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9. ABSTRACT
The objective of the IRRI rice equipment development program is to increase the income and welfare of small rice farmers by increased yields, removal of resource constraints, reductions in field and post-production losses, increased cropping intensity, and improvements in the quality and value of agricultural products. The IRRI design and development projects conducted during this reporting period consisted of eleven concerned with field machinery: steering clutches for a 5- to 7-hp tiller, an 8- to 14-hp tiller, a small four-wheel riding tractor, a deep-placement liquid injector, a deep-placement granule applicator, water jet pumps for lowlift applications, a tubular pump, a vertical-axle windmill, modifications to an axial-flow thresher, and a stripper harvester. Two other development projects concerned a solar heat collector for an IRRI grain dryer and improvements to a milling machine. Four projects involving mechanization research were concerned with a comparative evaluation of different threshers in the Philippines, compacted soil studies, an engineering training course, and a mechanization workshop. Work on mechanization systems was conducted in five subject areas: mechanizing upland cropping operations, cost budgets, farm-level rice post-production systems, marketable surplus, and mill-level rice post-production systems. With the expanded IRRI activities and worldwide interest in the manufacture of IRRI-developed machines, the machinery design program has been organized along more formal lines. The new organizational structure will permit better screening and evaluation of new projects, and will result in better feedback from end-users and manufacturers of the machines.

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RICE MACHINERY DEVELOPMENT AND MECHANIZATION RESEARCH

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THE IRRI RICE EQUIPMENT DEVELOPMENT PROGRAM

The objective of the equipment development program is to increase the income and welfare of small rice farmers. Use of improved mechanical technologies contribute directly to this goal by increasing production through a) increased yields, b) removal of resource constraints, c) reductions in field and post-production losses, d) increased cropping intensity, and e) improvements in the quality and value of agricultural products. Appropriate machines can also reduce production costs -- a direct benefit to the rice consumer. Mechanization based on local production reduces foreign exchange costs, creates expanded opportunities in rural based industries, strengthens backward linkages between agriculture and other sectors of the economy and enhances training opportunities in small-scale manufacturing.

In developing machines to meet these objectives, two major conditions must be met. First, designs must be compatible with the technical and economic needs of small farmers who will use them. Secondly, the manufacture and servicing of the machines must be within the technical capabilities of indigenous small and medium-scale machine shops. IRRI provides design information and limited technical support free of cost to qualified commercial manufacturers.

The main research and development effort is centered at the International Rice Research Institute in the Philippines with national liaison links throughout Asia, Latin America, and Africa. Reports describing program activities are issued semi-annually. Copies of these reports and a bibliography listing other departmental publications are available upon request.

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Summary and Introduction

Many versions of the basic IRRI axial flow thresher have been made by the manufacturers to suit different functional and production requirements. Efforts were made to further improve the design and develop simpler versions to meet the varying threshing requirements. A company in India has successfully converted the IRRI axial flow thresher for wheat and this has substantially expanded the market for such a machine to countries with both wet as well as dryland agriculture. A self-propelled axial flow thresher, which consists of two basic machines -- a thresher and a self-propelled cart -- was developed. The self-propelled machine offers many advantages for contract threshing operations since the machine must be moved often from one location to another.

Work on the development of paddy root-zone applicators for granular and liquid chemicals was continued. A single-row granular applicator is being field-tested in the Philippines before its release to manufacturers. Further work is being continued on this important problem and many different concepts are being evaluated to find a satisfactory low-cost machine. Technical assistance was provided to two companies in the Philippines who are now fabricating the 8- to 12-hp power tiller.

Work was continued on evaluating the effects of different land preparation equipment on the level of soil hard pan under wetland conditions. Present data indicate that the use of animals and lightweight power tillers does not deepen the hard pan after the third cropping season. Use of larger power tillers and four-wheel tractors indicates continued deepening of the hard pan in this ongoing study. Study on comparative evaluation of commercially available threshers was continued. The performance of the McCormick threshers, which are popularly used for contract threshing in Central Luzon, Philippines, was evaluated. These machines demonstrated an output of 2.7 t/h, with an average threshing loss of 4.1 percent.

The Institute organized an International Workshop on Agricultural Mechanization and Indigenous Production of Agricultural Machines from May 6 to 9, 1975. Sixty participants from 19 countries in Asia, Africa, Europe, and America participated. The workshop generated much interest in production of IRRI-designed machines and helped in the exchange of ideas and recent developments related to this problem. With increasing manufacturers' interest, a formal two-week course was initiated to train engineers from developing countries in the use and manufacture of IRRI-developed machines. Seven engineers from five countries attended the first short course which is now planned to be offered every six months.

Since its inception, the machinery development program has been funded at IRRI under a research contract with the Technical Assistance Bureau of the USAID/Washington. Many of the machines developed under this program have achieved considerable commercial success in the Philippines. Because of the program's location in the Philippines, it was not too difficult to generate interest among local manufacturers and production of these machines is moving very well. The machinery development part of the program at the Institute has matured to a level that new machines are being regularly developed to meet a broad range of farming needs in the developing countries. Efforts to extend this technology to countries other than the Philippines have, however, been relatively limited and commercialization has not progressed as fast. The success achieved in commercializing the machines in the Philippines indicates a potential for introduction of this type of mechanization technology to other tropical countries with similar agroclimatic areas.

Recognizing this need for increased commercialization efforts, the TAB/USAID agreed to support an Industrial Extension Contract with the Institute. Effective January 1975, the main program of machinery development was absorbed into the Institute's core budget. The new USAID/IRRI Industrial Extension Contract will be operative in July 1975 and will focus on extending the new machinery designs to manufacturers worldwide. Under the industrial extension program, an industrial liaison engineer will be added to the core program at IRRI to backstop the industrial extension efforts worldwide. Engineering teams will be responsible for evaluating and adapting the IRRI-developed machines to local conditions and will provide a feedback to the core program at IRRI so more appropriate machines could be developed. The program's ongoing industrial extension efforts in the other countries through cooperating organizations will continue under the subcontract arrangement.

In the past new machinery design projects were primarily initiated on the basis of a personal assessment of the project leader. With the expanded activities and the worldwide interest in the manufacture of the IRRI-developed machines, the program has now been organized along more formal lines as shown in fig. 1. The new organizational structure will permit better screening and evaluation of new projects prior to their initiation and will help to increase the program's productivity. It will also result in better feedback from the end-users and manufacturers of the machines to the machinery design team at the Institute and will help to expand indigenous production worldwide. The reorganized program has four major sections: (1) machinery design, (2) machinery utilization, (3) machinery manufacture, and (4) mechanization systems. The primary responsibilities of each section, as indicated in fig. 1, are complementary along functional lines.

During the 1974 Center Week Meeting in Washington, the Consultative Group on International Agricultural Research (CGIAR), donors of IRRI, had raised some doubts about the desirability of incorporating the machinery development program in the IRRI core budget. A Technical Advisory Committee of the CGIAR reviewed this program and made appropriate recommendations for its absorption in the IRRI core budget. The team was composed of the following members: Mr. B.P. Pothecary, FAO Consultant in Agricultural Engineering and Land Development, Colchester, England; Mr. C.G.E. Downing, Director, Agricultural Engineering Research Service, Department of Agriculture, Ottawa, Canada; Dr. Lee Kum Tatt, Chairman, Singapore Institute of Standards and Industrial Research, Singapore; Mr. W.J. van Gilst, Agricultural Engineer, Agricultural Services Division, FAO, and Dr. B.N. Webster, Deputy Executive Secretary, TAC Secretariat, FAO. The program was extensively reviewed at IRRI before the team visited the cooperating subcontractor organizations and manufacturers of IRRI machines in the Philippines, Thailand, Indonesia, Sri Lanka and India.

Dr. C.C. Lee, Visiting Associate Agricultural Engineer, left the Institute to join the Asian Development Bank, Manila, after spending one year with this program, during which he was engaged on rice milling studies.

Mr. Don Kuether joined the program as Associate Agricultural Engineer and will be responsible for the machinery utilization section. He was previously associated with the Allis Chalmers Co. in the U.S. for 15 years and is a valuable addition to the program's staff.

Mr. Consorcio Padolina, Senior Research Assistant, took up an assignment in Papua New Guinea with the Department of Agriculture and Fisheries and hopes to help in the introduction of the IRRI-developed machines in that country.

The program's leader, Dr. A.U. Khan, spent one month in the People's Republic of China as a member of the National Academy of Sciences Delegation on Rural Small-Scale Industries. The delegation visited many agricultural machinery manufacturing establishments in China and was impressed with the progress made on the local production of a wide range of farm implements to support Chinese agriculture.

PROGRESS REPORT NO. 20
JANUARY 1 TO JUNE 30, 1975

The following projects were undertaken during the reporting period:

Design and Development

Field machinery

1. Steering clutches for 5- to 7-hp tiller	S. Gutierrez
2. 8- to 14-hp tiller	S. Gutierrez
3. Small four-wheel riding tractor	G. Espiritu, A. Khan
4. Deep-placement liquid injector	N. Navasero
5. Deep-placement granule applicator	N. Navasero
6. Water jet pumps for lowlift applications	J. Samuel
7. Tubular pump	G. Salazar, A. Khan
8. Vertical-axis windmill	G. Salazar, M. Khan
9. Axial flow thresher modifications	J. Policarpio, A. Khan
10. PTO thresher	J. Policarpio, A. Khan
11. Stripper harvester	G. Espiritu, A. Khan

Drying and processing

12. Solar heat collector for IRRI grain dryer	N. Navasero
13. Milling machine improvements	J. Arboleda, C.C. Lee

Mechanization Research

14. Comparative evaluation of different threshers in the Philippines	B. Ramos
15. Compacted soil studies	C. Padolina
16. Engineering training course	C. Padolina, D. Kuether
17. Mechanization workshop	

Mechanization Systems

18. Mechanizing upland cropping operations	E. Escover, G. Villaruel
19. Cost budgets	C. Maranan
20. Farm level rice post-production systems	Z. Toquero
21. Marketable surplus	Z. Toquero

Design and Development

Field machinery

Steering clutches for 5- to 7-hp tiller

The IRRI 5- to 7-hp tiller has a single hexagonal axle on which the two wheels are mounted. Farmers have experienced difficulty in turning the power tiller in the field and have indicated a desire for steering clutches to facilitate field operations. An externally mounted steering clutch (fig. 2) was designed for installation on tillers which are already with the farmers. The clutch was operated in a completely submerged condition and clogging with mud was encountered which prevented proper functioning.

A totally enclosed steering clutch was designed (fig. 3) which was lighter and more compact. The original hexagonal axle was machined to 2.85-cm diameter at both ends to fit the cage wheel hubs. The hubs had four drive-engaging jaws on one end and a flange for attaching the cage wheel. The drive-engaging sleeves of the clutch were designed to slide on the hexagonal axle. The clutch sleeve is normally maintained in the engaged position through spring pressure. Cam-actuated forks were used for disengaging the clutch sleeves. Trials indicated that this steering clutch was still difficult to disengage under loaded condition. The large contact area between the clutch sleeves and the hexagonal axle and the high axle torque do not permit easy disengagement and smooth movement of the drive-engaging sleeve.

The hexagonal sliding arrangement was subsequently replaced with a six-spline sliding arrangement (fig. 4) to provide easier clutch disengagement. Preliminary tests indicate that the clutch disengagement force is still high. Most Japanese power tillers have steering clutch mechanisms on intermediate shafts which are operating at high speeds and lesser torques than the axle. An easy-disengaging driving clutch on the final axle is preferred for it can be incorporated by manufacturers in their existing power tillers with minimum changes in the basic design. Continued efforts are being made to develop easy-disengaging steering clutches on the main axle shaft.

8- to 14-hp tiller

Large power tillers of 8- to 14-hp size are being imported in many rice-producing countries. In the Philippines these tillers are being marketed at very high prices ranging from $2500 to $3500. The high price results in a small market which does not permit the development of adequate spare parts and service facilities. To meet the growing need of the medium-sized farmers, the development of a low-cost 8- to 14-hp tiller was initiated. The IRRI 8- to 14-hp tiller was designed to make use of locally available materials and standard machine components. A prototype unit was fabricated and was tested at the Institute. During the testing and evaluation phase, many modifications and improvements were made on the transmission, steering clutches, and the rotovator drive assembly. The design was released to some companies in the Philippines for trial production.

Two Philippine companies, GAMI Industries, Valenzuela, Bulacan, and IMAG Manufacturing Division of Zuellig, Inc., Quezon City, are now fabricating their prototype machines. Frequent contacts are being maintained, through personal visits by the department engineering staff, with these two companies to provide technical assistance in the fabrication of the production prototype machine. These manufacturers' power tillers will be evaluated by the Institute prior to their regular production.

Small riding tractor

Earlier work on the development of a low-cost 15- to 20-hp four-wheel riding tractor was described in the semiannual report No. 19. The small riding tractors originating from the industrialized countries are scaled-down versions of larger tractors and are too expensive for developing countries. During the last year, machine shops in Thailand have started the production of some rather heavy, crudely designed riding tractors. These tractors are sufficiently low in price and are finding a good market among Thai farmers. Many farmers and some manufacturers in the Philippines have indicated a need for a low-cost 15- to 20-hp riding tractor.

Test and modification activities on the Economy tractor have been completed. The modified Economy tractor was tested in one experimental field at the Institute under lowland conditions for three continuous cropping seasons. The machine did not encounter any mobility problems and soil penetration readings did not indicate any deepening of the soil hard pan in the field due to continuous use of this tractor. Comparative tests in an adjoining field with a larger four-wheel tractor indicated considerable deterioration of the soil hard pan.

On the basis of the experience gained with the Economy tractor on wetland fields, the following specifications were established for a small riding tractor for wetland cultivation work:

1. The weight of the small tractor must be kept low to minimize the power lost in overcoming rolling resistance in wetland fields. This will provide

more power to the tillage implement and result in more efficient power use. A tractor weight of about 500 kg is desirable.

2. The tractor should be designed to meet the requirements for dryland agriculture by the attachment of low-cost concrete or cast iron weights to permit its use with traction-dependent implements.

3. Maximum use of standard off-the-shelf components must be made in the design to facilitate local manufacture.

4. A diesel engine is desirable for most developing countries because of the lower fuel costs and longer life.

5. The small tractor should be capable of doing three times more work than the 5- to 7-hp IRRI power tiller.

6. The tractor should be capable of a full range of farming operations with appropriate attachments such as land preparation, threshing, transport, irrigation, cultivation.

7. A full-width rotary tiller should be developed to permit tillage of land next to the levees.

8. Adjustable lug wheels should be provided to improve mobility in wet land.

9. A differential lock would be desirable if it does not add too much to the cost.

10. A 1000-rpm PTO shaft should be provided for operating a rotary tiller and other powered attachments.

Based on the above specifications, a small 15- to 20-hp, four-wheel tractor is now being designed. A review of the locally available 15- to 20-hp lightweight diesel engines was made. Subsequently a two-cylinder, 15-hp aircooled diesel engine with an aluminum alloy block weighing 95 kg was selected. Since facilities to fabricate gears and other complex parts are not available with small metalworking firms in the developing countries, standard automotive transmission, differential, and steering gearbox assemblies that are popularly available in most developing countries are being used in its design.

Deep-placement liquid injector

A manually drawn machine for injecting urea and insecticide in solution form into puddled soils was developed. The machine has a ground-driven peristaltic pump to meter the chemical to four injector nozzles which deposit it below the soil surface (report No. 19). The machine weighed 30 kg and had two 1-m diameter wheels (fig. 5) which provided sufficient clearance for the plants. During tests at IRRI, it was found that this applicator was rather heavy for one-man operation.

Work was done to lighten the machine by reducing the wheel diameter to 80 cm and by using thin-walled tubing for the frame. The solid axle was changed with a thin-walled steel pipe and the galvanized metal tank was replaced with a light plastic tank. These modifications reduced the weight from 30 kg to 22.5 kg. The previous machine had separate injector-lifting and pump drive-engaging levers which were inconvenient to operate. A system of levers was designed to simultaneously lift the injector and to release the peristaltic tube tension to stop the metering of the chemical.

Since the application rate of the fertilizer and insecticide solution can be changed by different concentration levels, the machine was designed to meter a fixed volume of 300 liters of solution per hectare. The amount of solution required, however, can be affected by the solubility of different chemicals in water. For example, about 105 kg of urea can be dissolved in about 100 liters of water. Due to the large volume of water that would be required for preparing ammonium sulfate solution, the machine is not recommended for application of ammonium sulfate. It can be used, however, for application of urea. According to the IRRI Agronomy Department, there are two rates of application recommended for root-zone application of nitrogenous fertilizers -- 60 kg N/ha during the dry season, and 30 kg N/ha during the wet season -- which can be handled by the machine. This machine is being further evaluated at the IRRI farm and at farmers' fields in the neighboring areas.

Deep-placement granule applicator

A single-row, push-type fertilizer applicator for root-zone placement of granular fertilizer was reported in the semiannual report No. 19. The machine had a 5-kg capacity hopper with a ground-driven fluted roller feed and an adjustable sliding-gate type metering feed. Modifications to prevent the wetting of fertilizer in the hopper were also discussed in the previous report. Further modifications were made to improve machine stability to prevent the machine from tipping sideways when refilling the hopper. The wheel tread was increased from 17 cm to 45 cm by installing a longer axle to permit straddling of two plant rows.

It was felt that an adjustable orifice for metering may be too complicated for farmers, so a fixed two-hole metering plate was tried. The hole sizes were based on the popular combination of urea and carbofuran that are applied by farmers in the Philippines. The two rates were: 60 kg N + 1 kg a.i. carbofuran (130 kg of 46% N urea + 30 kg of 3% a.i. carbofuran granules) for the dry season, and 30 kg N + 1 kg a.i. carbofuran (65 kg of 46% N urea + 35 kg of 3% a.i. acarbofuran) for the wet season.

Fertilizer metering tests with these machines indicate some of the dimensions of the metering mechanisms are very critical and must be accurately maintained. The roller diameter and depth of flute are important and must be precisely adhered to to obtain reasonable metering performance. The roller axis must also be aligned exactly above the center line of the metering hole. When the clearance between the fluted roller and the metering orifice was minimum, grinding of the fertilizer granule was observed, which interferred with the smooth rotation of the metering roller. On the other hand, when the clearance was greater than 3/16 in., fertilizer flowed continuously from the hopper without any metering action. Tests with different clearances indicated that a clearance of 1/16 in. was optimum to provide satisfactory metering.

Calibration tests with two fixed-orifice applicators were made to study the performance of the metering mechanism with different batches of fertilizer. Four samples of the same brand of urea but from different bags were used in the tests. Mixture A, B, and C came from newly opened bags while mixture D was from a half-filled bag that had been opened some time ago. Table 1 shows no significant different among machines. Table of the means in kilogram per hectare, however, showed that all four mixtures are significantly different from each other at 5 percent level.

The two machines were also tested to determine metering rate of application of 160 kg/ha and 100 kg/ha with the 11/34-in. and 19/64-in. diameter orifices, respectively. Table 2 shows the data and the average positive and negative deviation of the output from the target rate. Table 3 summarizes the average deviation of the two machines at 160 kg/ha rate of application. Range of deviation shows that the output of both machine No. 8 and No. 9 is less than the target rate for mixture A, whereas it is greater than the target rate for mixture B. The average output of the applicator is from 141 to 164 kg/ha at 160 kg/ha rate of application while about 94 to 117 kg/ha range was observed in the 100 kg/ha level.

A fixed-orifice metering device is simple and does not require much experience on the part of the user. The above test, however, indicates that it is not a very precise metering device. These tests indicated that the differences in the fertilizer sample are responsible for the variations in the metered rate from the same orifice. An adjustable metering orifice would be desirable although it would require some experience and training of the operator. An optional adjustable metering device which can be used to replace the fixed-orifice design has been designed and is being tried by the IRRI Entomology Department.

The applicator is now being field-tested in different locations in the Philippines. Based on the field evaluation, appropriate modifications will be made in the design before it is released to manufacturers.

Water jet pumps for low lift applications

Pump requirements for rice irrigation and drainage are essentially one of low lift and high capacity. The use of a water jet pump or ejector system should permit the conversion of a high-pressure, low-delivery pump into a high-capacity, low-lift pumping unit. Such an attachment made at low cost would have potential application in rice pumping operations. Initial studies made in this project were presented in previous reports. During the current reporting period, the experiments on physical proportions were continued and concluded.

This investigation was undertaken to study the performance of a prototype jet pump of very low area ratios for use in conjunction with centrifugal pumps for low lift irrigation.

The investigation yielded the following principal results:

1. Jet pumps can be used to multiply the discharge of a centrifugal pump several times at the expense of its pressure head. The maximum multiplication obtained in the present study was approximately ten times the original flow from the primary pump.

2. Experimental data gathered on the performance of several low area ratio water jet pumps indicated that these pumps can achieve relatively higher efficiencies than was previously reported.

3. For the lowest area ratio of 0.028, the maximum measured efficiency of 24.96 percent was achieved at a capacity ratio of 7.82. This pump had a throat length of 7 diameters, a 5^{o} diffuser, a throat entry angle of 90^{o} and zero nozzle spacing.

4. For the highest area ratio of 0.125 the maximum measured efficiency was 40 percent against a predicted efficiency of 44 percent. This difference

in performance was due to the low approach chamber angle and the high diffuser included angle used in the particular configuration.

5. Reduction of the throat length from 7 diameters to 5 throat diameters and increasing nozzle throat distance from near-zero spacing to 1 throat diameter, along with a wide angle throat entry profile, improved cavitation without appreciable reduction in overall pump performance and indicated optimum geometric sizing for practical use.

6. The head capacity characteristics of a water jet pump were found to be similar to those for centrifugal pumps. For a change in the speed of the primary centrifugal pumps, the output from the combination increased in direct proportion to the speed and the head varied as the square of the operating speed. This indicated that the affinity laws used in centrifugal pump performance are applicable to centrifugal jet pump combinations.

7. A conventional one dimensional analysis which predicted efficiency performance to within one percentage point was compared with simplified analytical efficiency equation. The simplified equation provided reasonably accurate predictions of maximum efficiency and gave satisfactory overall agreement with experimental data.

8. An empirical design equation relating area ratio and maximum efficiency, derived from reported data on higher area ratios in jet pump literature, was experimentally verified and found valid (fig. 6).

9. Comparison with popular pumping systems for rice production in the Philippines and Thailand showed definite advantages and flexibility for a pumping system which utilizes a medium-pressure centrifugal pump and a low-cost jet pump attachment. The estimated cost of pumping water with a centrifugal-jet pump combination compared favorably with other low lift pumping systems (fig. 7).

10. Initial designs for a commercial jet pump attachment were developed. (fig. 8).

Tubular pump

Efforts were continued to study the performance of the tubular pump that was reported previously. This pump is rather simple and can be easily fabricated in most developing countries, with a few pieces of pipes. The pump consists basically of two horizontal pieces of pipes which are connected to a vertical pipe to form a T-shaped assembly. This assembly is mounted on two bearings such that it can be rotated along the vertical pipe. Different shapes and configurations of the horizontal arm were tried to achieve self-priming capacity and were discussed in the semiannual report No. 19. During the reporting period a pump made from 25-mm diameter pipes with the two horizontal radial arms of 1.2-m length pipes was fabricated and tested on a test stand. The performance of the pump at different lifts are shown in fig. 9.

The following observations were made during the tests:

1. The rpm at which water starts to flow when the pump is started from rest is considerably higher than the rpm at which the water flow stops when the pump speed is gradually reduced from normal operating speed as indicated in fig. 10. It was also observed that when the pump was started from rest and the speed was gradually increased, a sudden increase in pump output occurred at certain speeds. The possible reason for this behavior is that beyond certain speeds, all air is expelled from the two arms (fig. 11b), thereby permitting more smooth water flow.

2. When the pump was stopped from normal operating speed, it lost prime. As previously explained, all air was expelled from the pump at normal operating speed, and when the pump was stopped, water was siphoned back from the tubular arms through the central pipe and this emptied the pump. Air was not able to enter the central pipe fast enough to retain sufficient water in the tubular arms for self-priming (fig. 11c). If the pump was operated below 48 rpm, there was no loss of prime because the pump retained sufficient air in the arm during operation (fig. 11d).

The 1.2-m . radial arm tubular pump was later connected to the Savonius rotor windmill. In periods of gusty winds, the windmill operated briefly at fairly high speeds which expelled all air from the delivery arms and the pump lost prime whenever the windmill stopped. To overcome this problem, two 1/4-in. diameter breather tubes were installed to connect the outer end of the radial tube with the central portion as shown in fig. 12. As the pump is about to stop, water from the outer containers flows back through the two radial arms to the central pipe. As soon as water level at the outer end of the radial arms drops below the breather tube level, air flows through to the central pipe, thereby stopping further flow of water to the central pipe. The pump with the breather pipe is self-priming in all cases except when the windmill is stopped very abruptly by exerting strong braking force. In such sudden stops, it seems that the water in the thin breather tubes takes longer to flow back to let the air in than the water in the radial arm. For normal windmill operations, however, stops would be sufficiently gradual to permit self-priming operation. Further tests are being continued on the pump and the power requirements at different heads, speeds, and radial arm lengths are being studied.

Vertical-axis windmill

An S-shaped, vertical-axis rotor windmill was developed by Mr. S.J. Savonius in 1929 but this windmill did not gain popularity due to its low efficiency. The omnidirectional feature and simple construction of Savonius windmills, however, offer better potential for the developing countries than propeller-type machines because of their simplicity and low costs.

The semiannual report No. 19 described a project on evaluating different vertical-axis rotor windmill designs. A 20-in. diameter wind tunnel was built to test different versions of the Savonius rotor. The object was to study the power-generating characteristics of different Savonius rotor designs in which the following parameters were varied: (1) shape of the rotor blades, (2) overlap between the rotor blades, and (3) separation distance between the rotor blades.

