International specialized media for agricultural mechanization in Asian developing countries.

AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL. V, NO. 1, SUMMER 1974

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

TEST YOURSELF

1. You are farming wet paddy. The weather has turned and it's time to prepare the ground for planting. The problem is, you have more land than you can till by yourself. In order to get the paddy planted you need:

   A. Many friends and relatives.
   B. A Kubota K120 Power Tiller.
   C. To sell some of your land.

2. You have some good land which has been used to grow coconuts. You want to convert the land for use in cultivating sugar. For this you need more water than is available on the land itself. You have a good source of water but it is some distance from the land you wish to use. In order to get the water from your source to the land you need:

   A. 3,000 water buffalo.
   B. Rain every day.
   C. Kubota pumps and pipes.

3. You are raising grapes in vineyards in the Saône Valley of France. You have acquired some new land which is perfect for grapes. However, the land is not level but rolling and, in places, almost mountainous. You want to till the land but do not have the manpower to use on the slopes and most farm machinery is too heavy and bulky to use on the steep terrain. You need:

A. A Kubota L175 Tractor.
B. Trained mountain goats.
C. Dynamite to level the terrain.

4. It is late September. Your rice fields are bursting with one of your best crops. You had intended to spend the next two weeks harvesting, binding, and separating the rice prior to refining. Now you hear that a sudden typhoon is about to strike before you will have a chance to complete the harvest. You need:

A. Weather insurance to cover your losses.
B. A Kubota HX 700 Combine.
C. Neighbors and their children to help harvest.

ANSWERS

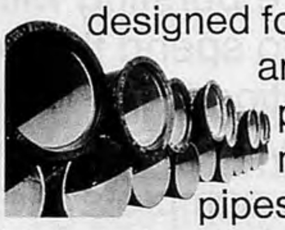
1. B

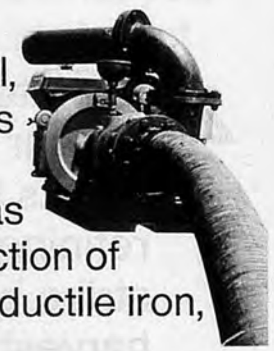
KUBOTA K120 Power Tiller

The K120 is one of three Kubota Power Tillers designed for wet paddy use. Along with the K75 and the K700, the K120 is compact, efficient and loaded with extra features. Tough, lightweight construction means the K120 can go anywhere to perform any job.

2. C

KUBOTA Pumps and Pipes





Quick to install, easy starting, compact and powerful, designed for easy maintenance, Kubota Pumps are the answer to any irrigation problem. And Kubota technology has made it a world leader in the production of pipes. From PVC piping to super strong ductile iron, Kubota has the pipe to solve the problem.

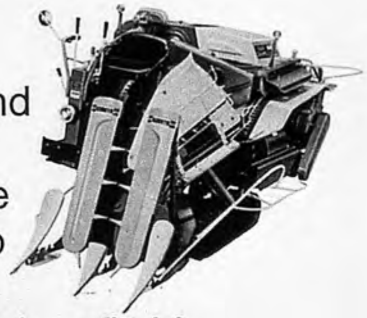
3. A

KUBOTA L175 Tractor

Along with the L225 and the L260, the L175 is the perfect tractor for jobs requiring heavy power from a medium sized design. Perfect grow power for jobs ranging from vast wheat fields or mountain vineyards to wet paddy. With ten speeds (two reverse) and a four speed Power Take Off you have extra flexibility.

4. B

KUBOTA HX Combine



The Kubota series of combines and cutters and binders provides the easy, efficient way to harvest your crop. Special design features, like sturdy rubber crawlers on the HX Combine, to prevent getting stuck in a muddy paddy, ensure that your work will get done quickly and profitably.

MORE ANSWERS

Kubota has the answers to the preceding test and to any test you may face in the agricultural area. As an example of other Kubota solutions to agricultural problems consider:

Irrigation systems

As a leading manufacturer of both water transportation equipment and agricultural equipment it is only natural that Kubota has been responsible for the evolution of complete irrigation systems. Starting with the pumps and engines necessary to draw, carry and drain water for irrigation and drainage, Kubota carries water in high quality PVC or asbestos-cement pipe. Once at the destination water is pumped through a range of Kubota sprinklers, all offering high quality, maintenance free performance.

Agricultural Machinery

In addition to the machinery shown above Kubota has a complete line of agricultural machinery ready to help you with any agricultural task. Power tillers, cultivators, tractors, combines, cutters and binders, are only part of the Kubota picture. There are also mechanized fertilizers and seeders, weeders, threshers and hullers and mowers. Finally, to protect your crops, Kubota markets a wide variety of sprayers and dusters ranging from large high-speed sprayers to small hand dusters.

Diesel Engines

Sometimes the power to make Kubota machinery functional must serve more than one purpose in order to be truly useful and efficient. Kubota has the answer to the problem of safe, low-cost, convenient power. The Kubota range of diesel engines gives you portable power wherever you need it. Power generation for pumping, driving machines, irrigation, providing light. Whatever your power needs in agriculture there is a Kubota diesel engine to get the power to you.

TEST KUBOTA

The tests of agricultural productivity are not all black and white. But they are all difficult. And there is evidence that the tests and problems of food production are growing every day. In order to answer the questions that arise, to solve the problems that face us, we will have to turn to higher technology for agricultural production.

Kubota has been hard at work for several generations, trying to meet the challenges in this area. Efficient use of land, irrigation of non-arable land, greater crop yields, mechanized systems of production; these are all demanded by the future. Kubota is working today to meet those demands.

The time when hand implements and human or animal power could suffice, is fast coming to an end. Labor saving, production expanding machinery, operating efficiently and profitably, is part of the new age of agriculture. As you enter this new age, think of Kubota. Whether your needs be in diesel engines to provide generator power, tractors for the steepest hills or the muddiest paddies, tillers, combines, cutters, binders, excavators, pumps, pipes or valves, Kubota can help you enter the new age of agriculture. Whatever the test, whatever the challenge, Kubota has answers.

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AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL. V, NO. 1, SUMMER 1974

Edited by

YOSHISUKE KISHIDA

Published by

Farm Machinery Industrial Research Corp.

Cooperated by

Shin-Norinsha Co., Ltd.

The International Farm Mechanization Research Service

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Printed in Japan

Preface

This is the 7th Edition of AMA. The editor is very thankful, because a close cooperation and strong support has been extended to the series of publications by a number of specialists in the world, a wonderful fact in which he has never experienced before. As a result, AMA is being circulated among no less than 120 countries. AMA is most probably the one publication of its kind in the world.

Various comments from many nations have been given to the editor before the 7th Edition was published. One of them : AMA should be renamed as AM3A, which aims at the study of the mechanization of developing countries centering on Africa, Asia and America. The editor is of the same opinion in principle, however, he wishes to have a preparation period of one year in order to realign the concept.

To cut the cost down, AMA has been and is beeing compiled by a very few but very able staffmembers, a task which requrires a heavy burden. There is another suggestion raised by a reader : AMA should focus its attention on tropical farming.

The theme of farm mechanization involves a variety of aspects. It is concerned with not only rural life or the supply of foodstuff but also the explosive increase in population, particularly in Urban areas.

This is the case with every and each country. In the region where commercial farming is still in embryo, fúll-time farmers usually represent about 80 per cent of total population. Under such circumstances, an exodus of 1,000,000 farmers to cities would cause a keen shortage in foodstuff for 1,200,000 citizens. Even if land productivity increased, new varieties were created and a new technology was developed, it could not be helped at all, so long as the farm mechanization were not introduced effectively.

Farm mechanization in the developing nations involves the manufacturing of even hoes and sickles having a splendit performance. In this sense, it will become vital that the mechanization should be promoted on a world-wide basis.

Farm mechanization is, of course, important. However, even more important is that every and each country should foster its own experts who can develop machinery most suitable for their own countries. This is indeed the editor's cherished desire. To attain this target, the editor assures the readers of his utmost effort to continue to provide global information. Please do not hesitate and feel free to directly contact the editor at all times, in case the readers have a comment of any sort on this publication.

While the 6th Edition treated the one subject exclusively, the 7th Edition contains a wide range of problems. The editor's standpoint on compilation is very flexible ; he will occasionally sheft his own attention from a variety of challenges to a concentrated one and vice varsa. The editor is on the plan to compile reports on farm machinery industry and the extension system of agriculture. Good cooperation and strong support from the readers will be appreciated.

Yoshikuni Kishida

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AGRICULTURAL MECHANIZATION IN ASIA

Vol. V No.1 Summer, 1974

Selective Mechanization: A Hope for Farmers in Developing Countries

by

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Introduction

The type of agricultural mechanization which fits the cultural economic, employment, and production needs of a country we refer to as selective mechanization.

It has been said that employment will be the critical issue of the 1970s and that it is the key not only to development but political and economic stability of the "Third World". The renowned "Pearson Report" stated: "The failure to create meaningful employment is the most tragic failure of development".

Selective mechanization is an approach to mechanical technology compatible with the goals of development and employment.

Abercrombic (1) has stated that "the most obvious symptom of employment problems of the developing countries is that people are migrating from rural areas to the towns much faster than urban jobs can be created for them". Granting this is a fact, what is the cause? Shaw (15) concluded that..."Motives for this migration (rural to urban) are a complex mixture of urban 'pull', the attraction of higher wages, social, cultural, and educational activities and the glamor of the towns; and the rural 'push', the desire to escape from a stagnation that offers only heavy, unrewarding jobs in the atmosphere of little hope". We suggest that the lack of employment opportunities in rural areas, low remuneration for agricultural work, the seasonal nature and drudgery of agricultural employment, and the unattractiveness of rural living under existing conditions all contribute to this urban drift. Thus, creating job opportunities in agriculture is only a partial solution. The most important factor is to improve working and living conditions in the rural areas to compete with the visible amenities of the cities.

We believe selective mechanization of an appropriate type, used under carefully selected conditions, can provide hope for agricultural workers. Selective mechanization can thus provide a "counter-pull" to resist the attraction of the city.

In discussing technological change, Yudelman, et al. (17) defined "selective mechanization" as any form of mechanization which does not decrease the demand for labor per unit of land (removing labor peaks, intensification of production, multiple cropping, etc.). We accept this definition but would like to add that selective mechanization requires not only stabilization or an increase in labor per unit of area,but also must reduce cost and increase production per man. Development is for people and the only means of improving the welfare of people is through an increase in the productivity of labor (real income).

Selective Mechanization and Timeliness

Agricultural mechanization has one major advantage over indigenous methods--the timing of operations. Using hand labor or

* The editorial assistance of L. Faidley, Graduate Assistant in Agricultural Engineering, Michigan State University, is gratefully acknowledged. Approved for Publication as Journal Article Number 6679 Michigan Agricultural Experiment Station.

draft animals often requires that the farmer wait until there is sufficient moisture in the ground to facilitate primary tillage. Timeliness is particularly critical in low rainfall regions where conservation of moisture through timely planting is essential to achieve the maximum production potential of the crop.

Some crops are very sensitive to planting dates and each day's delay in planting reduces the yield. Clayton (4) reported that cotton yield increases of 25% in Uganda were due to the fact that tractor mechanization facilitated timely seedbed preparation in May rather than in June as was the practice with traditional means.

Giglioli (11) found that tractor cultivation (seedbed preparation) had a dramatic effect on increasing rice yields, in the Kenya Mwea Rice Irrigation Scheme, again because of more timely seedbed preparation and planting.

As further evidence of the value of selective mechanization on timeliness, Sprague (16) described a statistically designed experiment in maize production in Kenya. Of six variables in the experiment (time of planting, variety, plant population, weed control, phosphate and nitrogen fertilizer) one of the most important was the time of planting. The conventional system of maize production involved soil preparation by hand labor in the case of subsistence farmers after the rainy season had begun. Thus, planting was delayed at least two weeks later than optimum. Animal power available to the farmer was not adequate. Tractors, either owned by the farmer or leased through a rental service appear to provide the answer to this power problem.

Mechanization and Inadequate Indigenous Farming Methods

Selective mechanization often has an application where a farming operation can not be performed adequately or effectively using indigenous methods. High yielding varieties require accurate placement of the specified quantity of seeds and fertilizer. Metering of herbicides and insecticides can only be done accurately by mechanical means. The production of high quality crops requires timely harvesting, threshing and handling, which is often difficult to achieve with traditional implements and methods. Engine-driven pumps can provide water for irrigation to supplement rainfall and promote double and triple cropping. Multiple cropping in turn requires that one crop be removed quickly and a seedbed prepared and another crop planted in a very short interval of time.

Drew and Bondurant (8) noted that irrigation pump sets are India's most important form of farm mechanization. Two million stationary power units were in use in 1970. The original investment in power units alone is twice that for farm tractors and the power purchased is three times that of all the tractors in India. Pump set irrigation requires labor for leveling fields, making channels and dikes and for diverting and controlling water during the growing season. Because of the higher yields and multiple cropping resulting from irrigation, more labor is required for harvesting operations.

As another example, Shambaugh (14) reported a situation in northeastern Nigeria (near Maiduguri) where a local sorghum (Masakwa) is commonly planted by poking a hole in the ground with a stick and dropping a few seeds in. Weather and seasonal conditions are such that the grass grows tall prior to planting time. The factor limiting the amount of sorghum that can be planted is the labor requirement of cutting the grass and removing it. Experiments with a tractor-powered rotary mower eliminated this labor constraint and permitted an increase in production (and manual labor during the remainder of the season). There are also other operations such as deep ripping, deep plowing and some aspects of land development which are impractical and uneconomic by any other means than tractor mechanization.

Selective Mechanization and Lavor Employment

Let us look closely at the effect of tractor mechanization on employment. Can tractor mechanization actually increase total labor requirements and at the same time increase labor productivity and income? Shaw(15) stated "We must design agrarian systems that are capable of using labor more intensively while increasing agricultural output".

Admittedly the evidence is inconclusive. Some studies show an increase in the total labor required as result of tractor mechanization whereas others show the opposite. Perhaps this is not surprising as some schemes have been conceived with one of the objectives being <u>not</u> to displace human labor. We believe that the tractor schemes which have succeeded in increasing total labor input should be used as models for further study.

Donde (6) conducted a study of 76 farms In the Dhulia district in Hamharashtra, India. These farms had a total of 79 tractors. The following changes in land utilization were noted:

1. Fifty percent of the waste-

land was reclaimed.

2. Net irrigated area was increased by 24 percent.
3. The double cropped area increased from 14 percent of the net sown area before tractors to 20 percent.
4. There was a change in cropping patterns toward intensively grown crops.
5. 0.3 horsepower was added per acre.

In addition, Donde noted an increase in both casual labor employed per hectare and in total labor employed per hectare as a result of tractor mechanization.

S. S. Johl of the punjab Agricultural University also found that increased tractor usage increased the total manual labor as a result of increasing the intensity of cropping, (Drew and Bondurant, 8).

Johl's findings were supported by Rao (13) who concluded:

1. Bullock labor is reduced 45-60 percent after a tractor is obtained.
2. The intensity of cropping is higher on a tractor farm, that is, multiple cropping is more common.
3. Because of increased cropping intensity, employment of human labor has shown some increase.

Esmay and Faidley (9) emphasized that agricultural mechanization in labor surplus countries should and can generate employment as well as increase total food and fiber production. They reported on Comilla, Bangladesh, where 35 HP tractors are owned by a central cooperative association and rented to groups of farmers through their local village cooperatives. They found that persons renting the tractors hired more labor, 56.5 man-days/acre with tractors compared to 51.8 man-days/acre with bullocks when improved varieties of rice were grown and 35.8 man-days/acre compared to 34.5 man-days/acre when non-improved varieties were grown.

Similarly, Yudelman, et al. (17) found in Geylon that mechanized farms used more hired labor than non-mechanized farms. Perhaps, the most important factor is that the use of family labor was 60 percent less on farms using tractors as compared to the farms using buffalo as the source of power. Release of women and children from arduous farm work provides hope of a better life for farm families and can be a significant social benefit for they can then take advantage of educational opportunities or leisure.

Selective Mechanization and Agricultural Production

The overwhelming fact remains that agricultural production is a primary concern of the agricultural scientists, institutions and governments the world over. Dr. A. H. Boerma, Director-General of the Food and Agriculture Organization of the United Nations, made this clear in a recent (2/1/73) press statement in Rome where he stated that a major problem facing the world was food production. "It is inescapably clear that many developing countries must give much higher priority to their agriculture and that most developed countries must give much higher priority to helping them".

It is the responsibility as agriculturalists and agricultural-engineers to provide objective advice and assistance including an unbiased analysis of the relationship between the employment of labor and machines for agriculture production. We feel that selective mechanization has a real contribution to make to achieve increased production and at the same time meet the objectives of employment.

Dr. Boerma stated in his address to the Meeting of Experts on the Mechanization of Rice Production and Processing, held in Surinam 9/27/1971, that "there is no doubt that agricultural production, and thus, the general prosperity of the developing countries cannot advance sufficiently without mechanization. Even if the prospects for increased employment which I have just outlined are regarded as somewhat optimistic and I do not myself think they are-there is no choice for the developing countries but to press ahead with mechanization of their agriculture".

A careful analysis of yields of crops in many countries and the low percentage of arable land under cultivation, particularly in Africa and South America, leaves plenty of room for optimism. Clayton (4) found in a study of mechanization and employment in East Africa that tractor mechanization of seedbed preparation was economical (pyrethreum crop farming) provided the land/labor ratio did not fall below 2.5 acres per man. At that level, tractor mechanization produced a gain of 20 percent over manual cultivation.

Chancellor (3) reporting on tractor contractor services in Malaysia and Thailand found that production and profits were increased from enterprises selected specifically not to displace labor from rural to urban areas. He concluded "tractors can increase agricultural production, not necessarily through increased yields, but by giving enterprising farmers a time resource to be combined with other locally available resources in the development of new, more intensive, agricultural enterprises".

Mechanization Planning

Agricultural mechanization is a complex subject requiring the expertise of many skilled individuals. Consider some of the components of a mechanization system. It involves design, development, testing, manufacturing, marketing, finance, operation, repair and maintenance. If any component is missing or weak, the entire system can fail.

Careful planning is essential to ensure that every requirement is met. Training and extension programs are essential for users along with university level programs for training design engineers, manufacturing specialists, and marketing specialists. Too frequently, failure of a mechanization system is due to faulty planning and execution rather than to the concept itself.

In many cases mechanization begins in developing countries through a direct transfer of technology. This may be a satisfactory method provided a proper system of selection and adaptation is used. However, judicious selection and application of existing machines or modifications of these machines requires a thorough analysis of the production process on the farm (7). Only with such an analysis can we ensure rational selection, proper operation, organization, and management that is compatible with local needs (agricultural, social, economic). Unfortunately, little deliberate effort is made by manufacturers (exporters of machinery) and importers (manufacturers' local agents) to determine what equipment is most suitable and what modifications, if any, need to be made.

Abercrombie (1) emphasized the need for agricultural mechanization research "not purely in the engineering context, but in relation to the whole technological package..., the problem is urgent, with unemployment and underemployment spreading rapidly..., there is already sufficient basis for this to be done, as indicated by the fact that several countries have recently tried to formulate more consistent mechanization policies"

FAO, in collaboration with the Universities of Berlin, Michigan State, and Wageningen, recently sent a mission to Latin America to explore the possibilities for providing joint agricultural engineering research assistance to selected countries in the region. The mission with the concurrence of government officials recommended strengthening of agricultural mechanization research, including the effects of various levels of mechanization on employment at the micro- and macro- level (10).

Conclusions

National mechanization policies are desperately needed in every country. The role of mechanization should be clearly understood by planners, economists and engineers. Shaw (15) wrote "so important is mechanization in defining the future of the agricultural sectors in developing countries that their governments should give the highest priority to conceiving coherent national strategies to deal with the whole set of issues raised. Special care must be taken to analyze the labor displacement effects of any mechanization that is permitted".

Interdisciplinary teams in every country should conduct research to establish mechanization policies and priorities and adopt an objective attitude toward mechanization.

Admittedly, conclusive evidence on either side of the mechanization question is scarce. Opinions are many and we are adding to the list.

But one of the reasons for so many failures in the past is that competent and experienced engineers were seldom involved in the planning and execution of mechanization projects. Davies (5) and many others have clearly outlined the prerequisites for introducing successful mechanization schemes, but usually one or more critical components have been overlooked or ignored, leading to a predictable failure. We argue that mechanization in itself is not inherently bad. Rather, man as an intelligent being always has and should continue to devise tools and implements to ease and speed his work, increase his capacity and, in general, make his life better. Rather than condemning mechanization because of these human shortcomings, we should resolve to improve planning and execution of projects so that they will not fail. We strongly support the concept of selective mechanization. It can provide the hope and attraction to slow the dangerous migration from rural to urban areas.

An agricultural engineer himself, Bondurant (2) asks "How long will engineers be content merely to develop systems to implement scientific advances, rather than to design systems for the needs of particular social and cultural situations?"

A historian who specialized in the history of science and technology, Kranzberg (12) says "Engineers must enlarge their system and redefine their concept of efficiency ... The public is beginning to demand that engineers ... be held accountable for the social and human consequences of their actions".

Applyiog the concept of selective mechanization is a partial answer to the pleas of Bondurant, Kranzberg and others; and it is time for agricultural engineers to give selective mechanization more attention.

Criteria for selective mechanization for varying sets of conditions (region, country, crop, soil, climate) must be developed to reach the objectives of production, employment, return to farmers, income distribution, easier working conditions, and higher standard of living in the rural areas.

Although much is known about mechanization it is commonly misunderstood. Almost every farmer wants it, but its role in a developing country where capital is scarce and labor abundant is not clear. Both advocates and opponents of mechanization have failed to make their case based on hard data and scientific analysis. The tools for systematic analysis exist. It is time for comprehensive feasibility studies including analyses of cost-benefit ratios, effect on employment and other social factors. Studies are needed at both the farm and national level; and agricultural engineers should be involved at both of these levels.

Mechanization is a reality. It is not just an academic theory or a vague concept. Mechanization is being used in every country of the world. Is it not in the best interest of humanity to define the proper role of mechanization in order to provide the highest quality of life for all of the people of a country?

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INDEX TO ADVERTIZERS

Studies of Relations between Farm Mechaization and Crop Yield

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Those concerned with planning for agricultural development require factual, quantitative data on the differences in yield that can be expected if crop operations are done with mechanical power and associated implements, instead by hand or animal power with traditional implements.

Quantitative data on the effects of mechanization on yield are generally obtained either by conducting field experiments at agricultural research stations, or by measuring yields on fields managed by farmers using either mechanical or traditional methods. Although data from farmers' fields tend to integrate the effects of many realistic factors, this procedure is subject to the problem that farmers who can afford mechanical equipment are frequently those can also afford more fertilizer, better seed, more irrigation water, and more pest controls than can farmers who have only traditional power sources and implements.

Research Station Results :

During 1949 amd 1950 in Malaya (now West Malaysia), a concentrated strated study was made by a sizable grop of researchers (1)* on the mechanical cultivation of rice. The yield results of trialv are presented in **Table 1.**

Additional reports (2) from the study provided the following data: **(Table 2.)**

It is evident that although there was a slight tendency for yields to be higher with tractor tillage than with animal tillage, there were several instances were the reverse was true.

Investigations undertaken in the 1952-1954 period at the Risalewala Power Farming Station near Lyallpur, Pakistan (3) provied the information in **Table 3.**

For all crope but cotton there was a slight yield advantage for tractor cultivation.

At the International Rice Research Institute comparisons were made among rice yields obtained with various intensities of tillage operations applied either by tractor (plow and harrow) or water buffalo (plow and harrow). It was found that for equal numbers of passes with either a tractor or a water buffalo, the tractor-tilled plot subsequently developed less weed growth and thus had higher yields. However, when the number of water buffalo tillage passes was three times the number of tractor passes subsequent weed growth levels were the same for either treatment. Data are presented in **Table 4.** for water buffalo and tractor tillage practices having approximately equivalent levels of weed growth.

The data in **Table 4** indicate no consistent yield difference between animal and tractor - powered tillage.

