force and threshing for BPI-76 at seven grain moisture levels.

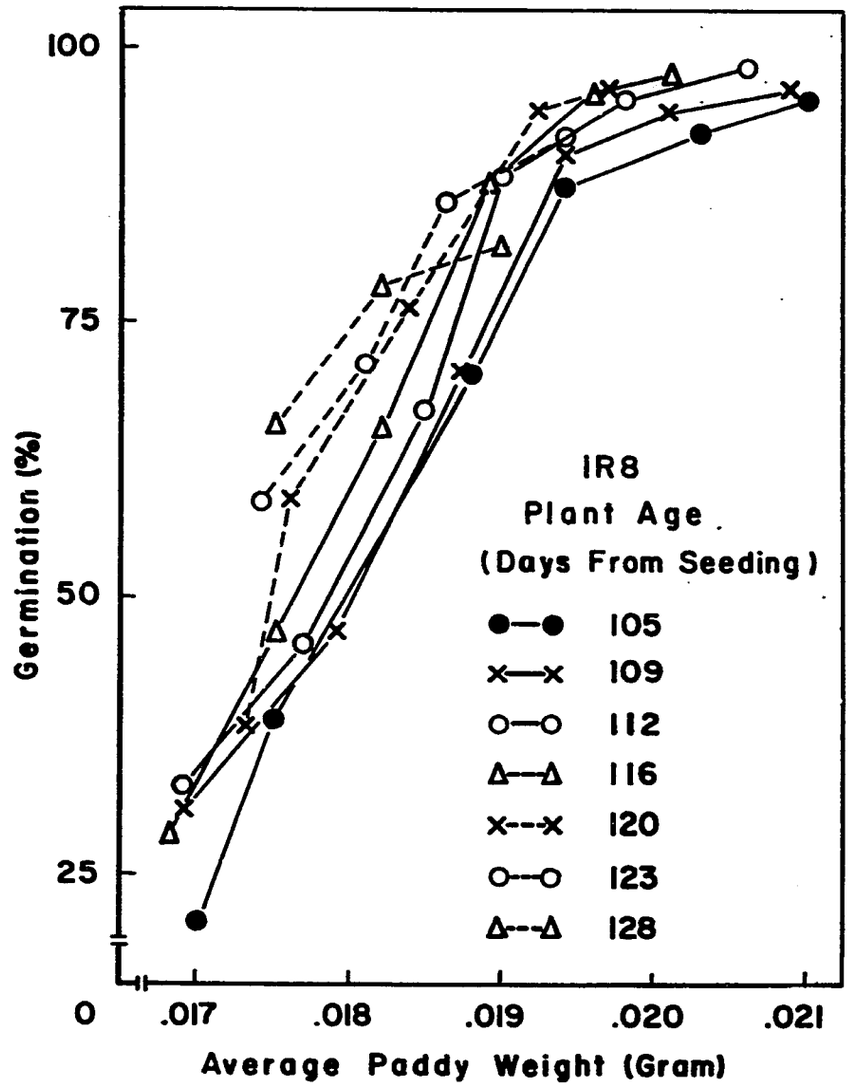


FIG. 22. Relationship between paddy weight and germination for IR8 variety.

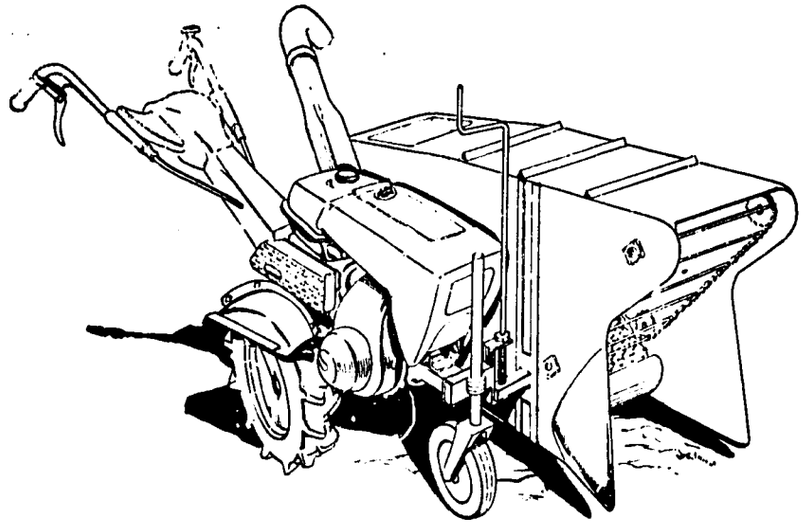


Fig. 23. Schematic drawing of experimental paddy stripper combine mounted on a walking tractor.

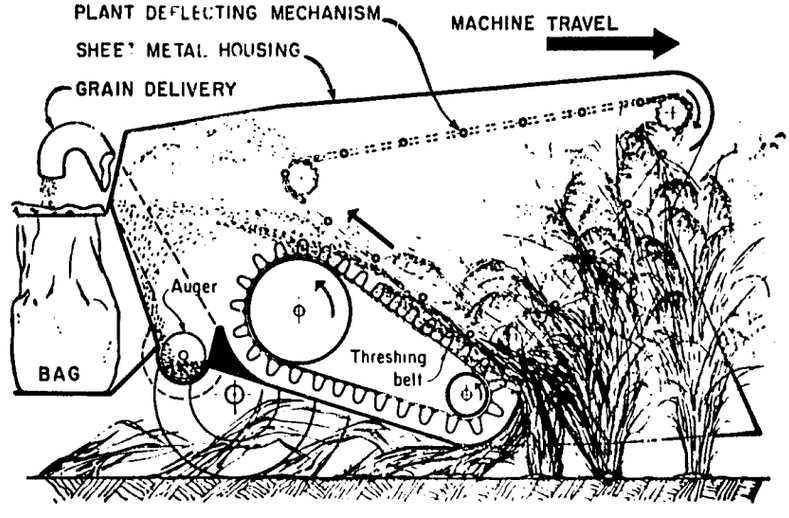


Fig. 24. Schematic drawing of paddy stripper combine.

Fig. 25. Walking tractor with conventional comb harrow.