Figure 13 shows the different rotor configurations which were evaluated for power-generating capabilities. All rotors were 961 sq cm (144 sq in.) in projected area. The models were subjected to three sets of air velocities in the wind tunnel. The power coefficients were calculated from the torque and speed data (fig. 14). Preliminary tests indicated that model 4 has poorer performance as compared to models 1, 2, and 3. On the basis of these results, further tests for different blade overlaps were not conducted on this model. The remaining models were tested for three blade overlaps which are tabulated below:

Rotor model	Percent blade overlap		
	A	B	C
1	16.0	26.0	34.0
2	17.6	27.6	39.5
3	26.0	30.0	35.0

Tests indicated that 1A, 2A, and 3B configurations gave the maximum power coefficient in each class under all wind velocities. Thus optimum "overlap" of the rotor blades seems to be highly influenced by the shape of the rotor blades. B.G. Newman[1/] reported that Savonius rotors with semicircular blades have maximum power coefficient at 20 percent blade overlap. In our study, the maximum efficiency was obtained at 16 percent overlap with the semicircular blades (Model 1A). Model 3B gave the most efficient

1/Newman, B.G. "Measurements on a Savonius Rotor with Variable Gap." Paper presented at Sherbrooke University Symposium on Wind Energy, May 1974.

performance among all models tested and this was achieved at 30 percent overlap.

Tests were conducted to study the effect of separation distance between blades. A blade separation distance of 8 percent of the projected width was tested on Model 3A rotor with 26 percent overlap. Performance with this separation distance was drastically reduced and was the lowest among all the Model 3 rotors. Because of this observation, no other tests were conducted on separation distance.

Based on the comparative tests, a 103-in. high and 43-in. wide prototype windmill was constructed using three 44-gal oil drums. The section profile of the prototype windmill was similar to Model 3B except the length/diameter ratio was 2.14 as compared to 1.0 with the model. The rotor was mounted on two 1-in. ball bearings and anchored to the ground with four guy wires (fig. 15). The prototype windmill was coupled to a tubular pump that is described elsewhere in this report. Tests indicate that the rotor-pump combination can start pumping water at wind speed of only 3 mph. At 3 mph wind, it pumps 3 gal of water per minute at a 3-ft head. Further tests are being made to study the power generated by the Savonius windmill and the power required by the tubular pump in order to match them for optimum performance.

Axial flow thresher modifications

The IRRI axial flow thresher, which has been released for commercial production, was last reported in semiannual report No. 18. This machine is now commercially produced by 15 companies in 5 countries. The axial flow thresher has a 4-ft long, pegtooth threshing drum with a full-length oval concave. A centrifugal blower winnows the lighter impurities as the grains fall from the concave. The winnowed grain is conveyed with an auger to a rotary screen for removing residual pieces of straw which cannot be separated by winnowing.

Several verions of the thresher based on the original IRRI design have been developed by the manufacturers to improve performance and to suit their production facilities. A shortcoming of the original IRRI thresher was that the machine did not do a good job of grain cleaning. Grain cleaning is highly influenced by the type of crop and the weather and crop conditions. The original IRRI thresher which has a rotary screen works satisfactorily with both dry as well as wet crops but it leaves short pieces of straw with the grain. In wet crops the tumbling action of the rotary screen dislodges the grains that cling to the straw and keeps the screen from clogging up since impurities lodged in the screen fall off when the screen is inverted during rotary motion.

The tumbling action, however, permits some pieces of straw to slip through the screen perforations.

A few manufacturers have installed flat oscillating screens and these work quite well with dry crops. With wet, high-moisture crops or crops with decomposed straw, perforations on the flat screens get clogged due to sticking or lodged trash and a high amount of grain is then carried over the screen. Under such conditions, threshers equipped only with oscillating screens have to be stopped periodically to remove the accumulated material from the screen. Machines with rotary screens, however, can be operated continuously under such difficult conditions. In dry crops, however, both machines can work continuously with the oscillating screen doing a better-quality job of screening.

There are four basic versions that have been developed by our cooperating manufacturers and these are briefly described below:

(1) Messrs. Oberly & Co., Quezon City, Philippines, has installed a full-width oscillating screen under the concave with the blower located above the oscillating screen. Their machine retains the original rotary screen, thus resulting in a dual-screen machine. The threshed material falling from the concave is first winnowed to remove airborne impurities before it reaches the oscillating screen. The manufacturer claims that this reduces screen overloading and results in better performance. This manufacturer is using higher-powered engines of 8 to 14 hp and claims higher threshing output for both dry and freshly harvested paddy. The machine has a rather high frame which is not too convenient for direct feeding while standing on the ground.

(2) Messrs. Kaunlaran Industries, San Pablo City, Philippines, has replaced the rotary screen with a 4-ft wide oscillating screen under the full length of the machine. The blower is located under the screen and all material falling from the concave drop on the oscillating screen which separates the grain and trash and other impurities are conveyed over the screen. Grain falling under the screen is then winnowed for removing airborne impurities. Cleaned grain is then conveyed by an auger to one end of the machine for delivery. This machine works very well with dry crops. The manufacturer has very good quality control and it is receiving very good market response in the Philippines.

(3) Messrs. C & B Crafts, Valenzuela, Bulacan, Philippines have not made any major change on the basic IRRI design but have added a detachable oscillating screen-air cleaner at the grain delivery spout. The detachable oscillating screen cleaner has a small blower for final winnowing. Thus

their machine has dual screen-air cleaning arrangements. This machine performs quite well for both dry and freshly harvested crops, however, the additional cleaner adds to the cost. This firm has also installed a simple arrangement to recycle tailings and other semi-threshed material from the rotary screen back to the threshing drum. The arrangement consists of a series of wire prongs inside the rotary screen. The semi-threshed panicles and other larger unscreened material are lifted by the wire prongs and dropped into the chute for delivery to the intake end of the threshing cylinder.

(4) The American Spring & Pressing Works, Malad, Bombay, India has developed a rather low-cost axial flow thresher in which they have dispensed with all screens. They depend only on winnowing for cleaning. The company feels that crop and weather conditions during harvest are sufficiently dry in India that the cleaning requirements can be adequately served by mere winnowing. They have installed a thrower-type grain elevator to lift the grain to a bagging height. Their machine works well in dry crops but it is doubtful that it can work satisfactorily under wet conditions in Southeast Asia.

The company has also modified the threshing drum and other components of the machine so it could be used for threshing wheat which is a major crop in India. This company has tested 16 machines in India during the last wheat or rice harvest season and have reported satisfactory performance. The company expects to produce 50 threshers for marketing in India during the coming threshing season.

In order to lower the price of the axial flow thresher and on the basis of the feedback received from the users of the machines, attempts were made at the Institute to improve the original design. Threshers with four different cleaning mechanisms (fig. 16) are now being evaluated in the department to select the least-cost design which could be used under varying crop and climatic conditions. These are:

(1) In this version, the rotary screen is replaced with a small, flat oscillating screen that is located at the auger outlet. Since the existing blower removes most of the airborne impurities prior to screening, an oscillating screen of only 30x75 cm is adequate to remove the residual straw pieces from the threshed grain. The screen is oscillated at 220 cycles per minute with a 3-cm stroke directly from the auger shaft. The screen assembly is designed such that it can be swung upwards to provide increased ground clearance for transporting the machine. This machine performs quite well for both dry and freshly harvested paddy. With wet paddy or with decomposed straw, however, the small, flat screen cannot adequately separate all the grain and recycling of the material passing over the screen is necessary to recover grain.

For dry and freshly harvested crops, this thresher design is the most economical to manufacture among all the thresher versions that have been developed so far by the Institute and the cooperating manufacturers. This thresher with the oscillating screen is now released to commercial companies.

(2) In another version, provisions have been made to combine the small oscillating cleaner with a bagging arrangement. The grain delivery spout of the original axial flow thresher is only 35 cm high from the ground, which does not permit direct bagging. In this machine, the rotary screen was replaced with a thrower-type mechanism to elevate the grain delivered from the auger. The thrower-type elevator, however, did not perform well with high-moisture and wet crops. Clogging of the elevator and milling of grain were two problems encountered with such a thrower. A chain elevator with rubber flaps was then installed which works well with dry and wet crops. The elevated material is delivered to a small oscillating screen (44x92-cm screen) for removal of residual straw pieces before bagging.

(3) In the third version, the original rotary screen was retained and an additional small oscillating screen was added at the delivery spout. This version is somewhat similar to the C & B thresher, however, it does not have a second winnowing fan and the oscillating screen cleaner need not be removed for transport.

Comparative tests are being continued to obtain a better idea of the different thresher versions to select the least-cost alternative for threshing both dry and wet crops.

The axial flow threshers are being used widely for contract threshing which requires repeated movement of the machine from one location to another. Contract operators often use small power tillers, that are often equipped with engines similar to the one on the thresher, to tow the machine from one location to another. Some owners use jeeps, large tractors, and trailers to transport the thresher which requires high investments. Work was started to facilitate transport of the thresher and to reduce cost for contract threshing operations by the following two approaches:

(1) Power tiller-thresher combination

This arrangement was developed to use the power tiller engine for powering the axial flow thresher. A power tiller hitch and a countershaft was installed on the right front side of the thresher frame. This permits hooking of the two machines such that the thresher can be operated from the power tiller engine by using the standard V-belt normally provided on the power tiller (fig. 17). The simple hitching arrangement offers an attractive low-cost "power tiller-implement-thresher" package for meeting a wide range of farming needs and is now being released to manufacturers.

(2) Self-propelled thresher-trailer

Most threshers are used only during the threshing season and these machines remain idle during the remaining period. The present axial flow thresher has its own engine, two wheels and a heavy chassis. It was felt these components could be more effectively utilized if these could be used to form a motorized cart which could serve as a transport vehicle for the farmer. The cart could have provisions to mount the thresher such that it could be transported over dirt roads and also powered by the cart engine. Such a concept offers better utility of the different components and offers possibilities for meeting the threshing and transport needs at a lower cost.

A three-wheel motorized cart was designed for mounting the thresher. The aircooled engine, the two rubber-tired wheels, and the chassis from the original thresher were used to form the motorized cart. The engine was used to drive a front-pivoted wheel through a simple chain sprocket transmission. A 5^{o} negative caster angle has been provided on the steering pin for better road tracking. The cart has a maximum speed of 15 kmh. The powered front wheel has a band brake mechanism which provides adequate braking for the vehicle.

The thresher drive was modified so that the cart engine could power the thresher. The powered front wheel assembly was connected to the thresher through a double-pivot bracket such that it could be swung 90^{o} to align the engine pulley with the thresher drive pulley.

The same clutching system is used for both the transport and the threshing modes. A screw jack mechanism has been developed to load and unload the thresher from the cart by one man. Manufacturers have shown considerable interest in this self-propelled thresher/cart version (fig. 18) and it is being released for commercial production.

PTO thresher

The PTO-operated thresher is being developed as a high-capacity machine for contract threshing operations. The prototype thresher can thresh 2 to 4 tons of grain per hour but grain cleaning capacity is still not very satisfactory. In the semiannual report No. 19 it was reported that three distinct zones of air movement were found in the straw thrower intake opening. These were: (1) an air suction zone around the central shaft, (2) a concentric neutral air zone surrounding the central zone, and (3) an outer pressure zone which has a blow-back effect. It was found that the threshed material from the second and the third rotary screens was being discharged into the outermost pressure zone. Chaff and other light impurities were being blown back into the outer cylindrical shell of the rotary separator assembly. Inadequate transfer of threshed material from the rotary separator assembly to the straw thrower is a major cause for poor grain cleaning performance with the machine.

In order to match the diameter of the rotary separator assembly with the neutral zone in the straw thrower intake, attempts were made to reduce the number of screens from the rotary separator. Screening performance of each rotary screen was studied separately and it was found that the inner two screens moved most of the straw. To ensure delivery of all straw and chaff into the thrower intake, the external cylindrical shell of the rotary separator was replaced with a frustrum-shaped shell such that the smaller end matched the diameter of the neutral zone in the straw thrower intake opening. This permitted smoother air movement through the separator and eliminated the blow-back problem. The frustrum shape of the outer shell also helped in the smooth transfer of straw and chaff to the thrower because of the elimination of sharp curves.

It was observed that whenever the thresher was operated without the small winnowing fan and the grain-collecting pan, grain falling from the concave was adequately winnowed by the suction draft from the straw thrower. The thrower functions like a giant fan and sucks large quantities of air through the separator assembly. Attempts were made to take advantage of this air movement in order to eliminate the extra blower under the concave. The concentric rotary separator openings at the threshing cylinder end were partially closed with sheetmetal to concentrate the air movement in the lower part of of the rotary screen where grain falls from the concave and the rotary screens. A small oscillating conveyor was installed under the concave to convey the grain towards the rotary screen openings for cascading at one point to improve winnowing. Grains falling from the rotary separator are conveyed to the paddle elevator for delivery (fig. 19).

The elimination of the grain auger, the small winnowing fan, the cylinder from the rotary separator, and the reduction in size of the outer cylindrical shell have reduced the machine weight considerably. This will improve machine mobility in the fields and will reduce production cost. Further design improvements are being made and field testing is expected to follow in the near future.

Stripper harvester

During the period limited work was done on the stripper harvester project. Work on the machine was concentrated on obtaining more precise speed control during harvesting. The machine ground speed was somewhat higher for proper field operation and consequently the speed had to be reduced during operations by engaging and releasing the band brakes on the skid-steer transmission which did not result in precise speed control. An additional reduction of 2:1 was added to the final drive and this provided a ground speed of 0.74 kmh in the field. With this modification the harvester exhibited excellent maneuverability and speed control on all types of surfaces and the machine can now pivot 360^{o} in either direction.

The cantilevered header in the front of the machine results in higher loading on the front wheels. Because of the greater weight on front wheels, the machine pivots on the front wheels during turning and the rear tires spin against the road surface, resulting in excessive wear. Another problem that remains unsolved is the high amount of grain scatter loss in front of the header. The losses at the blower and perforated screen, however, have been minimized.

Experience with the present machine indicates that grain scatter loss is less when the gathering bar velocity is about four times the ground speed. In order to minimize the scatter loss the machine is being modified. This modification involves a considerable departure from the original design in which only one threshing belt was used. The modified machine will have the gathering bars mounted only on two shafts and a baffle behind the bars will almost completely block the front opening to minimize the grain that is thrown out of the machine. The second threshing belt will thresh the paddy on the top side and will restrict grain from bouncing out. This arrangement will have two almost parallel threshing surfaces and plants will be threshed in-between.

Drying and processing

Solar heat collector

Efforts were continued to develop a solar heat collector attachment for the IRRI batch dryer as reported in report No. 19. A black-painted, 3-sq m corrugated iron sheet was mounted in a polyethylene-covered wooden frame to form the collector. Two 3.5-sq m aluminum foil-covered reflector panels were attached to the collector to reflect additional heat on the panel. Preliminary tests with this solar heat collector indicated a very low efficiency

It was also observed that not all the heat reflected by the two reflector panels reached the collector panel. This arrangement was too heavy (80 kg) and bulky and four persons were needed to carry and install it. The material cost and wood work were also high for small farmers in most developing countries.

Based on the experience gained from the first collector, the following guidelines were developed for a solar energy collector for use in developing countries:

(1) Efficiency is not the prime criterion but factors such as low cost, light weight, ease of production are equally important in the design of a collector for developing countries.

(2) It should be made from readily available, low-cost materials such as wood, cardboard, paper, bamboo, matting, etc. The panels for the IRRI dryer should cost less than US$60.

(3) The panel should be light in weight to facilitate transport and installation. It should weigh less than 30 kg.

(4) It should have a thin polyethylene cover since glass is costly, heavy, and liable to break.

(5) The panel should be capable of convenient stacking for storage.

Five different panels were fabricated to fit the test stand. Figure 20 illustrates the construction details of the panels and Table 4 includes the specifications and bill of materials. A 16-channel temperature recorder was used to record the following: (1) three channels for ambient temperature, (2) nine channels for average temperature, and (3) three channels to record the output temperature in the blower opening. Direct sunrays in calorie-sq cm was recorded with a pyrometer. The five panels were fabricated to fit the test stand.

The comparative performance of the five panels is given in Table 5. Among the five panels, panel B (made of corrugated cardboard) demonstrated the maximum efficiency of 34.39 percent, followed by panel A (32 aluminum wire mesh with accordion fold) with 33.62 percent efficiency. Panel C, made of corrugated iron sheet, gave 30.01 percent, and panels D and E gave 24.42 and 21.41 percent, respectively.

Further work is being continued on the development of low-cost energy collector panels based on the A and B concepts to achieve satisfactory performance and to simplify construction. Tests would be conducted to improve the air passages that would permit more efficient heat transfer without overloading the blower.

Engleberg mill improvement

Results of the tests on the Engleberg rice mill with the various modifications and comparative tests on other commercial mills have been reported previously. Analysis of all the test results showed interrelationships of the variable factors affecting machine performance. It was noted that there was a trend of increased milled rice temperature with decrease in capacity irrespective of the modifications made. Also, there was a reduction in total recovery with the use of the wider perforated screen in both the test and the commercial mill. It was further observed that combinations of some of the modifications produced higher total and head rice recovery compared with the original and commercial machine.

The results of all the tests made on the improvements of the Engleberg show that the following modifications can be made to improve performance:

(1) The use of the smaller screen perforation (0.79 mm x 12.70 mm), instead of 1.19 mm x 12.70 mm, can generate a savings of up to 4 percent in total recovery.

(2) The use of the cut blade in the milling section can increase the head rice yield by as much as 9 percent.

(3) Redesigning the top cover of the milling section to accommodate the same smaller perforated screen that is used on the bottom can increase head rice recovery by 5 percent and produce a much cleaner milled rice.

(4) Although the modifications are expensive for the operator, the redesigned cylinder, screen, top cover insert, and discharge produced a consistently higher total and head rice recovery when compared with the original Engleberg rice mill.

(5) Modification of the discharge from a slide to a weight-loaded gate is recommended not only for improved performance, but also improved control of the milling machine.

Work on the experimental single-pass rice milling machine (fig. 21) has been reported in previous semiannual reports. This machine was made primarily to study the variable factors in milling that were fixed in the Engleberg mills and to explore the possibility of redesigning this machine as a modified Engleberg rice mill. The experimental machine was completed and exploratory test runs were conducted to detect defects. Modifications were made until the machine operated satisfactorily. The effects of the following on the milling performance will be determined on this machine: (1) cylinder speed, (2) cylinder-blade clearance (milling section), (3) cylinder-screen clearance, (4) screen (number and size of perforations), (5) cylinder design, (6) air jet stream through the grain, (7) discharge mechanism and locations.

The results included in this report were from tests used to determine optimum cylinder speed and blade-cylinder clearance. Four cylinder speeds -- 690, 865, 1200, and 1430 rpm -- and four blade clearances -- 2.46, 3.94, 5.31, and 6.71 mm -- were used in the tests. An 8-kg sample of IR1561 rice variety at 13.3 moisture content and 95 percent purity was used for each test run, which was replicated three times. Rice mill adjustments, milling rate, milled rice temperature, total and head rice recoveries, and other observations were recorded.

The results of tests using different cylinder speeds, with a screen-cylinder clearance of 20 mm and blade-cylinder clearance of 7.22 mm are shown in fig. 22. A slight variation was observed in the total recovery and capacity of the machine at different cylinder speeds. The average recovery of 69.15 percent is high compared with reported values of 60-63 percent on commercial Engleberg mills. Although the variation in capacity was small for all cylinder speeds, the average value of 130.94 kg/h is about 50 percent lower than the rated capacity of the smallest commercial size kiskisan mill. The head rice recovery increased with cylinder speeds up to 1200 rpm and decreased at higher speeds. The lowest head rice recovery value of 36.17 percent is high when compared with the commercial Engleberg mill and the highest value of 45.32 percent at 1200 rpm is comparable to the big commercial cone-type rice mill. The shape and trend of the grain whiteness curve followed that of the milled rice temperature. It is interesting to note that in all test runs the milled rice temperature remained high and increased with cylinder speed. In spite of this the machine maintained high total and head rice recovery. Based from these results, the cylinder of the experimental single-pass rice mill was set at 1200 rpm.

Figure 23 shows the performance of the machine at different blade-cylinder clearances with the cylinder speed set at 1200 rpm and a screen-cylinder clearance of 15.9 mm. The figure shows a distinct increase in head rice recovery as the blade clearance was increased. The lowest head rice recovery of 31.63 percent is high compared with existing commercial Engleberg mills and the highest value (43.86%) at the widest blade clearance used is comparable to the cone-type rice mills. Also, the total recovery increased by about 2.8 percent with blade clearance. Closer blade adjustment causes an increase in pressure and intense rubbing of the grain inside the rice mill, which results in lower total and head rice recoveries, whiter grain, and high milled rice temperature. The situation, however, reverses at wider blade adjustments. Although the milled rice temperature in the previous test was already high compared with the regular Engleberg mill, the results of this test are much higher.

Results of these initial tests on the experimental single-pass rice mill indicate the following:

(1) The cylinder speed of 900 rpm specified by the manufacturer of the Engleberg mill must be increased up to 1200 rpm to improve the performance.

(2) The blade clearance of the mill must be adjusted to a minimum clearance of 5 mm. These results corroborate the previous findings on the Engleberg mill tests.

These findings for the improvement of the Engleberg ricemill will be verified in existing commercial mill establishments to determine their effectiveness in improving performance, and to evaluate the response of the mill operators and customers. If found favorable, the design will be released to the owners and manufacturers of Engleberg mills.

Mechanization Research

The mechanization research section's responsibilities include investigations in machine utilization and assistance to the design section. Design assistance includes testing and field evaluation of prototype designs and the evaluation of manufacturers' production prototypes. Machinery utilization studies will be conducted to provide information to aid in the selection of new machine development projects and the writing of engineering specifications for the proposed machines.

Comparative evaluation of different threshers in the Philippines

The results of rice thresher tests conducted from July to December 1974 were presented in semiannual report No. 19. This report will discuss the tests conducted from January to June of this year. Tests on the large McCormick-type thresher were completed and the machine's performance is tabulated in Table 6.

The McCormick thresher is classified as a Type V with a single drum, straw walker, and winnowing fan. The machine is of all-steel construction, mounted on four wheels, and is towed either by a crawler tractor or a standard four-wheel tractor. The threshing cylinder has peg-teeth and a grill-type concave is used. (fig. 24).

The material to be threshed is fed into the top of the threshing cylinder and leaves after completing a 3/4 turn of the cylinder circumference. The straw falls on the straw walker which causes it to travel rearward to the straw thrower. The threshed grain falls through an air stream and the winnowed grain is collected and conveyed to the bag by the auger. The impurities are carried away by the high-velocity air. Good grain that is blown by the air is recycled to the threshing chamber and recovered.

Table 6 illustrates the comparative performance of the different types of threshers. Type V exhibits the highest output and best cleaning performance. Labor input is highest on Type V but capacity per man-hour is also higher than any of the other threshers tested. Type IV and Type V have the lowest total grain loss.

Compacted soil studies in continuously cropped wetland rice

This study was initiated during the wet season of 1973 and is on its fourth cropping season. As stated in earlier reports, this study will provide data to assist in determining appropriate prime mover designs for use in continuously cropped wetland rice.

Table 7 shows that there is an apparent stabilization of the hard pan in tillage treatments using the 5- to 7-hp and 10-hp power tillers. The treatment using the big four-wheel tractor still shows a continuing increase in hard pan depth.

This study will continue for at least another two cropping seasons to confirm present trends in the movement of the hard pan depth level.

Engineering training course

Agricultural Engineering Dept. offers a two-week training course on the manufacture and utilization of IRRI machines. It is primarily intended for individuals from engineering staffs of manufacturers who are now, or plan to be, closely involved in the manufacture of IRRI machines and representatives of governmental agencies concerned with agricultural mechanization.

The course offers instruction in the function, manufacture, assembly, field operation, and maintenance of IRRI designs; plus field demonstrations and visits to Philippine manufacturers.

Seven students from five countries received training during the reporting period. In the future, the course will be conducted approximately every six months, during the first and third quarters of the year.

Mechanization workshop

The Agricultural Engineering Dept. sponsored a "Workshop on Agricultural Mechanization and Indigenous Production of Agricultural Machines in the LDC" that was held at IRRI on May 6-9, 1975. Sixty participants from 19 countries in Asia, Africa, Europe, North and South America attended. The participants represented government institutions, international organizations, and manufacturers.

The Workshop included the presentation of formal papers, panel discussions, field trips, and machinery demonstrations. The papers covered such subjects as: "Local Production of Aircooled Engines in Sri Lanka," "Rice Mechanization Developments in Thailand," "Farm Machinery Market Research and Product Planning," "Indigenous Production of Threshers in India," and "Growth Strategy of Small Farm Machinery Manufacturing."

The Workshop proved to be an excellent forum for the exchange of ideas on agricultural mechanization and machinery manufacture. Recommendations resulting from the Workshop discussions included:

(1) IRRI should continue to emphasize simple machines that can be built by small manufacturers.

(2) Studies are needed on the effect of mechanization on labor displacement.

(3) Government policy should give preference to locally manufactured machines through bank lending policies, technical aid to local manufacturing, and import policies.

(4) IRRI should provide increased training opportunities for engineers and manufacturers.

(5) More market research is required to determine the farmers' mechanization needs and preferences.

Participants recommended that another workshop be held in two years.

Mechanization Systems

Beginning with this report, all analytical work carried out to examine the economic impact of mechanization on use, patterns, adoption, employment, distribution of benefits, alleviation of constraints, manufacturing and distribution systems, and policy formulation will be summarized under the heading "mechanization systems". This change is an attempt to better reflect the focus of economic activity in the engineering department and to consolidate and systematically evaluate mechanization alternatives within various farming environments.

Mechanizing upland cropping operations

This study, being carried out in close cooperation with the Cropping Systems Dept., is an attempt to intensively examine the current range of cultural operations employed in upland farming systems where rice is the dominant crop. The overall objective is to assess the potential for mechanizing upland cropping operations and to explore the possibilities for developing technically and economically suitable equipment designs that will selectively meet the requirements of both existing and improved cropping systems.

