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(For the Period January 1, 1968 to June 30, 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

By

AMIR U. KHAN
Agricultural Engineer

STANLEY S. JOHNSON
Agricultural Economist

The International Rice Research Institute
Los Baños, Laguna, Philippines

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U.S.D.A. NATIONAL TILLAGE MACHINERY LABORATORY STUDY ON ROTARY TILLAGE AND TRACTION, January to June 30, 1968

INTRODUCTION

This is the sixth semi-annual substantive report on Contract AID/csd-834. The Contract, originally scheduled to terminate on June 27, 1968, has been extended for another year. The activities under the Contract are broadly divided into two categories: (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 development of the paddy thresher for threshing freshly harvested paddy. The machine has successfully progressed through the initial design and development phases and is now ready for final field evaluation. Its release for regular manufacture is contemplated after the next threshing season. Many local manufacturers have shown considerable interest in embarking on a program to manufacture this machine.

Work on the general engineering and economic research was diversified and increased emphasis was placed on the testing and evaluation of agricultural equipment. Additional survey activities in Cotabato and Isabela provinces were initiated.

The laboratory set up and test equipment for the rotary tillage and traction study at the U.S.D.A. National Tillage Machinery Laboratory, Auburn, Alabama was completed. Considerable data was gathered on the different types of rotary tiller blades. The progress report on this study is appended to this report.

Papers were presented on the machinery design and development activities and on the economics of mechanization by the senior Contract personnel at the annual meeting of the Japanese Society of Agricultural Machinery at Kyoto, Japan. The Annual Project Committee Meeting scheduled in June was not held this year. An NBC-TV documentary entitled "Food for Billions" which was shown in the United States covered some of the machinery development activities under this Contract. During the period of this report, a number of distinguished personalities and agricultural engineers from the United States and other countries visited the Institute's Agricultural Engineering department to acquaint themselves with the work being undertaken under this Contract.

PROGRESS REPORT
JANUARY 1 TO JUNE 30, 1968

A. AGRICULTURAL MACHINERY RESEARCH

Summary

The industry-oriented machinery development program continued to receive considerable attention from the project personnel. Major effort was exerted in testing and evaluating the machines built during the period covered by the last semi-annual report. The test and evaluation program pinpointed the weak areas of the machines. Subsequent modifications and improvements were undertaken to further develop the designs. While the test and evaluation program is still in progress, sufficient data on two machines have been obtained and are presented in this report to give an idea of their performance.

Work on the drum-type thresher has made considerable headway, with the second prototype machine approaching the final stages for a trial production release. Some local manufacturing companies have shown interest in its manufacture and it is hoped that the machine would be produced in the near future for widespread field-testing.

The applied research program on tractor tillage and mobility has shown considerable promise by substantiating the validity of the hypothesis on which this study was based. The concept offers a definite advantage over conventional equipment under soft land conditions.

Two additional projects, "The Application of Anhydrous Ammonia by Small Tractors" and "Physical Properties of Paddy," were initiated during the period covered by this report. Equipment for the ammonia project has been built and the test and evaluation program has been planned for the forthcoming paddy season.

The projects handled by the Contract staff during the period covered by 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	M. 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 paddy	E. O. Casem

The progress of each of the projects is presented in the succeeding pages.

DRUM-TYPE POWER THRESHER

A second prototype thresher (Figure 1) incorporating several improvements has been completed. The machine is simple in construction and can be manufactured with locally available materials. It can thresh and separate freshly harvested paddy even under heavy dew or rain conditions. In some tests the machine was able to thresh and clean satisfactorily when the grain moisture level was beyond the maximum 30% M.C. limit on the moisture testing scale. The machine does a better job of separating grain from straw with freshly harvested crops than with dry crops. This is because green leaves are flexible and do not break easily, thereby lending themselves well for rotary screen separation. On the other hand, dry leaves tend to break into very fine pieces which are difficult to separate from the grain.

The machine was field-tested in the provinces of Laguna and Isabela, Philippines. Based on these tests, some design modifications and improvements were made on the separating mechanism. The design of the rotary screen separator was considerably improved by spiral baffles (Figure 3) which control the movement of the grain and chaff in the separator. Two sets of baffles move the material in the separator to two sets of tumbling pockets which elevate and drop the material on a grain-spreading chute located above the air stream. Mixed grain and straw from the threshing drum are delivered into the wide end of the rotary screen separator where the first set of baffles collects and delivers the material to the initial elevating pockets (A). As the rotary screen separator rotates, the material is elevated and dropped on the grain-spreading chute. The spreading chute is fitted with guide rails which direct the threshed material into the air stream. As the material goes through the air stream, the relatively light straw is carried out with the air through the rear outlet. The heavier grain falls on the rotary screen and is delivered out of the separator. The grain-straw separation is not thorough in the rear portion of the separator. The second set of baffles collects the material from this part of the separator and transfers it to the elevating pockets (B) for a second pass through the air stream.

The first prototype machine was designed on the assumption that the grain could be collected satisfactorily by laying a canvas sheet underneath the rotary separator. Field experience and comments from observers indicated the necessity to elevate the threshed grain for direct delivery into a sack or a container. Since the limitations on costs excluded the possibility of using a separate mechanism for elevation and delivery, a simple semi-circular sheet metal trough was fitted under the rotary separator. The three rubber flaps were fitted on the rotary separator to sweep, elevate, and deliver the grain from the trough at a suitable container height. The arrangement, shown in Figure 2, is quite simple and has proved very satisfactory.

Another premise of this thresher design was that the market will accept a thresher if it can thoroughly thresh both dry and wet paddy, even if it may only do a reasonable degree of grain-straw separation. The machine has demonstrated excellent threshing performance on both dry paddy (14% M.C.) and

freshly harvested paddy (over 30% M.C.). The grain-straw separation is excellent under wet and high-moisture crop conditions. However, under dry conditions, some amount of chaff and dust is present with the grain. Observers have occasionally commented about the desirability of thorough winnowing and cleaning of the grain. Generally, the threshed paddy is dried to a safe moisture level before it is stored, and winnowing is better performed after the grain has been dried. Nevertheless, it was felt that increased emphasis should be placed on improving the winnowing of the grain in the machine. Since one of the desirable features of the machine is its low cost, the problem needs to be tackled with an extremely cost-conscious approach. Work is underway on a possible solution to improve the cleaning of the grain by using an oscillating sieve.

Test and Evaluation of the Drum-Type Thresher

The thresher was subjected to a series of tests to establish its performance. Its recovery of grain was better than that of the manual threshing method on a threshing board. It also can recover additional grain when it rethreshes samples of hand-threshed straw.

The unthreshed grain left on the panicles after threshing is the nonrecoverable threshing loss. This loss was evaluated by carefully hand-stripping all the unthreshed grains and recording them as percent of total grain fed through the machine. Four 10-minute trials were conducted with two men simultaneously feeding bundles of IR8 paddy at 20 percent grain M.C. An average value of 0.97 percent threshing loss was obtained during these tests.

The methods of feeding and the number of men feeding the machine have a significant effect on the total machine output and the output per man. Tests were conducted to establish the optimum method of feeding and the optimum number of men required for threshing with this machine. Figure 4 shows three basic methods of feeding the paddy bundles to the thresher.

Method I is the Pick-Thresh method, in which the men stand at fixed locations near the thresher, pick handfuls of paddy from a stack, and then turn and feed the bundles to the threshing drum. The number of men which can conveniently feed a machine is restricted by the length of the drum. Experience has shown that a maximum feeding space of 20 inches per man is required for convenient feeding. During the tests with this method, the number of men was varied from one to five.

Method II illustrates the Pick-Walk-Thresh method, in which the men walk continuously in a cycle, picking the paddy bundles and threshing while walking beside the threshing drum. There is no specific limit to the number of men which can simultaneously thresh by such a method. The threshing drum should only be long enough to completely thresh the paddy before the men reach the end of the drum. A longer drum would result in an ineffective use of the extra threshing surface. During tests of this method, the number of men was varied from two to eight.

Method III illustrates the Pick-Transfer-Thresh method, in which the men are split into two groups. Men from the first group, located close to the paddy stacks, pick and transfer convenient-sized handfuls of paddy to the men of the second group. The men from the second group, located close to the threshing drum, do the threshing. All the men are stationed at fixed locations, and there is no definite limit to the total number of men which can be used. However, the number of men located at the threshing drum is limited by the length of the drum. In tests of this method, the number of men in both groups was varied from one to four.

Table 1 and Figure 5 show the results of short-duration (15 minutes) tests, each with three replications, conducted at Bay and Calauan, Laguna on May 8-10, 1968. A total of 22 different combinations of men and methods was tested for threshing output. The rice variety Intan, with yields of 4.3 metric tons per hectare at 14% M.C., was used throughout these tests.

With a labor force of up to four men (feeding methods I to X), method No. 1 (Pick-Thresh) resulted in higher threshing output. However, with five or more men (method XI onward), method No. 3 (Pick-Transfer-Thresh) gave better output. Method No. 2 (Pick-Walk-Thresh) consistently resulted in poor output.

Trials of longer duration with methods XII, XV, XVII, and XXI, which had given encouraging results in the short-duration tests, were repeated with the high-yielding IR8 rice variety (yields of 7.2 metric tons per hectare at 14% M.C.). Table 2 and Figure 5 show the results of the continuous one-hour test using these four methods. The results were not only consistent but also indicated slightly higher output than those of the 15-minute trials, perhaps because a higher yielding variety was used.

TABLE-TYPE POWER THRESHER

The design of a light-weight engine-driven thresher with a rotating flat threshing surface has been reported earlier. The machine could thresh dry and wet paddy but its performance in separating and cleaning the grain needed improvement. Excessive grain scatter was also a problem, but this was partly solved with the use of curved canvas shields. Although this project requires considerable work, no further work was undertaken due to the preoccupation with the drum-type thresher. Development work on this machine will be initiated in the near future.

TRACTOR TILLAGE AND MOBILITY STUDIES

The objectives and design details of an experimental wetland rotary tiller (Figure 6) built at IRRI were described in the last semi-annual report. Special cage wheels (Figure 7) for this wetland tiller have been completed. Each cage wheel is designed with two sections with 12 blades. The blades are bolted around the rim and each blade angle can be fixed in nine positions at 15° intervals. The degree of tillage or support effect of each blade can be altered by changing the blade angle. With this feature the cage wheels could

be used for maximum tillage or maximum support or any combination of the two conditions. These cage wheels will be used in studying the optimum blade angle required for adequate support and tilling characteristics under soft wetland conditions.

A series of tests has been conducted under submerged wetland conditions on the IRRI experimental wetland rotary tiller. Figure 8 shows this rotary tiller (henceforth referred to as the IRRI rotary tiller) operating under wetland conditions. The effect of tillage at the low and high tiller blade velocities of 2.10 m/s and 3.77 m/s, respectively, when the tractor was travelling in the II speed (0.75 m/s), is illustrated in Figure 9(a) and (b). An objective of these tests was to study the pushing behavior of the tiller on the tractor under relatively hard and soft wetland conditions. Tests comparing the IRRI rotary tiller with a conventional rotary tiller were also conducted. A commercially available conventional rotary tiller of similar weight and width was used in making the comparison.

A 55-hp conventional four-wheel rubber-tired tractor equipped with a standard 540 rpm PTO and a standard Category II three-point linkage was used in all the tests on the IRRI and the conventional rotary tillers. Four rubber-tipped crown type lug wheels (Figure 8), one on each side of the two rear wheels, were fitted to improve the field mobility of the tractor. Table 3 lists the specifications of the tractor and its accessories while Table 4 lists the specifications of the two rotary tillers used during the tests.

The average slippage of the two tractor drive wheels was used as an indication of the pushing reaction from the tiller to the tractor. High wheel slippage indicated lower pushing reaction for a specific combination of tractor speed and tiller blade velocity. The distance travelled by the two rear wheels during two complete revolutions was marked and measured on the ground with the help of stakes by two men walking beside the tractor rear wheels as shown in Figure 8. The average wheel travel distance during two wheel revolutions was computed. A limited slip differential lock was used during all the tests to avoid excessive slippage on any one wheel. The percentage of wheel slippage was calculated as follows:

$$\text{Percentage of wheel slippage} = \frac{\text{No-slip travel distance of rear wheel per 2 revolutions on concrete} - \text{Measured rear wheel travel distance per 2 wheel revolutions}}{\text{No-slip travel distance of rear wheel per 2 revolutions on concrete}}$$

The tillage depth was fixed at 12 cm by the depth control lever on the tractor hydraulic system. However, there were unavoidable variations due to the uneven ground and wheel sinkage. To reduce these variations, the working depth was measured with a measuring stick at three spots after every test run. A soil penetrometer with a 30° cone and a 3.2 cm^2 base area was used to measure the depth at certain soil penetrating resistance. Five penetrometer depth readings at a soil resistance of 35 psi and 70 psi were taken prior to every test in an area just ahead of the tractor.

The IRRI tiller had provisions for four peripheral blade velocities while the conventional tiller had three blade velocities. Four forward tractor travel speeds were used, thus providing 16 combinations of tractor travel speed and tiller blade velocity for the IRRI rotary tiller and 12 for the conventional rotary tiller. Tests were also made to determine the rear wheel slippage at different tractor speeds while the power take-off drive to the tiller was disengaged. These tests indicated the wheel slippage when the tractor was towing a free-rolling tiller. Finally, tests were made to establish the tractor wheel slippage without the rotary tiller in the four forward tractor travel speeds. To minimize errors due to variations in the soil conditions, each test was conducted on an undisturbed part of the field.

Experimental data from three tests, (1) IRRI rotary tiller on relatively harder soil conditions, (2) conventional rotary tiller on relatively harder wetland conditions, and (3) IRRI rotary tiller on relatively softer wetland conditions, are presented in Tables 5, 6 and 7. These results are plotted in Figures 10, 11 and 12, respectively.

Figure 10 (Table 5) shows the relationship between tractor travel speed and rear wheel slippage at different blade velocities of the IRRI rotary tiller under relatively harder wetland conditions. The pushing effect of the IRRI rotary tiller was indicated by the substantial reduction in wheel slippage whenever the tiller was powered from the tractor PTO. The pushing effect of the IRRI rotary tiller, under relatively harder soil condition, was so pronounced that sometimes the tractor rear wheels registered a negative slippage.

Results of a test to compare the pushing reaction of the IRRI rotary tiller with that of a conventional rotary tiller, conducted under similar soil conditions, are shown in Table 6 and plotted in Figure 11. The specifications of the conventional rotary tiller used in this test are listed in Table 2. There are apparent differences in rear wheel slippage between Figures 10 and 11. The IRRI rotary tiller had less rear wheel slippage than the conventional rotary tiller. For the same peripheral blade velocities of the two rotary tillers, tractor wheel slippage in the case of the IRRI rotary tiller was considerably lower.

One of the factors contributing to the reduced tractor wheel slippage is the increased soil reaction due to the 30 cm by 13 cm flat blades of the IRRI rotary tiller. The sharp conventional spading blades provide good tillage, but are unable to provide enough soil reaction under soft wetland conditions. The large diameter of the IRRI rotary tiller also provides an increased horizontal component from the soil reaction as compared with the small diameter of the conventional rotary tiller.

Generally, a wider variation in tractor wheel slippage was observed with the IRRI rotary tiller when the blade velocity was changed by only 180% from 2.10 m/s to 3.77 m/s, whereas a smaller variation was found when the blade velocity of the conventional rotary tiller was changed by 200% from 2.78 m/s to 5.56 m/s. This shows that the pushing force of the IRRI rotary tiller is influenced more by the peripheral blade velocity. This suggests the possibility of controlling the pushing force by changing the tiller blade velocity.

Figure 12 plots the test results of the IRRI rotary tiller under softer soil conditions. The rear wheel slippage of the tractor without the tiller was excessively high under these soil conditions than under harder soil conditions (Figure 10). However, with the IRRI rotary tiller, the tractor rear wheel slippage was still lower than with the conventional rotary tiller under relatively harder soil conditions (Figure 11). This result indicates that the IRRI rotary tiller is more effective in reducing tractor rear wheel slippage under softer soil conditions.

Under all conditions the lower peripheral blade velocity of the rotary tiller results in lower tractor wheel slippage. Increased soil reaction due to increased tilling pitch at lower blade velocities of the rotary tiller seems to provide the increased pushing reaction.

The following conclusions can be drawn:

1. The IRRI rotary tiller decreases the tractor wheel slippage to a greater degree than a conventional rotary tiller.

2. The pushing effect of the IRRI rotary tiller is more pronounced under softer soil conditions.

3. With the IRRI rotary tiller there is a more significant reduction in wheel slippage whenever the tractor speed is increased.

4. Higher peripheral blade velocity of the IRRI rotary tiller increases the tractor rear wheel slippage. Slower peripheral blade velocity of the tiller seems desirable for increased tractor mobility.

5. The large diameter cage wheel-type IRRI rotary tiller offers improved mobility when used as a tilling device under softer wetland conditions.

The results presented in this report are preliminary. Further experimentation is required to establish the above findings under different field conditions. More elaborate tests using strain gauge equipment for direct field recording of the pushing reaction from the tiller are being planned.

USE OF MECHANICAL POWER FOR ROTARY WEEDING

Work was continued on an experimental portable power weeder described in the last semi-annual report. The machine (Figure 13) used a back-mounted 50-cc, two-stroke, high-speed gasoline engine equipped with a centrifugal clutch. The power from the engine was transferred through a partly flexible shaft to a 40:1 reduction worm gear box. Three weeding rotors were mounted on the worm gear shaft which rotated at a speed of 110 to 130 rpm. The worm gear box offered high speed reduction with minimum addition of weight. Results of a preliminary field trial were included in the last report.

The main objective of this project was to use a rather light-weight machine to achieve maximum field coverage at a shallow practical weeding depth. Further testing and modification of the weeder blades were undertaken to provide self-cleaning action, adequate ground support, and enough cutting-scraping action for proper weeding. The blades were designed to provide adequate ground reaction and avoid excessive machine sinkage. The cutting and scraping edges on the blades were designed for a very shallow working depth of 2 to 3 cm (Figure 17). Working on the soil to a greater depth would consume power without any additional benefit. Rotor blades and spokes were designed as illustrated to prevent weeds and mud from clinging to them. The 12-1/2-inch diameter rotors equipped with six blades provided good slippage with minimum traction and shallow soil working ability.

In their early growth stages, rice plants are flexible and can be safely bent to 3- to 4-inch height. A 12-1/2-inch diameter rotor provides enough axle clearance for the plants in the rows to bend and pass under during weeding. In some field trials at IRRI, weeding was performed with this machine on 18-inch tall rice plants. The plants were able to straighten themselves after weeding without any adverse effects. Guide-shields to direct the rows of rice plants into the space between the rotors have been provided on the machine. These guides also protect the plants from getting caught by the edges of the rotor blades. Two blade-mounting arrangements were built for easy adjustment to suit the considerable variation found in row spacing. The minimum clearance between two rotors for one row of plants is 9 cm. In crops planted at 25-cm row spacing, a width of 16 cm is available for each weeding blade. It seems difficult to maintain the minimum 9-cm spacing for rows if fixed width blades are used for all row spacings. Perhaps blades of variable width may have to be designed to meet the variations in row spacing.

Attention has also been directed to reduce operator fatigue by minimizing machine weight and studying the various suspension and mounting arrangements of the machine. The flexible shaft arrangement of the first experimental machine permitted the strapping of the engine on the operator's back. During weeding only 12 kg, out of the total weight of 24 kg, was supported by the operator. However, at the end of the row, the operator had also to lift the additional 12-kg weight of the weeding rotor, which was located at the end of a 1.2-m long shaft. Considerable effort was required to lift the rotor.

It was felt that an alternate design in which the engine weight could be balanced against the rotor weight, would result in reduced lifting effort at the ends of the rows. A second machine was designed (Figure 15) in which the engine and weeding rotor were connected by a long rigid shaft. A sliding hitch suspension (Figure 14) enabled the operator to balance the engine against the rotor when turning at the end of the rows. This arrangement has been preferred by most of the operators who have used this weeder.

The engine and worm reduction gear box of the first experimental machine was quite heavy, so a smaller 32.5-cc engine and a lighter worm reduction gear box (35:1) were used on the second experimental machine. Work is under way on the third machine which is expected to weigh about 17 kg, a reduction of 7 kg from the first experimental machine. Tests have also been made with a five-row weeding head using the first experimental unit (Figure 16). The 50-cc engine had sufficient power for weeding five rows; however, the weight of the unit was excessive. A five-row weeding unit is being built for the light-weight second experimental machine which will be tested in the near future. Investigations are being made to evaluate operator fatigue for comparing the different versions of weeding machines being built under this contract.

It is felt that one light-weight portable power unit with a number of quick-change attachments, such as weeder, harvester, and sprayer, can find a substantial market in the tropical rice-growing countries. This project was briefly discussed in a paper presented at the annual meeting of the Japanese Society of Agricultural Machinery. Considerable interest was generated among Japanese engineers in this concept for mechanical weeding.

APPLICATION OF ANHYDROUS AMMONIA WITH SMALL TRACTORS

Past experimental work by the Agronomy and the Agricultural Engineering Departments at IRRI has established that anhydrous ammonia(82%N) is a promising fertilizer material for flooded rice fields. Suitable equipment for application of anhydrous ammonia in flooded rice paddies is not available. The recent popularity of small tractors for tropical rice mechanization prompted the initiation of a feasibility study on using small tractors for anhydrous ammonia application.

An anhydrous ammonia attachment (Figure 18) which can be attached or detached by only two pins was fabricated for a small walking tractor. The applicator is patterned after a standard tractor comb harrow and is 125 cm wide with six 14-inch long applicator shanks spaced 25 cm apart. The shanks are of the back-swept type to reduce trash collection. The pressure regulator, flow distributor and control valve are all mounted directly on the comb applicator for easy attachment and detachment from the tractor.

A 1,000-cu.in. tank with an 8.5-kg ammonia capacity is mounted with a tubular bracket on the front end of the tractor. The front-mounted tank arrangement counterbalances the rear-mounted applicator assembly and improves the tractor balance. A flexible 3/8-inch rubber hose from the ammonia tank is connected to the pressure regulator assembly on the comb applicator.

The applicator has been tried on puddled soils and no mechanical or ammonia leakage problems were encountered. Field tests under wetland conditions are planned for the forthcoming paddy season.

PHYSICAL PROPERTIES OF PADDY

There is a shortage of information related to physical properties of paddy. Such information could be useful for the thresher and stripper harvester development projects of the department. Design of a testing apparatus to measure threshing force by non-impulsive acceleration has been completed and fabrication of the same is underway.

Eight varieties of rice were planted at appropriate dates to ripen at about the same time for a series of tests on their mechanical properties. Plant and grain samples will be tested on alternate days beginning 12 days prior and ending 12 days after the optimum maturity date.

B. GENERAL ENGINEERING AND ECONOMICS RESEARCH

Summary

The research program in general engineering and economics has followed the program outlined in the work plan for 1968. These study areas are:

1. Studies on the performance and economics of use of power units, including comparative analyses of carabao and hand tractor operations, and a preliminary analysis of medium and large tractor operations in land preparation;

2. A study of the performance and economics of use of harvesting-threshing machines;

3. Weekly agronomic-engineering surveys of the three major rice-producing areas of the Philippines: Central Luzon, Laguna Province, Isabela Province of Northeastern Luzon, and Cotabato Province of Mindanao; personal interviews with the operators of the sampled fields in order to obtain data on farm management and on factors relating to mechanization, and

4. Analysis of soil resistance (trafficability) to determine the magnitude of very soft fields in the major rice areas of the country, between one-crop and two-crop areas, and between stages of the sequence of farm operations.

PERFORMANCE AND ECONOMICS OF POWER UNITS

Increased emphasis has been placed in the project on the analysis of the performance and economics of current and newly designed farm machinery. In attempting market research to better understand the need for the specification of new machinery, we found that existing test data were inadequate for our purposes. Therefore, testing programs have been started on the two main farm power equipment - those used for land preparation and harvesting-threshing. The tests also will involve weeding and planting equipment. Since the testing program can proceed only during the short time periods when these operations are underway, we have only sketchy data to present in this report. Each operation is discussed separately.

In Philippine agriculture, including the cultivation of 2 million hectares of lowland paddy, a total of about 3.5 million carabaos plus several thousand tractors are used. A rough estimate is that there are between 7,500-10,000 standard-sized tractors, and over 5,000 units of hand tractors. Sales of hand tractors are localized, especially to small farmers who have irrigated 2-crop farms, that is, those with repayment capacity, and in areas of soft soils. Data from interviews with hand tractor owners in Laguna Province are presented in Table 8. Laguna Province has the largest number of hand tractors mostly of the smaller type (between 4 and 6 hp). Recent sales figures indicate that the larger power tiller is gaining in popularity. In Table 8, of 434 machines reported, roughly two-thirds are 3 years old or less. The machines were used for a combination of land preparation on the owner's farm and for contract work. The owner typically reported that he had 4.0 hectares of his own land to be prepared twice a year. In addition, about 30 days per year were spent on contract hire. The hiring fee for the 4-6 hp tractors, with operator, is about ₱35 (including meals) per day.[1/] For the power tiller, a typical rate is ₱60 per day.

For the small hand tractor, the replacement of the carabao is almost 1:1 as the size of the moldboard plow and comb harrow of the carabao and tractor are about the same. The tractor gains advantage in speed, endurance, and by the effect of the cage wheels. The power tiller uses the rototiller to replace plowing and some of the harrowings. Land preparation with the small tiller involves typically one plowing followed by 3-5 harrowings. The final harrowing may follow a week after the others to bury germinating weed seeds.. For the power tillers, the rotovation may be done twice, followed a week later by 2-3 harrowings. The contract cost per plowing is ₱75-₱115; for each harrowing, ₱10-₱17; for each rotovation, ₱32-₱65.

In report #5, a table comparing carabao and hand tractor plowing and harrowing times was presented and contract costs for these operations were computed. Further field testing have revealed that many of the farmers with hand tractors have firmer fields than those used in the controlled experiment. Their

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[1/] ₱3.90 equals US$1.00.

plowing-harrowing time is much closer to the time necessary for one complete coverage than was the case in the experiment. To compare the time used in the controlled experiment with the actual time used in the firmer soils, the effective field capacity[2] was computed for the experimental fields.

The efc for the plowing operations indicate that the carabao and tractor were turning over only half the soil in the experimental fields. The harrowing operations were much closer.

A contract hire cost can now be attached to the efc times as a likely indication of the cost of preparing firm fields. These theoretical figures would indicate a similar total cost for 4-6 hp tractors and carabao.

The number of days required to prepare one hectare then is:

tractor (8-hr day): actual, 3.4 days; efc, 5.9 days.
carabao (6-hr day): actual, 20.0 days; efc, 24.3 days.

To determine the capacity of each during the crop year, perhaps we can start with an assumption of a 60-day period of land preparation for each crop. Remember that the crop requires 110-120 days to mature, or about 4 months; for 2 crops, that is 8 months. When we add 60 days to each, or 120 days, this is another 4 months, or the entire year.

For the carabao, with 20 to 25 days per hectare, the maximum is 2.5 to 3.0 hectares per season. We can turn to the later table on farm size and the average number of carabaos to see actually how many carabaos there are for this size grouping.

For the hand tractor, with 3.5 to 6 days per hectare, the maximum hectarage per 60 days is 10 to 17 hectares per season. The interview data on hand tractors indicate a median of 4.0 hectares own land and 30 days contract hire. By our figures, this is roughly 4+6 = 10 hectares, and compares favorably with our assumptions.

Several large and medium-sized tractors were tested in Isabela Province where soils are firmer than at IRRI. The data are contained in Table 10.[3]

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[2] Effective field capacity is a measure of the time needed to perform a field operation on a particular-sized field. The equation is:

efc (sq m/hr)60x2:N:L:W/t, where:

2 = number of trips per round
N = number of rounds
L = length of trip, in meters
W = width of implement, in meters
t = time used during operation, in minutes.

[3] These field tests and much of the trafficability studies were conducted by E. L. Ruiz.

Three large tractors of 55-70 hp, three medium-sized tractors of 11-14 hp, and one power tiller of 8.5 hp were tested during rotovation. One of the 55-70 hp tractors in second gear (high speed) had the highest effective field capacity. It rototilled 1.07 hectares in one hour with a fuel consumption of about 6.38 liters of diesel. However, the engine overheated at this high speed so that the operation was impractical. The other two large tractors registered an almost identical efc of about 0.71 ha/hr with a fuel consumption of 11.34 liters per hectare for one and 8.45 liters per hectare for the other. Wheel slippages were 24.38, 12.19, and 3.36 percent.

The medium-sized tractors had an efc of about 0.22, 0.19, and 0.12 ha/hr. The least fuel consumption was about 9.24 liters of diesel per hectare. Others: 14.65 liters (diesel) and 50.76 liters (gasoline). It can be noted in the table that the depths of cut for the medium-sized tractors were slightly deeper than for the large tractors; this is because the areas where the former had worked were previously plowed while the areas for the latter were not.

Four makes of large tractors were tested for harrowing. One tractor with a 2.90-meter wide comb harrow which allowed about 19 percent slippage on its cage wheels harrowed 1.03 hectares in one hour using 5.71 liters of fuel. Another harrowed a hectare of dry clay loam soil with a 2.04-meter peg-tooth harrow in one hour and consumed 5.14 liters of diesel. In another field which was flooded and which had a silt loam texture, the same kind of tractor trailing a 2.50-meter comb harrow had an efc of about 0.82 ha/hr. A 15-year-old tractor was also tested. It harrowed only 0.65 hectare in one hour and had a high fuel consumption of 9.37 liters per hectare. Another tractor had an efc of about 0.62 ha/hr and 6.32 liters per hectare of fuel consumption. It had a very high slippage of 25.34 percent.

Tests on plowing were conducted using five different kinds of large tractors. One had the highest efc of about 0.61 ha/hr, followed by 0.50 ha/hr, 0.42 ha/hr, 0.30 ha/hr, and 0.21 ha/hr. The fuel consumption was in this order: 17.89 liters, 14.76 liters, 9.63 liters, 8.01 liters, and 6.53 liters per hectare. All the tractors were fitted with pneumatic tires during the operations on dry fields. The least slippage was about 13.42 percent, followed by 14.03 percent, and the others had an almost identical 16 percent.

Ara-wheeling is a type of land preparation using only cage wheels. The tractor uses no attachment and pulverizes with its cage wheels the area which had been previously plowed. With a 55-70 hp tractor, an efc of 0.57 ha/hr was obtained, consuming 8.23 liters per hectare. Traction on the wheels was fairly good and allowed only 2.49 percent slippage during the operation. The operator goes around and ends at the center of the field. This operation requires that he make three complete rounds before starting on a new pass. (Figure 19).

Methods of Land Preparation in Isabela Province:

		Unit Cost/Ha	Total Cost/Ha
First method:	1 pass rotovator	₱65.00	₱ 65.00
	2 passes harrow drawn by tractor with leveling board	80.00	160.00
	Final harrowing + leveling with carabao	———	———
Second method:	Dry plowing	₱40.00	₱ 40.00
	2 passes harrow drawn by tractor with leveling board	80.00	160.00
	Final harrowing + leveling with carabao	———	———

Note: After plowing, the area is idle for 2-4 weeks before the next operation is made. (Given that the operator has the time).

Third method:	Dry plowing	₱40.00	₱ 40.00
	1 pass rotovator	45.00	45.00
	4 passes harrow drawn by carabao	———	———

Note: All operations are done on flooded conditions except when stated otherwise. All charges are on a contract basis.

Tractor operators are paid ₱5 to ₱6 per hectare and there are usually two operators for one tractor.