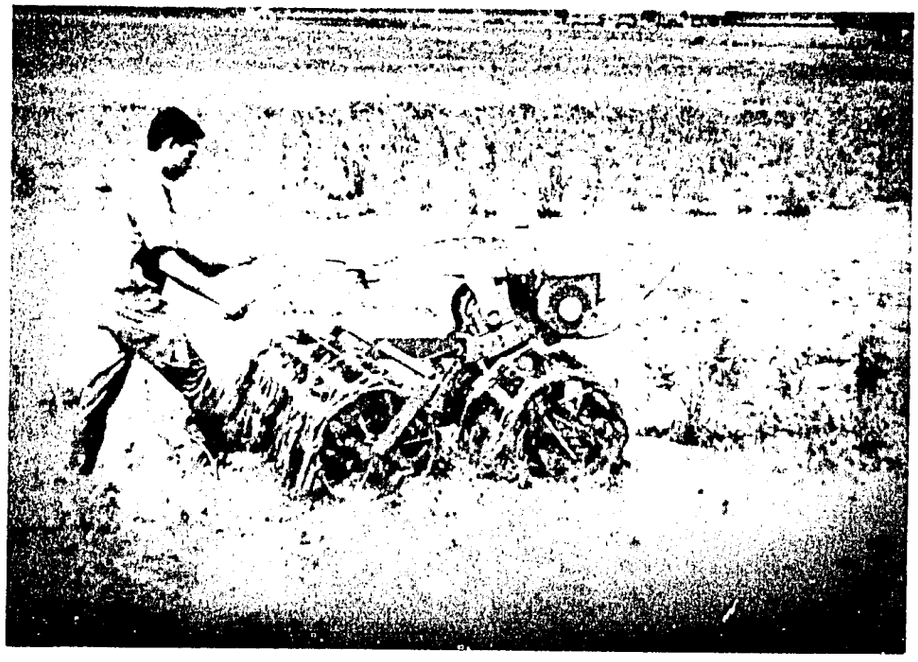
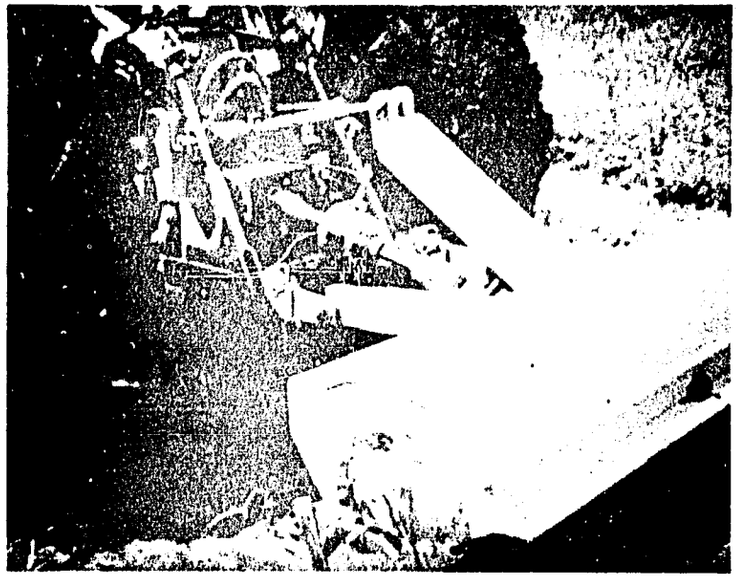


Fig. 26. Walking tractor with experimental rotary harrow.

(a)



(b)

Fig. 27. Measuring equipment used for power requirement studies.
(a) Two channel direct recorder and accessories.
(b) Conventional type IRRI rotary tiller with strain gage and slip ring assembly for PTO torque measurement.