A farm level survey covering 100 farmers was conducted in two upland cropping villages in Batangas and Laguna provinces of the Philippines (fig. 25). Simple random sampling with provisions for replacement was used in selecting the sample which was distributed evenly between the two villages. Intensive interviews were conducted with each farmer to gather baseline data describing currently employed cultural techniques, the nature and extent of possible constraints in the existing pattern of land cultivation, crop care and harvest and post-production operations. A profile of these farmers is presented in Table 8. Analysis of data from the survey is currently underway and the results will be presented in report No. 21.

Cost budgets

To provide a benchmark for projections of market size and potential ownership patterns for the IRRI-designed axial flow thresher, batch-type dryer, and power tiller, a series of cost budgets were constructed.

5- to 7-hp tiller

Table 9 contains the data and assumptions underlying the average total cost curves (ATC) shown in fig. 26. Under conditions prevailing in the Philippines in 1975, hand tractor ownership for lowland rice cultivation appears to be profitable over a range of 4 to 50 hectares. The exact point of annual use at which an owner covers all costs is affected by the level of initial investment, prevailing contract rates, and, to a lesser degree, the level of variable costs such as fuel and labor.

Axial flow thresher

There has been considerable controversy regarding the impact of initial investment costs on the size of the market for the axial flow thresher. In figs. 27 and 28, a series of average total cost curves for this machine are presented which illustrate the impact of both investment cost and productivity (output per hour) on annual use requirements. The budgets from which these curves are derived are shown in Table 10. With low productivity levels and high investment costs, annual utilization must be high to justify ownership. If initial investment costs are low and/or hourly output high, the breakeven point will be correspondingly lower.

By charging a high initial price for the machine, firms producing the thresher severely restrict the market to those with larger holdings or with the potential to develop custom threshing services. Understandably, most individual manufacturing firms are too small to perceive this "elasticity" in the demand for their product and do not yet face sufficient price competition in the market to force a downward adjustment in the initial investment cost.

Batch-type dryer

Concern with rising energy costs and expanded potential for drying equipment caused us to re-examine the costs of owning and operating the 1-ton batch drying unit. Table 11 contains the fixed and variable cost components for this machine at different levels of initial investment. Figure 29 presents these data graphically. In order to examine the effect of each cost element on total average costs, a further chart was developed and is shown in fig. 30. In the case of the kerosene-fueled unit, energy costs constitute both a high absolute and relative share of TAC. Using rice hulls for fuel reduces both the average total cost and the levels of annual use required for ownership at all levels of investment cost.

Farm level rice post-production systems

To examine rice post-production systems currently used in the Philippines, a detailed field survey consisting of 591 farmers located in Camarines Sur, Southern Luzon and Central Luzon was undertaken during 1973-74.[1/]

1/This survey is part of a four-phase study of Philippine rice post-production systems which is being undertaken by the Agricultural Engineering Dept. Selected aspects of this study are also being replicated in Thailand to provide the basis for some cross-country comparisons.

The objectives of this survey were to determine the nature and characteristics of practices commonly used, to identify and measure constraints in existing field level systems and to compare resource use and institutional arrangements embodied in each element of these systems. Using summary data, we present in the following sections a few of the most relevant findings as they relate to the issue of farm level post-production mechanization.

Harvesting

More than one-half of the farmers harvest their crop at maturity,[2/] 71 percent in Central Luzon, 51 percent in Southern Luzon, and 55 percent in Camarines Sur (fig. 31). Delaying harvest beyond the maturity date was reported by 35 percent of the farmers while 7 percent harvest their paddy before the grain is mature (fig. 32).

Farmers usually harvest at maturity to minimize field losses resulting from shattering, unfavorable weather, and pilferage. On the other hand, delays in harvesting were due to unfavorable weather and the lack of harvest labor, especially during peak months of harvest. Other farmers claim that delayed harvesting allows the full and uniform ripening of the grain. Studies, however, show that if harvest is delayed beyond the optimum date, shattering losses increased and over-drying results in poor milling recovery and decreased head rice yields.

Harvesting is commonly performed with the scythe or sickle (fig. 33). Harvested stalks are either laid loosely on the ground, bundled or stacked in a variety of ways to facilitate field drying. The length of drying depends on the season, local weather conditions, the general practices in the area, and the type of thresher to be used.

Threshing

The most common method of threshing inCentral Luzon is with the use of the McCormick-type thresher or "tilladora" (fig. 34). It was used by 58 percent of the farmers during the wet season and 62 percent during the dry season (fig. 35). The machine has a threshing capacity ranging from 0.5 ton

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2/Maturity is defined as the duration in days from seeding to the time when more than 80 percent of the grains on the panicle are fully ripened. When the above information is not available, maturity is estimated by adding 30 days to the duration from seeding to full heading (Catalog of Rice Cultivars and Breeding Lines in the World Collection of IRRI, April 1970).

per hour or less for smaller threshers to more than 1.5 tons per hour for large threshers.

In Southern Luzon and Camarines Sur, threshing is performed with either human or animal labor or a combination of both as reported by 78 and 100 percent of the farmers, respectively. Threshing is accomplished by either beating the rice panicles against a slotted bamboo frame, using flails or sticks, or by treading the harvested stalks with people or animals.

Utilization of mechanical threshers

Out of 591 farmer-respondents, only 48 percent are users or potential users of mechanical threshers. Central Luzon reported the highest percentage, 63 percent, and Camarines Sur, the lowest with 35 percent (Table 12).

Twenty-three percent of the farmers gave no comment or have no idea about the use of mechanical threshers. They would require additional information and actual observation of the machine's performance before they could arrive at a decision regarding its use.

There were various reasons for the farmers' lack of interest in mechanical threshers. Twenty-four percent do not want to use mechanical threshers because they sympathize with the harvesters and threshers who might be displaced. Moreover, 18 percent of the farmers believe there is adequate labor to perform harvesting and threshing operations. In some cases, there exists a harvesting/threshing relationship with other farm operations. Under this arrangement, harvesters and threshers do the planting and weeding operations on a certain portion of the field and at harvest time share the output of that lot.

Small farm sizes and low yields also affected the farmers' lack of interest in mechanical threshers. They argue that they could easily do the job without the aid of mechanical thresher.

Cleaning

Farmers using McCormick-type threshers usually depend on the machine to clean their threshed paddy. This was reported by 56 percent of the farmer-respondents in Central Luzon and 14 percent in Southern Luzon (fig. 36).

Paddy threshed by hand or animal treading is usually cleaned with a winnowing basket or "bilao" as reported by 67 percent of the farmers in Camarines Sur. Other paddy cleaners reported include the winnower or "hunkoy," wooden or metal boxes with perforations, and a combination of the above.

Drying

With the exception of one farmer in Southern Luzon, solar drying is the most common method practiced by farmers in all the three regions studied (fig. 37). There were two methods of sun-drying reported. In the first, the paddy is harvested and left to dry for several days in the field in loose bundles, shocks or "mandalas". The length of drying depends on local weather conditions, the practices in the area, and the availability of a thresher. This practice was reported by 44 percent of the farmers in Central Luzon and 14 percent in Southern Luzon.

In the second method, the high-moisture grain is spread under the sun immediately after threshing using drying surfaces such as concrete pavement, mats, plastic sheets, canvas, etc. Forty-eight percent of the farmers in Camarines Sur reported use of this method for drying.

Storage

Paddy for home consumption is stored in sacks, metal or wooden boxes, bamboo baskets ("bayong"), cans or drums, small granaries or bodegas, or special rooms within the house where it is stored in bulk form (fig. 38). Paddy which is sold is either stored in the farmer's house or bodegas. Usually, the marketable surplus is sold immediately following harvest. Only 19 percent of the farmers studied utilized the warehouse of the mill for storage; 21 percent in Central Luzon, 22 percent in Southern Luzon, and 14 percent in Camarines Sur.

Harvest and post-harvest problems

The majority of the farmers interviewed found it difficult to specify common or recurring problems. Most of the problems noted were general and vague. In some instances, farmers tried to ignore the question claiming they had encountered no problems.

Harvesting and drying were the two major post-harvest problem areas as indicated by 60 percent of the farmers reporting problems (fig. 39). On the other hand, cleaning and storage are the two post-harvest operations in which the least number of farmers reported problems.

Unfavorable/unpredictable weather was the most common problem reported in harvesting. This difficulty causes undue delay, resulting in quantitative and qualitative losses from lodging, shattering, rotting, discoloration, and sprouting of grains. Aggravating these losses is the scarcity of labor, especially during the peak months of harvest. Problems of pilferage bird attack, insects, rats and other pests were also mentioned as problems tending to reduce the total potential harvest.

In the drying operation, unfavorable/unpredictable weather was also a major problem area. This is to be expected since almost all farmers interviewed utilized solar energy in their drying operations. Southern Luzon, and more specially Camarines Sur, reported drying as their most serious constraint.

The farmers in Central Luzon consider cleaning as the least important problem. The majority of the farmers used mechanical threshers in their threshing and cleaning operations. The machine has a grain cleaning section which separates the grain from the straw and chaff and delivers a clean, marketable product. In the case of Camarines Sur farmers, weather was cited as a major problem area since the majority of the farmers clean their paddy using winnowing baskets or "bilao".

Marketable surplus

In order to determine the quantity of rice retained for home use and consumption, the form and manner in which it is stored and the factors affecting decisions to sell paddy, a careful analysis was made of the production, consumption, and marketing behavior of a subset of farmers in the survey mentioned in the previous section. The patterns of consumption and market sale and their relationship with production are shown in fig. 40. It is immediately apparent from an examination of these charts that small farms, low production, and large family size significantly affect the quantity of paddy retained in the home. Price did not appear to be a significant factor in determining home consumption requirements. The results of the analysis are more fully presented in two working papers available upon request from the department.

Mill level rice post-production systems

The second phase of the department's study of post-production systems included a survey of 187 rice mills in three locations of the Philippines. The survey included 96 Engleberg huller mills used for village level processing -- principally for home consumption -- and 91 under-run disc-sheller mills. These mills were sampled in the same areas included in the farm level survey outlined in the previous section. Tables 13 and 14 indicate the distribution of the mills by location, capacity and type of user. Analysis of data acquired in this survey is presently underway and the preliminary results will be presented in subsequent semiannual reports and in the working paper series.

PERSONNEL LIST

Personnel and their respective man-months engaged on the project during the past six months, January 1 to June 30, 1975:

Position	Name	Fr: 1- 1-75 To: 6-30-75
Agricultural Engineer & Project Leader	A. U. Khan	6
Assoc. Agricultural Economist	B. Duff	6
Assoc. Agricultural Engineer	D. Kuether	3
Visiting Assoc. Agr. Engineer	C. C. Lee	5
Asst. Design Engineer (Design)	J. Policarpio	6
Asst. Design Engineer (Processing)	Open	0
Sr. Research Assistant (Design)	J. Arboleda	6
Sr. Research Assistant (Design)	N. Navasero	6
Sr. Research Assistant (Design)	S. Gutierrez	6
Sr. Research Assistant (Mech. Res.)	C. Padolina	6
Sr. Research Assistant (Economics)	Z. Toquero	6
Research Assistant (Design)	G. Espiritu	6
Research Assistant (Design)	G. Salazar	6
Research Assistant (Mech. Research)	B. Ramos	6
Research Assistant (Economics)	T. Taguiang	2
Research Aide (Economics)	V. Cueno	2
Research Aide (Economics)	C. Maranan	6
Research Aide (Economics)	L. Ebron	6
Research Aide (Economics)	F. Juarez	6
Research Aide (Economics)	E. Escover	6
Research Aide (Economics)	G. Villaruel	6
Draftsman	M. Diestro	4
Draftsman	F. Jalotjot	6
Draftsman	Open	0
Secretary	E. Co	0.5
Secretary	A. Martinez	2
Secretary	E. Manalo	5.5
Secretary	C. Jizmundo	6
Shop Foreman	E. Dungo	6
Machinist	A. Dizon	6
Machinist	Z. Borja	6
Tinsmith	R. Santos	6
Tinsmith	C. Flojo	6
Welder	A. Barot	6
Shop Mechanic	M. Macatangay	6
Shop Mechanic	R. Dignadice	6
Shop Mechanic	P. de Mesa	6
Shop Mechanic	A. Camacho	6

Mechanic Helper	M. Fabellar	6
Mechanic Helper	M. Salac	6
Mechanic Helper	M. Castro	6
Mechanic Helper	E. Macatangay	6
Laborer	L. Villegas	6
Laborer	R. Capule	6
Laborer	N. Silab	6

Table 1. Accuracy test of granule applicators to give an output of 160 kg of material per hectare (130 kg urea + 30 kg furadan), IRRI, 1975.

ANOV for output (kg/ha)

Source of variation	df	MS	F
Total	39		
Machines	1	6.7733	1
Mixture	3	12384.7269	241.33**
Machine x mixture	3	70.6359	1.38^{ns}
Error	32	51.3195	

CV = 4.5%

Table of means for output (kg/ha

Mixture	Machine no.		Mixture means[a]
	8	9	
A	147.13	142.26	144.69 c
B	163.95	159.67	161.81 b
C	208.71	207.87	208.29a
D	122.81	129.50	126.15 d

a/Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 2. Accuracy of granule applicator metering device (roller dia = 1.35"; 46% urea of bigger particle sizes carbofuran 3% a.i. granule) using A & B mixtures. Engineering, IRRI, July 29, 1975.

Machine No.	8				9			
Rate/ha - Hole size	160-11/32"		100-19/64"		160-11/32"		100-19/64"	
Mixture A Trials	$g/3m^2$ [a]	kg/ha	$g/3m^2$	kg/ha	$g/3m^2$	kg/ha	$g/3m^2$	kg/ha
1	42.00	140.00	27.20	90.67	43.64	145.47	27.88	92.93
2	42.94	143.13	27.23	90.77	42.00	140.00	28.80	96.00
3	48.82	162.73	28.95	96.50	43.70	145.67	28.59	95.30
4	41.88	139.6	28.08	93.60	42.32	141.07	28.51	95.03
5	45.05	150.17	28.03	93.43	41.72	139.07	28.24	94.17
6	45.15	150.5	30.15	100.50	41.67	138.90	27.60	92.00
7	41.95	139.83	31.45	104.83	41.57	138.57	27.27	90.90
8	42.33	141.10	30.94	102.00	41.14	137.13	27.64	92.13
9	43.84	146.13	30.60	102.00	42.15	140.50	27.34	91.13
10	45.14	150.47	31.18	103.93	41.27	137.57	27.51	91.70
11	42.57	141.90	30.49	101.63	40.38	134.60	27.39	91.30
12	40.24	134.13	31.35	104.50	41.12	137.07	29.06	96.87
13	40.07	133.57	30.32	101.67	42.07	140.23	29.67	98.90
14	46.72	155.13	31.49	104.97	42.57	141.90	29.94	99.80
Rate + Average - Deviation	160	+ 2.73 - 17.21	100	+ 2.89 - 7.01	160	+ 0 - 18.81	100	+ 0 - 5.84
Ave. rate kg/ha	156		99.36		141		94.15	
Mixture B								
1	46.70	155.67	35.37	117.90	46.53	155.10	37.19	123.97
2	47.66	158.87	38.48	128.27	48.90	163.00	34.84	116.13
3	52.96	176.53	34.74	115.8	48.44	161.47	32.47	108.23
4	47.85	159.50	40.51	135.03	45.98	153.27	38.70	129.00
5	50.75	169.17	39.17	130.57	49.66	165.53	35.65	118.83
6	45.46	151.53	35.47	118.23	51.18	170.60	34.62	115.40
7	51.55	171.83	32.27	107.57	49.22	164.07	36.15	120.50
8	48.79	162.63	32.43	108.10	46.61	155.37	37.21	124.03
9	52.50	175.00	32.93	109.77	48.14	160.47	30.97	103.23
10	47.71	159.03	34.17	113.90	47.28	157.60	32.60	108.67
Rate + Average - Deviation	160	+ 11.03 - 3.08	100	+ 15.45 - 0.00	160	+ 4.19 - 3.65	100	+ 16.80 - 0.00
Ave. rate kg/ha	164		115		160		117	

[a] $g/3m^2$ = output per 12 linear distance travelled by the applicator in the field.
roller to hole clearance = 1/16".

Table 3. Total range of deviation and average output considering both the difference of A and B mixtures and difference of machines No. 8 and 9, using 160 kg/ha and 100 kg/ha rates of application.

Rate	Deviation kg/ha	Average output range kg/ha
1) 160 kg/ha (130 kg urea + 30 kg furadan 3%)	+ 11.03 - 18.81	141 to 164
2) 100 kg/ha	+ 16.80 - 7.01	94 to 117

Table 4. Specifications and cost of materials of five solar collectors.[a/]

Collector panel	Materials	Cost/m² ₱	Description of reflector surface
A. "Accordion" wire mesh with 32 folds	Cardboard Aluminum wire mesh PVC plastic sheet Black & white flat wall enamel	30	Black-painted 1/4" aluminum wire mesh folded 32 times across air passage
B. "Dovehole" cardboard box	Cardboard PVC plastic sheet Black & white flat wall enamel	18.83	Black-painted cardboard designed to form zigzag air passage
C. Corrugated G.I. sheet	Cardboard G.I. sheet PVC plastic sheet Black & white flat wall enamel	23.00	Black-painted G.I. sheet with 2" air passage above and below it.
D. "Accordion" wire mesh with 8 folds	Cardboard Aluminum wire mesh PVC plastic sheet Black & white flat wall enamel	21.33	Black-painted 1/4" aluminum wire mesh folded 8 times across air passage
E. Corrugated cardboard	Cardboard G.I. sheet brace Black & white flat wall enamel	19.50	Black-painted cardboard with corrugations exposed

a/The five different collectors have identical dimensions (4"x4"x8").

b/US$1 = ₱7.00

Table 5. Comparative evaluation of five types of solar panels,[a] Engineering Dept., IRRI, 1975.

Solar panel	Solar radiation cal/cm^2	Ambient temperature ^oF (T_1)	Output[b] ^oF (T_2)	Air flow lb_m/h	Heat gain BTU/h	Solar panel potential BTU/h	Efficiency %
A	1.68	93.38	141.26	349.89	4020.66	11958.45	33.62
B	1.37	91.67	130.46	358.10	3333.77	9694.13	34.39
C	1.33	93.53	125.97	362.71	2823.91	9411.09	30.01
D	1.34	97.67	126.16	338.70	2315.90	9481.85	24.42
E	1.38	99.05	124.61	340.77	2090.42	9764.56	21.41

a/All panels were of the same size, 4'x8'x4'.

b/Includes warm air from biower which raised the T_2 not more than 1^oF.

Table 6. Comparative performance of thresher types.

Items	Thresher type**				
	I	II	III	IV	V
Operating speed, rpm					
Threshing drum 1	1200	900	900	520	750
Threshing drum 2	-	1200	1200	-	-
Blower	-	1400	1400	1000	700
Auger	-	1200	1200	270	400
Separator	-	250	250	17	200
Horsepower rating, hp	3	8	11	7	65-80
Crop condition					
Grain moisture content, %	23	23	21.3	20	20
Material length, cm	35	35	35	38	40
Grain-straw ratio	0.65	0.49	0.53	0.53	0.49
Labor requirement	4	6	7	4	8
Men feeding	1	1	1	1	3
Men handling	3	5	6	3	2
Others (tractor operator, collector, checker)	-	-	-	-	3
Test duration, min	-	3.75	12.13	6.25	3
Output, kg/test (total)	44	60.58	68.52	97.53	122.50
kg/h	704	249.65	1148.38	936.36	2449.4
Labor output, kg/man-h	176	49.9	164	234.09	306.18
Capacity, kg/hp-h	234.6	27.24	104.40	105.19	33.78
Unthreshed loss, kg/test	7.49	.787	2.26	.195	1.28
Unthreshed loss, percent	17	1.3	3.3	0.2	0.98
Separation loss, kg/test	24.85	9.25	2.74	2.6	3.84
Separation loss, percent	56	15.27	4.0	2.67	3.14
Blower loss, kg/test	-	13.93	26.03	1.5	-
Blower loss, percent	-	23	38	1.54	-
Purity, percent	92.1	98.1	98.3	97.4	99.5

**Threshers tested were all throw-in feeding.

Table 7. Depth of compacted soil layer with four different power sources for land preparation on continuously cropped wetland during four successive cropping seasons.

	Treatment[a/]							
	T_1		T_2		T_3		T_4	
Penetrometer pressure (kg/sq m)	2.46	4.92	2.46	4.92	2.46	4.92	2.46	4.92
	Pan depth in cm*							
Cropping season								
1973								
1st (wet) Before land preparation	7.3	10.9	9.0	14.1	12.5	18.4	9.1	13.6
1st (wet) After land preparation	11.1	14.9	11.9	16.2	19.9	23.6	10.7	23.1
2nd (dry) Before land preparation	10.5	14.1	12.8	17.0	18.7	23.1	19.7	22.3
2nd (dry) After land preparation	12.5	14.9	12.6	16.5	21.1	24.1	25.5	26.9
1974								
3rd (wet) Before land preparation	14.4	18.0	13.1	17.2	20.6	24.3	24.0	26.4
3rd (wet) After land preparation	15.4	19.0	14.1	18.6	23.4	25.3	31.7	33.9
4th (dry) Before land preparation	15.5	18.6	13.5	17.9	20.9	23.7	28.2	30.7
4th (dry) After land preparation	16.3	19.1	14.3	18.7	23.3	25.6	32.0	34.9

a/
T_1 -- Water buffalo, 452 kg approximately.
T_2 -- 5-7 hp single-axle tiller , 50 kg.
T_3 -- 10 hp tiller with separate rotary tiller, 145 kg.
T_4 -- Large four-wheel tractor (67 hp), 4400 kg.

* Mean of 13 readings taken at different locations within the plot.

Table 8. Summary data for 100 farmers in two upland villages, Philippines, 1975.

	Cale Batangas	Perez Laguna	Total	Average
No. of farmer-respondents	50	50	100	50
Farm size (ha)	0.55	0.99	1.54	.0.72
Area cultivated/farmer (ha)	1.92	2.13	4.05	2.02
No. of parcels/farmer	3.5	2.2	5.6	2.8
No. of years in farming	26	24	50	25
No. of crops grown/year	7	3	10	5
Size of household	6.0	6.7	12.8	6.4
No. of animal users	47	49	96	48
No. of tractor users	3	1	4	2
No. of draft animals				
Cow	45	29	74	37
Carabao	1	24	25	12.5

Table 9. Cost analysis for IRRI 5-7 hp power tiller at alternative initial investment levels.

Items	4000	5000	6000	7000
	Initial investment			
	Fixed costs (₱)			
Depreciation[a/]	600	750	900	1050
Repair & maintenance[b/]	400	500	600	700
Interest on investment[c/]	264	350	396	462
Total fixed cost/h[f/]	2.53	3.16	3.79	4.42
Total fixed cost/day	20.24	25.28	30.32	35.36
Total fixed cost/year	1264.00	1580.00	1896.00	2212.00
	Variable costs (₱)			
Fuel & lubricants[d/]				
Gasoline		3.12		
Motor oil		0.51		
Labor[e/]		1.00		
Total variable cost/h		4.63		
Total variable cost/day		37.04		
Total variable cost/yr[f/]		2315.00		
Average total cost (₱)				
Per hour[f/]	7.16	7.79	8.42	9.05
Per day	57.28	63.32	67.36	72.40
Per year	3579.00	3895.00	4211.00	4527.00
Per ha[g/]	171.84	186.96	202.08	217.20
Custom rate (₱)				
Hourly	10.00	10.00	10.00	10.00
Daily	80.00	80.00	80.00	80.00
Per ha	240.00	240.00	240.00	240.00

Assumptions:

a/Depreciation - straight-line basis with 10% salvage value and machine life estimated at 6 years.

b/Annual repair & maintenance - 10% of initial acquisition cost.

c/Interest on investment - 12% on average balance over life of machine.

d/Fuel & lubricants: Gasoline - 2.5 liter/h @ ₱1.25/liter.
SAE 30 (engine oil) - 1.3 liter/application every 25 hours of use.
SAE 30 (transmission oil) - 1.0 liter/application, both at ₱5.50/liter

e/Man-hours - 1 person working 8 h/day; wage rate - ₱8/day.

f/Annual use - 500 h/yr and 8 h/day.

g/Custom rate - ₱80/day; 3 days/ha.
Field capacity - plowing wet soil - 1 day/ha (1 pass).
harrowing flooded soil - 2 days/ha (2 passes).

Table 10. Cost analysis for IRRI axial flow thresher using alternative initial investment costs.

Item	I	II	III	IV
Investment cost, ₱	7,000	9,000	11,000	13,000
		Fixed costs		
Depreciation[a]	1166.70	1500.00	1833.30	2166.70
Repairs & maintenance[b]	700.00	900.00	1100.00	1300.00
Interest on investment[c]	420.00	540.00	660.00	780.00
Total fixed cost, ₱/year	2286.70	2940.00	3593.30	4246.70
		Variable costs		
Fuel & lubricant[d]		1.66		
Gasoline		1.50		
Grease		0.05		
Motor oil SAE 30		0.11		
Labor[e]		3.00		
Total variable cost, ₱/h		4.66		

Assumptions:

a/ Depreciation -- calculated on straight-line basis with a 6-year machine life.

b/ Repairs & maintenance -- calculated as percentage of initial acquisition cost, 10% in present example.

c/ Interest on investment -- at 12% on average balance over life of machine.

d/ Fuel consumption -- gasoline - 1.3 liter/h @ ₱1.15/liter
motor oil SAE 30 - 1.3 liter/week @ ₱5.50/liter
grease - 1 lb/3 weeks @ ₱7.30/lb

e/ Three man-h/machine-h @ ₱8/8-h day per person.

f/ Price of paddy - ₱1/kg -- ₱1000/ton.