Table 1. Averages of rice yields obtained in trials in which tractor and animal powered tillage methods were compare -kg/hectare

Trial No.	Tractor tillage	Animal tillage
1	1712	1575
2	1384	1226
3	1261	1049
4	2990	3326
5	2290	2204
6	1326	1173
7	597	767
8	770	622
9	800	643

This article has been excerpted from ASAE Paper No.73-511 entitled Relations Between Farm Mechanization and Crop Yield For A Farming District in India, which was presented at the June 1973 meeting of the American Society of Agricultural Engineers in lexington Kentucky, USA. The full paper will appear in the Transactions of the ASAE.

* Numbers in parentheses refer to the appended references.

Table 2. Rice yields. kg/hectare

Trial No.	Method	Weeded	Unweeded
10	Tractor (deep plowing)	1659	1267
	Tractor (shallow plowing)	2485	1868
	Buffalo Plowing	2351	1953
11	Average of 9 Tractor Tillage Methods	2274	1730
	Buffalo Plowing	1941	1602

Table 3. Crop yields. kg/hectare

Crop	Tractor Cultivation	Bullock Cultivation
Sugarcane (stripped)	9554	8176
Cotton	960	1202
Maize (corn)	1926	1464
Wheat	1551	1178
Gram	963	660
Oilseed Crops	1081	896

Table 4. Rice yields. kg/hectare

1967 Season	Variety	Water Buffalo		Tractor	
		Passes	Yield	Passes	Yield
Dry	H-4	3	3618	1	3819
Dry	H-4	6	4178	2	3875
Dry	IR8	3	4850	1	4570
Dry	IR8	6	4948	2	4654
Wet	H-4	3	2676	1	2414
Wet	H-4	12	2638	4	2761
Wet	IR8	3	2878	1	2794
Wet	IR8	12	3774	4	4066

Table 5. Average rice yields. kg/hectare

		Tillage		Transplanting		Weeding		Harvest	
Location	Variety	Power Tiller	Cattle	Machine	Hand	Herbicide	Hand	Binder	Hand
1	A	2311	1999	1906	2399	2154	2176	2209	2101
1	B	2139	2411	2223	2352	2113	2333	2334	2226
2	B	3587	3595	3607	3562	3539	3629	3486	3886*
3	B	5208	5309	5006	5502	5183	5332	5146	5376
4	B	4164	4508	3808	4855**	4314	4456	4190	4478

* Significantly higher at the 5 percent level
** Significantly higher at the 1 percent level

In a comprehensive set of experiments in Taiwan, modern and traditional technology were compared at four stages of rice production, i.e., tillage, transplanting, weeding, and harvest (5). Average results from two replicated trials at one location are given in **Table 5.**

In most of the comparisons afforded by **Table 5,** average yields with traditional technology were slightly higher than those with modern techonlogy, but only in two instances were these differences significant.

Yields on Farmers' Fields :

In a field study in Lyallpur District, Pakistan, 25 tractor-powered farms were compared with 25 bullock-powered farms (6). There were no significant differences between average cropping intensities, average capital input per hectare, average gross income per hectare, and average net income per hectare between these two groups, although the bullock farms had a significantly higher per hectare labor input.

In all instances, average yields of tractor farmers were higher than those of bullock farmers, but none of the differences were significant at the 5 percent level **(Table 6).**

Table 6. Average crop yields. kg/hectare

Crop	Bullock farms	Tractor farms
Wheat	2,649	2,837
Maize (corn)	1,675	1,938
Cotton	1,029	1,167
Sugarcane	45,360	46,480

Yield comparisons between wheat sown with a bullock-drawn seed-fertilizer drill, and that sown with traditional equipment and methods, were made in numerous demonstration plots on farmers' fields in three districts in India(7). Average yeild increases in the three districts due to the use of the drill, were 218, 244 and 320 kg./hectare, which represented increases of 23.4, 26.0 and 10.2 percent, respectively.

A farm management survey was conducted in 19 villages throughout the Indian Punjab in 1969/1970 (8). The data for tractor farms and nontractor farms encountered in the survey were analyzed in terms of the economics of the production process. Although nontractor farms were about half the size (4.61 hectares vs. 11.0 hectares) of tractor farms, they used 367 percent more animal power per hectare, 30 percent more labor per hectare, and 50 percent less physical capital per hectare than did tractor farms.

Average wheat yield for nontractor farms was 2300 kg/hectare vs. 2275kg/hectare for tractor farms. Both tractor and nontractor farms operated on the same logarithmic input-output relationship for wheat, and there were no differences between the two types of farms in technical efficiency, price (or allocative) efficiency with respect to labor use, and overall economic efficiency.

Field Survey in North Central India

In 1971-1972, a year-long survey zas conducted of inputs and outputs connected with 500 crop plots on the holding, of 26 farmers in seven villages in Meerut District in North Central India (9). The survey was conducted primarily to detail energy inputs by farmers using various levels of mechanical technology. However, information on yields and on irrigation and fertilizer inputs were also obtained in the interviews conducted once every two weeks with each farmer.

Farms were categorized according to power source. Bullock farms used mainly man and animal power for all operations including water lifting with a persian wheel. Tube well farms used electric power for water lifting and in some cases for threshing and cane crushing. Tractor farms used electric power for water lifting and farmstead processing while tractors were used for field operations and transport.

For the HYV* wheat crop, yields obtained by tube well farmers and by tractor farmers were significantly higher than

Table 7. Yields of HYV wheat, maize, and ratoon sugarcane crops grown by the farmers in various categories

	Yields (hundreds of kg per hectare)		
	HYV Wheat	Maize	Ratoon Sugarcane
Category	Mean	Mean	Mean
Bullock	25.49 a*	11.86 c	336.81 d
Tube well	36.23 b	14.77 c	424.44 e
Tractor	33.42 b	15.68 c	502.32 f

* Mean values in any one column followed by the same letter are not significantly different from each other at the 5 percent confidence level.

those by bullock farmers. However, differences between yields by tube well farmers and those by tractor farmers were not signifficantly different (**Table** 7). Yields on tube well and tractor farmers were higher because farmers could provide adequate and timely irrigations, which also permitted them to use higher amounts of fertilizers. Bullock farmers couid not provide sufficient irrigation due to energy limitations.

Tube well farms had higher yields of maize than did bullock farms, and tractor farmers had higher yields than did tube well farms. The differences, although sizable, were not statistically significant because of a high degree of variability of the data obtained.

Yields of ratoon sugarcane obtained by tube well farmers were significantly higher than those obtained by bullock farmers, and yields by tractor farmers were sighificantly higher than those by tube well farmers (**Table** 7). As with wheat, yields on tube well and tractor farmers were higher because of better irrigation and fertilizer practices.

Regression Equations :

It is of interest to know whether mechanization per se increases yields or merely helps to get the operations done more quickly. However, it is difficult to compare yields among categories. For example, bullock farms may have had less money to spend on inputs such as fertilizer and less power to use for tillage and irrigation than did tractor farms. Therefore, regression equations were chosen as a basis on which the production processes for each category could be compared, as these equations allow adjustments so that categories can be compared at common levels of inputs.

Linear regression equations were developed reating the value of output for a crop to the cost of inputs in tillage, irrigation, inter-row operations (weeding, etc.) and fertilizers.

The linear regression equation used was of the form

$Y = a_0 = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4$

in which

Y = value of output for a crop, Rupees

x_1 = cost of tillage operations, Rupees

x_2 = cost of irrigation, Rupees

x_3 = cost of intercultural operations, Rupees

x_4 = cost of fertilizers and manures, Rupees

a_0, a_1, a_2, a_3, and a_4 are coefficients.

For each category, i.e., bullock, tube well, and tractor farms, regression equations were developed for HYV wheat and for maize (there were insufficient data to obtain sufficiently representative equations for sugarcane). The values of the variables included in the regression are in terms of Rupees.

HYV Weat Crop :

Mean values of magnitudes of each of the independent variables were determined using data from farms in all categories. Then, nine additional sets of values for the independent variables were formulated, using typical variations on either side of the mean values. These 10 sets of independent variables were applied to each of the three equations and the 10 sets of three yield values were used as entries to paired t-tests. This procedure permitted comparison of yields expected with each level of mechancial technology under circumstances in which production inputus were equivalent.

The results for HYV wheat indicate that if farmers in all categories could use the same production inputs, there would be no significant differences in yield despite the variation in types of power sources used (**Table** 8).

Maize (Corn) Crop :

A procedure similar to that used with HYV wheat was used for maize.The results (**Table** 8) indicate that, for this crop, the use of mechanical power, at least for irrigation, permits a type of production process which gives greater yields with the same production inputs, than would be the case if mechanical power was not used. Maize yields predicted for tractor farms were lower than those predicted for tube well farms. This difference, however, was not significant.

Relations between Yields and Field Rractices :

Bullock farmers obtained significantly lower yields of HYV wheat than did tube well or tractor farms (**Table** 7). It is believed

Table 8. Yields predicted using linear regression equations-all farms having equal levels of production inputs (Yields in Rupees per hectare)

Farm Type	HYV Wheat	Maize
Bullock Farms	2443 a*	711 b
Tube Well Farms	2734 a	988 c
Tractor Farms	2532 a	911 c

* Values in any one column followed by the same letter are not significantly different from each other at the 5 percent confidence level.

* In this paper HYV is used to denote the "high yielding varieties" now in use in India.

that this was due to the fact that bullock farms using Persian wheels were not able to provide the same level of irrigation as could the farms in the two more mechanized categories. Thus,yield increase are linked to high power characteristics of mechanical energy sources used for irrigation. The fact that there were no significant differences among predicted yields for HYV wheat, however, indicates that the mere substitution of mechanical power for animal power sources does not, by itself, result in increased yields of this crop.

The increase in wheat production with use of mechanical power came about in two ways. In the first instance, bullock farms just could not feasibly arrange to maintain sufficient bullocks throughout the year to meet the intensive energy demands during the irrigation season. Thus, they could not obtain full yield potential of the HYV wheat varieties. Farms with mechanical power sources for irrigation pumping could, however, obtain full yield potential. Secondly, many bullock farms chose to use the traditional lower-yielding wheat varieties because of the much higher financial risk involved with HYV varieties in circumstances where irrigation would likely be inadequate. There was a nonsignificant trend toward higher yields of maize for farms using mechanical power sources **(Table 7).** However, predicted yields for uniform input levels were significantly higher where mechanical power sources were used. It is believed that both these trends were linked to the fact that bullock farms planted maize on later dates than did tube well or tractor farms. Bullock farms planted maize in July after the first heavy rains (which provided sufficient moisture for germination), whereas tube well and tractor farms planted before July, using tube wells for irrigation before planting. Although bullock farms might have been able to irrigate their maize fields for early planting using the Persian wheel, their bullocks were busy threshing wheat and in irrigating and cultivating the sugarcane crop. Thus, it is believed that the regression equations for bullock farms represent a different maize production process than do the regression equations for tube well and tractor farms. This is perhaps the reason for the predicted yield values being higher for tube well and tractor farms than for bullock farms, although input levels were the same for all. It appears that the availability of large energy flows at critical times (associated with the use of mechanical power sources) makes possible the use of a fundamentally more efficient production process for maize.

For HYV wheat and maize, both observed field practices and actual yields, as well as predicted yields, indicate that the increase in actual land productivity associated with the introduction of mechanical power sources, is related mainly to the application of this power to pumping irrigation water. There is little evidence of increased land productivity for HYV wheat and maize due to use of tractors, once powered water pumping has been instituted. This latter finding may not apply to sugarcane (see **Table 7**). Farmers using mechanical power sources had, despite use of more extesive production inputs, lower casts of production per 100kg of crop than did farmers relying soley on animal power sources (**Table 9**).

Cost reductions per unit of product appeared mainly between bullock and tube well farms, rather than between tube well and tractor farms. Thus, tractor use did not affect production casts much, once mechanical power was available for water pumping.

Table 9. Cost to Produce 100 kilograms of Crop·*(Rupees)

Farmer Category	HYV Wheat	Maize	Planted	Ratoon
Bullock	66.80	57.17	5.10	3.36
Tubewell	43.70	37.70	4.10	2.66
Tractor	43.50	40.07	3.71	2.73

*All operational costs figured at 1971-1972 custom rates. Land costs not included.

Conclusions

1. There is little evidence to show that the mere substitution of mechanical power for animal power in farm operations can effect a significant increase in crop yields.
2. Under certain circumtances, the availability of mechanical power for high rates of application during specific permits farmers to use different production strategies than used when restricted to economic levels of animal power. These new strategies can result increased annual production of food or commercial crops per unit of land area.
3. In the zone of north central India surveyed, the use of mechanical power for irrigation water pumping and for farmstead crop proessing, permitted farmers to reorganize and intensify their crop production operations to achive greater total production per unit of land area and lower per-unit production costs. Further use of mechanical power in the from of tractor tillage did not, in general, result in further increases in total production or further reductions in production costs.

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Agricultural Mechanization as related to Increased Yields and Production

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Agricultural mechanization has been an area of concern for man since the beginnings of agriculture. Early forms of agricultural mechanization yielded positive benefits with relatively few drawbacks; the use of animal power to augment human power, the invention of the sickle to replace the knife, and of the scythe to replace the sickle are typical examples. Even as recently as the nineteenth century, agricultural mechanization was often in the form of a beneficial change with no noticable detrimental repercussions. However, with the advent of the twentieth century and an increasingly sophisticated agricultural technology, the introduction of additional innovations appears to be creating undesirable side effects which could outweigh the benefits of agricultural mechanization.

America, in many ways, has demonstrated to the world the implications of a highly mechanized agriculture. The freeing of farm labor to follow urban pursuits and the low cost of food and fiber which permitted us to enjoy nonagricultural good (e.g., television sets, plays, etc.) because we had the time to enjoy them and the income to pay for them are all viewed as being among the societal benefits of agricultural mechanization. The social costs of migration from rural to urban areas, of retraining farm labor to urban tasks were recognized but considered acceptable. Even during the 1950's when labor displacement was at its zenith, no one seriously suggested that an effort be made to turn back the clock on technology as a cure for the social ills of displaced farm labor.

However, in the 1960's a new social cost was being examined with regard to agricultural mechanization. Pollution in the form of pesticides that worked too well and in the form of wastes that were generated at the farm or at the processing plant became major concerns. Again, there was no suggestion that the technological clock be turned back. Instead, alternatives were put forth. To replace DDT, more readily degradable insecticides were to be used. To replace coal or oil for greenhouse heating, natural gas was required. Etc.

In the 1970's, the largest social cost associated with agricultural mechanization appears to be its contribution to the energy crisis. Last year some areas of the United States experienced shortages of LP gas for grain drying. This year we are experiencing shortages of gasoline and diesel fuel for trucks and tractors. This final social cost may be the most important for this country and the world. For decades, this country has held out the promise that agriculture in other parts of the world could be as productive and efficient as that which we enjoyed. Since World War II, hundreds of millions of dollars have been spent in an effort to transform the agriculture of much of the world from its centuries old form into a replica of America's highly mechanized agriculture.

The authors of this paper participated in a recent effort to increase agricultural productivity in South Korea through mechanization. During a period of ten months, using a team of researchers which included agricultural engineers, economists and agricultural economists, this study team carefully evaluated the physical and economic pros and cons of mechanization using various equipment mixes. The study effort included visitations to Japan, Taiwan and the Philippines by various members of the study team in order to develop a well rounded perspective of the advantages and disadvantages of mechanization of agricultural crops similar to those in Korea.

In many parts of the world, mechanization has been one of the critical inputs into the in-

Paper prepared for presentation at the 1973 Annual Meeting of the ASAE, Lexington, Kentucky, June 20, 1973. Contribution No. and Scientific Article No. A1910 of the Maryland Agricultural Experiment Station, University of Maryland, College Park, Md. 20742.

creased production and preservation of food. The primary characteristics of meaningful mechanization of agricultural production include:

(1) Increased productivity of the land
(2) Increased economic returns to the farmers
(3) Reduced losses of already produced crops and food products
(4) Timeliness of operations
(5) Precision of operations
(6) Reduction of the drudgery of farm work
(7) Improvement of the working environment
(8) Improved dignity of the farmer

The proper application and management of mechanization will increase the capacity to produce more food, feed and fiber crops. Improved water control, better soil preparation, and more efficient weed and insect control will result in increased productivity per unit of land. Properly applied mechanical techniques of harvesting, handling, drying, storing and processing of the products will result in saving more of the yield and maintaining it at a higher quality. Timeliness and precision of production operations provide for maximization of production of each unit of land area. The reduction of the laborious and tedious aspects of farm tasks, the improvement in the health and safety of the individual, and the fulfillment of human desires and dignity are very important but are difficult to translate into economic terms.

There were two key factors at the heart of the study to determine the feasibility of mechanizing agriculture in the Republic of Korea.

First, the Korean economy has experienced a phenomenal growth rate in recent years. This has resulted in a farm to nonfarm migration as urban wages rose and jobs in the city offered a better and more exciting life than remaining on the farm. This migration resulted in labor shortages in rural areas with resultant crop losses. This was especially important in those areas where double cropping of rice and barley created peak labor demands during two short critical periods: June and October. In the early summer period the barley had to be harvested, the land cleared, and the rice transplanted. A delay in transplanting rice beyond optimum dates has an adverse effect on yield and increases the potential of damage from colder weather prior to heading. In the fall, the rice had to be harvested and the land prepared for the planting of barley. If labor shortages delayed or prolonged the rice harvest, it could result in a delayed planting of barley with a subsequent reduced yield the following spring or no planting at all. To compensate for farm labor that is being lost to urban occupations, mechanical power is the substitute that comes most readily to mind.

The second factor involves a current food grain deficit. The problem becomes more acute as the projected population and income growth make increased demands on agricultural production.

Certain crop production operations lended themselves readily to mechanization: plowing/seedbed preparation/puddling, transportation of production materials and farm produce, pest control and threshing. All of these operations, except pest control, fell to a large degree during the peak labor demand periods for growing the traditional rice and barley crops.

Using available data, with projections on wage rates, etc., a thorough analysis was made of the costs and benefits that would be derived through the mechanization of Korean agriculture. It was concluded that with all factors considered, the mechanization program would be profitable to farmers and beneficial to the country even when alternative investment opportunities were permitted to compete for the needed investment capital.

All of these analyses carried the implicit assumption that the energy necessary for this mechanization program would be available. Given the size of the Korean economy, the magnitude of its agricultural sector and the modest dimensions of the recommended program, this assumption concerning energy may be acceptable. However, such an assumption concerning the availability of energy may be greatly in error when one views the prospect for mechanizing agricultu e around the world.

As we stated at the beginning of this paper, the United States has benefited from a continuing increase in agricultural productivity for nearly two centuries. This increasing agricultural productivity has had many repercussions throughout our society. Some of these impacts are readily observable in such ways as: (1) our transition from a rural to an urban society with the resulting social and economic implications, (2) costs of food and other agricultural products are low relative to other countries of the world both developed and underdeveloped, etc.

However, there are aspects of the increasing agricultural productivity which are not readily apparent but which raise serious questions for the near and distant future. The increased agricultural

Table 1. Comparison of Energy Expenditure in Grain Production

	1870	1970
Approximate Man Hours	40	4
Approximate Horsepower Hours	40	160
H.P. Hours Equivalent of Man Hours	5	0.5
	45	160.5

productivity has been measured in terms of output per man hour or output per acre. It has been achieved in part by substituting mechanical power for human and horse power. Another major factor has been the continuing increase in the use of chemical fertilizers, pesticides, herbicides, etc. As An indication of the magnitude of this increasing consumption of energy Norman Smith, in ASAE Paper NA 70-402, Engineering a Food Supply, made the following analysis:

This partial analysis succinctly demonstrates the current situation. In traditional terms, the table shows that human productivity has increased tenfold. However, in terms of an energy budget, the analysis shows that the agriculture of a century ago produced the same grain with one-third the energy. But the true energy consumption is much higher than indicated by Smith because his analysis is only concerned with on farm activities excluding the energy required to produce needed inputs (e.g., nitrogen fixation in the manufacture of fertilizer) or the energy needed to process agricultural goods, store them, distribute them to an urban population, etc.

In 1972, for the United States, the consumption of nondurable goods associated with agricultural products ("food and beverages" and "clothing and shoes") was 206.7 billion dollars. This was 28.7 percent of personal consumption expenditures or 17.9 percent of Gross National Product. However, due to the nature of modern agricultural production, the energy consumption associated with this sector may be far more important than these dollar figures indicate.

A summary of the energy needs that exist for modern American agriculture might be as follows:

I. Farm Inputs
  A. Production of Fertilizers (Nitrogen Fixation)
  B. Production of Machinery
  C. Production of Fuels
  D. Production of Pesticides and Etc.
II. On Farm Activities
  A. Mechanical and Electrical
    1. Tractors
    2. Cultivation
    3. Hauling
    4. Pumping and Etc.
  B. Human and Animal Use
III. Processing of Agricultural Goods
  A. Foodstuffs
    1. Packaging
    2. Preserving and Etc.
  B. Non-Foodstuffs
    1. Textiles
    2. Shoes and Etc.
  C. Production of Inputs for Processing
    1. Production of aluminum for packaging
    2. Production of plastics for packaging and Etc.
IV. Wholesaling
  A. Storage
  B. Distribution and Etc.
V. Retailing
  A. Storage
  B. Display and Etc.
VI. Consumption
  A. Heat for Cooking and Etc.
VII. At nearly every stage I — VI the energy needed for transportation must be considered.
VIII. At nearly every stage I — VI the energy needed for waste disposal must be considered.

It is readily apparent that energy uses in a modern mechanized agriculture are interrelated in complex ways. Changes in the input of one variable, its effect on other variables and on ultimate energy requirements per unit of final good consumed are not readily predicated.

It is the judgment of the authors that the agricultural sector is a major part of the current energy needs of the total economy. Further, it is our judgment that this situation has important implications for mechanizing world agriculture and the future yields and productivity of agriculture in the United States.

In a general sense, agriculture can be viewed as the transformation (through the input of energy) of basic elements into materials suitable for human consumption. Early in the development of man, the energy input that man controlled was his own labor. Today he controls a variety of energy inputs. Within the United States the cost of energy was kept artificially low in many instances. One of the impacts of the oil depletion allowance was an accelerated program of development of oil fields and hence a lower price for gasoline and oil than would otherwise be expected. A related factor was the controlled price of natural gas moving in interstate commerce keeping it lower than would otherwise have existed.

It appears that a substantial part of the productivity of American agriculture may be the result of cheap energy. Worldwide, we will not find energy as cheap as it has been in the United States during the past 50 years. This implies that world agriculture will never be able to duplicate the feat of American agriculture's tremendous productivity. More importantly, the end of cheap energy would also be the end of mechanized American agriculture as we know it today. Yet, we are unable to turn back the clock and attempt to farm as we did 30 years ago. It appears that the energy crises has pushed a new crisis upon us. A crisis in agricultural R and D. For more than 100 years, the Land Grant Universities have researched ways of increasing human productivity. We believe that for the next 25 (if not the next 100) years, a still greater effort will be needed to research and develop means of conserving energy in agricultural production. ■ ■

Impact of Farm Mechanization on Labour Use in Developing Agriculture under New Technology

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Introduction

Improved farm technology has brought, in its wake, structural changes in the agricultural sector of the Indian economy. It is characterised by not only the introduction and adoption of the high yielding varieties (from now on referred to as HYV in this paper) of food grains, particularly wheat, and consequently an increasing use of improved package of practices but also of more pumpsets, large number of tractors, threshers, and even combines. Some of the mechanical devices are known to help in the intensification of agriculture and have beneficial effects on the employment of human labour. An opposite view is held about tractors, harvesters and threshers. These machines are known for their capacity to displace human labour. Depending on its effects on the employment of human labour, mechanization may be classified as (a) "labour consuming", (b) "labour saving or labour substituting", or (c) "labour neutral".

On the one hand, use of machines replaces human (and animal) labour in preparatory tillage, threshing and harvesting operations and may thus create unemployment. On the other hand, tractors help in timely completion of these jobs, thus enabling an increase in the frequency of cropping through multiple and relay cropping, which may affect the demand for labour favourably.