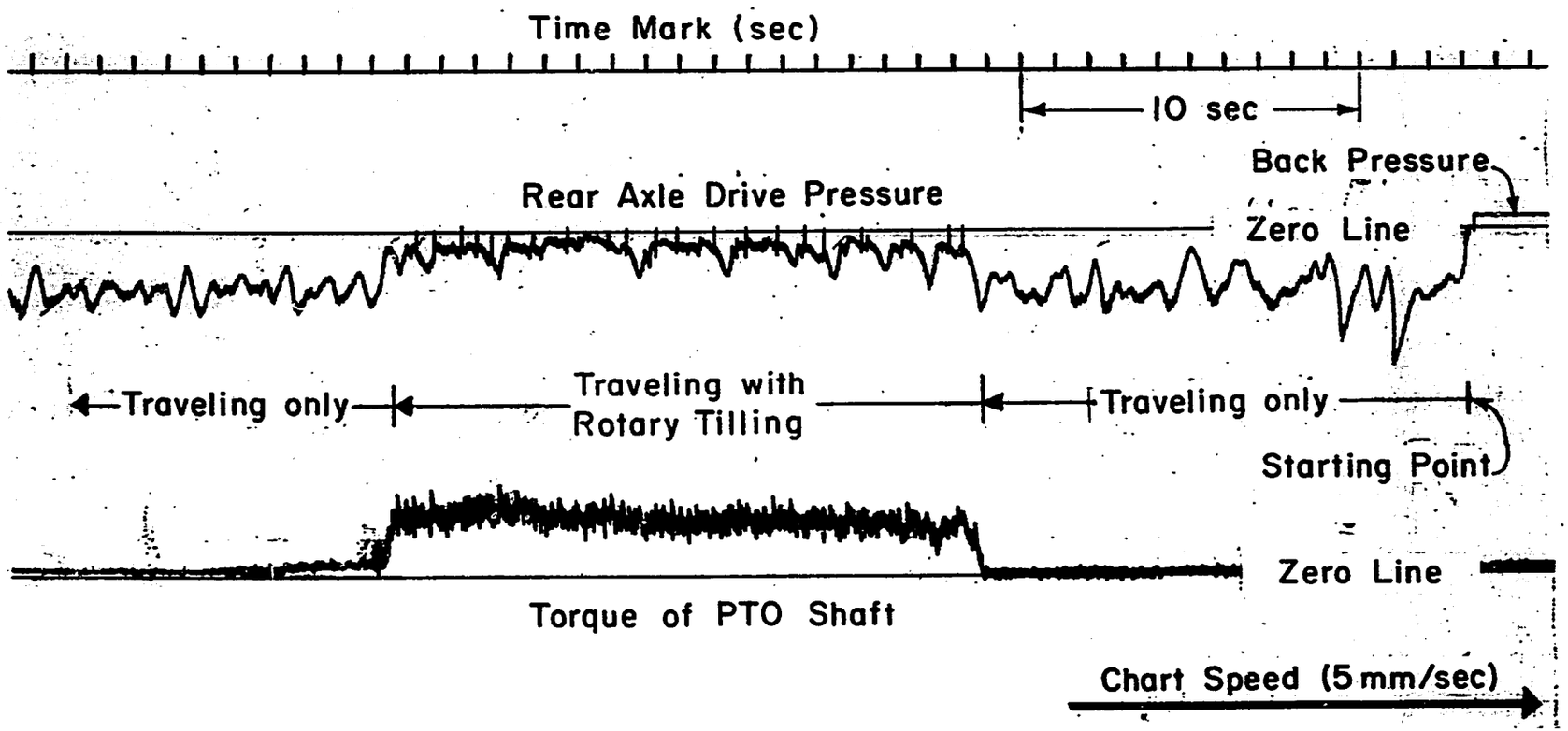


Fig. 28. Sample dynograph recorder tracings of tractor rear axle hydrostatic drive-pressure and tractor PTO torque to drive the rotary tiller.

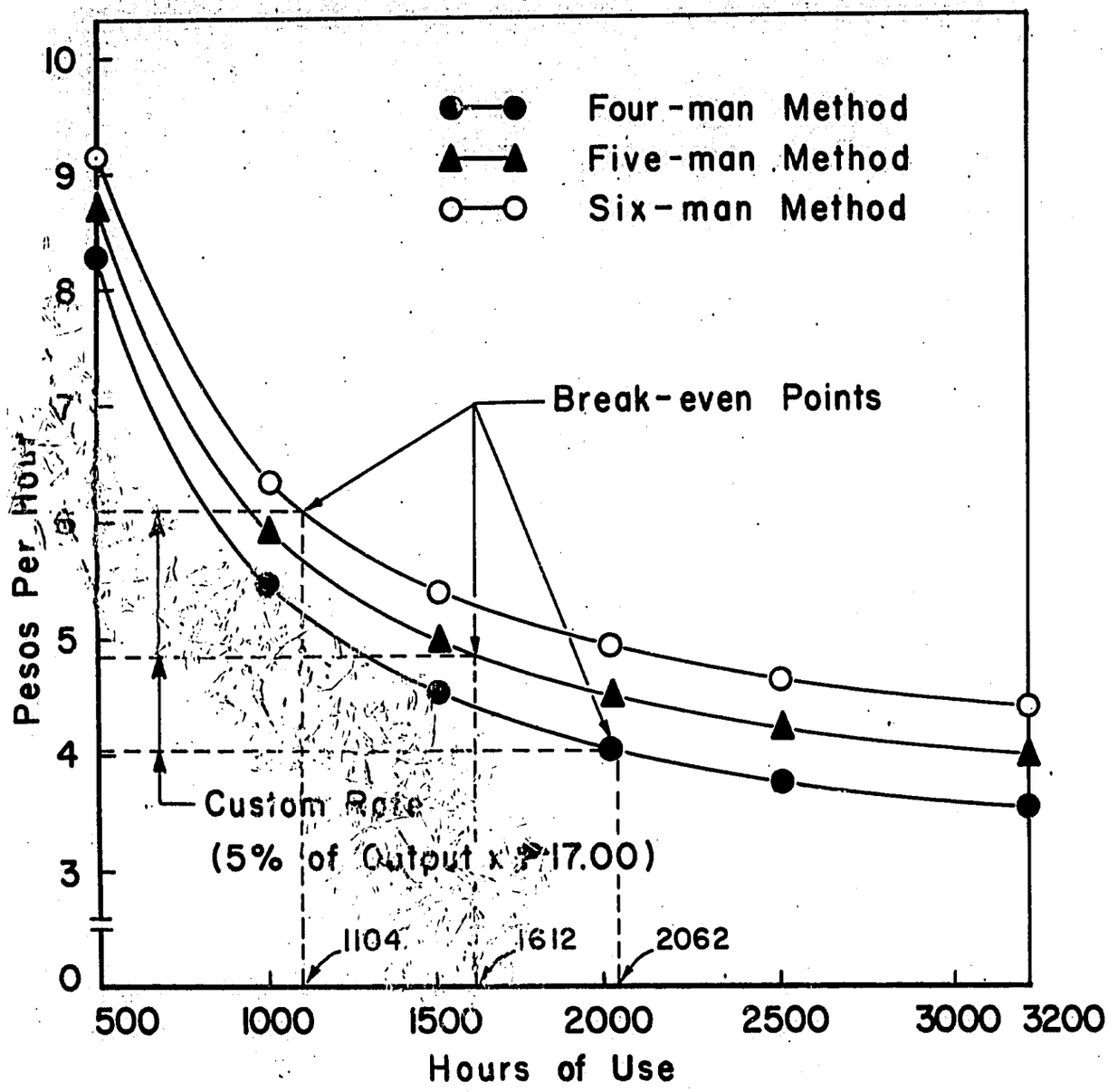


Fig. 29. Average cost curves, IRRI Drum-type Paddy Thresher.

