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# Machinery for Rice

Report on Evaluation of the Progress made under AID Contract on Development of Machinery and Equipment for Rice Culture in South Asia and the Impact on Rice Production by small farmers.

by

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# MACHINERY FOR RICE - SOUTHEAST ASIA


I. Synopsis

II. Review of Project Reports

III. Summary of Impact

- A. Farmers
- B. Agro Industry
- C. Socio-Economic

IV. Potential Impact

V. Recommendations

VI. Reference Material

VII. Country Reports

- The Philippines
- Korea
- Taiwan
- Singapore
- Japan
- Thailand
- Other countries in the Rice growing area not visited

I. Synopsis: Utilization of Results from Research conducted under the AID Contract on "Agricultural Equipment Development Research for Tropical Rice Cultivation"

Survey & Evaluation study made in 1972, by Don E. Davis, in compliance with directive from TA/AGR (AID-Washington); "To review, evaluate and measure impact of new farm implements and equipment (developed by AID - sponsored research activities IRRI Farm Machine Contract) at the farm level; and development of Agro-industry in selected countries."

Complete report by Davis is attached hereto.

Project Contractor: IRRI

Research Leader: Dr. Amir V. Khan Ag. Engineer, Project started 6/28/65; scheduled termination 1/28/75.

Project Purpose: To increase efficiency of production and crop yields of rice; and to improve harvesting and processing of the crop by the development and application simplified powered equipment and machines appropriate for small farmers in LDCs of the tropics. The ultimate objective is to more fully utilize rural human resources, land and water to meet food needs and to contribute to the quality of living of the rice farmers.

The earlier years of this contract were devoted primarily to basic studies on land preparation for irrigated rice culture, and more effective use of power and equipment in growing the crop to alleviate the constraints on productivity. Subsequently, efforts were directed to the adaptation of smaller scale machinery and equipment produced elsewhere (Japan, U.K., U.S., etc.), for use on small farms in the Philippines, with intended application to other tropical countries producing rice under irrigation. The adaptations include the re-design and simplification of machines so that they are suited to small-

holder farming, and which may be fabricated and marketed by local machinery companies.

All of the patentable features of the machines developed under this contract have either been patented in the Philippines or in the United States. Licenses for fabrication of these machines have been granted to individuals and corporations on request, but these licenses are non-exclusive and without remuneration. The machines developed to date are listed below:

Machinery and Equipment for Rice Culture, Redesigned or Modified for Small Farmers, under this Contract.

1. Power tiller (1-man, walking type)
2. Row seeder (1-man propelled)
3. Multi-purpose seeder (carabao powered)
4. Multi-hopper (6) seeder-hand drawn
5. Savonius type water lifter
6. Low-lift bellows water pump (foot-power)
7. Power rotary weeder (shoulder carried engine)
8. Field stripper-harvester (powered, 1 row)
9. Axial-flow thresher (mobile)
10. Table thresher (stationary, portable)
11. Tractor PTO driven thresher
12. Batch type, flat bed dryer (for paddy)
13. Sand dryer.
14. Rice Hull furnace
15. IRRI grain cleaner
16. Lab. centrifugal huller

These machines are relatively simple, low cost, and have proven to be readily fabricated by local shops in the Philippines and in several other LDCs in Asia, using local materials and standardized components, particularly small engines. The 4 principal Philippine manufacturers are: Marsteel Corporation, Kalayaan Engineering, Carlos Wapfana, and A.P. Rodrigues, Cabanatuan. There are additional local shops in the Philippines that are fabricating certain machines. Marsteel Corporation is a diversified metal works company with capacity of 4 power tillers per day, and marketing machines through 43 dealers. It is anticipated that fabrication of all improved machines will be undertaken by local or national companies as the merits of each machine have been demonstrated. Local manufacture of certain machines has been undertaken also in Korea, Thailand and Taiwan.

The advantages of these improved machines are that they are specifically oriented toward dealing with identified constraints in irrigated rice culture, and are particularly designed for use by small farmers. They are relatively low-cost, maintenance is simple, the powered machines utilize small standard engines fueled by kerosene, gasoline or diesel, and machine adjustments and operations are easily mastered by small-farmers. The present stage of utilization of each machine varies greatly, following the time sequence for its perfection. Fabrication and marketing generally has begun in the Philippines where the contractor is located, but as the usefulness of individual machines became known in other rice growing Asian countries (Korea, Taiwan, Thailand, Malaysia), the fabrication and marketing of machines was undertaken.

Several aspects of the impact made possible by the type and degree of mechanization with these machines were discussed by Davis in visits to farmers, technical assistance specialists, and agri-business companies in South Asia.

The following conclusions may be drawn:

1. Time saved in farming systems

These machines facilitate multi-cropping by expediting land preparation, planting and harvesting. As much as 4 weeks for one rice crop may be saved by such mechanization in addition to performing each cultural practice (land preparation, planting, tillage for weed control, harvest, threshing and drying) in a more efficient manner. There is little or no need for tractor hire since the small farmer operates all these small machines.

2. Reduced crop losses

The small farmer realizes greater net returns from his crop because of significant reductions in losses that occur under traditional practices. The improved threshers will handle grain with moisture content as high as 24% with less than 2% loss, and shattering and handling losses are largely eliminated. Combining the improved threshing process with a batch dryer, and a centrifugal huller and mill, at least half of present losses are eliminated. Present losses in harvest and processing range from 25 to 50% of the standing crop.

3. Type of mechanization

The machines developed under this contract are suited to small farmer operations. The initial cost is low, maintenance is feasible with minimum assistance from local shops, family labor is usually adequate for all operations, and the machines may be operated long hours where this is expedient, in contrast to a 4-hour day with carabao; reducing the problems with mobilizing contract labor forces in critical periods.

4. Effect on rural employment

Since these machines make possible multi-cropping not previously feasible, there is a greater total labor requirement during the year, without changing the size of the farm. The total tonnage of crop produced per man year is increased

by such small-scale mechanization, which is an important contribution to meeting local and national food needs. The manufacture, marketing and servicing of such machines adds to total employment, whether done in local shops or in larger centers for wider markets. Labor is more effectively used when mechanization augments manpower. Multi-cropping and mechanization distribute the man work load more uniformly during the year.

The potential impact appears to be very large. If these machines are widely and fully adopted by small farmers, the impact may be equivalent to a 25 to 50% increase in total productivity per farm. This might constitute a second "green revolution". However, there is an inconsistency between local fabrication by small local shops that produces machines at lower cost, but only serve local rice growing areas; or the fabrication and marketing by large national or international companies that manufacture in volume and conduct aggressive marketing compaigns over large regions. Since the machines are protected by open patents, the large companies do not have exclusive use of patentable features, and must capitalize on more efficient production and marketing. If reliance is placed on local manufacture, then governments or external assistance agencies must take responsibility for stimulation fabrication of machines, and for introducing their use to all rice growing regions.

Ohtake company in Japan has undertaken the manufacture of the rotary tiller with a line of different attachments for various crop and tillage work, and plans a yearly production of 2600 units. They have produced and sold over 7000 units. Marsteel Corporation in the Philippines is planning production of tillers at a rate of 150 units per month. It remains to be seen whether such private corporations will find it profitable to manufacture and market the full line of machines developed under this contract, to serve the entire form market in South Asia. AID should have a keen interest in monitoring the developing

situation to insure the widest effective use of the improved (and proven) machines devised under this contract.