Objective

Since the employment situation in the country is already acute, the unemployment creating aspects of mechanization will be socially undesirable. However, increased productivity from land due to new technology is economically desirable. In this context, one may ask the question as to what has been (or shall be) the impact of mechanization accompanying the new technology on the likely future demand for farm labour on different sized farms. In this study an attempt has been made to know the relationship of mechanization and farm labour employment in the context of new technology in the TARAI region in India.

Methodology

Rudrapur and Bazpur Blocks (1) of Nainital District in the State of Uttar Pradesh in India were selected for the study. These two blocks are situated in the foothills of the Mimalayas and represent the TARAI (humid) region of the state. The region is quite progressive and farmers follow improved package of practices and grow high yielding varieties of wheat and paddy. The area could be safely considered to be a representative of new technology in India agriculture. The region is also characterized by a substantial degree of farm mechanization specially on large farms.

The area under study is quite homogeneous in terms of agricultural and climatic conditions. Six villages were randomly selected from these two blocks. All the farmers in these villages were listed and classified into four groups (2) viz. small, medium, large and very large, on the basis of their operated holdings. A sample of sixty farmers, fifteen from each size group, was randomly selected from these selected villages: The data pertain to the agricultural year 1969-1970 for these selected farmers.

"Linear in logs" type of production function was used to explain the input-output relationships. Regression equations for important crops of the area, namely wheat (high yielding and traditional), paddy (high yielding and local), and sugarcane (improved Coimbatore varieties) were fitted as follows:

$$Y = x_1^{b_1} x_2^{b_2} x_3^{b_3} x_4^{b_4} x_5^{b_5} x_6^{b_6}$$

Where.

Y = Total value of the produce of a particular crop (in rupees)

Table 1: Regressior coefficients and R^2 for wheat crop on farms of different sizes

Sl. No.	Type of farm	Log a	Fertilizer	Irrigation	Human labour	Animal labour	Machinery	Cropped area	R^2
H.Y.V.									
1.	Small	6.4057	.2893§+ (.1760)	—	−.0077 (.3670)	−.3831 (.2555)	.1021 (.2046)	−.9223+++ (.5031)	.97
2.	Medium	2.4237	.6170+ (.1346)	.1044§+ (.0516)	−.1451§+ (.0777)	.1534++ (.0387)	.3682++ (.0890)	−.3864 (.2782)	.98
3.	Large	6.6092	—	—	.5616++ (.2425)	—	−.5679+++ (.2795)	1.1994§ (.3421)	.94
4.	Very Large	3.9288	—	—	.3690++ (.1506)	—	.2287§++ (.1870)	.4465§++ (.2426)	.89
LOCAL++++									
5.	Small	4.1054	—	.0955++ (.0276)	.1423+++ (.0714)	−.2918 (.0352)	.2471+ (.0711)	.6221§ (.0899)	.99
6.	Medium	1.1962	—	.2204 (.2077)	−.5065 (.3684)	.6079§+ (.2704)	.9043+++ (.3749)	.6100§+ (.2824)	.95

Figures in paranthesis denote standard errors of respective regression coefficients.
§ = Significant at 1 % level
+ = Significant at 2.5% level
++ = Significant at 5 % level
+++ = Significant at 10 % level
§+ = Significant at 15 % level
§++ = Significant at 20 % level
++++ = No equation for the large and very large groups was fitted because handly any farmer in these size groups cultivated Local wheat.

x_1 = Total expenditure on manures and fertilizer applied to the crop (in rupees)

x_2 = Total expenditure on irrigation (excluding pumpsets, and human labour) applied to the crop (in rupees)

x_3 = Total expenditure on human labour used in the crop (in rupees)

x_4 = Total expenditure on animal labour used or the crop (in rupees)

x_5 = Total expenditure on machinery items (including pumpsets used for irrigation) apportioned to the crop (in rupees)

x_6 = Area under the crop (in acres).

b_1, b_2, b_3, b_4, b_5, b_6 are the coefficients of regression (also elasticities of production In this case).

It was observed that holdings above 30 acres used bullock power only sparingly. Likewise, the farmers in the range of 15-30 acres (large-size holders) did not generally use bullocks as a major source of power. Therefore, in these two groups, variable x_4 (expenditure in animal labour) was not included in the equation.

Moreover, for statistical reasons, the crops where observations were less than ten in number (even this was quite a small size) were not considered for the purposes of analysis.

Economic analysis included the estimation of production function (for different crops and the farm business as a whole separately) and computation of marginal rates of substitution of machines for human labour and animal labour at the existing geometric mean levels of these inputs. These estimates of marginal rates of substitution hold good within the existing range of resource use, cropping pattern yield levels and price structure.

Table 2: Regression coefficients and R^2 for paddy on farm of different sizes

Sl. No.	Type of farm	Log a	Fertilizer	Irrigation	Human labour	Animal labour	Machinery	Cropped area	R^2
H.Y.V.++++									
1.	Large	5.2161	—	−.0800 (.1172)	.3492 (.4622)	—	.0270 (.0683)	.6634 (.6014)	.77
2.	Very large	4.3502	—	—	.3165 (.3645)	—	.2440++ (.0957)	.4030§++ (.2732)	.84
LOCAL++++									
3.	Medium	−.0937	.8404§ (.1837)	—	.2087§++ (.1818)	−.0191 (.1724)	.5971§ (.1885)	−.5964§++ (.4012)	.95
4.	Large	2.3857	—	—	.7620++ (.2195)	—	.0544 (.1740)	.4041§++ (.2077)	.97
5.	Very large	4.6297	—	—	.2247 (.2479)	—	.2470§+ (.1439)	.5916§+ (.3222)	.96

Figures in paranthesis denote standard errors of respective regression coefficient.
§ = Significant at 1 % level
+ = Significant at 2.5% level
++ = Significant at 5 % level
+++ = Significant at 10 % level
§+ = Significant at 15 % level
§++ = Significant at 20 % level
++++ = No regression equations were fitted for HYV of Paddy on small and medium farms and local varieties of paddy for small farms due to small number of observations.

Table 3: Regression coefficients and R^2 for sugarcane on farms of different sizes

Sl. No.	Type of farm	Log a	Fertilizer	Irrigation	Human labour	Animal labour	Machinery	Cropped area	R^2
1.	Small	.4827	.6074+++ (.2126)	−.3293+++ (.1101)	−.7852+++ (.3399)	.1189++ (.0396)	1.8820+++ (.7205)	−.4216 (.6388)	.99
2.	Large	4.2358	—	—	.4877+++	—	−.0138	.6153+++	.90
3.	Very Large	1.2000	—	−.2400§++ (.1667)	.8164+++ (.3726)	—	.3748 (.2984)	.1275 (.3363)	.95

Figures in parenthesis denote standard errors of respective regression coefficient.
++ = Significant at 5% level
+++ = Significant at 10% level
§++ = Significant at 20% level
No equations could be derived for medium farms due to insuffiency of data.

Results and Their Discussion

We first discuss the estimated crop-wise equations for different farm groups which are presented in **Tables 1, 2 and 3.** Then the marginal rates of substitution, derived from these equations and given in **Table 4,** are discussed. As we are interested only in the employment aspects, the discussions are confined to human labour, animal labour, and machinery only.

1. Crop-wise Results:

A. HYV Wheat: Except on the small farms, both machinery and human labour were found to be significant. On large and very large farms, human labour had a positive coefficient indicating that its contribution was not only significant but productive. It was probably due to the fact that human labour was used in relatively smaller quantities. Machine use was relatively excessive, only on large farms yielding a negative coefficient. An interesting feature about the relationship of human labour to the machinery was that, except vor very large farms, the sign of the coefficient of human labour was opposite of that of the machinery for each size group showing complementarity of these two factors of production in the cultivation of HYV wheat.

B. Local Wheat: In case of local wheat, co-efficients of both, the machinery and human labour were found to be positive and significant for small farmers. On medium farms, animal labour and machinery contributed significantly to the crop income.

C. HYV Paddy: Small and medium farmers did not grow any HYV of paddy. In spite of fairly high R^2 values, the regression co-efficient of only machinery was found to be significant and that too for very large farms only.

D. Local Paddy: The equations were fitted for medium, large and very large farms. All of them yielded a very high R^2 of .95 and above. In case of medium farms, both human labour and machinery were found to have a significant impact on crop income. On large farms, coefficients of human labour, and on very large farms, the coefficients of machinery were found to be significant.

E. Sugarcane (Improved Coimbatore Varieties): The coefficients of human labour had a positive and significant effect on crop returns on large and very large farms, because of a high demand for this factor in sugarcane cultivation. On small size farms, the regression co-efficient for human labour was found to be negative but significant, indicating thereby an excessive use of this input factor. Animal labour was used as a major source of power only on small farms and its co-efficient was positive and significant. The productivity of machinery was significant on small farms only, having a numerical value of more than unity, probably because of very little use of this input on these farms.

2. Resource Substitutions

Crop-wise marginal rates of substitution (3) and elasticities of substitution (4) of machinery for human labour as well as animal labour on different farm sizes have been calculated only where the coefficients of both the factors (whose marginal rates of

Table 4: Cropwise comparative study of resource substitution on farms different sizes

Sl. No.	Name of Crop	Substitution of	Size of farms: Small MRS	Small ES	Medium MRS	Medium ES	Large MRS	Large ES	Very large MRS	Very large ES
1.	Wheat (H.Y.V.)	Machinery for human labour	—	—	+1.95	+2.53	+.91	+1.01	−1.05	−.61
2.	- do -	Machinery for animal labour	—	—	−0.28	−2.40	—	—	—	—
3.	Wheat (local)	Machinery for human labour	−3.44	−1.73	—	—	—	—	—	—
4.	- do -	Machinery for animal labour	—	—	−1.45	−1.48	—	—	—	—
5.	Paddy (local)	Machinery for human labour	—	—	−6.12	−2.86	—	—	—	—
6.	Sugarcane	Machinery for human labour	+7.40	+2.39	—	—	—	—	—	—
7.	Sugarcane	Machinery for animal labour	−8.70	−15.82	—	—	—	—	—	—

MRS = Marginal rate of substitution
ES = Elasticity of substitution

substitution are being calculated) are found to be significant. These are given in **Table 4.** It is interesting to note that:

i) On very large farms, at the present level of resource use and input-output relationship, human labour and machinery are competitive. This is because of the fact that, on the very large farms, machinery is used quite extensively even for wheat harvesting operations which otherwise need large quantities of human labour.

ii) In case of HYV of wheat, as well as sugarcane (of which nearly all the acreage is under improved coimbatore varieties), on farms other than the very large ones, a fairly high degree of complementary relationship exists. For example, each rupee spent on machine use, in the cultivation of HYV wheat, is likely to result in increased use of human labour worth about Rs. 1.95 on medium and .91 on large farms.

iii) In local varieties of both Wheat and paddy, the marginal rates of substitution of machinery for human labour are negative indicating a competitive relationship between these two factors.

iv) In all cases, irrespective of the variety of crop or size of farm, where the marginal rates of substitution have been derived between machinery and animal labour, a competitive relationship is observed.

Limitations of Study

In addition to the assumptions mentioned earlier, the present study has following limitations:

i) It considers only two broad groups of wheat and paddy varieties viz. (a) HYV, and (b) Local. It would have been much more interesting if, for example, variety-wise analysis and inter-variety comparisons could have been made. Small number of observations on different high yielding varieties rendered this type of analysis infeasible.

ii) The adoption of new agricultural technology by the farmers is confined largely to wheat and to some extent paddy and sugarcane (if we consider the fact that almost all area under sugarcane is under improved coimbatore varieties) and hence only these three crops were studied in detail. Even here, the scope of comparison was limited because of the fact that hardly any of the large and very large farmers grew local wheat and also because the number of observations was found to be inedequate for both HYV and local paddy on the small and HYV paddy on the medium farms.

iii) All the variable (except the area under the crop) were expressed in money terms (rupees) rather than appropriate physical quantities (e.g. quintals for yields of wheat, paddy and sugarcane, hours for use of human labour, machinery and animal labour). This was done to overcome the problems of aggregating heterogenous inputs of machinery and also because some operations like weeding were conventionally performed by human labour on contract (and hence no records of hours of human labour were available for these operations).

Conclusions

In the light of the above analysis and results, the following conclusions could be drawn from this study with due regard to the above mentioned limitations.

1. In most cases, except on very large farms, if mechanization is accompanied by the use of improved technology, represented by high yielding varieties of crops, specially wheat, it is likely to have beneficial effect on employment of human labour. Under traditional technology, there exists a competitive relationship between these two factors of production.

2. Use of machinery, at the present level of its use, displaces animal labour irrespective of the type of technology and by the farmer.

3. While, it is not explicitly brought out by this analysis, it was observed that as long as the machines were used primarily for quick land preparation and lifting water thus helping in raising the intensity of cropping, and human labour was used for intercultural and harvesting operations, under improved technology, this should result in an increased demand for human labour. Therefore, what may be needed are machines which help in timely preparation of land and sowing of the crops and irrigation to push up the yields and the intensity of cropping to a level which require so much additional labour for interculture and harvesting operations that this additional requirement more than offsets the loss in demand for human labour as a consequence of ploughing and lifting water by machines.

REFERENCES

(1) A development Block in India is an administrative unit for execution of development programmes and usually covers about 100 villages.

(2) Small-Having less than 7.5 acres of the operated area. Medium-Having 7.5 to less than 15 acres of operated area. Large-Having 15 tolless than 30 acres of operated area. Very large-Having 30 acres and more operated areas.

(3) For the 'linear in log' type of production function (as used here) the marginal rate of substitution of the j^{th} factor for i^{th} factor is given by the following equation:

$$\frac{dx_i}{dx_j} = \frac{b_j\, x_i}{b_i\, x_j}$$

(4) The elasticity of substitution of resource i for resource j is defined here as being equal to

$$\frac{dx_i}{dx_j} = \frac{x_j}{x_i}$$

■ ■

Mechanization of Rice Cultivation in Sri Lanka

by
Manuelpillai George Pillainayagam

Introduction

Agricultural Mechanization is to a great extent an essential part of any long term programme of Agricultural Development. Mechanization alone can bring vast area of unarable land, economically and quickly into agriculturaly productive land. In developed countries mechanization is a proven method of increasing output per man and it can provide a satisfactory means of dealing with the increased unit yield which results from more timely and better controlled cultivation. It eliminates a great deal of human drudgery from farm work and in the long run gives the farm worker a much higher standard of living and a standing in his society.

For increased rice production in Sri Lanka, Mechanization is applicable to those operations where high labour requirements are called for and very limited time is available for the operation is to be completed or when better quality of work is needed. On these considerations the research that is being carried out on mechanization is confined to land preparation, seeding, harvesting and threshing operations in rice cultivation.

Present Objectives

During a period of 25 years after World War II commencing in 1945, individuals and Government had attempted at mechanizing agriculture in Sri Lanka. A large number of different types and models of costly machinery, often without technical advice and usually not applicable to local conditions were imported. Such ventures were nccessorily doomed to fail even from the very start. But such experience showed us that new designs have to be developed to satisfy the local requirements. Since the inception of the Farm Machinery Research Centre in 1968, it has tested many of the imported agricultural machinery and reported to the respective Ministries about their suitability for local agriculture. Besides, at this centre new and improved machinery were designed, and their prototypes developed have shown promising results that can be of great value in the future agricultural mechanization in Sri Lanka.

Today's urgent need of increasing food production will largely depend first by increasing the yield economically on existing land and secondly by bringing more land under production. The farmers in Sri Lanka are fully aware of the value of using fertilizers and agro chemicals in increasing the yields, and the due demand is being met by the private and the public sectors. In the paddy growing areas, particularly of the dry zone, there is a shortage of labour during the period such as land preparation, harvesting and threshing where the demand for tractors and allied machinery are not adequately available.

The youth of today are no more illiterate and very few of them have ventured into agriculture. As most of them are reluctant to go chasing after a pair of buffaloes which is capable of very little output of work. But by providing them means with less tedious and more skillful operation resulting in increased work output and there by more income, they can be easily induced to take up to agriculture.

Present Situation of Draught Power

In rice production tillage operation requires much more power than any other work. Hand work with mamoty and use of animal power with country plough, limit the depth of cultivation and timing of such work. Introducing an engine driven machine allows work to be done on hard soil and a more thorough incorporation of green manure. Any shortage of power during the tillage period results in poor, late or no land preparation and hence it becomes a limiting factor in agricultural production.

Table 1. (Hire charge for a man-Rs. 6.50 per day of 8 hours)

Operation	Man hour per acre	Cost per acre (Rs.)
Ploughing	64	52.00
Puddling	64	52.00
Levelling	32	26.00

Manual Power (Man with Mamoty)

Where human power is the only accessable power source, the short handled hoe, usually refered to as Mamoty, is the most common hand tool used for preparatory tillage in the rice fields. There are of course, a variety of shapes and sizes of hand hoes which are in use depending mainly on the soil texture and to a great extent on their traditional or customery use. It is a versatile tool and may be used for the construction of bunds as well as for the tillage. Man is not a very powerful machine. Over a short period he may develop a work output of 0.4 horse power, but un cintineous work over longer periods his capacity is about 0.1 horse power on an average (1). **Table 1** shows the manpower performance on land preparation work in wet paddy lands.

Animal Power

The view that the buffaloe should be largely used for paddy land preparation overlooks a variety of problems that have to be resolved in the process of modernising rice cultivation in Sri Lanka. In the first place the buffaloe population available in Sri Lanka is insufficient to meet all the tillage requirement of the existing paddy lands. Among the estimated 0.8 million baffaloes only 20 percent if it is accounted as draught animals. A pair of baffaloes for a day on an average, can plough 1/3 acre of land. Approximately 26600 acres of single operation or 8880 acres of complete tillage up to seeding (average 3 operations) can be done in a day with the present baffaloe population. In a season where the preparatory tillage is continued over forty days this strength of baffaloes can work about 355,000 acres. This is 27.5% of the acreage cultivated under paddy in maha 1972, at a power utilization rate of 0.27 horsepower per acre. (1). Since the baffaloe population is not uniformly distributed over the paddy growing areas and being displaced by the aswedumization of new lands, relying entirely on the baffaloes for the paddy cultivation is not a feasible proposition.

In places where the baffaloes are the sourse of power for rice land preparation, it is necessary to soften the soil with water in order to induce the draught requirement for adequate penetration. Generally it is undesirable to make an animal pull more than 10 percent of its life weight contineously. A plough body of wedge type with relarively wide point (country plough) is commonly used, as it cuts off weeds more effectively. But the semi inversion plough (with small metal mould board type) is also being used in weedy areas where in the process of soil inversion trash and weeds are buried for effective weed control. The peg tooth harrow is widely used for puddling and also in the final stages of levelling. The cost of land preparation with a pair of baffaloes and a driver is given in **Table 2.**

Two Wheel Tractor

The two wheel tractor appears to have come into this country in 1960 with Mitsubishi one of the heavy duty Japanese make, and the Landmaster which is a part assembled tractor. It was not until 1968 this range of tractors made any impression in local agriculture. The imported three classes of two wheel tractors are, the Diesel, Kerosene and petrol machines which posses a horse power range of 5-7. The available tractor population during the last decade is given in **Fig. 1**, which shows that the number of units available in 1972 was about 6,000. On an average a two wheel tractor can cultivate a maximum extent of 20 acres of paddy land per season of 40 days (upto seed bed preparation). The total extent they could have cultivated in Maha 1972 was 120,000 acres, at the rate of 0.3 horse power per acre.

The tests carried out indicate that the diesel tractor of this horse power range gave the highest field performance resulting in reduced cost per acre, though the investment cost of diesel tractor is high. It was also observed that the diesel cngine is relatively free from troubles, particularly when operated under wet and muddy field conditions. As far as paddy cultivation is concerned, rotary tilling with two wheel tractor appears to meet the requirements of the farmer and is cheaper than ploughing, except in instances of land heavily infested with weeds and stubles as in fallow rice fields, where ploughing is essential. In order to obtain the maximum benifits from the two wheel tractor it must be utilized for 1000 hours anually on land operations. However, the owner of this class of tractor may be able to use his tractor for 320 hours in one season, and in both season 640 hours on land preparation, but this tractor could be used on

Table 2.

Operation	Man hour per acre	Animal hour per acre	Cist per acre (Rs.)
Ploughing with country plough.	24	24	50.50
Puddling with peg tooth harrow.	16	16	37.00
Levelling with level board.	8	8	18.50

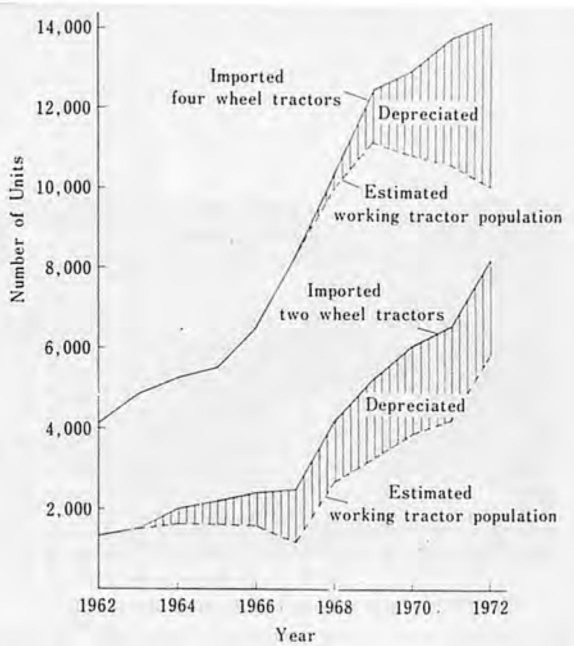

Fig.1. Tractor population in Sri Lanka

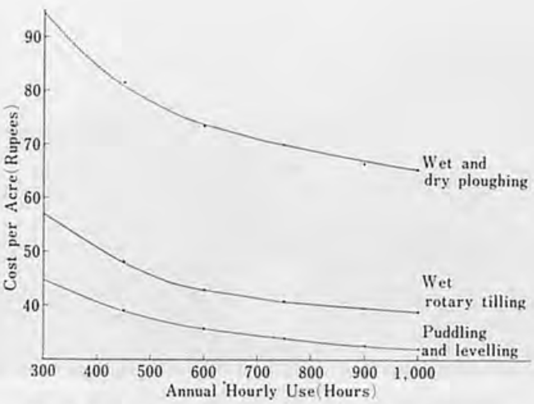

Fig.2. Two wheel tractor (Diesel) operational costs.

subsequent operations as seeding, harrowing, to power threshing machines, water pumps and for transportation etc., which total upto 1000 hours of annual use and brings the owner additional income.

The all island Two wheel Tractor survey (2), conducted by the Farm Machinery Research Centre revealed the practical use of this class of tractors and how the farmers are selecting different makes and models suitable to their soils, crops and cultivation practices. Since this class of tractors were designed to suit the typical small size paddy field in Sri Lankd, they are 1/2 refered by farmers both in wet and dry zone areas. The minimum cost per acre for preparatory land operations by this class of tractors are given in **Fig. 2.**

Four Wheel Tractor

The first large scale introduction of four wheel tractors in Sri Lanka appears to have been the Maseey Ferguson TE 20 model with type tiller in 1949/50. During the past 10 years the total number of tractors imported and the estimated working tractor population are given in **Fig. 1.** Among the four wheel tractors ranging from 20 to 60 horse power catogory it was noticed that the 45 horse power tractor with related implements was a about the ideal. On an average a four wheel tractor can cultivate an extent of 75 acres per season of 40 days (% operations). Assuming that all the four wheel tractors are available during the season, the maximum extent they could have been cultivated was 750,000 acres in Maha 1972. Thereby the maximum power utilization works out to 0.53 horse power per acre. But estates, municipalities and contractors are using a fair number of these tractors for non agricultural work such as transportation. Hence approximately 60% of the tractors would be available during seasons for only paddy cultivation work, and assuming, all these tractors were working at their maximum capacity, the maximum cultivable extent would be 450,000 acres in Maha 1972 at 0.53 porse power per acre.