Table 11. Budget for IRRI batch-type dryer using alternative initial investment costs and heat sources.

Item	I	II	III	IV
Initial investment cost, P	3,000	4,000	5,000	6,000
		Fixed costs		
Depreciation[a/]	375	500	625	750
Repair & maintenance[b/]	300	400	500	600
Interest on capital investment[c/]	180	240	300	360
Fixed cost per year	855	1140	1425	1710
Fixed cost per hour[f/]	0.95	1.27	1.58	1.90
Fixed cost per ton[h/]	4.94	6.60	8.22	9.88
		Variable costs		
Fuel & lubricant[d/]			3.03	
Gasoline			0.92	
Kerosene			2.00	
(Rice hull)			(0.32)	
Motor oil			0.11	
Labor[e/]			1.00	
Total variable cost/h, with kerosene			4.03	
(with rice hull)			(2.35)	
Total variable cost/t, with kerosene			20.96	
(with rice hull)			(12.22)	
		Total average costs		
With kerosene, P/h	4.98	5.30	5.61	5.93
With rice hull, P/h	3.30	3.62	3.93	4.25
With kerosene, P/t	25.90	27.56	29.18	30.84
With rice hull, P/t	17.16	18.82	20.44	22.10

Assumptions:

a/ Depreciation -- computed on a straight-line basis; machine has 8-yr life.

b/ Repairs & maintenance -- calculated on yearly percentage of initial acquisition cost, 10% of initial investment cost.

c/ Interest on capital investment at 12% on average balance over life of machine.

d/ Fuel consumption: Gasoline - 0.75 liter/h @ ₱1.23/liter.
Kerosene - 2.0 liter/h @ ₱1/liter.
Rice hull - 4 kg/h @ ₱0.08/h (used as alternative to kerosene; cost incurred is ₱0.20/sack for transportation; 1 sack contains 10 kg).

Table 11 - cont.

Grease - negligible.
Motor oil - 1 liter/week @ ₱5.50/liter (6 days/week, 8 h/day or ₱0.11/h).

e/ Labor - 8.53 man-h/batch (1 MT paddy) @ ₱8/day.
Loading - 2 persons for 40 min.
Unloading - 2 persons for 60 min.
Tending the dryer - 1 person for 5.2 h.

f/ Annual use of dryer -- 9000 h/year.

g/ Capacity - 1 MT/batch.

h/ Drying rate - from 26% moisture content to 14% - 5.2 h.

Table 12. Utilization of mechanical threshers by region, 1973.

Item	Central Luzon	Southern Luzon	Camarines Sur	All
	Percent reporting			
Users or potential users of mechanical thresher	63	43	35	48
Non-user of mechanical thresher	10	39	41	29
No comment	27	18	24	23
Reasons for lack of interest in use of mechanical threshers:				
Job displacement for harvesters and threshers	30	21	25	24
Small farm size	10	18	27	21
Availability of harvest labor and tie-up of harvesting & threshing with other operations	-	4	35	18
Lack of capital	5	18	5	10
Dissatisfied with McCormick thresher	25	5	8	9
No reason given	30	34	-	18

Table 13. Regional distribution of sample rice mills by type and milling capacity, Philippines, 1973.

Mill type and capacity (tons/12 hours)	Central Luzon	Southern Luzon	Camarines Sur	All regions
Cono mill				
4.5 & below	10	10	10	30
5.0 - 8.5	10	10	10	30
9.0 & above	11	10	10	31
Sub-total	31	30	30	91
Kiskisan mill				
2.5 & below	10	12	10	32
3.0 - 4.0	13	10	11	34
4.5 & above	10	10	10	30
Sub-total	33	32	31	96
Total	64	62	61	187

Table 14. Type of rice mills used by 591 sample farmers in three regions of the Philippines, 1973.

Regions	Cono mill		Kiskisan mill[a/]		All mills	
Central Luzon	84	(40)[b/]	127	(60)	211	(100)
Southern Luzon	81	(43)	108	(57)	189	(100)
Camarines Sur	50	(26)	141	(74)	191	(100)
Total	215	(36)	376	(64)	591	(100)

a/Kiskisan refers to the Engleberg or steel huller type mill found in rural areas.

b/Figures in parentheses are percentage.

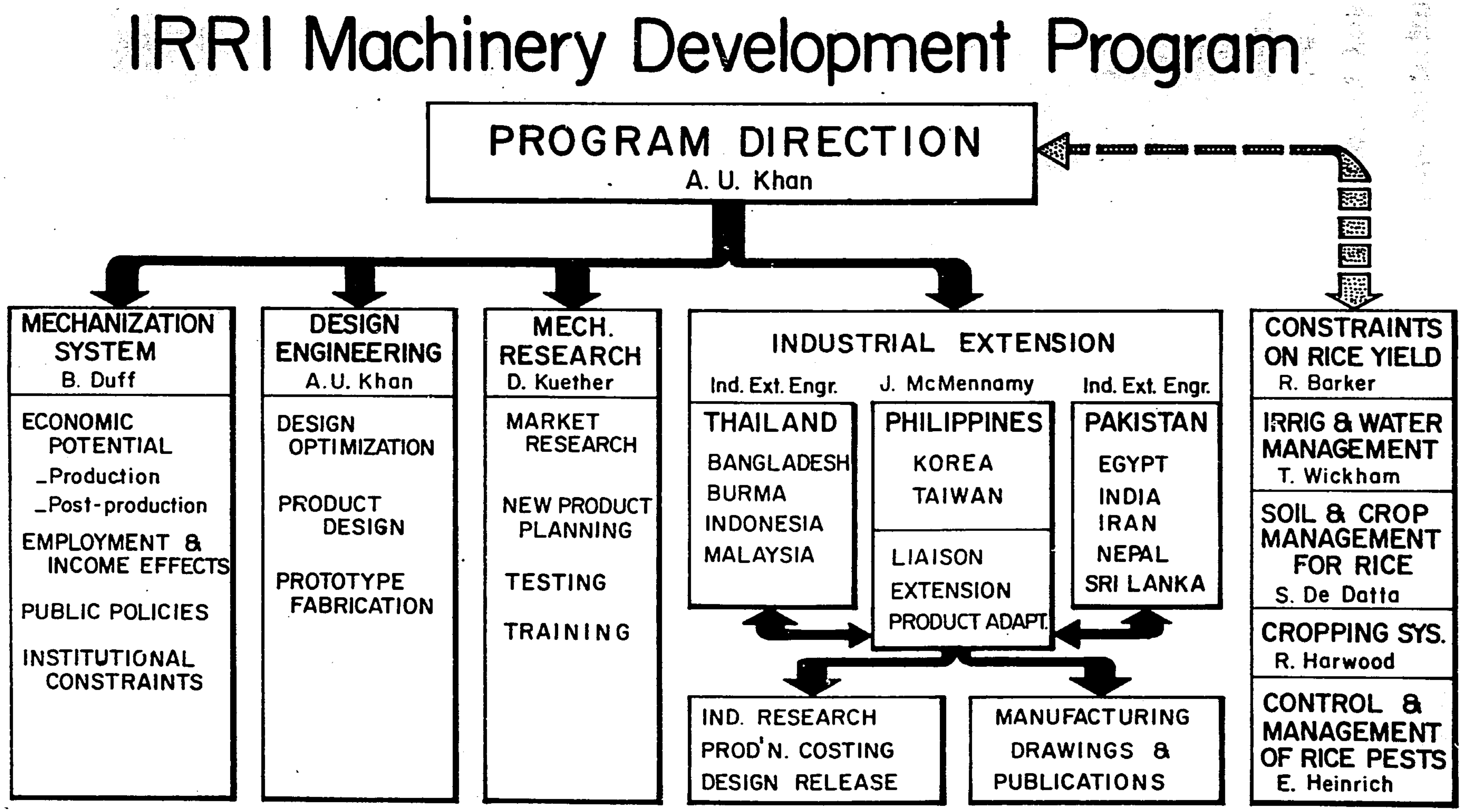


Fig. 1 Agricultural Engineering Department Organization.

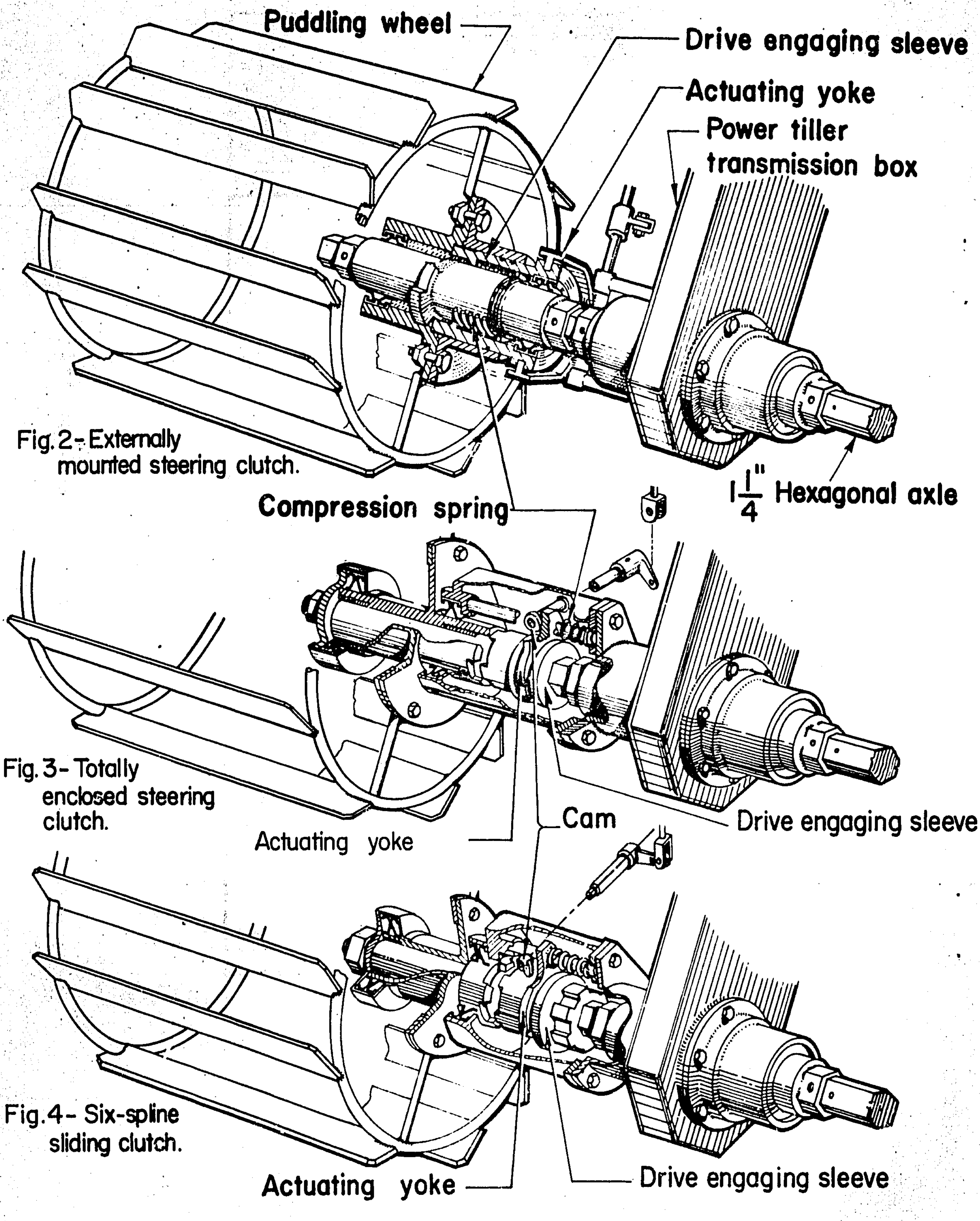


Fig. 2- Externally mounted steering clutch.

Fig. 3- Totally enclosed steering clutch.

Fig. 4- Six-spline sliding clutch.

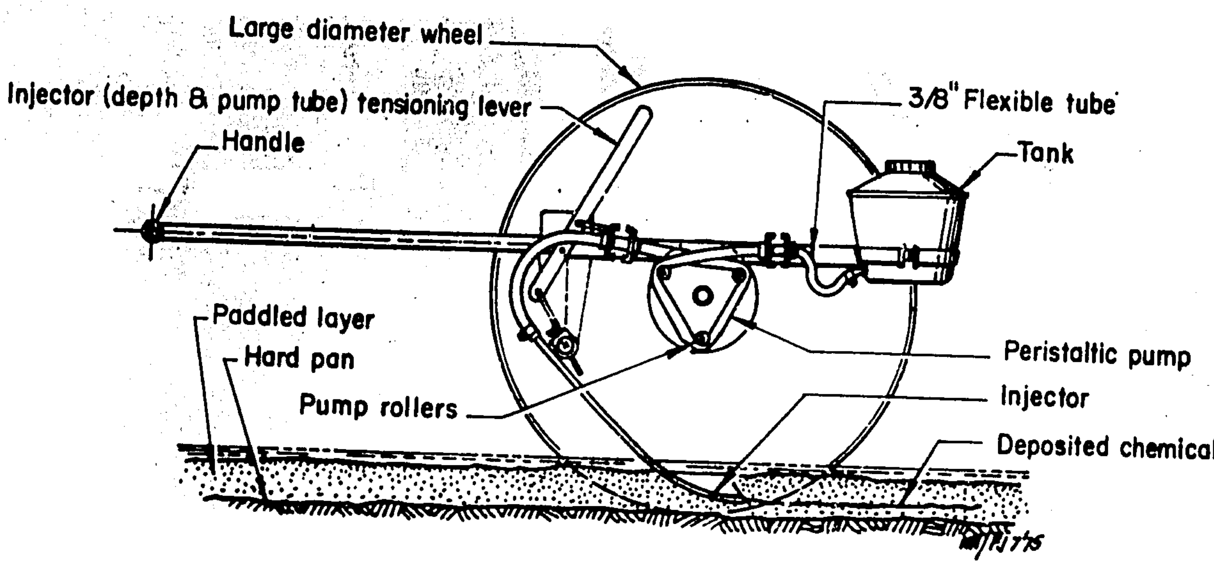


Fig. 5 Deep-placement liquid injector.

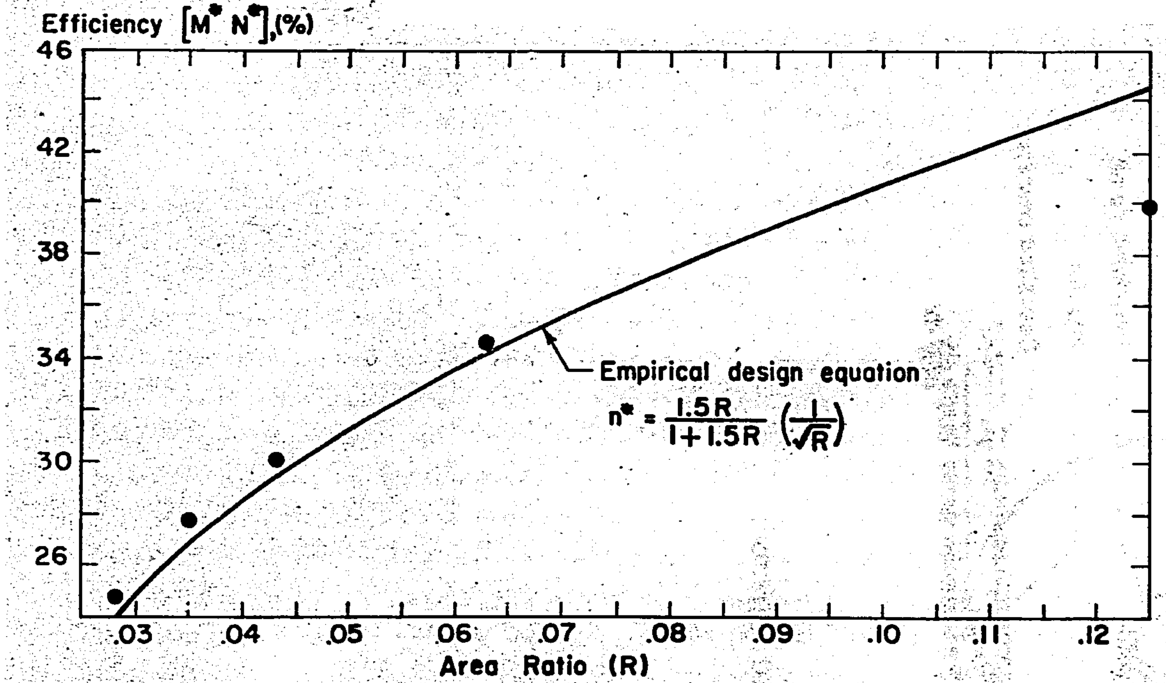


Fig. 6 Maximum performance efficiency of 5 jet pumps with different area ratios.

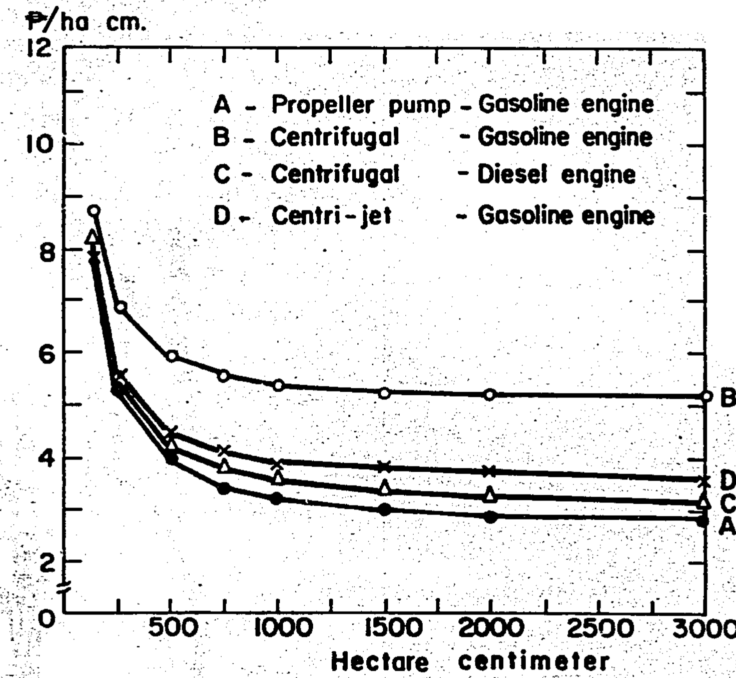


Fig. 7 Cost of lifting water with different pumping systems.

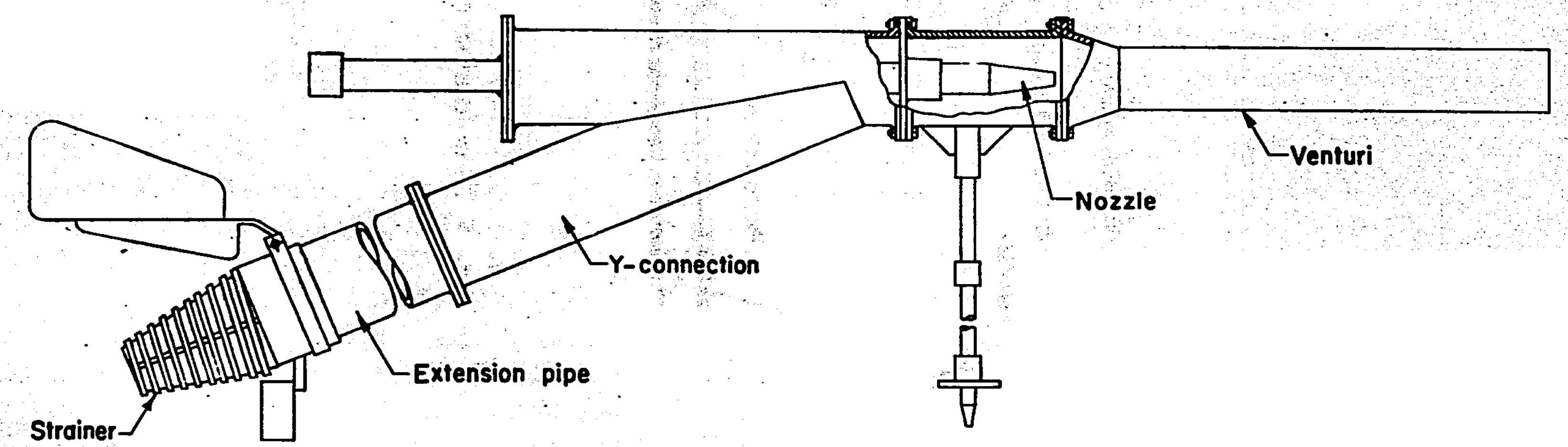


Fig. 8 Jet flow paddy pump

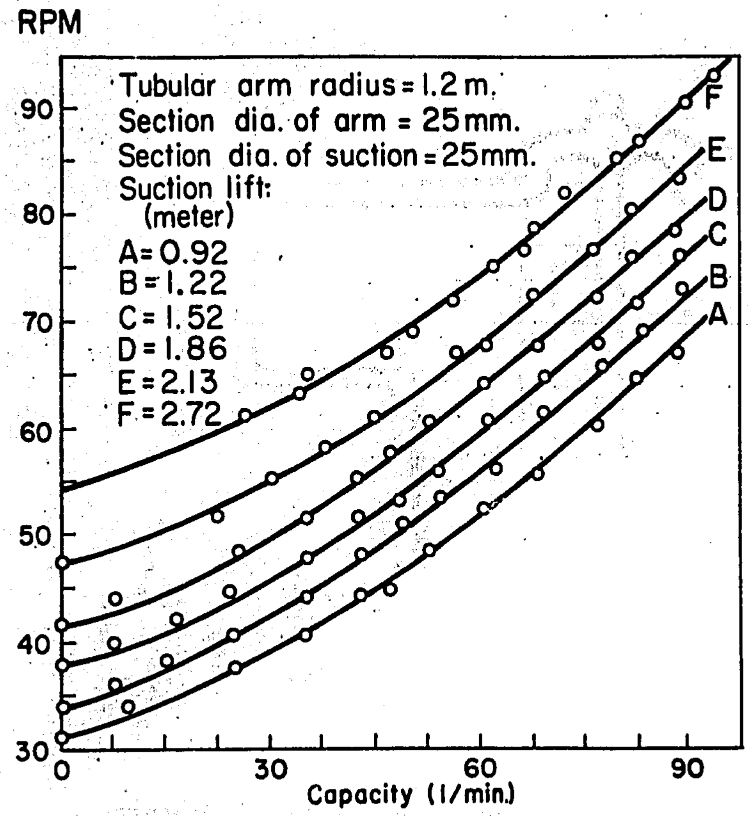


Fig.9 Tubular pump performance at different suction lift.

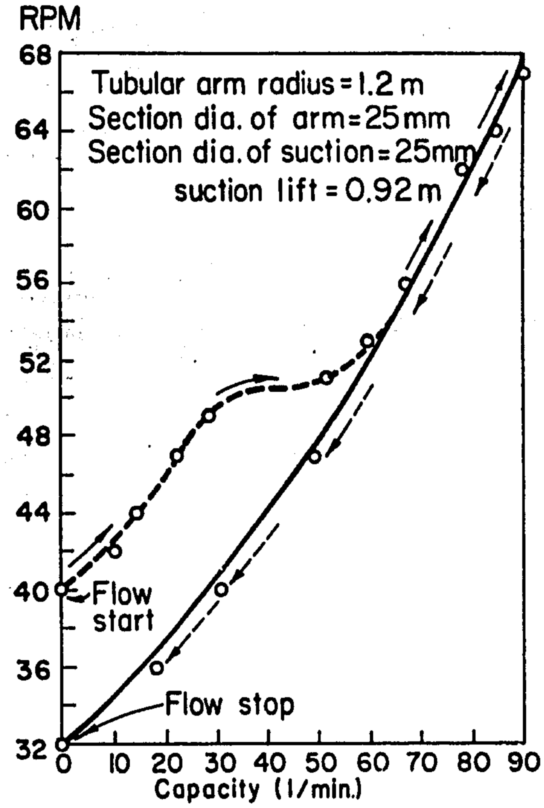


Fig.10 Tubular pump operating cycle.

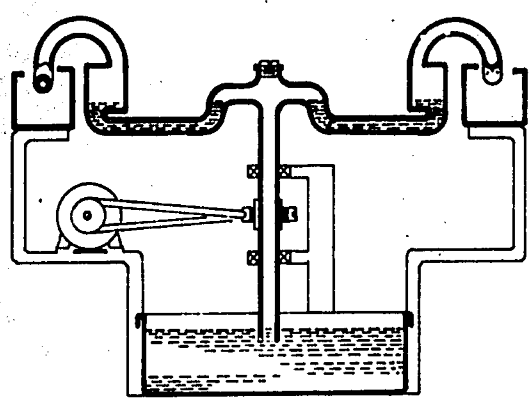


Fig11a. Pump at rest but primed.

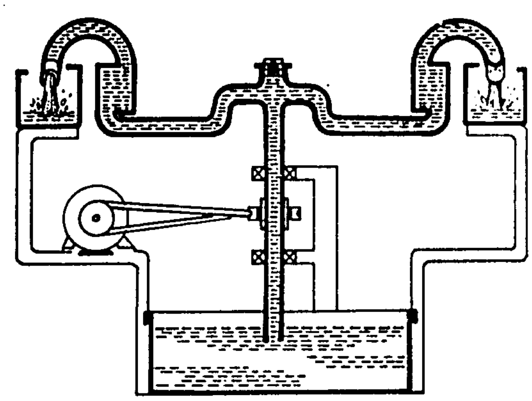


Fig11b. Pump operating above 48 rpm.