## II. Review of Project Reports

The project has been faithful in providing semi-annual reports showing programs being worked on and time distribution. The project activities are summarized, a short statement as to the use and effectiveness of each is listed below.

1. Analysis of rice farm operations in central Luzon

This program was carried on for the period, July 1-66 to July 1-67. In it are some conclusions re use of machinery, yields, etc. at that time. This work needs further summarization but is of some use to planners for design work on new or improved machinery.

2. A study of hand tractors in the Philippines

Report written. Most important conclusion is that rental work with tractors at a cost of 0.25 per RHP per hour as compared to $0.40 per RHP hour with carabao. These are 1966 cost figures but are useful in economic comparisons between machine and animal power.

3. A related study conducted by IRRI on the relation of yield to land preparation, weeding and fertility level

Worked on only in 1966. Short report written. Concludes that advantage of weeding is pronounced when land preparation is inadequate.

4. Adapting, testing and development of equipment and contacts with manufacturers

A one time program in 1966. No report, and of limited value.

5. A study with USDA National Tillage Lab on rotary tillage and traction on flooded soils

Work was done on this during all of '66, but then dropped. Not clear as to what, if anything was accomplished.

6. Land preparation with hand tractors

Worked on during last half of 66. Actually a follow up of #2 above. Shows time required for 1 ha. of land preparation with hand tractors equals 4.5 days against same amount of work with animals equals 20 days. Cost factor at that period; prices peso 107.2 for hand tractor, 149.69 with carabao.

7. A study on adequacy of land preparation

Last half of 66. Results, if any not in report.

8. Rotary tiller development

Last half of 66. No conclusions in report.

9. Interviews of central Luzon rice farmers

Last half of 66. Basic background information gathering.

10. Tractor PTO driven threshing drum design

July 67 to present. Evaluation complete, planned to go into production by private company by end of 72. A very promising machine for a country such as Thailand where fields are dry after harvest and tractors are available. Could save as much as 10% of the total crop from loss now experienced under traditional harvest methods.

11. Drum type power thresher design

July 67 - June 69. Did not prove acceptable and dropped.

12. Table thresher power thresher design

July 67 to present. Now in production by two private Philippine manufacturers. Under test and evaluation in other sub-contract countries.

13. Tractor tillage and mobility studies under soft, wetlands conditions

July 67 - June of 70. This resulted in design and rather widespread adoption of the slip lug wheel for 4 wheel tractors in Philippines. Used extensively on larger tractors in Malaysia, etc. Unknown if this original design or a copy.

14. Use of mechanical power for rotary weeding

July 67 - June 70. This basic machine taken over by Hotake Co. of Japan, modified and put into production. Some 7,000 produced and sold to date with annual production for Japanese market planned of some 2,600 machines per year.

15. Application of anhydrous ammonia with small tractors

July 67 - June 70. Method and sprayer perfected and available for production.

16. Physical properties of paddy

Planned but not implemented.

17. Performance and economics of power units

January - July 68 and again in 71. Comparison of different size tractors and methods. Limited conclusions drawn. Re carabao vs 6 HP tractor for land preparation;-Carabao--peso 159.27 per ha., tractor--P 117.38.

18. Performance and economics of harvesting threshing machines

January - July 68. Testing of Japanese automatic thresher, reported in Table II, report #6, page 37. Useful as basis comparison other machines.

19. Agronomic engineering survey of major rice areas and farm management interviews

January - June 68. Gathering basic data to determine potential for mechanization. Inconclusive in this report. There was definite relation or correlation between irrigated 2 crop systems and use of hand tractors. A seasonal labor shortage during any one operation is conducive to mechanization for that operation.

20. Analysis of soil penetration resistance

January 68 - July 69. Tests to determine time factor and penetration under flooding to determine possibility of tractor use on different soil types. Gives basis for determining suitability for various types of tractors for land preparation. Useful for planning sales programs by areas.

21. Physical properties of the rice plant and paddy

July - December 68. Basic data gathering to be used for thresher design and improvement of thresher.

22. Development of a paddy stripper combine

July 68 to date. Ohtake interested. Needs one more prototype before production.

23. Rotary harrow for small tractors

July - December 68. Comparison rotary harrow with comb harrow. Economy and performance did not justify added cost of the rotary harrow over comb harrow.

24. Power requirements for wetland rotary tillage

July - December 68. Basic information for rotary tillage design.

25. Row seeder for lowland rice

July 68 - July 70. 2 manufactures in Philippines. 600 produced to date. India is building.

26. Economics of use of different threshers

July - December 68. Determination of situations for separating ownership of thresher from custom hiring of threshing operation. See figure 30, report #7.

27. Economic evaluation of alternate weeding methods

July - December 68. See table 4, report #7.

28. Survey data collection

July - December 68. Comparison 4 to 6 HP hand tractor and carabao for land preparation. Inconclusive.

29. Comparative performance of thresher cylinders

January 68 - July 69. Determined optimum cylinder peripheral velocities for minimum 2% unthreshed paddy, a 1% max. milled paddy loss and an 85% min. head grain yield. See page 7, report #8. Essential for design work.

30. Development of a rotary screen winnower

January - July 68. A seed cleaner. This machine presently under evaluation and limited sales distribution. Excellent machine for small mills for cleaning paddy prior to milling.

31. Correlation of estimated yields with observations on the growth of crop

January - July 69. Inconclusive.

32. Hand threshing

January - June 69. Results reported as typical for yield of 4,500 kg per ha. 18% moisture content, 2 tests--output 18-22 kg/man hour or 220-235 man hours per ha. Threshing loss 5.8 and 8.6% of output.

33. Use of farm labor

January - July 69. Area studied, central Luzon. Average labor input per ha. in 8 hour man days. For wet season--79, for dry season 72. Of this, average 15 man days by operator and family, balance hired or exchanged. Peak requirements--May - July and October and December.

34. Cost of production estimates

January - July 69. Cash costs per ha--Peso 214.34, 178.35 and 137.13 for irrigated 2 crop, irrigated 1 crop and rainfed 1 crop.

35. Present state of weeding

January - July 69. Update of former report. See table 25 report #8.

36. Differential cage wheel slip for wetland preparation

July 69 to present. Still under study.

37. Accelerated paddy drying with heated sand

July 69 to present. Prospects excellent. U.S. patent pending potential manufacture by Pemar Corp., Florida.

38. Direct flame drying

July - December 69. Tested, but determined not to try to perfect process.

39. Analysis of hand tractor ownership

July 69 - July 71. No final report found.

40. Farmers attitude towards the use of tractors for land preparation

July - December 69. Results of sample (307); 75% desired to hire, 12% not interested in use, 13% no response. Reason for wanting to hire or use; - Timely operation, no carabao, easier to control weeds.

41. Consumer preference tests of heated sand and flame dried paddy

January - July 70. Little or no significant difference between treated and control samples.

42. Accelerated drying of sorghum

January - July 70. Appears possible to use, however, a lesser degree of moisture removal possible with sorghum than with paddy.

43. Drying chemically treated paddy to break seed dormancy

January - July 70. IR-22 dormancy broken within 4 days after harvest by soaking in 0.2 N nitric acid solution for 24 hours followed by heating or drying at 43-45°C in batch dryer for 6 hours. The batch type dryer temperature should not exceed 46°C if seed viability is to be maintained.