From operational point view it will be noticed that of the three dry land operations, namely rotavating, ploughing and tyne tilling, the cost of tyne tilling is the least, followed by rotavation, where as the ploughing costs are high. Wet field operation using tyne tiller with bage wheel involves the highest cost. It is common knowledge, that almost all types of four wheel tractors that are being used for paddy cultivation in Sri Lanka are not designed for work under local paddy field conditions (wet ploughing and puddling). The high cpst of wear and tear and consequently high repair costs are attrubutable shiefly to this factor. About 50% of the tractor owners in the paddy growing areas prefer to use their machines for road haulage work than on mud land preparatory tillage. The laulage work gives them regular returns over longer periods, where as the charge for mud land tillage are high ranging from Rs. 80 to Rs. 120/- per acre; and there is the risk of frequest breakdown on the machine. The minimum cost of operation per acre using different implements are given in **Fig. 3.**

The practice of dry tillage and dry sowing of ungerminated paddy had been used with considerable success specially in North Sri Lanka. The four wheel tractor with standard tynentiller was economically used for such tillage work. Improving the tillage operation in other districts (dry zone) based on dry tillage where ever possible before the on set of heavy rains can prove to be benifital. Dry tilling of the first operation in preparatory tillage alone, would result in rice planting being done a month earlier with an additional saving of 5 acre inches of water which can be made available to the crop. Further this will not only increase the capacity of the machines but save the machine from frequet repairs, operational time and bring more land under rice production.

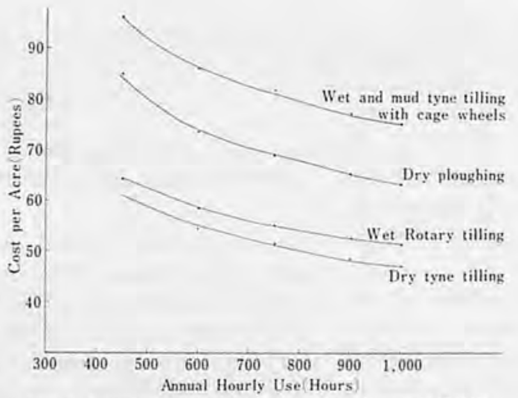

Fig.3. Four wheel tractor operational costs (45HP).

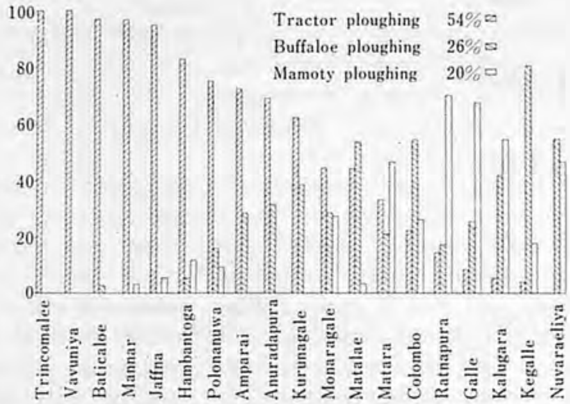

Fig.4. Percentage area under various of ploughing.

Power Utilization and Tractorisation

As discussed earlier the maximum extent of land that utilized power for tillage operations during Maha 1972 would have been as follows:

Baffaloe power—355,000 acres at 0.27 h.p/acre.

Two wheel tractor—120,000 acres at 0.30 h.p/acre.

Four wheel tractor—450,000 acres at 0.53 h.p/acre.

Assuming a forty day season the total possible extent that utilized draught power would have been 925,000 acres at an average of 0.40 h.p per acre. But 1,277,000 acres of land were estimated to be under paddy cultivation in Maha 1972. From this it can be inferred that 353,000 acres of land would have been left to be cultivated by manual power (mamoty). **Fig. 4** shows that the actual percentage extent of land that utilized tractor, baffaloes and manual power were 54,26 and 20 percent respectively in Maha 1972. (3). But from above analysis the maximum power utility limit in terms of percentage of land was estimated to be 45% for tractor, 27% for baffaloe and 28% left for man power cultivation.

From these observations it would appear that where as the present baffaloe population is fully utilized, tractor power was used in place of human power over 9; extent of land to take out the drudgery of human labour. This will imply that either the increased extent of 9% land that utilized tractor power would have been done within the forty days season resulting improper land preparation or that the assumption of the forty days season would have been exceeded by about 10 days without affecting the quality of operations.

Seeding Rice

The methods of establishing rice crops in the wet and dry paddy fields depends mainly on environmental conditions, such as climate and soils, the variety grown, number crops grown per year, labour costs and availability, size of fields and many other sociological factors. There is no doubt that the plant population and spacing have an important effect on rice fields. The traditional methods practiced in Sri Lanka are mainly broad casting in wet and dry fields over approximately 75% of the land and transplanting over the remaining area. Broad casting is a means of scattering pre germinated seeds on puddled fields and ungerminated seeds on prepared fields under dry conditions before the on set of rains. This method was acceptable when paddy cultivation was at a subsustabce level of farming. Although it is recignised that in many areas (drv and wet) seeding in rows is prefered for better weed control, the non availability of such seeding equipment limit this practice.

A number of mudland seeders were developed in Sri Lanka but were not extensively introduced to the farmers. Row seeders powered by four wheel tractor, imported from developed countries were found to be expensive and of limited use in row seeding paddy in our small paddy fields. A four wheel tractor drawn eight row seeder (**Fig.5**) a two wheel draw, three row paddy seeder (**Fig.6**) (prototypes) were developed at the Farm Machinery Research Centre and successfully tested in the farmer's fields. The results were encouraging. These machines are cheap, casy to fabricate locally with available technology and could be used to seed other crops like sorgum, maize, soyabean, green gram and many other crops.

In wet zone where abundet labour is available and controlled irrigation facilities are provided, transplanting is done in order to grow two or more crops per year. No transplanting machine imported or locally made, was able to work satisfactorily under local paddy field conditions.

Pest and Weed Control

A large number of different chemical are being introduced to control the various posts attacking paddy crops at different stages of growth. The farmers are familiar with the selection of suitable chemicals and they use

Fig.5. Tyne tiller mounted 8 row paddy seeder. (Could be used to seed other crops : soyabeans, green gram & cowpea)

Fig.6. Two wheel tractor drawn 3 row seeder for paddy. (Could be used to seed other crops : maize, soyabeans, pulses, sorgham, groundnut, etc.)

hand operated (Knapsack) sprayers and engine driven sprayers (power spayers and dusters) to spray their crops. With the introduction of high yielding varieties, herbicide for efficient weed control is made use by farmers to realise the potential yield of the variety. Such plant protection equipment are manufactured locally by some industrial firms and supplied to the farmers.

In row sown paddy crops, the Japanese rotary weeder (locally manufactured by the Department of Agriculture) could be effectively used to control weeds between rows by operating it in 1"-2" standing water.

Water Management

In the dry zone, the success of paddy cultivation mainly depends on the availability of water to the crop at the required time. Rainfed paddy cultivation in North Sri Lanka often needs supplementary irrigation, (lift irrigation from wells) specially when varieties of 4 months duration or longer are cultivated. The engine driven, electric motor drivenor tractor engine powered pumps could be used to provide supplementary irrigation and thereby save the crop during periods of drought But the water pumps are not freely available to the farmers and the purchase is restricted through permits issued by the Government Agents.

When water is available to the farmers through surface irrigation, the farmer should acquaint himself with the correct water requirements at different stages of the ice crop for a controlled and efficient irrigation. The farmer's personal attention and efficient water management will enable them to reap good harvest.

Harvesting

Second to the tillage operation, harvesting and threshing of the paddy crop requires more power, time and labour for satisfactory operation. Once the Paddy crop is mature and neady for harvesting, it is of utmost importance to harvest and thresh the rop without delay and store the paddy safely and as possible.

In Sri Lanka the entire paddy crop is harvested by manual labour using sickles. These method has the advantage of being a selective process of harvesting a lodged crop and in ill drained paddy fields and thereby the grain losses are minimised.

Many harvesting machines imported into this country were tested and the collowing improvements on crop and field conditions are suggested are suggested to introduce them successfully.

a. A non-lodging, non-shattering and high yielding variety has to be cultivated.
b. Water must be drained off at the proper time and the field must be dry enough to drive the machine.
c. Time of harvest should be determined by the date of maturity or perferably on the moisture percentage of seed in order to minimise the shattering losses caused by impacy whilst the machine is working.

However on a well managed crop, pocessing all the above characteristics, the two wheel tractor driven harvesting machine or a small combine could be worked satisfactorily.

Threshing of Paddy

The most popular threshing methods practised are by treading the harvested crop either under the feet of baffaloes or with a tractor. The harvested crop is spread on the threshing floor and the threshing is achieved by driving the animal or tractor around it. The disadvantages of these methods are, that there is no control on grain damage, stones and animal dung would get mixed with the grain, more dependance on labour efficiency for churing the straw with farks and finally wear and failure of the tractor axle.

However, in large farms threshing by tractor treading give speedy and large output when

Fig.7. Four wheel tractor Power Take off driven thresher for paddy (Could thresh soyabeans and sorgham also)

one tractor and a group of workmen work on 2, 3, or even 4 threshing floors with the minimum labour idling time.

The threshing machines imported from other countries are being tested at the Farm Machinery Research Centre, and their comparative performance were reported in (4), The Japan made threshers which are transported manually from field and powered by a two wheel tractor engine (-7HP) have not been accepted in this country, due to their complicated mechanism. One of this make was modified to suit the thresing of our local paddy varities and even other crops such as soyabean sorgham etc. at higher capacity. The Garvie drum thresher recommended by the National Institute of Agricultural Engineering (NIAE) Lond. powered by a 2-3 HP engine has a capacity of 1/2 acre/day. This was modified at F.M.R.C. and a winnowing fan was incorporated into it to get increased capacity of 3/4 acre/day, giving cleaned paddy. Introduced by IRRI the GAMI drum thresher powered by a 4-5 HP engine or a two wheel tractor engine requires freshly harvested paddy with uniform length of straw for optimum performance.

The large combine harvesters imported from North America and Europe were found unsuitable for our paddy cultivation and were abandoned. The small combine introduced by Japan, though a complicated machine, will have a future in Sri Lanka especially when our culltivation techiniques and plant characteristics are improved to cater to the efficient working of small combines.

The Power Take Off (P.T.O) thresher powered by a four wheel tractor, designed and developed at the F.M.R.C. (**Fig.7**) has been successfully tested for threshing all varieties of paddy even under adverse conditions (15-40% moisture in seed). This machine is becoming popular because of its high capacity of 2-3 acre/day with 4 men and low field losse

Further research work is scheduled to be carried out on harvesting, drying and threshing of paddy.

Discussion

It will be seen from the above discussion that while the animal power and the human power continue to be used in areas where they have been traditionally used, mechanized power will largely be used in newly developed arable lands and areas where there have been labour shortages during peak cultivation seasons. From Fig.1 its clear that the import of tractors have greatly reduced due to the restriction of foreign exchage. This resulted in the population of working tractors to decline since 1970 which will effect the agricultural production in the coming year causing more shortage of power.

It has been reported (5) that unless the developing countries increases food production more rapidly than they do now, the demand for food will exceed the supply by 32% in 1977. To bridge this gap the expenditure on mechanization should increase by 0.5 billion in 1977.

The proposed new technology for mechanization is basically similar in all developing countries. It is essential that mechanization programme is co-ordinated with the development of manufacturing industry at the current level of technology and facilities. Such development will make the best and the most economical use of foreign exchage, by restricting its use to import the most essential components that cannot be manufactured locally and produce our own agricultural machinery. There is at the moment a great deal pressure to produce a two wheel tractor in Sri Lanka and the first prototypes manufactured are showing promising future in this country.

If the programme of manufacturing two wheel tractors and other agricultural machinery is carefully steered, in future we can manufacture all our requirements of power and mafhincry for agricultural production. But it is needless to say, the farmers must improve their field conditions to introduce small machines for productive agricultural mechanization.

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A Small Development Project in Northern Thailand

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To begin with, I have to mention that this project is not directly connected with mechanization, specially not so at the beginning.

If however this method should find adherents and be used on a large scale in other places, it might be that the production basis could be improved and lead sooner or later to a direct mechanization in this place.

Fig. 1. General map of Northern Thailand where our experimental site is marked (arrow)

Northern Thailand is inhabited, besides the original Thais, by different aborigines. These are in the main the Akha-, Lahu-, Lisu-, Pwo-Karen-, Meo and Yao-tribes. They live mostly in Burma, West China, North Vietnam, Laos and Northern Thailand. Of an approximate total of 10 millions, 130-140'000 live in Northern Thailand.

The livelyhood of these tribes is mostly half nomadic, self-supporting rice cultivation. Maize and soybeans are planted and domestic animals, specially poultry and pigs, play a large part. Amongst certain tribes are some excellent tradesmen who occupy themselves with cattle breeding. Opium is still partly one of the main income sources, although this kind of income declines, as the marketing gets more and more difficult as far as the "hot drugs" are concerned, i.e. if it is not used for legal medicinal purposes.

The main basis however is rice-growing. But the majority uses a primitive method of dry rice-growing. They clear so much of the woods and burn afterwards the dry ground, as they need for their sustenance. As it is known from experience, this kind of rice-growing does not yield very much. Consequently, each year relatively big parts of the forest have to be cleared. On these patches rice is grown. But as the input to keep the land clear from weeds for years is greater than the clearing itself, the thus prepared area is used only once for rice-growing. For the next year's planting, a new land--clearing takes place. Moreover, all this land-clearing is not done in the lowland, but mostly on the mountain chains which are of great importance for the water supply. As the natural growth of the forest, even that of the quick--growing bamboo, is in no relation to the land-clearing, many of these mountainslopes are threatend by deforestation. We find already mountainslopes that are barren, have only a sparse or no new growth at all. In future, this method is absolutely unjustifiable, as the whole structure of the region is being changed. A classic example about the results of an irrational land--clearing and neglecting of forest areas is found in the countries south and east of the Mediterranean Sea. Here experiments are made, at tremendous capital investments, to amend for mistakes that were made lightheartedly hundreds of years ago.

In consequence of this land-clearing methods, the people are half-nomads, i.e. they change their dwellings from time to time and build new villages.

This spring, in connection with the OMF (Overseas Missionary Fellowship), we had a labor-camp about 40 km southeast Chiang-Rai, in a Christian village. **(Fig. 1.)** In 2 stages of 1-2 months each, 10-12 young Swiss worked with this project. The idea was to show the aborigines that rice-growing in paddy-fields was possible in their region. For the preliminary work and method it was important that we used material which will be always at hand without difficulties. With this new project, we did not want to give them a finished solution, but make a beginning and let the inhabitants see what could be done. That this new rice-growing is possible, is proved by the fact that the Pwo-Karen in the lowlands have already rice-growing in paddy-fields. In addition, we have as a pattern vast regions, where hundreds and thousands of years ago rice terraces were used in the Philippines (near Baguio), in Taiwan and partly also in Japan.

We found near the village a small valley through which a river is flowing. With the aid of a levelling instrument, the whole region was measured and in the most elevated place, a canal of about 1 km length was digged out along the hillslope. Now the whole region between the canal construction and the river in the bottom of the valley can be watered.

On the opposite side of the valley we made another canal that was several hundred meters long, where we drew the water directly out of a well.

Fig. 2. The leader of the project doing levelling work

In different places we began with the terracing of the ground in order to let the inhabitants see what we had in mind.

It is planned (in the bottom of the valley) to set up bigger rice paddys and make small terraces in the higher regions and so clear the question if fruittrees and table-grapes would grow here.

On the newly built terraces, rice, maize and soybeans were planted, as well as a small experimental patch of pineapples.

In connection with this project, a sprinkler from Israel is also tested that I had sent directly from there. This sprinkler works reliably with relative little pressure, is easy to set up and is not quickly out of function. It is my opinion that with the aid of a sprinkler, a considerable lot of water could be saved in comparison with the method of flood-watering. Presupposition is, that the water is not sprinkled during the great heat, but primarely during the night, as otherwise a high percentage of water evaporates directly.

Fig. 5. The sprinkler from Israel (Pressure-regulated irrigation sprinkler SB120)

The above project is, as mentioned, only a small beginning and rather meant as a signpost. However, it looks as though this project was of great interest to the people.

Furthermore, it is not easy to change people's way of working whose religion is animistic and mixed with ancestral worship. In a Christian village there is less opposition in this respect.

But if we are successful in convincing only a small part of the population about the worth of the new methods, the food situation for mankind and for animals could be greatly improved and the irresponsible deforestation could be stopped which, in the long run, is very important too. ■ ■

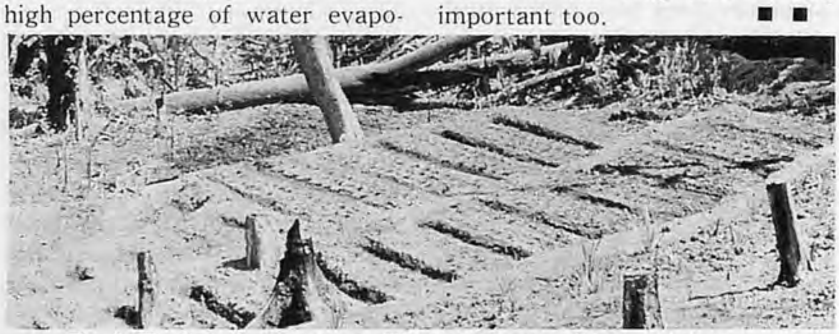

Fig. 3. The first planted terraces. The cut trees are still here and there

Fig. 4. Akha people inspect the digged out canal in which already water is flowing

Nead of Training Manpower for Mechanized Agriculture in IRAQ

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Introduction

Lately in developing countries, the number of tractors and modern agricultural machinery is on the increase. There is also a growing awareness among the developing nations of the role which Agricultural Engineering Technology namely Agricultural Mechanization can play in increasing agricultral productivity and improving rural life. However, the facilities for the education and training of personnel at all levels to man this new technology in agriculture is lagging far behind this trend. This situation in many instances is entrusting the planning, implementation, and operation of Agricultural Mechanization projects, both in public and private sectors, in the hands of personnel who have either no or in-adequate formal education and training in the field of Agricultural Mechanization. The end result is that instead of reaping benefits from the mechanization of agriculture, these countries are bearing colossal financial losses on this type of investment. This gap between the need and the available manpower for mechanized agriculture in these countries is becoming a serious problem and considerable efforts are necessary to remedy this state of affairs.

Before dealing with this problem in Iraq, it will be not out of place to explain some of the relevant concepts for the interest of common understanding. Hitherto, Agricultural Mechanization has been taken to imply to only the use of modern machinery in agriculture including horticulture and animal husbandry. This is one of the many aspects of this discipline. In fact, Agricultural Mechanization cuts across all activities relating to agriculture and rural life and extends the application of machines and/or relevant engineering methods and practices to: (i) production operations in agriculture; (ii) irrigation and drainage of agricultural lands as well as soil and water conservation; (iii) processing, handling, and storage of agricultural products; (iv) farm service buildings, rural housing and roads; and (v) electrification in agriculture, and rural areas. Many a time, the difference between Agricultural Engineering and Agricultural Mechanization is not clearly understood. It is mentioned here for general information that Agricultural Engineering deals with design and development i. e. analytical aspects of all the above mentioned activities; whereas Agricultural Mechanization covers the application and utilization aspects of machines, and methods and practices which have been developed in Agricultural Engineering.

Present Situation of Iraqi Agriculture

After crude oil, agricultural sector is the second most important source of Iraq's economy. Since 1968, the Revolutionary Government of Iraq has given its first and foremost attention to the development of this sector in order to achieve self-sufficiency in food and fiber as well as in realizing the cherished goals of raising the standard of living of the masses. In view of the probable World food shortage in the years to come, this sector has to be mobilized in its all dimensions to meet this challenge of the present and future and to relieve the Country from dependence on alien sources for ever for certain food and fiber commodities.

The total area of Iraq is 43,844,600 hectares. It is estimated that 27.4% of this area (12,000,000 hectares) is culturable

Table 1. Population Statistics of Iraq (in numbers)

Year of Census/Estimates	Urban	Rural	Total
1965 (Census)	4,162,106	3,935,124	8,097,230
1972 (Estimates)	6,065,000	4,009,000	10,074,000

agricutural land whereas the remaining land is under deserts, mountains, lakes, and marshes, etc. The culturable agricultural land includes 8,000,000 hectares of irrigable land and 4,000,000 hectares of land in the rainfed region. At present, only 50% of the irrigable and rainfed lands are cropped annually. It is estimated that by further harnessing of water of the Twin rivers (Euphrates and Tigris) nearly 75% of the irrigable land could be brought under farming.

The Southern region of Iraq has an arid climate where only irrigated agriculture is possible on culturable land. The climate of Northern region is semi-arid where agriculture depends on natural precipitation. Some irrigated agriculture is also practiced along the banks of the river Tigris and its tributaries in this region.

The main problem facing agriculture in the Southern region is that of salinity and water logging. On the other hand in the Northern part, water and soil conservation practices need immediate enforcement for enhancing agricultural productivity and maintaining soil fertility.

The four principal field crops of the Country are wheat, barley, rice, and cotton. Dates and grapes are leading fruit crops. The areas under field crops, vegetables, and fruit trees constitute approximately 90%, 5%, and 5% respectively of the total cropped land. Out of field crops, the grain crops alone occupy about 85% of the total cropped area.

An interesting phenomenon which is taking place in the rural Iraq and which is also going to influence and accelerate the pace of mecha"ization of agriculture, is the drift of agricultural labour to urban areas. The data given in Table I below will give an idea of the magnitude of this migration from rural to urban areas.

It can be safely said that this migration will further ascend in the coming years in view of the revolutionary policies of the present regime of Iraq which aims at providing basic industries within the Country.

From the preceding discussion of the present situation of Iraqi agriculture, it may be said that it presents a classical setting for mechanization of agriculture. This situation has arisen from: (i) the drift of agricultural labour to urban areas; (ii) the ease with which 85% of the total cultivated land under grain crops can be mechanized; (iii) the need of applying engineering principles and practices in solving soil and water problems; and (iv) the national goals of achieving self-sufficiency in food and fiber by utilizing all modern inputs of agricultural production and modernization of all activities related to agriculture and rural life.

Present Status and Future Scope of Agricultural Mechanization in Iraq

The following table presents the true picture of the rate at which Agricultural Mechanization has developed in Iraq during the last I5 years. These numbers of the major items of Agricultural Mechanization are estimates from different valid sources.

Table 2. Agricultural Mechanization Situation in Iraq

Item of Agricultural Mechanization	Numbers in the Given Years		
	1958	1970	1973
·Tractors	2,400	10,400	12,464
Agricultural Implements and machines	2,600	12,745	15,000
Combines	1,000	2,280	2,669
Irrigation Pumps	5,400	9,150	16,500

The above mentioned agricultural machinery is owned both in the public and private sectors. The utilization of agricultural machinery in the public sector is administered through the Agricultural Machinery Renting and Repairing Stations. The total number of such stations for the whole of Iraq, at present, comes to I9. The Sales and Service of agricultural machinery for the private sector is also managed by the State. These services are being further organized, developed, and expanded with the objective of extending their availability throughout Iraq.

The authors hold that Iraq has presently the equivalent of 0.24 h.p. (human+animal+mechanical) per hectare of cropped area※. While the minimum need for achieving reasonable productivity in agriculture is considered to be 0.5 h.p. per hectare. This target can be best reached in Iraq by increasing the number of tractors, combines and irrigation pumps. To meet this requirement and also keeping in view the possibilities of drift of agricultural labour to urban areas in future, the number of tractors, and irrigation pumps by the end of this decade have to be increased three times as compared to the present level. The above estimates are also supported by the targets worked out by the concerned Ministries which are aiming at having 32,000 tractors, and 8,000 combines by the end of the current decade. Keeping in line with this trend, Iraq would have to go beyond this minimum need of power per hectare in the coming decades in order to match

※ The calculation for this estimate has been given in the appendix to this paper the agriculturally advanced countries in the World.