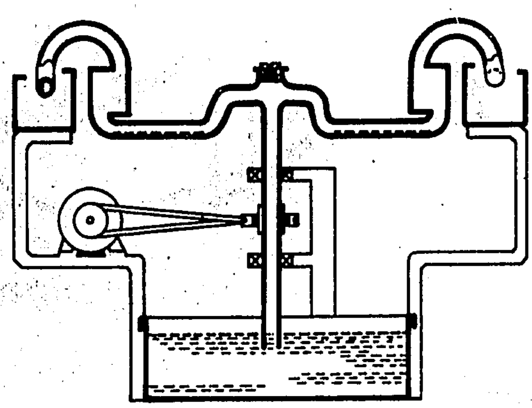


Fig11c. Pump stopped (prime lost) after operating above 48 rpm.

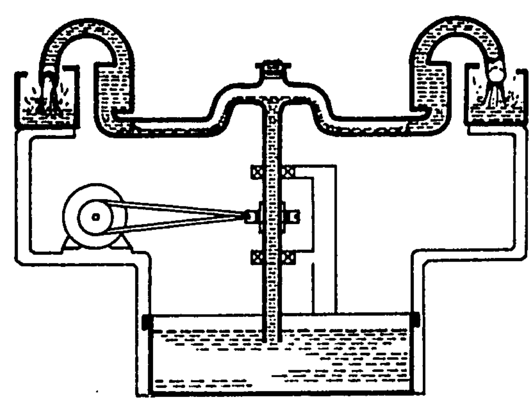


Fig11d. Pump operating below 48 rpm.

Fig. 11 Four operating conditions with tubular pump.

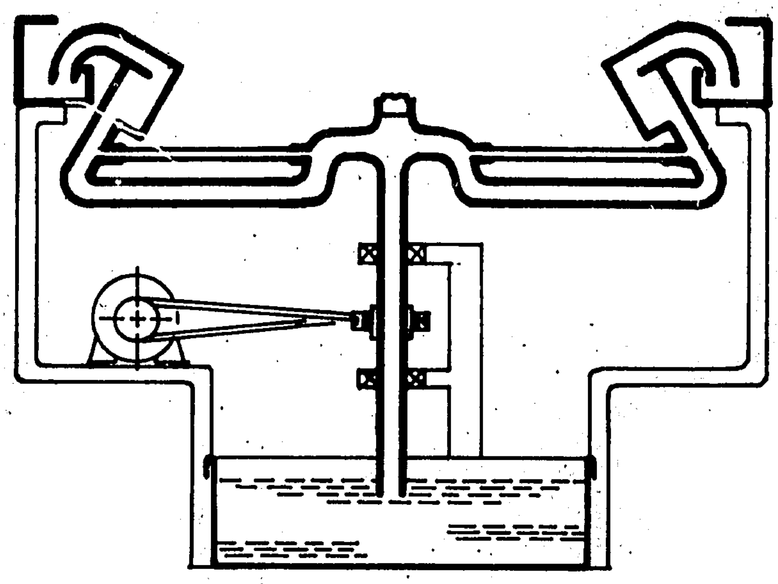


Fig. 12 Tubular pump with breather tubes.

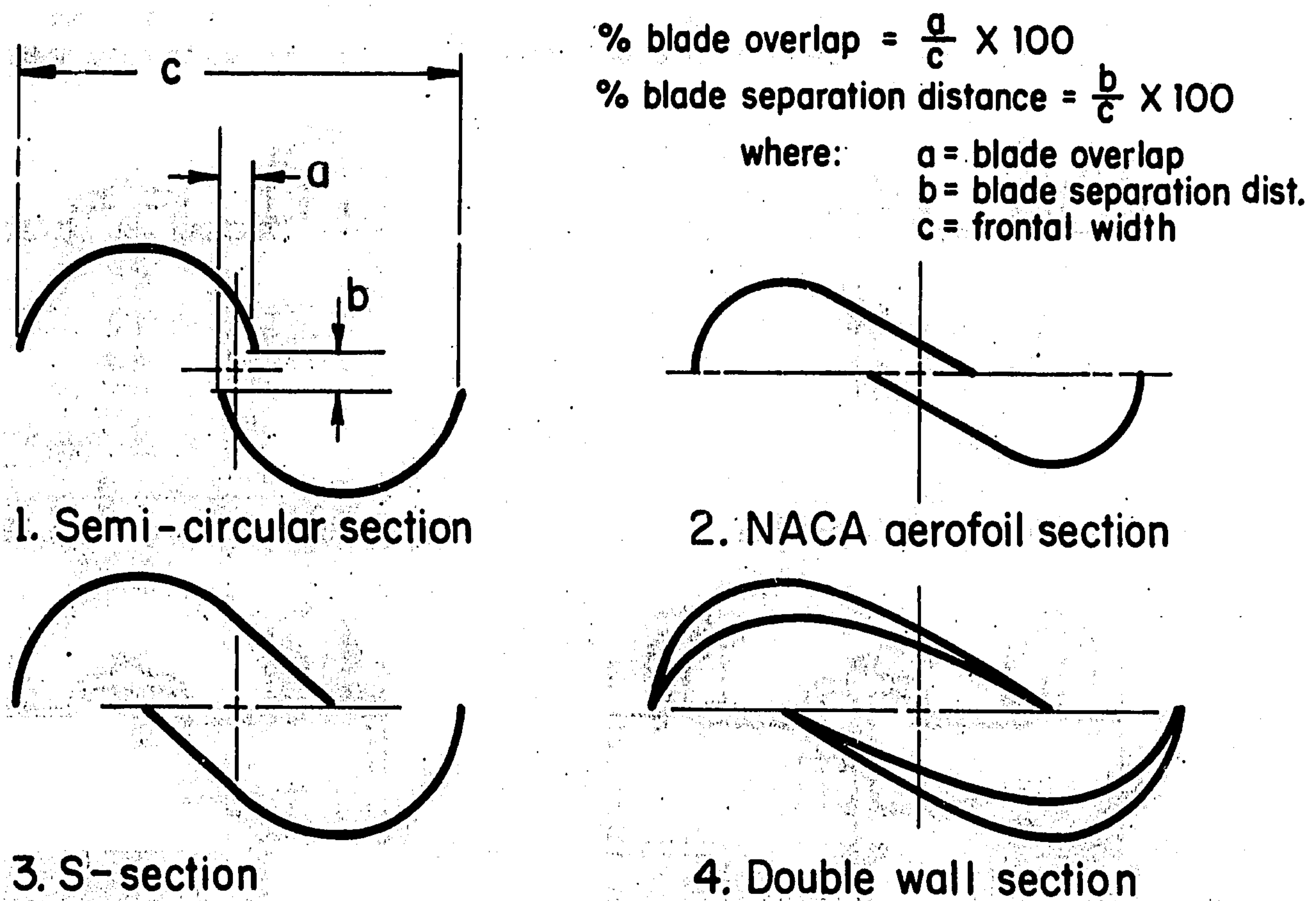


Fig. 13 Different Savonius rotor models.

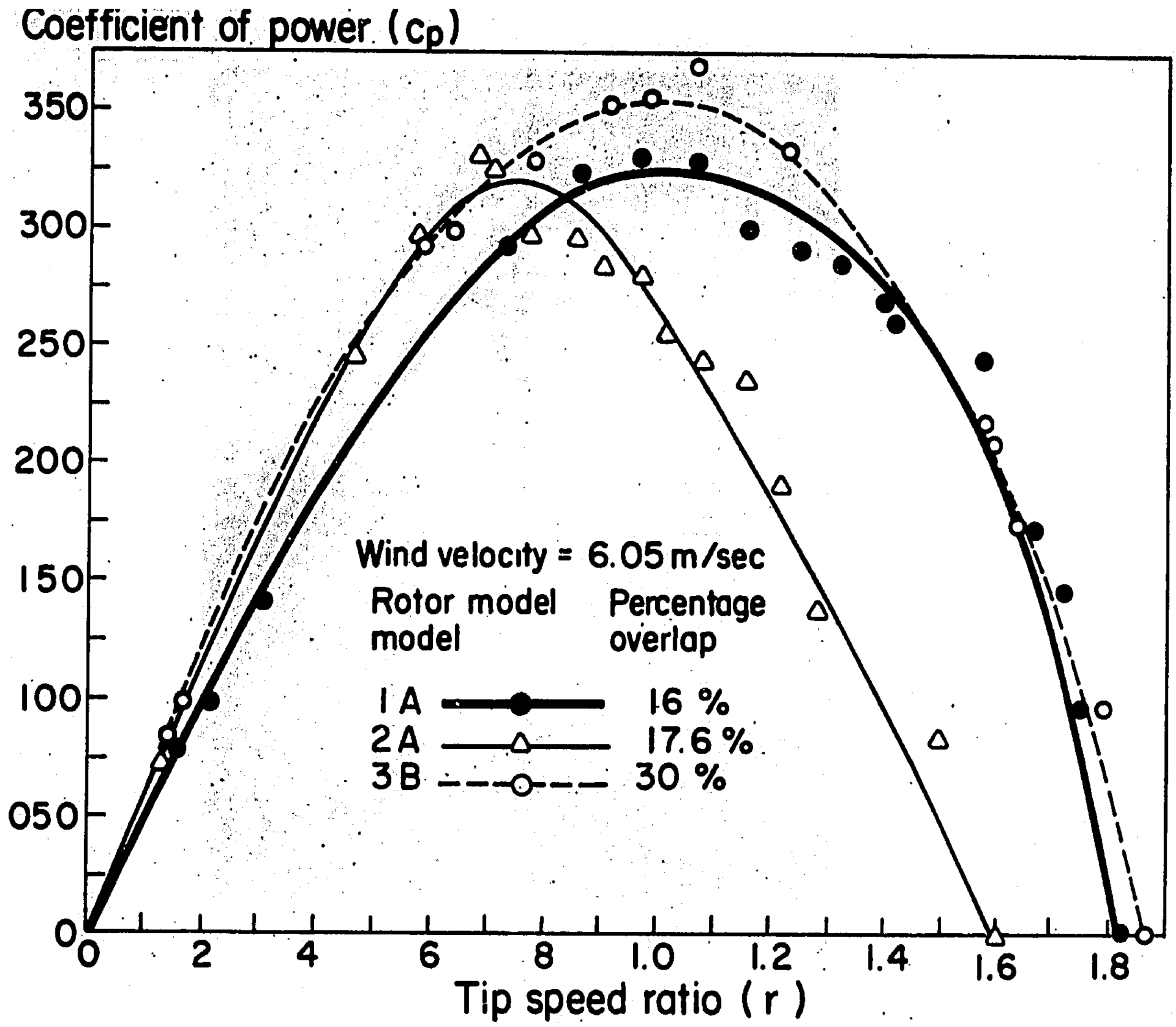


Fig. 14 Power coefficient profiles of different Savonius rotor models.

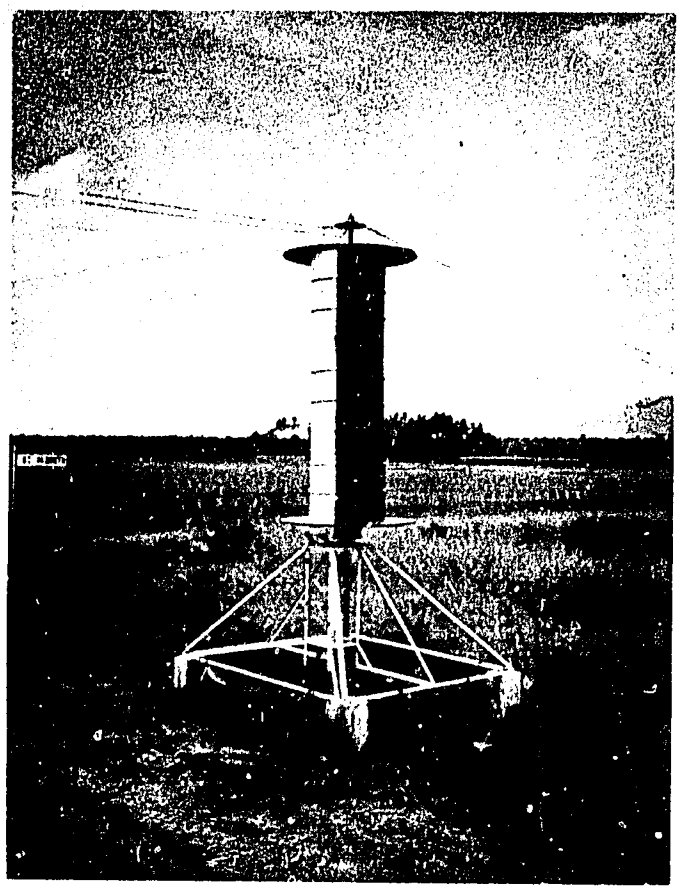


Fig. 15 Prototype Savonius rotor with tubular pump.

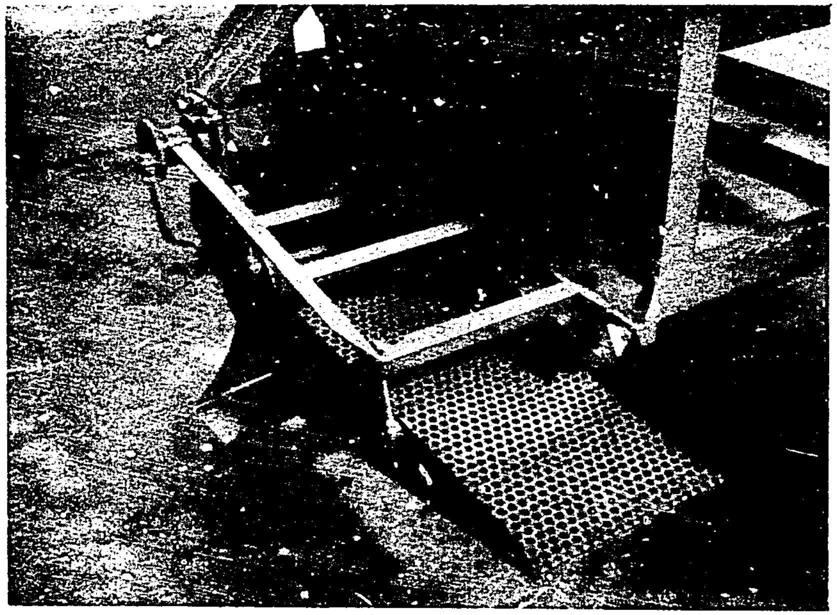


Fig. 16a Single oscillating screen.

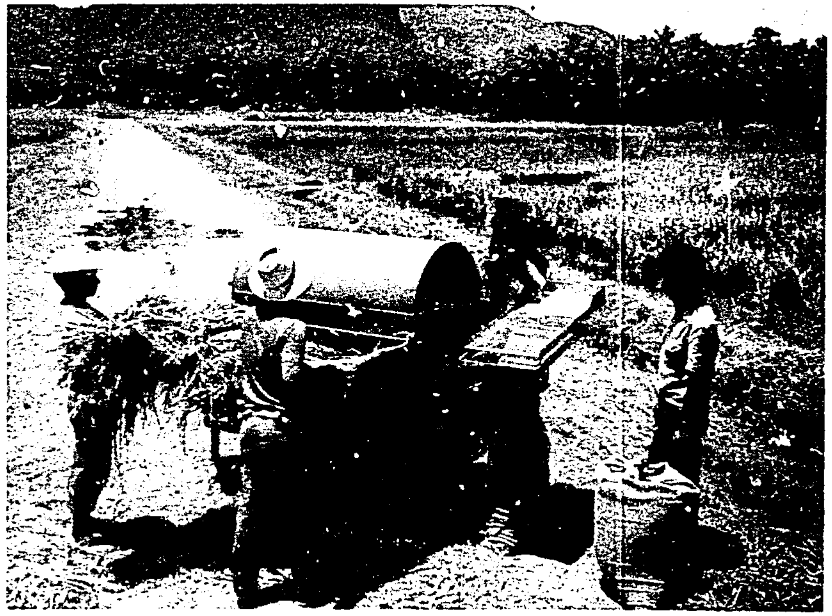


Fig. 16b Oscillating screen with bagger.

Fig. 16c Rotary screen with small oscillating screen.

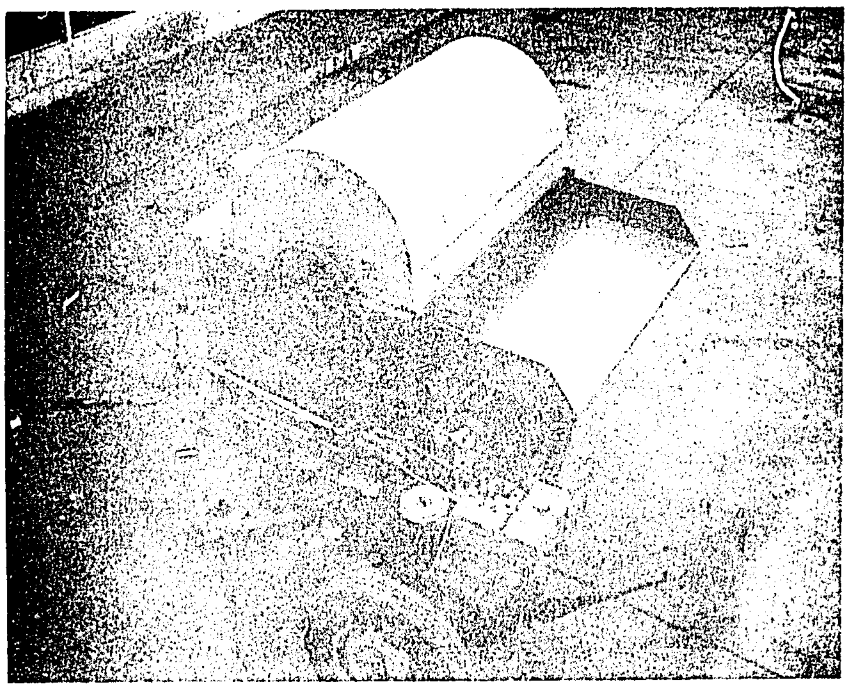


Fig. 17 Power tiller-thresher system.

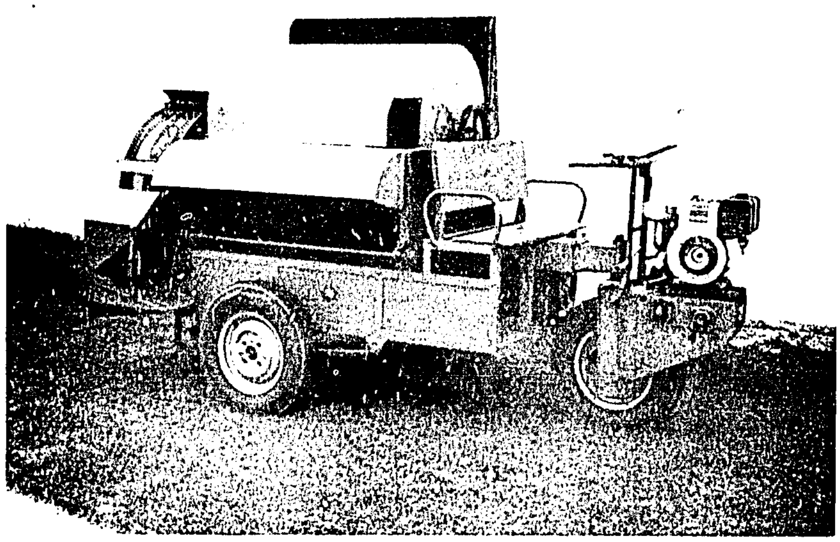


Fig. 18 Self-propelled thresher.

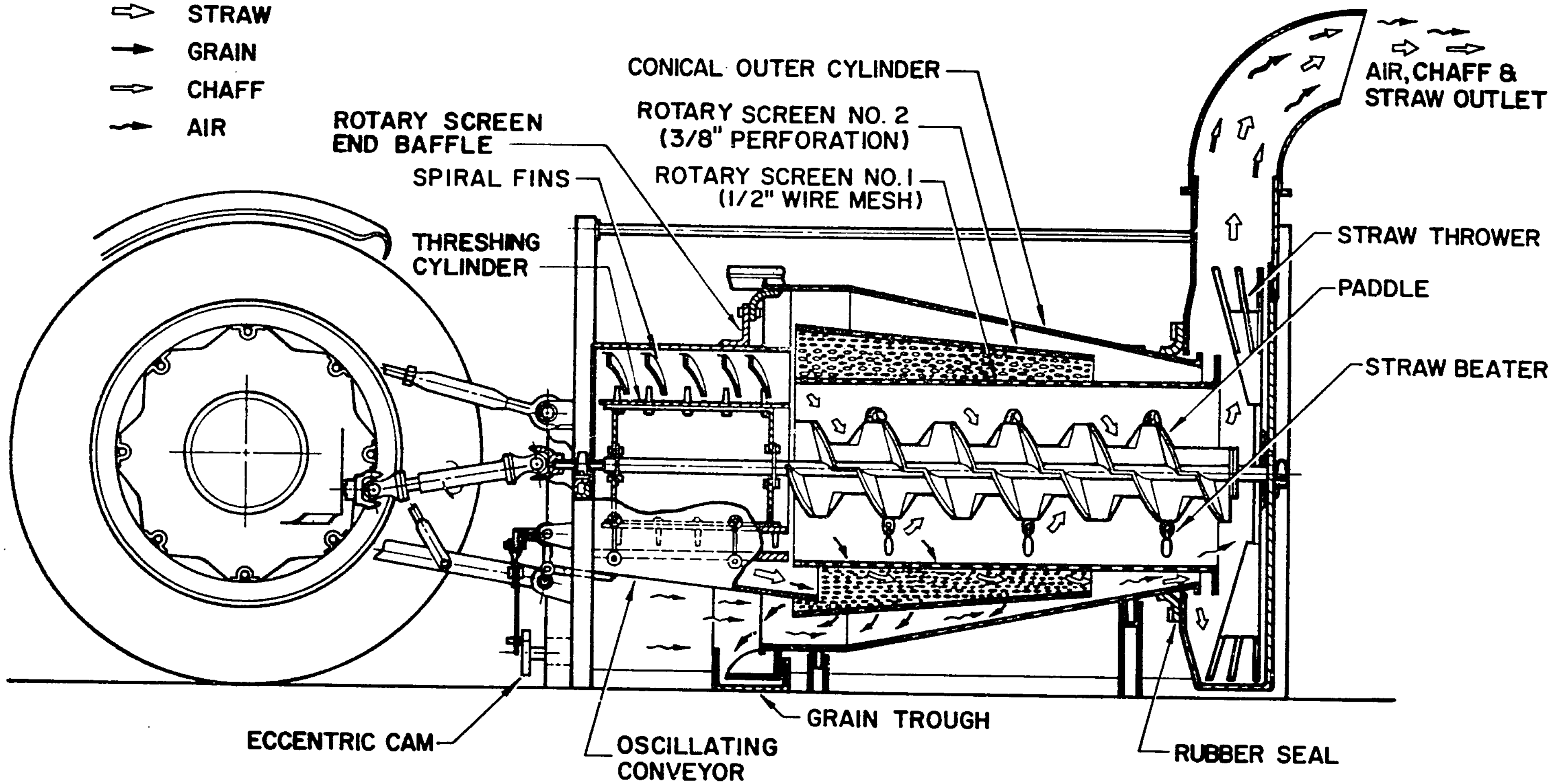


Fig. 19 Schematic drawing of modified tractor PTO-driven thresher.

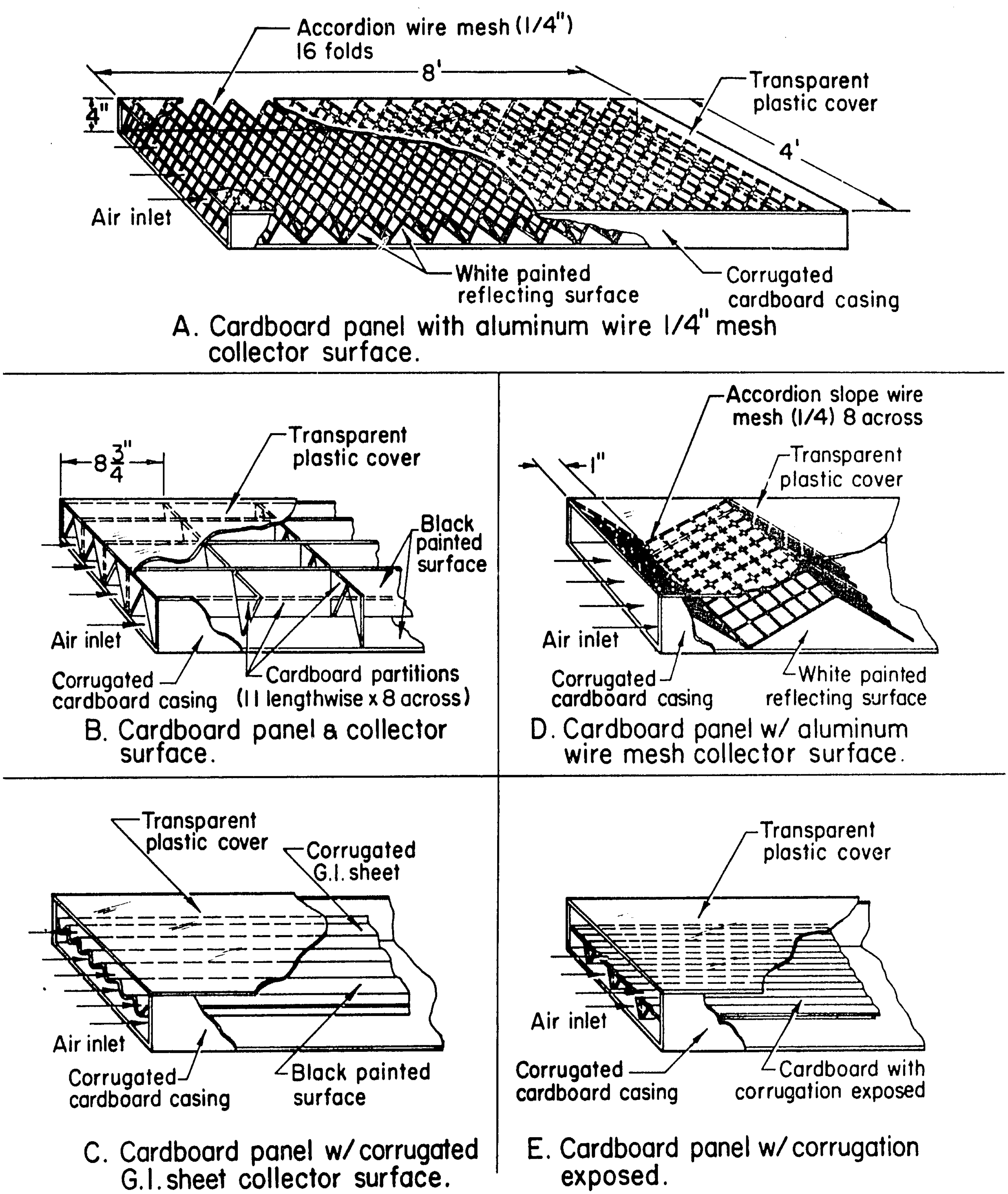


Fig. 20 Solar heat collectors.