44. Rice hull furnace

January 70 to present. Design stabilized but still testing with batch dryer.

45. Multi-purpose seeder

July 70 - July 71. Prototype proven and ready for production.

46. Thresher for Taiwan

January - July 71. Design with modification completed and drawings. Specifications sent to Taiwan.

47. Individual row metered seeder

January - December 71. In production with one producer in Philippines, 20 units fabricated.

48. Multi-crop thresher

January 71 to date. Prototype under testing, very promising for high moisture content threshing.

49. Blade lug wheel

January 71 to date. Designed and under test. In Philippines John Deere, Ford and IHC selling with their 4 wheel tractors.

50. Manual submersible sump pump

Since January 71. Under production by one Manila company.

51. 4-6 HP tiller

July 71 to date. In local production, 4 Philippine companies. Demand appears greater than local production potential.

52. Batch drier

July 71 to date. In production, 2 Philippine companies.

53. To 59. Following started in July of 71, still under development.

a. Seed placement studies for lowland rice.

b. Small scale industry study.

c. Human energy measurement study.

d. Mechanization and employment study.

e. Retail survey of agric. machinery industry.

f. Application of value analysis in design studies.

g. Subcontract development, extension and training activities.

## III. Summary of Impact.

### A. Farmers.

Only a relatively few of the machines developed have actually reached and been used by farmers to date and these only in the Philippines. However, an attempt was made to talk with farmers at two demonstrations of the power tiller and to actual users of the direct row seeder, the table thresher and the seed cleaner.

Power Tiller: Farmers interviewed at the tiller demonstrations were keenly interested. They had been contracting for big tractor tillage for the first tillage and preferred this to the traditional carabao primarily on the basis of time required and due to the fact that the tractor could work all day, not an approximate 4 hours as limited by the carabao. They do, however, realize that the practice of double cropping and thus never letting the paddy really dry down has, and will limit the use of the large tractor due to softness of the field. They are interested in the IRRI contract machine because; - it is cheaper, it is possible to locally get repair parts and maintenance work, it is equally efficient under their conditions as the much more expensive imported tillers, it is lighter and therefore easier to transport and move. (Demand by farmers is reflected by Marsteel who only started production of the tiller in mid August. He states that he has firm orders for 500 machines and believes that up to 5,000 units could be sold in the near future.)

There have been some 600 of the row seeders produced and sold. I talked to only two farmers who were using these. One uses the seeder exclusively on 20 ha. and the other is planning on 100% use next year. Their reaction to the seeder was that there little savings in cost due to extra land preparation and extra weeding cost. However, they liked the machine because of the time saved in getting a crop in, and the relief it gave them from the transplanting crew contractors. These contractors are often unreliable and will raise the price of their services halfway through the planting.

I visited three rice mills using the seed cleaner. This, according to them, is a much more efficient and desirable machine than the typical winnowing machines they have been using. The small mills and cooperatives will probably be the place best suited to the cleaner.

Rather extensive farmer acceptance tests in use of the table thresher have been conducted in Laguna and Central Luzon. Acceptance has not been good due partly to mechanical problems and partly to social causes. Probably the sociological problems are the hardest to overcome. The traditional practice is to pay for the harvesting and threshing with 1/6th of the grain threshed. This operation is one of the best paid, especially with the new varities, for the laborer in the rice cycle and an operation he will not give up easily.

B. Agro Industry.

The impact on the Agro Industry of the work under the contract has only started. Again, mainly in the Philippines but starting in the other sub contract countries, an effort has been made to hunt out small to medium sized fabricators and manufactures and to interest them in manufacturing and selling the developed and tested machines. Detailed drawings and specifications are furnished free and assistance given in evaluation of the companies product. In the Philippines, there are 4 companies that I have seen, and a reported two more on Mindanao, that are manufacturing contract developed machines. The machines are designed so that they can be fabricated out of locally available material and with the equipment that the small shops have.

The two outstanding examples are the Marsteel Corp. In Manila and Hotake Company in Japan. Marsteel started producing tillers in mid August. He is up to a production rate of 150 per month, claims 500 firm orders and believes there is a potential for some 5,000 of the machines in the immediate future. He sells to farmers through a 43 dealer outlet set up on the basis of a 30% markup with 10% of this to the dealer. Under this he can provide a machine to the farmer consisting of tiller, motor (7½HP), cage wheels and plow for from pesos 3,500 to 4,000. This price is compared to a price of a comparably powered tho more sophisticated machine of Japaneese import of from pesos 10,000 to 12,000.

Hotake Co. in Japan has taken the three row weeder design, designed 11 different attachments for various crop and tillage work and has to date manufactured some 7,000 of them and plans a yearly production of 2,600 units.

Other companies visited are awaiting the release of the PTO thresher, the multi-crop thresher and the batch dryer. As a part of the assignment, I made the effort in each country visited to determine the production capacity of the locally owned, private shops and companies. In every country, these facilities exist with machine tools, presses and skills adequate to fabricate the machines. Many are already manufacturing pumps, tillers, etc. and are looking for other machines to manufacture. Thailand, Taiwan and Korea produce their own gasoline, kerosene or diesel 5 to 24 HP motors.

In the rice growing countries, the demand for mechanization, especially of the land preparation cycle is growing due to the introduction of the new varieties, improving irrigation through both gravity systems and pumps, and the practice of double cropping. Imported machines to satisfy this demand is generally beyond the means of all but the more prosperous farmers. Introduction of the IRRI contract type machines capable of doing the same work but at a cost of from 40% to 50% much broadens the market. The establishment of the local industry connected can do much to improve the local economy.

C. Socio-Economic.

Economists working with the contract and other economists connected with IRRI have, over the years collected a great deal of socio-economic data; again primarily on the Philippines, but generally applicable over a broader geographic region. From these studies, they have proven that mechanization, at least through the land preparation stage is not labor displacing. It is labor shifting but the total labor requirements (hired labor) may actually be increased. Since the processing of the crop is already mechanized to a large extent, improved mechanization or improved machines in this area do not reduce labor, but do markedly effect the quality and quantity of the end product.

Again they point out that full mechanization such as practiced in Japan or the US in rice could be labor displacing. Full mechanization is not likely to happen in most of the countries involved due to various reasons, such as size of units, availability of capital, incentive to produce, etc. It is questionable that many country Governments will have either the resources or the desire to follow a practice of high subsidies on both crop prices and availability of machines that was followed by Japan which largely has led to its mechanization. Korea is facing the choice, as is Taiwan, of ever-increasing imports of food due to a diminishing labor supply, or of faster and fuller mechanization. Under a choice of options between farming and shifting his labor to industry, the farmer will choose that option which gives him the greatest reward for his labor. Thus, as countries continue to develop and to offer choices to the individual, the role of mechanization in farming becomes inevitable, but work done under this contract shows it not to be the total bugaboo generally accepted.

From the standpoint of agencies providing assistance to developing countries in agriculture, a statment by Johnston and Kilby further clarify the issue:

> "Since producers in every sector of the economy will combine labor, capital, and production imputs in that proportion which minimizes their costs, for any given state of technology, the pervasive and dominant determinant of differential national employment levels will always be the impact of a given set of policies on the relative prices of labor, capital, and production inputs. Hence, it is the impact of a given development strategy upon relative factor prices, rather than the considerations of labor employment per se, which should command the attention of planners and policymakers.