PERFORMANCE AND ECONOMICS OF HARVESTING-THRESHING MACHINES

The testing of threshing equipment was limited to two types of stationary threshers: the IRRI paddy thresher, the testing of which is described earlier in the preceding pages, and the Japanese automatic thresher. Only the Japanese thresher will be reported here.

Since all the automatic machines are similar, brand names have been omitted. The thresher uses the drum with wire loops to thresh the grains. The rice is harvested and the stalks laid on a table attached to the thresher. The grain is fed gradually into a chain drive which carries the panicles under the drum. The stalks are carried past thre threshing drum to the other side of the machine and fall to the floor. The grain is winnowed in the machine, and then augered and delivered through a pipe for sacking (Figure 20).

The tests reported here were conducted in March 1968 in the municipality of Biñan, Laguna. The machine did not operate as well as expected, particularly in threshing wet stalks and grain. Further tests will be conducted on other

makes of threshers to confirm these results. In conducting the tests, we divided our analysis into three categories - one, a slow feeding rate when threshing wet grain; two, an average speed; and three, as fast as possible - and used a three-man crew - one man to feed in the stalks; another to prepare rice stalks on the adjoining table; and the third to sack the rice and watch the machine.(Figure 20).

The results of the trials, shown in Table 11, indicate an average output of 100 kg/hr for a minimum rate of feeding, 200 kg/hr for average feeding, and 400 kg/hr for maximum feeding.

The large rice-growing areas currently rely on the large McCormick stationary threshers for threshing the major part of the crop. In Isabela Province, Northeastern Luzon, data were obtained from farmers about their reaction to the machines. The procedure is to harvest the rice by hand, bundle the rice, and place these in small stacks (called mandalas) to dry, later to be restacked in large mandalas for threshing. The threshers operate on a contract basis; 5 percent of the threshed crops is usually sufficient for paying for their own crew and the large-hp tractor that drags the thresher through the paddies. Farmers interviewed in Isabela Province indicated that they were able to get their crop threshed within one to four weeks after harvest, subject to the availability of a threshing machine. Only a few indicated an unduly long wait before threshing. They did indicate that they thought the threshing charge was too high. The harvesting and threshing was not paid for together. The operator contracted and paid for the harvesters separately. A common practice is to pay a specific price per head per day. The most commonly mentioned price was P2.50 per day.

Thus, where the threshing was mechanized, the harvesting and threshing crews were separate. In contrast, in Laguna Province, harvesting and threshing are still done by hand, and the practice is to pay a crew for both operations.

AGRONOMIC-ENGINEERING SURVEYS OF MAJOR RICE AREAS AND FARM MANAGEMENT INTERVIEWS

The purpose in collecting these data is to examine the technical relationships involved in growing rice in the major rice-producing regions in order to assess the extent of and potential for mechanization. We are looking at the mechanization potential both from an over-all (macro) approach and from the view of the individual farmer (micro).

The International Rice Research Institute/Agency for International Development (IRRI/AID) Reports #4 and #5 described the results (both survey and interview data) obtained from the large Central Luzon valley rice area. These results included the sequence of farm operations, the relation of yield to various measured factors, size of farms, labor requirements, and farm equipment. This paper reports data from three areas (1) a more concentrated survey on the east side of Central Luzon and in Laguna Provinces; (2) Northeastern Luzon, Isabela Province; and (3) Western Mindanao, Cotabato Province (Figure 21).

The sequence of farm operations in these three areas is similar since all the areas expect to receive monsoon rains in June and July. However, the Central Luzon area is markedly seasonal in rainfall, with the rain being heaviest from June to September. In Isabela Province, some rain is expected in June and July, but heavier rainfall is from September to November. The timing in this area is to start an early crop in June and a late crop during the heavier rains. In Cotabato Province, the rainfall is more evenly distributed, but without the heavier rainfall of the other areas. Thus, on the one hand, the province may be subject to droughts, and on the other, it is able to utilize the rainfall for a complete year-round growing cycle. Two areas were studied, one, the Midsayap area, is irrigated for two crops, and the other, Tacurong, is not irrigated. Prior to the recent introduction of irrigation, Midsayap was largely a rice-corn area. The pattern is now for two crops of rice. The data for Midsayap will be analyzed later.

For Tacurong, the sequence of farm operations for 66 rice fields is presented in Figures 22 and 23. The survey started only in January 1968 so that data prior to this period is unavailable. The period covered is one of relatively lower rainfall, so that many of the farmers grow corn at this time. For both crops, early March is devoted to land preparation and transplanting (rice) or sowing (corn). The crops would then be harvested in time to plant rice during the heavier rains of June and July. In May, land preparation is intensified to prepare for the rice crop.

Past reports have indicated a high degree of share tenancy and an average farm size of less than 3 hectares in the Central Luzon Valley. However, national statistics indicate larger average farm sizes and more owner-operators in the more recently developed areas. Table 12 presents data on the surveyed rice fields of Isabela and Cotabato Provinces. In Isabela, the median farm size was 3.0 hectares, with only three out of the 115 farms being over 15.0 hectares in size. Of these 115 farms, slightly less than half were operated by full or part owners. The median farm size for full owners and share-tenants was about 3 hectares, and for part-owners, 5.0 hectares. In the Tacurong area of Cotabato (corn-rice), roughly two-thirds of the farms were owner-operated. Median farm size for the owners was 5 hectares, and for the tenants 3 hectares.

Four farm sizes were between 50 and 89 hectares. On the other hand, in the Midsayap area of Cotabato, only one-fourth of the farms were operated by full or part owners, and median farm sizes ranged from about one hectare for tenants and 3 hectares for owners. Thus, in the same province, there exists a large difference in tenure and farm size.

One would expect the Tacurong area to have relatively more farm equipment because of its larger farms and the fact that corn is more readily adaptable to mechanization. The percentages of farm equipment and carabaos owned by farm size groupings are presented in Table 13. In the Isabela area, of 124 farms reporting, 5 owned tractors. At Midsayap 2 out of 45 farmers owned tractors. At Tacurong 16 out of 63 farms had tractors.

In all three areas, the majority of farmers relied on animals for farm power. At Tacurong, the average number of carabaos for farms less than 5.5 hectares was 1.5, and 3.0 for farms larger than 5.5 hectares in size. At Midsayap, the average number of carabaos was 1.5 for farm sizes less than 2.5 hectares, and 2.5 for farms of larger size. The number of carabaos per farm in Isabela was 1.0 head for farms less than 2.5 hectares, 1.5 for farms of 2.5 - 4.5 hectares, and 2.5 for farms larger than 4.5 hectares. These data are similar to those presented for Central Luzon in Report #5.

Thus, in contrast to the results obtained from sample areas in Central Luzon, the outlying areas of Isabela and Cotabato are using tractors for land preparation to a much greater extent. The rice areas with a high proportion of share tenants and small operating units are slower to adopt farm machinery. However, Laguna Province may be an exception - while farm sizes in this province are larger than in Central Luzon, tenancy is high; however, hand tractors are being used to a great extent in this area.

In assessing the potential for mechanization in an area, we have looked at farm sizes and the type and numbers of equipment already being used. Further, we have found a correlation between hand tractor owners and irrigated 2-crop farms. Irrigation and the income provided by two crops is an important factor in mechanization. Machinery cannot proceed without the means to pay for the equipment.

What other factors are indicative of an area that will mechanize? First, a reliance on hired labor, and therefore a cash cost, can indicate a possible potential for change. Secondly, high seasonal labor demands may be accompanied by labor shortages, indication production bottlenecks.

Hired labor is commonly used in the Central Luzon areas for transplanting, harvesting, and to some extent, weeding. Threshing in this area is done by custom operation, so it, too, is "hired" service. The other cultural operations are typically performed by the family. When asked about labor shortages, however, the farmers consistently answered that this occurred only during land preparation. Thus, while most of these farms are of the "subsistence" type, several of the key operations are performed by hired labor, thus constituting a cash or "in kind" cost. If an operation is already a cash cost, then the operator may be interested in minimizing his outlay, and may turn to mechanical power. If there is a production bottleneck, this happens during land preparation. Lastly, threshing is already mechanized in many of the rice areas.

Table 14 indicates the response of farmers in Isabela and Cotabato provinces to queries about labor shortages. The Tacurong and Midsayap, Cotabato farmers indicated no serious labor-hiring difficulties. However, in Isabela, 50 percent of the farmers encountered difficulty in hiring labor for land preparation. Further, there was some labor shortage in each farm operation. Of the three major rice areas, Isabela may suffer a serious labor shortage.

Varieties planted are indicative of the change taking place in a region. A change in cultural practices may well indicate a propensity to change towards mechanization. Tables 15 and 16 list the varieties planted in Central Lzuon and in the Laguna and Isabela Provinces. For Central Luzon and Laguna one-crop farms, which are usually rainfall-dependent, no sampled farm grew an improved variety. Yet, for the two-crop farms, 26 of 41 farms in Laguna grew an improved variety in the wet season, and 13 of 27 farms in the dry season. For Central Luzon two-crop farms, 6 of 24 in the wet season and 4 of 4 in the dry season grew improved varieties. This indicates that changes are taking place in the irrigated farms, but not in the rainfall-dependent farms.

For Isabela Province, 24 of 104 farms, or about 20 percent, indicated that they were growing an improved variety.

Rice yields were obtained by harvesting 4 square meter plots. The yields for Central Luzon are summarized in Table 16. Data on factors affecting these yields have also been collected and will be presented in a later report. These data, however, do not accurately reflect the realized yield to the farmer as several factors are left out. One is the usual field loss during harvesting and threshing. Another is an upward bias in the yield estimate due to the sampling method. Also, none of the levees and unproductive areas are contained in the samples. In Report #5, it was estimated that the yield as gathered from interview data was, on the average, 25 percent less than the harvested samples. Considering a 25 percent reduction, these yields are not high. It is interesting to note that the improved varieties had distinctly higher over-all yields than the more traditional varieties.

ANALYSIS OF SOIL PENETRATING RESISTANCE

The major purpose of the study of soil resistance and trafficability is still to obtain quantitative data on soil characteristics, i.e., what percent of the lowland rice-growing areas have soils too soft to support power equipment? Perhaps a future objective will be to look more into tractor mobility indices for specific power units.

Research on soil trafficability was and is being conducted in two major rice areas in the Philippines - Central Luzon and Cagayan Valley in Northeastern Luzon. Rice soils in these areas are generally clayey, varying from sandy clay loam to heavy clay soils. The randomly selected fields were either non-irrigated (one-crop) or irrigated (two or more crops per year).

Two instruments were used: the U.S. Army Corps of Engineers WES Cone Penetrometer and the self-recording Japanese-made penetro-shear graph called Soil Values Meter TN-4. Both consist of a 30-degree circular cone having a surface area equal to one-half square inch (3.2 cm^2). A schematic drawing of the WES Cone Penetrometer is presented in Figure 24, showing the following parts: (1) circular handle, (2) dial indicator, (3) dial support stud, (4) machine bolts, (5) proving ring, (6) mounting block, (7) extension graduated rod, and (8) cone.

This cone penetrometer can measure the cone index of the soil, which refers to the pounds of force that must be applied to the handle of the instrument per square inch of end area of its cone tip in order to push it into the ground. The cone is pushed slowly downward into the soil and readings at the pressure gage are read at desired vertical increments which are shown by graduations in centimeters on the instrument's shaft. A schematic drawing of the Soil Values Meter TN-4 is shown in Figure 25, with numbered parts as follows: (1) handle bar, (2) rotatable recording cylinder, (3) coil spring, (4) cylinder rotating mechanism, (5) terminal for attaching the measuring rod, (6) penetration cone and its holding rod, and (7) vane for shear test.

When the cone is used, the TN-4 meter prints a cone diagram which shows the relationship between the cone penetrating resistance and soil depth. It is done in the following manner. First, the cone with the penetrating rod is attached to the measuring device and a millimeter-graphing paper is wound around the recording cylinder and fastened with cellophane tape. The pen is fixed in a recording position. Next, the cone is placed on a hard plane and the recording cylinder is allowed to rotate by pulling the end of the wire down to the plane parallel to the rod. This operation will allow the pen to draw a line which indicates the spring load zero. The spring load zero means that the dead weight of the handle alone (about 800 grams) is acting on the upper end of the wire. At this position, the handle is pressed so the pen moves up and down, indicating the "zero" depth. The instrument is now ready for the test. Testing is done by pressing the handle which causes the cone to penetrate into the ground while the cylinder rotates as the wire is tightened. The contraction of the spring corresponding to the hardness of the ground surface is recorded as the cone diagram. By repeating this operation, similar cone diagrams can be drawn on the same paper, from which an average value can be obtained.

The penetrating resistance is recorded on graduated paper so that 20 mm of the graph paper shows a depth of 10 cm. The soil cone index is calculated from the penetrating resistance and is expressed in kg/cm^2.

Measurements with the WES Cone Penetrometer were made on 145 rice fields in Central Luzon during 1966-1967 and have been reported earlier. The results demonstrated that the irrigated, two-crop fields were, on the average, considerably softer than the one-crop fields (Figure 26). Furthermore, the analysis showed that, on the average, the soils of Laguna Province were softer than those of Central Luzon. Based upon a rule of thumb that a critical index is reached at a depth of 30 cm (12 inches) under a pressure of 70 psi where a 50-hp standard tractor can expect to encounter bogging problems, 62 percent of the fields measured in Central Luzon were firmer than the 30 cm depth; for Laguna Province only 42 percent of the fields were as firm at plowing and 30 percent at harrowing time. In Northeastern Luzon (Isabela Province), a majority of the fields measured apparently offer no bogging problems to large equipment (Figure 27).

Measurements with the Soil Values Meter TN-4 were taken recently in the Central Luzon area at three stages of operation: immediately before land preparation, during final harrowing, and just after harvest. Similarly, these

measurements demonstrated that the irrigated two-crop fields and the Laguna soils are softer than those in Central Luzon (Figures 28, 29 and 30).

In Isabela Province, measurements with the TN-4 meter at different stages of the cropping season (Figure 31) show that, on the average, the two-crop rice soils are softest during the harrowing stage and firmest at harvest. Furthermore, the graph confirms the result of the test with the WES Cone Penetrometer that the soils in the area apparently offer no bogging problems to large equipment.

As we wanted to examine some fields that are continuously under water, a test was conducted on some continuously cropped fields (three crops per year) at The International Rice Research Institute. The results (Figure 32) showed that at a penetrating resistance of 35 psi (2.464 kg/cm^2) and 70 psi (4.928 kg/cm^2), the average soil depths were 39 and 57 cm, respectively. Under these conditions, the standard tractor is not workable. The soil resistance of a water-logged area in Isabela Province was measured and the results are presented in Figure 33. Average soil depths at 35 psi and 70 psi were 44 cm and 48 cm, respectively.

Two tests on cone index measurements with respect to time were done using the TN-4 meter. The first case (Figure 34) was to measure the change in soil resistance from a dry state to a condition after it has been continuously flooded for a time. This was done to establish the optimum time for land preparation and to avoid work in excessively softened flooded soils. In this experiment the change in penetrometer reading was abrupt after the first five hours, and then decreased until it became insignificant with respect to time. This particular field, one of IRRI's maximum production plots, will not be workable by a standard tractor after it has been flooded for five hours. The cone index at the time was 70 psi at a depth of 30 cm. However, further tests are needed, as the TN-4 meter indicated the sub-soil was already moist, although dry on top.

The second case (Figure 35) was a change from the harvesting stage to a dry state. The change in soil resistances was more or less gradual with respect to time. This field, also a maximum production plot but in another location, could be prepared for the next crop with a standard tractor about three days (70 hours) after harvesting. The soil at the time had a unit resistance of 70 psi at 30 cm depth.

WORK PLAN: JULY 1, 1968 TO JUNE 27, 1969

A. AGRICULTURAL MACHINERY RESEARCH

Continuing Projects

1. Design and Development of a Drum-Type Power Thresher:

The second prototype thresher has been satisfactorily field-tested under wet and dry crop conditions. The thresher is ready for extensive field evaluation during the next threshing season. Additional machines will be built by companies who show interest in manufacturing the thresher on a regular basis. Project personnel will assist these manufacturers in adapting the basic design to suit their own manufacturing requirements. The new machines will be distributed in different areas of the Philippines for field evaluation. Requests to import the thresher for testing have been received from many countries, including India, Pakistan, Ceylon, Vietnam. Machines will be sent to these countries for field-testing and evaluation after the program for local manufacture shows satisfactory progress.

2. Design and Development of a Table-Type Power Thresher:

Work is on hand to improve the straw-grain separation. A cyclone-type approach is being investigated to achieve straw-grain separation. Earlier attempts of combined threshing and separating proved unsatisfactory. Current attempts are confined to threshing first and then separating in a different part of the machine. Experimental work will continue on this project until satisfactory performance is achieved.

3. Tractor Tillage and Mobility Study under Wetland Conditions:

Preliminary test on the experimental wetland tiller has been completed. Further tests using strain gage equipment will be undertaken. Variable hydraulic transmission to drive the tiller rotor at wider speed range and to provide an on-the-go speed control is being procured for the machine. The pushing reaction at different blade velocities in varying soil conditions will be studied in detail. Power consumption of the experimental and other conventional tillers will be compared.

4. Use of Mechanical Power for Rotary Weeding:

A second prototype machine which is lighter than the first prototype has been completed. Extensive field trials comparing the manual, chemical and power weeding methods are planned for the next season. A few manufacturers have shown interest in this machine and attempts will be continued to interest these manufacturers in commercial production.

5. Anhydrous Ammonia Applicator for Power Tillers:

An applicator attachment for small rotary tiller tractors has been designed. Field tests, modification and further development of this attachment

will be continued. Work will be done to arrive at the optimum design of applicator shanks to maintain a self-cleaning action when working in puddled fields which are full of weeds.

6. Physical Properties of Paddy:

A device to measure threshing force is being built and will be used to study the eight varieties of rice at different degrees of maturity. Studies will be undertaken to establish the force required to break the rice panicle stem and to uproot rice plants at harvest time. The results will be useful to establish the threshability of different varieties at different maturity levels.

Future Projects

7. Paddy Stripper-Harvester:

The desirability of efficient handling of paddy from the field to the storage has always intrigued engineers. It is felt that current practice of harvesting and then threshing in two separate operations is inefficient. Use of combines for paddy harvest in tropical areas has not been so practical. The development of a stripper-harvester to harvest paddy from standing plants without cutting the plant will be undertaken since a stripper-type machine seems to offer certain advantages for rice cultivation.

8. Rotary Harrow for Small Tractors:

Most traction-type tillers use a comb rake which helps in puddling the soil and acts as a drag to the traction to achieve tillage from the cage wheels. The rake tends to build trash which interferes with proper operation and results in very slow forward motion. It is felt that a rotary cage rotor could perform the same function without collecting trash. It may also be possible to permit a man to ride, thus offering a riding attachment to small walking tillers. A rotary harrow attachment will be built and tested to evaluate this concept.

9. Power Requirement for Rotary Tillage under Wetland Conditions:

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

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 with each manufacturer claiming superiority of his design over others. 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 and cage wheel-tire diameter relationship 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.

11. Rice Seeder Design for Wetland Conditions:

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. Attempts will be made to develop a portable light-weight two- to four-row seeder for pre-germinated seeds.

B. GENERAL ENGINEERING AND ECONOMIC STUDIES

Continuing Projects

1. Performance and Economics of Use of Harvesting-Threshing Equipment in South East Asia.

2. Performance and Economics of Use of Power Units in South East Asia.

3. Performance and Economics of Mechanical and Chemical Methods in Weed Control.

4. Machinery Cost and the Cost of Producing Rice.

Proposed Projects

5. An Analysis of Machine Ownership:

An analysis of credit needs of farmers in order to purchase and maintain farm machinery. Analyses of costs of machine use and purchase costs, and decision criteria about specific machine purchase and use.

6. Farm Machinery Industry and Marketing Structure: Philippines and South East Asian Countries:

An analysis of the structure of the farm machinery industries in South East Asia, and the consequent system of marketing equipment in the major rice-producing countries.

7. Economics of Size and Machinery Use:

Analysis of the relationship of scale of farming, profitability, and the necessary inputs including optional machinery and equipment use. Role of con-

tract operations. Intensity of land use on small and large farms. Substitution of capital for labor (mechanization) and for land (yield-increasing technologies).

8. Product Development Research:

Market studies to assess need for existing and for special machinery; assist in developing field specifications for needed machinery.

PROJECT PERSONNEL

Personnel and their respective man-months engaged in the project for the past six months, January 1 to June 30, 1968, are presented below. Anticipated personnel needs for the coming year are presented in the last two columns in man-months.

Name	Category	Actual	Projected	
		January 1 to June 30, 1968	July 1 to Dec. 31/68	Jan. 1 to June 27/69
		(man - months)		
Amir U. Khan	Agr. Engineer	6	6	6
Stanley S. Johnson	Agr. Economist	6	6	0
Emilio O Casem[1/]	Asst.Agr.Engineer	6	2	0
Makoto Hoki	Visiting Asst. Design Engineer	5	6	2
Eliseo L. Ruiz[2/]	Jr. Technician	6	0	0
Ben Hur Aguila[2/]	Jr. Technician	4	0	0
Norberto Orcino	Research Assistant	0	6	6
Nestor Navasero	Research Aide	6	6	6
F. C. Jalotjot[1/]	Draftsman	6	2	0
F. Cabrales	Draftsman	0	6	6
C. Ll. Jizmundo	Secretary	6	6	6
Videlia L. Go	Clerk-Stenographer	6	6	6
Position Open	Shop Foreman	0	6	6
Pedro Malabonga[2/]	Head Machinist	6	0	0
E. Velasco	Bench Mechanic	1	6	6
J. Silos	Mechanic-Operator	1	6	6
Benjamin Tamisin[2/]	Diesel Mechanic	3	0	0
Rodolfo Tamisin	Welder	6	6	6
E. Dungo	Tinsmith	1	6	6
R. Santos	Tinsmith	1	6	6
Antonio Mangahis[2/]	Tinsmith	2	1	0
Juan P. Reyno[1/]	Laborer	6	2	0
Miguel Fabellan[1/]	Laborer	6	2	0
Marcelino Castro	Laborer	5.5	6	6
Josue Munan[3/]	Laborer	1	1	0
Francisco Babac[3/]	Laborer	1	1	0
Felix de la Cruz[3/]	Laborer	1	1	0
D. Suten[3/]	Consultant	1	1	0

1/ Transferred to Agricultural Engineering Staff.

2/ Resigned.

3/ Part-time.

TABLE 1. DRUM-TYPE POWER THRESHER OUTPUT USING DIFFERENT FEEDING METHODS AND NUMBERS OF MEN FOR SHORT-DURATION THRESHING TRIALS

Method No.	Threshing method	Number of men in the team*	Total or machine output** (kg)	Output per man** (kg)
I	1 man pick-thresh	1	24.9	24.9
II	2 men pick-thresh	2	41.8	20.9
III	1 man pick-transfer and 1 man thresh	2	33.8	16.9
IV	2 men pick-walk-thresh, cyclic	2	32.1	16.1
V	3 men pick-thresh	3	52.5	17.5
VI	1 man pick-transfer and 2 men thresh	3	39.5	13.1
VII	3 men pick-walk-thresh, cyclic	3	36.1	12.0
VIII	4 men pick-thresh	4	61.9	15.5
IX	2 men pick-transfer and 2 men thresh	4	54.3	13.6
X	4 men pick-walk-thresh, cyclic	4	42.2	10.5
XI	5 men pick-thresh	5	59.7	11.9
XII	2 men pick-transfer and 3 men thresh	5	77.5	15.5
XIII	5 men pick-walk-thresh, cyclic	5	54.1	10.8
XIV	3 men pick-transfer and 3 men thresh	6	86.3	14.4
XV	2 men pick-transfer and 4 men thresh	6	89.2	14.8
XVI	6 men pick-walk-thresh, cyclic	6	61.7	10.2
XVII	3 men pick-transfer and 4 men thresh	7	96.2	13.8
XVIII	2 men pick-transfer and 5 men thresh	7	66.8	9.5
XIX	7 men pick-walk-thresh, cyclic	7	64.1	9.2
XX	3 men pick-transfer and 5 men thresh	8	76.5	9.6
XXI	4 men pick-transfer and 4 men thresh	8	108.4	13.6
XXII	8 men pick-walk-thresh, cyclic	8	61.4	7.7

*No. of men in team does not include 1 man who collects and sacks the grain.

**Clean grain threshed per 15 minutes at 14% M.C. (average of 3 trials).

Note: Tests conducted at Bay and Calauan, Laguna on May 8-10, 1968. Variety - Intan; Grain yield per hectare - 4270 kg at 14% M.C. (average of 3 samples).

TABLE 2. DRUM-TYPE POWER THRESHER OUTPUT FOR DIFFERENT NUMBERS OF MEN AND METHODS OF THRESHING, ONE HOUR TRIALS

Method No.	Threshing method	Number of men in the team*	Total or machine output** (kg)	Output per man** (kg)
XII	2 men pick-transfer and 3 men thresh	5	316.2 (79.0)	63.2 (15.8)
XV	2 men pick-transfer and 4 men thresh	6	358.5 (89.6)	59.7 (14.9)
XVII	3 men pick-transfer and 4 men thresh	7	415.4 (103.8)	59.3 (14.8)
XXI	4 men pick-transfer and 4 men thresh	8	459.6 (114.9)	57.4 (14.4)

*Kg. of clean threshed grain at 14% M.C.

Note: Figures in parentheses are computed output values per 15 minutes.

Tests were conducted at Plot B-3 (IRRI) on May 14-15, 1968. Plot area - 2500 sq.m.; Variety - IR8-68; Total grain yield - 1796 kg; Grain yield per hectare - 7185 kg (14% M.C.).

TABLE 3. SPECIFICATIONS OF THE TRACTOR AND ATTACHED ACCESSORIES

Ford 4000 Tractor			Accessories	
Maximum engine horsepower:	55	HP	Total front frame ballast:	112.8 kg
Maximum PTO horsepower:	47.5	HP	Total front wheel ballast:	40.4 kg
Weight:	1882.4	kg	Total weight of rubber-tipped crown-type lug wheels attached to both sides of rear wheels:	476.0 kg
Tractor travel speed based on zero slippage at 1800 engine rpm: 1st	0.48	m/s		
2nd	0.75	m/s		
3rd	1.27	m/s		
4th	1.73	m/s		
Total tractor weight with accessories				2511.6 kg

TABLE 4. SPECIFICATIONS OF ROTARY TILLERS

	IRRI Experimental Wetland Rotary Tiller	Conventional Rotary Tiller
Tilling width	1.6 m (A 30 cm length in the middle of the rotary tiller has no blade.)	1.6 m
Number of blades	48	36
Shape of blades	30 cm long, 13 cm wide, flat blades.	Conventional Japanese spading blades.
Blade arrangement	Alternate arrangement of 12 blades, 6 for tilling and 6 for support, in 4 sections.	Each set of 4 blades is mounted spirally at 18 cm spacing.
Outside diameter of rotary tiller	100 cm	50 cm
Drive method of tilling shaft	Left side chain drive.	Left side chain drive.
Weight	450 kg	430 kg
Peripheral tiller blade velocity at 1800 engine rpm	1st 2.10 m/s (40 rpm) 2nd 2.66 m/s (51 rpm) 3rd 3.00 m/s (57 rpm) 4th 3.77 m/s (72 rpm)	1st 2.78 m/s (106 rpm) 2nd 4.07 m/s (155 rpm) 3rd 5.56 m/s (213 rpm)

TABLE 5. IRRI EXPERIMENTAL WETLAND ROTARY TILLER TEST UNDER RELATIVELY HARDER SOIL CONDITIONS

Tractor used:	Ford 4000 (55 HP)	Field condition:	Loamy soil flooded to 5 cm for 24 hrs and covered with rice stubble and harvested straw.
Tractor engine speed:	1800 rpm		
No-slip travel distance of tractor rear wheel per 2 revolutions on concrete:	9.22 m	Average depth of cone penetrometer:	15.4 cm at 35 psi 21.4 cm at 70 psi

Test No.	Tractor travel speed based on zero slippage		Peripheral tiller blade velocity		Tilling depth[1/]	Rear wheel travel distance per 2 revolutions[2/]	Cone penetrometer depths at[3/]		Slippage of rear wheels
	m/s	speed	m/s	gear	cm	m	cm 35 psi	cm 70 psi	%
1	0.48	1st	2.10	1st	10.7	8.96	18.2	22.4	2.8
2	0.75	2nd	2.10	1st	7.9	9.01	16.8	23.2	2.3
3	1.27	3rd	2.10	1st	9.9	9.19	17.2	20.8	0.3
4	1.73	4th	2.10	1st	9.4	9.09	13.2	18.4	1.4
5	0.48	1st	2.66	2nd	11.2	8.72	16.2	20.0	5.4
6	0.75	2nd	2.66	2nd	10.8	8.94	15.0	19.2	3.0
7	1.27	3rd	2.66	2nd	12.2	9.28	13.4	21.0	-0.7
8	1.73	4th	2.66	2nd	12.6	9.17	14.4	23.4	0.5
9	0.48	1st	3.00	3rd	10.9	8.87	16.0	21.4	3.8
10	0.75	2nd	3.00	3rd	8.6	8.94	14.2	20.8	3.0
11	1.27	3rd	3.00	3rd	10.3	9.06	14.2	21.4	1.7
12	1.73	4th	3.00	3rd	9.9	9.24	16.8	20.8	-0.2
13	0.48	1st	3.77	4th	12.4	8.87	14.0	21.2	3.8
14	0.75	2nd	3.77	4th	10.7	8.99	15.8	23.4	2.5
15	1.27	3rd	3.77	4th	10.3	8.96	13.8	23.4	2.8
16	1.73	4th	3.77	4th	8.6	9.23	13.6	20.8	-0.1
17	0.48	1st)	With rotary			7.81	17.2	21.8	15.3
18	0.75	2nd)	tiller trailed,			7.98	16.4	22.4	13.4
19	1.27	3rd)	PTO disengaged.			8.07	16.2	21.2	12.5
20	1.73	4th)				8.02	15.4	21.0	13.0
21	0.48	1st)	Tractor only,			7.95	15.6	21.0	13.8
22	0.75	2nd)	rotary tiller			8.01	17.6	22.0	13.1
23	1.27	3rd)	removed.			8.07	15.0	20.2	12.5
24	1.73	4th)				8.22	14.2	18.6	10.8

1/ Average of 3 readings.

2/ Average of both rear wheels.

3/ Average of 5 readings.

TABLE 6. CONVENTIONAL ROTARY TILLER TEST UNDER RELATIVELY HARDER SOIL CONDITIONS

Tractor used:	Ford 4000 (55 HP)	Field condition:	Loamy soil flooded to 10 cm for 6 hrs and covered with rice stubble and harvested straw.
Tractor engine speed:	1800 rpm		
No-slip travel distance of tractor rear wheel per 2 revolutions on concrete:	9.22 m	Average depth of cone penetrometer:	12.8 cm at 35 psi 21.1 cm at 70 psi

Test No.	Tractor travel speed based on zero slippage		Peripheral tiller blade velocity		Tilling depth 1/	Rear wheel travel distance per 2 revolutions 2/	Cone penetrometer depths at 3/		Slippage of rear wheels
	m/s	speed	m/s	gear	cm	m	35 psi cm	70 psi	%
1	0.48	1st	2.78	1st	12.0	8.21	15.2	21.6	11.0
2	0.75	2nd	2.78	1st	12.3	8.37	12.0	18.8	9.2
3	1.27	3rd	2.78	1st	11.9	8.53	12.8	24.4	7.5
4	1.73	4th	2.78	1st	9.0	8.44	11.0	18.0	8.5
5	0.48	1st	4.07	2nd	11.7	8.17	12.8	19.2	11.4
6	0.75	2nd	4.07	2nd	12.3	8.32	14.0	20.0	9.8
7	1.27	3rd	4.07	2nd	11.0	8.47	12.2	20.6	8.1
8	1.73	4th	4.07	2nd	9.0	8.65	12.4	21.4	6.2
9	0.48	1st	5.56	3rd	11.8	8.26	13.4	21.0	10.4
10	0.75	2nd	5.56	3rd	11.3	8.45	13.4	21.2	8.4
11	1.27	3rd	5.56	3rd	11.8	8.46	12.0	20.8	8.2
12	1.73	4th	5.56	3rd	12.8	8.47	11.6	21.4	8.1
13	0.48	1st)	With rotary			7.48	11.6	21.4	18.9
14	0.75	2nd)	tiller trailed,			7.69	13.2	20.6	16.6
15	1.27	3rd)	PTO disengaged.			7.65	11.0	20.6	17.0
16	1.73	4th)				7.56	13.8	22.4	18.0
17	0.48	1st)	Tractor only,			7.77	12.0	20.6	15.7
18	0.75	2nd)	rotary tiller			7.83	13.4	22.4	15.1
19	1.27	3rd)	removed.			7.88	14.4	22.2	14.5
20	1.73	4th)				7.66	14.6	23.4	16.9

1/ Average of 3 readings.