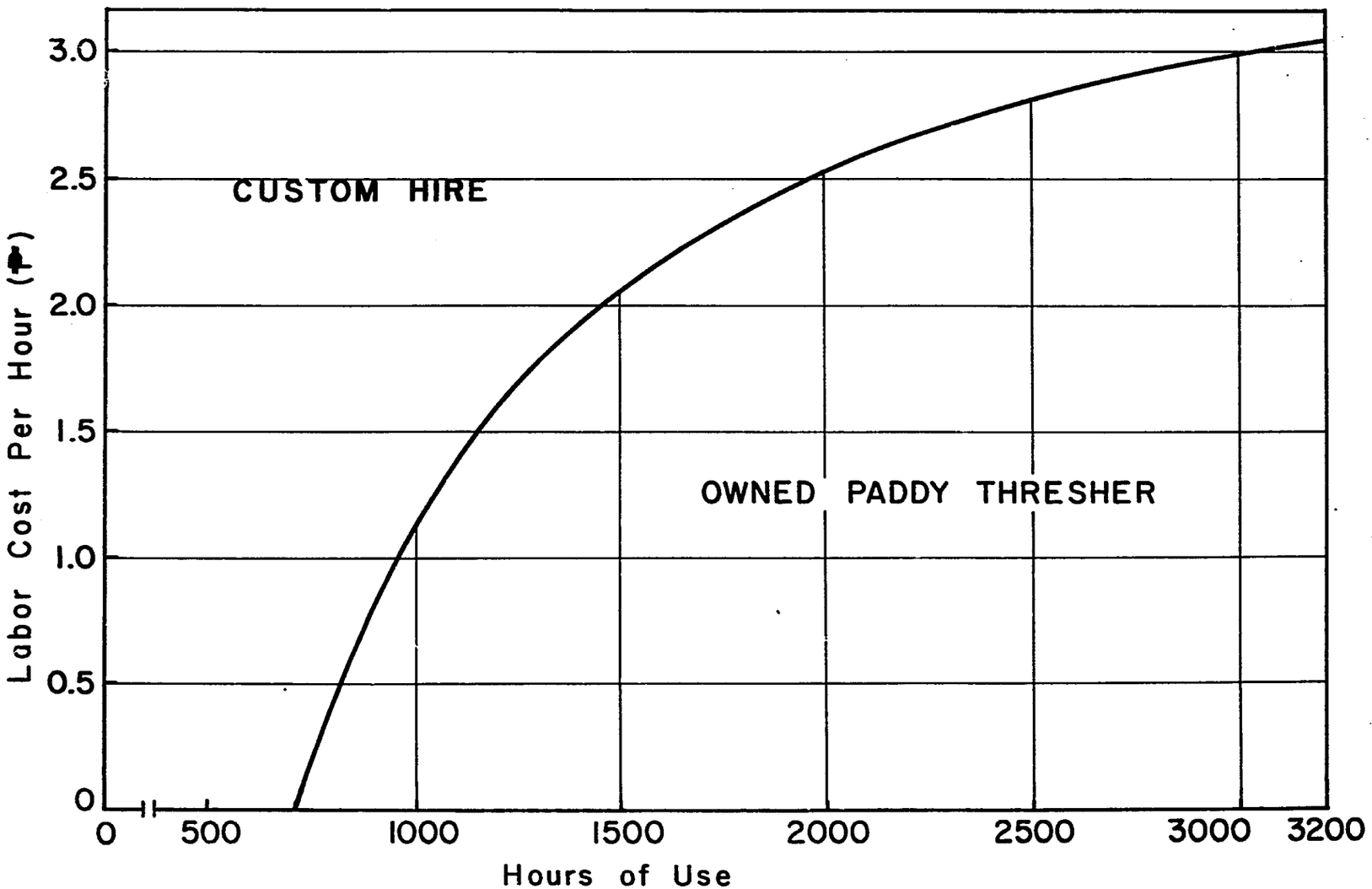
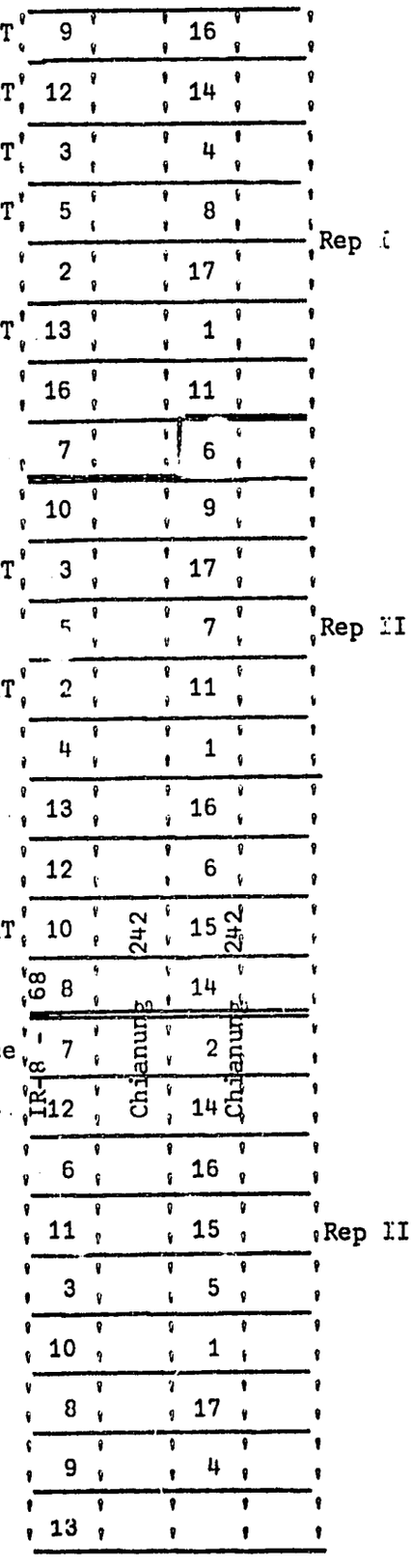


Fig 30. Zones of cost advantage: custom hiring vs owning IRRI paddy thresher using five man-method.

Fig. 31. Experimental plow layout for evaluation of weeding methods in flooded rice, 1968 wet season at IRRI (date of transplanting, Aug. 31 (21-day old seedling).