There are three basic inputs for having a perpetual Agricultural Mechanization so far as agricultural machinery activities are concerned. These are the energy, national agricultural machinery industry, and the trained manpower at all levels for this programme. Nature has bestowed Iraq with abundant energy resources. The present regime has also recently established at Iskandariya, the National Agricultural Machinery Industry for catering the need of mechanized agriculture. This industry, though in its infacy, is progressing in the right directions. The third and the most important input i.e. the trained manpower at all levels for mechanized agriculture, needs immediate attention of the concerned authorities; as the success or failure of the whole programme pivots on it.

A review of the existing educational and training facilities in Agricultural Engineering and Agricultural Mechanization in Iraq with suggested guidelines for remedying the shortcomings, is valid at this point of discussion.

Survey of Existing Educational and Training Facilities

In any technical profession, the various levels of education and training can be grouped under:

1. Higher Level,
2. Intermediate Level, and
3. Vocational Level.

A brief description of the existing educational and training facilities in Agricultural Engineering and Agricultural Mechanization in Iraq, according to the above levels of education and training, is presented below.

1. Higher Level

The colleges and universities are the right place for offering higher level programmes of study in Agricultural Engineering and Agricultural Mechanization. These programmes can be at either undergraduate level or postgraduate level or both. As undergraduate programme of study in any discipline has to be instituted and developed first before the post-graduate programme is offered, so the discussion which follows here, refers only to the undergraduate programme of study. Undergraduate education in Agricultural Engineering and Agricultural Mechanization at the college or university level is usually as given below.

i) B.Sc. Degree in Agricultural Engineering
ii) B.Sc. Degree in Agricultural Mechanization
iii) Service Courses in Agricultural Mechanization for the students of Agriculture and its related disciplines

The above programmes as they exist In Iraq at present are discussed below.

i) B.Sc. Degree in Agricultural Engineering

The Colleges of Engineering at the Universities of Baghdad, and Mosul are presently offering first degree programme in Agricultural Engineering at the professional engineering level. The first group of graduates was out in 1971 from the Mosul University; whereas the University of Baghdad would be turning out the first batch of graduates in 1974.

The Departments of Agricultural Engineering at these institutions are in their initial stages of development and are demanding immediate attention in the areas of teaching staff and well-equipped laboratories which are so essential for producing first quality agricultural engineers. Presently, these departments are partially staffed by foreign teachers. However, this is not the permanent solution.

Iraqi agriculture and its related industries offer a host of opportunities of employment for qualified agricultural engineers. These graduate engineers would be particularly needed on the design, development, testing, and analytical work in the profession.

ii) B.Sc. Degree in Agricultural Mechanization

There is a dire need of Agricultural Mechanization projects at the planning, implementation, and extension levels. These graduates are required to work as extension, advisory and administration personnel in Governmental and Semi-Governmental organizations dealing with Agricultural Mechanization projects; sales and service personnel in commercial agricultural machinery firms; and progressive mechanized farmers. Because of their education and training in the disciplines of Agriculture and Agricultural Mechanization, such graduates will also be proficient in agricultural production technology. As such they would prove more effective and useful agricultural extension workers.

However, no academic institution in Iraq is presently offering this programme of study. Such programmes of study should be instituted at an early date in the two well-established colleges of Agriculture in Iraq which are located at Abu Ghraib and Hamman Al-Alil.

iii) Service Courses in Agricultural Mechanization

Every graduate of Agriculture and of its related disciplines must have adequate instructions in selected courses of Agricultural Mechanization relevant to his field, so that he is conversant with the available machines and methods which he will be dealing so often during his professional practice. Such courses should, therefore form an integral part of all the curricula in Agriculture and its related disciplines.

Except the College of Agriculture and Forestry at Hammam Al-Alil, the number and course contents of these courses at the other Colleges of Agricultue would require exquire expansion and development. The Colleges of Agriculture in Iraq have the same problem of inadequacy of qualified Iraqi teaching staff and well-equipped laboratories as that of the Departments of Agricultural Engineering at the Colleges of Engineering. This situation demands active attention of the concerned authorities on priority basis.

2. **Intermediate Level**

Middle-level technicians in Agricultural Mechanization fill the gap between the agricultural engineers/agricultural mechanization technologists, and the skilled workers and should not be underestimated for the success of the whole mechanization programme. Hundreds of such technicians would be required for successful introduction and implementation of mechanized agriculture in the Country.

Presently, the Institute of Agricultural Technology at Abu Ghraib is the only institute which offers intermediate level programme in Agricultural Mechanization. The existing curriculum of the Institute of Agricultural Technology at Abu Ghraib would also need some revision in order to increase the scope of the training. It would also be desirable to name this programme as Agricultural Mechanization Technician Course.

The Government of Iraq is also planning to establish four more such institutes at Kufah, Maysan, Baquba, and Eske-Kalak in the near future. These four additional institutes would be able to provide the need of middlelevel workers for mechanized agriculture in the Country.

3. **Vocational Level**

Vocational level training in Agricultural Mechanization would cover the training of agricultural machinery operators, and mechanics. Presently, no formal training programme is available for this group of skilled workers. In view of thousands of tractors, combines, and other agricultural machinery which are in operation with rapidly increasing numbers; the institution of Agricultural Machinery Operators, and Mechanics Courses at the appropriate centers is a MUST.

It is suggested that these training courses can easily be instituted at the existing 19 Agricultuqal Machinery Renting and Repairing Stations, with the provision of requisite additional facilities. These stations should offer both regular courses for new trainees, and short in-service training courses for existing agricultural machinery operators, and mechanics. The Ministries of Industry, Agricuiture, and Agrarian Reforms can jointly bear the financial responsibilities of these training courses.

Trained Manpower Requirements

Taking the estimates of the concerned Ministries, which are on the conservative side, as to the number of tractors and combines in Iraq by the end of 1971-80 decade; the number of trained personnel at various levels required for this purpose are given in the table below.

It is clear that there will be one operator, one mechanics, one supervisor/foreman, one agricultural mechanization technologist/agricultural engineer for 1, 10, 50, and 100 selfpropelled agricultural machines respectively. This yardstick, as used in reckoning the needs of trained manpower, has been based on the authors' experience. This may be noted at this stage of discussion that these requirements are only one aspect of Agricultural Mechanization i.e. agricultural machinery activities. More personnel would be required for providing services in other aspects of Agricultural Mechanization. In this connection, it is emphasized here again that in modern farming the Agricultural Mechanization is not only the connecting link between the pure agricultural sciences and their application for crop production operations on the farms, but it also cuts across all activities concerning agriculture and rural life.

In the opinion of the authors, at least one agricultural mechanization technologist/agricultural engineer, and two agricultural mechanization technicians would be required for covering other aspects of Agricultural Mechanization for each agricultural cooperative in the Country. There were 992 agricultural cooperatives in Irap in 1972. Each agricultural cooperative covers an area of 2,500 hectares on the average. The needs of these personnel are also presented in Table 3 above.

It is strongly held that the above are the minimum requirements of such manpower which would increase mainfolds in the coming decades. There are two suggested choices for organizing the training of the required manpower. The first choice is by instituting regular training programmes and extending the period of achieving the targets beyond the year 1980. The second alternative involves more intensive traning programmes with the objective of achieving the above

Table 3. Trained Manpower Requirements for Agricultural Mechanization in Iraq by the end of 1980

Category of Manpower	Numbers Needed by the end of 1980
A. For Agricultural Machinery Activities	
1. Agricultural Engineers/ Agricultural Mechanization Technologists	400
2. Agricultural Mechanization Technicians	800
3. Agricultural Machinery Mechanics	4,000
4. Agricultural Machinery Operators	40,000
B. For Other Agricultural Mechanization Activities	
1. Agricultural Engineers/ Agricultural Mechanization Technologists	1,200
2. Agricultural Mechanization Technicians	2,400

targets by 1980. This suggestion comprises of two-stage training activities i. e. in addition to the regular training programmes as given under Choice I above, special short-term condensed conversion study programmes of about one year duration should be offered. These short-term training programmes should be designed and developed for the graduates of agriculture and engineering, and diploma holders from technical institutes.

Conclusion

It is evident from the above discussion that there is an acute shortage of trained manpower at all levels for mechanized agriculture in Iraq which is so essential for successful and perpetual mechanization in the Country. Enormous efforts are needed to remedy this state of affairs. In this connection, the following guidelines are suggested.

1. An Action Programme of higher education and training abroad for Iraqi personnel should be chalked out and got underway so that the Iraqi personnel are availble within the Country to assume leadership role in education, research, extension, testing and development, and planning work related to Agricultural Engineering and Agricultural Mechanization.
2. The Departments of Agricultural Engineering at Baghdad, and Mosul should be further strengthened both in respect of staff, equipment, and other facilities.
3. Programme of study leading to B. Sc. Degree in Agricultural Mechanization should be instituted at the Colleges of Agriculture at Abu Ghraib, and Hammam Al-Alil at an eraly date.
4. The number of Service Courses in Agricultural Mechanization need to be increased in the curricula of all Colleges of Agriculture in the Country. A good initiative has already been taken to this effect in the College of Agriculture and Forestry at Hammam Al-Alil.
5. Agricultural Mechanization Technician Course being ofered at the Institute of Agricultural Technology, Abu Ghraib should be revised in order to increase the scope of the training.
6. The process of the establishment of four additional Institutes of Agricultural Technology similar to the one at Abu Ghraib should be accelerated so that the much needed middle-level workers in Agricultural Mechanization can be produced.
7. Training courses for agricultural machinery operators, and mechanics should be instituted at all the Agricultural Machinery Renting and Repairing Stations with the provision of requisite additional facilities. The expenditure on the conduct of these courses should jointly be borne by the Ministries of Industry, Agriculture, and Agrarian Reforms.

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APPENDIX

Estimate of the Horsepower Per Hectare Availabe of Crop Production in Iraq at the end of 1973.

1. Agricultural Area
   Cropped area including permanent crops like fruit trees and fallow cultivated area.
   8,000,000 hectares
2. Human Labour
   Taking agricultural labour equal to 1/5 of the total population of 10,396,000 (1973 estimates)
   2,079,200 numbers
   @ 1/15 H. P. each
   138,613 H.P.
3. Work Animals
   Taking estimated heads of 1,100,000 work animals comprising of horses, mules, donkeys, and camels
   1,100,000 numbers
   @ 0.5 H.P. each
   550,000 H.P.
4. Mechanical Power
   i) 12,464 tractors @ 50 H.P. each
   623,200 H.P.
   ii) 2,669 combines @ 75 H.P. each
   193,575 H.P.
   iii) 16,500 irrigation pumps @ 25 H.P. each
   412,500 H.P.
   1,917,888 H.P.
   Therefore, Horsepower per unit of cropped area
   $= \frac{1,917,888}{8,000,000}$
   =0.24 Horsepower per Heactare

■ ■

The Educational Role of the Agricultural Equipment Industry in Developing Countries

by

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The agricultural equipment industry, consisting of those firms which manufacture, distribute and sell agricultural equipment, has participated in the education for agricultural mechanization in the United States and other economically developed countries by training people for operation, maintenance, and repair of agricultural equipment. In this training, they have used many approaches including preparation and publication of training literature, holding demonstration days, supplying material and equipment to schools and by conducting training programs for dealers and mechanics. This training for agricultural mechanization has undoubtedly been one of the factors which has led to the high level of mechanization on U.S. farms.

The same approaches to education in agricultural mechanization may not be appropriate in underdeveloped countries since an entirely different set of conditions may exist. Literacy levels are often comparitively low. Educational institutions may be few and limited in scope, particularly for vocational training. Agricultural holdings are often small and agricultural capital is almost always limited. Communications and transportation systems often lack development. These and many other conditions may exist to make agricultural mechanization education problems in the developing countries very different from those in developed countries.

Many organizations, ranging from small privately funded efforts to large international efforts like FAO, and including the agricultural equipment industry, are assisting in programs with the objective of encouraging agricultural mechanization in the developing countries. It is desirable to have a clear understanding of the proper role of each participant in these programs. In particular, we are going to examine, in this paper, the appropriate role of the agricultural equipment industry in agricultural mechanization education in developing countries.

The Study

A study was conducted to identify the appropriate role of the agricultural equipment industry in agricultural mechanization education in developing countries as perceived by men experienced in agricultural mechanization in these countries. It was assumed that industry and education leaders who have had experience in developing countries can effectively identify: (a) the appropriate level in the educational system for industry to assist in education, (b) the appropriate type of educational activity for the agricultural equipment industry to conduct in these developing countries. The objectives of the study were:

1. To identify the levels, within the educational system, that appeared most appropriate for the agricultural equipment industry to assist in agricultural mechanization education in developing countries.
2. To determine the types of educational activities that were perceived most appropriate for the agricultural equipment industry to conduct in agricultural mechanization education in developing countries.
3. To determine if there was any significant difference in the types of educational activities that were perceived most appropriate for different groupings of developing countries according to geographical location, levels of economic development and levels of educational development.
4. To determine if there was

Paper prepared for presentation at the 1971 Annual Meeting ASAE

any significant difference between the perceptions of representatives of industry and education concerning the appropriate educational role of the agricultural equipment industry in developing countries.

5. To determine if there was any significant difference between the perceptions of United States and non-United States respondents concerning the appropriate educational role of the agricultural equipment industry in developing countries.

Fifty questions pertaining to possible agricultural mechanization educational assistance activity were posed. The questions were grouped into five clusters related to the kinds of educational assistance; **Tables 1-5.** Following are the descriptions of the five clusters.

1. Questions pertaining to assistance within the environment of the educational systems of the developing countries,

2. Questions pertaining to assistance outside the environment of the educational systems of the developing countries,

3. Questions pertaining to assistance in the form of instructional aids,

4. Questions pertaining to assistance by conducting workshops or seminars on agricultural mechanization,

5. Questions pertaining to assistance in the form of scholarships and grants.

Eighty-six individuals throughout the world who had first-hand experience in agricultural mechanization in developing countries were involved. Each respondent was asked to identify the country in which he had the most mechanization experience and to base his answers on that country. A total of thirty-three different developing countries were represented.

Each respondent was asked to indicate his perceptions as to the appropriateness of the agricultural equipment industry's participation by rating each question on a five point scale ranging from very appropriate to very inappropriate. Each response was weighed as shown below.

5-Very appropriate
4-Appropriate
3-Undecided
2-Inappropriate
1-Very inappropriate.

For the purposes of interpretation, only those items or clusters of items which received mean scores of 3.50 or above were considered as appropriate for the agricultural equipment industry.

To identify differences in responses that might be due to various experiences and background of the individuals, they were classified in sub-groups by nationality and occupation. The nationality sub-groups were U.S. and non-U.S. personnel. Forty-three of the persons were of U.S. nationality while the other forty-three represented many different nationalities. The sub-groups for the occupational classifications were educational personnel, industrial personnel, foreign graduate students and others.

Differences in responses which might be due to the various countries represented were identified by classifying the countries by geographical location, levels of economic development, and level of educational development. The geographical classification included:

1. Mediterranean and Middle East
2. Sub-Sahara Africa
3. South Asia
4. Central and South America.

The economic development classifications were:

1. Primitive, which consists of countries with an estimated gross national product per capita of less than $100.00,
2. Traditional, G.N.P. per capita $101.00-$200.00,
3. Transitional, G.N.P. per capita of $201.00-$300.00 and,
4. Industrial revolution, G.N.P. per capita of $354.00-$569.00.

The educational development classifications were:

1. Level I, which consisted of countries having from 2-14% of the population between the ages of 5 and 19

Table 1. The perceived appropriateness of the agricultural equipment industry providing educational assistance at various levels within the established educational systems of developing countries.

Question	Mean Score	Rank
6. Assist in basic literacy education of elementary level students	2.78	9
7. Assist in agricultural mechanization education in elementary schools in the use and care of:		
(a) animal powered agricultural equipment	2.93	8
(b) engine powered agricultural equipment	3.26	5
8. Assist in agricultural mechanization education in the secondary schools in the use and care of:		
(a) animal powered agricultural equipment	3.21	6
(b) engine powered agricultural equipment	4.06	3
9. Assist in agricultural mechanization education in post-secondary, but non-university schools (e.g., agricultural schools, trade schools, and technical schools) in the use and care of:		
(a) animal powered agricultural equipment	3.41	4
(b) engine powered agricultural equipment	4.71	1
10. Assist in agricultural mechanization education in the university level for the:		
(a) animal powered agricultural equipment	3.13	7
(b) engine powered agricultural equipment	4.50	2
Cluster 1 Mean	3.58	

Table 2. The perceived appropriateness of the agricultural equipment industry providing educational assistance at various levels outside the established educational systems of developing countries.

Question	Mean Score	Rank
11. Assist in village level basic literacy of:		
(a) out-of-school youth	3.02	9
(b) adults	3.03	8
12. Assist in village level animal powered agricultural mechanization education for:		
(a) out-of-school youth	3.08	7
(b) adults	3.16	6
13. Assist in village level engine powered agricultural mechanization education for:		
(a) out-of-school youth	4.01	4
(b) adults	3.98	5
14. Assist in in-service agricultural mechanization education for governmental personnel working in agricultural mechanization	4.58	2
15. Assist in training of mechanics. (Not limited to employee of agency conducting the educational service).		
(a) pre-employment training	4.34	3
(b) in-service training	4.69	1
Cluster 2 Mean	3.81	

Table 3. The appropriateness of the agricultural equipment industry providing educational aids to schools.

Question	Mean Score	Rank
16. Provide teachers with detailed wall charts concerning the construction, operation, and maintenence of agricultural equipment.	4.30	2
17. Provide printed materials on the operation, maintenance, and repair of agricultural equipment.	4.35	1
18. Provide schools with filmstrips, and slides on the operation, maintenance, and repair of agricultural equipment.	4.29	3
19. Provide schools with educational films on the operation, maintenance, and repair of agricultural equipment.	4.28	4
20. Provide schools with audio-visual hardware such as motion picture projectors, overhead projectors, or slide projectors.	3.80	8
21. Provide school with shop tools and equipment.	3.87	7
22. Provide schools with tractor assemblies, such as engines, transmissions, and differentials, to be used for teaching purposes.	4.23	5
23. Provide schools with complete cut-away or sectioned tractors to be used for teaching purposes.	4.13	6
24. Loan tractors and other farm equipment to schools.	3.69	9
Cluster 3 Mean	4.12	

involved in primary and secondary schools,

2. Level II, 20 to 29% enrolled
3. Level III, 31 to 42% enrolled and
4. Level IV, 46 to 59% enrolled.

Information obtained from the questionnaire was processed by computer using the one way analysis of variance to determine if differences between means were significant.

Findings and Conclusions

The following conclusions were drawn.

1. It is most appropriate for the agricultural equipment industry to place a high priority on the development of instructional aids for the schools of developing countries. **(Figure 1.)** These aids should consist of printed materials, wall charts, film strips, and motion films pertaining to the area of engine powered agricultural machinery and should be directed towards the secondary, post-secondary, and university level students. **(Table 3.)** Although the respondents considered it appropriate for the agricultural equipment industry to provide the schools with projectors, tools and shop equipment, they did not rank laboratory type instructional aids as high as classroom type aids.

2. It is not appropriate for the agricultural equipment industry to become involved in elementary education or literacy training in these countries. **(Table 1., 2.)** Until these countries have developed a sizeable cadre of literate youth, it does not appear logical for the agricultural equipment industry to become greatly involved in agricultural mechanization education. However, from the international experience of the authors and review of literature, it appears that most of the countries have developed a sizeable population of literate youth and are ready for greater vocational and technical education in which the agricultural equipment industry can be of considerable assistance.

Although the respondents did not perceive it appropriate for the agricultural equipment industry to become involved in elementary education, it may be proper to give this further consideration as many attitudes about agricultural mechanization are formed during these early years.

3. It is appropriate for the agricultural equipment industry to conduct workshops and seminars on agricultural mechanization education but these should be directed towards government agricultural mechanization specialists of the developing countries and the agricultural mechanization instructors rather than the students of the school. **(Table 4.)** This relates to the first conclusion, development of instructional aids, in that after the agri-

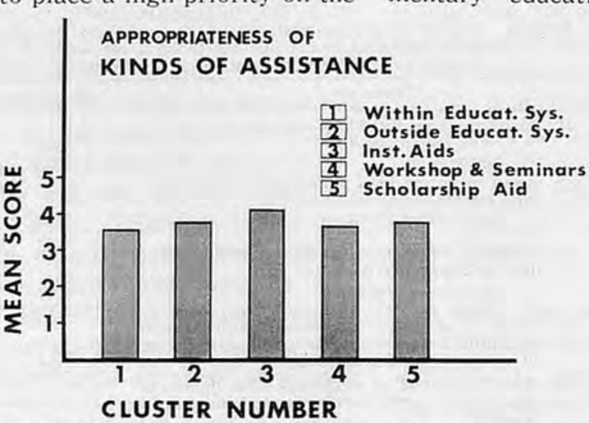

Fig. 1. The perceived appropriateness of the agricultural equipment industry assistance to agricultural mechanization education in five clusters.

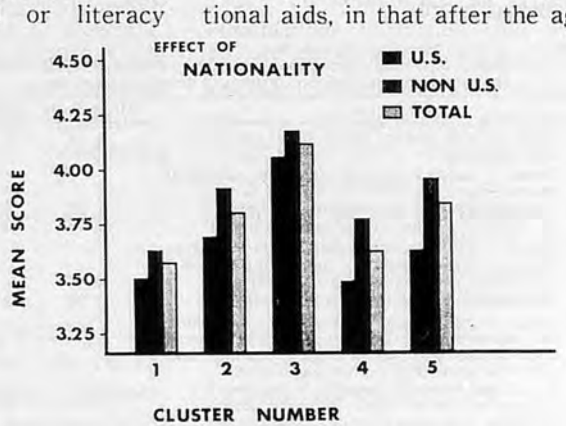

Fig. 2. Mean scores to clusters of questions by respondents representing U.S. and non-U.S. nationalities.

Table 4. The perceived appropriateness of the agricultural equipment industry conducting workshops or seminars on agricultural mechanization.

Question	Mean Score	Rank
25. Conduct workshops for students, on subjects such as hydraulic systems or new equipment, with a length of:		
(a) one to five days	3.40	7
(b) more than five days	3.19	8
26. Conduct workshops for in-service education of agricultural mechanization teachers, on subject such as hydraulic systems or new equipment, with a length of:		
(a) one to five days	3.77	4
(b) more than five days	3.99	1
27. Conduct workshops for elementary school teachers, to inform them of the value of agricultural mechanization, with the length of:		
(a) one to five days	3.51	5
(b) more than five days	2.87	9
28. Provide complete agricultural mechanization training for some agricultural mechanization teachers for the public schools.	3.90	3
29. Provide representatives to serve on advisory committees for:		
(a) conduct manpower needs surveys	3.48	6
(b) evaluate and develop agricultural mechanization curricula	3.96	2
· Cluster 4 Mean	3.63	

cultural equipment industry has developed a series of instructional aids, it will be desirable to have some formal method of introducting these to the instructors. This can be implemented through workshops and seminars where the instructors can be informed of the availability, value and correct use of these aids.

Many of the schools in developing countries have extended vacations during the year and, with proper planning, it should be possible for the agricultural equipment industry, with the cooperation of the educational systems, to schedule agricultural mechanization workshops or seminars for the instructors of these schools. The instructional aids which have been developed by the agricultural equipment industry could be used in these workshops to teach the instructors and at the end of the workshop each instructor could be supplied with a similar kit to take back to his school.

4. The agricultural equipment industry can make educational contributions outside the confines of the educational systems of developing countries. **(Table 2.)** These should be directed towards the training of mechanics or in-service education of governmental personnel and others already working in the field of agrIcultural mechanization.

In some countries, the major agricultural equipment companies cooperate in annual agricultural field days · where they demonstrate and explain new and modified equipment to interested people. Where agricultural officers are located in remote areas and have limited opportunities to keep abreast of new developments, such activities appear to make a major contribution to agricultural development.