Without further belabouring the point. I highly recommend the interested parties read two papers, THE NEW RICE TECHNOLOGY AND LABOR ABSORPTION IN PHILIPPINE AGRICULTURE, by Crisostomo, Meyers, Paris, Duff and Barker, and EMPLOYMENT AND TECHNOLOGICAL CHANGE IN PHILIPPINE AGRICULTURE by the same authors. These are on file with TAB/AGR

Project Evaluation. In its early years, this contract and its work suffered from lack of direction and definition of purpose by both the contractor and the contractee. As seen from the project reports review, the first four to five years of activity covered a wide variety of comparative studies, basic data studies and other loosely connected projects. Much time was spent in evaluation of various types of large machines in rice culture and attempts to adapt existing machinery to rice culture.

The shift in later years of researching, designing and improving to develop relatively simple, locally producible yet efficient machines for various steps in the rice production cycle has definitly begun to pay off as can be seen above. The establishing of sub contracts to test and evaluate the machines in the other countries of the rice growing regions has and will continue to broaden the base of effectiveness and impact from the contract. The present staff and organization are top drawer. They are fully capable of carrying forward and completing the job now so well started.

In relation to the above, while I do not believe they are the best possible, the project evaluations that have been carried out by various groups over the past two years have done much to sharpen the objectives and direction of this project.

IV. Potential Impact.

There is built into this project at the present time a vast potential to improve both the agriculture and the economy of the involved countries. The direction started by encouraging local industries to produce the machines for local use as a sound base upon which to build a strong Agro Industry in the developing countries. The machines themselves can improve production through assisting in overcoming the time factor. An example: In Korea, the practice of barley-rice rotation is followed. However, the growth period is very tight and the demand for rapid land preparation and close scheduling of crops is all important. At present under traditional methods of harvest and threshing, there is a general two to three week time loss between harvesting the barley and planting the rice. Usually also the barley is harvested before it is fully mature resulting in as much as a 25% loss in potential crop. The use of the multi-crop thresher right in the field for threshing both the barley and rice could pick up about two weeks time on both ends of the rotation, thus giving an additional month of growing time to the barley. This would in addition greatly minimize the field loss of both crops through shattering and other loss.

It is generally accepted by the plant breeders that a productivity level or plateau has presently been reached in the potential of the new improved varities to produce in the 6 to 8 ton per ha. range. Barring another major breakthrough in production potential, then the other potential for increasing food supply should be in the reduction of present losses in the harvesting, threshing and processing of the crop. A recovery rate of 65% through the bulling and milling process is considered about average in the developing countries. Add to this the estimated loss of from 10 to 20% in field loss through shattering, threshing, hauling, etc. and it is probable that no more than 50% of the crop reaches the table. True, the bran is used for feed for animals but is of general poor quality.

The PTO Thresher and the multi-crop thresher, used in the field on rice with up to a 24% moisture content has shown less than a 2% threshing loss, as well as reducing handling and shatter losses. Coupling this reduction in loss with the use of an easily operated batch dryer and the developed centrifugal huller and mill, it is estimated that at least half the present loss of rice could be recovered for table use. This is highly significant (estimates are that ½ of total losses up to 50% of total crop grown-could be salvaged)

V. Recommendations

In spite of the universally good report given this project. It may have nearly achieved those goals which can be achieved within the scope of the project. It can clearly be said that there is little or anything new in the farm machinery field. Each new piece of equipment is an adaptation or an improvement of an existing one. Every country in the region is in one stage or another of advancement in mechanization. Much more sophisticated machines for the rice industry covering every phase of the cycle are available when and if the demand and capital to purchase them is available. The goals of this research project can relatively well be met with the improvement of the existing machines now at hand. Therefore, I believe that little or no work should be done under the contract toward the development of new types of machines. Rather, efforts should be concentrated in demonstrating and getting into production, on a country by country need basis, the machines already developed and in getting the budding agro industry off to a sound start. This may take assistance beyond design and prototype assistance. I will take organization and training of operators and maintenance people, encouragement, etc. The groundwork is laid to accomplish the job.

In light of the above, serious consideration should be given to examining the contract to determine ways and means of carrying out an aggressive program of extension and training. This will extend the effort presently underway to attain greater utilization of small farm machinery.

I would further recommend that the Agency consider ways and means of providing support to a program in mechanization of upland crops. In all probability, ECAFE will develop some type of regional mechanization research program. In the event this does happen the ECAFE program would provide the base for linkage of country programs and private industry. The ECAFE program could be the focal point for bilateral and/or multi-lateral assistance in farm mechanization.

VI. Reference Material

Attached is a Bibliography of all materials published under this contract. These do not appear in the bi-annual reports and are much more informative. Single copies of each are available on file at TAB/AGR. In addition are up-to-date AMA publications and other miscellaneous publications informative on the subject.

## VII. Country Reports

### The Philippines.

The Philippines, especially Luzon has probably received more outreach from the contract than has any other country to date. Here also is where most of the economic studies have been carried out.

Starting as of this year, there are four manufactures that I have visited who are making or fabricating various IRRI developed machines. These are: Marsteel Corp.. This is a diversified metal works company, well equipped and financed, which employees 800 some odd workers. They are fabricating the Field Master Power Tiller. To date they have built 54 at a rate of 4 per day. Plans are to increase production to 20 units per day. Presently the work on the tillers employs 67 new workers in the shop and this will be increased to 107 when the 20 per day schedule is reached.

Kalayaan Engineering. A small 30 employee plant is producing the 6 and 8 row seeders as well as the foot pumps and seed cleaners. Some 300 seeders have been produced and sold to date.

Carlos Wafana. Small shop that has made 8 of the power tillers to date with 15 more in process. His shop has a goal of 25-30 tractors per month. Will increase employment by 15 people when reaches higher production. Also producing rice hullers and table threshers.

A. P. Rodrigues, Cabanatuan. Produces some table threshers but primarily produces the old McCormick Deering type stationary thresher.

Marsteel Corp. has a system of 43 dealers around the country. They are planning and carrying on demonstrations of the tiller. I attended two of these and talked to the farmers who were watching. The concensus among the farmers was that they liked the tiller because it was cheaper, lighter, locally made and equally efficient to an imported one which cost more than twice as much.

The use of machines developed by IRRI other than the power tiller is limited and will probably grow at a slower rate than the land preparation machines. The pre-germinated seeder is being demonstrated in Neuva Ecija province with some acceptance. One demonstration seen was planted in the rain on July 27 and shows an excellent stand. The farmer has 5 ha. of land and states that he plans to use the seeder on all his land next year. He states that even with the necessary herbicide the method is cheaper, easier and much faster. There is also the matter of timeliness. Labor is short at transplanting time as well as at harvest time. Further, the practice of hiring labor through a contractor is growing and often the contractor cannot deliver or ups the price when the job is about half finished. Another large

The Philippines (con't)

land holder (200 ha.) is using the seeder exclusively on the 20 ha. he himself farms. He believes that the rate of adoption will be slow because of the weed problem and the extra tillage necessary to prepare the paddy for seeding. Also, there is the problem of exacting water control requirement. Thus, the seeder will probably be limited to those areas and the larger farms where there is adequate water control and good management as well as available capital for purchase of herbicide.