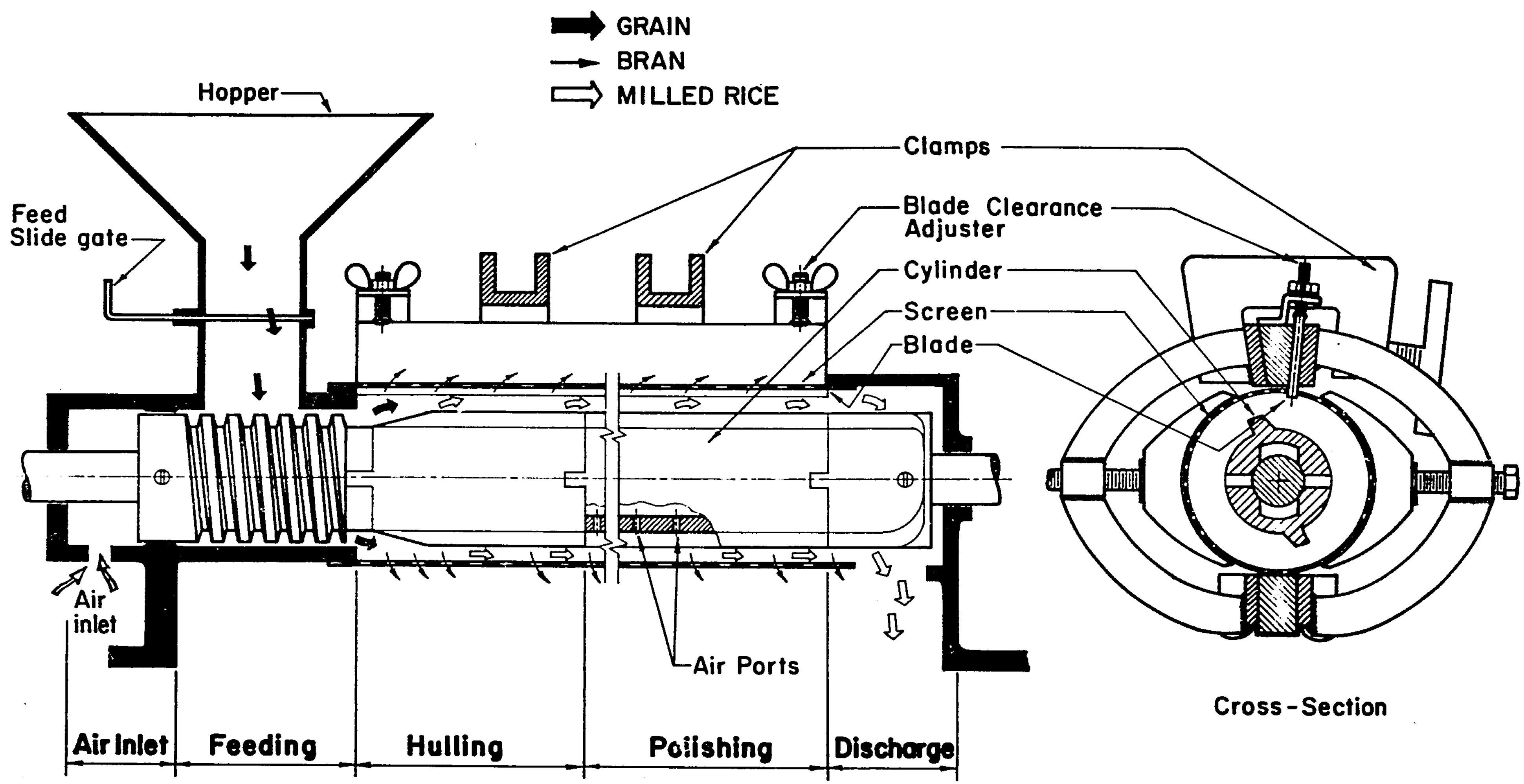


Fig. 21 Experimental single-pass rice mill.

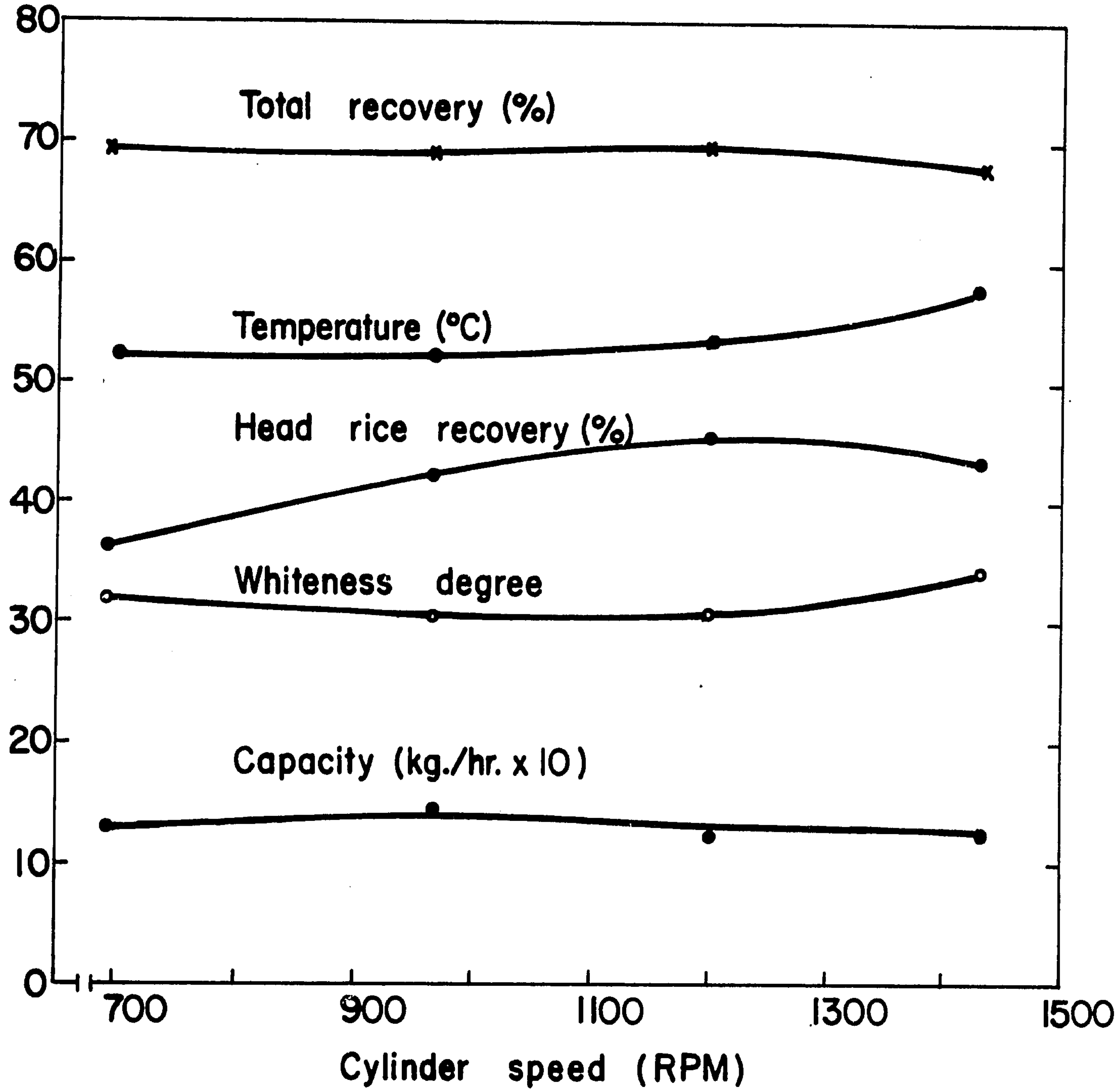


Fig. 22 Experimental single-pass rice mill performance using IR1561 paddy at different cylinder speeds.

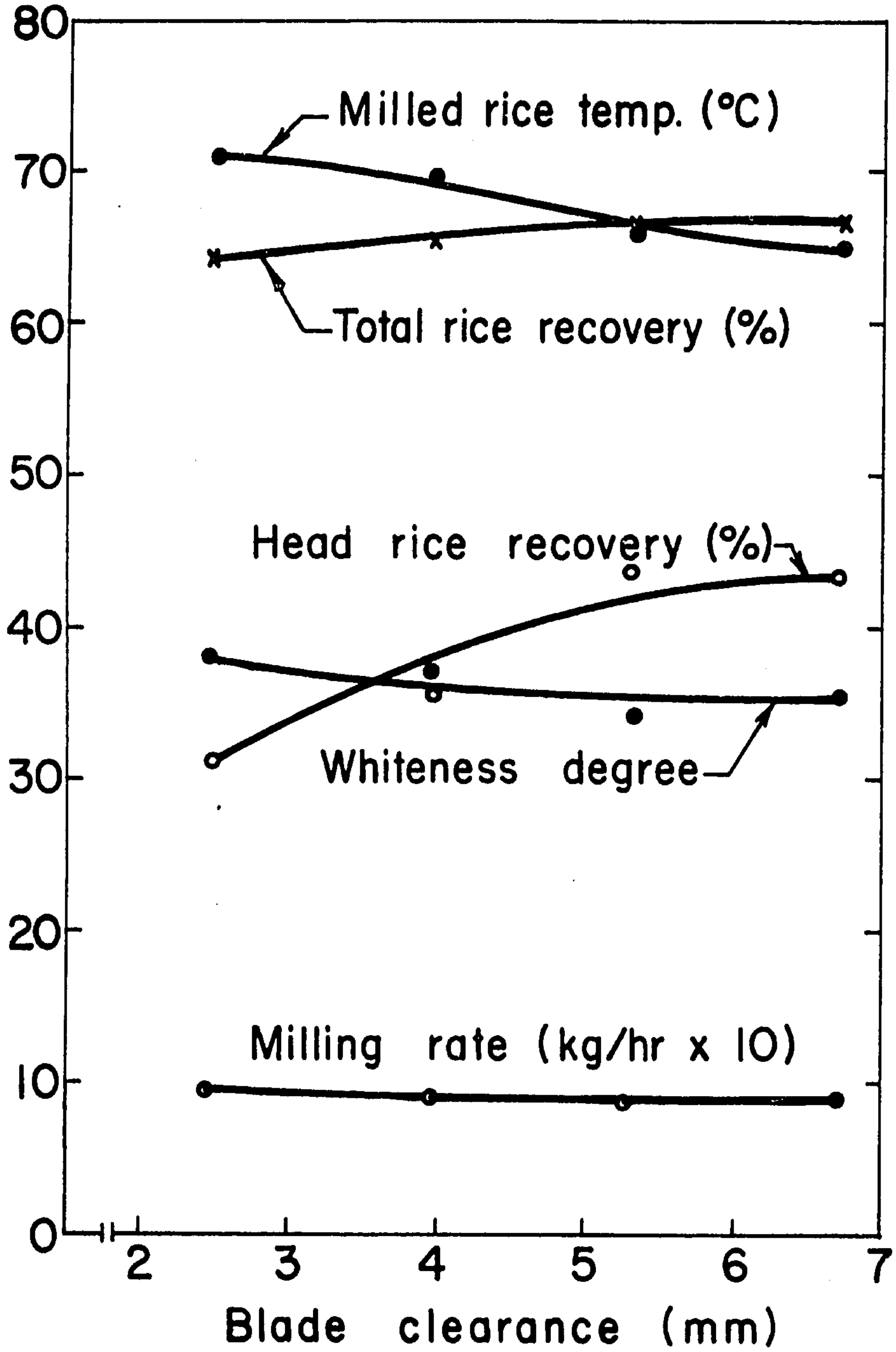


Fig. 23 Experimental single-pass rice mill performance using IR1561 paddy at different cylinder-blade clearances.

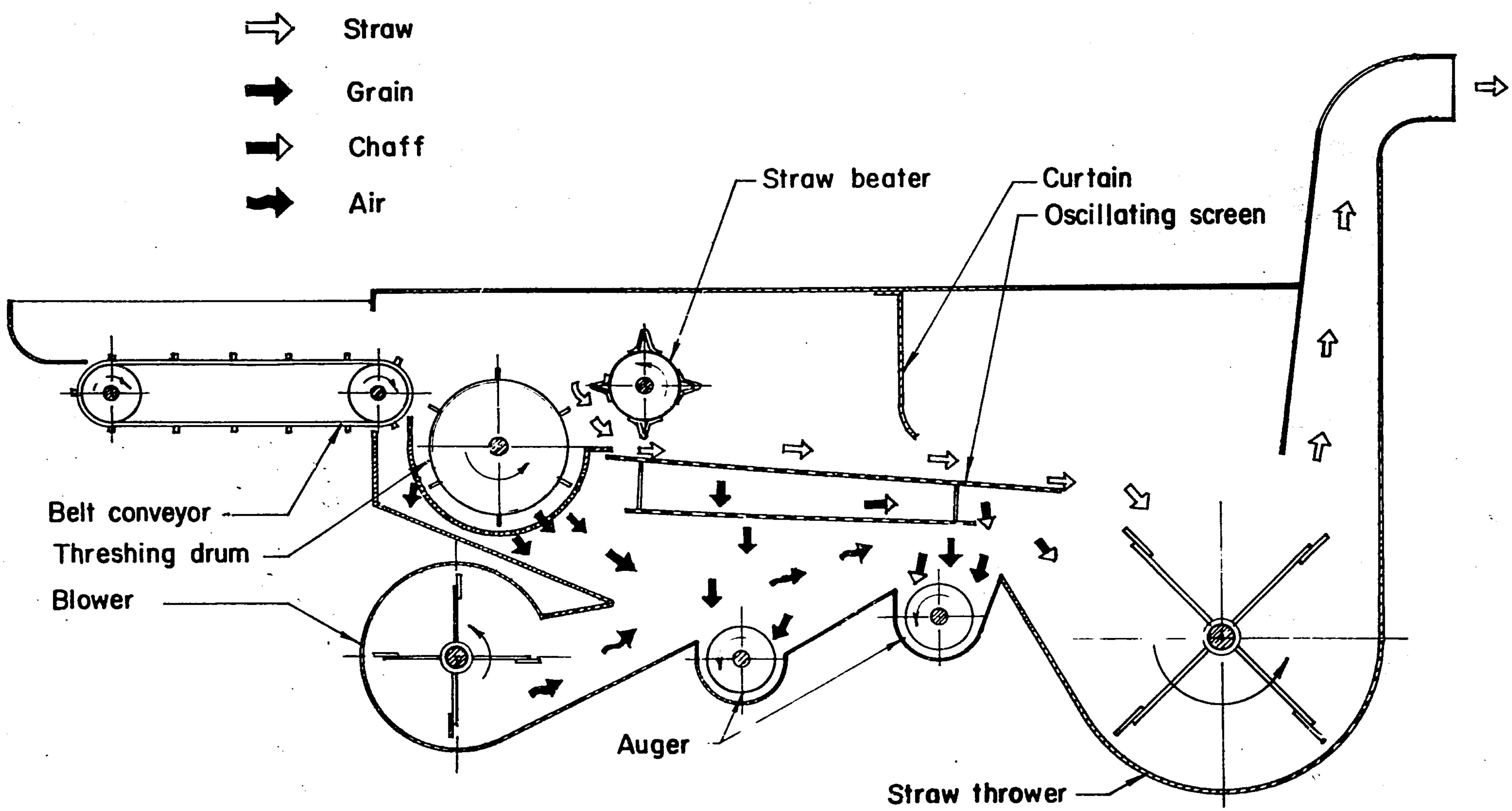


Fig. 24 Type V thresher.

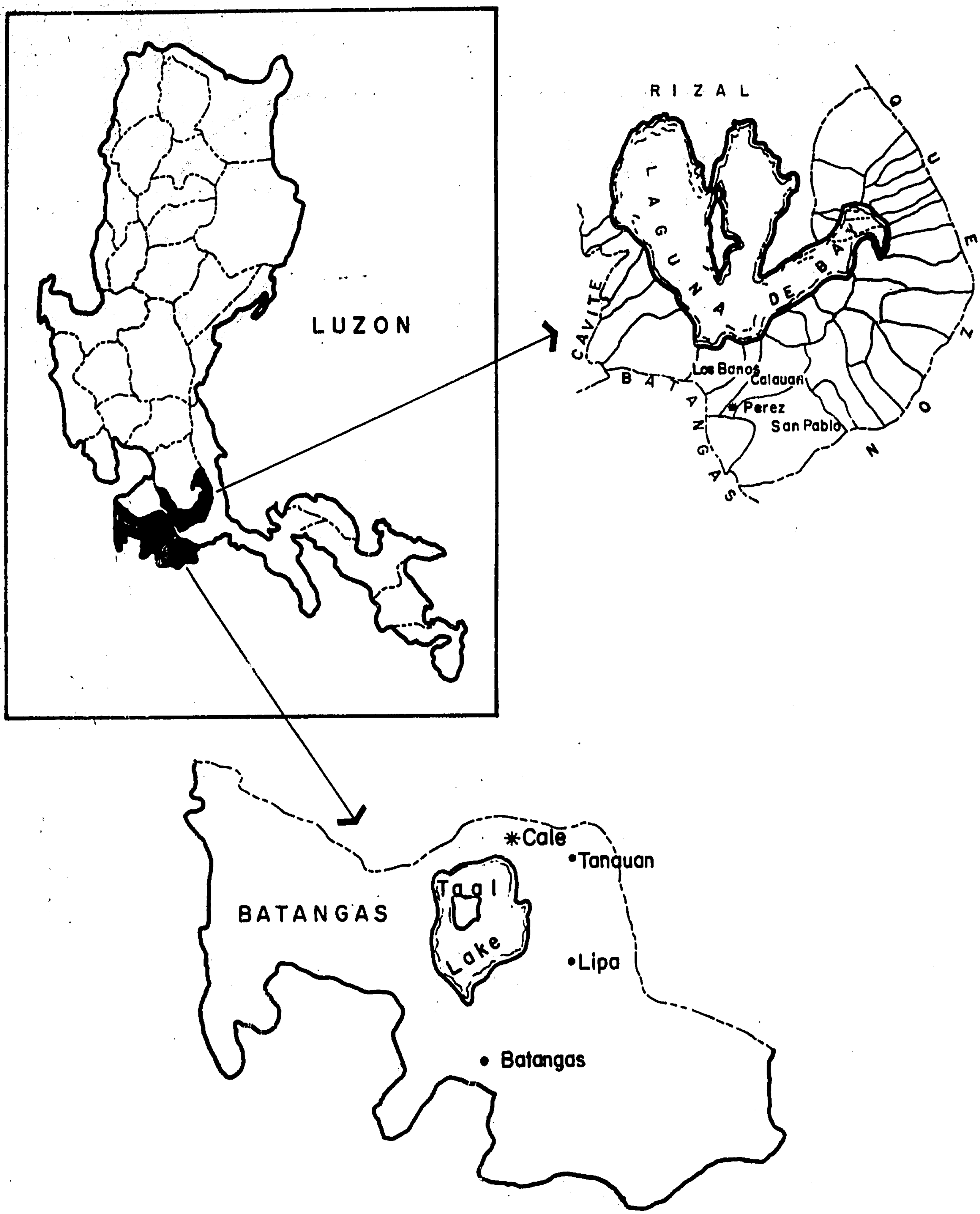


Fig. 25 Location of upland villages used in survey.

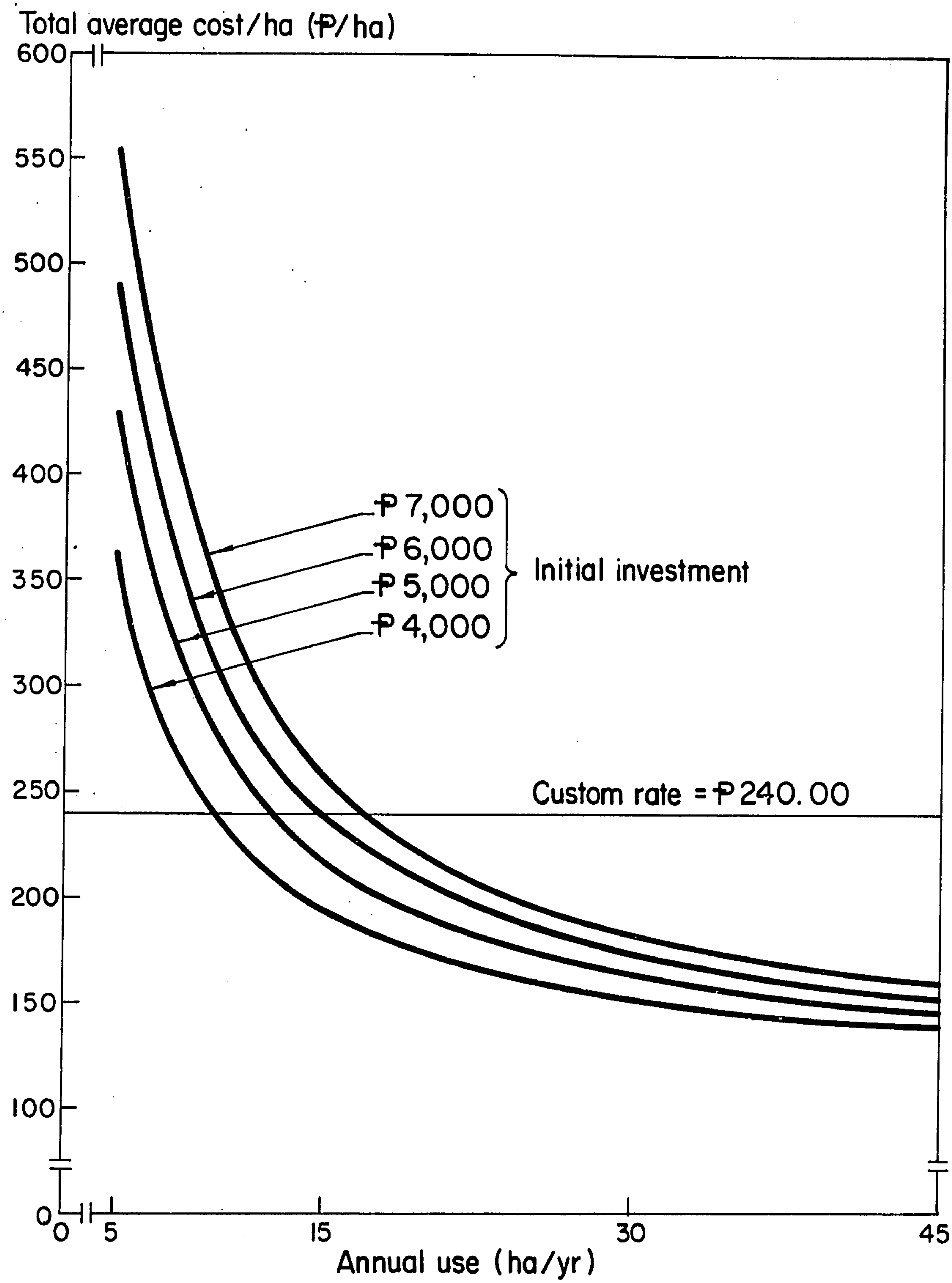


Fig. 26 Average total cost curves, 5-7 hp power tiller.