Throughout this study, the respondents indicated that the agricultural equipment industry should not deviate from educational programs that have direct application to engine powered agriculture. **(Table 1.)** This is the area in which they are specialists and can make the greatest contribution.

5. There was a high level of agreement on the scores when analyzed by nationality and occupation of the respondents **(Figure 2., 3.)** and by geographical location, **(Figure 4.)** levels of economic development, **(Figure 5.)** and levels of educational development of the countries. **(Figure 6.)** This information appears to be very important as it indicates that the agricultural equipment industry does not need to develop separate educational programs for individual developing countries. A broad overall educational program may be designed for all developing countries with limited modifications for individual countries. The language may need to be translated and different special machines covered to fit the crops of

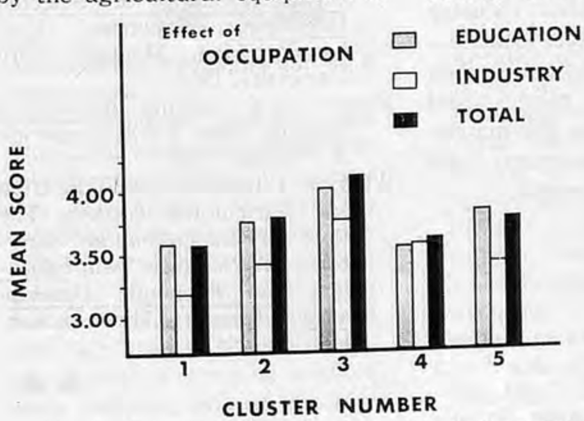

Fig. 3. Mean scores to clusters of questions by respondents representing educational and industrial occupations.

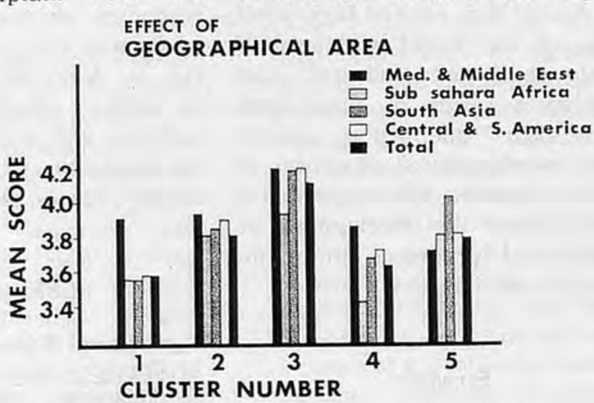

Fig. 4. Mean scores to clusters of questions by respondents representing four geographical areas of the world.

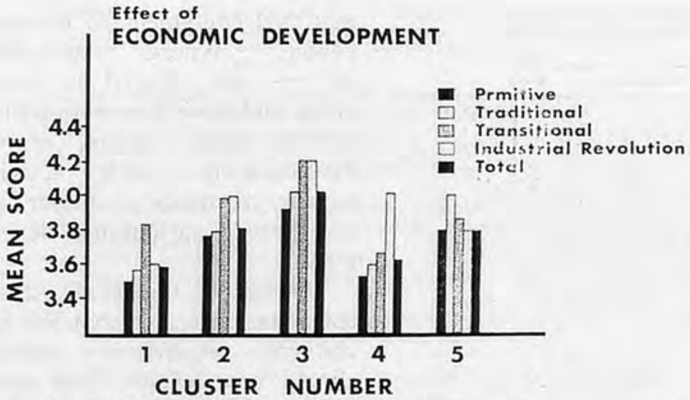

Fig. 5. Mean scorces to clusters of questions by respondents representing countries of four levels of economic development.

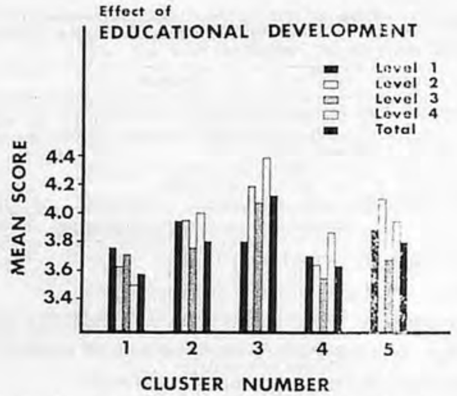

Fig. 6. Mean scores to clusters of questions by respondents representing countries of four levels of educational development.

Table 5. The perceived appropriateness of the agricultural equipment industry providing financial assistance in the form of scholarships and grants.

Question	Mean Score	Rank
30. Provide scholarships for students to attend non-degree agricultural mechanization training centers:		
(a) within their home country	4.00	3
(b) outside their home country	3.37	9
31. Provide scholarships for university students to obtain a degree in agricultural engineering or agricultural mechanization:		
(a) within their home country	3.45	8
(b) outside their home country	3.82	6
32. Provide scholarships for advanced university degree in agricultural engineering or agricultural mechanization:		
(a) within their home country	2.86	10
(b) outside their home country	3.90	4
33. Provide scholarships for teachers of agricultural mechanization to receive advanced training:		
(a) within their home country	3.57	7
(b) outside their home country	4.01	2
34. Assist agricultural mechanization education by making grants to schools to allow them to:		
(a) establish agricultural mechanization education	3.86	5
(b) expand agricultural mechanization education	4.06	1
Cluster 5 Mean	3.79	

a particular country but it does not appear necessary to emphasize financial aid for students in one area of the world, instructional aids in another, and the development of a program of workshops and seminars in a third part of the world. As instructional aids ranked high in all parts of the world, the agricultural equipment industry can develop a series of these and, with little adaptation, utilize them in educational programs in many countries. This continuity should make the development of educational programs more inviting to the industry.

Summary

An instrument was developed to study and determine the appropriate educational roll of the agricultural equipment industry in developing countries. The individuals who participated all had experience in developing countries and were involved in mechanization training.

The statistical analysis of the responses showed that industry can make the greatest contribution by developing software such as slides, charts, movies and bulletins and making the materials available to secondary and higher educational systems.

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News from Co-Operating Editors

The Present Status of Agricultural Machinery Development in Bangladesh

by M.S.U.Choudhury Bangladesh Agricultural University, No.431 AET. Mymensingh Bangladesh

At present Bangladesh has only one organization to work on the new machinery development for mechanization of its farms. This is the Agricultural Engineering section of the Directorate of Agriculture (Research & Education of the Ministry of Agriculture). This section is now headed by an Agricultural Engineer who is solely responsible for any kind development of agricultural machinery and implements. A few of the implements that the section designed and manufactured from its workshop are the following:

1) Chasi Plough
2) Light Mould Board Steel Plough
3) Winnower.
4) Pedal Pump
5) Iron rake
6) Hand Hoe
7) Rice Weeder
8) Improved Plough
9) Improved Sugarcane Crusher
10) Puddling rake (Philippine type)
11) Pedal thresher.

The Bangladesh Rice Research Institute recently has taken up a scheme for development of a few machineries and implements for mechanization of Rice Farming. The institute has not yet come out with definite machineries/implements worth mentioning. A few private organizations are manufacturing some of the agricultural machineries/implements, one of them which may be mentioned here is Comilla Co-operative Karkhana. This organization is mainly manufacturing the following:

1) Pedal Thresher
2) Weeder
3) Hand Hoe
4) Seed drill for Rice and Jute.

There is no definite programme for agricultural machinery industry in our country even though the Government is giving incentive to grow such industry in the private sector within the present financial limit as set out by the Government (Taka 3,500,000/–). Bangladesh Small Scale Industries Corporation established an agricultural machinery industry at Chandpur and could not run it successfully. As such this industry was sold to a private organization last year. There are a few small industries which are venturing for production of hand sprayers but their production quality is very low.

In order to modernise, a definite programme for agricultural machinery development industry is required to be taken up by the Government giving proper incentive to the private sector.

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Agricultural Mechanization News from America

by Merle L.Esmay Prof. of Agricultural Engineering, Michigan State University

Agricultural Mechanization on a Micro Basis

The systems analysis and simulation modeling approach to selective agricultural mechanization can greatly increase the probability of success for new programs. Agricultural economists have been developing macro models for some time and now agricultural engineers are getting into it more on a micro basis. Reliable data on machine performance, efficiency, quality of work, repair and maintenance, operation and labor requirements, as well as costs, must be provided by agricultural engineers.

The agricultural engineer must be one of a team, along with agricultural economists, agronomists, social scientists and systems analysts who do the feasibility evaluation, abstract modeling, planning, implementation and initial operation.

A New Ph. D. Graduate Program by Agricultural Engineering Department of Michigan State University

A new Ph. D. graduate program entitled Agricultural Mechanization Science has been started by the Agricultural Engineering Department of Michigan State University. The program pertains broadly to the physical aspects and the people involved in producing and processing food, feeds and fiber. Emphasis of study may be in one or more of the following areas of interest: machine utilization, feasibility analysis, project implementation, marketing and distribution, service and distribution, physical systems development and management, training and education, and safety and human factors. Systems analysis is a central theme of the program and two courses are required. Others may be selected. It is believed that this doctoral program my be appropriate for many students from developing. countries as well as our own domestic students.

Expert Consultation Meeting of the Mechanization of Rice Production held in Nigeria

Professor Emeritus G. Wallace Giles and myself, from the United States, had the opportunity to attend and participate in the recently held (June 10-14- 1974) Expert Consultation Meeting of the Mechanization of Rice Production at Ibadan, Nigeria. The meeting was jointly sponsored by FAO, the Government of the Netherlands and the International Institute of Tropical Agriculture. About 25 delegates from various countries repersenting numerous international organizations participated in the week-long conference. A proceedings of the papers presented and discussions will be prepared and published.

New Publications

Possibly some of the following publications might be of interest to the readers of AMA.:

1. Selective Employment of Labor and Machines for Agricultural Production, B. A. Stout and C. M. Dowing, Monograph No. 3, Institute of International Agriculture, Michigan State University, East Lansing, Mich. 48824, April, 1974.
2. Systems Analysis: A Guide to Technology Transfer, L. W. Faidley and M. L. Esmay, ASAE Paper 74-5039, Available from Agricultural Engineering Department. Michigan State University, East. Lansing, Mich. 48824, June, 1974.
3. The Mechanization of Rice Production -- A Systems Approach, Merle L. Esmay and LeVern W. Faidley, Expert Consultation Meeting on the Mechanization of Rice Production, June 10-14, 1974, Jbadan, Nigeria. Paper available from Agricultural Engineering Dept., Michigan State University.
4. Mechanization of Small Farms in Developing Countries, L. W. Faidley and M. L. Esmay, VIIIth International Congress of Agricultural Engineering, CIGR, Netherlands, September, 1974. Paper available from Agricultural Engineering Dept., Michigan State Univesity.

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Worldwide Focus for U. S. Agricultural Engineers

by William Chancellor Prof. of Agricultural Engineering, University of California

The December, 1974 meeting of the American Society of Agricultural Engineering in Chicago will be organized around the theme, World Food Needs--An Engineer's Apdate. The theme will be highlighted by a key-note speaker, and one program session will feature speakers of international renown who will discuss the subject of:

Worldwide development with multinational leadership

Foundation and institutional assistance

Bi-lateral assistances agencies

Private industry now mecchandising worldwide to agriculture

At the June, 1974 meeting of ASAE held at OKlahoma State University, Wtilwater, Oklahoma, one program session sponsored by ASAE's International Relations Committee addressed the topic. The following papers were presented:

Altamira Land Development Project, Brazil by L. G. Reeser and T. Sato. The heavy equipment and its operating procedures were described relative to Jungle clearing operations for an agricultural colonization project along the trans-Amazon highway. ASAE Paper 74-5035.

Young Farmers' Training Center of Maradi, Niger Republic by R. G. Koegel. General agricultural training was combined with introduction of trainees to animal power and associated basic implements. Successful post-training use of animal power by trainees was described. ASAE Paper 74-5036.

Agricultural Engineering Training for International Programs by A. P. Cobra and T. H. Burkhardt. Objective and considerations in selection, orientation training and employment were discussed for agricultural engineers planning to work in international development. ASAE Paper 74-5037.

Energy Imputs and Agricultural Production under Various Regines of Mechanization in Northern India, by G. Singh and W. J. Chancellor. Farms using higher levels of mechanical technology were found to have lower production costs higher energy inputs and lower labor inputs per unit of land area. ASAE Paper 74-5038.

Copies of these papers may be obtained by writing to the authors or by sending US $ 1.50 for each paper desired to ASAE, P. O. Box 229, St. Joseph, Michigan 49085, U.S.A.

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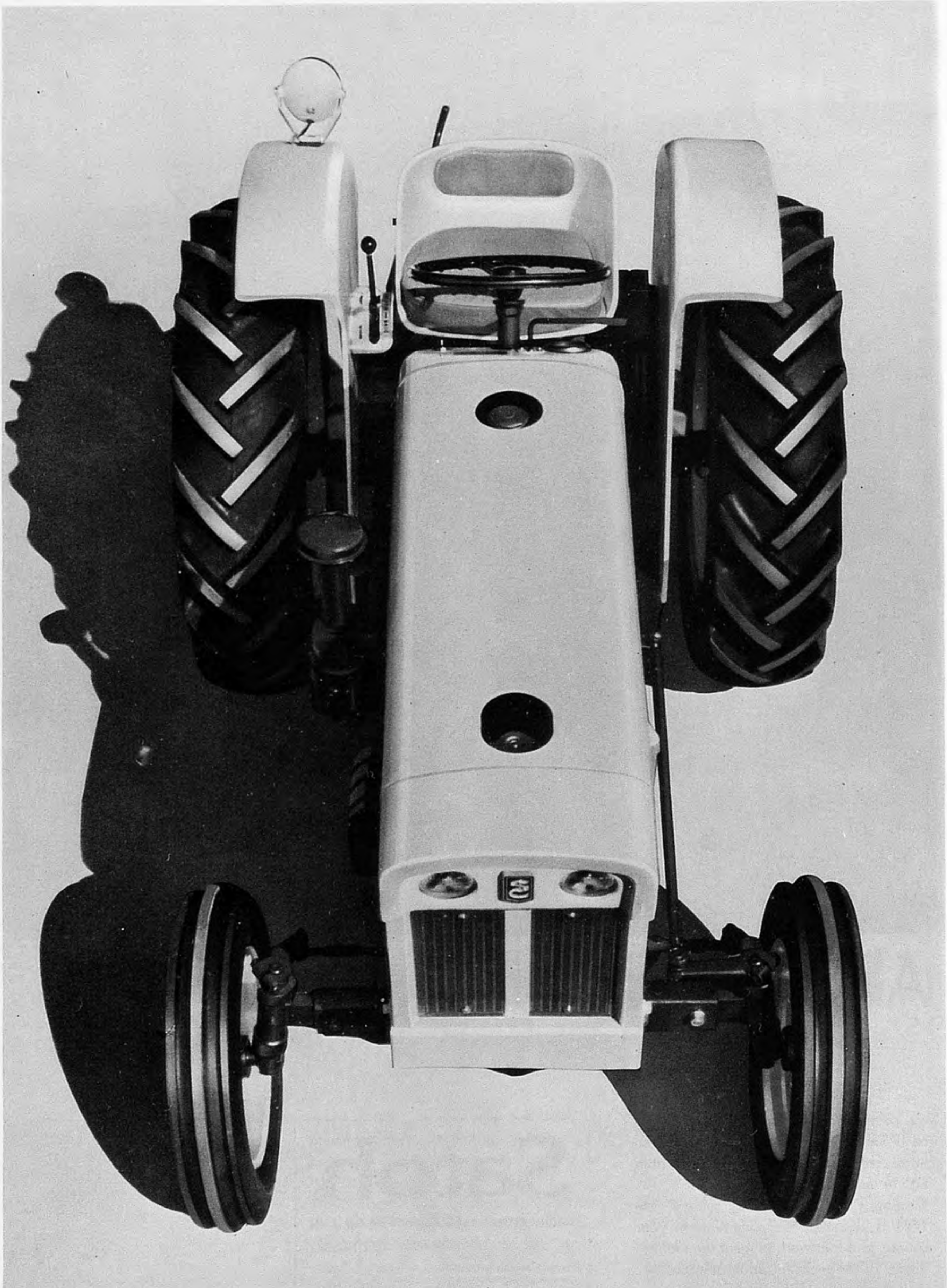

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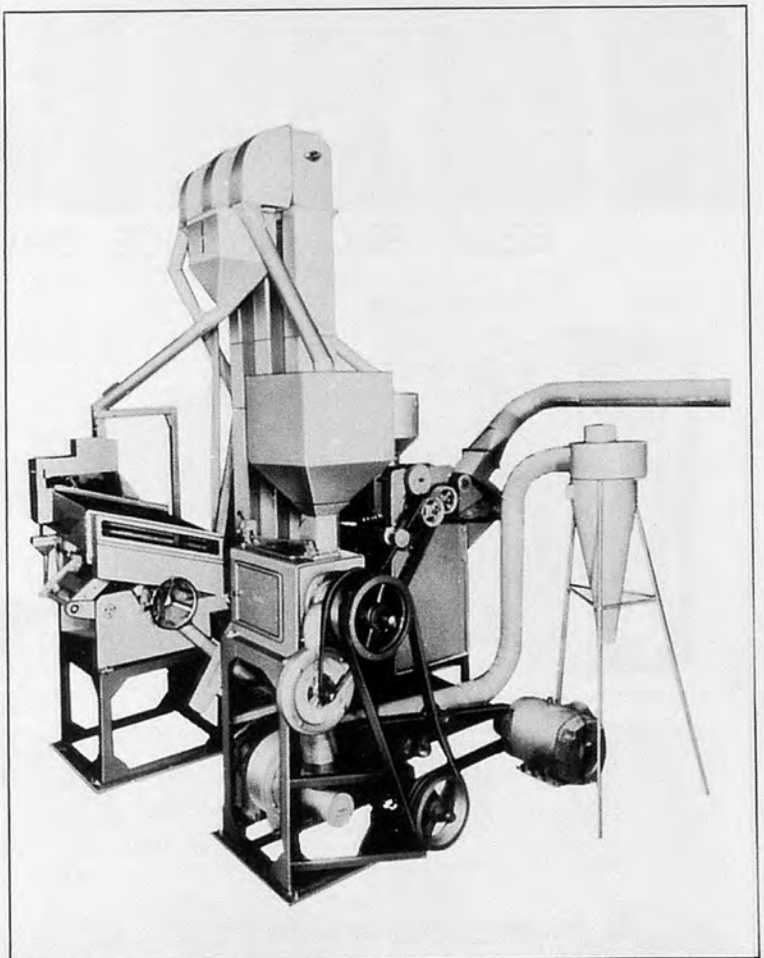

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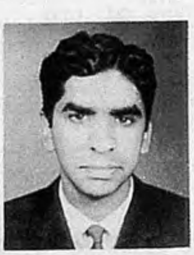
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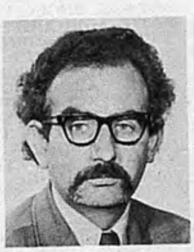
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Acquiring Technology for Manufacturing Agro-Equipment

by Rusi Lalkaka
Regional Adviser on Transfer of Technology, ECAFE/UNIDO

Agriculture in re-focus

The recurring cycles of food shortages and the unrealized promises of industrial ventures in developing countries have brought sharply into question the view that industry is the leader and agriculture the follower in economic growth. The new agricultural technology required by the so-called "green revolution" has reemphasized the complex inter-relationships between agriculture and industry. It is also realized that if there is to be a sustained impact, then cnanges are needed across the whole agricultural - and even social-sectors, not only at the farms.

Rising unemployment and widening income disparities require that a hard look be take at the problems of farm mechanization and development of suitable agro-equipmen. In no sector is the question of appropriateness of technology more relevant than in agriculture, and indeed, the agriculturists were among the first to recognize that the total transplantation of seeds - or of techniques - was a disaster; it is often better to transfer the science and develop the specific technology in each particular environment.

The structure of technology development

Apparent concern for transferring science and technology to developing countries has risen sharply in the last decade but practical research on this subject has not increased commensurately, and technology actually transferred has been quite negligible. There continues to be a dichotomy of views on preferred mechanisms of transfer, or indeed, on what these mechanisms really are. There are as many interpretations as persons, rather like the blind man trying to describe an elephant.

The pre-requisites for technology development **(Fig. 1)** in agricultural or other industrial sectors include:

—a clear definition of national policy on technology, in order to set the prioritied and pace;

—the available "human-ware", which must be rapidly upgraded and augmented by innovative training systems;

—the market - an analysis of minimum needs, taking social costs and benefits into account.

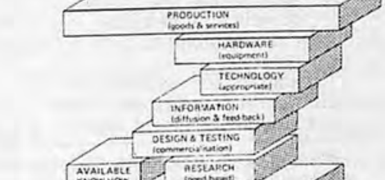

Fig.1. The edifice of technology development

Materials and money are essential elements in raising the edifice but where the foundation is sound, these could generally be arranged. Using the available knowledge and skills, an indigenous project evaluation capability could be developed together with some research effort, not "pure" or "applied" but "need-based". With this basic capability, the country could decide what technologies to inport from abroad as well as the terms and conditions that would be acceptable. The products developed at home have then to be tested, improved, retested and demonstrated. Their commercialization and diffusion together with the continuous feedback of industrial experience could, with some luch and much work, create a body of appropriate technology for manufacturing agro-equipment. At the apex sits the consumer - the farmer - without whose active co-operation there would be no progress.

The technology package

Agricultural machinery covers

a wide-range requiring different levels of technology - from hand tools, hand-operated machines and animal-drawn implements which can be fabricated in small artisan workshops in the Mekong basin countries and in most other developing countries; through tractor-drawn implements, irrigation and crop protection devices for which designs and manufacturing facilities can be progressively developed; and on to power equipment including tractors and tillers which need relatively complex technology, more investment in production facilities, and higher output volumes.

The bulk of farm equipment, including two-whool tillers, diesel engines and pump sets, can be manufactured on a small-scale with low investment, through the purchase of standard components from ancillary suppliers. Designs can be readily copied and modified while manufacturing skills can be learnt on the job, even by unskilled labour with no previous workshop experience.

It is only for heavy tractors, combines and advanced equipment that imported designs are needed. Moreover, designs and drawings alone are clearly not enough. The technology package must include a range of other inputs - for example, skills in management, marketing and maintenance. A balance is needed between those elements which could be developed nationally and those which must necessarily be imported. This in turn requires that, to the extent possible, technology be unpackaged and each component be acquired from the best available source, keeping in view long-term national aspirations and local skill development.

The heavy machinery industry involves the metal working and metallurgical sectors as well as the automotive and electrical engineering sectors at different levels of product sophistication. In the initial stages, developing countries adopt a policy of imports, local demonstration and maintenance, then take up local assembly and manufacture to foreign designs. This is followed by progressively raising the indigenous content, and eventually by some research and design work within the country itself.

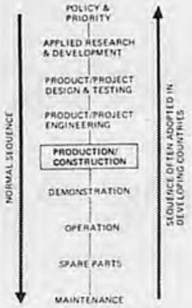

Fig.2. The normal (& reverse) progression of technology "up the down escalator"

This a reverse progression from that adopted in industrialized countries **(Fig. 2)**. Can the developing nations attempt the normal sequence of activities? How can the cycle be shortened? Some Asian countries, for instance, India and the Philippines(1) have already made progress in achieving a measure of technological independence. Their experience can be of considerable value in assisting other LDC's acquire these skills.

Demand for agro-equipment

After fertilizers, the purchase of agricultural machinery is the largest expenditure incurred by the farmer. This constitutes a substantial backward linkage to the manufacturing sector.

The requirements of agricultural machinery are rising significantly, with Asia itself importing over US$500 million worth in 1971 **(Table 1)**. Demand is expected to rise at around 15 per cent annually over the next decade.

Assuming a modest 20 per cent as cost of technological inputs, it means that Asian countries are already paying over US$1,000 million per year for such services. This is many times more than being spent on agricultural research in the region. In order to reduce dependence on imported inputs, the Asian countries have themselves to make greater efforts in developing the needed technological capability. Concurrently, import of essential know-how and equipment must continue.