Treatment	Rate (kg ai/ha)	Time of application
1. (RW) 2x		23 & 35 DAT
2. (HW) 2x		23 & 35 DAT
3. (PPW) 2x		23 & 35 DAT
4. (RW) fb (HW)		23 & 35 DAT
5. (PPW) 1x		40 DAT
6. (PPW) fb (HW)		23 & 35 DAT
7. (RW) 1x		25 DAT
8. (HW) 1x		25 DAT
9. (PPW) 1x		25 DAT
10. MCPA fb (RW)	.8	25 & 35 DAT
11. MCPA	.8	25 DAT
12. MCPA fb (PPW)	.8	25 & 35 DAT
13. Trifluralin+MCPA(G)	.7 + .4	4 DAT
14. Nitrofen + 2-4D IPE(G)	2.0 + .8	4 DAT
15. EPTC + MCPA	1.75+ .7	4 DAT
16. MCPA fb (HW)	.8	25 & 35 DAT
17. No (HW)		



Plot size: (2 varieties) 4.5 x 6 m = 54 m + 1 m space between plots for turning.
Design: Split block of 3 replications (with systematic arrangement of vareities).
Varieties: IR8-68 & Chianung 242
RW = push-type rotary weeding
PPW = IRRI portable power weeding (experimental)
HW = hand weeding
1x, 2x = 1 time, 2 times
fb = followed by
DAT = days after transplanting
Herbicides: MCPA, Trifluralin, Nitrofen, 2-4D IPE, EPTC
G = granules

APPENDIX I

REPORT OF THE U.S.D.A. NATIONAL TILLAGE MACHINERY LABORATORY STUDY ON ROTARY TILLAGE AND TRACTION - JULY 1 TO DECEMBER 31, 1968.

Semi-Annual Substantive Report No. 4 on the Cooperative Agreement No. 12-14-100-9058 (42) between IRRI and NTML was prepared by A. W. Cooper, J. H. Taylor, C. S. Chang, and J. G. Henrick III.

Paddy Wheel Study

Introduction:

In Substantive Report No. 1 four objectives were listed for the study of paddy wheels:

1. Develop a method for determining the performance of small wheels. (Performance factors to include drawbar force, power efficiency, and sinkage - each through a range of slip values.)

2. Determine relative performance of small wheels selected by IRRI and sent to us.

3. Analyze test data and develop wheels to extend information.

4. Analyze causes of power losses and forces acting on the wheel system.

In Substantive Report No. 3 data collection was planned for the summer and fall of 1968. The progress to date and when objectives will be realized are as follows.

The equipment necessary for making basic measurements from which performance can be evaluated has been built (Report No. 3). The tests were carried out on schedule in the fall of 1968. Some of the data reduction has been done but not a sufficient amount to determine the relative performance of the selected wheels. This will be included in the next report. Some indications on effect of diameter, width, number of lugs, etc., may be forthcoming, but the purpose of this study was to determine relative performance. It is hoped that one or two wheels may show superiority in several performance factors, but even if they do it may not be possible at this time to correlate performance with wheel geometry. Plans for extending the information by developing new wheels are being made. Dr. Khan of IRRI has suggested a study on a special wheel where certain geometrical dimensions can be varied. Other special research wheels may have to be built to isolate the effects of specific design factors.

Power losses were to be analyzed. This should be in the next report. Sinkage was measured in all tests and by using a modified mechanics such as proposed by Chang and Cooper in Report No. 3, losses and forces may be determined.

The next report should bring realization of all objectives with the exception of extending information to other wheels. The analysis of the data should help in planning for extension of the information.

This report contains detailed information on the tests conducted during this reporting period with examples of the type data reduction being done.

Test Wheels and Soil:

Six right-side and one left-side paddy wheels, as shown in Figs. 1 & 2 and described in Table 1, were studied in the outdoor soil bin of NTML. Two soils were used for the tests, the Decatur silty loam and the Vaiden silty clay. A hard layer with a cone index of 500 psi was induced in each soil about 6" below the soil surface. The soils were flooded and tests conducted with about 1" of water above the soil surface. The soil conditions were characterized by moisture content and flat plate sinkage measurements.

Defining Slip:

In tractor tire tests at NTML zero travel reduction has been used which is defined at zero pull. In soft soil conditions there is considerable slip at zero pull. After a series of special tests, it was found that zero slip is better defined at zero torque which was adopted by this study. Based on this new definition of slip the test data indicated that the applied negative (pushing) force above the zero torque is giving positive slip instead of conventional negative slip which is questionable. A theoretical study will be made and an explanation of the new slip definition will be given in the final report.

Test Specifications:

In order to pick up the zero torque and to meet the special requirement of complete power tiller performance (rotary operation and tractive operation), the wheel tests were operated from approximately -10% slip to +60% slip.

Four series of tests were conducted on each of the two soils:

1. Effect of wheel design - 6 wheels used

   V (Initial forward velocity) = 1.75 ft/sec (1.19 mph) for rolling radius (r_o) = 16.5" (for W-2, 4, 5) and 1.45 ft/sec for r_o = 13.5" (W-1, 3)

   ω (Angular velocity of paddy wheel) = 1.25 rad/sec

   W (Static weight) = 400 lbs

2. Effect of load (Wheel W-5 used)

   $\overline{W}$ = 290, 350, 400, and 450 lbs

   V = 1.75 ft/sec (1.19 mph)

   ω = 1.25 rad/sec

3. Effect of velocity (Wheel W-5 used)

   V_0 = 1.75 ft/sec (1.19 mph) ω_0 = 1.25 rad/sec

   V_1 = 2.45 ft/sec (1.68 mph) ω_1 = 1.75 rad/sec

   V_2 = 3.15 ft/sec (2.15 mph) ω_2 = 2.25 rad/sec

   V_3 = 3.50 ft/sec (2.40 mph) ω_3 = 2.50 rad/sec

   $\overline{W}$ = 290 lbs

4. Directional effect of wheel (Wheel W-5L)

   V = 2.45 ft/sec

   ω = 1.75 rad/sec

   W = 400 lbs

   Left-hand wheel operated on right-hand side for determination of performance in backing up.

Type of Information Obtained:

A set of typical measured data and analysis are shown in Fig. 2 to Fig. 8. Figs. 4-8 present sample performance data using wheel no. 2 in Vaiden soil with a static wheel weight of 400 lbs, 1.75 ft/sec initial forward velocity, and a constant wheel angular velocity of 1.25 rad/sec. The analysis of data was based on the modified Chang-Cooper mechanics by changing tan θ to sin θ and defining zero slip at zero torque (see Fig. 3).

Rotary Tillage Study

The project investigation leader, L. W. Larson, was transferred to Beltsville, Maryland, in June. J. G. Hendrick was assigned to conduct research in the area of powered tillage tools in November.