The table thresher has also been well demonstrated in this pilot area. Its acceptance by farmers is not high. They complain that it is too difficult to move, losses are too high and that the chaff causes condiserable discomfort to the men feeding the machine.

I visited Naga in Southern Luzon. There are two shops here making similar tillers to the IRRI design as well as various attachments. In almost every village you find at least one shop fabricating attachments and capable of performing repair work. In this area, double cropping using pump irrigation is becoming the rule. In the past, the initial land preparation was generally done by large tractor through jobbers. With double cropping, the paddies are becoming too soft for the larger tractors. This if forcing a shift in land preparation to the smaller tillers.

As of to date, the other machines designed are not being built with the exception of the seed cleaner. There is interest everywhere in the small batch drier. However, this type of equipment is seldom suitable for the small individual farmer. Perhaps it can be marketed to co-ops and the small mills.

Attached is a memo from Frank Sheppard which clearly shows the impetus being generated by the tiller.

Korea

The Korean agriculture mechanization situation is well covered, both as to present and future needs, by the Exotech studies, August 27, 1972 report titled, "Farm Mechanization Program for Korea."

In summary, this report (whose goals are already adopted by the ROK) sets up a program of greatly expanded farm mechanization over the next 10 years. Need for such a program is justified on the basis of out migration from rural areas. Extimates are for an overall 30% population increase by 1985. However, there is a predicted 43% drop in rural population.

This rural out migration becomes very rapid after 1975 and increasing to a point where in 1985 there will remain only 65 farm workers out of each 100 available in 1975.

The proposal to overcome this loss and still reach reasonable overall goals of an increased agriculture production of some 43% by 1982 provides for a phased increased production of farm machinery as follows:

1. For rice and barley - a phased production of 163,411 power tillers (8-10 H.P.) plus 415 4 wheet tractors, 163, 411 power threshers, 3,700 transplanters and comparable increase in power sprayers, irrigation pumps, other related machines and tools.

For other crops, 2977 power tillers, 415 wheel tractors and compliments of equipment. In addition, it is estimated that 34,289 replacement power tillers will be required plus comparable replacement and parts for other machines.

As a comparison to planned requirement, there were 17,136 power tillers in use in 1971 or 14.2 per 1000 ha. of paddy land.

Local production facilities are or can be expanded to meet these requirements. 1970 (latest available) show the following domestic production:

| | |
|---|---|
| Stationary engines - 6 - 43 H.P. | 11,933 |
| Power tillers | 3,717 |
| Irrigation pumps | 13,699 |
| Power sprayers | 24,010 |
| Manual sprayers | 73,093 |
| High pressure sprayers | 34,531 |
| Power threshers | 1,537 |

Domestic production is of relatively sophisticated machines copied from or adapted from Japaneese models. This includes individual clutches, 4 speed forward and 2 in reverse for power tillers. Price delivered to fa mers of a 10 HP power tiller with all implements runs to 372.608 wan or just over $1,000 at present rate of exchange.

Korea (con't)

One company visited, Dae Doug at Chinju has capacity to produce 20,000 power tillers and complement of machinery plus choice of 6 to 12 HP gasoline, kerosene or diesel motors. This plant is importing $1,000,000 of new production tools which is estimated to increase capacity to 30,000 sets per year. Incidently, this plant was provided an $860,000 AID (ICA) loan in 1958 which financed its modernization. Today it produces 95% of all component parts of a rather extensive list of machines. (2 Brochures are attached showing some of the production). This plant is only 1 of some 11 major plants manufacturing agriculture machinery in Korea.

Market demand in Korea is sharply limited by availability of purchasing power. At present, the primary source of capital available is through the ROK agriculture mechanization program. This credit program is through the agriculture cooperatives program. This program is providing up to 70% of the purchase price for power tillers with a 5 year repayment schedule, and a 50% loan and 2 year repayment schedule for lesser implements.

Purchasing power will, for instance, limit Dae-Doug's production of power tillers to 5,716 sets, of which 4,216 sets are under the companies allotment from the ROK's agriculture mechanization program. From this it appears that only some 26% of the production can be financed through non government sources of capital.

In relation to the IRRI contract machines, the sub-contract for evaluation has only started this year with a table thresher and 2 pre-germinated seeders. ROK officials and manufactures are keenly interested in receiving a testing for adaption of the powered multi-purpose thresher, the power tiller and the power weeder.

There is some question in my mind as to the acceptability of the IRRI power tiller by Korean farmers. They are accustomed to the more sophisticated locally produced machine and may prefer this, especially since the ROK provides liberal credit for this machine. However, the IRRI machine could probably be produced locally and sold at 40 to 50% of the price of present machines.

There is an apparent great need for the powered multi-purpose throw in thresher. The time element of getting the barley crop off and the rice planted in the spring and conversly in the fall is critical. It would appear that as much as two weeks could be gained at each harvest by use of the thresher in the paddy immediately following cutting. This time factor gain could increase barley-sheat production by as much as 30%. Another factor is the relatively high shattering tendency of the new 669 IRRI variety of rice. Reduced handling of the sheaves and higher moisture content threshing could save a large portion of the estimated 10-20% field loss of this crop. This type of operation may have a reverse effect in causing a need for drying. However, it appears well worth trying.

TAIWAN

Taiwan has industrialized to the point where there is a real labor shortage for farm work. This is forcing the Taiwanese farmer to mechanization. It is also reflected in a lowering of production per unit of land. The number of work animals is dropping at the rate of about 10,000 per year.

Taiwan is well equipped to manufacture and service its agricultural machines. They initially had some 30 small companies producing tillers and other implements. These gradually failed fpr lack of capital. Now, there are two large companies producing a full complement of machinery for rice. Their design and production is primarily copied from or adapted from Japanese machines, although quite sophisticated, they fit local conditions. The problem is that their final costs are approximately 30% higher than a comparable imported Japanese model.

The sugar companies have and use large tractors and do some custom work on adjoining rice paddies. However, the paddies are small and badly fragmented with several too many small paddies in different locations under one ownership.

Taiwan had just recently received seeders and table threshers. They have not had time to check them or demonstrate them to manufacturing companies. It is my belief that the throw in type thresher would go good here as well as the batch dryer. The practice of threshing in the paddy right behind the harvesters is well established.

Manufacturers I talked to are interested in looking at the IRRI machines. General opinion favor a cheaper machine; one with more attachments than the IRRI tiller. It is interesting to note that the Taiwan Agricultural Research Institute has already made changes and improvements in the seeder with a new drive wheel and with a new hopper box with plastic, instead of aluminum tubes.

In all probability, within 10 years or less, Taiwan agriculture will be almost wholly mechanized. Also, unless Government policy gives more reward for the farmers, labor in the form of subsidies or price stimulation, rice production will probably continue to drop by shifting to other higher paying crops. The choice as of now is clearly against the farmer staying on the land since reward for his labor and investment is greater in industry than in farming.

For those interested in a closer look at Taiwanese mechanization, an article "The Development of Mechanized Rice Culture in Taiwan" June 23, 1969 by the JCRR is on file in TAB/AGR.

Singapore

Purpose of visit to Singapore was to meet with and discuss plans of major agriculture equipment companies in East and South Asia in regard to their plans for development of specialized equipment for rice in the tropics. Singapore is the regional headquarters for major agriculture equipment manufactures and dealers for the area.