Constraints in manufacturing and technology acquisition

However, every developing country is encountering mile-high obstacles in creating and commercializing technology **(Fig. 3)**. For agricultural equipment and other manufactures the con-

Table 1. Trade in agricultural machinery in Asia, 1971 (in million US$)

	Asia and the Far East	Total developing countries	Total World
Total engineering products:	8,399	25,582	101,890
including			
(i) machinery, non-electric	4,277	11,725	43,116
(ii) transport equipment	2,213	8,795	38,782
Total agricultural machinery and allied products:	549	1,775	6,388
including			
(i) agricultural machinery	218	753	2,811
of which implements	32	150	943
dairy equipment	2	10	87
tractors	172	540	1,400
(ii) engines for agriculture ※	150	440	1,748
(iii) pumps for agriculture ※※	142	483	1,572
(iv) land development machine ※※※	29	95	257

※Assumed at 50 per cent of "other internal combustion engines".
※※Assumed at 60 per cent of pumps and centrifuges.
※※※Assumed at 10 per cent of construction and mining machinery.
Source: Bulletin of Statistics and World Trade in Engineering Products, 1971, United Nations, New York.

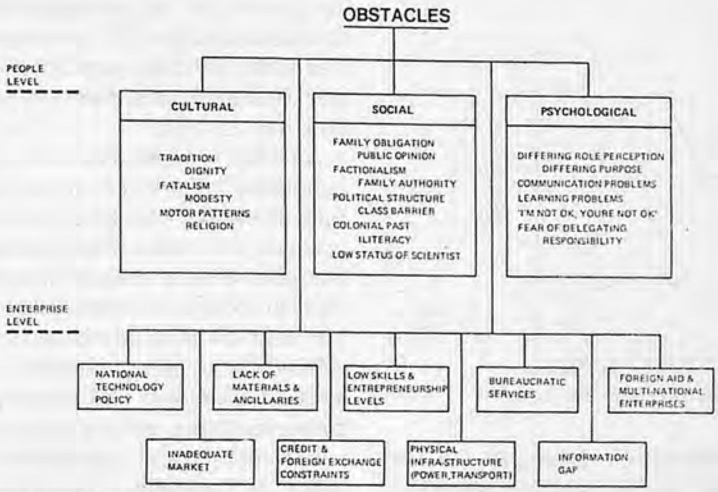

Fig.3. Barriers to the development of industrial technology

turaints are at two levels: those caused by cultural, social and psychological factors, and others at the specific enterprise level. One need not dwell on the all-too-familiar catalogue of difficulties - the lack of physical infrastructure facilities, of ancillary industries such as foundry and forge shops, of essential materials such as low-alloy steels, of capital - specially foreign exchange, of consistent government promotional policies; and the existence, on the other hand, of bureaucratic procedures and of "package deals" tied to foreign aid which tend to inhibit indigenous initiatives.

Existing systems of land tenure in many Asian countries also constitute a barrier. Unless the farmer has a long-term perspective based on clear ownership, he has no motivation to invest in expensive mechanization. The production of agro-equipment is hampered by the small size of existing markets together with their low purchasing power(2). The scale-economies of assembly line production of tractors, for instance, are not available; consequently manufacturing costs are high, and in turn, markets cannot be expanded so that the high cost-price structure persists. Larger cash receipts by farmers are necessary for them to invest in expensive equipment. At unrealistic low crop prices, the age-old farming methods will continue.

The evolution of better farm tools is further thwarted by limited indigenous research and follow-through to commercialization. To create a successful design is only the beginning of the battle! At many agricultural research institutes in Asia, one can find well-conceived prototype equipment which just could not be "sold" to the manufacturer due to a lack of production engineering and follow-up efforts. Even when equipment was successfully produced, it could not be "sold" to the farmer due to a lack of promotional and extension services.

This brings us to another constraint, namely, the low level of existing technical education in the developing countries. Some do not yet have agricultural or mechanical engineering curricula in their educational systems and vocational schools are also only now being initiated. However, learning by doing is generally more effective than formal technical education. A more serious gap is in management, entrepreneurial and consultancy abilities. These normally evole and are reinforced by the manufacturing process. But where an industrial heritage is either lacking or in a nascent stage, these missing elements can be in a bottleneck.

Appropriate designs for agro-eqipment

More serious is the lack of well-suited equipment designs for the crops and conditions on Asian farms. By appropriate we mean that which is in accord with local comparative advantage. A number of economists have been propounding theories on "appropriate", "intermediate", "scaled-down", "adaptive" and other brands of technology, but at times this theoretical work has little relevance to the practical problems of the developing countries.

The local conditions that must be faced include the sheer size of the agricultural population (almost 80 per cent of the total in Asia, ranging from 45 per cent in Republic of Korea to 85 per cent in Nepal); the small fields; the predominance of rice in the agricultural output; the open channel irrigation; the scarcity of capital; the low income and literacy levels requiring machinery which is economical to buy, simple to operate and to maintain. The problem of maintenance is quite critical:(3) the designer must appreciate that a mud-covered piece of machinery may have to be repaired under a tree by an enthusiastic but ill-equipped mechanic using a few rusty tools.

The favourable condition is the tropical climate which makes two or three or more crops a year possible with the new high-yielding varieties, provided that farm operations are performed with timeliness and peaks of labour required can somehow be evened out.

It needs to be realized that the large multi-national companies will generally not put in the effort and money for development of simple, economical machines for tropical crops when the market is small and returns are still far away. The reason why an international research effort like the International Rice

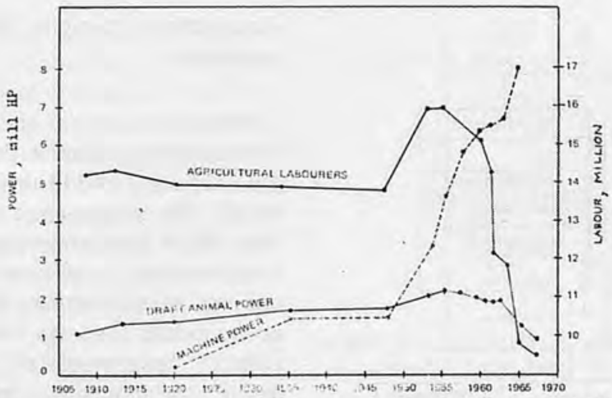

Fig.4. Historical changes in Labour and power used for agriculture in Japan

Research Institute (IRRI), Los Banos had to go into rice is that rice is of marginal interest to the developed countries. On the other hand, the requisite heavy agricultural machinery for wheat was developed in advanced countries.

Total employment and appropriate mechanization

The great impetus for mechanization in the developed economies came from their factor proportions. Rising labour wages and higher capital availability influenced technological development towards replacing men by machines. In Japan,(4) for instance, the pattern and objectives of farm mechanization were quite unique: farm machine power increased from a total of 1.6 million HP in 1953 to over 8 million HP in 1965, while farm labour dropped from 15.4 million to 9 million **(Fig. 4)**. Interestingly however, for 15 years or so after the onset of mechanization in Japan, the agricultural labour force actually increased. A similar pattern was experienced in UK.

Even in most advanced countries heavy mechanization is a fairly recent post-war phenomenon. The necessity for this arose only when the proportion of farm workers dropped to below 40-50 per cent of total population. (In the United States this happened as early as 1880.)

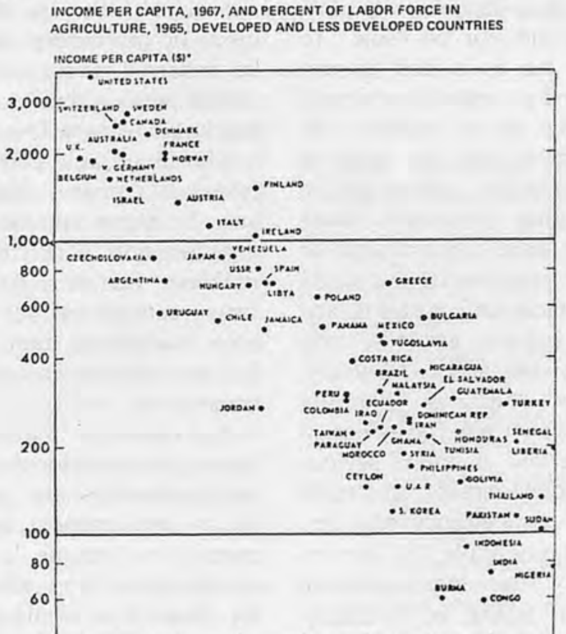

Fig.5. Percent of labour force employed in agriculture ("gross national product per capita, 1966 dollars")

As the proportion of total population employed in agriculture decreases, the gross national product per capita has tended to increase. **Fig. 5** clearly indicates that in countries with under 50 per cent of population on farm-related activities, incomes are above US$200.(5) The developing countries have before them the paramount - and paradoxical - tasks of increasing employment as well as raising GNP. To accomplish these, the traditional methods will have to be discarded in favour of innovative approaches and new mechanization strategies.

A man can deliver only about 150 KWH of muscular work per year; at say US cents 3/KWH, this is worth only US$4.50. His subsistence cost alone would be many times that figure. By attaching an engine to his farm implements in combination with other inputs, he could cover more ground, increase yields and raise production. However, the controversy on the type of agro-equipment suited to the factor endowment of developing countries continues.

Farm mechanization generally implies the use of additional power (although greater power application may not necessarily increase yields!). Power requires some form of energy and most developing countries of Asia have no resources of oil, the hitherto prime energy source. When a fuel-short world is trying desperately to find alternative ways (and also thereby help reduce environmental pollution), it would be foolhardy for developing countries to embark upon energy-intensive mechanization.

Eicher and others(6) in their study of tractor mechanization programmes in Africa, have pointed out that causes for their failure were:

- —short life of expensive equipment due to corrosion, poor maintenance and operation;
- —a low degree of utilization, due to poor management;
- —poor land clearance and small field size;
- —equipment inappropriate for the ecological conditions;
- —high cost (in foreign exchange) for equipment, spares and fuel, subsidized by governments through fiscal measures.

The main reason was that thorough analysis on selection of appropriate methods and machines were not made. What was pertinent for Africa, has equal force for Asia today.

In the long-term, heavy tractorization is generally labour substituting. On the other hand, total direct and indirect employment could actually increase through semi-mechanization using specially-designed implements drawn by animals or by small tractors and with suitable seed-fertilizer technology.

Studies in the Philippines[7] showed that with 31 per cent tractorization and planting local varieties required 79 man-days of operation; with increased tractor use to 75 per cent and high yielding varieties, labour input, in fact, rose to 91 man-days; yields and productivity increased appreciably. In addition, the employment generated in manufacture of agro-equipment and all its ancillary, service and supporting activities can be considerable.[8]

Giles suggests[9] that when yields in kilogram per hectare are plotted against HP hectare for a number of geographical areas **(Fig. 6)**, the curve has two sloped: the Linh AB (which most developing countries are following) rises steeply until machine intensity of 0.3 to 0.5 HP and yields over 2,000 kg/ha; line CD flattens out giving relatively small increases in yield with

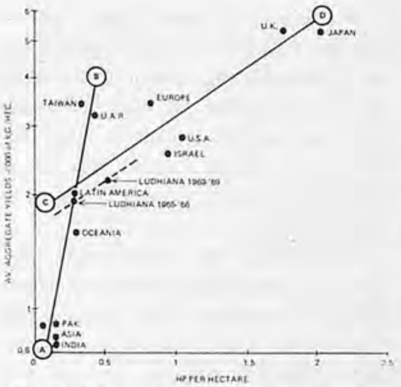

Fig.6. Effect of mechanization agricultural yields

further increases in power. If Asian developing countries are to reach - and surpass - the FAO "reasonable goal" of 0.5 HP/ha, the semi-mechanization of farms is inevitable.

A recent study by a UNIDO consultant[10] on rice mechanization in selected Asian countries indicated that the average agricultural labour force is 1.1-1.3 workers/ha and, in except a few countries, an absolute reduction in this may not come for the next 20 years. Some countries were moving towards heary tractors of the US type (with tractor density of up to 3,5 units/1000 ha in Iran) and others towards light Japanese-type power tiller (7 units/100 ha in Korea), however no real effort was being made to bridge the gap between these two types. Apart from the inappropriate choice of equipment size and implements, tractors were ofter not used in the right way and their utilization was low. Based on estimates of probable future demands of machinery and expected production, the study concluded that "no less than 50-70 years would be needed to mechanize paddy-growing". In areas where gross income was US$250 to 400/ha, the purchasing capacity is only US$28-50 per hectare per year and governments may have to subsidize between 50 and 10 per cent of the purchase cost of farm machinery.

Channels for acquisition of technology

The mechanisms available - and those which may be preferred - for the acquisition of technology for manufacturing agro-equipment emerge out of the above discussion.

As already noted, technology and capital are not barriers for the bulk of farm equipment. In most Asian countries, the artisan or urban workshop has the skills to imitate designs and to carry out fairly complex manufacturing operations. It can force the larger companies out of simple product lines into more sophisticated ones, or into greater dependence on low-cost components from a network of ancillary shops. Often these have been started by a progressive fitter or blacksmith from the large company itself in a fission process.

Thus, two effective channels for securing technology for simple farm machines are learning through imitation and through formation of ancillary relationships. For more complex machines, a third route is the purchase of know-how, either from national research institutes or from abroad.

A joint venture with a foreign company can be a valuable instrument. There has been a significant flow of agro-equipment manufacturing techniques into Asia through foreign capital investments, largely through multinational enterprises. The patterns for foreign investment very from country to country, with some (such as Iran and India) prohibiting foreign majority ownership and exercising rigid controls on the companies' operations while others have been more permissive. Undoubtedly, larger investment flows are needed, but recent world-wide experiences should serve as a warning against the uncontrolled entry of foreign capital. In all such arrangemenents, formal agreements for transfer of know-how are desirable, prescribing the responsibilities and liabilities of each side, the mechanisms of transfer, the appropriateness of the techniques and designs, and their costs.

In some situations, technology licensing agreements without foreign equity participation may be preferable. The know-how may be transferred through employment of individual foreign experts, training of local personnel, supply of manufacturing plant, or through a complete package of services from planning, construction through supervision of plant operations. Such turnkey type arrangements require even greater vigilance on the part of the buyer, and where the country has some basic technical capabilities it would be preferable to undertake part of the planning work indigenously and purchase foreign services on a selective basis.

High cost of purchasing technology

The costs of importing technology can at times be prohibitive. The licensor may not find it sufficiently attractive to transfer his technology, may fear the loss of a lucrative market or the future emergence of a competitor.

In negotiating a technology licensing contract, the licensee is in a vulnerable position as the market is undefined and prices which others have paid are generally kept secret.(11) There is the grave danger that the licensee may not get all the services he needs or for which he has contracted. Further, he may be forced to make additional indirect payments through purchase of intermediate materials and components from the licenser, thus greatly increasing the latter's "monopoly rent" earning.(12)

If the technology salesis from a parent company to its subsidiary in a developing country, it may not be possible to unravel from the company's accounts what indeed has been paid for components, know-how, personnel and so on.

According to UNCTAD estimates, the direct costs for technology purchase by developing countries would rise to a staggering US$9,000 million by the end of this decade.(13) Already these costs are amounting to 37 per cent of service payments on external public debt and represent two-and-half times the total expenditures on local research and development activities in the developnng countries.

Then again, while high fees may be paid by the LDCs for acquiring technology, in some situations no technology may be actually transferred - the foreign company merely extracts the oil or the ore or produces products or builds machines without really developing local personnel to do the job themselves some day. The real cost of this "non-transfer of technology", of indirect tie-in-payments and restrictive clauses may indeed be many times the direct costs mentioned earlier.

Mobilizing for self-reliance

How then, do the developing countries go about acquiring the technology which they urgently need? The solution may well be for the countries to make much greater efforts on the generation of their own appropriate designs and skills, relegating the purchase of foreign technology to a supportive role.

Of course, the LDCs do not have to start by re-inventing the wheel. Most of the design principles for agro-equipment have already been discovered in the nineteenth century. A vest body of knowledge exists - through publications, conferences and visits, available at practically no cost - to build upon. This "free technology" is not being properly mobilized. Even in advanced countries most honest technologists would admit that they barely glance through the avalanche of technical publications that lands on their desks. In developing countries, the need for comprehensive systems of industrial information, including agricultural machinery data, is even greater.

As already discussed, in most LDCs the real problem is not lack of technical personnel for developing a self-reliant agro-equipment programme, but that the available manpower is not properly mobilized and not given the opportunity to do responsible work. Technical leaders have to be found - or developed. Given this leadership, supported by forward-looking government policies, the existing technicians can themselves create the right agro-equipment and commercialize it, at indeed many are already doing.

Examples can be cited where individual entrepreneurs in developing countries have created a low-cost, low-volume technology, entirely suited to their factor endowments. In Thailand, a large number of workshops which formerly did automotive repairs are now engaged on manufacturing locally-designed puddling machines, two-wheel tractors, corn-shellers, pumps and "long-tail" out-board engines. They use local castings and sheet work while ball-bearings, gears, engines are imported. To better utilize their machine tools, some firms also manufacture other lines of equipment. An efficient filtration system for potable water has been developed using locally-available coconut fibre and burnt rice husks.(14) In Bihar, India, a farmer designed a simple tube-well made of a few bamboos, coir string and tar. Again, when a special drill was needed to place fertilizer below and to the side of the seed simultaneously with planting, local technicians designed, tested and commercialized an appropriate implement.

In the Philippines, the hand tiller developed by IRRI is being mass produced and solt at one-fifth the cost of an imported model which is more powerful but is less appropriate to the local conditions. The "Fierá" pick-up is another example where using functional design, low volume manufacturing methods and progressively less imported materials, the vehicle sells for half the price of an equivalent imported model. While these examples are heartening, many more are needed. The considerable innovative and manufacturing skills of local artisans need to be better mobilized and the learning process accelerated.

Johnston and Kilby point out: "Even in recent decades much of the creative work in the United States has been done by local tinkerers and machine shops, with the research divisions of large corporations commonly buying up the patents of the more promising inventions and carrying out the final stages of research and development before going into mass production".(15)

Once an indigenous technology movement gathers momentum, more sophisticated design and manufacturing activities can be tackled. We can visualize the flow of technology as a small trickle, which augmented in stages by selected imported technology, by the feed-back of information and by additional industrial experience, soon becomes a flood.

Systems approach to acquiring Know-how

In the progression of activities leading to the eventual manufacture of agro-equipment, applied reseacch, design, testing, product engineering and quality control constitute the input services. The output services, namely, operation, demonstration, spare parts and maintenance of the manufactured equipment are no less important.

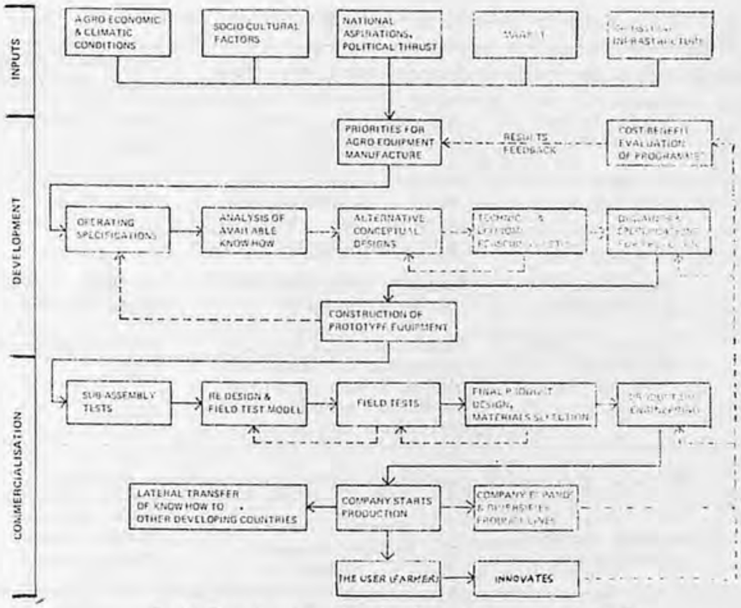

Fig.7. Development of technology for agro-equipment

In setting the priorities, commercial yardsticks alone are of little relevance when, in a traditional and rural setting, economics is intimately tied to social factors. Not only agro-economic conditions but a host of other factors must be considered, country by country, community by community. A systems approach is needed to develop the total technology required, covering all services up to the stage of commercialization and beyond, with frequent feed-backs of experience. A scheme for know-how acquisition and equipment development is shown in **Fig. 7.**

An example of good planning was the IT Rural African Development Project which first made an assessment of the whole farming calendar and cropping sequence, the major competing and complementary inputs, the "peak-demand" labour periods, and so forth. Based on a careful analysis of needs, the field stations started to design, produce prototypes and test appropriate tools and equipment, and later assisted in their local manufacture. Similar programmes are needed for South-East Asia.

The central figure in this drama must be the farmer. He will ultimately use the machines, and his full and willing participation would be the vital ingredient in the success of such programmes. If the farmer's needs are well satisfied, there will be a demand for the machine; with interaction between him, the designer and the manufacturer, there would be continuous technological improvement.

In the view of Giles, "Design and development activities should lead a country's anticipated rapid gain in agricultural production by as much as five to ten years".(16) He then goes on to identify priorities for agricultural machinery needed in Asia for "selective advanced mechanization" **(Table 2).**

International support for agro-equipment manufacturing

Over the last five years, UNIDO and ECAFE have undertaken a series of detailed studies to promote the design and manufacture of equipment appropriate

Table 2: Priority agricultural machinery for Asia

Priority	Category	Name of machinery items	Activity required to manufacture
1	Water supply and control	Pump sets, soil movers, land plane	Import, adapt and copy
2	Seedbed preparation	Power tillers mouldboard and/or disc ploughs disc harrows spike tooth harrows	Import, adapt and copy
3	Harvesting and threshing	Multiple crop stationary threshers combines	Develop Import, adapt and copy
4	Seeding and fertilizing	Grain drill with fertilizer applicator Row-crop planter with fertilizer applicator combination bed former and planter	Import, adapt and copy Develop

Table 3: Suggested specifications for manufacturing in Asia

Suggested regional specification	Small low-cost tractor 4-wheel riding			Small low-cost tractor 2-wheel walking power tiller		
HP	15−20			8 −10		
Type of fuel	Diesel			Diesel		
Number of cylinders	2			1		
Type of cooling	air			air		
Number of gears forward	4			2		
Number of gears rear	1			1		
Total weight kg	1.000			100		
Tyre front size	6.00−16			5.00−12		
Tyre rear size	8.3/8-24			—		
Attachments	N	N/N	O	N	N/N	O
Self starter			X		X	
Head lamps and rear lights	X					X
Differential lock			X		X	
Hydraulic	XAlternative				—	
3-point lift	mechanical available					
Fender seat			X		—	
Deluxe seat driver	X				—	
Swinging draw bar	X				—	
Power take off	X				—	
Belt pulley			X			X
Safety cab			X		—	
Fenders	X				—	
Type of implement mounting						
Pull	yes				—	
Hydraulic lift	yes				—	
Mechanical lift	yes				—	
Basic implements required	Ploughs Disc harrows Rotary cultivators Tyne cultivators			Ploughs Trailers Rotary cultivators Tyne cultivators		

N=necessary; N/N=not necessary; O=optional

to tropical farms. (17~22) The operational., supporting and promotional activities of UNIDO through various technical assistance programmes are playing a major role in this field.(22)

Recently UNIDO undertook a comprehensive survey to help identify the market for small low cost tractors.(23) Based on questionnaires sent out to government and agricultural organizations, the specifications generally preferred in Asia and the Far East were ascertained **(Table 3).**

Tractor manufacturers who were contacted expressed their interest in joint-ventures and sale of know-how.