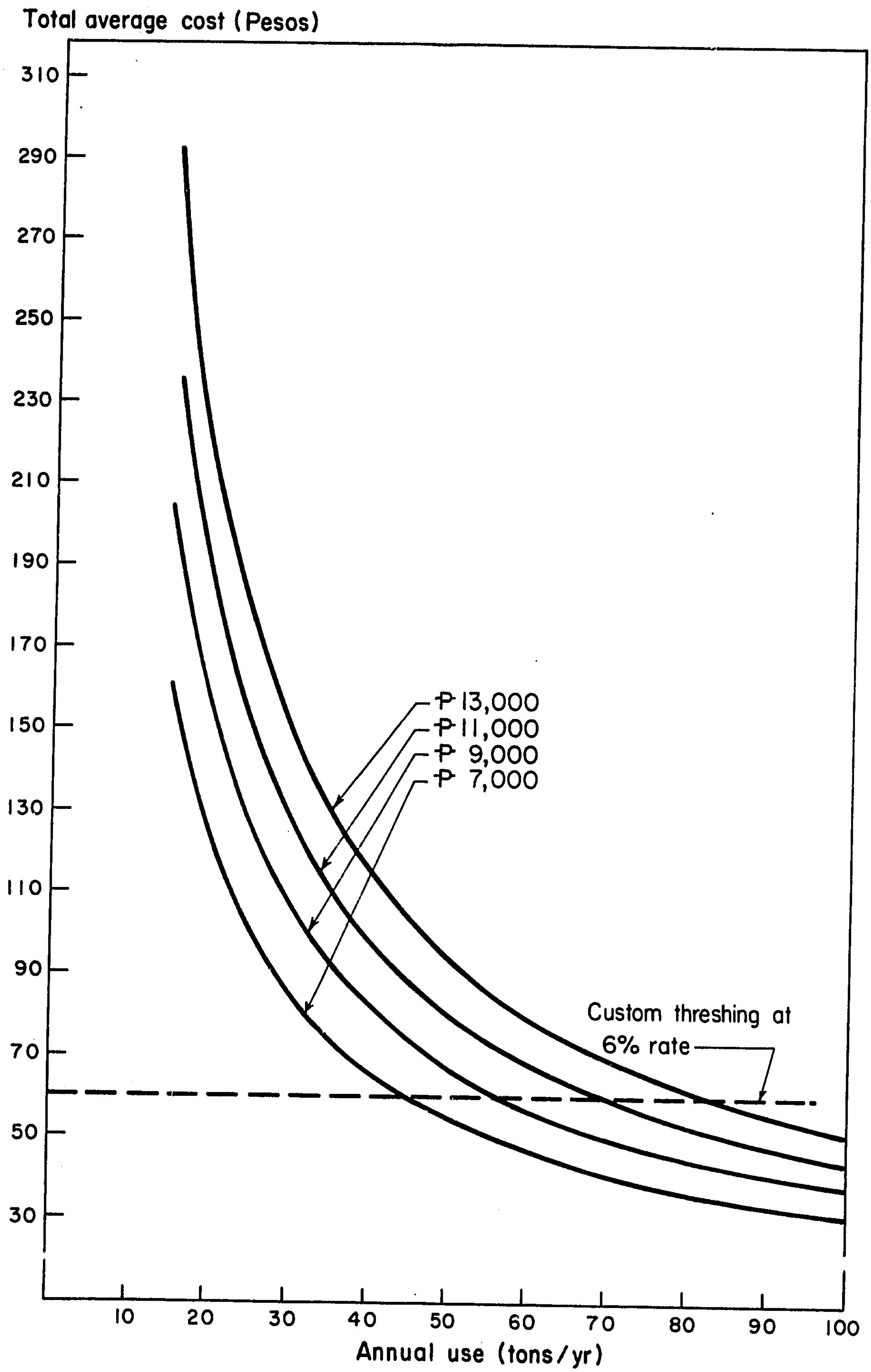


Fig. 27 Average total cost curves, axial-flow thresher.

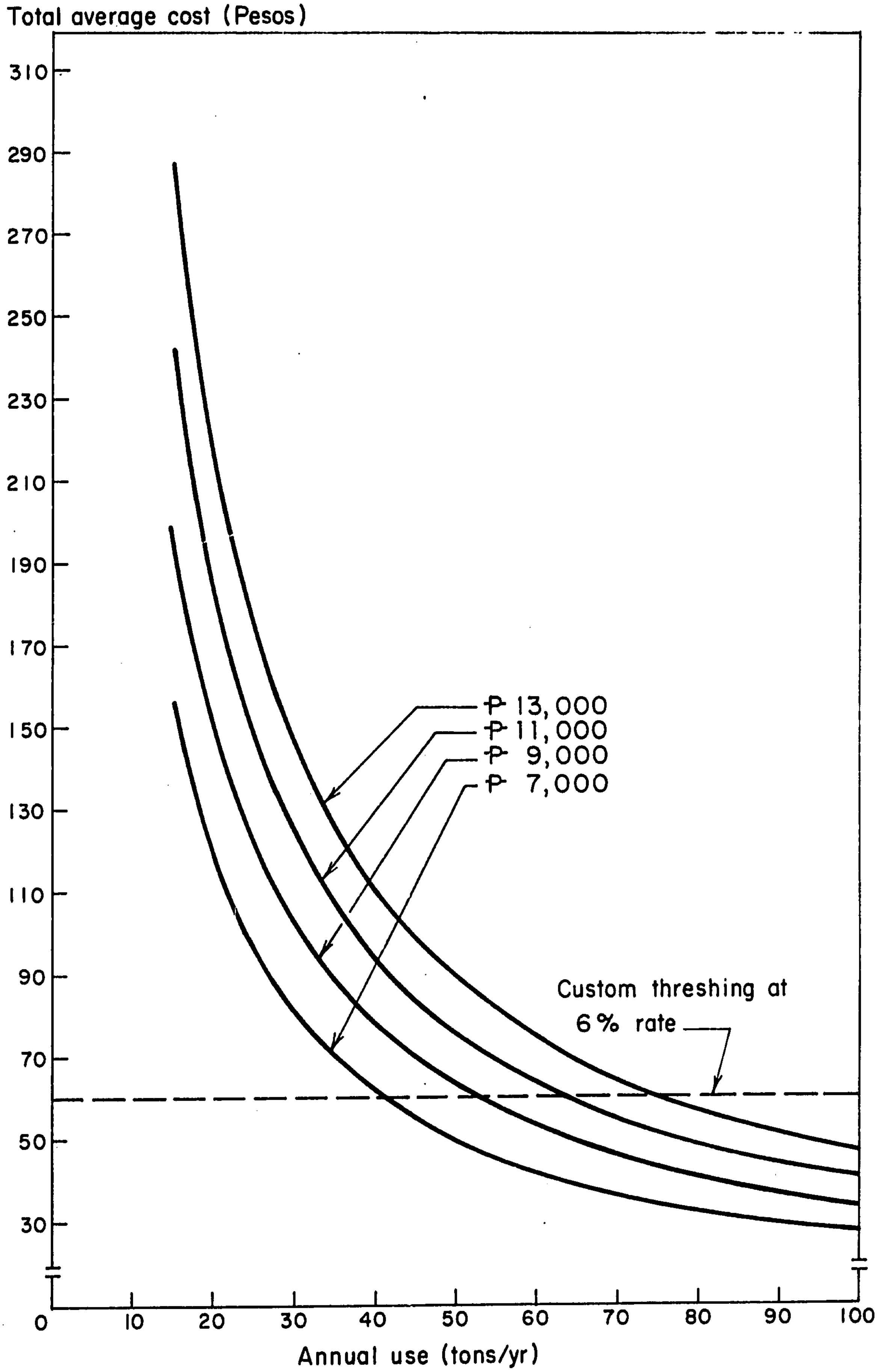


Fig. 28 Average total cost curves, axial flow thresher.

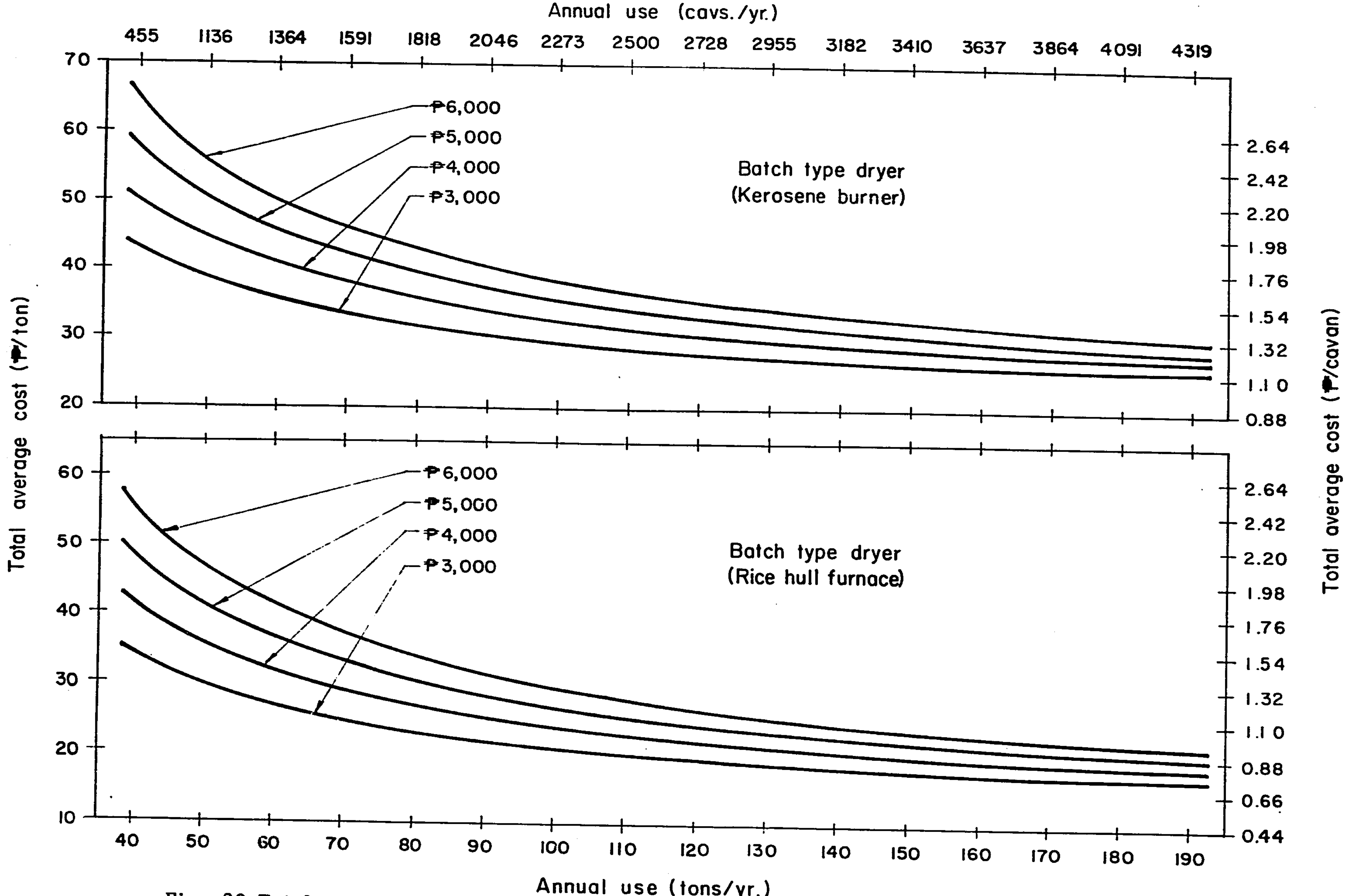


Fig. 29 Total average cost for IRRI batch dryer with kerosene and hull heating units.

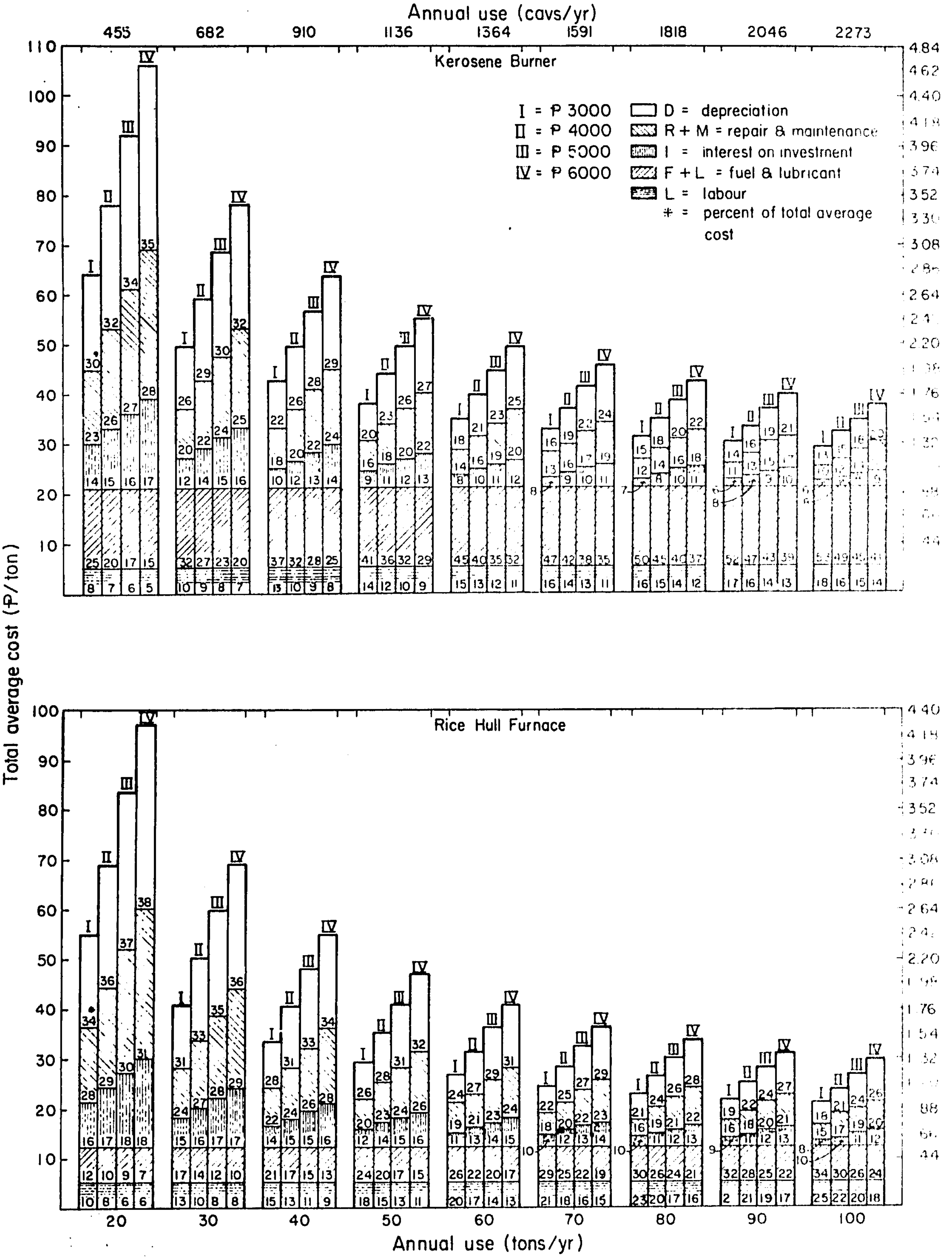


Fig. 30 Components of total average cost for IRRI batch dryer with kerosene and hull heating units.

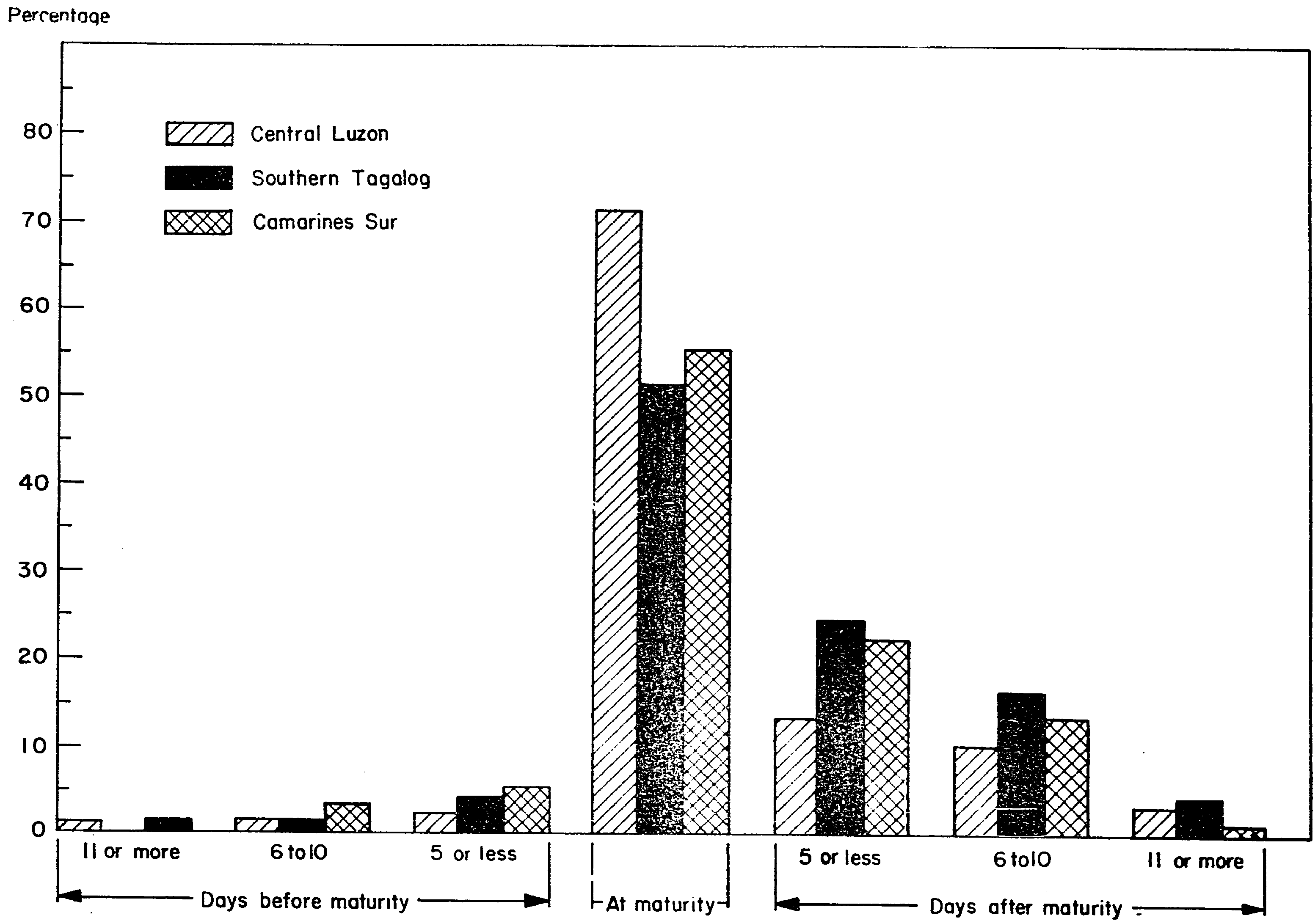


Fig. 31 Date of harvesting by region.

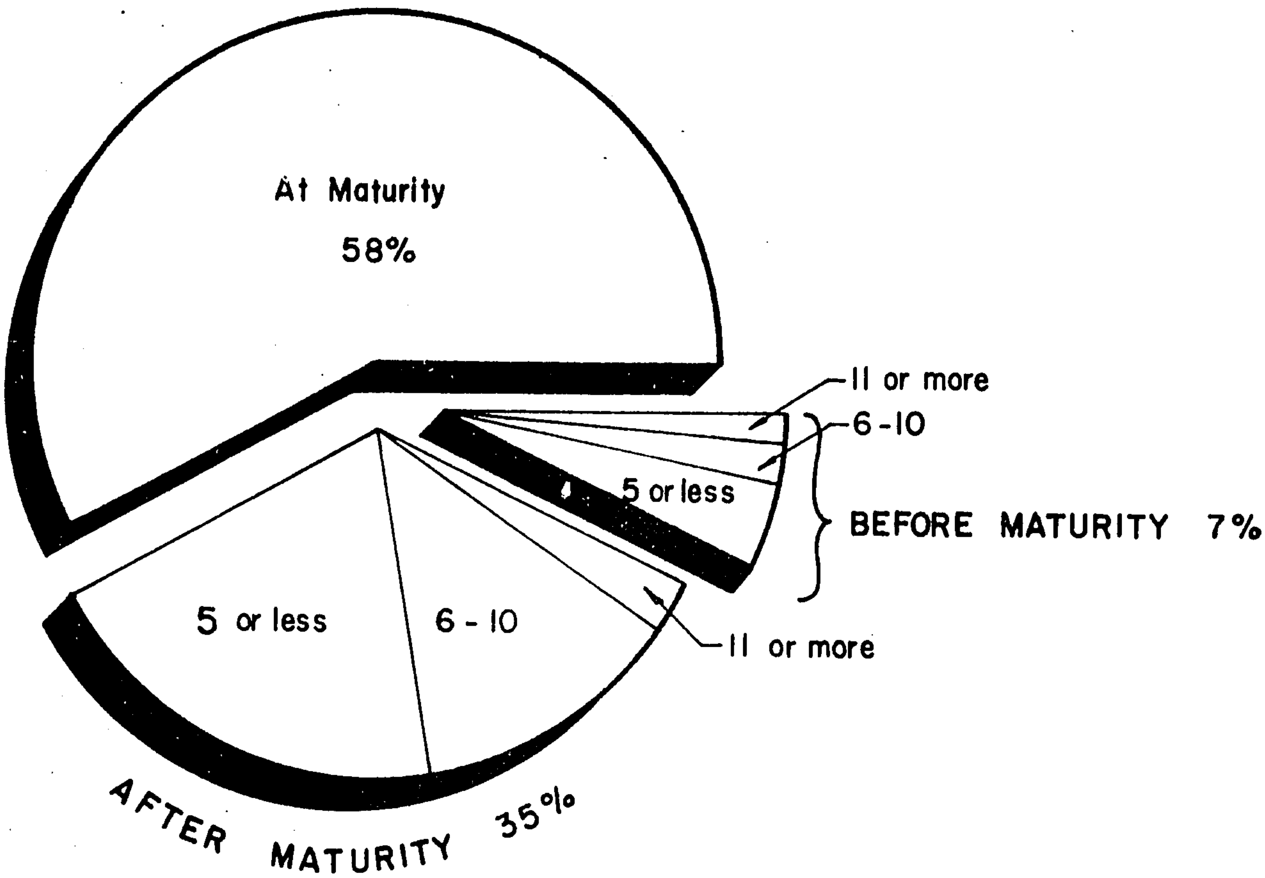


Fig. 32 Date of harvesting paddy, 591 farms.

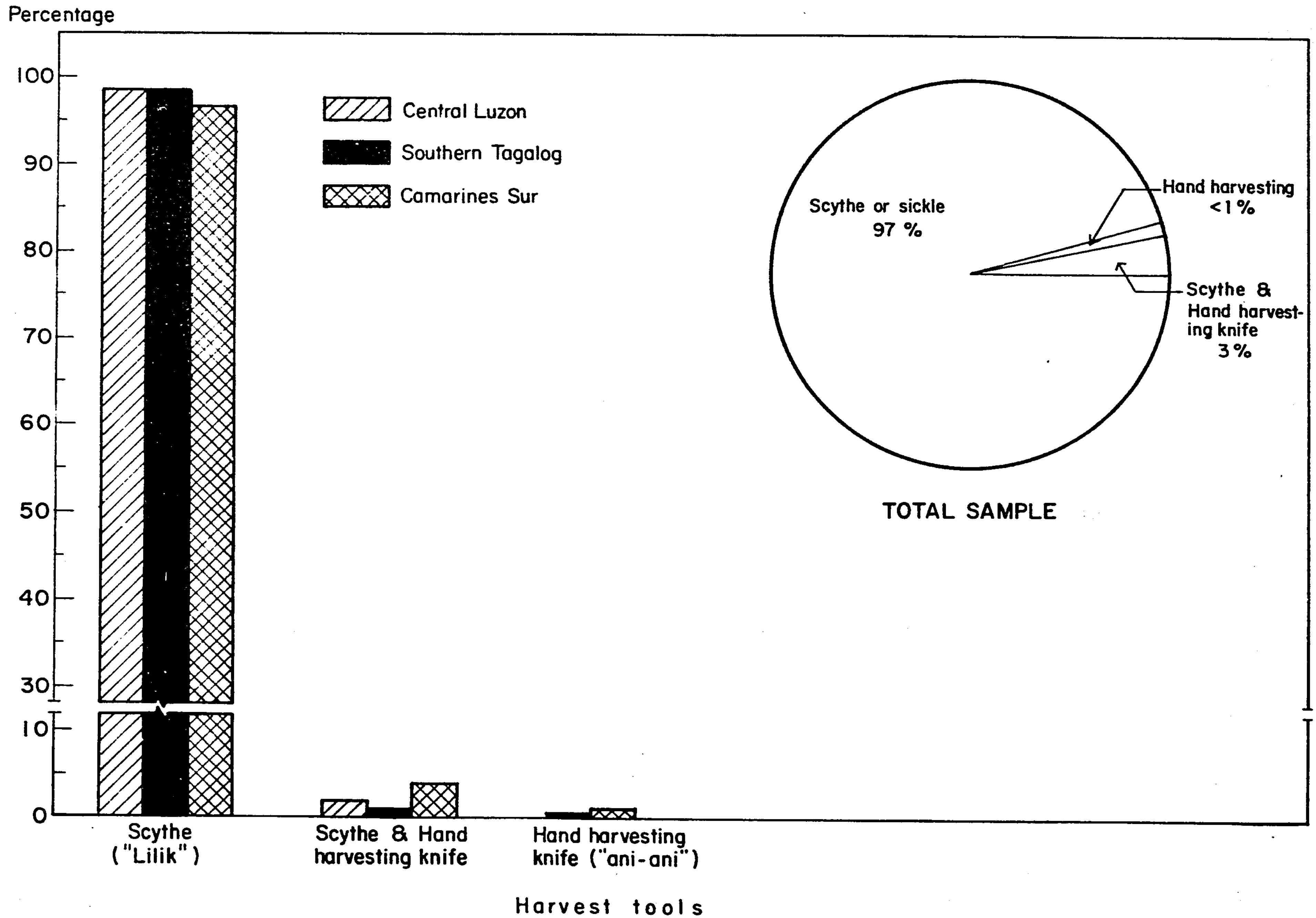


Fig. 33 Tools used for harvesting by region.