2/ Average of both rear wheels.

3/ Average of 5 readings.

TABLE 7. IRRI EXPERIMENTAL WETLAND ROTARY TILLER TEST UNDER RELATIVELY SOFTER SOIL CONDITIONS

Tractor used:	Ford 4000 (55 HP)				Field condition:	Loamy soil flooded to 5 cm for 5 days and covered with rice stubble and harvested straw.			
Tractor engine speed:	1800 rpm								
No-slip travel distance of tractor rear wheel per 2 revolutions on concrete:	9.22 m				Average depth of cone penetrometer:	18.3 cm at 35 psi 29.4 cm at 70 psi			
Test No.	Tractor travel speed based on zero slippage		Peripheral tiller blade velocity		Tilling depth[1/]	Rear wheel travel distance per 2 revolutions[2/]	Cone penetrometer depths at[3/] cm		Slippage of rear wheels
	m/s	speed	m/s	gear	cm	m	35 psi	70 psi	%
1	0.48	1st	2.10	1st	13.0	8.67	20.6	30.4	6.0
2	0.75	2nd	2.10	1st	10.3	8.75	33.4	39.0	5.1
3	1.27	3rd	2.10	1st	13.2	8.85	27.2	31.4	4.0
4	1.73	4th	2.10	1st	9.5	8.81	18.6	29.0	4.4
5	0.48	1st	2.66	2nd	9.3	8.52	17.8	27.6	7.6
6	0.75	2nd	2.66	2nd	10.0	8.71	19.2	31.4	5.5
7	1.27	3rd	2.66	2nd	10.2	8.70	17.2	32.4	5.6
8	1.73	4th	2.66	2nd	10.3	8.96	18.8	32.4	2.8
9	0.48	1st	3.00	3rd	11.7	8.62	16.0	25.4	6.5
10	0.75	2nd	3.00	3rd	10.7	8.58	15.4	33.6	6.9
11	1.27	3rd	3.00	3rd	9.7	8.70	16.6	29.0	5.6
12	1.73	4th	3.00	3rd	10.3	8.86	17.0	34.0	3.9
13	0.48	1st	3.77	4th	12.5	8.34	16.2	26.8	9.5
14	0.75	2nd	3.77	4th	11.5	8.44	17.6	28.4	8.5
15	1.27	3rd	3.77	4th	8.9	8.66	13.2	24.0	6.1
16	1.73	4th	3.77	4th	9.3	8.90	13.0	27.4	3.5
17	0.48	1st)	With rotary			6.27	14.0	32.2	32.0
18	0.75	2nd)	tiller trailed,			7.00	17.2	28.4	24.1
19	1.27	3rd)	PTO disengaged.			6.94	19.0	25.8	24.7
20	1.73	4th)				6.96	18.0	27.8	24.5
21	0.48	1st)	Tractor only,			7.02	21.2	29.6	23.9
22	0.75	2nd)	rotary tiller			7.26	18.6	27.6	21.3
23	1.27	3rd)	removed.			7.35	16.4	24.6	20.3
24	1.73	4th)				7.46	17.0	26.8	19.1

1/ Average of 3 readings.

2/ Average of both rear wheels.

3/ Average of 5 readings.

TABLE 8. HAND TRACTOR SURVEY DATA: LAGUNA, 1967

AGE OF ALL MACHINES

TOTAL NO. OF MACHINES	MONTHS 1	2-5	6-12	YEARS 1	2	3	4	5	6	7	8	10	12	13	14	NO DATA	NEW
434	11	54	34	93	88	55	35	33	12	4	4	1	1	1	2	3	3

HIRING FEE FOR ALL MACHINES (PESOS/DAY)

	₱7	₱25	₱30	₱35	₱40	₱45	₱50	₱55	₱60	₱65	₱70	₱75	₱80	₱90	₱120	NO DATA	NO IDEA	MACHINE NOT HIRED
434	1	69	191	13	10	1	2	1	6	1	5	1	5	9	5	28	51	35

AREA WORKED ON OWN FARM BY ALL MACHINES (HECTARES/TRACTOR)

	0.7	1.5	2.5	3.5	4.5	5.5	6.5	8.0	9.0	11	13	18	19.5	21	NO DATA	NO IDEA
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.5	10	12	14	19	20	24		
	1	16	22	28	11	3	2	13	4	4	2	3	3	1	19	
434	10	54	55	75	37	23	12	3	16	5	3	1	2	2		4

NUMBER OF DAYS THE MACHINES WERE HIRED OUT PER YEAR

	1-5	11-15	21-25	31-35	41-45	51-55	61-65	81-85	91-120	NO DATA	NO IDEA
	6-10	16-20	26-30	36-40	46-50	56-60	76-80	86-90	121-160		
	4	41	8	11	26	2	3	1	2	89	
434	22	48	55	33	13	15	2	5	1		62

TABLE 9. PLOWING AND HARROWING: CARABAO AND THE HAND TRACTOR (6 HP)[1/]

(per hectare)

	Mean Time hr/ha		Range
	EFC[2/]	Actual	Actual
Plow: Carabao	72.5	36.3	28.8 - 41.2
Tractor	32.2	12.9	11.2 - 14.6
Harrow: Carabao	73.3	83.4	55.5 -109.5
Tractor	14.7	13.9	11.3 - 16.6

Contract rates: Tractor, ₱ 35.00 per 8-hour day, or ₱ 4.38/hr.

Carabao, ₱ 8.00 per 6-hour day, or ₱ 1.33/hr.

Cost Comparisons:

	Average Cost			Average Cost	
	EFC	Actual		EFC	Actual
Plow: Carabao	₱96.67	₱48.33	Land Prep'n: Total Cost/ha		
Tractor	141.04	56.50	Carabao	₱194.37	₱159.27
Harrow: Carabao	97.70	110.94			
Tractor	64.39	60.88	Tractor	205.43	117.38

1/ Tests conducted on IRRI soils. Plowing - one pass. Harrowing - judged to be "adequate" at 9-13 passes of the carabao and 3-4 passes of the tractor.

2/ The efc times are computed to provide a relative indication of the time to prepare a field fully. During actual land preparation, considerable undertilling is noted.

TABLE 10. PERFORMANCE OF LARGE AND MEDIUM-SIZED TRACTORS: LAND PREPARATION IN THE RICE FIELDS OF ISABELA PROVINCE, CAGAYAN VALLEY, PHILIPPINES, 1968

CODE	HHP	AGE OF TRACTOR/ ATTACHMENT	SPEED COMBINATION USED DURING OPERATION	TYPE OF TRACTIVE DEVICE, CM (W x DIA.)	SLIPPAGE %	WIDTH OF ATTACHMENT M	EFFEC. FIELD CAPA. M^2/HR	EFFEC. FIELD CAPA. M^2/RHP-HR	FUEL CONSUMP. LIT/HA	UNROTOTILLED/ UNPLOWED/NOT HARROWED, M^2	OVERLAP M^2	DEPTH OF TILLAGE CM	SOIL TYPE	SOIL DEPTH AT RESISTANCE OF 35 psi BEFORE THE OPERATION IN	SOIL DEPTH AT RESISTANCE OF 70 psi BEFORE THE OPERATION CM	SOIL COND. ON DAY OF OPERATION	DURATION OF FLOODING, DAYS BEFORE OPERATION	DEPTH OF WATER CM	NO. OF YEARS EXPER. OF OPERATOR
1. ROTAVATION																			
I-A	55-70	T - 8 mo R - 1 yr	Engine - 2nd (H) Rotor - (L)	Paddy Wheel (51 x 141)	12.19	1.66	10705.75	194.65	6.38		684.48	14.5	Sandy cl-loam	12	18	Flooded	7.0	14.8	3.0
I-B	55-70	T - 3 yr R - 1 yr	Engine - 1st (H) Rotor - (H)	Paddy Wheel (51 x 141)	24.38	1.52	7116.96	121.66	11.34	11.45		10.3	-do-	12	17	-do-	4.0	9.4	2.0
I-C	55-70	T - 8 mo R - 1 yr	Engine - 2nd (H) Rotor - (L)	Paddy Wheel (51 x 142)	3.36	1.52	7095.30	113.52	8.45	1779.40		14.8	-do-	12	15	-do-	1.0	7.8	2.0
I-D*	14.0	T & R-7 mo	Engine - 2nd (L) Rotor - 1st (L)	Paddy Wheel (17 x 84)	20.58	1.00	2178.43	115.60	9.24		64.80	14.0	Silt loam	5	22	Saturated	0	0	2.0
I-E*	11.0	T & R-3 yr	Engine - 2nd (L) Rotor - 2nd (L)	Paddy Wheel (20.5 x 74.5)	10.54	0.94	1229.42	111.77	14.65	75.22		16.4	-do-	21	24	Flooded	1.0	1.0	2.0
I-F*	12.0	T & R-2 yr	Engine - 2nd (L) Rotor - (H)	Paddy Wheel (36 x 69)	7.38	1.03	1928.12	160.68	50.76		7.66	17.0	-do-	21	24	Saturated	0	0	1.0
2. HARROWING																			
II-G	55-70	T & H - 2.5 yr	Engine- 4th (L)	Ara Wheels (61 x 145)	3.36	Home-made comb 2.51	8243.89	122.13	5.10	17.58		15.4	-do-	16	20	Flooded	0	11.7	5.0
II-C	35-45	T & H - 1.25 "	Engine- 3rd (L)	Cage Wheels (61 x 126)	25.34	Home-made comb 2.97	6166.99	158.13	6.32		546.12	13.5	-do-	13	15	-do-	1.0	13.2	5.0
II-G	35-45	T & H - 15 yr	Engine- 2nd (L)	Ara Wheels (61 x 149.5)		Two-way disc 2.00	6523.76	144.97	9.37		4132.80	9.0	-do-	2	4	-do-	3.0	10.3	2.0
II-G	55-70	T & H < 1 yr	Engine- 1st (H)	Pneumatic tires (33 x 155)	13.21	Pegtooth 2.04	10054.28	148.95	5.14		86.14	12.0	-do-	4	6	dry			44.0
II-C	55-70	T & H 2 yr	Engine- 2nd (L)	Cage Wheels (61 x 140)	19.02	Home-made 2.90	10308.37	187.42	5.71		545.95	12.1	-do-	14	17	Flooded	0	3.0	4.0
3. ARA-WHEELING																			
III-G	55-70	T - 2.5 yr	Engine- 4th (L)	Ara Wheels (61 x 145)	2.49		5676.39	84.09	8.23	45.30		16.1	-do-	18	23	Flooded	0	9.6	5.0
4. PLOWING																			
IV-A*	28 BHp	T & P-1.5 yr	Engine- 3rd (L)	Pneumatic tires (28 x 140)	16.15	2 - disc 0.80	2074.84	74.10	14.76	124.95		18.0	-do-	2	4	dry	- 09		5.0
IV-H*	55-70	T & P-1.66 "	Engine- 3rd (L)	Ditto(40 x 140)	13.42	4 - disc 1.40	6075.30	110.46	9.63		551.88	18.0	-do-	2	3	dry	- 10		5.0
IV-G*	55-70	T & P < 1 yr	Engine- 4th (L)	Ditto(33 x 155)	16.56	4 - disc 1.22	4152.50	61.52	17.89		79:24	20.7	-do-	3	5	dry	- 09		10.0
IV-C	35-45	T & P 3 yr	Engine- 2nd (L)	Ditto(28 x 140)	16.83	3 - disc 1.07	3036.01	84.33	6.53	1097.36		15.0	-do-	2	4	dry	- 05		< 1
IV-R	55-70	T & P 3 yr		Ditto(33 x 158)	14.04	4 - disc 1.40	5003.34	85.53	8.01		82.19	14.8	-do-	1	3	dry	- 05		4.0

* Tractor demonstration at San Mateo, Isabela.
ARA-WHEELING: Land preparation by cage wheels only.

TABLE 11. PERFORMANCE OF JAPANESE AUTOMATIC THRESHER

	TIME TRIAL, Minutes										
	15-minutes trials										
	1 3/	2 3/	3 3/	4 3/	18.24 3/	19.28 2/	25.59 3/	29.60 3/	38.06 1/	58.10 2/	60.00 3/
Weight of threshed grain, kg	96.25	100.00	92.75	110.95	119.00	83.25	204.80	177.06	66.41	159.95	432.01
Average moisture content at threshing, %	15.30	16.80	19.80	19.50	15.00	26.80	17.20	19.20	23.20	17.00	15.90
Weight of threshed grain at 14% M.C., kg	94.80	96.74	86.49	103.85	117.62	70.86	197.18	166.35	59.31	154.37	422.46
Thresher output kg/hr	379.20	386.96	345.96	415.40	386.91	220.52	462.32	337.20	93.50	159.41	422.46
Grain yield at 14% M.C., kg/ha	3080 - 3520 IR-8 variety		(70 - 80 cav.)				3080 - 3520 (70-80 cavans) IR-8 variety			3080-3520 (70-80 cav.) IR-8 variety	

Average loss: kg/hr

a. That go with the chaff 0.32

b. At the base of blower 0.83

c. That go with straw 4.26 4.50

		Average Output, kg/hr	Average M.C. at threshing, %
1/ Minimum feeding	-	93.50 (2.125 cav.)	23.2
2/ Average feeding	-	186.96 (4.317 cav.)	21.9
3/ Maximum feeding	-	392.05 (8.910 cav.)	17.3

TABLE 12. NUMBER OF FARMS, BY SIZE AND TENURE, TACURONG AND MIDSAYAP, COTABATO, AND ISABELA, 1968.[1/]

Size of Farm (hectare)	Tenure: Full Owner	Part Owner	Tenant	All Tenure Groups
(1) TACURONG, COTABATO	No. of Farms			
0.1 - 1.9	1	-	3	4
2.0 - 3.9	11	-	14	25
4.0 - 4.9	19	-	6	25
6.0 - 7.9	2	-	-	2
8.0 - 9.9	1	-	-	1
10.0 -11.9	1	-	-	1
12.0 -13.9	-	1	-	1
46.0 & above*	4	-	-	4
All Farms	39	1	23	63

*Sizes are: 89, 65, 50 and 75.

(2) MIDSAYAP, COTABATO	No. of Farms			
0.1 - 1.9	2	-	20	22
2.0 - 3.9	3	2	14	19
4.0 - 5.9	-	-	-	-
6.0 - 7.9	2	1	1	4
All Farms	7	3	35	45

(3) ISABELA PROVINCE	No. of Farms			
0.1 - 1.9	6	2	18	26
2.0 - 3.9	7	8	28	43
4.0 - 5.9	7	9	10	26
6.0 - 7.9	0	6	5	11
8.0 - 9.9	0	0	3	3
10.0 - 11.9	1	1	0	2
12.0 - 13.9	0	0	0	0
14.0 - 15.9	0	0	1	1
16.0 - 17.9	0	1	0	1
26.0 - 27.9	1	0	0	1
44.0 - 45.9	1	0	0	1
All Farms	23	27	65	115

1/ Sample of farms.

TABLE 13. FARM EQUIPMENT AND ANIMALS OWNED, BY SIZE OF FARM, 1967-1968, COTABATO AND ISABELA 1/

Size of Farm	No. of farm reporting	Tractor		Plow	Harrow	Weeder	Sprayer	Cart	Others*	Carabao					Cattle	Horse
		Owned	Rented							Owned		Worked		Total		
										M	F	M	F			
				(percent)												
TACURONG, COTABATO																
< 1.6	3	-	-	200	233	-	67	33	-	133	33	133	33	166	-	-
1.6 - 2.5	15	-	-	160	180	-	53	47	20	93	13	73	13	86	127	-
2.6 - 3.5	11	-	-	145	200	9	73	64	9	118	109	118	91	209	9	9
3.6 - 4.5	11	-	-	136	154	-	64	54	36	73	91	73	91	164	36	-
4.6 - 5.5	13	38	-	161	185	-	62	46	23	138	46	123	46	169	-	-
5.6 & above	10	110	-	270	280	10	590	210	140	270	30	260	30	290	130	10
All Farms	63	25	-	173	196	3	146	76	40	133	54	124	51	175	59	3
MIDSAYAP, COTABATO																
< 1.6	21	-	5	167	100 /5/	-	28	14	114	100	43	100	43	143	14	-
1.6 - 2.5	13	15	-	138	131	8	69	15	231	92	54	92(8)	54	146 (8)	-	-
2.6 - 3.5	6	-	-	103	250	-	50	167	67	100	167	100	167	267	-	-
3.6 - 4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.6 - 5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.6 & above	5	-	-	260	160	60	60	20	180	200	40	200	40	240	-	-
All Farms	45	4	2	171	135 /2/	9	47	35	149	109	62	109(2)	62	171 (2)	7	-
ISABELA																
< 1.6	20	-	-	100	95	15	5	30	70	65	35	60	35	95	15	-
1.6 - 2.5	21	-	-	148	105	71	24	43	81	110	28	105	24	129	76	5
2.6 - 3.5	29	3	-	141	128	21	28	45	93	117	45	110	41	151	21	-
3.6 - 4.5	14	-	-	150	164	64	21	71	114	136	50	128	43	171	7	-
4.6 - 5.5	18	-	-	169	172	39	33	78	106	144	89	144	78	222	11	-
5.6 & above	22	18	-	204	204	45	59	73	132	204	82	191	68	259	23	5
All Farms	124	4	-	155	143	40	29	56	98	129	54	122	48	170	27	1

*Includes sled, calesa, harvest tools, etc
/ / - - Borrowed
( ) - - Rented
1/ - - Sample of farm

TABLE 14. INDICATIONS OF A LABOR SHORTAGE, TAKEN FROM INTERVIEW DATA, 1968*.

Operation	YES: All Hired Labor	YES: Some Hired Labor	YES: No Hired Labor	YES: Total	NO: All Hired Labor	NO: Some Hired Labor	NO: No Hired Labor	NO: Total	No Answer
(1) Tacurong - 63 farms									
Plowing - Harrowing		8	2	10	5	40	6	51	2
Pulling Seedling and transplanting/plant.	12	1		13	17	9	22	48	2
Weeding and/or cultivation	3		5	8	5	6	42	53	2
Hiring more weeders				7				54	2
Harvesting & threshing	2		1	3	16	22	20	58	2
(2) Midsayap - 45 farms									
Plowing - Harrowing	1		3	4	1	13	27	41	
Pulling seedlings and transplant./planting	2	2	1	5	12	22	6	40	
Weeding and/or cultivation			4	4	2	3	36	41	
Hiring more weeders				6				36	3
Harvesting & threshing			1	1	17	17	10	44	

*Farmers responses are listed under the category of whether the farmer used hired labor for that operation, some or no hired labor.

Continued next page

TABLE 14 - continued

INDICATIONS OF A LABOR SHORTAGE, TAKEN FROM INTERVIEW DATA, 1968*.

(3) Isabela - 124 farms

Operation	YES				NO				No Answer
	All Hired Labor	Some Hired Labor	No Hired Labor	Total	All Hired Labor	Some Hired Labor	No Hired Labor	Total	
Plowing - Harrowing	3	22	37	62	1	30	31	62	
Pulling Seedlings and transplanting or planting	22	14	4	40	36	42	6	84	
Weeding and/or cultivation	1		25	26	3	16	79	98	
Hiring more weeders				24				59	41
Harvesting and threshing	6	23	4	33	15	72	4	91	

*Farmer responses are listed under the category of whether the farmer used hired labor for that operation, some or no hired labor.

TABLE 15. RICE VARIETIES PLANTED IN LAGUNA AND CENTRAL LUZON, 1967-1968 CROPPING SEASON[1/]

Variety	ONE-CROP FARM		TWO-CROP FARM				Total
			1st Crop	1st Crop	2nd Crop	2nd Crop	
	Laguna	C. Luzon	Laguna	C. Luzon	Laguna	C. Luzon	
	No. of farms						
Tjoremas		15		1			16
Intan		13	1	1	12		27
Ramajah		7					7
BE-3		5					5
RPI-121		3					3
Laminad		2					2
Lata		1	1				2
Binato		1		14			15
Darrah		1					1
Piling Baybay	1		1				2
(Not Listed)	3	3					6
IR-5*			2				2
IR-8*			22	6	13	4	45
Glutinous			9		1		10
BKI-76*			1				1
CR-63*			1				1
Magwag			1		1		2
Thailand			1	1			2
Milagrosa				1			1
Cotabato			1				1
TOTAL	4	51	41	24	27	4	151

*Improved varieties

1/ Sample of farms

TABLE 16. RICE VARIETIES PLANTED IN ISABELA PROVINCE, 1967 WET SEASON CROP

Variety	No. of Farms Grown
Intan	19
IR-8*	17
Raminad	12
Wagwag	8
Ramadja (Ramajah)	6
BPI-76*	5
Los Baños	4
Magsaysay	3
Ketchel (Seraup Ketchel)	4
Glutinous	2
Besar	2
Magralia	2
Peta	2
Milfor	2
Buenketan	2
IR-5*	1
BPI-121	1
F-76	1
Milagrosa	1
Binato	1
Tjeremas	1
C-4*	1
Bicol Selection	1
Magrasia	1
Miniranda	1
Zero	1
Londion	1
Binuldozer	1
Squad	1
TOTAL	104

*Improved Varieties

TABLE 17. CENTRAL LUZON: MEAN YIELDS FROM SAMPLED 4 M^2 PLOTS, 1967-68 CROP YEAR[1/]

Variety		First Crop
		Kg/ha of rough rice
IR-8	(28)*	4882.04
IR-5	(2)	4865.50
C4	(1)	4619.00
BPI-76	(1)	4548.00
Glutinous (Malagkit)	(9)	4132.67
Piling Baybay	(1)	3706.00
Darrah	(1)	3698.00
Thailand	(2)	3336.50
Binato	(15)	3148.93
BE-3	(5)	3136.60
Ramajah	(7)	3126.57
Raminad	(2)	3115.50
Cotabato	(1)	3055.00
Tjeremas	(16)	2987.81
Intan	(14)	2972.93
Peta	(2)	2827.00
Wagwag	(1)	2326.00
BPI-121 (Macapagal)	(3)	2142.00
Milagrosa	(1)	1758.00

*Numbers of fields sampled.

[1/] Sample of field.

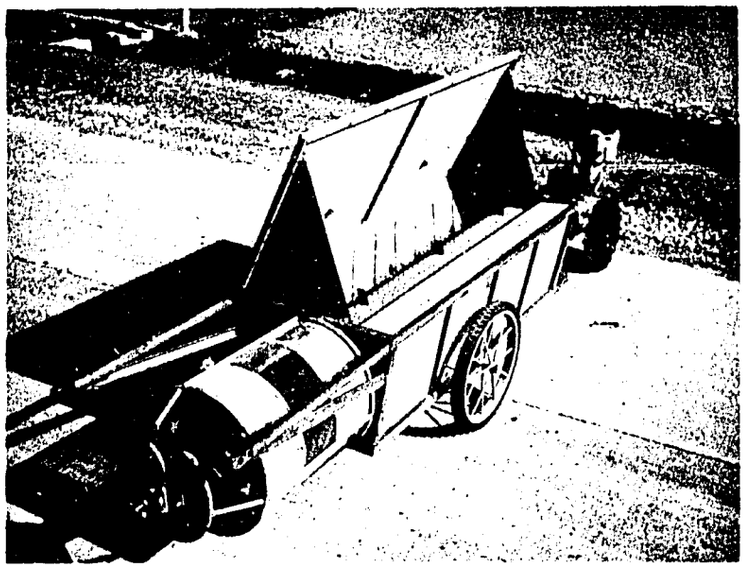


Fig. 1. Second prototype drum-type power thresher.

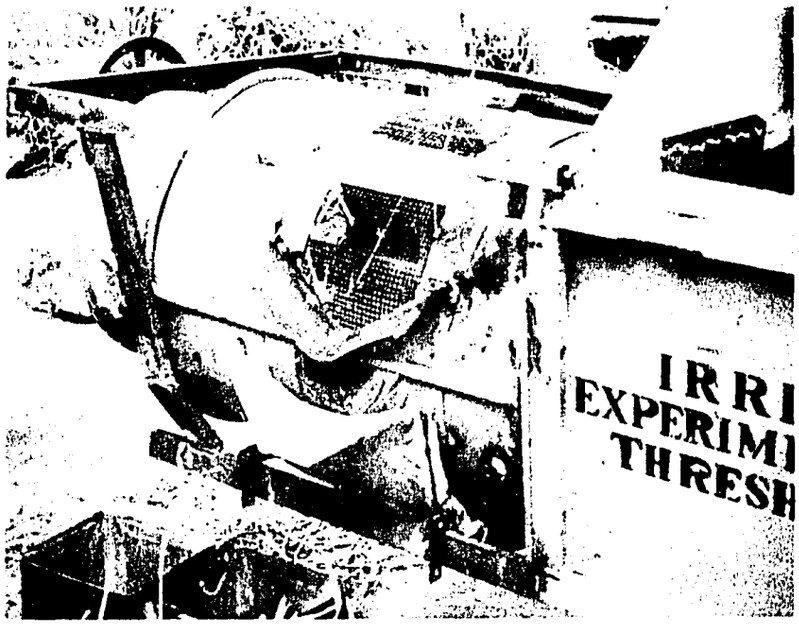


Fig. 2. Drum-type power thresher showing rotary screen separator with integral grain elevating and delivery mechanism.

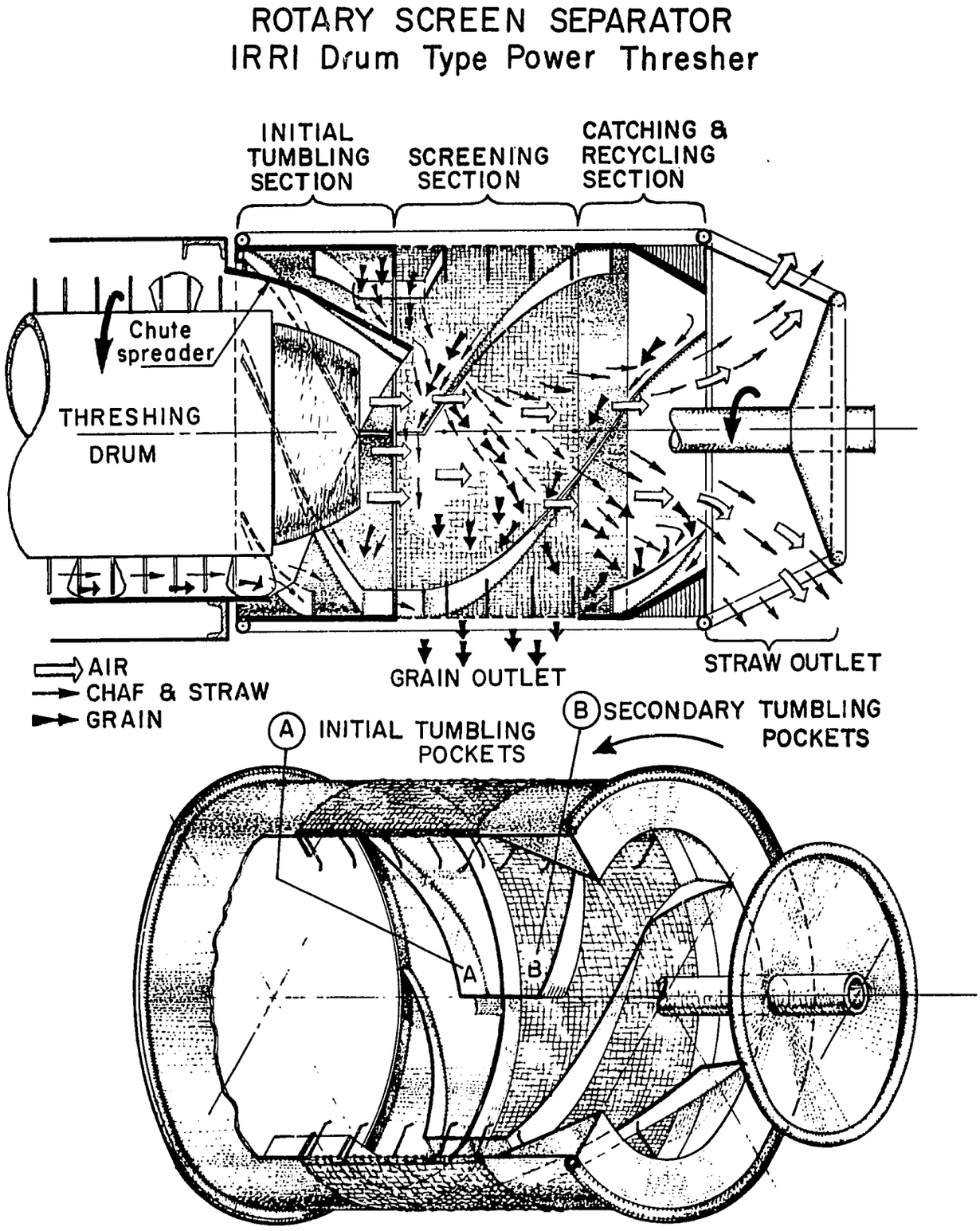


Fig. 3. Schematic drawing showing details of rotary screen separator.