The analysis of data on the special blades constructed at NTML and described in Substantive Report No. 3 is still underway. F. P. Smits, who returned to Holland in July, has the data and is completing the analysis. The report of this work will complete the tentative blade evaluation study

from the standpoint of power requirements.

Currently, it appears that there are four large areas in which research on rotary tillage is needed. Research must be conducted to provide:

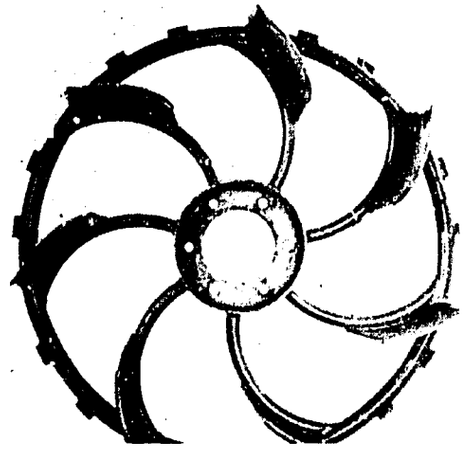
1. A method (or methods) to measure the performance of various powered tillage tools from a soil change standpoint. This will require an understanding of the cultural requirements of rice production and the intended function of the tillage tool.

2. An analysis of the comparative performance and energy requirements of selected existing rotary tools. Such research would provide information presently needed, and it should give insight into which phenomena need to be investigated in a more basic manner.

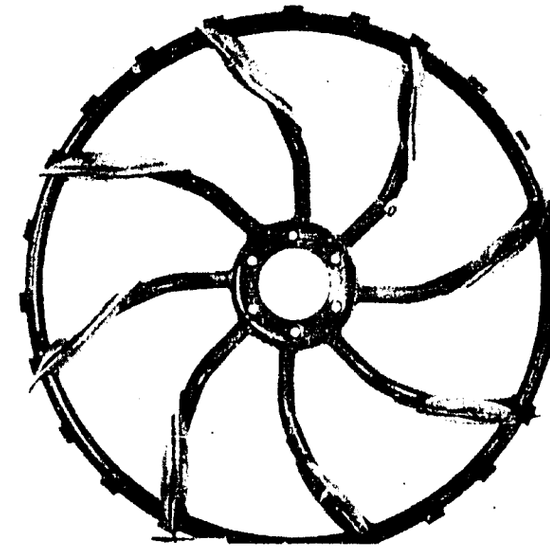
3. A better understanding of the soil-tool relationships in such relatively high speed tillage operations as rotary tillage in a wide range of soil conditions, to develop criteria for the design and production of efficient powered tillage tools.

4. The development of a tillage-mobility system for wet- and/or dry-land culture, since it is apparent that tillage and mobility can't be isolated from one another in many instances.

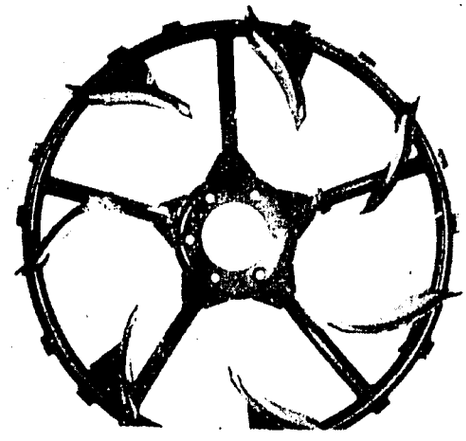
Research plans are being developed in these areas. Those projects which appear to have the most immediate need and those which appear to have the best potential for future benefit will be given priority.