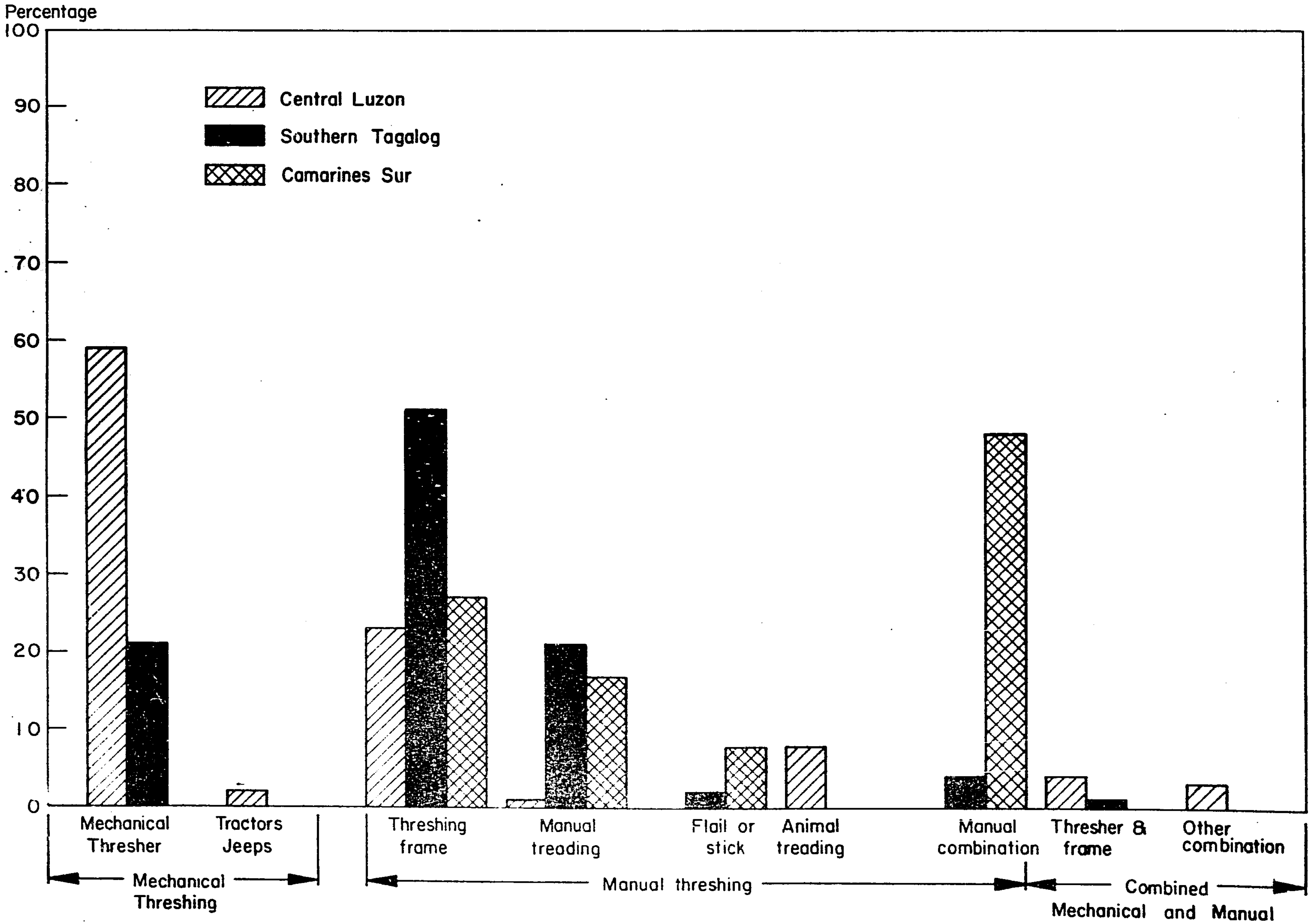


Fig. 34 Methods of threshing by region.

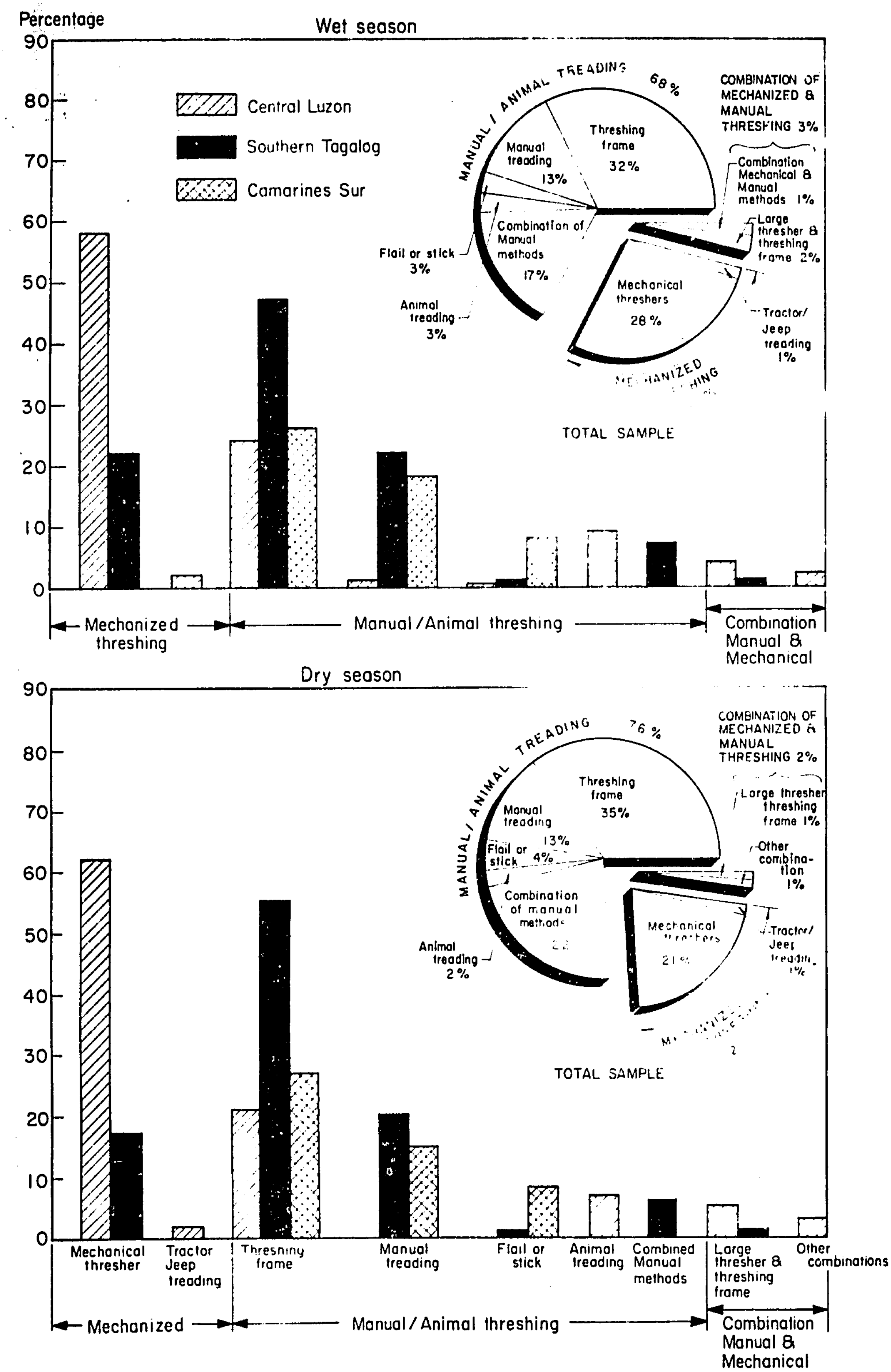


Fig. 35 Methods of threshing by season and region.

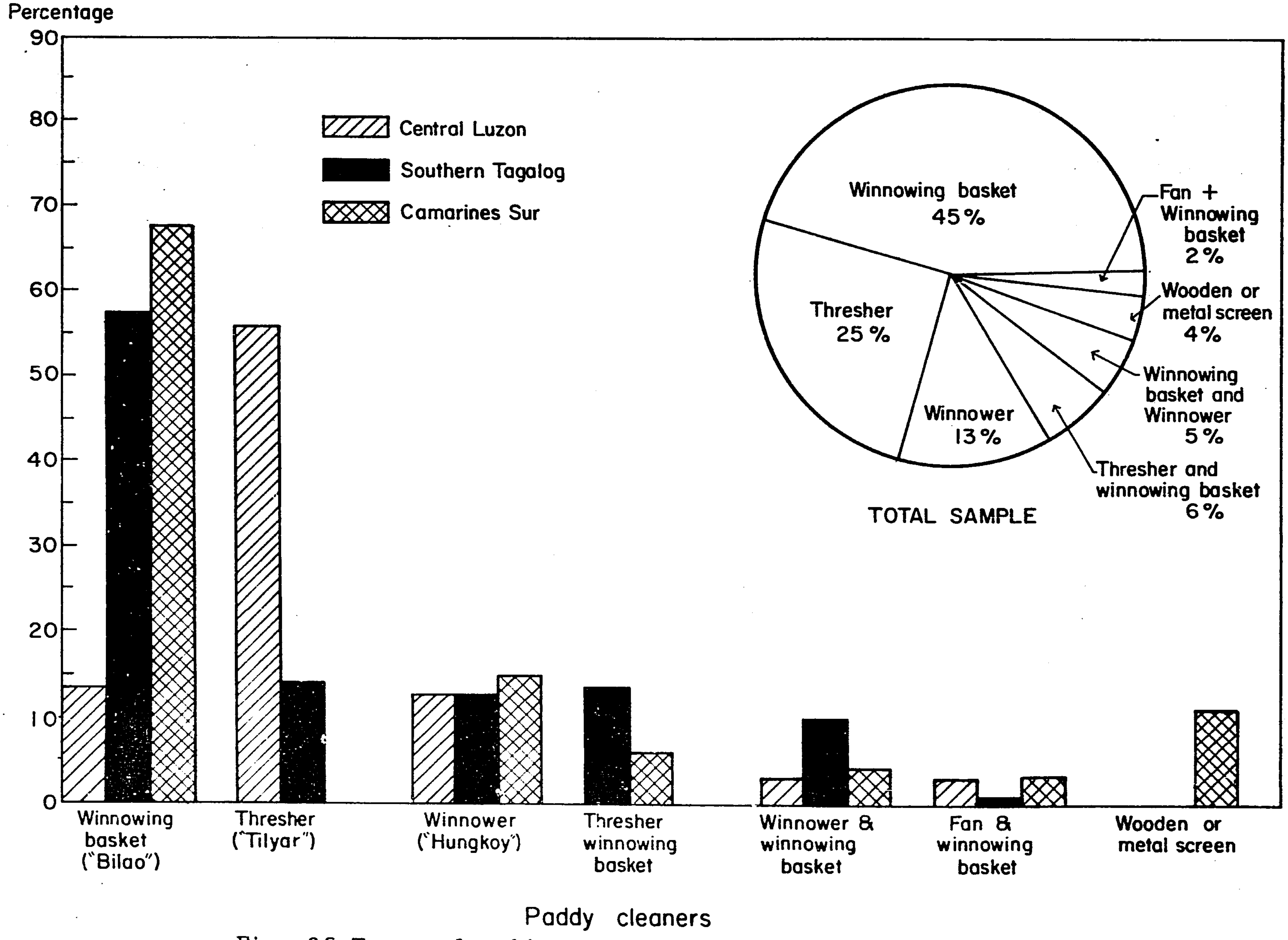


Fig. 36 Types of paddy cleaners used by region.

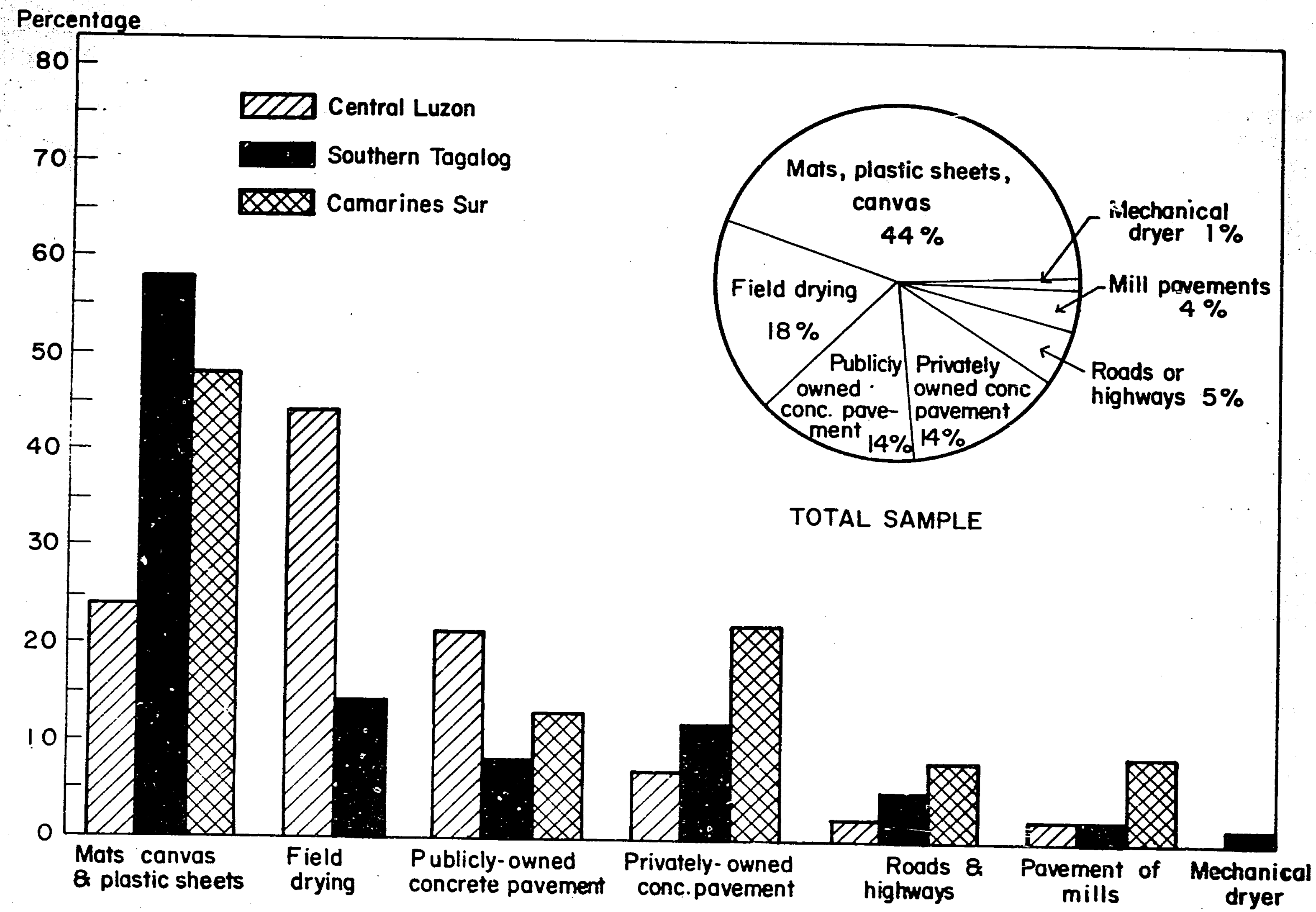


Fig. 37 Method of drying paddy by region.

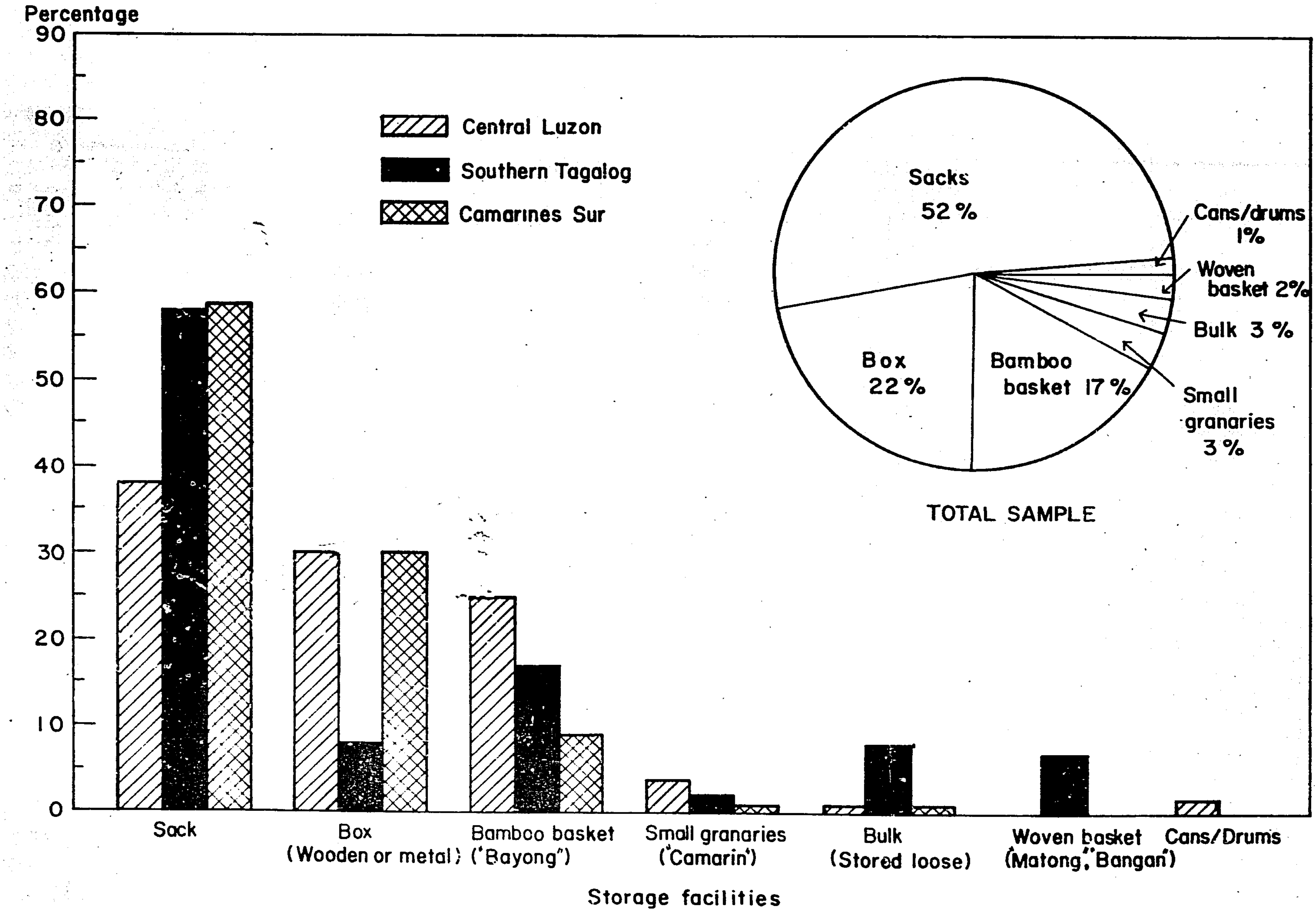


Fig. 38 Storage facilities of paddy used at home by region.

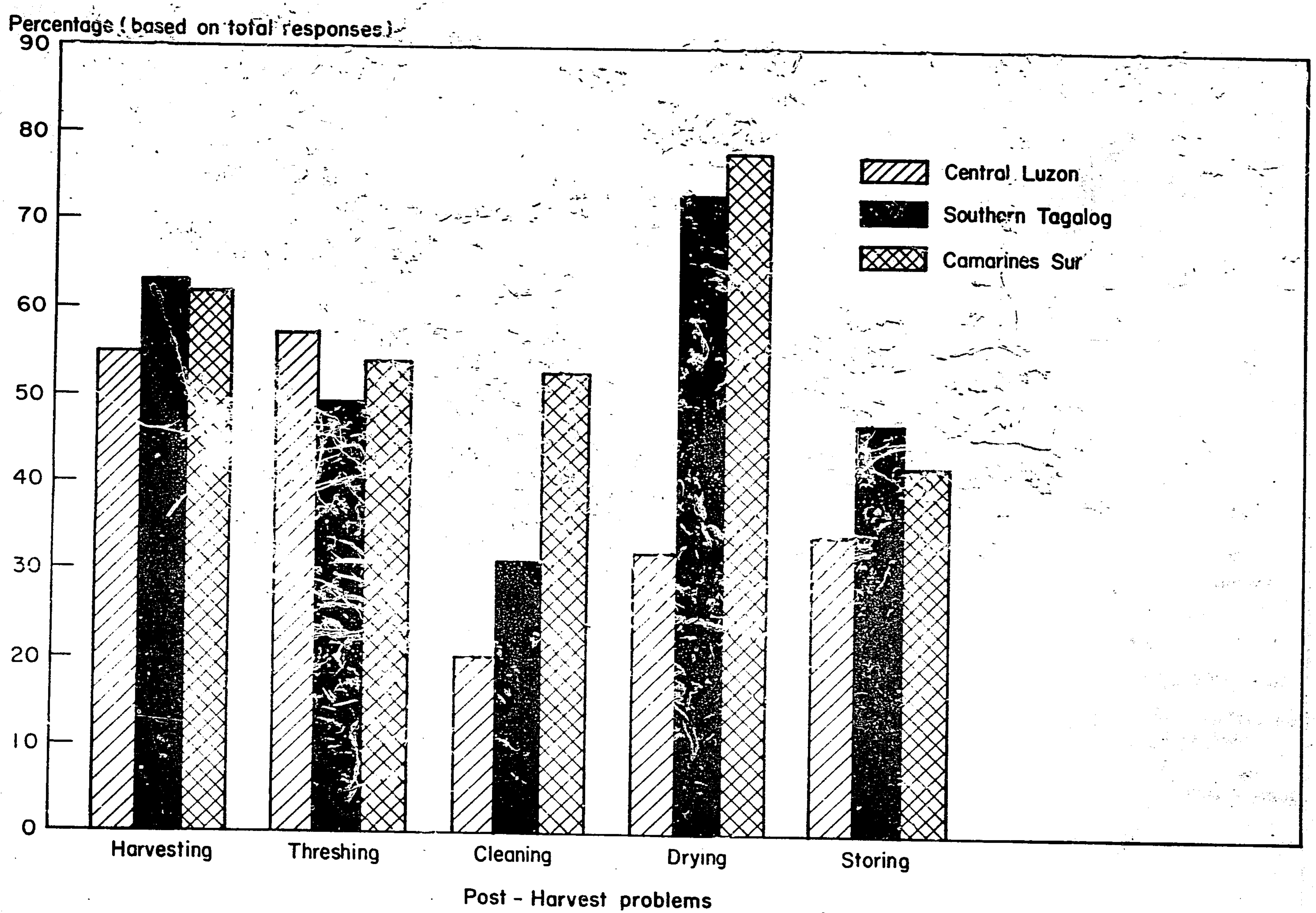
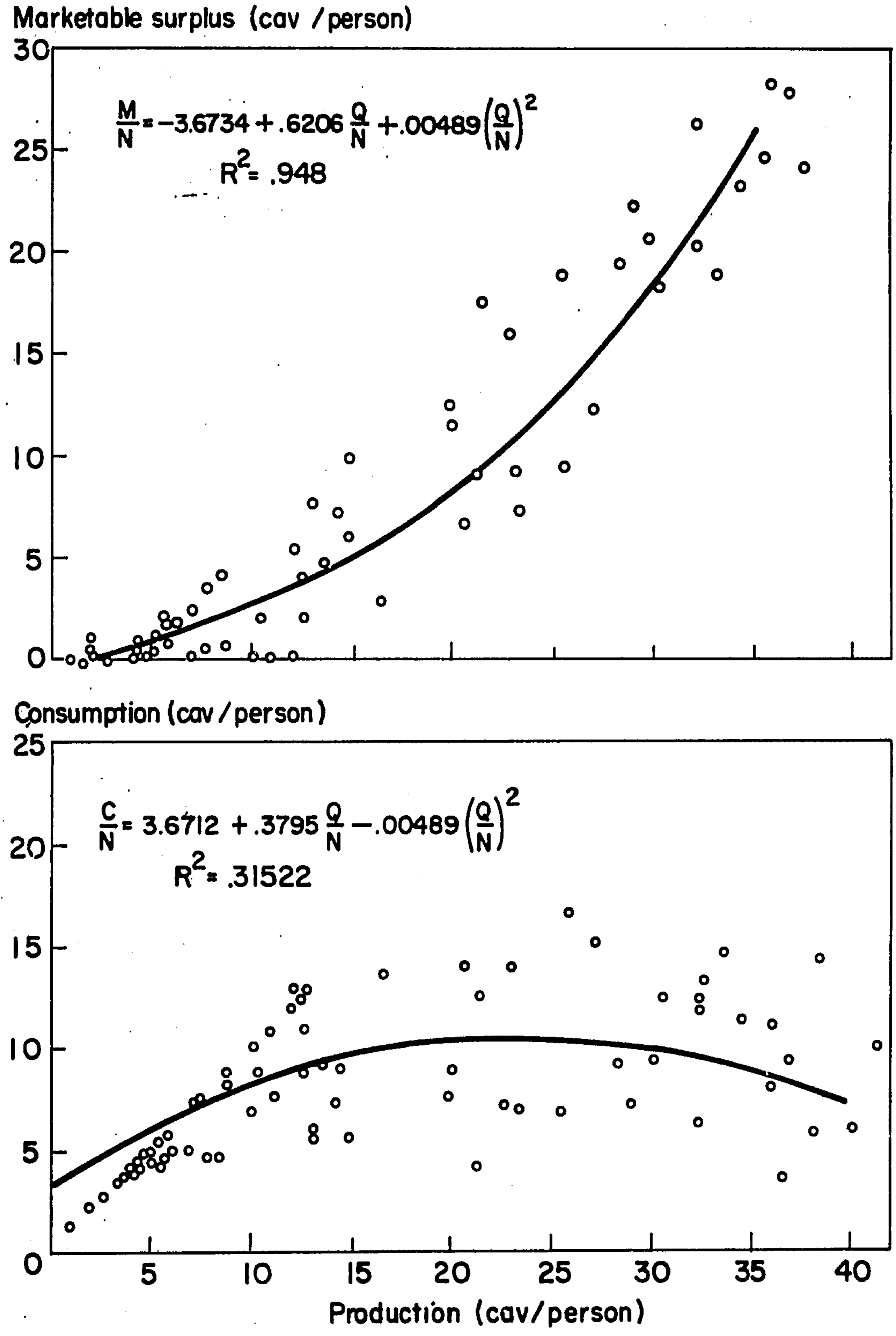


Fig. 39 Post-harvest problems by farm operation and region.



(One cavan paddy = 44 kg)

Fig. 40 Relationships between household consumption, marketable surplus and production for Philippine rice farms.