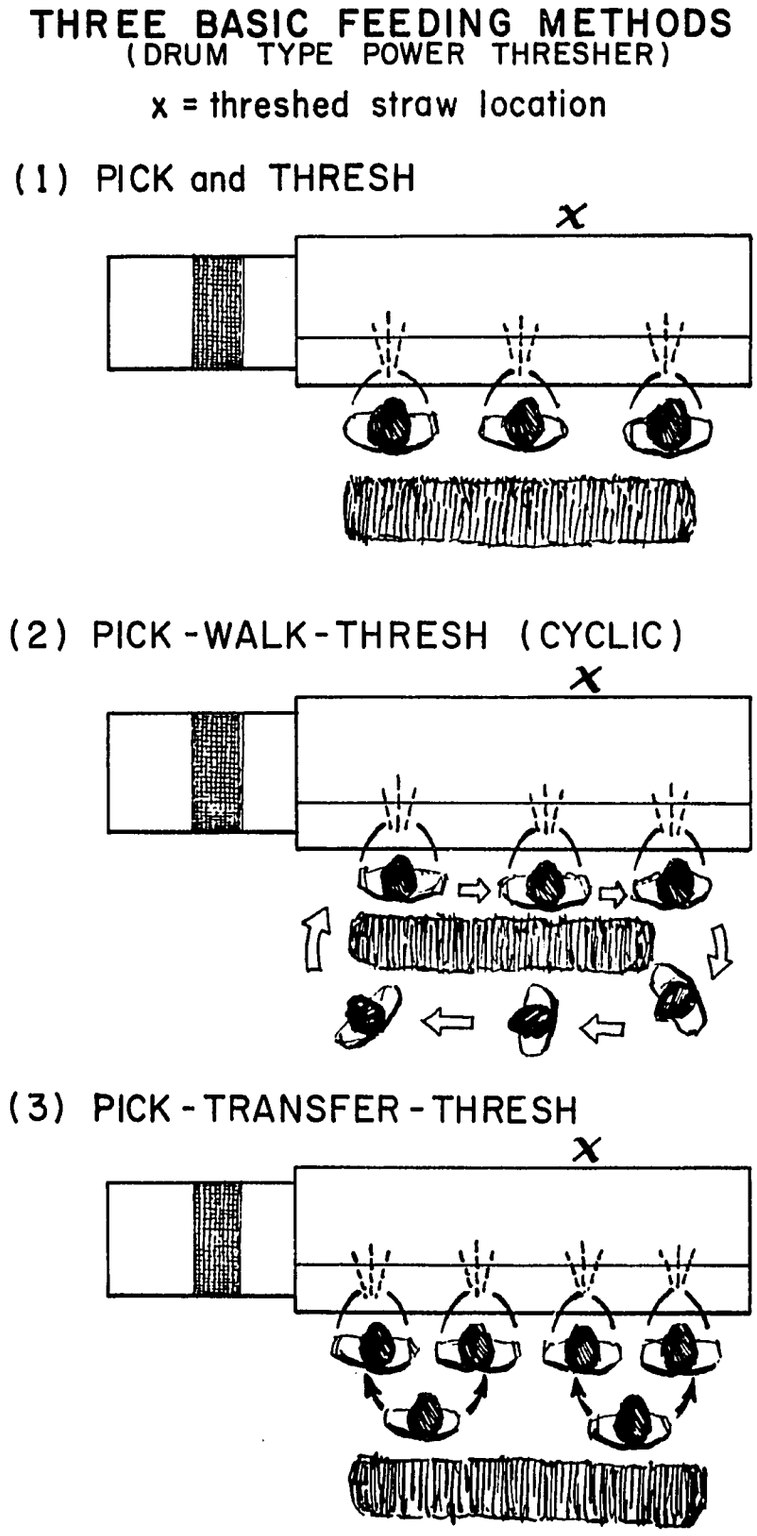


Fig. 4. Three basic methods of feeding the drum-type power thresher.

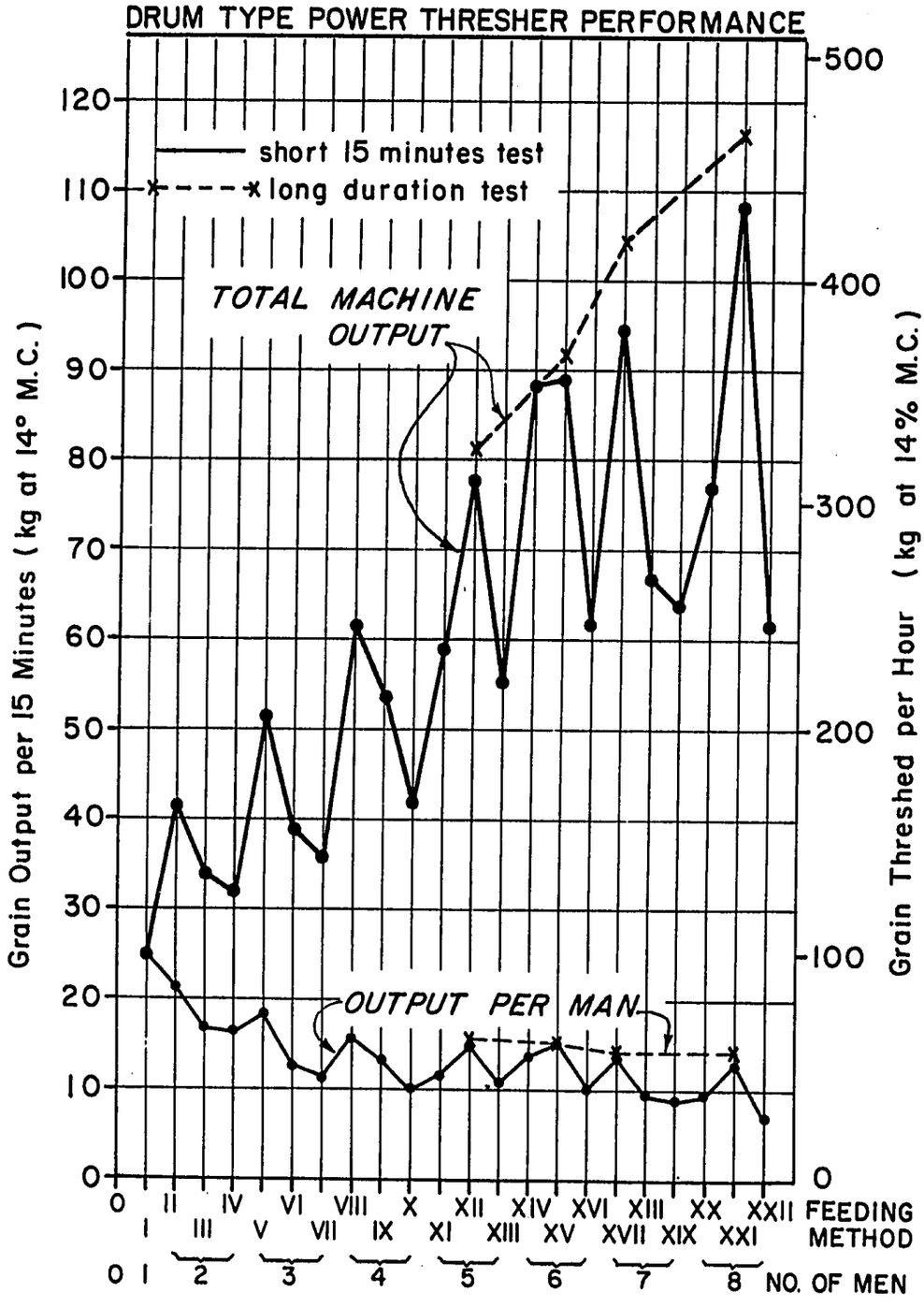


Fig. 5. Threshing performance of drum-type power thresher using different methods and numbers of men in feeding.

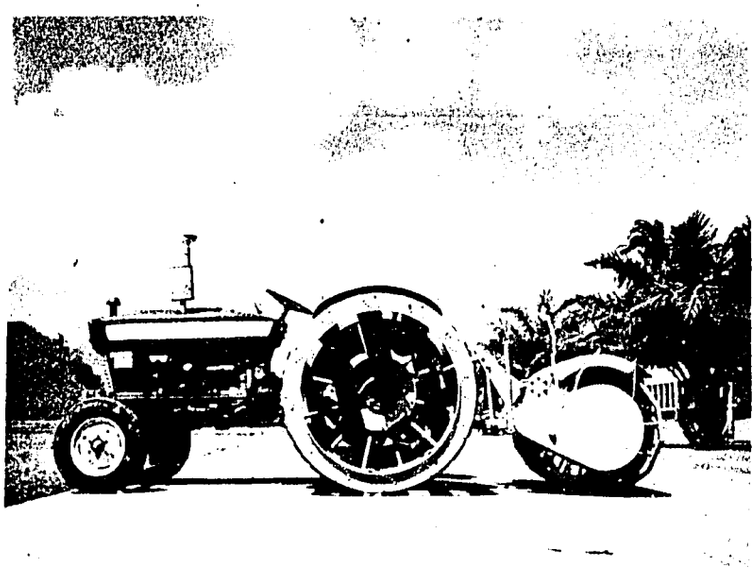


Fig. 6. Experimental rotary tiller with special cage wheels mounted on Ford 4000 tractor.

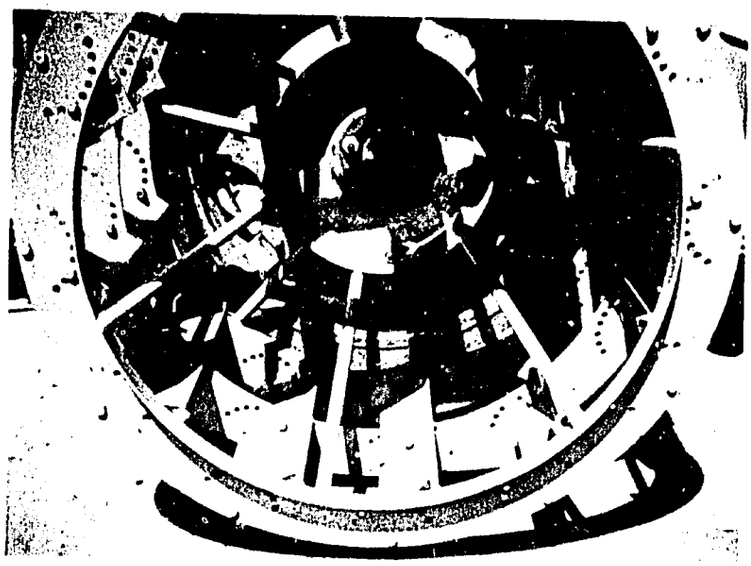


Fig. 7. Special cage wheels with adjustable blade angles.

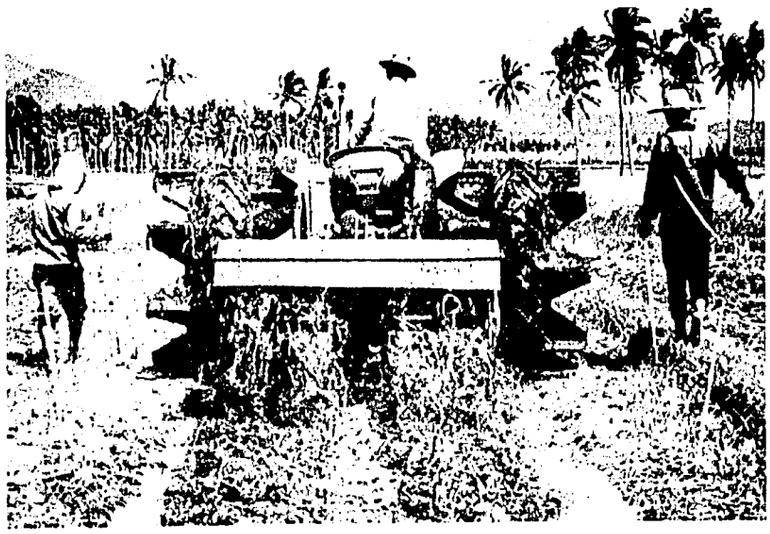


Fig. 8. Experimental rotary tiller being tested under wetland conditions.

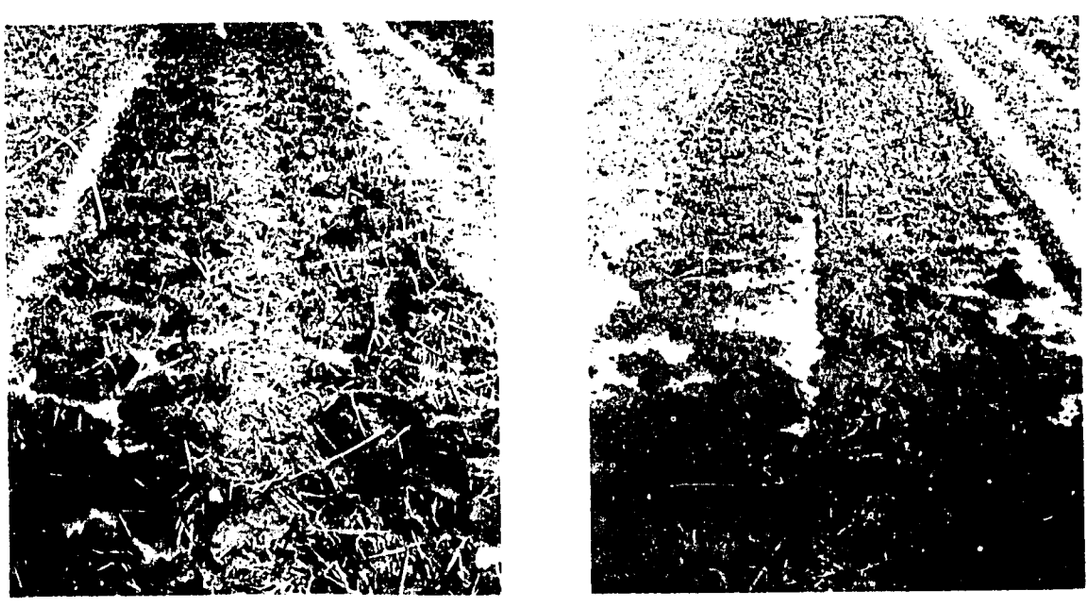


Fig. 9. Effect of tillage at II tractor travel speed (0.75 m/s) and (a) low tiller blade velocity of 2.10 m/s; (b) high tiller blade velocity of 3.77 m/s.

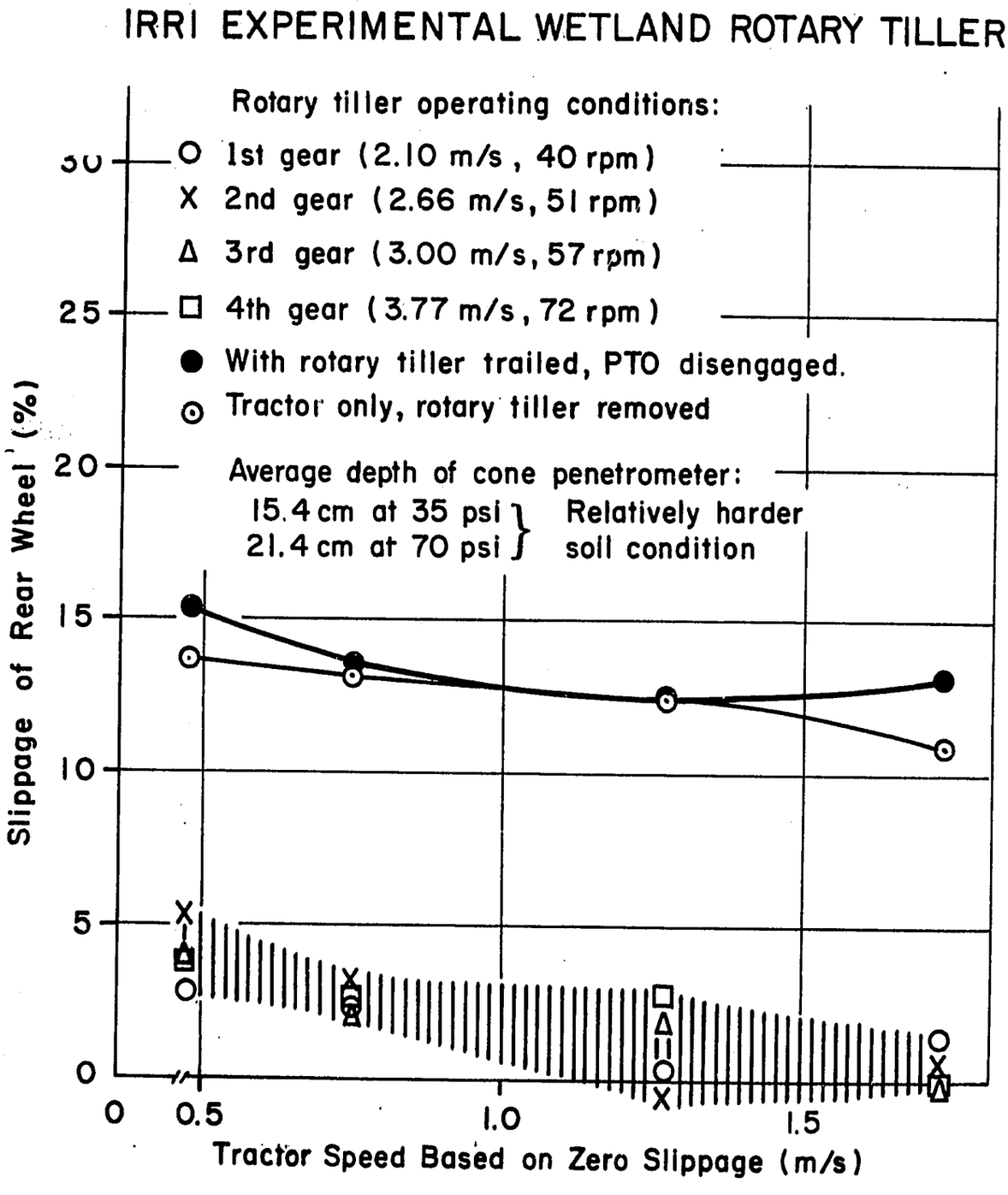


Fig. 10. Tractor rear wheel slippage at different tractor forward travel speeds and different IRRI rotary tiller drive conditions under harder wetland conditions.

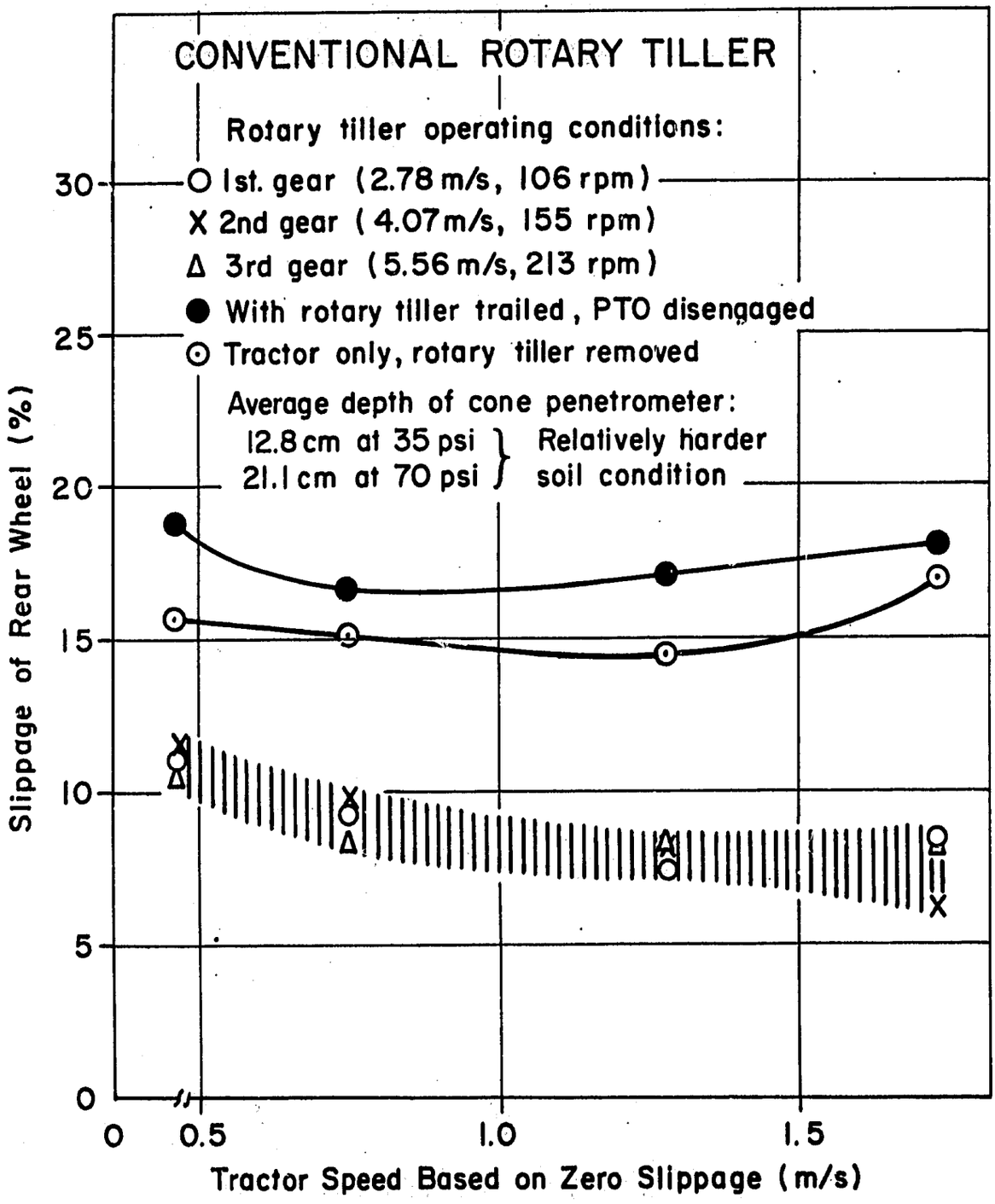


Fig. 11. Tractor rear wheel slippage at different tractor forward speeds and different conventional rotary-tiller drive conditions under harder wetland conditions.

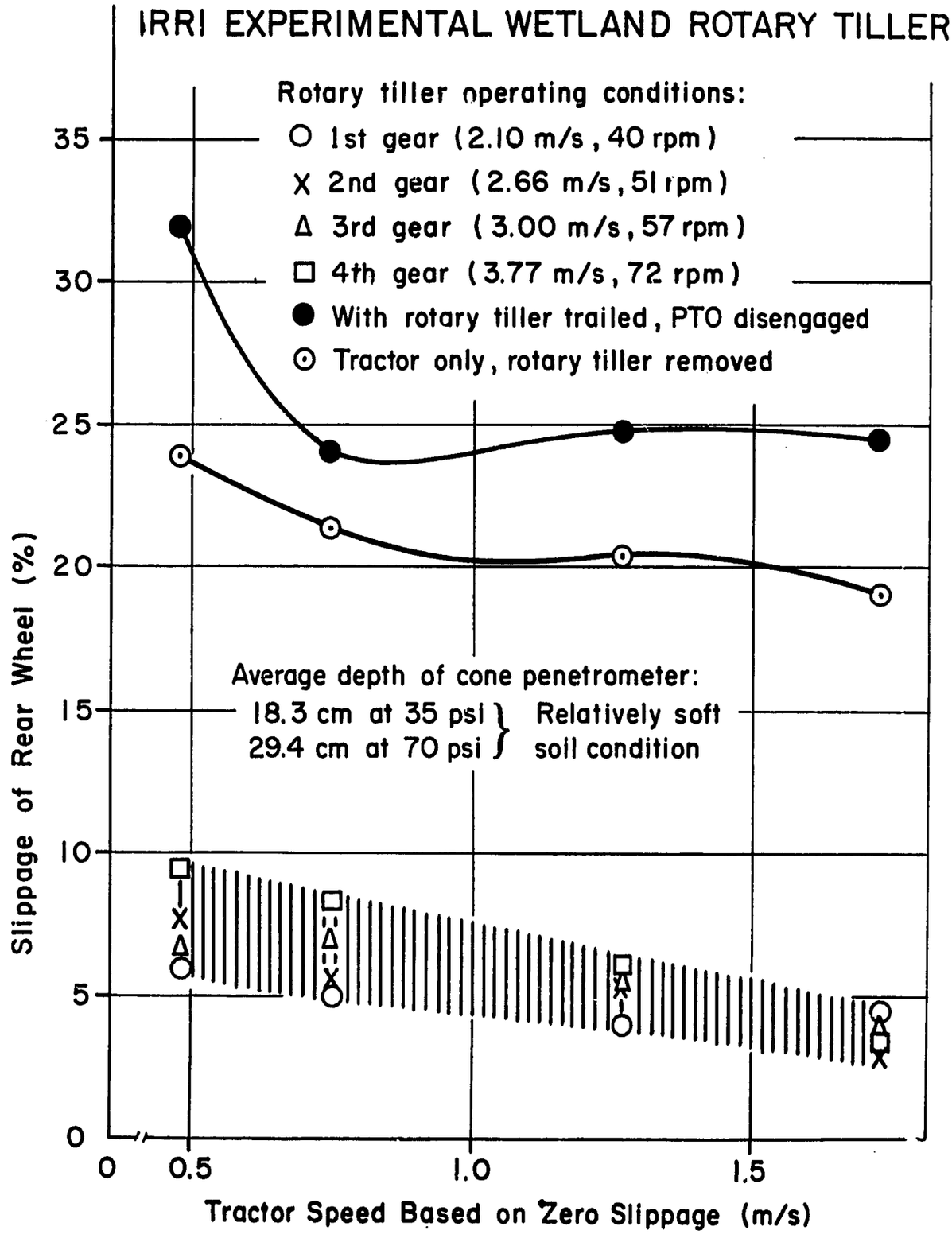


Fig. 12. Tractor rear wheel slippage at different tractor forward travel speeds and different IRRI rotary-tiller drive conditions under softer wetland conditions.

Fig. 13. First experimental 3-row power weeder using flexible shaft drive.

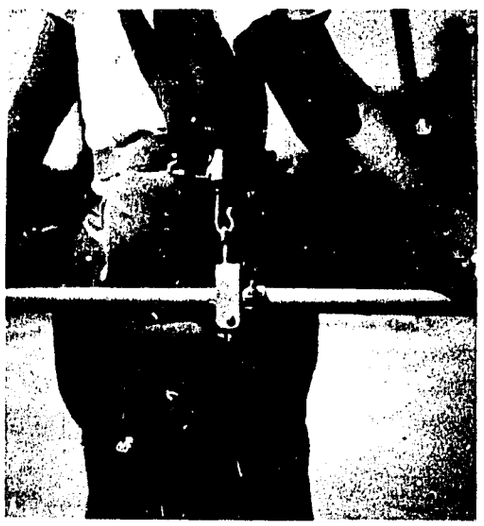


Fig. 14. Sliding suspension for improved balance.

Fig. 15. Second experimental power weeder using rigid shaft drive and sliding suspension hitch.

Fig. 16. Five-row experimental power weeder.

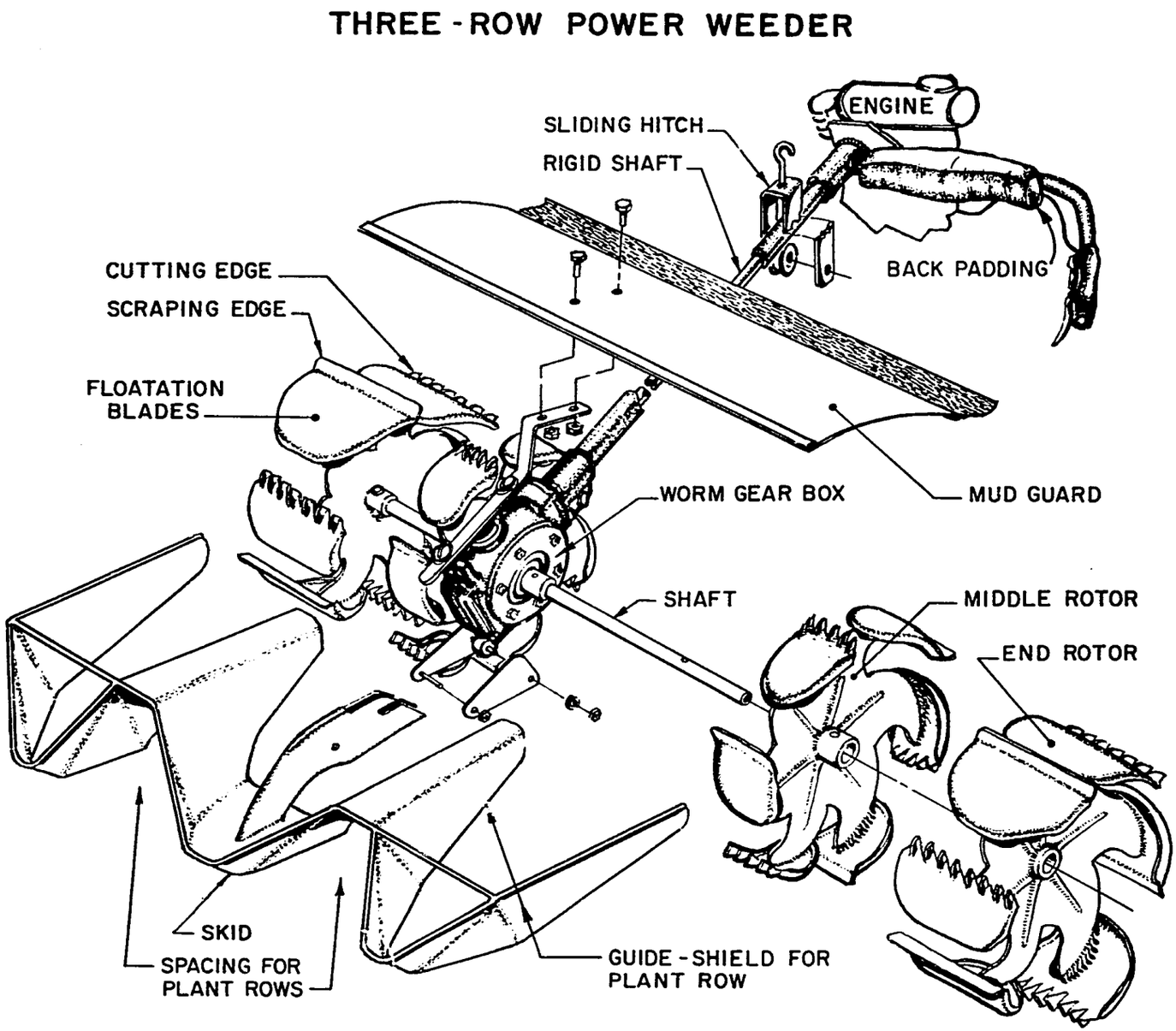


Fig. 17. Schematic drawing of a three-row experimental power weeder with rigid shaft drive and sliding suspension hitch.

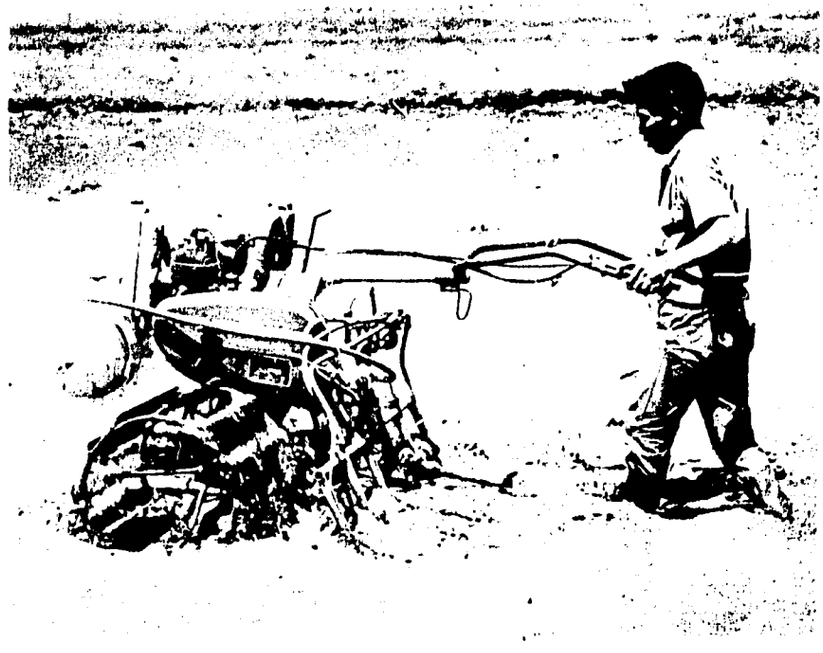


Fig. 18. Experimental anhydrous ammonia applicator for small walking tractors.