Interviews were held with SHC - Ford, John Deere and David Brown. None of these companies are planning anything for specialized rice mechanization. They believe that with flotation tires, cage wheels and wheel lugs that conventional tractors can do the land preparation job under most conditions and that the market is good enough to keep them in business and expanding with conventional U. S. designed machines. They do not believe there is a market in Asia for specialized rice combines. Ford had given up on introduction of the "Iron Mule" for rice work.

I was unable to ascertain whether or not the Glade Lug wheel was an IRRS design or a copy of U. S. Development. They are wildly used on the larger tractors under wetland conditions.

IHC was planning on introduction and sales promotion of an even larger standard 4 wheel tractor of 110 H.P. for wetland work.

I visited several smaller local fabrication shops. They have industrial capacity for fabricating or manufacturing IRRS design machines but due to a limited local market, none are presently manufacturing them.

JAPAN

Japan was visited to follow up on the development one company has made with the three row mechanical weeder developed by IRRI. This company, OHTAKE in Nakajima took the original design, modified it and developed some 11 different attachments. They have manufactured and sold 7,000 to date and believe there is a continuing market for about 2,600 a year in Japan. They have exported 50 machines for use in cultivating aro fields.

The company manufactures several types of threshing machines in addition to the Mini Cultivator.

There is little need to comment on Japan's ability to produce farm machines. They produce a full line of machines for every phase of rice cultivation. Japaneese production of rice is nearly 100% mechanized. In addition, they are exporting their machines to every country in the area.

Attached is a one page catalogue on the Mini-cultivator and the attachments.

Mr. Ohtake, President of the company gives full credit to the IRRI project for the original design of the basic machine. He does not have plans at present to produce the machine for export.

Thailand

The sub-contract with the Engineering Division, Rice Department and the Rockefeller Foundation had received two of the table threshers and two sets of the pre-germinated paddy row seeder. Two tests had been run on the table thresher. As in the Philippines, there was reluctance on the part of the farmers to accept the machine because of the difficulty of movement from field to field and because of discomfort from the chaff to the men feeding the machine. Coupled to this problem, output was relatively low--219 kg/hr at higher speeds with 16.55% shatter and separation loss and 190 kg/hr at lower speeds with 8.46% shatter and separation loss. Two tests with the seeder had been run at Khon Khen. (Stands were fair even in the face of the drouth.) However, farmers hired to prepare the land objected to the amount of preparation required and stated that they would not spend the time and effort to prepare their own land to receive mechanized equipment.

The Thai capacity to fabricate and build land tillage equipment is relatively well advanced. They have been porducing the iron buffalo locally for some 15 years and are presently producing and selling some 3,000 units per year. This machine is considerably heavier than the IRRI model but seems well accepted by the Thai farmer. It works on the same chain driven-single axel principle. There are an estimated 200 plus local shops producing the iron buffalo on an order basis.

Thailand is manufacturing their own small motors. These run from 5 to 14 hp and are presently gasoline driven. They are planning to manufacture diesel next year. The Winner Machinery Co. was visited at Chacherngsao. This plant employs 170 workers about 40% of whom are young girls. The girls operate all the lathe and drilling machines. The factory fabricates all parts of the motors except for the ball bearings, spark plugs, wiring harness and magnetos. They manufacture about 1,000 motors per month and plan to expand production to 3,000 per month.

The Engineering Division, Rice Department has developed and tested a number of machines for rice production. It is interesting to note that they started work 6 years ago on the centrifugal hulling machine and a connecting polisher. They have built and tested a prototype machine with good capacity and efficiency. However, it is sitting on display at the Kings garden. They have also developed a prototype throw in type thresher on wheels, barrel type cleaner. All of their designs are more massive and hence cost more to fabricate than the IRRI models.

Dr. Ben Jackson of the Rockefeller Foundation estimates that about 90% of the initial land preparation for upland crops and paddy land in Thailand is performed by large 4 wheel tractors of which it is estimated that there are now some 30,000 units in operation in Thailand. At present, there are three tractor assembly plants situated in the Bangkok area, Fordson, Massey Ferguson and Stevr.

Thailand (Con'T)

The following is a list of farm machinery and implements presently produced locally and used by the rice farmers:

Modified from imported Tractor Equipment

1. 1-8 disks (plough) - for paddy soil preparation.
   The production of this type of implement is completely fabricated by local workshops and plants.

2. Earth moving blades - for Land levelling, are locally manufactured meeting approximately 80 per cent of the annual demand; the rest is imported.

3. Centrifugal pumps - for irrigation purposes, are manufactured locally meeting approximately 90 per cent of the total demand; only 10 per cent is imported.

Locally designed and manufactured farm machinery and implements are as follows.

1. Different types of low-lift propeller pumps; driven by low horse-power engines, used for paddy field irrigation. The present annual production is 30,000 units.

2. Various sizes of puddling machines; These machines vary from 10-15 hp. andare used for soil preparation under wet field conditions.

3. Hand tractors (Iron Buffalo Type); driven by a 7-10 hp. gasoline or diesel engines, used for wet paddy soil preparation; approximately 3,000 units are manufactured annually.

The rice mechanization situation in Thailand is somewhat unique. There is rice available export in good years that may even exceed the market demand. Thailand is largely a one crop per year economy with only limited double cropping. The new varities are not adapted to much of the country because of lack of water control. Incentive to produce is not great due to price control which holds the price to the farmer some 30% under that of the world market.

Thailand (Con't)

Tractors for land preparation are preferred with little or no machinery entering the other processes except for spraying. Threshing is largely by hand and is a family labor process. Harvesting is largely family labor due to high cost of hired labor. Rice is harvested over a long period of time at the end of the rainy season with little effort made to quickly remove the crop and plant another crop to use residual moisture. However, the present method of harvesting and threshing results in very large field losses. Dr. Jackson estimates that this may run as high as 20% of the rice crop. He believes that the introduction and use of the IRRI PTO thresher could reduce this loss to around 5% and that with the large number of 4 wheel tractors and the established system of contracting, relatively rapid acceptance of this machine is possible. Mechanization of harvesting and threshing could increase rice available for human consumption by a very significant amount.

OTHER COUNTRIES IN THE RICE GROWING AREA NOT VISITED.

India, Vietnam, Indonesia, Ceylon and Maylasia were not visited. However, with the exception of Vietnam and Indonesia these countries are quite well along the road to mechanization. Indonesia is probably the least mechanized and will probably be one of the last countries to mechanize, especially Java due to such a large surplus of agriculture labor available and traditional methods of harvesting. However, increased double cropping will eventually demand some mechanization of land preparation if only due to the time factor. Also, a relatively inexpensive batch dryer is badly needed for small rice mills. Vietnam has started a tiller factory in a joint venture with Mitsibushi. It is reported they are having problems but are producing machines. There is no sub-contract in Vietnam. The AID Mission there has imported many tillers and tractors especially for the Delta area.

For further information about these countries, those interested can find considerable information as to the state of mechanization in the 4 AMA publications on file in TAB/AGR.

ATTACHMENT

# B I B L I O G R A P H Y

## AGRICULTURAL ENGINEERING DEPARTMENT
## THE INTERNATIONAL RICE RESEARCH INSTITUTE

MAY, 1972

The materials listed in this bibliography represent the major publications, articles, and working papers of the Department from 1963 to 1972. Efforts will be made to fill reasonable requests for items which are available in adequate numbers. Inquiries should be directed to the Department of Agricultural Engineering, IRRI, P.O. Box 1300, M.C.C., Makati, Philippines D-708.