W - 1

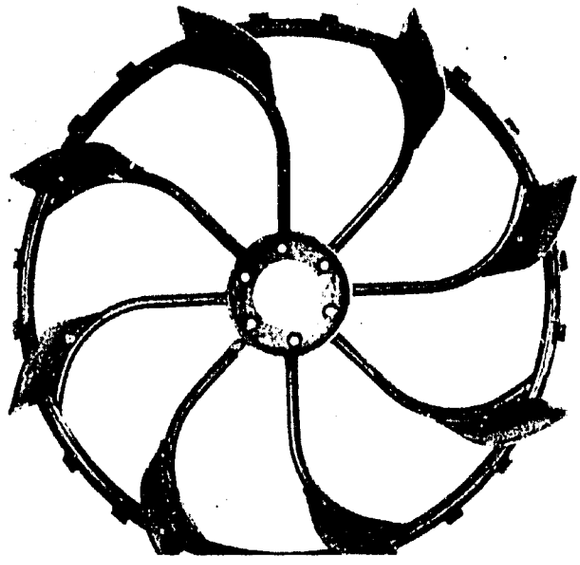


W - 2

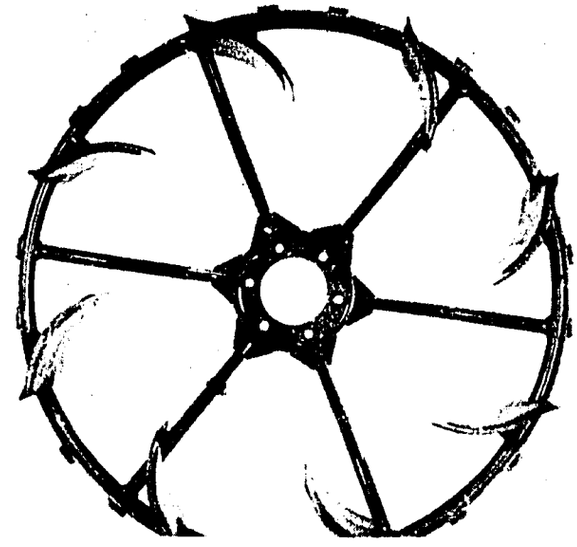


W - 3

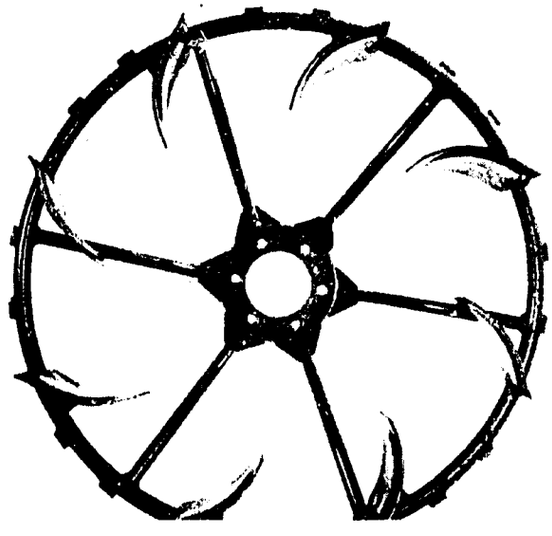
Fig. 1-1. Tested Wheels



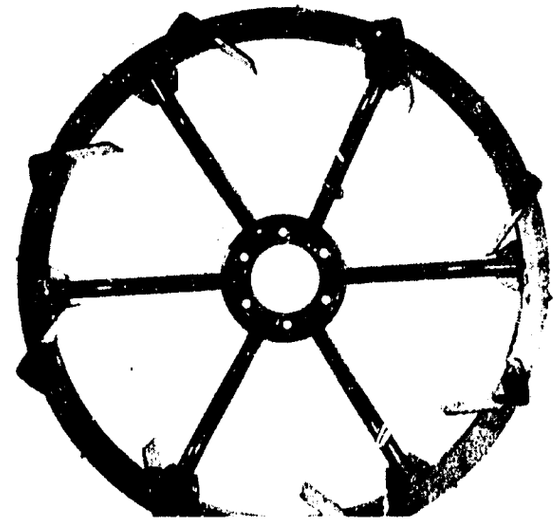
W - 4



W - 5



W - 5-L



W - 6

Fig. 1-2. Tested Wheels

Table 1. Dimension of the Tested Wheels (See Fig. 1, 2)

	Overall Dia. D (in)	Lug Width B (in)	Hub Length b (in)	Lug Length a (in)	Lug Radius R (in)	Lug Angle α (°)	No. of Lugs	Remarks
$\bar{W}$-1	27	8	0	6-1/2	6	45	7	Bent at end
$\bar{W}$-2	32-1/4	12	3	6(avg)	9	50	8	Hollow lug
$\bar{W}$-3	27	8	5-3/4	7-1/2	8	45	7	Bent at end
$\bar{W}$-4	33	9	4	7	6	45	8	Bent at end
$\bar{W}$-5	33	7-3/4	8	7-1/2	8	45	8	Bent at end
$\bar{W}$-5-L	33	7-3/4	8	7-1/2	8	45	8	Bent at end
$\bar{W}$-6	32	5	5	4-1/2, 2-1/2	∞	55	8	Bent 80°

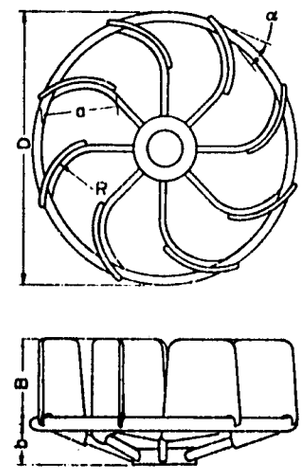
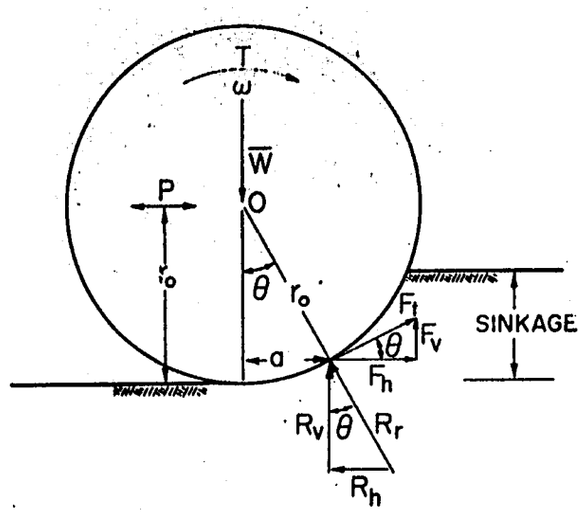


Fig. 2. Dimensions of the Tested Wheels



$\overline{W}$ - Dynamic weight

T - Torque

ω - Angular velocity

F_t - Resultant Tangential force

F_h - Thrust force

F_v - Vertical frictional force

R_r - Resultant radial force

R_h - Rolling resistance

R_v - Vertical compor .t of R_r

θ - Rolling angle

P - Push & pulling force

r_o - Rolling radius

Fig. 3. Proposed force diagram for the tested paddy wheels

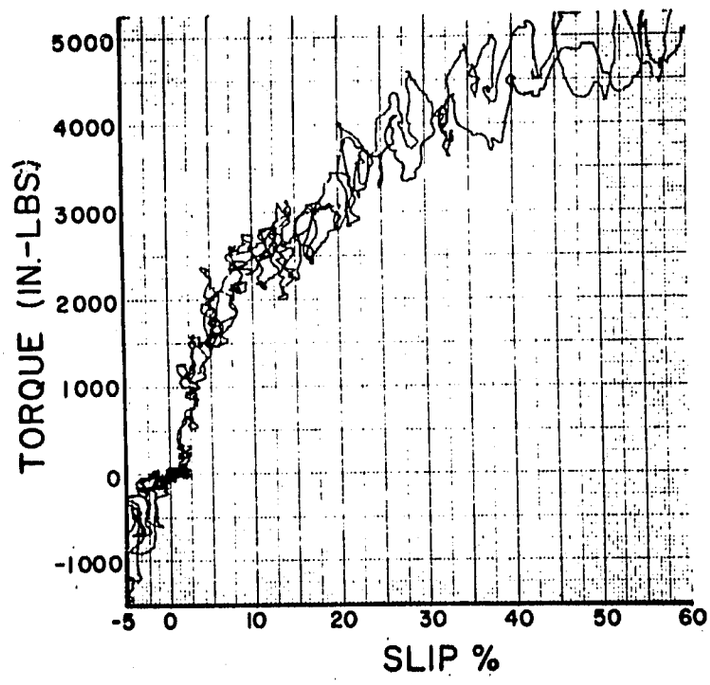


Fig. 4. Original torque-slip curve plotted by X-Y plotter for W-2, 2 replications PW-8 and PW-9