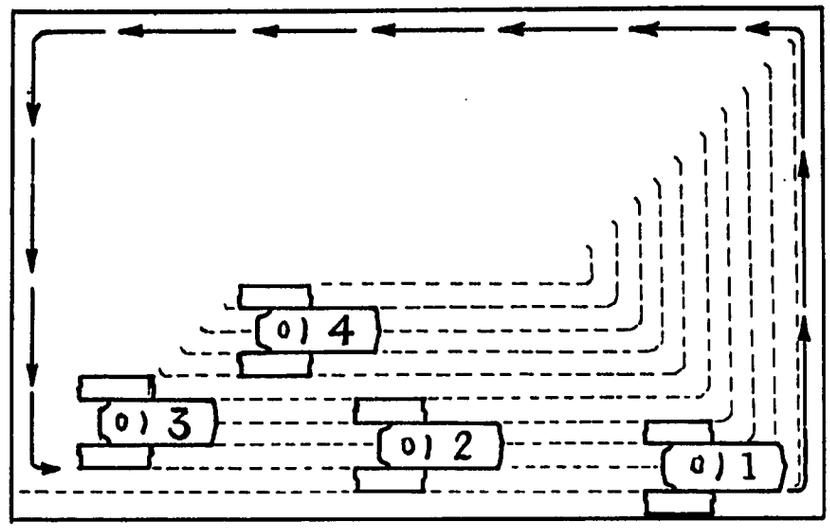


Fig. 19. Ara-wheeling, tillage by tractor cage wheels only.

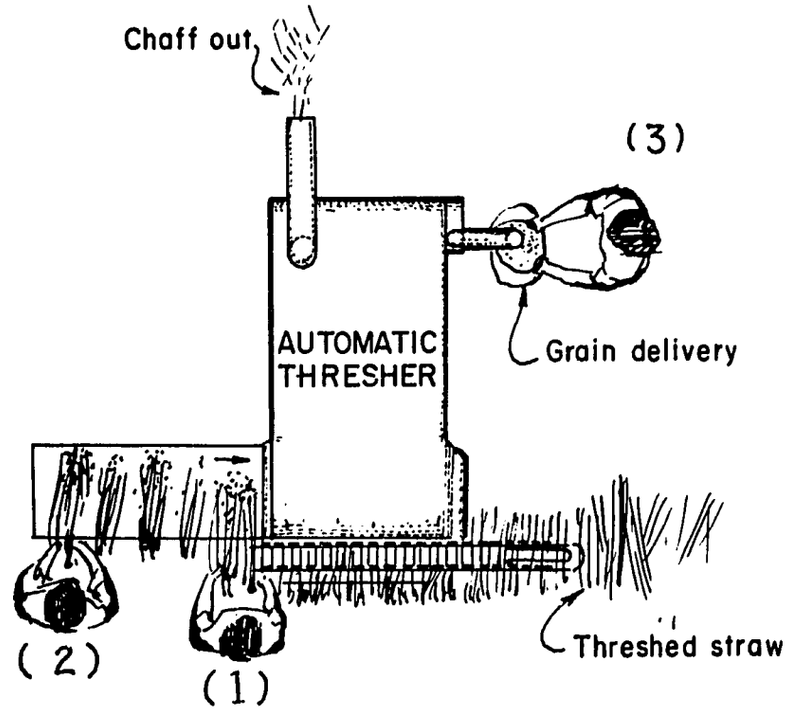


Fig. 20. Japanese Automatic Thresher.

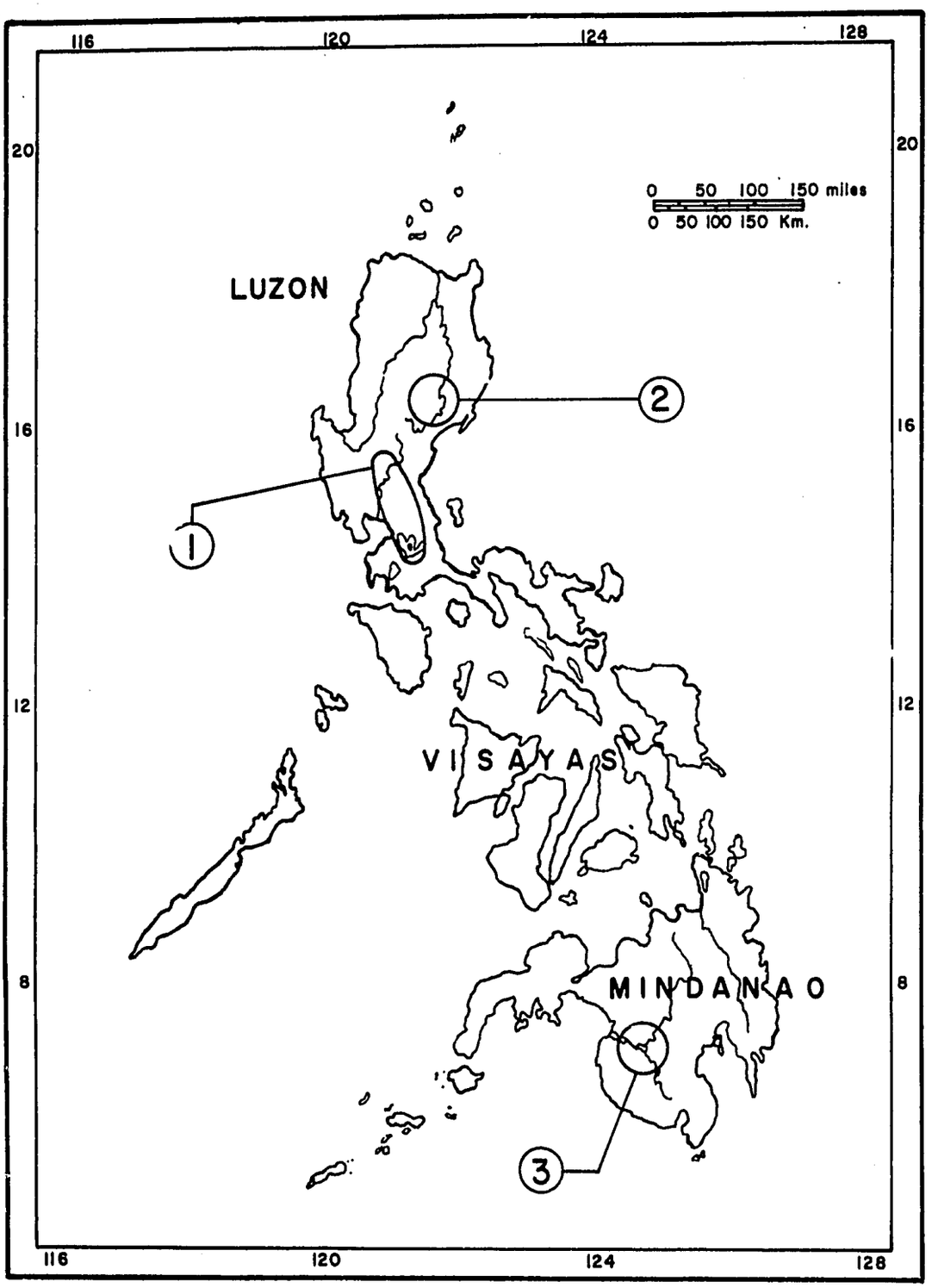


Fig. 21. Map of the Philippines. Three surveys undertaken in the Philippines: (1) Central Luzon; (2) Cagayan Valley (Isabela Province); and (3) Mindanao (Cotabato Province).

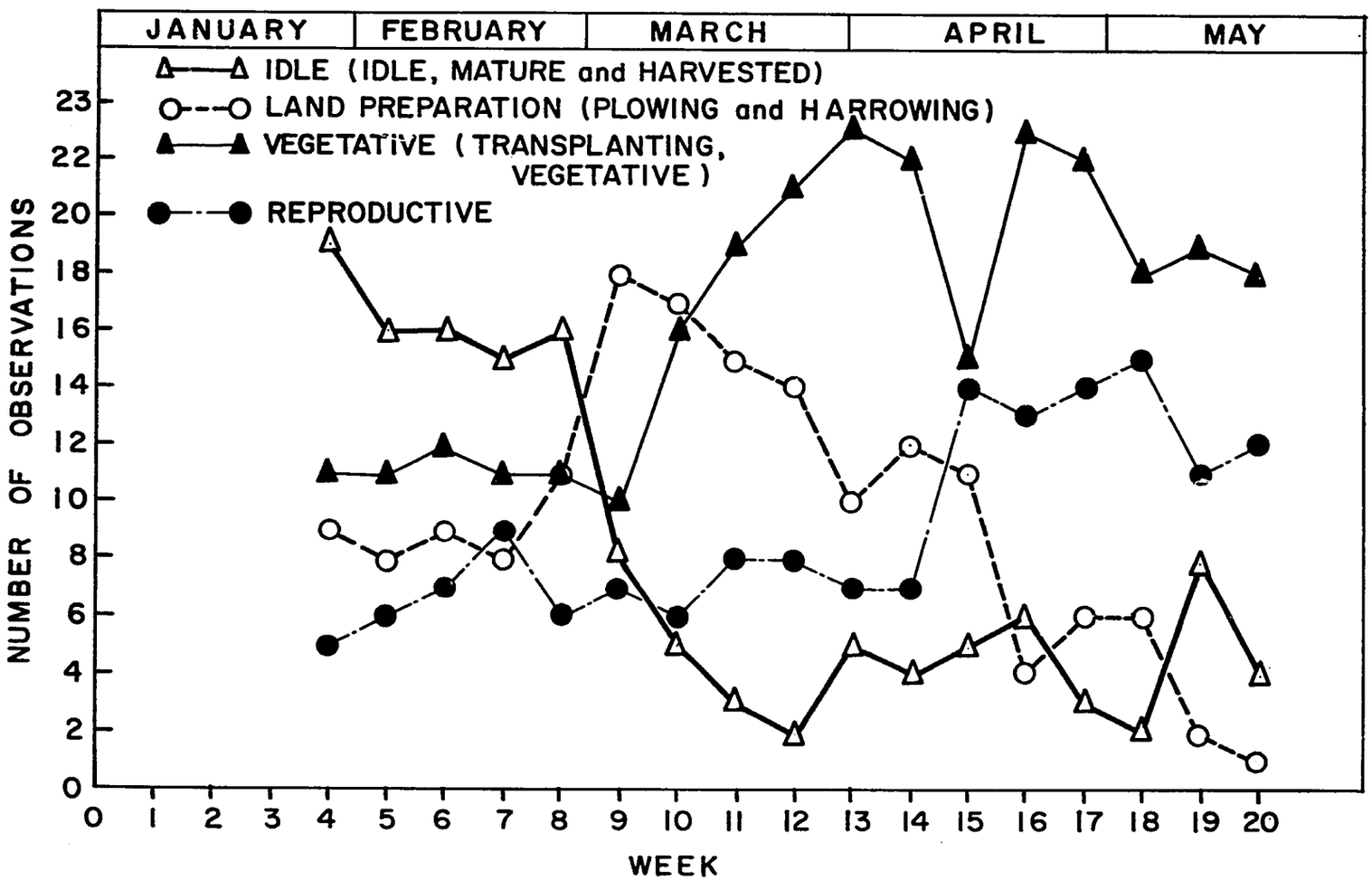


Fig. 22. Sequence of farm operations: Mindanao (Tacurong) Survey, Corn 1968.

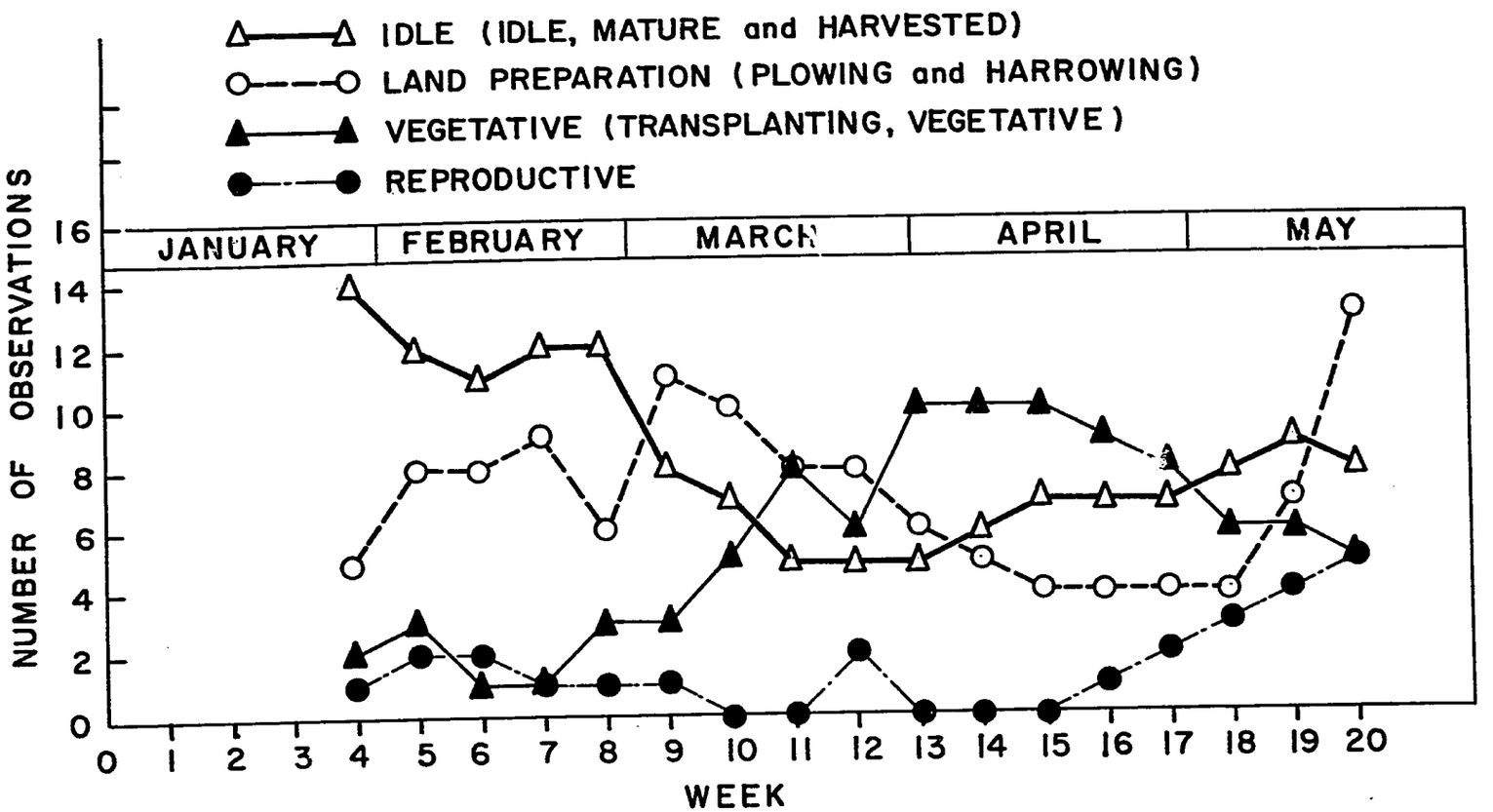


Fig. 23. Sequence of farm operations: Mindanao (Tacurong) Survey, Rice 1968.

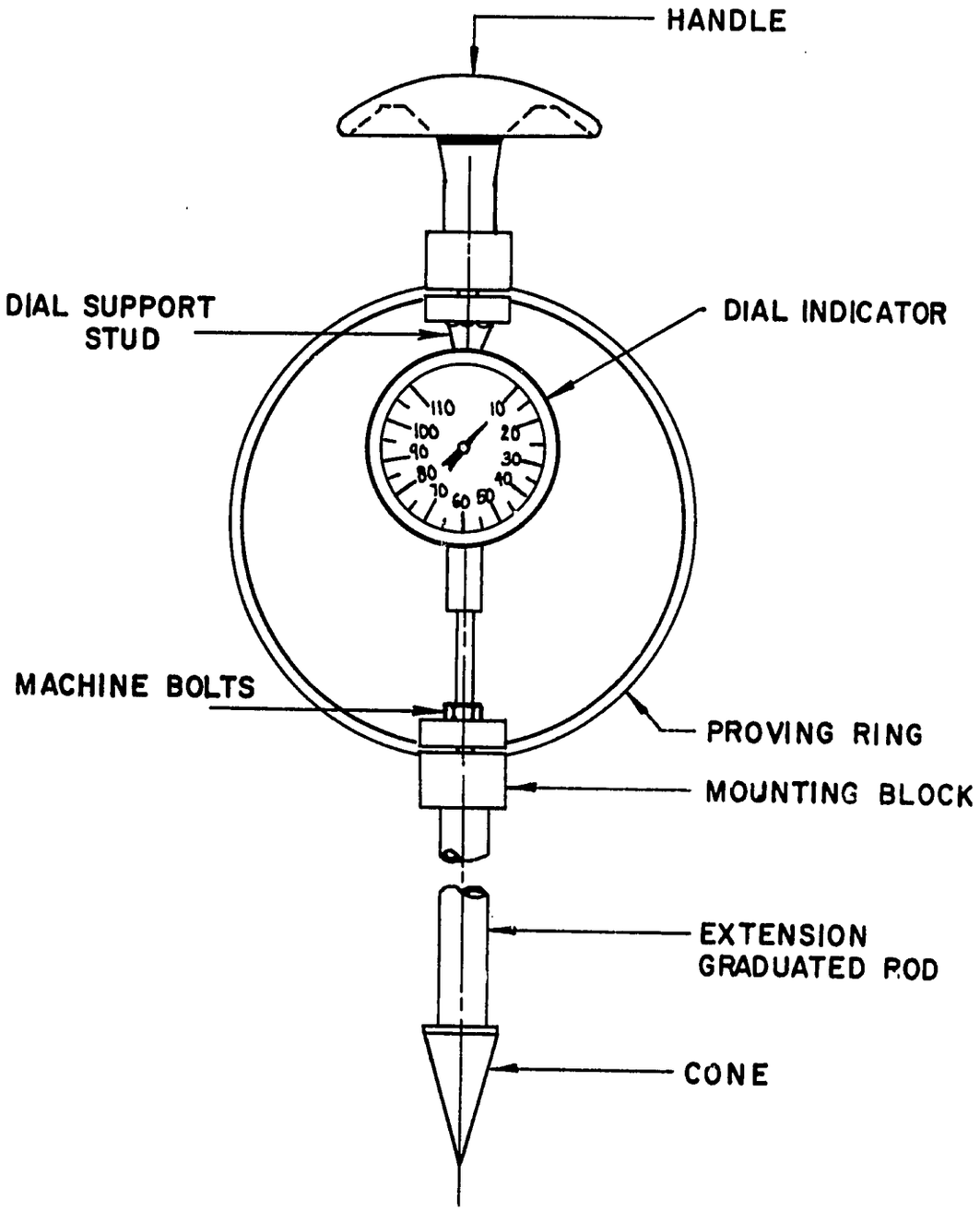


Fig. 24. Cone Penetrometer

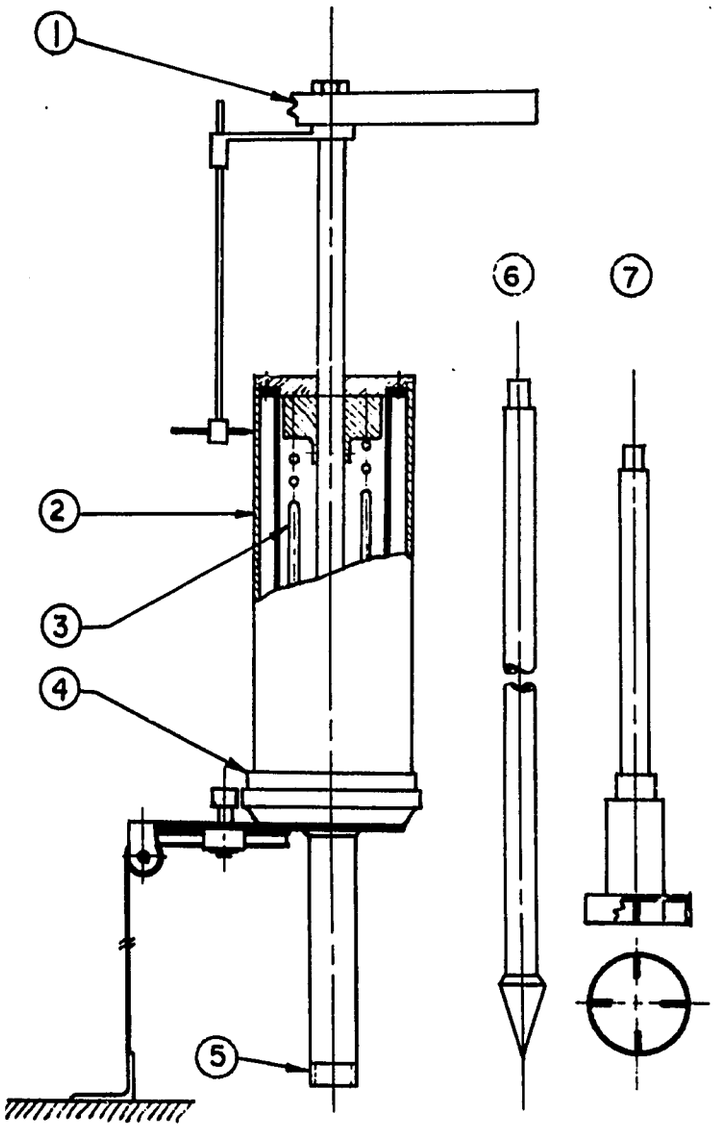


Fig. 25. Schematic Drawing of a Soil Values Meter TN-4.

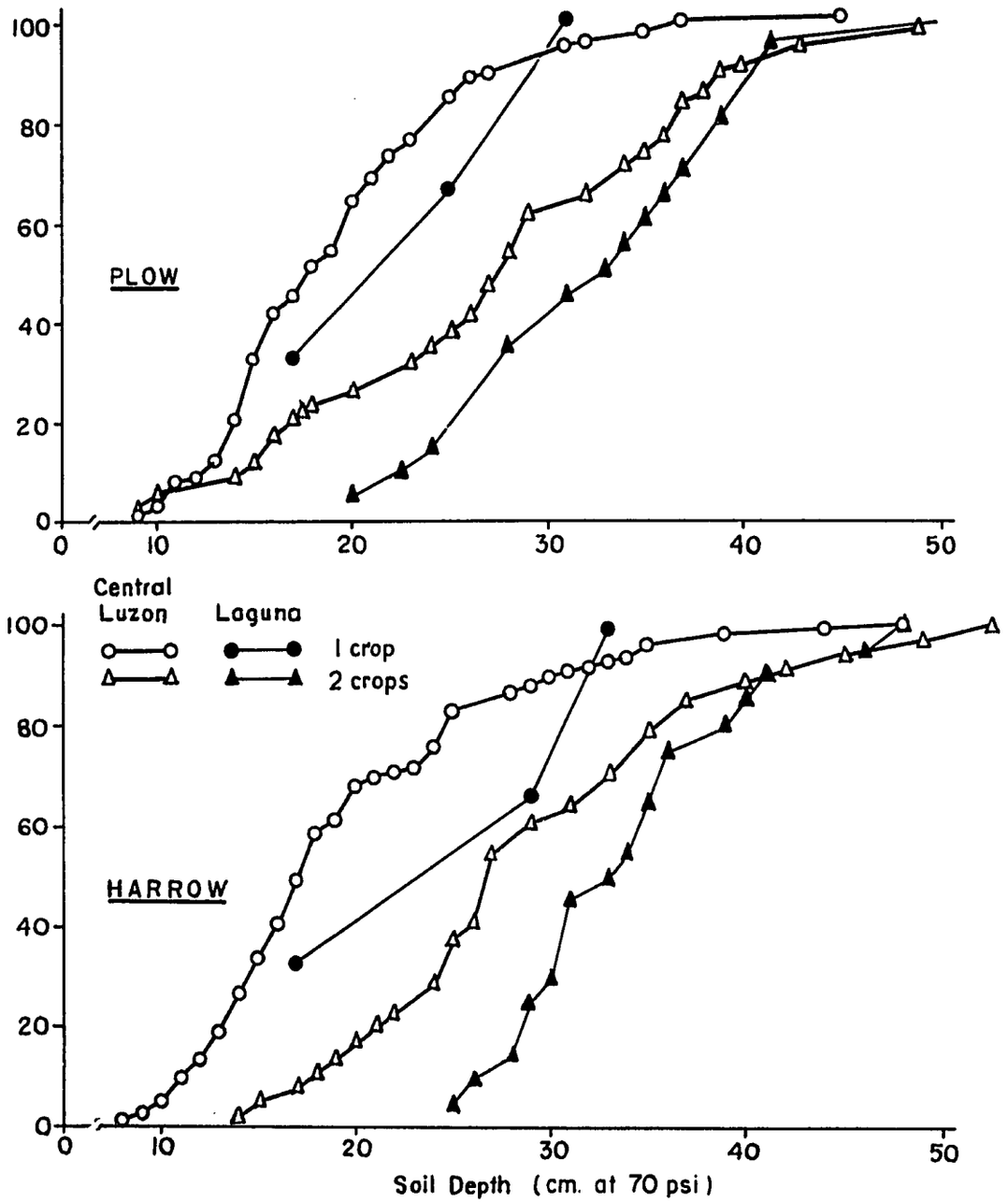


Fig. 26. Cumulative frequency of various mean soil depths (cm) during plowing or harrowing at which a U. S. Army Corps of Engineers WES Cone Penetrometer had a resistance of 70 psi: Central Luzon and Laguna Provinces, Philippines (1966-67).

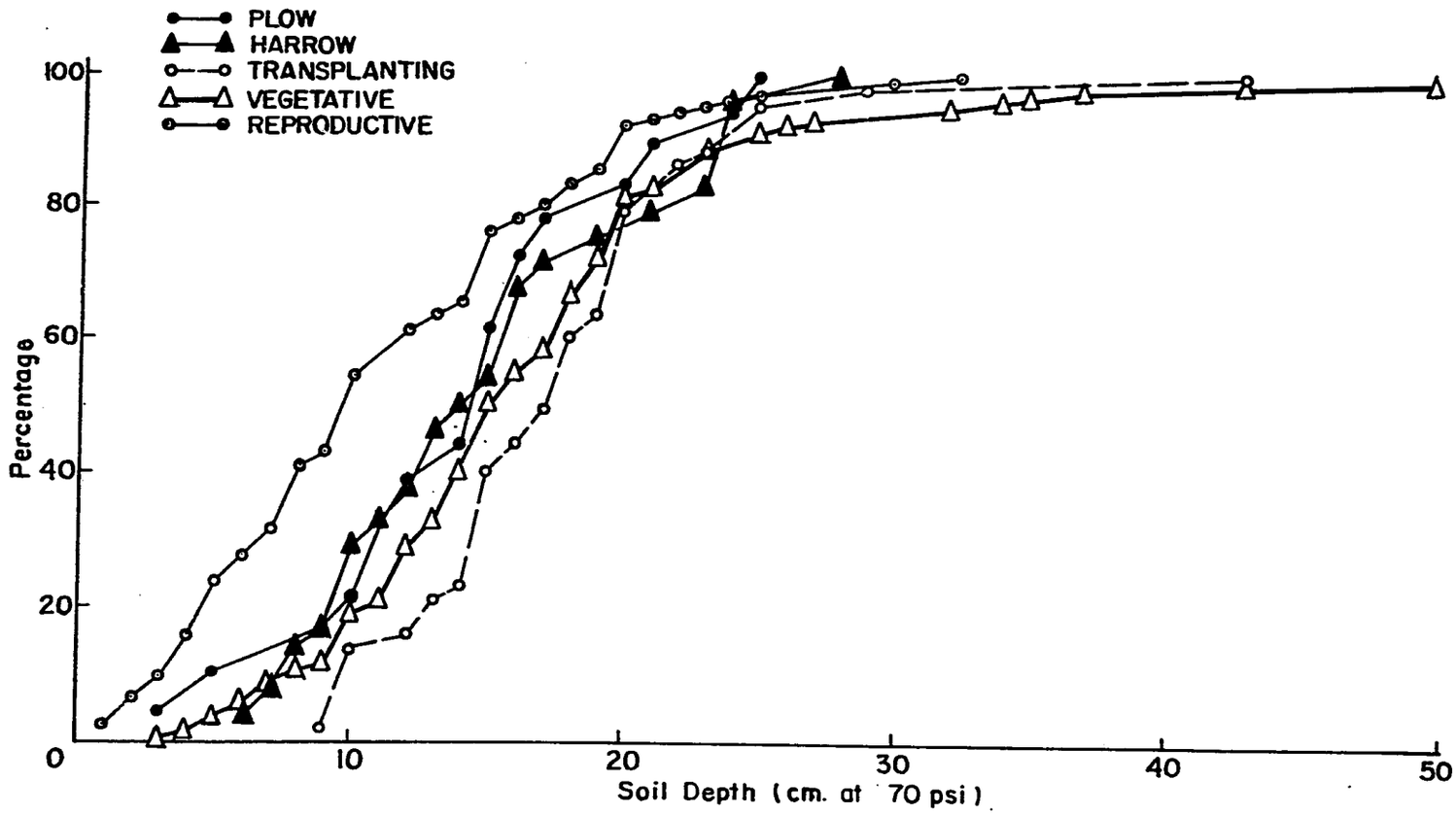


Fig. 27. Cumulative frequency of various mean soil depths (cm) during the plowing, harrowing, transplanting, vegetative, or reproductive stages at which a U.S. Army Corps of Engineers WES Cone Penetrometer had a resistance of 70 psi: Isabela, Philippines (October 23, 1967-January 13, 1968).

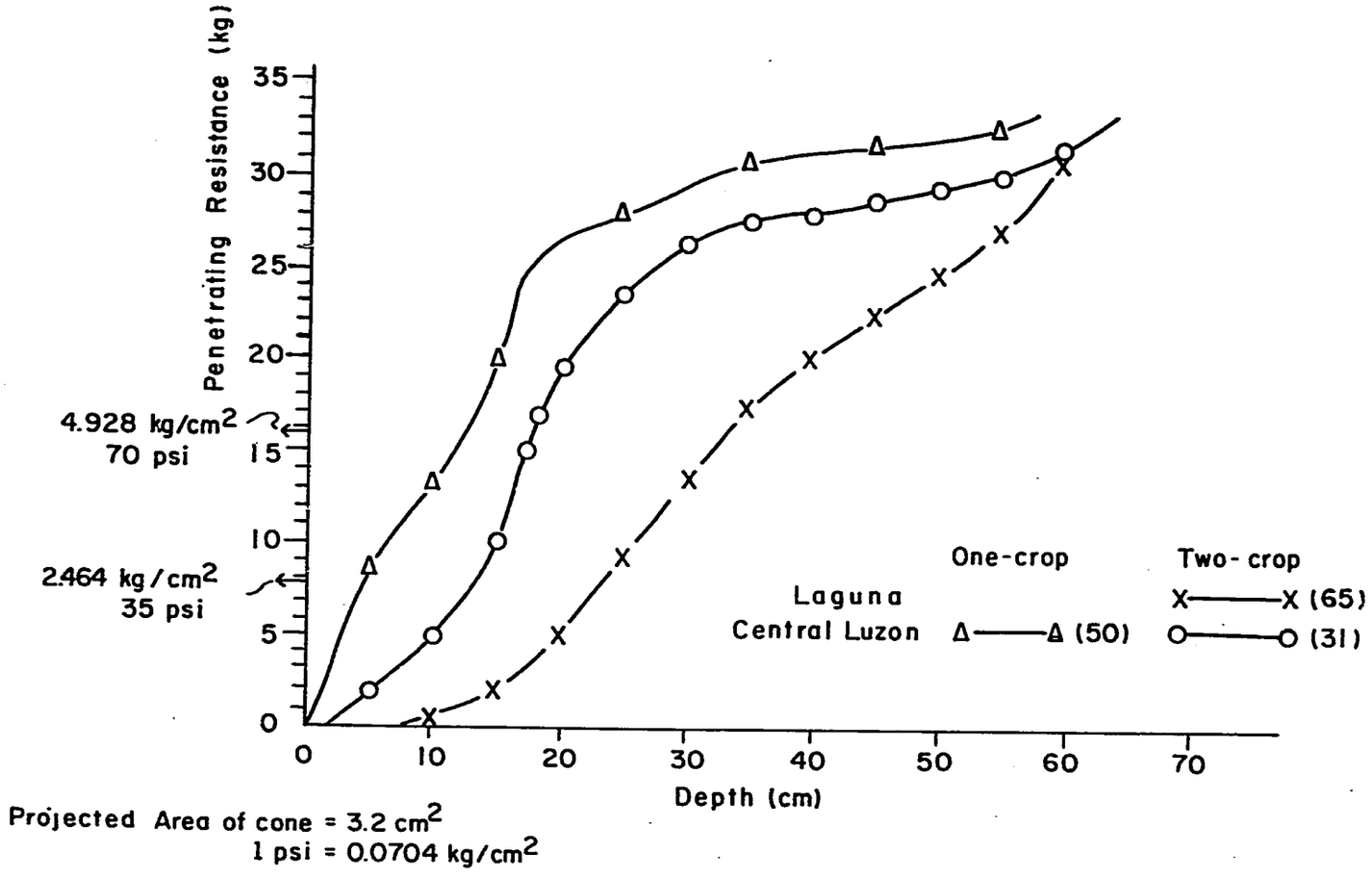


Fig. 28. Mean soil resistances at different depths (cone index) measured just before land preparation with the Soil Values Meter TN-4. The numbers enclosed in parenthesis refer to the number of measured sites. Laguna and Central Luzon Provinces (1967 - 1968).