I. FIELD OPERATIONS, MACHINERY AND IMPLEMENTS

A. Irrigation and Drainage

1. Thongtawee, N. "Measurement of Evapotranspiration and Water Losses in Flooded Fields". Research project conducted under the supervision of Mr. Loyd Johnson. (Mimeo.)

2. Johnson, Loyd. 1963. "The Relative Importance of Evaporation, Transpiration, Percolation and Seepage in Flooded Rice Culture". Seminar Paper. April 25.

*3. Johnson, Loyd. 1965. "Traction Problems on Flooded Rice Soils". Paper presented at the Annual Meeting of the Amer. Soc. of Agr. Eng., University of Georgia, June 20-23.

4. Johnson, Loyd. 1965. "Irrigation of Rice". Saturday Seminar Paper. August 21.

5. Casem, E.O. 1966. "Soil Depth Effects on Rice under Lowland Conditions". Paper presented at the convention of the Phil. Soc. of Agr. Eng., Manila, May 6.

6. Johnson, Loyd. 1967. "Water Use and Management". Saturday Seminar Paper. September 9.

B. Tillage

1. Johnson, Loyd. 1963. "Report on the Conference on Agricultural Engineering Aspects of Rice Production". International Rice Commission Newsletter. Vol. 7, No. 3. September. (Reprint).


*Out of print.

2. Casem, E.O. 1965. "Tillage Studies at IRRI". Saturday Seminar Paper. August 28.

3. Johnson, Loyd. 1967. "Land Preparation". Saturday Seminar Paper. September 2.

4. Cabanos, P. 1970. "Mobility Studies in Wetland". Saturday Seminar Paper. August 22.

5. Koike, Masayuki. 1970. "Dynamic Analysis of Rotary Tillage," Terminal Research Report.

C. Fertilization

1. Manalo, A. 1966. "Anhydrous Ammonia Applications for Lowland Rice". Saturday Seminar Paper. April 23.

2. Casem, E.O. 1968. "Fertilizers and Fertilizer Applicators for Lowland Rice". Saturday Seminar Paper. September 14.

D. Planting

1. Reyes, Rodolfo. 1966. "Plant Spacing in Direct Row Seeded and Square Hill Transplanted Rice". Paper presented at the convention of the Phil. Soc. of Agr. Eng., Manila, May 6.

2. Navasero, N.C. 1969. "A Row Seeder for Lowland Rice Soils". Saturday Seminar Paper. September 6.

3. IRRI. 1970. "Fast Seeder". The IRRI Reporter. Vol. 6, No. 2. March-April.

4. Wikramanayake, V.E.A. 1971. "Direct Seeding and Transplanting of Rice". Paper presented at the International Rice Conference, IRRI, April 19-20.

5. Row Seeder Instruction Manual.

E. Pest Control

1. Takenaga, T. 1971. "Technical Problems in Mechanization of Pest Control". Inst. of Agr. Mach., Omiya, Japan. (Reprint).

F. Weeding

1. Navasero, N.C. 1968. "Mechanized Weeding in Wetland". Paper presented at the Joint UPCA-IRRI Seminar. September 30.

2. Navasero, N.C. and A.U. Khan. 1969. "Use of Mechanical Power for Rotary Weeding". Paper presented at the Annual Meeting of the Phil. Soc. of Agr. Eng., IRRI.

3. Navasero, N.C. and A.U. Khan. 1970. "Use of Mechanical Power for Rotary Weeding". PANS. Vol. 16, No. 1. March 1. (Reprint).

4. IRRI. 1970. "Power Weeder for Paddies". The IRRI Reporter. Vol. 6, No. 2. March-April.

G. Harvesting and Threshing

1. Casem, E.O. 1967. "Harvesting and Threshing". Saturday Seminar Paper. September 9.

2. IRRI. 1967. "Lightweight Paddy Thresher". The IRRI Reporter. Vol. 6, No. 3. May-June.

3. Casem, E.O. and A.U. Khan. 1969. "Physical Properties of the Rice Plant and Paddy". Saturday Seminar Paper. August 23.

4. Khan, A.U. 1971. "Harvesting and Threshing of Paddy". Paper presented at the International Rice Research Conference, IRRI, April 19-21.

5. Table Thresher Instruction Manual.

6. Khan. 1972. "New Harvesting and Threshing Equipment for Small Tropical Farms". For presentation at the IAMFE Third International Conference on the Mechanization of Field Experiments, Brno, Czechoslovakia, July 10-15.

II. DRYING AND PROCESSING

A. General Papers on Rice Milling and Processing

1. Khan, A.U. and V.E.A. Wikramanayake. 1971. "A Laboratory Test Tube Rice Miller". Agr. Eng. Dept. Paper No. 71-08 (Mimeo.)

2. Van Ruiten, Harry. 1971. "Recent Developments in the Rice Milling Industry of the Philippines". Paper presented at the International Rice Research Conference, IRRI, April 19-21. Agr. Eng. Paper No. 71-09.

3. Khan. A.U. "Rotary Grain Cleaner for Tropical Countries". (Mimeo.)

4. Wimberly, James. 1972. "Review of Storage and Processing of Rice in Asia". Agr. Eng. Dept. Paper No. 72-01. (Mimeo.)

5. Khan, A.U. 1972. "Rice Drying and Processing Equipment for Southeast Asia". ASAE Paper No. 72-339. For presentation at the ASAE Summer Meeting, Hot Springs, Arkansas, June 27-30, 1972.

6. Grain Cleaner Instruction Manual.

7. Bibliography of Drying and Processing Studies in Southeast Asia. 1972.

B. Drying

*1. Amilhussin, A., A. Manalo and A.U. Khan. 1970. "Accelerated Drying of Paddy". Saturday Seminar Paper. September 5.

2. IRRI. 1970. "Drying Paradox: Wet Is Better". The IRRI Reporter. Vol. 6, No. 2. March-April.

3. Manalo, A., A. Amilhussin and A.U. Khan. 1970. "Drying Chemically Treated Paddy to Break Dormancy". Saturday Seminar Paper. September 5.

4. Manalo, A. 1970. "Design Data on Counterflow Drying of Rice". Paper presented at the Seminar Workshop on Grain Processing. Univ. of the Phil. Coll. of Agr., December 7-10.

5. Manalo, A. 1970. "Paddy Drying Research at IRRI". Paper presented at the Annual Convention of the Phil. Soc. of Agr. Engineers, Univ. of the Phil. Coll. of Agr., December 11-12.

6. Manalo, A. 1971. "Rice Hulls as Fuel for Drying Paddy". Saturday Seminar Paper. September 11.

III. MACHINE TESTING AND EVALUATION

1. Nichols, F.E. 1971. "The Role of Preventive Maintenance in Agricultural Equipment Development". Saturday Seminar Paper. August 28.

IV. MECHANIZATION IN AGRICULTURE AND ECONOMIC DEVELOPMENT

1. Johnson, Loyd. 1963. "Power Requirements in Rice Production". Paper presented at the Conference on Agricultural Engineering Aspects of Rice Production, August 11-17.

2. Johnson, Loyd. 1964. "Mechanization of Philippine Farms". Paper presented at the Second Irrigation Institute Conference, May 29.