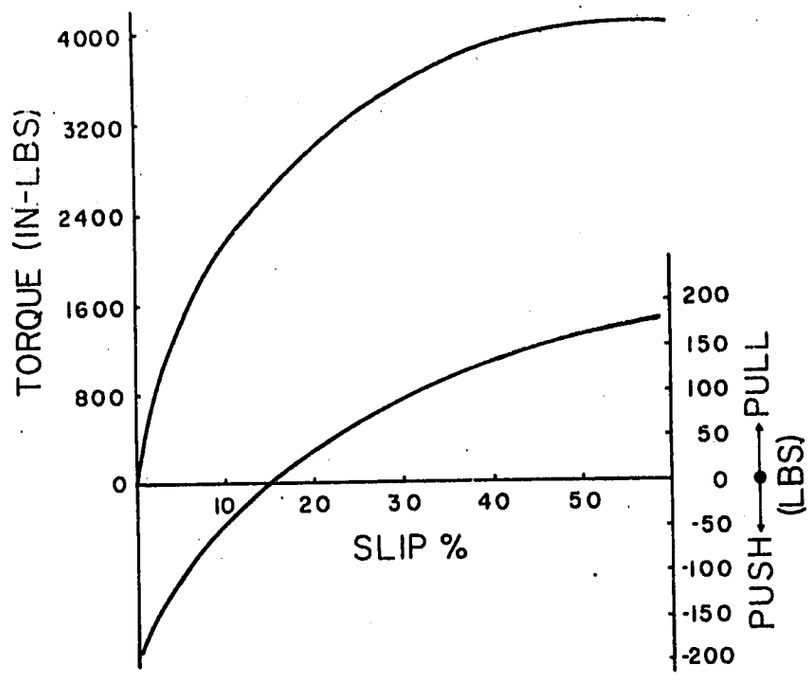


Fig. 5. Torque push and pull versus slip for W-2 (Test PW-9 - W-2)

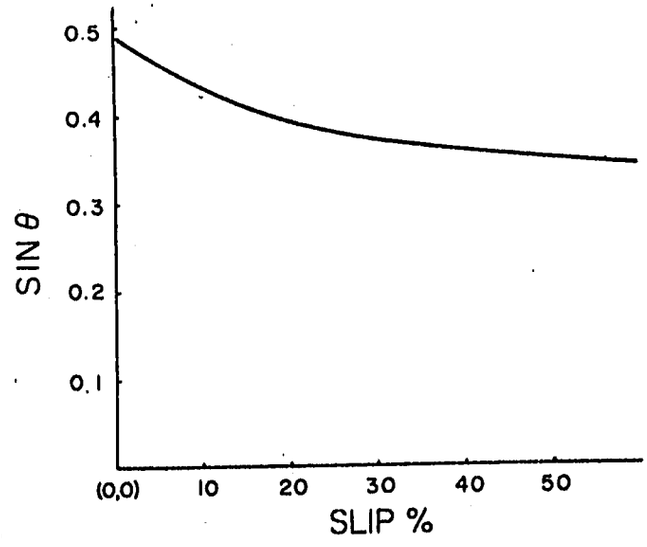


Fig. 6. Sin θ versus slip for W-2 (Test PW-9 - W-2)

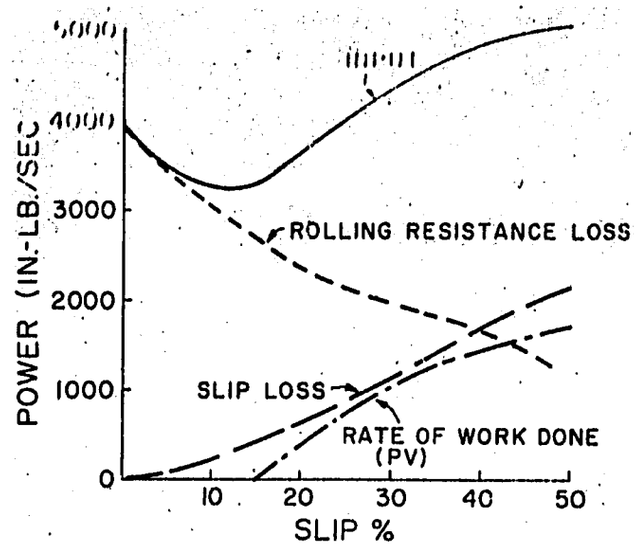


Fig. 7. Input and output versus slip for W-2 (Test PW-9 - W-2)

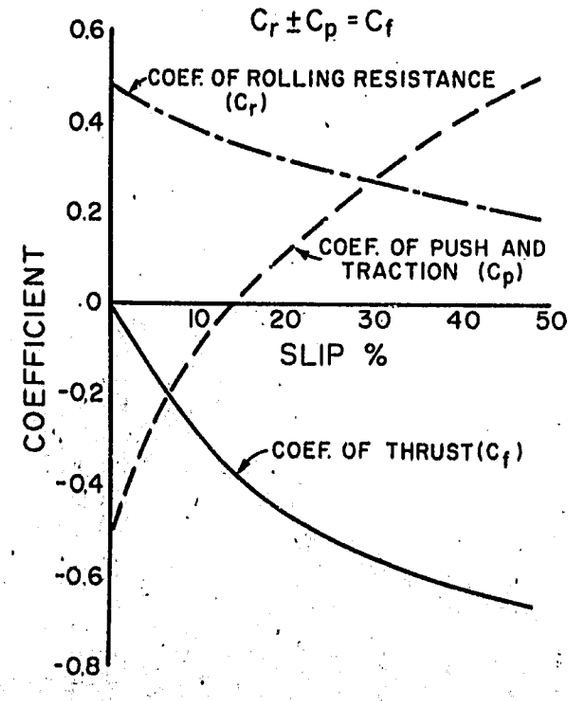


Fig. 8. Coefficient of horizontal forces versus slip for W-2 (Test PW-9 - W-2)