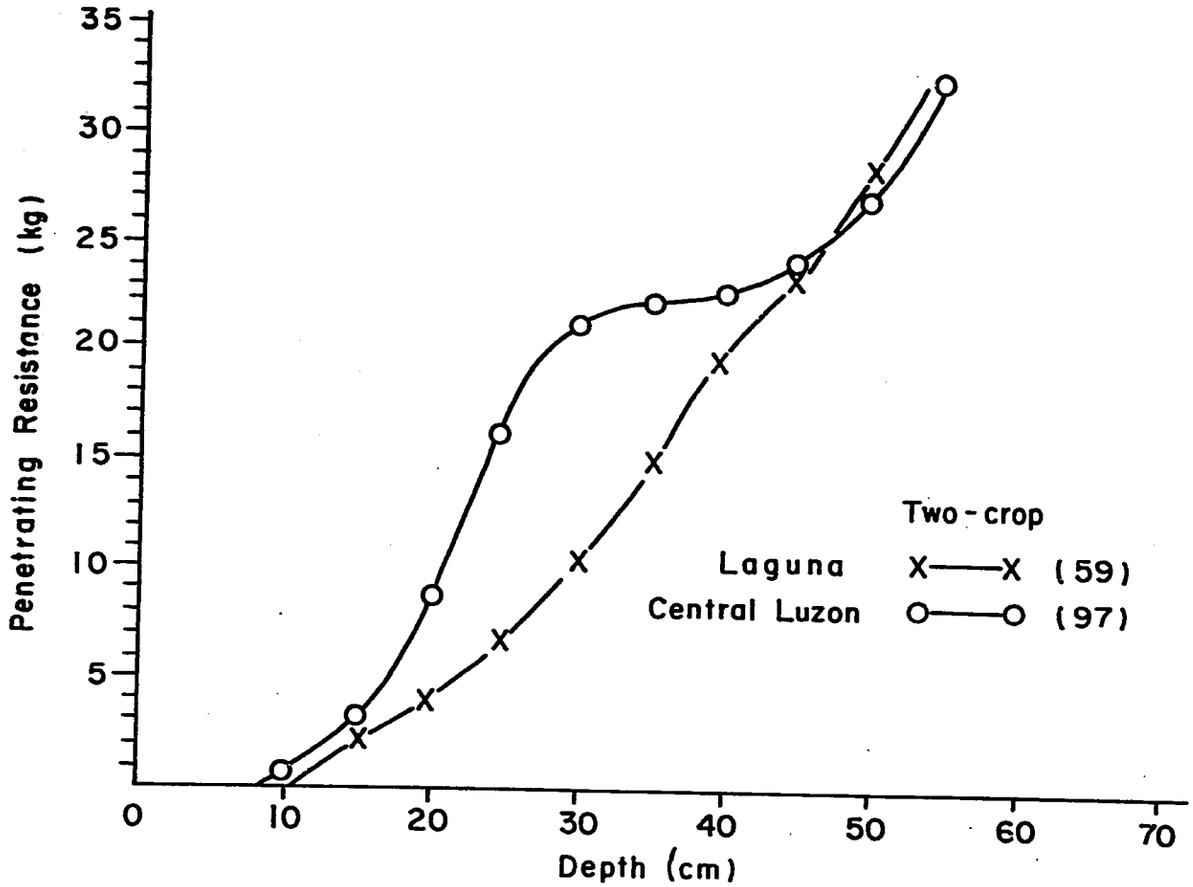


Fig. 29. Mean soil resistances at different depths (cone index) measured during final harrowing with the Soil Values Meter TN-4. The numbers enclosed in parenthesis refer to the number of measured sites. Laguna and Central Luzon, Philippines (1967-1968).

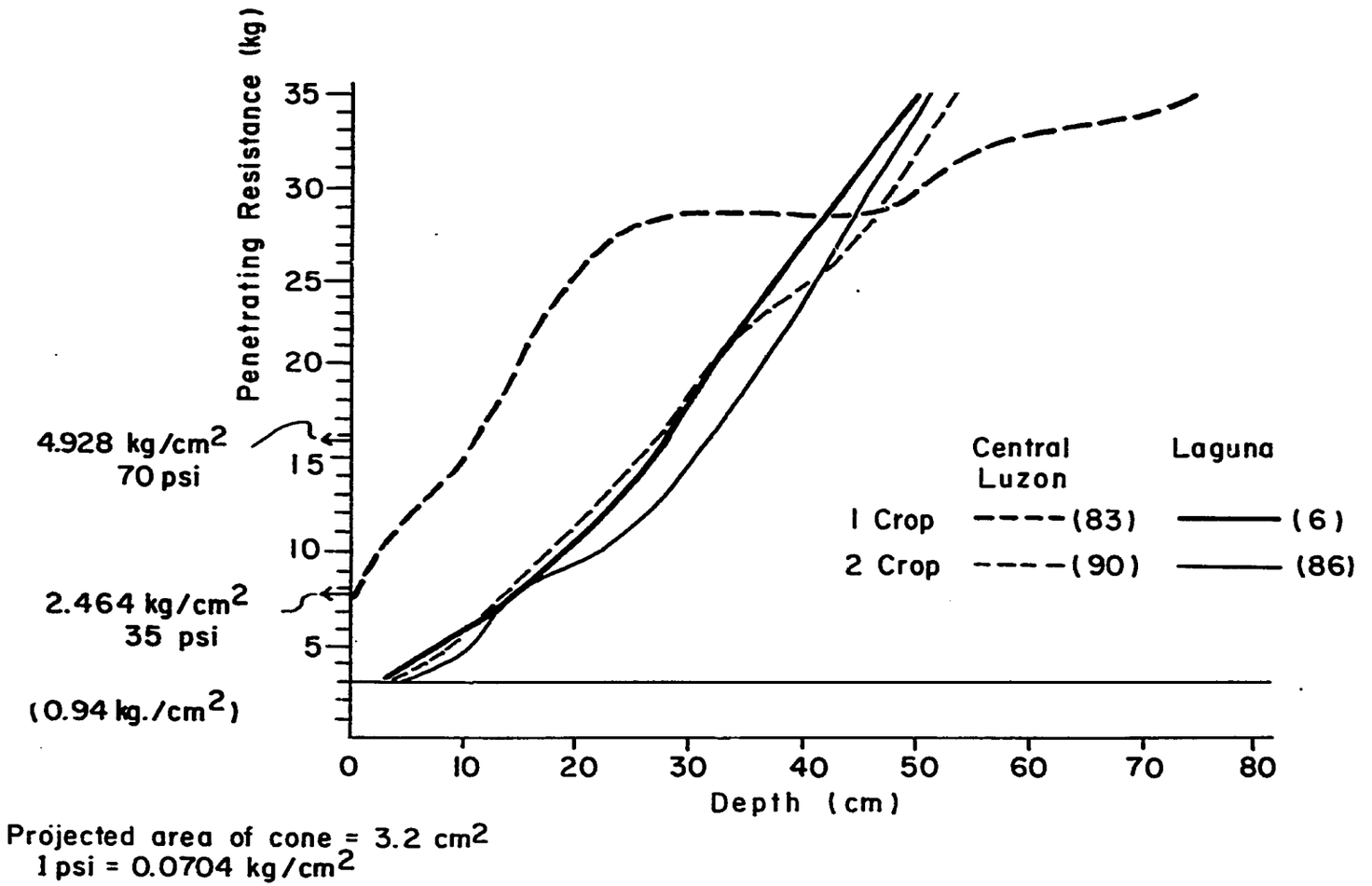


Fig. 30. Mean soil resistances at different depths (cone index) measured just after harvest with the Soil Values Meter TN-4. Numbers enclosed in parenthesis refer to the number of measured sites. Central Luzon and Laguna Provinces, Philippines (1967).

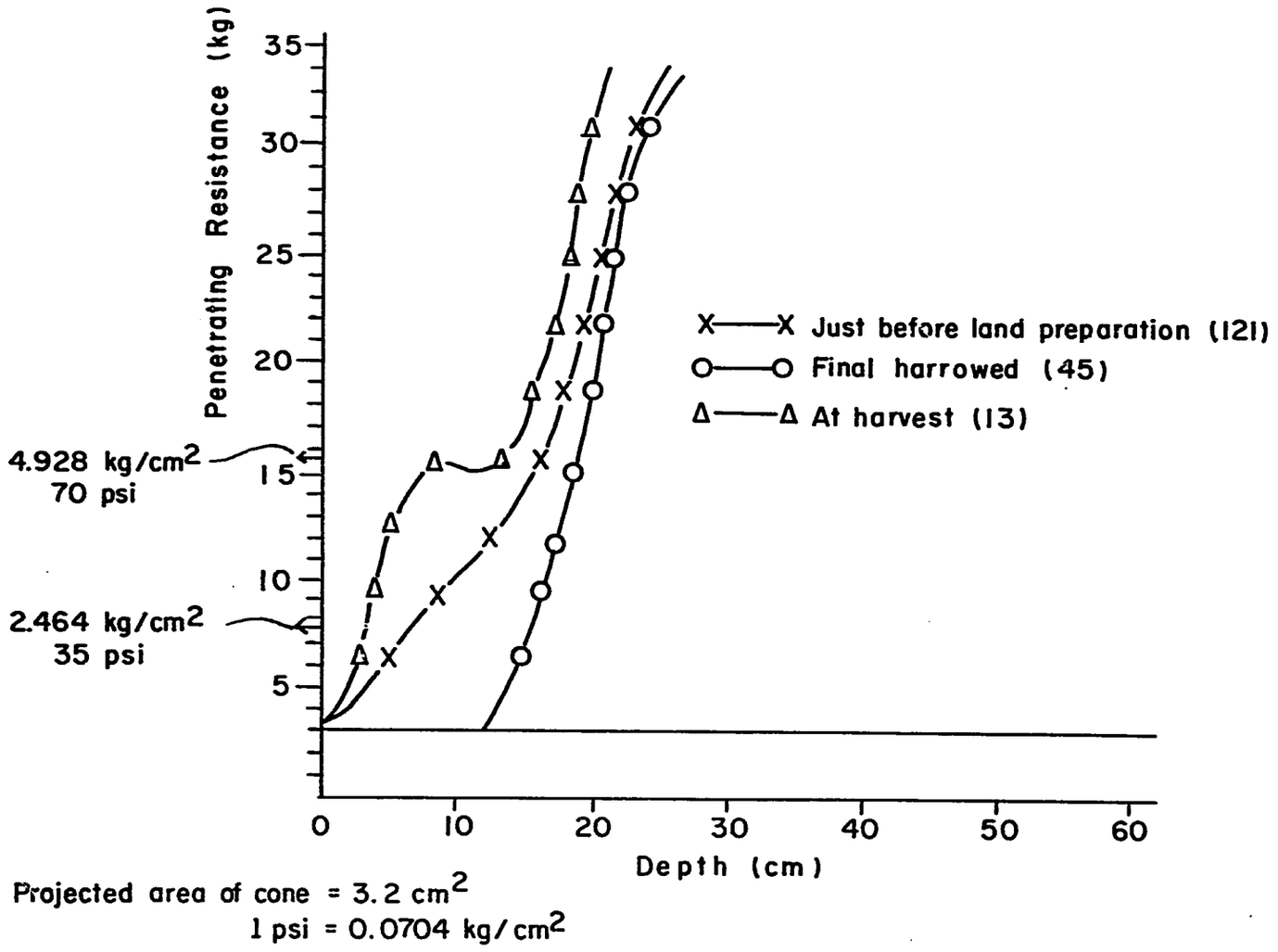


Fig. 31. Mean soil resistances at different depths (cone index) measured at different stages during the cropping season of two-crop fields with the Soil Values Meter TN-4. Figures enclosed in parenthesis refer to number of measured sites. Isabela Province, Philippines (1968).

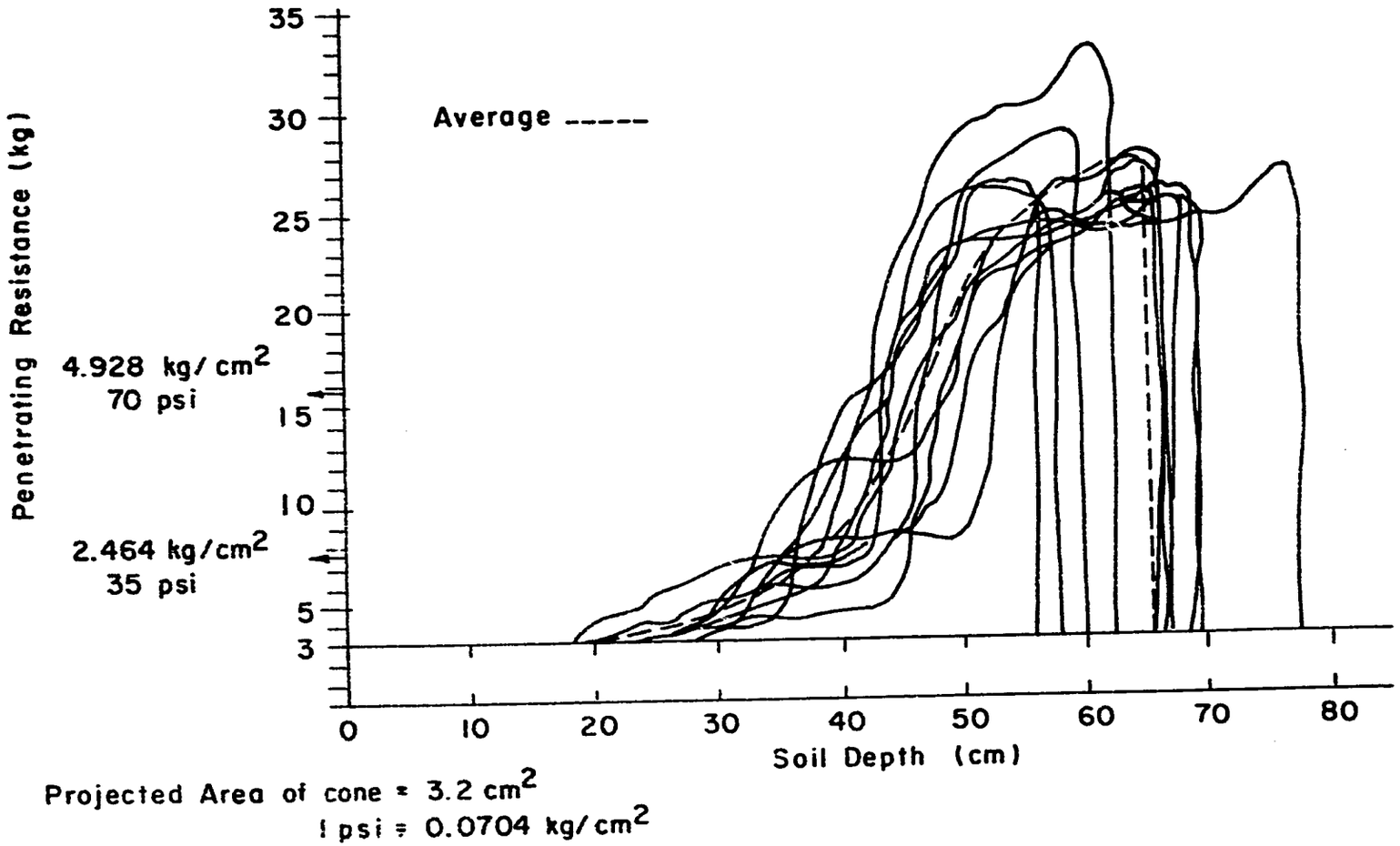


Fig. 32. Actual measurements recorded by the Soil Values Meter TN-4 on one of IRRI's Maximum Production Plots (3 crops per year), Laguna Province, Philippines (1967).

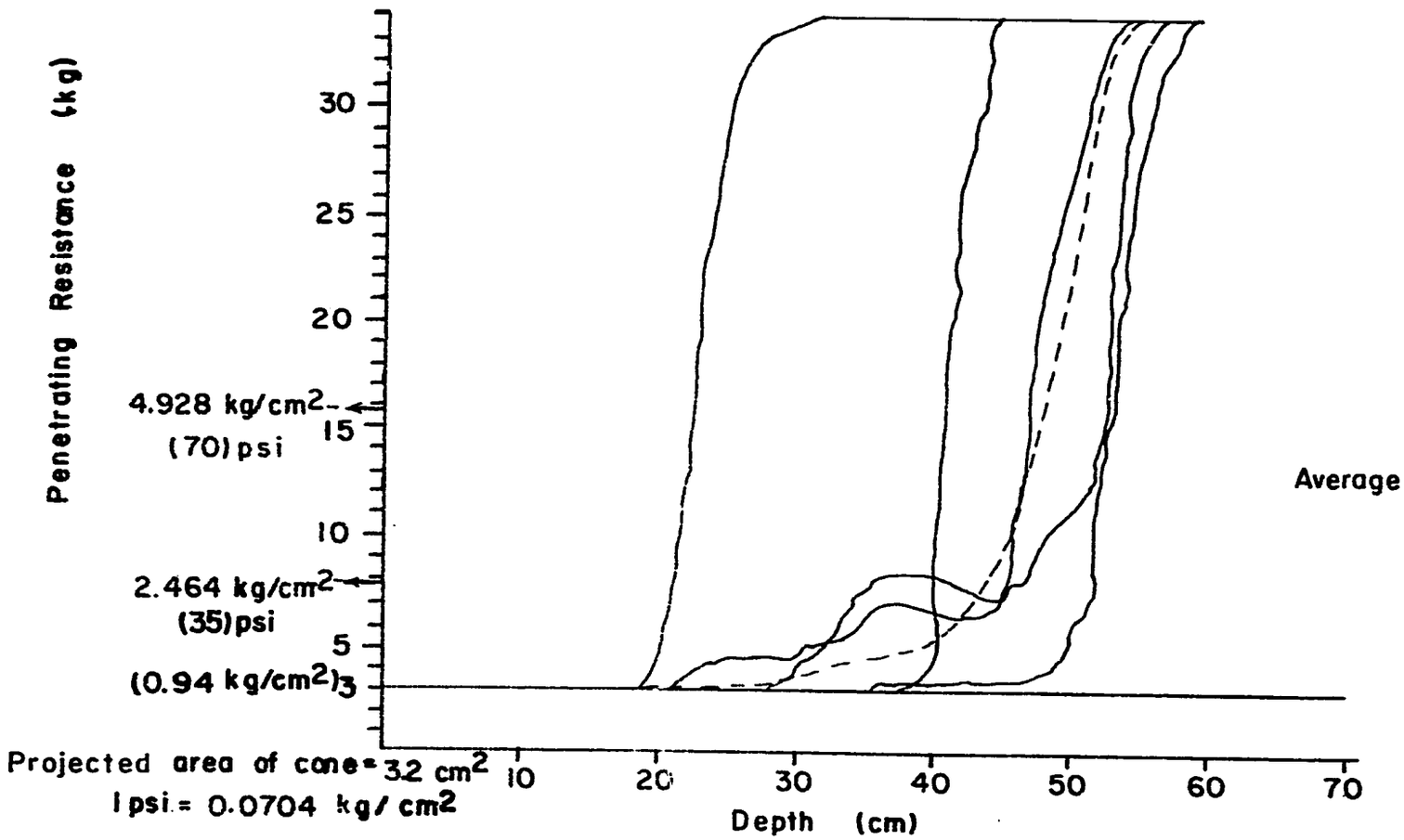


Fig. 33. Actual measurements recorded by the Soil Values Meter TN-4 on a water-looged area. An ISEKI KF-850 was tested on this field and bogged down. Isabela Province, Philippines (1968).

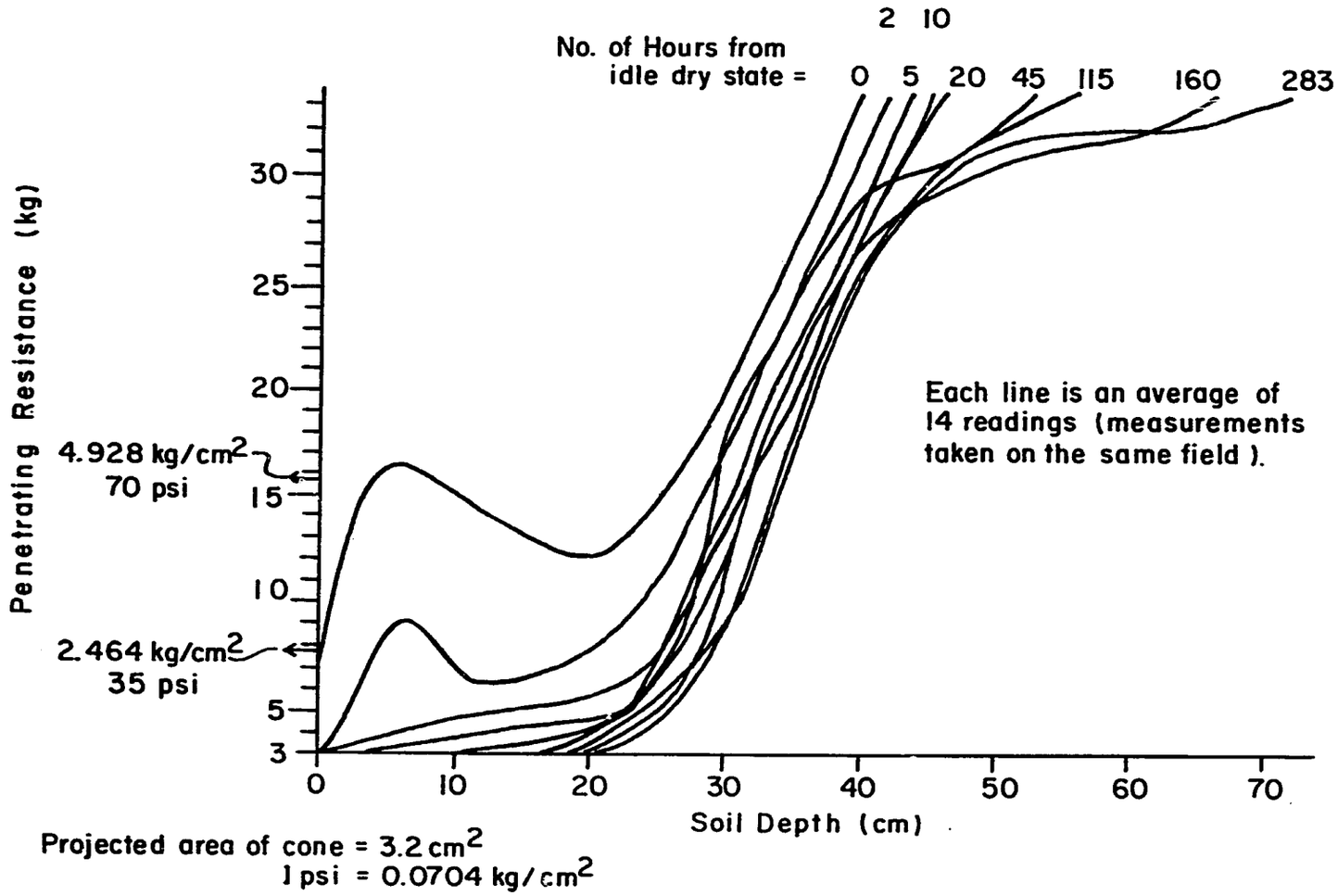


Fig. 34. Change in soil resistance from an idle dry state to a condition after soil has been flooded for a time. Measurements made with TN-4 Soil Values Meter. IRRI, Laguna Province, Philippines (1968).

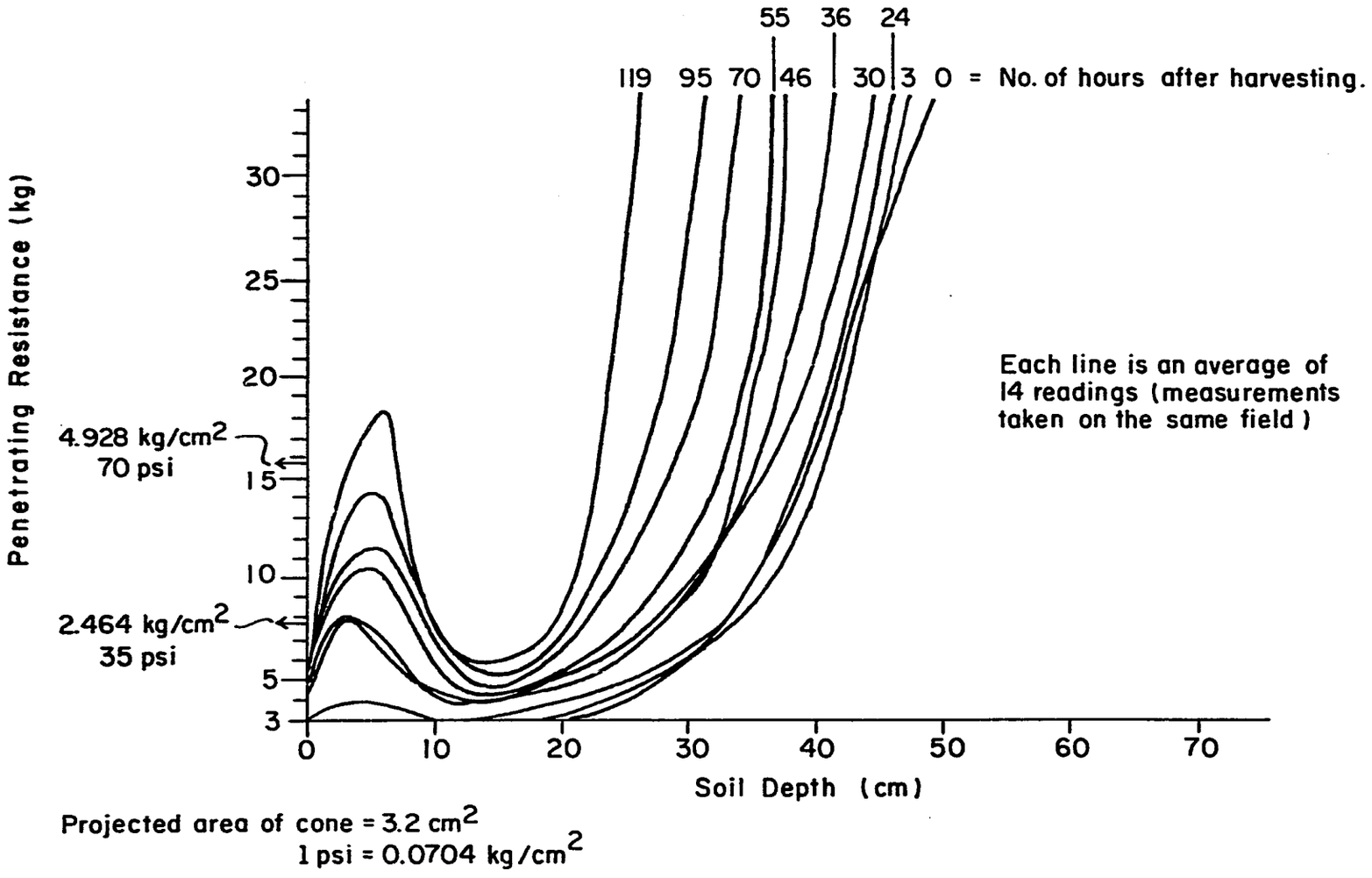


Fig. 35. Change in soil resistance from harvesting to a dry state measured with TN-4 Soil Values Meter. IRRI, Laguna Province, Philippines (1968).

APPENDIX I

REPORT OF U.S.D.A. NATIONAL TILLAGE MACHINERY LABORATORY STUDY ON ROTARY TILLAGE AND TRACTION - January to June 30, 1968.

Substantive Report No. 3 on the Cooperative Agreement #12-14-100-9058 (42) between IRRI and NTML was prepared by A. W. Cooper, L. W. Larson, F. P. Smits, J. H. Taylor, and C. S. Chang.

Introduction

During this report period measurements of horizontal and vertical forces and shaft torque were made on seven Japanese-made rotary tiller blades in three different non-saturated soil conditions. Samples of measurements are included to show the type information being gathered. This information was obtained using the small rotary tiller blade dynamometer developed under this project.

A large rotary tiller blade dynamometer was constructed. Data were gathered to determine the influence of tool design and operational factors on power, torque, and energy requirements. The data are now on magnetic tape and will be analyzed using an analog computer and XY plotter. No data from this study are included in this report. The factors studied are reported.

A power modified disk was constructed to investigate the possibility of an active tillage implement that has the active tillage character of a rotary tiller and the soil displacement character of a disk plow. This unit will be evaluated.

The construction of the small wheel test device was completed. A plan of study using this unit is given in the report.

Rotary Tillage Project

Study of Japanese Blades

One of the stated objectives of the project was to obtain data on operating characteristics of specified blade shapes, in an attempt to determine rational bases for design of rotary tillers and to establish limits of operating parameters.

During the report period a study was made of a group of Japanese-made rotary tiller blades of the type in use in the Orient on small tillers. Blades were mounted on the test equipment as shown in Figs. 1 & 2. Two mating blades (one right hand and one left hand) were spaced 3" horizontally apart at their shank ends and oriented 180° apart around the shaft. The supporting shaft was equipped with a torquemeter and had its bearings mounted on force transducers oriented to sense vertical forces and horizontal forces in the direction of travel. Torque for operation was supplied from a shaft equipped with universal joints, thereby eliminating transmission of drive train forces to the transducers. Reaction torque was absorbed by a fixed gearbox.