3. Johnson, Loyd. 1964. "Mechanization to Improve the Standard of Living in Tropical Rice-Growing Areas". Paper presented at the ASAE Winter Meeting, New Orleans, Louisiana, December 8-11.

*4. Johnson, Loyd. 1965. "Mechanization to Improve the Agriculture of Developing Countries". Paper presented at the Annual Meeting of the Ind. Soc. of Agr. Eng., New Delhi, November 11.

5. Johnson, Loyd. 1966. "Is Mechanization Possible Where Rice Is King?" Agricultural Engineering. Vol. 37, No. 3. March. pp. 132-135.

6. IRRI. 1966. "Labor and Procedure for the Pedal Thresher". Tech. Paper No. 2. September.

7. Casem, E.O. and E. Ruiz. 1967. "An Analysis of Rice Farm Operations in Central Luzon". Paper presented at the convention of the Phil. Soc. of Agr. Eng., May.

8. Johnson, Loyd. 1967. "Mechanization of Rice in Tropical Areas". Thursday Seminar Paper. May 25.

9. Khan, A.U. 1968. "Agricultural Machinery Research and Development at The International Rice Research Institute". Paper presented at the meeting of the Jap. Soc. of Agr. Mach., Kyoto, Japan, April 6-8.

10. Khan, A.U. 1968. "Agricultural Machinery Research and Development at The International Rice Research Institute". Paper presented at the Fifth Session of the Internatinal Rice Commission Working Party on the Agricultural Engineering Aspects of Rice Production, Storage and Processing, Kandy, Ceylon, September 5-9.

11. Khan, A.U. 1969. "Position Paper on Agricultural Engineering Research in the Philippines". Paper presented at the meeting of the Advisory Committee on Agricultural Research, Nat. Sc. Dev. Board, Manila, August 28.

*12. Khan, A.U. 1969. "Agricultural Machinery Development Program at The International Rice Research Institute". Paper presented at the VII International Congress of Agricultural Engineers, Baden-Baden, West Germany, October 6-12.

13. Khan, A.U. 1970. "Mechanization Research for Tropical Agriculture". ASAE Paper No. 70-114, presented at the Annual Meeting of the Amer. Soc. of Agr. Eng., Minneapolis, Minnesota, July 8-10.

14. Khan, A.U. 1970. "Mechanizing the Tropical Farm". Agricultural Engineering. Vol. 51, No. 11. November. pp. 640-642. (Reprint).

*15. Khan, A.U. 1971. "Equipment for Mechanized Tropical Agriculture". Agr. Eng. Dept. Paper No. 71-02. Paper presented at the seminar on the Mechanization of Agriculture in West Africa, Bambey, Senegal, January 25-29.

16. Khan, A.U. 1971. "Agricultural Machinery Development at The International Rice Research Institute". Agr. Eng. Dept. Paper No. 71-07, presented at the seminar on Mechanization of Rice Production and Processing, Paramaribo, Surinam, September 27-October 2.

17. Khan, A.U. 1971. "Machinery Development for Tropical Agriculture". Agricultural Mechanization in South East Asia. Spring. pp. 35-37.

18. Khan, A.U. 1972. "Agricultural Mechanization: the Tropical Farmer's Dilemma". World Crops. (Forthcoming).

V. ECONOMICS OF MECHANIZATION

A. Mechanization and Employment

1. Johnson, Loyd. 1963. "More Farm Power for More Days of Farm Production per Year". Paper presented at the First National Convention of Pump Irrigators sponsored by the National Federation of Pump Irrigation Associations, Manila Hotel, January 23.

2. Johnson, S., E.U. Quintana and L. Johnson. 1967. "Mechanization of Rice Production". Paper presented at the Seminar Workshop on the Economics of Rice Production, IRRI, December 8-9.

3. Johnson, S. 1968. "Performance and Economics of Small Equipment in Tropical Monsoon Countries: The Case of the Philippines". Paper presented at the Annual Meeting of the Jap. Soc. of Agr. Mach., Kyoto, Japan, April 6-8.

*4. Orcino, N. 1970. "Economic Aspects of Hand Tractor Ownership and Operation". Saturday Seminar Paper. September 22.

5. Duff, B. 1971. "The Impact of Improved Varieties and Agricultural Mechanization on the Labor Force Absorption Problem in West Pakistan". Tables and charts accompanying. Thursday Seminar Paper. February 25.

6. Duff, B. and N. Orcino. 1971. "Economic Research in the Department of Agricultural Engineering". Saturday Seminar Paper. August 21.

7. Crisostomo, C., W.H. Myers, T. Paris, B. Duff and R. Barker. 1972. "The New Rice Technology and Labor Absorption in Philippine Agriculture". Malayan Economic Review. (Forthcoming).

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9. Duff, B. 1971. "Economics of Mechanizing Large versus Small Farms in West Pakistan". Paper presented at the International Rice Conference, IRRI, April 19-21.

B. Comparative Economic Studies of Rice Production and Processing

1. Alicbusan, L.C. 1964. "The Rate of Substitution of Man-Hours by Animal or Machine Horsepower Hours in Rice Production". August. (Mimeo.)

2. Ruiz, E.L. and E.O. Casem. 1967. "An Analysis of Rice Farm Operations in Central Luzon". Presented at the convention of the Phil. Soc. of Agr. Eng. May.

3. Barker, R., S. Johnson, N. Alviar and N. Orcino. 1969. "Comparative Economic Analysis of Farm Data on the Use of Carabao and Tractor in Lowland Rice Farming". Paper presented at the Farm Management Seminar with Focus on Mechanization sponsored by the Institute of Small-Scale Industries, Manila, February 24-March 1.

4. Johnson, S. 1969. "Terminal Report on the General Engineering and Economic Research Portion of Contract No. AID/csd-834".

C. Economic Aspects of Machinery Manufacturing and Marketing

1. Johnson, Loyd. 1967. "Comments, Definitions, and Personal Opinions to Explain the Tropical Rice Producers' Conditions and Problems of Machinery Manufacture". Project Committee Meeting of Contract No. AID/csd-834.

*2. Cabanos, P. 1971. "Jeepney Manufacturing in the Philippines, A Model for Developing the Agricultural Machinery Industry". Agricultural Mechanization in South East Asia. Vol. 2. Autumn. (Reprint).

## VI. SEMIANNUAL PROGRESS REPORTS

In addition to materials prepared for meetings and publications, the Department submits a regular semiannual progress report describing the status of individual research and development projects conducted under a joint IRRI-AID contract. These reports are listed below:

*Semiannual Progress Report No. 1 by Loyd Johnson
* " " " " 2 by Loyd Johnson
" " " " 3 by Loyd Johnson and S. Johnson
" " " " 4 by Loyd Johnson and S. Johnson
" " " " 5 by A.U. Khan and S. Johnson
" " " " 6 by A.U. Khan and S. Johnson
" " " " 7 by A.U. Khan and S. Johnson
" " " " 8 by A.U. Khan
" " " " 9 by A.U. Khan
" " " " 10 by A. U. Khan
" " " " 11 by A.U. Khan, F.E. Nichols and B. Duff
" " " " 12 by A.U. Khan, F.E. Nichols and B. Duff
" " " " 13 by A.U. Khan, F.E. Nichols and B. Duff

## VII. MISCELLANEOU

1. Johnson, Loyd. 1966. "Mathematics, Engineering and Agriculture". Thursday Seminar Paper. February 17.