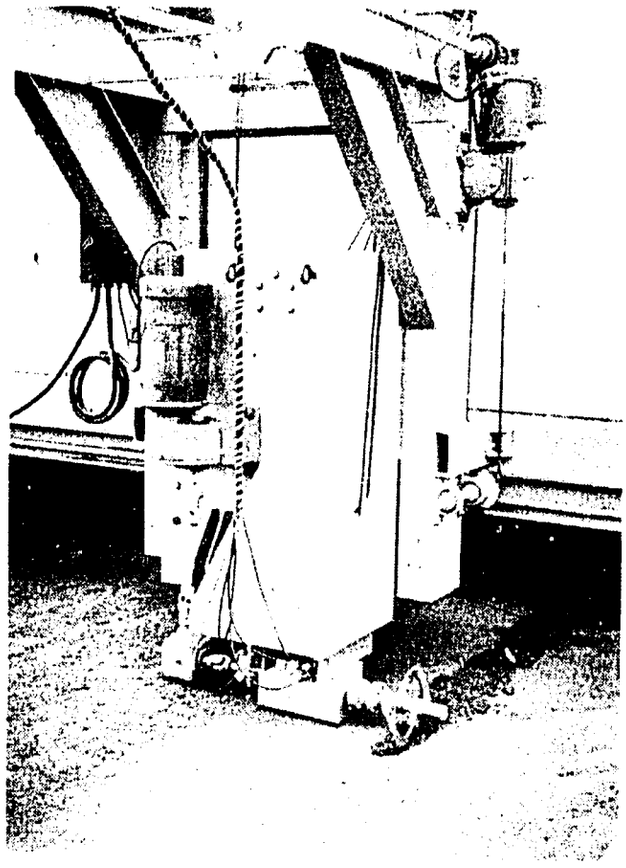


Fig. 1. Small rotary tiller blade dynamometer. (NTML Photo No. M10, 239[a])

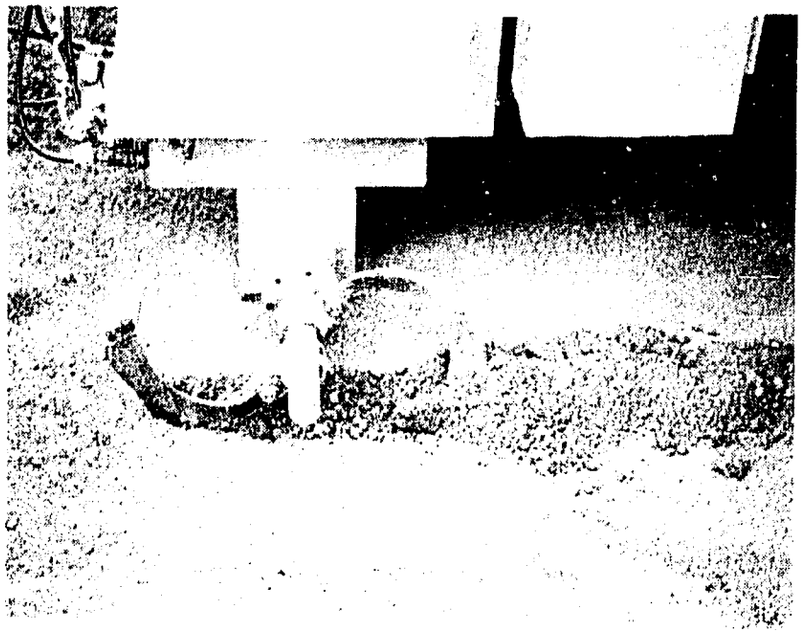


Fig. 2. Closeup of Japanese blades mounted on small rotary blade tine dynamometer. (NTML Photo No. M10, 239[b])

Seven blade types, Fig. 3, were studied in three different non-saturated soil conditions. A cutting depth of 6" was used for all tests with lengths of cut of 2, 4, 6, and 8 inches.

Records for any one blade were essentially similar in character for the three soil conditions, except for the relative magnitudes of the forces and torques. The graphs included with this report show the results of operation in a clay soil having a density of 0.95 gm/cc and 23% moisture at 3" depth. Each graph includes superimposed traces of three consecutive strokes with the same blade. Horizontal scaling of the graphs is not the same because of differences in the chart speed and the rotational speed of the blade shaft for individual tests.

The graphs are included to show a sample of the type of data that were gathered. The data have not been completely analyzed to draw specific conclusions. Conclusions that are obvious from data reported to date are:

1. Increasing length of cut causes higher peak forces and torque.

2. Peak horizontal forces occurred at approximately the same point of rotation regardless of the length of cut. Negative drafts (negative horizontal force) occurred for all lengths of cut from 2" to 8". Negative draft indicated that the blade was pulling the machine in the direction of travel.

Study of Tool Design Factors of Experiment Blades

It is felt that a rotary tiller study for rice field tillage using mainly existing Japanese-made rotary tiller blades, cannot give objective results without more basic information on rotary tillage. A comparative study with the many odd-shaped Japanese blades, slightly different from each other, cannot provide well-founded information because there is lack of systematic variation in the blades. To reveal influence and importance of blade design differences upon power requirements a clear distinction has to be made, especially in view of the variation and heterogeneity of the test medium soil, between adjacent steps in a design factor; e.g., if the influence of blade width is studied, it is more meaningful to use blade width differences of 2" than of 0.5" or less. Also of importance is to make distinction between different tool design factors; e.g., separate tests should be planned for the influence of blade width, cutting angle, blade length, etc.

From an earlier similitude study on rotary tiller (an unpublished thesis of F. P. Smits) it has been found that there is an optimum relation between rotational and forward speed, respectively ωR and V, of a rotary tiller for minimum power and energy requirement and that this relation holds for different geometrical models operating at proportional

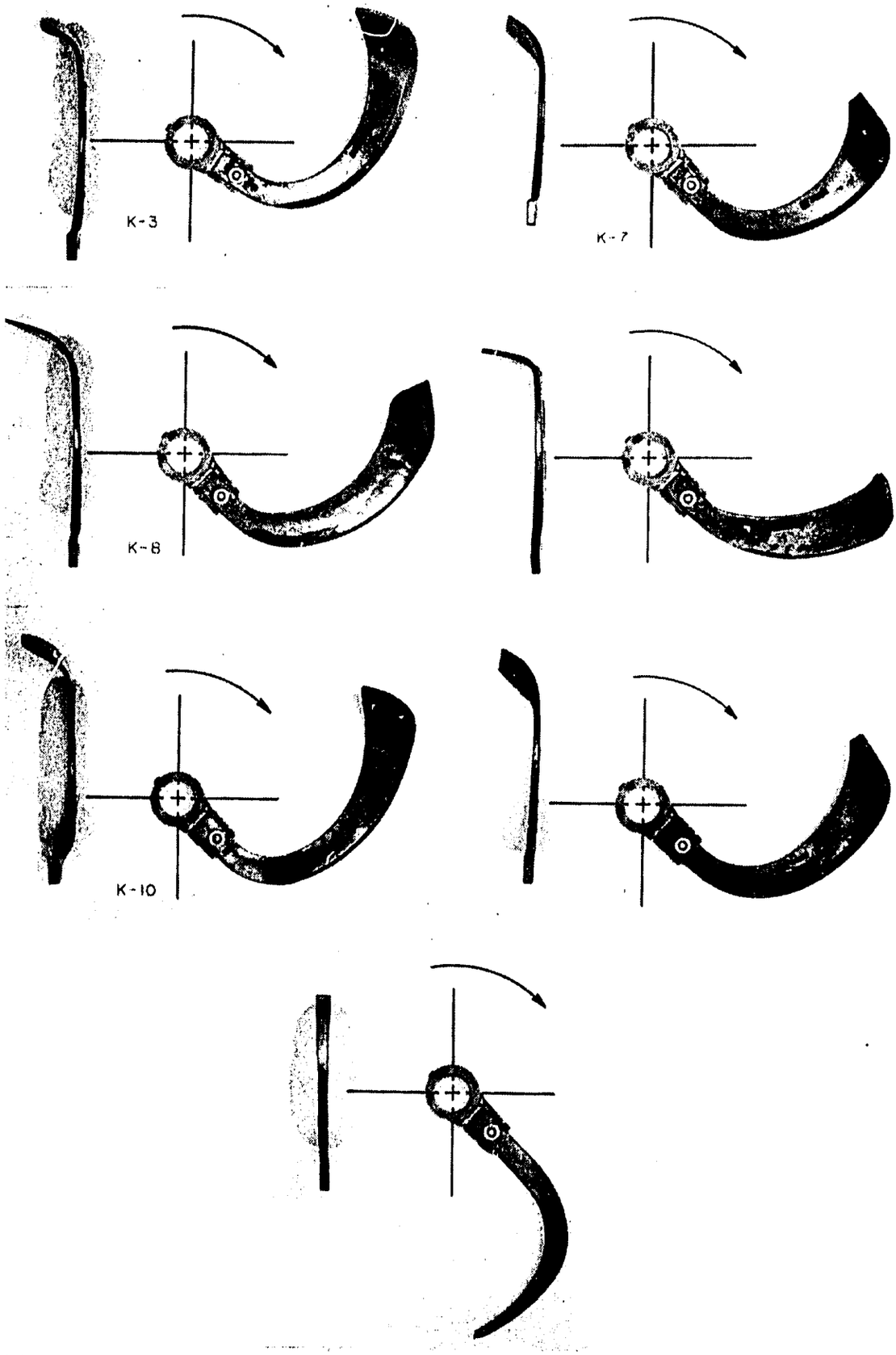
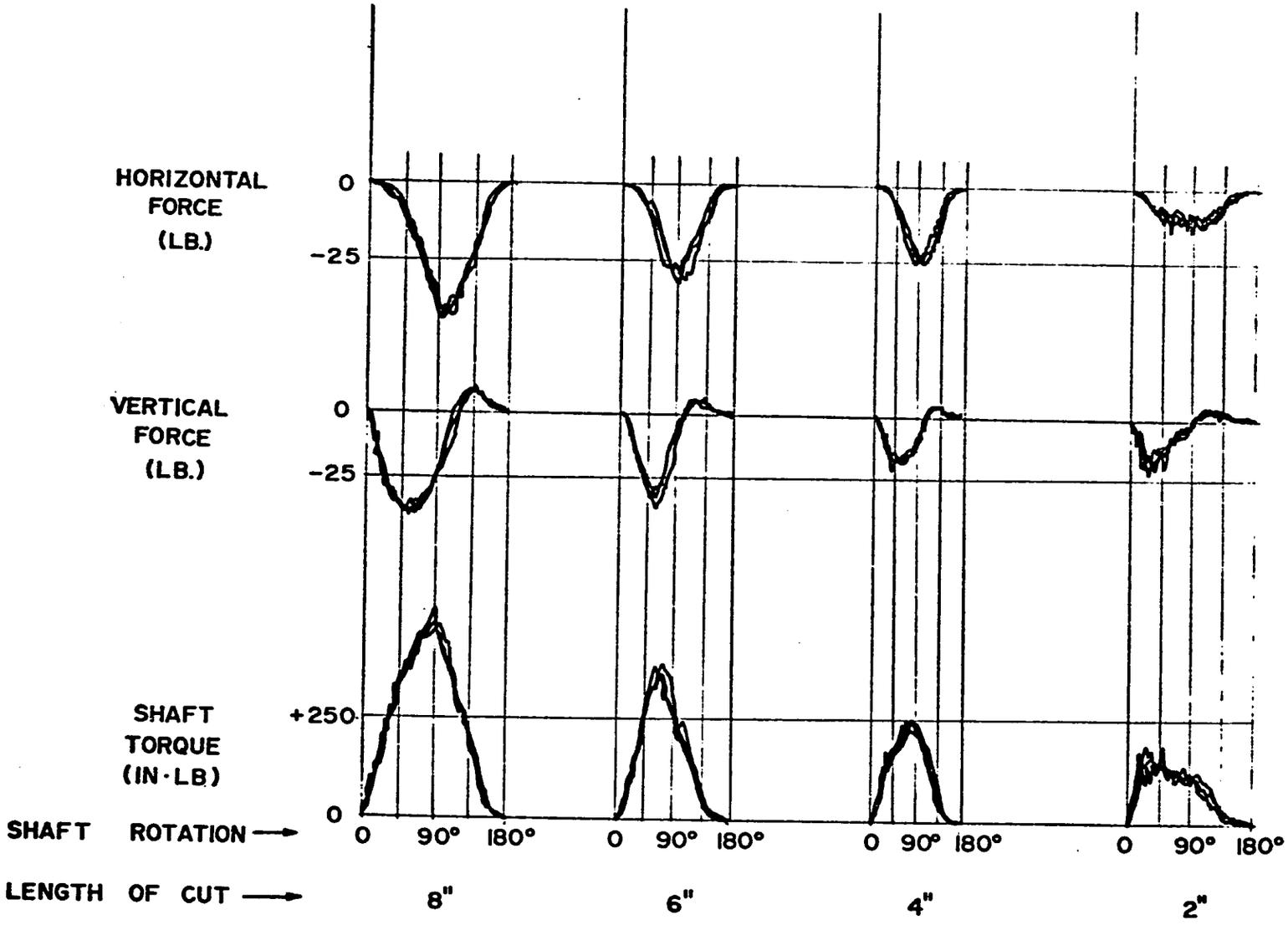
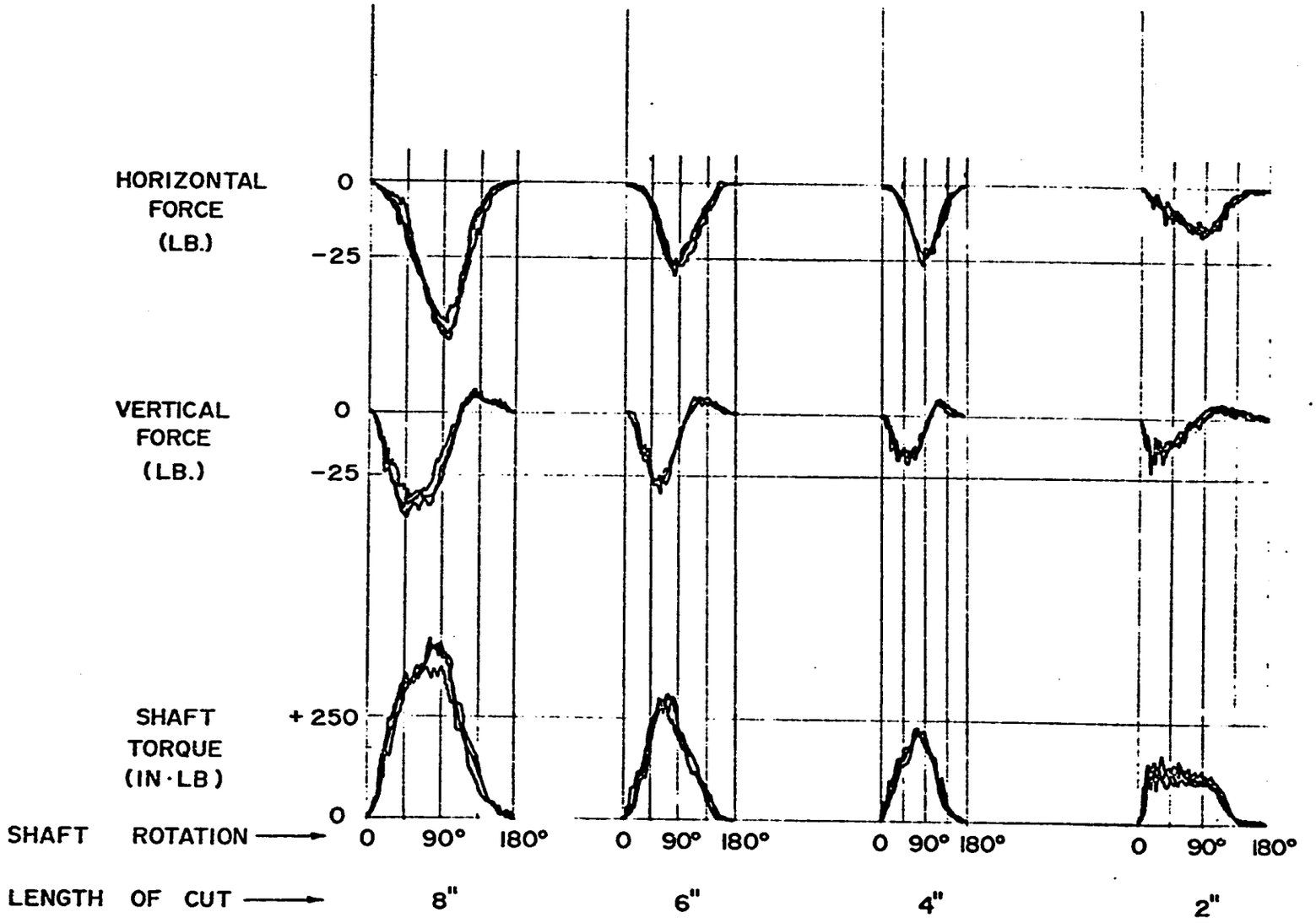


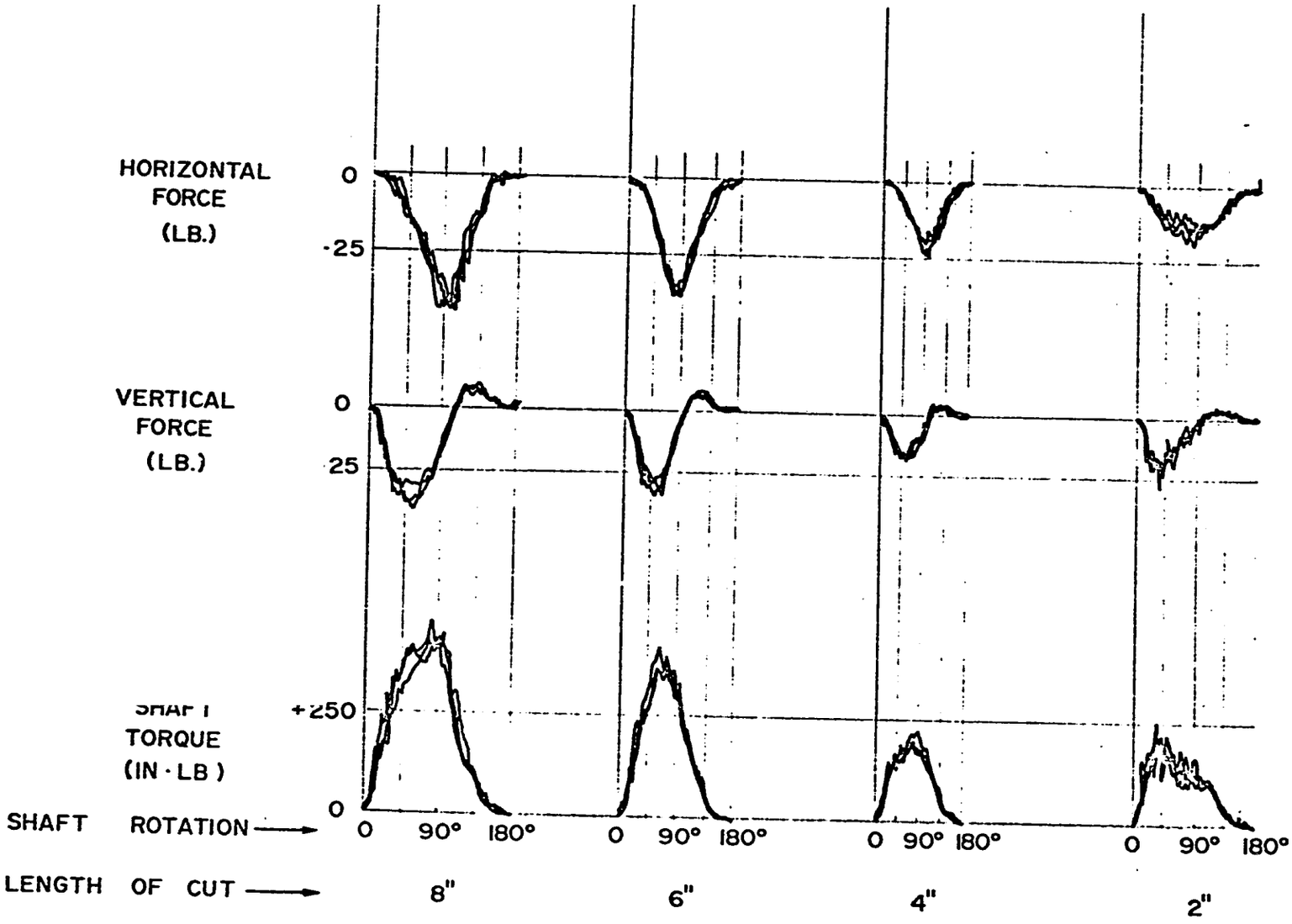
Fig. 3. The seven Japanese rotary tiller blades studied.
(NTML Photo No. A10, 188)



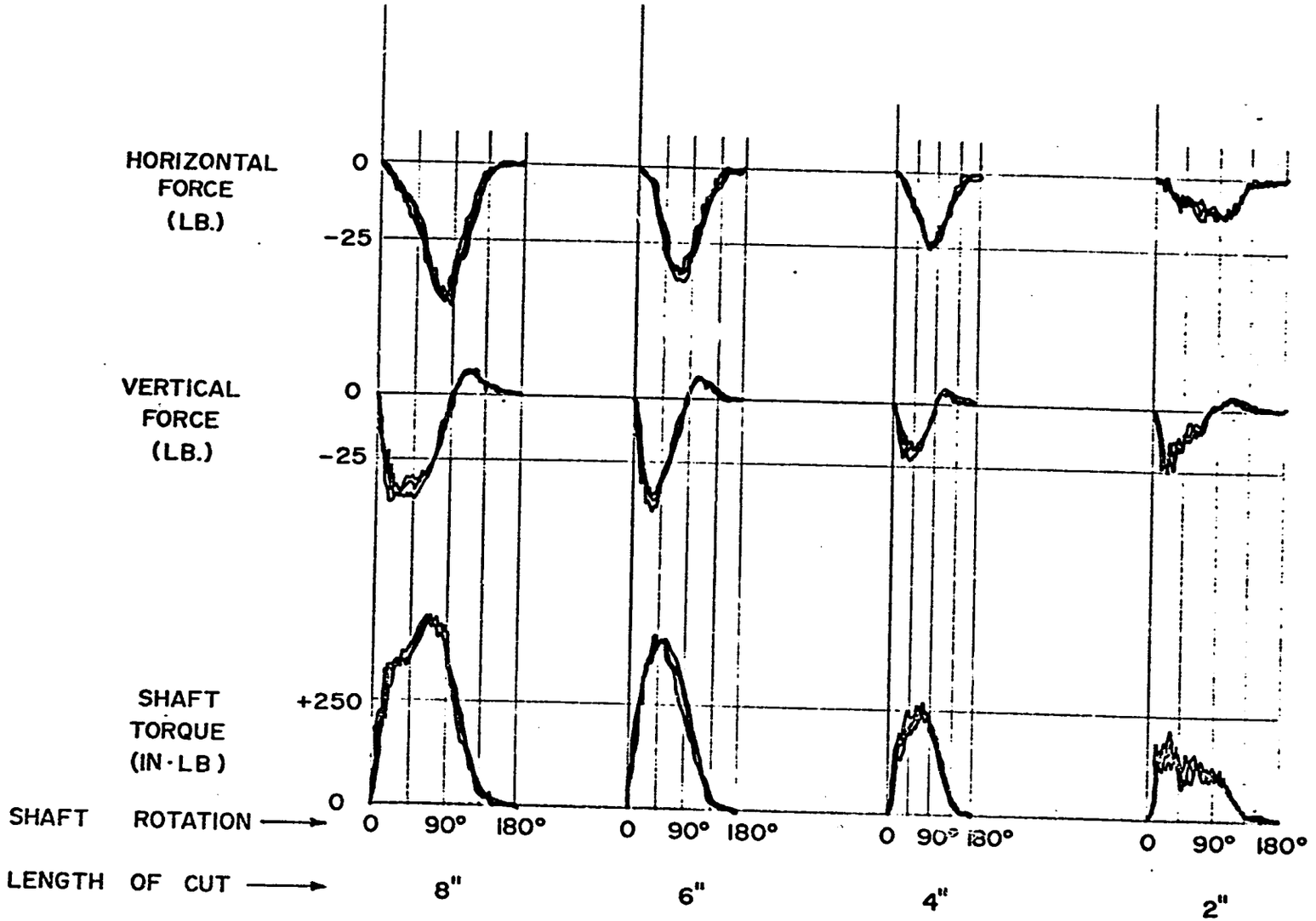
BLADE K-3
6" DEPTH
LLOYD CLAY



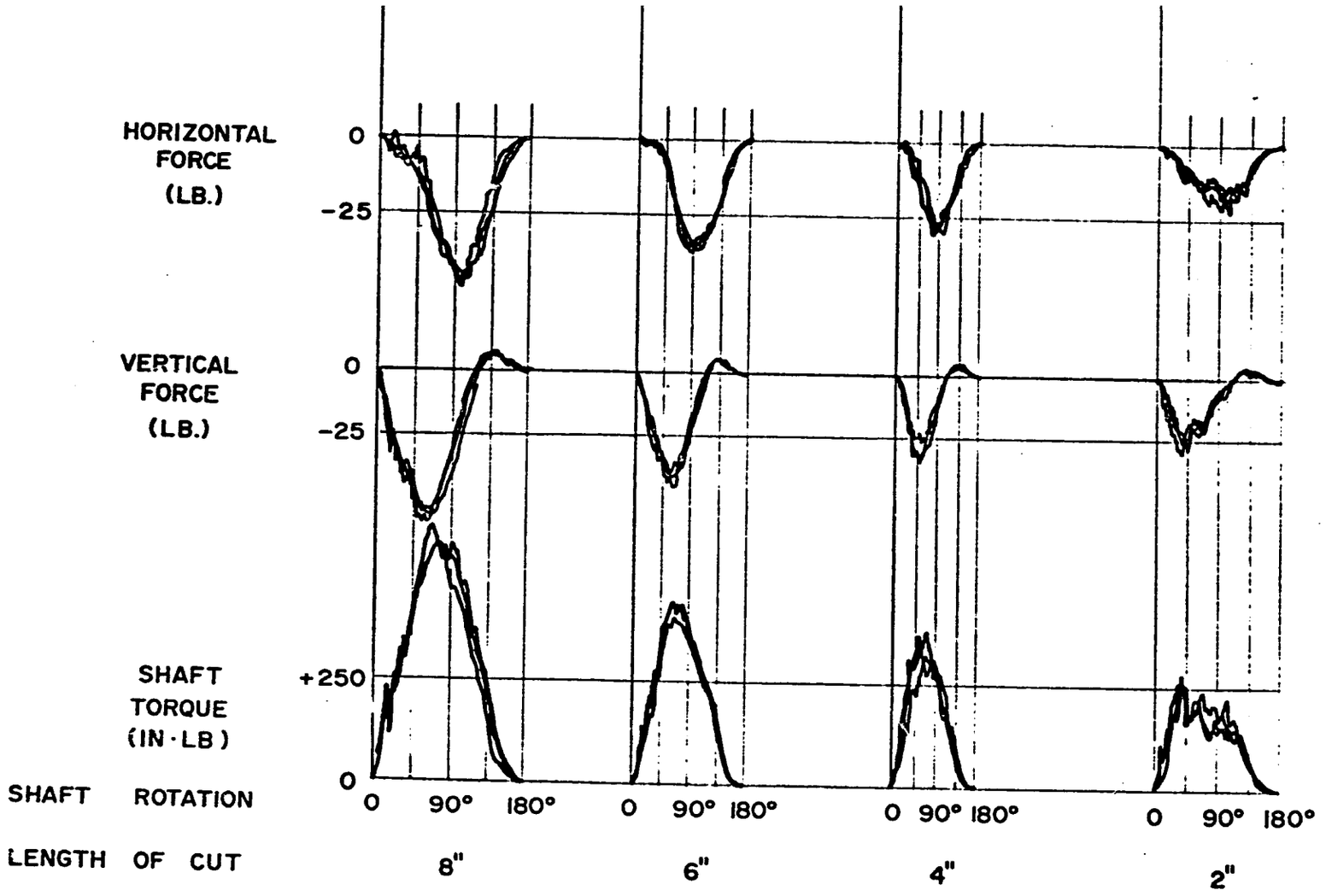
BLADE K-7
6" DEPTH
LLOYD CLAY



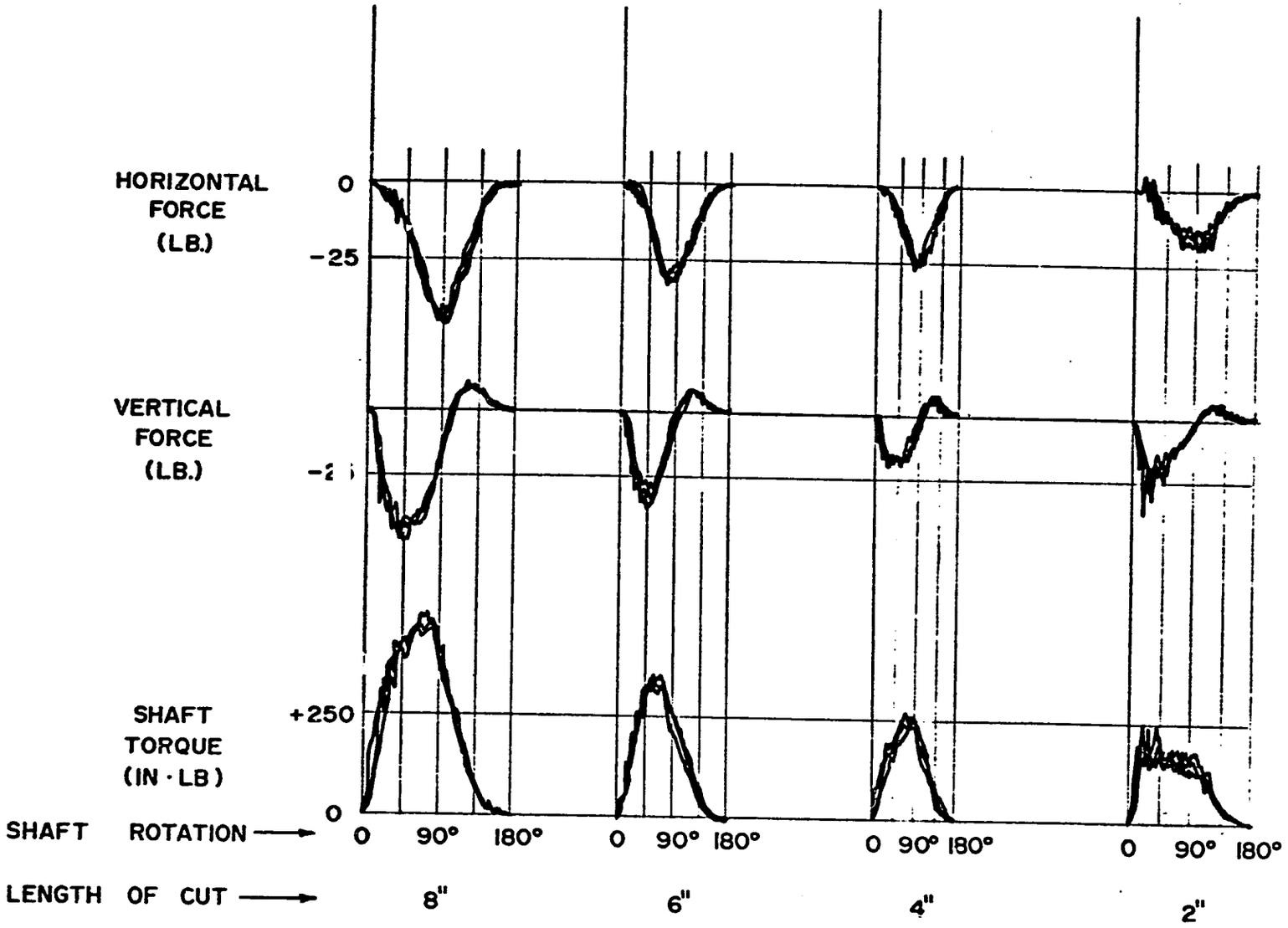
BLADE K-8
6" DEPTH
LLOYD CLAY



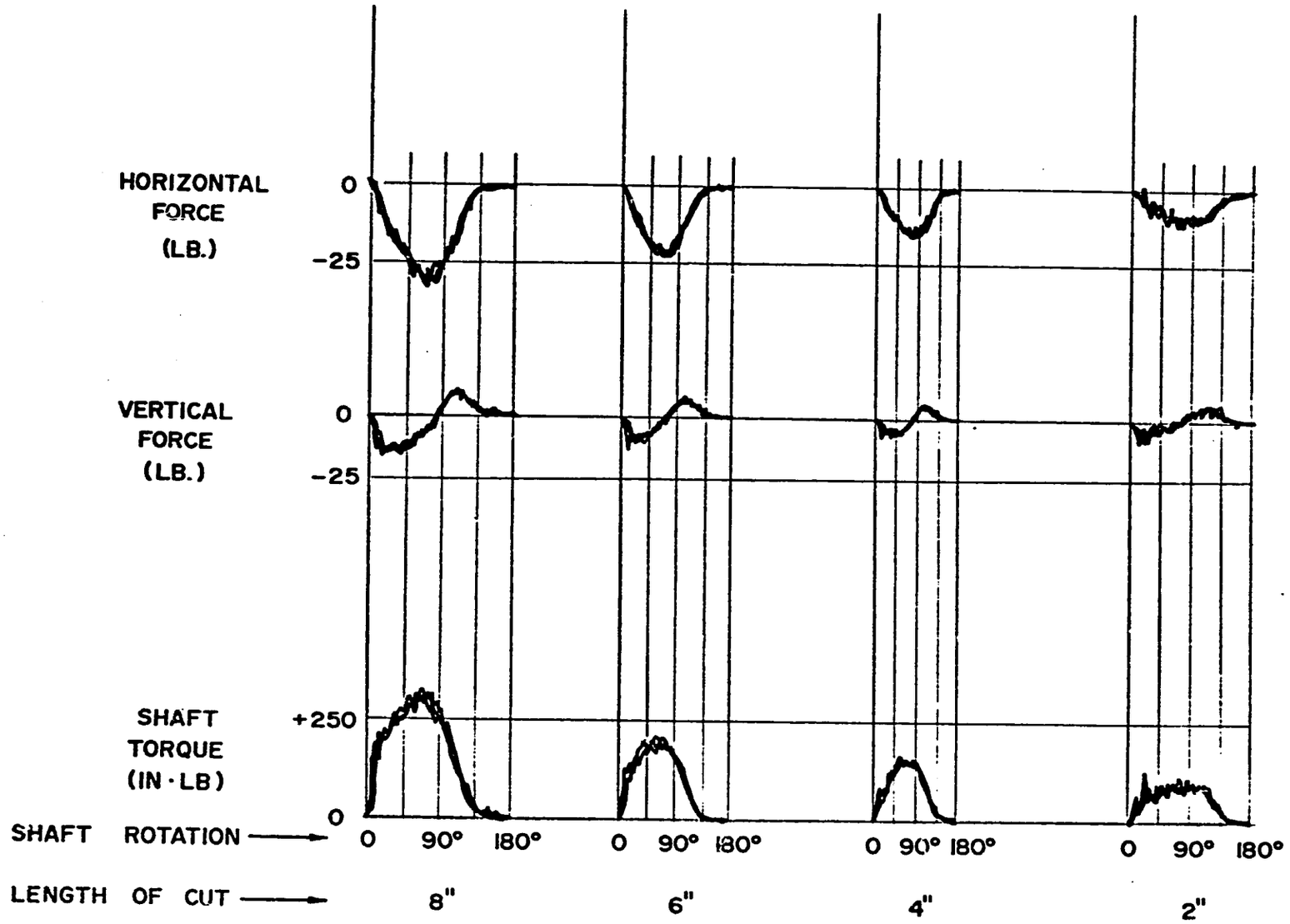
BLADE K-9
6" DEPTH
LLOYD CLAY



BLADE K-10
6" DEPTH
LLOYD CLAY



BLADE K-27
6" DEPTH
LLOYD CLAY



BLADE K-30
6" DEPTH
LLOYD CLAY

depths. This relation is:

$$\frac{\omega\sqrt{R}}{\sqrt{g}} = \alpha_1+\alpha_2 \frac{V}{\sqrt{gR}} \qquad \alpha_1 \text{ and } \alpha_2\text{: constant}$$

or

$$\frac{V}{\omega R} = \beta_1 + \beta_2 \frac{\sqrt{g}}{\omega\sqrt{R}} \qquad \beta_1 \text{ and } \beta_2\text{: constant}$$

$\frac{V}{\omega R} = \frac{L_B \cdot S}{2\pi R}$, with L_B: the slice length and S: the number of blades in one plane of a rotary tiller. The above result means:

a) there is an optimum slice length

<u>or</u> b) the volume of soil, cut by a blade every time, has an optimum size

<u>or</u> c) there is an optimum trachoid path of the cutting edge of the blade.

To solve between (a) and (b) tests at different depth and different width with the same geometrical size rotary tiller have to be performed. To decide between (c) and (a) or (b) tests with a different number of blades in a plane have to be done.

Tool design factors that are involved in the above tests are:

width of the blade,
radius of the blade,
number of blades in a plane.

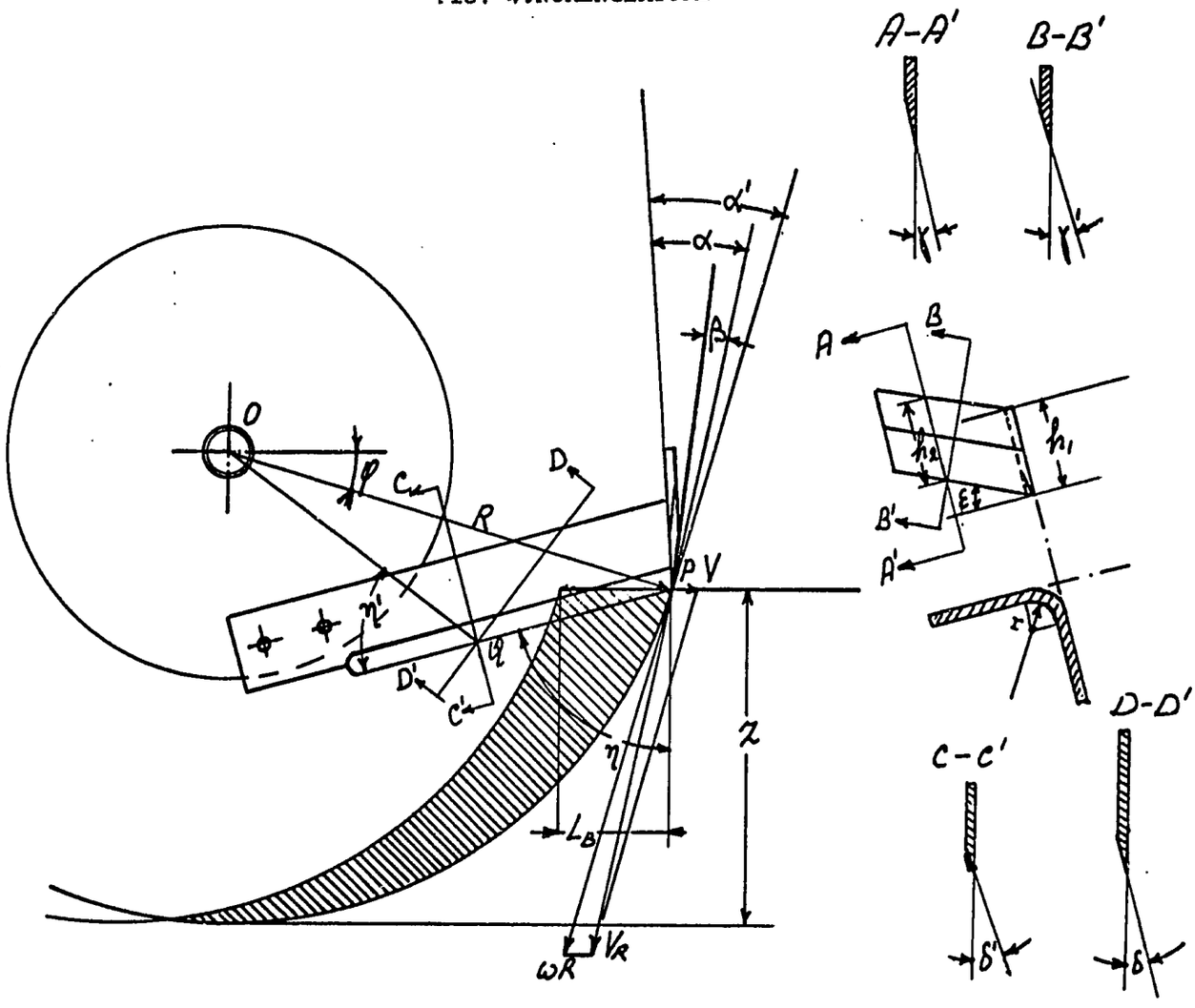
Other tool design factors that can influence the power requirements are:

the blade shank angle,
the blade share angle,
the cutting angle of the blade share,
the wedge angles of shank and share,
the clearance angle of the share,
the height of the shank,
the height of the share,
the sharpening directions of shank and share,
the radius of curvature of the blade.

(For nomenclature see Fig. 4.)

Some of these design factors are interrelated; some are dependent on the ratio of forward speed to rotational speed. Shank angle, share angle, wedge angle of shank, and wedge angle of share are closely [illegible]ated. If we define an apparent wedge angle as the construction [illegible]le of the wedge and an effective wedge angle as the wedge angle with which the soil is cut, then a shank angle of 90° means that the effective wedge angle of the shank equals the apparent wedge angle. A decreasing shank angle reduces the effective wedge angle and may result in a lower cutting force. The same applies to

FIG. 4:NOMENCLATURE



α = effective cutting angle

α' = apparent cutting angle

β = clearance angle

γ = effective wedge angle of share

γ' = apparent wedge angle of share

δ = effective wedge angle of shank in point Q

δ' = apparent wedge angle of shank

ε = share angle

η = shank angle in point P

η' = shank angle in point Q

ϕ = angle of rotation

h_1 = height of shank

h_2 = height of share

r = radius of curvature of blade

Z = depth of operation

L_B = slice length

V = forward speed

ωR = rotational speed

V_R = resultant speed

the share angle. Therefore, it seems logical to vary the angles of shank and share in the same test by the same amount and compare tests with different shank-share angles. With a straight blade a shank angle other than 90° causes also a different shank angle on different places of the shank edge. Some Japanese blades are curved so that the shank edge describes a logarithmic spiral for which the angle between radius vector and tangent vector is constant and thus also the effective wedge angle. Because only a small part of the shank usually does cutting work, we have a good approximation by using the shank angle on the tip of the shank as the design shank angle. (Note. A vector normal to the radius vector at a point of the shank edge is tangent to the trochoid path of the blade only in the case of zero forward speed and determines only in that case the direction of the cutting speed; the intersection of the blade shank and the plane through this tangent perpendicular to the shank determines therefore only approximately the effective wedge angle.)

The cutting angle, the clearance angle, the wedge angle, the sharpening direction, and the height of the share are five factors that are interrelated in their influence on the power requirement. The clearance angle should be larger than zero and a minimum wedge angle is required for strength of the blade; these together determine the minimum cutting angle. For minimum power we wish to get as close as possible to this minimum cutting angle. Söhne found (1956) for a wedge angle of 10° that the optimum cutting angle for minimum power and energy was about 20°. A minimum height of the share is required for rigidity of the blade; again we wish to get as close as possible to this minimum height to minimize power requirement. The height of the share is related with the sharpening direction. If sharpened as in the sketch the height can be larger than when sharpened on the other side, before the back edge of the share hits the soil. So for a minimum required height of the share the cutting angle can be smaller when sharpened as in the sketch.

The height of the shank we don't expect to be very critical as long as the shank is sharpened on the side as shown in the sketch and as long as there is clearance on the side of the shank that faces the hard soil. If there is no clearance torque and power can increase considerably with increasing shank height.

The radius of curvature of the blade, between shank and share, can cause an increase in power when this gets small. Söhne found that a radius larger than 1.2" didn't reduce the power requirement very much.

Literature has shown that rotary tillers have a much larger power requirement than most passive tillage implements. From the other side, active tillage implements like rotary tillers can make more efficient use of the available tractor power and can be driven by lighter tractors. When power availability of future engines is no limitation but power availability on the drawbar is limited by the maximum tolerable tractor weight, this means a definite advantage for active tillage implements. Power efficiency however has another

aspect too. Can we build an implement that requires less power, meets the weakly defined tillage requirements, and can use as efficiently the available power? Because of the basic minimum weight of a tractor for stability reasons we can interchange PTO and drawbar power to a certain degree without loss of efficency due to power transmission to the implement. Therefore we should look for combined tillage implements or for active tillage implements where part of the required PTO power is shifted to drawbar power, both forms, however, with a reduction on total power requirement. It is felt that rotary tillers require much power mainly because they try to move the soil in an unfavorable direction: down. We should combine the active and splicing rotary tiller working with the oblique soil movement of the plow. A preliminary study with a powered modified disk is therefore planned.

The large rotary tiller blade dynamometer is designed primarily to allow for testing different blade arrangements with blades in more than one plane and even a complete rotor unit. In addition this dynamometer should give more versatility in varying the geometry of the blades and should allow for similitude tests up to a rotor diameter of 28".

Fig. 5 is an overall view of the unit, which is mounted on the 3-dimensional dynamometer by means of the existing disk test unit, to make it possible to vary the angle of the rotary tiller shaft with respect to the direction of movement. This mounting was required for the disk test as shown in Fig. 6. The shaft here makes an angle of 45° with the direction of movement and a 20° angle with the vertical direction. The rotary tiller shaft is a hexagonal shaft, supported by two bearings and rigidly mounted on the gearbox with taper lock bushings. The connection between gearbox and hydraulic motor is flexible by means of an Oldham coupling. Between the gearbox and the hydraulic motor a magnetic speed pickup is mounted; between the gearbox and the shaft a magnetic switch is mounted to give a trigger signal for starting the torque integrating operation during analysis of the results with the analog computer.

On both ends of the shaft between the bearings strain gages are mounted to measure the torque on the rotary tiller shaft. By subtracting the torque values measured at these two places the torque produced by the tiller elements between the two bearings is obtained. On the free end of the rotary tiller shaft a slip ring assembly is mounted. The torque capacity of the rotary tiller shaft is 12,000 in.-lb.

A hexagonal shaft and flanges were chosen to allow for as many experimental blade arrangements as possible. Slotted holes were bored in the flanges to vary the shank angle. The whole construction is made so that a maximum depth of tillage is possible. The rotary tiller can drop downtill 3" below the center of the shaft, determined by the minimum size gearbox that could be obtained.

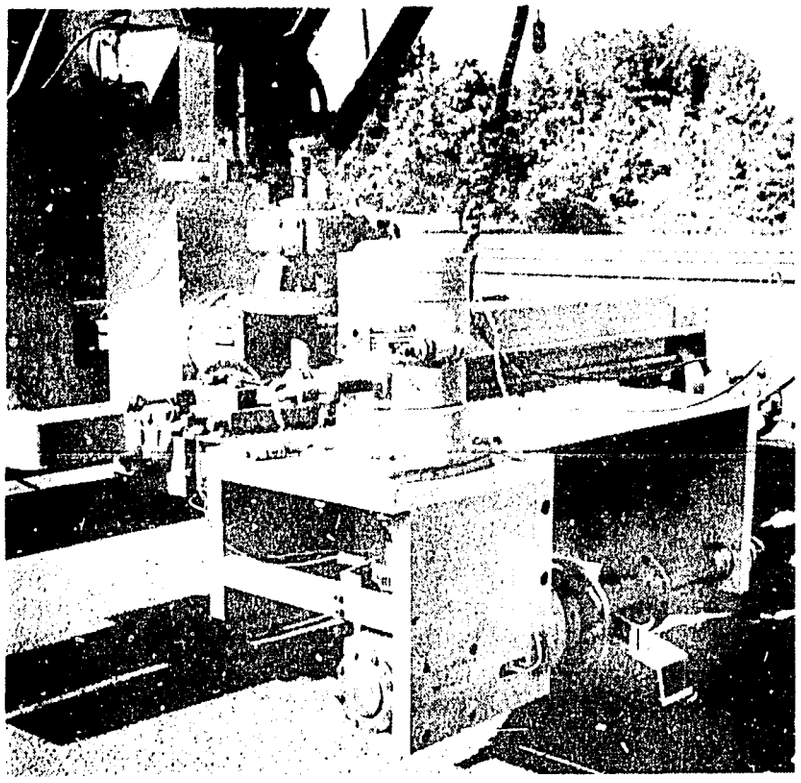


Fig. 5. Overall view of large rotary tiller blade dynamometer mounted on three dimensional dynamometer. (NTML Photo No. A10, 186[m])

Fig. 6. Large rotary tiller blade dynamometer mounted on disk test unit and three dimensional dynamometer. The disk test unit allowed the shaft to be set at an angle of 45° with respect to the direction of travel and 20° with respect to the vertical direction. The powered modified disk is mounted on the unit. (NTML Photo No. A10, 186[d])

Tests

The standard blade in this test series was the straight blade with 90°shank angle, 90°share angle, 30°cutting angle, 12" radius, and 4" width. All test series were done with varying forward and rotational speed. In every single test a forward speed was set and kept constant and the rotational speed was continuously varied from high to low.

1st test series: Influence of shank-share angle. Fig. 7 shows on the left the standard 90°angle blade, and on the right the 60°angle blade, also 4" wide and with a 30°cutting angle.

2nd test series: Influence of blade width: shank, 2", 4", and 6", Fig. 8.

3rd test series: Influence of number of blades in the plane: 1, 2, and 4 blade in a plane, Fig. 9.

4th test series: Influence of working depth: 2.5", 4.5", 6.5", and 8.5" deep. This test was done again with a standard blade and 2 blades in a plane.

5th test series: Influence of working depth with respect to different density of the soil. This was the same test as 4, but this time the bin was compacted with a flat tire to achieve a larger density.

6th test series: Different blade arrangements to decide on the best configuration in a full rotor assembly and to measure the difference in power requirement of outside and inside blades in a rotary tiller, Fig. 10.

7th test series: Powered modified disk, Fig. 6.

Every test series was completed in one soil bin preparation. Moisture content and density measurements were made. Penetrometer measurements were made after every bin preparation on different places in the bin to control the homogeneity of the soil condition and to compare different bin preparations. This comparison of different bin preparations is not essential for the test, but gives more information in view of replicability. Penetrometer measurements were also made to investigate if there occurs soil compaction by rotary tillage.

The current study of the influence of tool design differences was performed on unsaturated soil conditions. Plans are to repeat the same study on submerged soil conditions.

Additional components for the analog computer had to be ordered to make the necessary calculations to analyze this data.

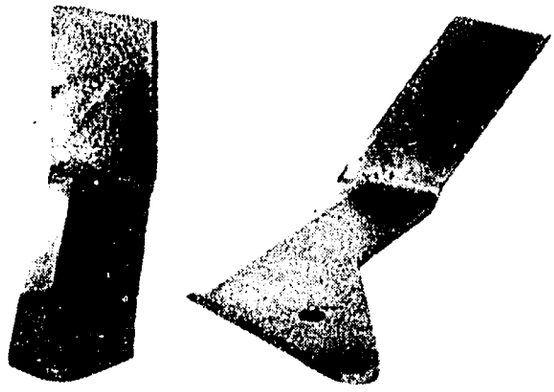


Fig. 7. Blades used to study the influence of shank-share angle; Left: standard 90° blade; Right: 60° angle. Both are 4 inches wide with 30° cutting angle. (NTML Photo No. A10, 187[h])

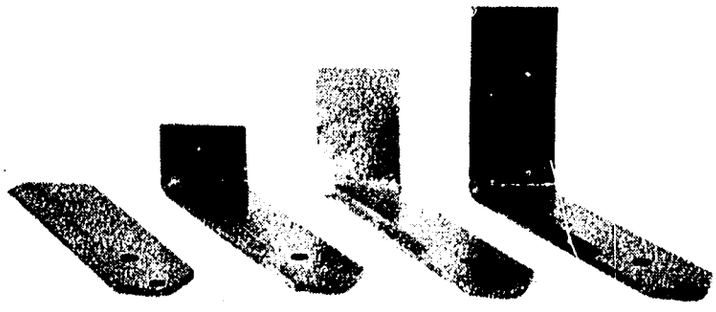
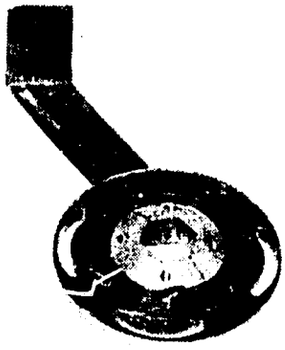


Fig. 8. Blades used to study the influence of blade width. Left to right: shank, 2-inch, 4-inch, and 6-inch blades. (NTML Photo No. A10, 187[i])



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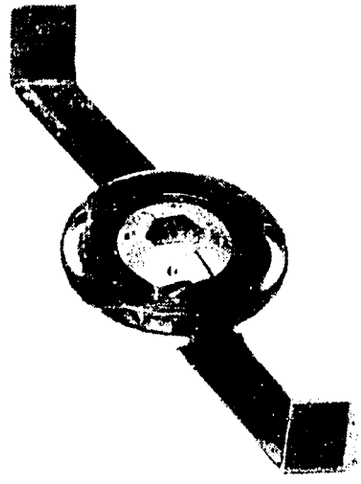

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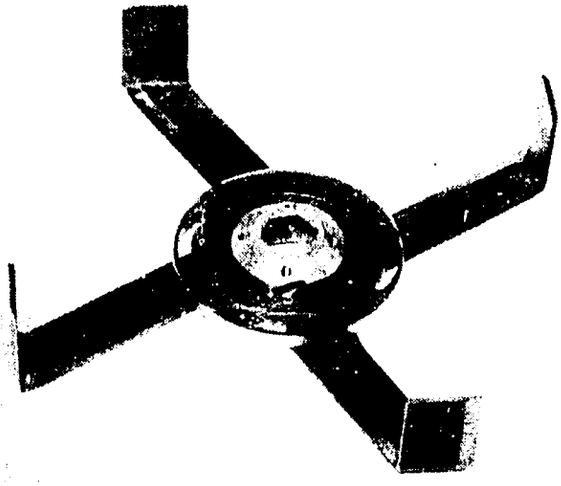

NTML Photo No. A10, 187[d]

Fig. 9. Blade arrangements used to study the influence of number of blades in the plane: one, two, and four blades in a plane.

NTML Photo No. A10, 187[e]

NTML Photo No. A10, 187[f]

Fig. 10. Blades used to study different blade arrangements. Four arrangements as shown, a, b, c and d, to decide on the best configuration on a full rotary tiller assembly and to measure the differences in power requirement of outside and inside rotary blades in a rotary tiller.

Power Tiller Wheel Studies

Introduction

The main problem of power tillers running in paddy fields with soil moisture contents near saturation is the high sinkage of the traction devices. High sinkage results in high power loss, due to high rolling resistance, and a low thrust force generating capacity. In order to carry out a detailed study to examine this basic problem, a special small wheel test unit was designed and built (Fig. 1). The unit includes a pair of two dimensional dynamometers (500 lb. vertical and 250 lb. horizontal) for measuring vertical and horizontal forces and a torquemeter for measuring moment (10,000 in.-lb.), a wheel speed pick-up device for recording speed and slippage and a potentiometer for recording the wheel sinkage. The unit is powered by a 5 hp variable speed motor with a specially designed remote control. The details of the design were attached to substantive report No. 1. This includes a summary of a preliminary theoretical study for analyzing the problem and a study plan which is scheduled for this summer and fall.

Theoretical Analysis

Since the rolling resistance, thrust force, and bearing capacity are not directly measurable quantities, a prediction mechanics is needed. Chang and Cooper (1) developed a mechanics, part of which may be applicable in this analysis. The possible mechanics to be adapted in this analysis are stated below:

A. Power Equilibrium and Power Loss in the Case of Pulling Work (1)* (Fig. 1)

The power equilibrium with rolling angle θ is

$$T\omega = + T\omega \cos^2\theta + PV + W \tan\theta \qquad (1)$$

in which

T = input torque on the wheel shaft
ω = angular velocity of the wheel shaft
θ = rolling angle
S = travel reduction
P = drawbar pull
V = forward velocity
W = dynamic weight
$T\omega$ = input power
$T\omega \cos^2\theta\, S$ = slip loss
$W \tan\theta\, V$ = rolling resistance loss.

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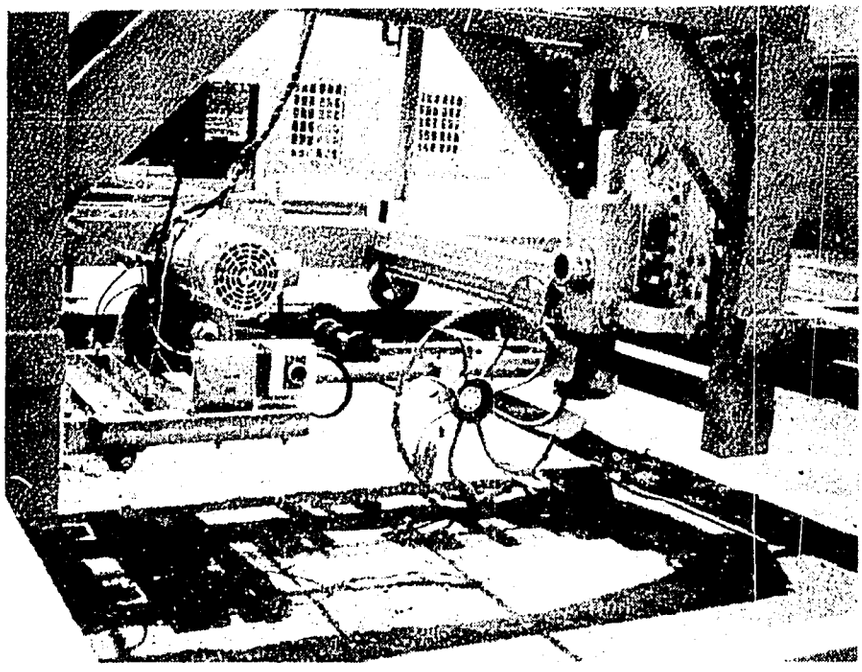
* Refers to references.



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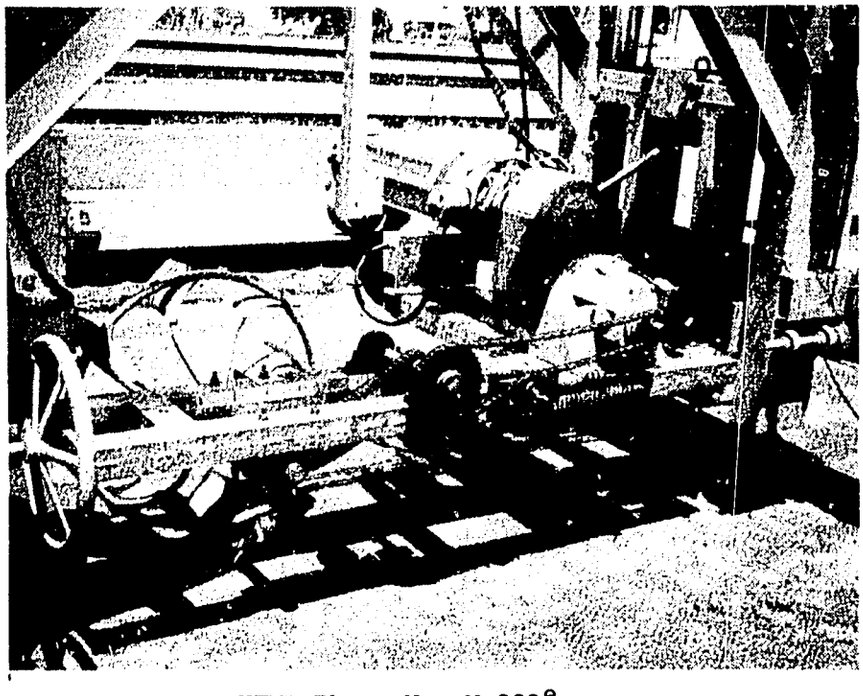

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Fig. 1. Test unit for small wheels.

Rolling Resistance (R_h)

$$R_h = W \tan \theta - \frac{F_h}{(1 - S)} \tan^2\theta. \qquad (2)$$

F_h, the thrust force, can be obtained as follows:

$$F_h = P + W \tan \theta - \frac{T}{r} \sin^2\theta \qquad (3)$$

$$r = \frac{V}{\omega}.$$

B. Rotary Tiller Operation

The wheel input thrust force (P_t) from the rotor is negative. The mechanics needs to be developed and studied.

C. Bearing Capacity

The basic equation of bearing pressure (P_b) first introduced by Bernstein (2) may be used as below

$$P_b = KZ^n \qquad (4)$$

in which Z is the sinkage and K and n are constants and P_b is unit pressure. P_b, Z in equation (4) generally are measured by a flat plate. As we know, any soil strength measured by a device is a function of both soil and device. However, in order to predict a bearing capacity of a special wheel the following equation will be considered

$$P_b = KZ^n = \frac{W}{A} \qquad (5)$$

in which Z is the mean depth of sinkage and A is the wheel projected area.

$$Z = \frac{C}{2Z_o} \int_{Z_o}^{r} \sqrt{R^2 - y^2}\, dy \qquad (6)$$

in which R is the wheel radius, and Z_o is the measured sinkage based on the center vertical axis. C is some

kind of reduction factor which should be studied. K and n should be varied with different wheel construction or device under various soil conditions. Some related work (3), (4), (5), has been referenced. The bearing capacity predicted in this way still has problems. Further study is needed.

References

1. Cheu-shang Chang and A. W. Cooper, A Study of the Mechanics of Tractor Wheels. ASAE Paper No. 68-131, June 1968.

2. William R. Gill and G. E. Vanden Berg, Soil Dynamics in Tillage and Traction. Agriculture Handbook No. 316, U. S. Department of Agriculture, 1967.

3. E. T. Vincent, Pressure Distribution on and Flows of San Past a Rigid Wheel. First International Conference on the Mechanics of Soil-Vehicle Systems, 1962.

4. S. Masuda, T. Tanaka, Tractive Performances of Wheel-Type Tractor (VI) Theoretical Analysis of Stress Distribution on the Lug Surface by the Soil. Journal of the Society of Agricultural Machinery, Japan, Vol. 26, No. 1, June 1964.

5. M. Kisu, U. Kohada, S. Yagi, K. Seyama, Studies on Trafficability: Tractive and Rotary Tilling Performance of Tractor. Institute of Agricultural Machinery, September 1966.

Test Plan

Objective:

Determine performance of the 8 types of steel lugged wheels on hand.

Performance factors will include: drawbar force vs slip, power efficiency vs slip, and possibly others. A range of vertical loads for each soil condition will be used and the effect of sinkage on each performance factor will be studied.

Measurements:

Wheels: Rim diameter, number of lugs, lug geometry.

Soil: Soil Type, moisture content, bulk density, penetrometer resistance, depth of hard pan, bulk density of hard pan.

Test: Torque, pull, vertical load, sinkage velocity of vehicle, angular velocity of wheel.

Data Reduction:

Slip (or travel reduction) will be calculated from forward velocity (V) ft/sec and angular rotation (ω) rad/sec by the formula:

$$\text{Slip} = \frac{\omega - aV}{\omega}$$

where a is a constant determined by wheel diameter and scale factor.

Power efficiency (%) will be calculated by the formula:

$$PE = \frac{PV}{T\omega}$$

where P is pull (lbs.) and T is torque (ft.-lbs.).

Pull will be plotted vs slip or coefficient of traction vs slip.

Power efficiency will be plotted vs slip. Sinkage will be plotted vs various factors seeking a correlation.

Range of Variables: (For Programming)

Soils: High clay content to high sand content; flooded soil to 40% moisture.

Wheels: Eight wheels as furnished.

Test: Vertical load: 100 - 400 lbs.
Pull: - 150 lbs. to + 150 lbs.
Slip: - 20% to + 70%.
Velocity: .4 m/sec to .8 m/sec.

Analysis:

The data will be searched for a correlation between wheel geometry and wheel performance. If general relations can't be found then interpretations will be sought for the various interactions with soil conditions and/or other system parameters.