National, regional and international efforts to strengthen research and information exchanges warrant much greater support than they have received in the past. Recognizing the expressed need for co-operative design and development facilities in the Asian region ECAFE, supported by UNIDO, has taken the initiative in proposing the establishment of an Asian Centre for Agricultural Machinery (ACAM). An Expert Working Group(24) which met at Bangkok in October 1972 concluded that the main functions of such a centre should be to create appropriate designs for indigenous manufacture, assisting their commercialization, disseminate information, and undertake training and advisory services. Such a regional centre would supplement the activities of national institutes where they exist. At the Asian Industrial Development Council meeting in January 1974 it was decided to go ahead with the establishment of this centre. The Governments of Japan and other countries have expressed strong support.

For implementation in the near future, other UNIDO activities are being programmed for technical assistance to the farm equipment manufacturing industry. For instance:

—Training programme on various aspects of agricultural machinery development for senior planners and middle level executives from selected LDCs.

—UNIDO-IRRI Project for assisting LDCs in testing IRRI prototype machines and their local manufacture.

—Feasibility investigations on agricultural machinery manufacture in Mekong Basin countries.

—Strengthening and expansion of existing equipment design, adaptation, testing and manufacturing facilities in selected LDCs.

—Establishment of pilot engineering workshop for fabricating agricultural tools, implements and machines, together with repair and maintenance facilities.

The South Asian countries represent a sufficiently homogenous sub-region to justify a co-operative approach. With minor modifications to suit local peculiarities, equipment for say Viet-Nam should, for instance, be useful in the khmer Republic. In this manner, resources of men and money can be effectively pooled. While UNIDO, FAO, ECAFE and other international agencies can provide some technical inputs to catalyze action, the initiatives, the formulation of policies, and their implementation, of course, depends upon the governments themselves. As the agro-equipment industry gathers momentum, other institutions - such as professional societies and manufacturers, trade associations - could play a significant role in accelerating the technology transfer process.

Conclusions

The main points can be simply re-stated:

- —it is necessary to introduce more HP per hectare of tropical farmland, but conventional heavy machine-methods may be inappropriate in many situations. The equipment should be custom-designed to suit the farmer, his resources, his habits;
- —it is logical that this design and development effort originate in the developing countries themselves, supplemented by selective purchase of technology where required;
- —it is essential that national policies be devised to cover all technical inputs, including development of management, marketing, maintenance and manufacturing skills;
- —it is desirable that the resources of tecenical manpower and facilities be pooled by the South Asian countries in à co-operative self-help effort. The policy decisions and continuing support must come from the governments with UNIDO and other international organizations playing a catalytic role;

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Marketing Farm Equipment

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The modern farm equipment industry in the country is quite young as it has just completed its first decade. The contribution of the industry to the green revolution is well recognized. Mechanization of farm operations improves productivity. It takes away the drudgery from chores. It improves the farmer's standard of living through higher income and reduced costs of operation. It reduces his hours of work thus improving his health. Timeliness and accuracy of operation resulting from mechanization of farm operations are also important for the high yielding crop varieties.

One of the biggest challenges facing the industry today is the successful penetration and development of the rural market. Let us first review the present marketing scene.

Tradition

Village shops are ill-housed and inadequately equipped for consumer services. They keep only fast-moving items to meet the villagers' minimum requirements. More often than not, articles required are not available. Delivery of goods cannot be guaranteed. Whatever little is available is badly stored in damaged cartons covered with dust. Neither is the buyer nor the local seller aware of the risks of mutilated packaging. Items made of rubber and such perishable material harden or deteriorate during storage. In some cases articles are sold even after the date of expiry. There is no proper pricing policy. The common practice is to operate on an "own cost-plus" basis. If the product turns out to be bad or defective, it is the buyers' ill luck as there is no warranty on it. The shopkeepers are not given any operating instructions or training. Their "tutors" are workshop mechanics, the quacks of the trade, or the buyer's ill paid employees.

The rural citizen also goes to a nearby "haat". This is a bazaar held at a predetermined frequency either weekly, fortnightly, or monthly. whatever is not available at his village shop he can buy at the "haat", but his choice of wares is limited to what is on display. Though there is no warranty on the goods here too, they are in a better condition. The "haat" also provides the farmer and his family with an outing and comes as a welcome change from his monotonous life. The third shopping centre for the farmer is, of course, the town. The wares are a little better and the choice a little wider. However, the cost of procurement goes up as the farmer must travel to town and back with his purchases.

The buyer is a loser whicherver way he shops. He does not get what he wants, quality-wise or quantity-wise and the procurement cost is high. Sellere are losers too. Their selling costs are high as their business techniques are outmoded. Their outstandings are large and unsecured. They are also got well spoken of.

This is the background of the traditional marketing outlets in the rural areas.

Marketing

It would be tempting to seek a solution to the task of rural marketing by applying the principles of contemporary marketing technology, perhaps with some adaptation. While we have a lot of knowledge about the spending habits and needs of an urban population, we know little about our village brethren. A proper concept of selling will have to be developed and exploited before we can succeed in the rural areas.

A new distribution channel capable of handling sophisticated engineering goods and certain specialized services is required to reach the farmer. It is not enough merely to appoint dealers who are often poorly equipped to render after-sales-services. The repair shops are also ill-equipped and not conveninitly located. The farmer is not yet mechanical minded or educated enough to these problems of repair. What is needed in these conditions is an integrated and comprehensive service to the farmer which embraces a variety of enqineering and chemical inputs and which may even extend to assisting and guiding him in the disposal of the resulting crops.

Merchandise has to be produced to answer the farmer's needs and wants. It has to be brought to him in large quantities at low prices and with a guarantee of regular supply. He has to be given a warranty of reliability and honesty on part of the supplier, since his physical isolation makes it impossible for him to inspect merchandise before delivery or seek redress if dissatisfied. Given the present literacy levels, sales techniques have to rely heavily on practical demonstrations and audio-visual aids. Extensive field training is, therefore, necessary.

Most important of all is the timeliness of the sales and service operations. A farmer cannot afford to wait. If a pumping set is not repaired in time, he may lose his crop. If a tractor breaks down and remains idle during preparatory tillage operations, the damage is irreparable. One manufacturer of agro-industrial products had virtually captured a particular market solely because his representatives moved from village to village demonstrating the equipment, offering the farmer free technical advice, and carrying out on-the-spot repairs for any equipment that needed it. Rural marketing is, therefore, an expensive business and one in which there will be no quick profits; but in the long run, the returns are certain.

Market Data

One missing link in rural marketing is the data on which to base marketing policies. There is a great need to conduct market surveys to find out answers to a number of problems which the selling organizations confront today.

During a survey conducted among tractor owners in July—August 1967, some interesting information was collected. It included the classification of tractor ownere according to their holding size; more than half the number of 35 HP tractor owners (53%) had holdings of the sizes of 25 to 100 acres. The survey also revealed that 62% of the farmers were buying tractors for the first time and 44% of the owners were operating the tractors themselves.

Another survey revealed that only 17% of the tractor owners went to authorized dealers for servicing, while 53% of the owners got their tractors serviced by local mechanics. Only 35% tractor owners bought spare parts from authorized dealers. Seventy-three percent of the tractor operators received no training of any sort. When there was a seller's market in tractors, only 12% of the tractor owners were contacted by the dealers. Popular advertising media include the radio, varnacular newspapers and magazines, hoardings and cinema slides.

This then, is the general background of the farm equipment market. Let us now deal with some of its important aspects.

Assessment of Demand

An important starting point is a proper assessment of the demand for the major inputs. Projections of demand can cover the foreseeable future. Figures of demand should be arrived at after a careful analysis of all the factors which influence the demand. For example, for working out the demand for farm tractors, items requiring study include cultivated area under large holdings, area under irrigation, command area per tractor unit, tractor population and its growth, pace of mechanization, equipment costs and apital requirements, identification of important crops and areas, and availability of labour and wage rates.

A break-up of equipment demand within the country can be worked out in terms of different regions and different specifications and sizes. Accessories, matching equipment, components, and replacement parts also require to be consolidated. Technological forecasting will greatly assist long range planning.

In case of tractors, a major item, there has been a great variation in the demand figures worked out by various authorities. The National Council of Applied Economic Research has now been asked to make an assessment. It is hoped that this report will soon be available and that more assignments of this nature will be entrusted to bodies like NCAER for other farm equipment items. The National Sample Survey Organization can also be, perhaps, utilized for such work. Despite attempts by various organizations, we still do not have a realistic estimate of demand for pump-sets, diesel and electric-motor driven; the industry continues to pass through a diffcult period.

Finace

Finance is vital for the development of the industry. The industry has to ensure timely availability of sufficiet funds for its products from factory to farm. Requirements of finance by the manufacturer, the marketing network, (distributor, wholesaler, stockist, dealer and retailer) and the farmer have to be met.

The procedure for grant of

Table 1. Estimates of annual investment in some farm equipment inputs

Item	Unit invest-ment Rs.	Estimates of annual require-ments.	Estimates of annual investment Rs. crores
1. Wheel tractors and equipment	50,000	40,000	200
2. Crawler tractors and equipment	1,500	200,000	30
3. Power-tillers & equipment	10,000	12,000	12
4. Engine driven pumpsets	100,000	3,000	30
5. Electric pumpsets	200,000	2,000	40
6. Plant protection equipment			6
7. Power threshers	50,000	2,000	10
8. Combines	200	150,000	3
9. Water-well drills	100	600,000	6
10. Replacement spare parts	-		15
11. Bullock carts, pneumatic tyred	250,000	1,000	25
12. Improved bullock drawn implements			20
13. Fuels and lubricants for farm prime-movers	2 m. tonnes		203
		Total	600

loans should be simple, prompt, practicable and able to meet the needs of a vast number of borrowers. The cost of financing adds to the input price and should be kept at a reasonable level. Grant of loans should be business-like and based on feasibility studies, in particular on the ability of the borrower to earn and repay. The size of industry/business, in many cases, may be small and financing policies should suit such small-scale operations. National laws should encourage sales on hire-purchase basis.

Financing institutions can assist in organizing financing consultancies and technical services, such as developing specifications and reliable sources of supplies, purchasing quality equipment, and obtaining prompt and efficient after-sales-services. It may be necessary for the financing agencies to set up technical cells to service loans. If the aggregate finance available is not sufficient to meet the requirements, priorities should be determined.

About Rs.600 crores will aoon be invested every year in important farm equipment inputs alone (**Table 1**):

We will have to take into account the farmer's increased dependence on borrowings. In 1967, 72% of the farmers were buying tractors from their own funds. Last year, only 50% utilized their own funds. This trend is continuing. A problem area is that those who are in a great need for such financial assistance are not eligible for it due to land records, their dealings with the co-operative financing institutions and the requirements of margin moner. On the one hand, there are financing institutions eager to lend money. On the other hand, we have the needy farmers ready to utilize the loan for farm equipment inputs. Those in the trade can, perhaps, bring these two agencies together and assist in complying with the formalities required.

Logistics

Training of operators assumes great significance. Though every manufacturer does train the buyer in the operation and maintenace of the equipment, this is not enough. There is a need for training on a mass scale. This training should embrace the manufacturer's personnel, the personnel of the marketing organization, the end-user, and also the way-side garages and mechanics. Unauthorized mechanics do more damage to the product than is realized. Yet, they are quite affective as counsellors to the farmer in his choice of equipment.

Training aids have to be developed though the cost of training is high. Audio-visual aids like educational films are a great help. It is important that the training material be in local languages. The industry's joint efforts with the government, the teaching institutions, the extension agencies, the voluntary organizations and the farmers' associations will be a great help in facing this herculean task. An institution like a National Institute for Training in Agro-Services (NITA) can be organized by the Government of India (on the lines of the NITIE in Bombay).

Availability of fuels and lubricants is sometimes a problem. Besides getting the adequate quantities at the time and point of use, the quality is also important. Adulteration of fuels is a menace and should be curbed with deterrent punishment. It ruins the equipment, increases maintenance costs, and results in more down time. Oil companies should impart training to the user personnel and to the personnel in the industry. Lubrication charts and quides on local equipment should be made freely available. A Farm Fuels Advisory Service can be organized by the Indian Oil Corporation to handle all fuel problems for farm prime-movers.

Prompt and efficient after-sales-services and genuine replacement parts shold be available to the farmer. The farmer requires a whole gamut of pre-sale to post-sale services, such as a study of his need, a survey of operating conditions, assistance in selection of equipment, installation of equipment at site, training in operation and maintenance, repair services, service clinics, contract service, mobile service, door delivery of parts, fuels and lubricants. A local dealer can be the farmer's best friend and guide.

Agricultural machinery has not received due attention from the underwriting (insurance) companies. Insurance should cover the machine, the owner, the operator, and the third party. For the first year of equipment life, perhaps, there can be a package policy to cover equipment insurance from factory to the farm. Animal drawn equipment involves an insurance of both the animals (livestock) and the equipment. The insurance tariffs should be at economic rates. The sale of equipment on hire purchase and institutional loans will result in more business to the underwriters.

With increased use of machines on the farm, hazards will grow. Regulations will have to cover safety and safety consciousness will have to be aroused through a mass movement. This will involve training, publication of safety material, development of safety attachments, collection of data on accidents and corrective actions. Some items requiring attention include overturning of tractors, noise levels, vibrations, hazards due to exhaust gases and dusting/spraying operations, and accidents on the high-ways caused by slowmoving agricultural vehicles. Ensuring better safety of farm operations will greatly contribute to improving productivity per worker and per hectare.

Selling expenses in rural marketing are high; It is important that the price structure allows adequate expenses and margins for farm equipment inputs so that the markets can be properly developed and served. Taxes and levies on farm equipment inputs should be kept at a reasonable level as it is to be appreciated that high cost of input will increase cost of farmer's output. It is wrongly believed that only rich farmers invest in farm equipment inputs.

Ceiling on landholdings should be fixed at a level that will not hinder a rise in farm productivity or spread of farm mechanization, but will ensure a reasonable standard of living and provide an incentive to the farmers to utilize new and improved technology. If not judiciously implemented, the imposition of ceilings on landholdings at a lower level will adversely affect the farm equipment market. Efforts should be made to increase the farmer's purchasing power so that he can afford the utilization of improved technology.

The market for farm equipment is different as compared with the market for other nondurable farm inputs, such as fertilizers and seeds. An equipment may be bought only once in five to ten years. The buyer greatly relies on the advice received from friends, neighbours, and and relatives. A bazaar mechanic also is a farmer's good friend and guide. The reputation of the product and the local dealer and the availability of prompt and efficient after-sales-services weigh much with the buyer in his selection.

Sears Roebuck

One has heard of Sears, Roebuck of USA, which revolutionzed agrarian marketing around the turn of the century with the realization that the American farmer represented a separate and distinct market. Separate, because of his isolation which made existing channels of distribution virtually inaccessible to him; distinct because of his specific needs which in most respects were different from those of the city consumer. While the farmer's purchasing power was individually low, it represented a tuemendous, almost untapped buying potential in the aggregate. The agricultural revolution, which formed the basis of the industrial and economic prosperity of America and Western Europe, will also play a similar role in the Indian economy.

Can we adapt the Sears Roebuck approach to our conditions, or, let us say, can we Indianize it? The following are some of the areas which we could examine for adaptation:

1. Compiling of mailing lists for direct mailing campaigns.
2. Cataloguing goods and services and offering farmers a wide range.
3. Organizing a "store" with equipment, seeds, fertilizers, pesticides, and other inputs as a retail point with a wide range of productmix and developing a chain of such retail stores.
4. Developing a petrol pump as an agro-service centre, a base of operations and a mini shopping centre. Operations can iuclude custom service, service round the clock, and door delivery besides sales of fuels, lubricants, and replacement parts.

The farm equipment industry will make further progress in the decade of the seventies—the decade to be devoted to improving farm productivity. A lot of capital is being invested in the indusry and the young industry requires to be carefully developed. It is a "growth" oriented industry with potential for creating vast employment opportunities, improving productivity per worker and per hectare, removing the drudgery from hard farm work, and raising the standard of living of our people.

These then, are some of the new opportunities in changing agriculture. I have no doubt that marketing organizations in the country are aware of these challenges and are fast developing skills for a successful penetration and development of markets for farm equipment inputs.

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Presented at the 7th Alumni Conference of the Indian Institute of Management, Ahmedabad, held at New Delhi, on March 17 & 18, 1972.

The Development of Farm Mechanization in Japan

by
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Farm Mechanization in Japan

Japanese agriculture has developed from mechanization centering on rice cropping. Especially in these years has there been a sudden increase in demand for rice planters, 4-wheel tractors, combines, binders, etc. In the application of rice dryers, circulation type has taken the place of a conventional one.

The total production of farm machinery in 1970 exceeded ¥180,000,000,000 in terms of Japanese currency. However, the production in 1971/2 dropped owing to the decrease in the sales of farm machinery; this was due to the restriction to rice cropping acreage imposed on by the Japanese Government. In 1973 there occurred "oil crisis", which has caused a remarkable rise in commodity prices. The "purchase boom" that followed the oil squeeze has been activated drastically. Favoured by this boost, it is estimated that the total production of farm machinery will reach more than ¥350,000,000,000 in 1974.

In 1970 agricultural population in Japan exceeded 10,000,000. It is certain, however, that in 1974 the number of farmers will to a level of about 8,000,000.This exodus from the farming population will be absorbed by industires other than agriculture. This has resulted in the increase in the number of parttime farmers. Consequently, farmers are able to enjoy more income from sources other than their original jobs.

It is estimated that 65 per cent of total income in farmhouseholds comes from a non-farming source. It is siad that overinvestment has been made in agriculture in this country. However, this is not true, for it is a well-known fact that an effective investment rate in farm machinery by farmers has indicated an upward tendency. This has been proved by statistic figures that the total of per-farm-household income combined with non-farm one is about 3 1/2 times the amount twenty years ago.

Let us take an example of a completely mechanized rice cropping area. A few year ago, national cropping yield averaged 3.75 kilo grams per hour in terms of husked rice. In 1974, it is expected that this will rise as much as 5.5 kilo grams or more. Some farmers who have completed a mechanized system are enjoying the productivity of more than 10 kilo grams of husked rice per hour. It can be safely said that almost all Japanese farmers have nearly completed rice cropping mechanization in this field. It is a natural course for manufacturers and laboratories to try to make effort to develop new machines such as harvesters for vegetables and fruits.

Production of Farm Machinery and Implements in Japan

The following are statistic

Table 1. Production on farm machinery and implements & population Engaged in Agr.

Unit: ¥million, 1,000 persons, kg per working hour

Year	1970	1971	1972	1973	1974
Total amount	181,362	154,932	163,655	247,883	350,000
Farming population	10,252	9,596	9,002	8,487	8,000
Productive capacity of pady and husked rice			4.65	5.20	5.60

Remarks: Productives capacity of husked rice shows a national averaged figure. Completely mechanized system may produce 10 kgs per working hour.

Table 2. Yearly production of selected farm machinery and implements (Unit: 1,000)

Year	1970	1971	1972	1973	1974
Tractors	43	34	51	99	142
Less than 20ps	25	17	28	63	96
20~30ps	16	14	20	35	42
30ps or more	1.5	2	2	2	3.7
Power tillers	370	297	297	352	358
Rice planters	81	130	132	186	288
Power sprayers	118	154	198	228	235
Power dusters	183	126	135	222	226
Binders	322	245	165	223	237
Combines	45	38	50	68	100
Dryers	135	110	79	103	115

Remarks: 1. Figures up to 1973 according to statistic by the MITI of the Japanese Government
2. Figures of 1974 according to estimation by Farm Machinery Industrial Research Corp.

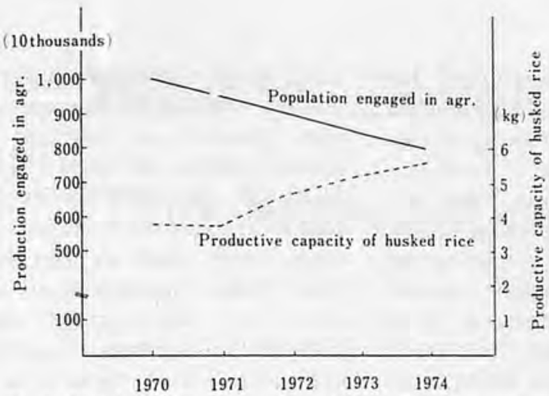

Fig.1. Population engaged in agr. & productive capacity of husked rice

Fig.2. Production on farm machinery and implements
Remarks: 1. Figures of 1974 according to estimation by Farm Machinery Industrial Research Corp. 2. Figures do not include machinery for live-stocking, mountain and forestation and civil engineering.

figures on the production of farm machinery and implements, of which we point out several remarkable examples:

Ten years ago, the annual production of walking tractors exceeded 500,000 units. However, it has now fallen to a level of 350,000 units. It is presumed that the production will go down to 200,000 units within 10 years to come. In its place, the numbers of 4-wheel tractors has suddenly increased. Which the production of these tractors was 43,000 units in 1970, it is auticipated that they will number about 140,000 units including 96,000 units with a horse power of 20 or less. Tractors with 20 or less horse power are most popular among Japanese farmers. Power sprayers have been manufactured twice as many as those in 1970. Power dusters have shown about 25 per cent increase; no more increase may be possible, however.

The numbers of 330,000 units of binderes was made in 1970. a peak of production; however, it dropped to 230,000 units in 1974, because they have been outvied by combines. About 80,000 units of rice planters were manufactured in 1970, and it is expected that their production will reach about 280,000 units in 1974. It is felt that this year's figure may be maxinum and that the future annual demand less than 200,000 units. The capacity of dryers has been improved and it is more than twice that in 1970, they are speed dryers with a circulation system, capable of drying in 8-10 hours. While their monetary value increased, their production is estimated at 115,000 units in 1974 compared with 136,000 units in 1970.

Combine have been introduced not only from a walking type to a riding one, but also from a 1-row system to a double-row one. It is not before long that a 4-row system may become a main current. At present, double-row rice planters are most popular; however, 4-row types are gradually increasing in number.

Table 3. Selected farm machinery and implements in use (Unit: 1,000)

Year	1970	1971	1972	1973	1974
Tractors	267	270	291	383	517
Less than 20ps	220	213	219	275	365
20~30ps	28	34	44	75	110
30ps or more	19	23	27	33	42
Power tillers	3,201	3,259	3,312	3,300	3,300
Rice planters	46	127	248	430	700
Power sprayers	1,149	1,175	1,214	1,285	1,340
Power dusters	1,251	1,255	1,306	1,340	1,350
Binders	465	719	920	1,120	1,350
Combines	84	117	159	220	310
Dryers	1,616	1,676	1,719	1,760	1,810

Remarks: Population up to 1972 according to the MAF to the Japanese Government. Population in 1973 and 1974 according to Farm Machinery Industrial Research Corp. judging from the production units in the respective years.

Rice planters for larger seedlings are more and more demanded. Nowadays, demands for rice planters have spread throughout Japan and they have become indispensable machines to many farmers.

Current prices for rice planters have shown more than 40 per cent increase than one in 1973. Accordingly, it is necessary for us to take into consideration this price incease, when we figure out the number of production and sales value of these machines.

Total Population of Farm Machinery and Implements in Rural Areas

Total population of farm machinery and implements, as per an attached sheet, indicates the following facts, trends and tendencies:

The population of 4-wheel tractors was 267,000 units in 1970; it is expected that the number will be likely to reach more than 510,000 units.

It is beyond doubt that the population of 4-wheel tractors may exceed 1,000,000 units have 20 or less horse power. The numbers of power tillers has remained almost the same for the past five years. It is presuemd, however, that the tiller population in rural areas will drop substantially in 1974 and beyond. Rice planters, emerged as newcomers, numbered 46,000 units in 1970 and they will reach 700,000 population in 1974.

In 1970 there were 84,000 units of combines and their population will increase to 310,000 units by now. Binder population has reached 1,350,000 units by now. It is certain that the number of binders may dwindle and instead, the population of combines may become larger in the future. As we pointed out already, Japanese farmers are more and more attaching importance to labour-saving machines and have a stronger inclination for working in industries other than agriculture. As result, an overinvestment in machinery and implements has been made by them, simply judging from a criterion on agricultural economics. However, their investment in farm machinery does not constitute so large a portion of their total outlay, as it was feared, since their total household expenditure are mostly subsidized by an income source other than agriculture. It is entirely due to the fact that economic conditions surrouding Japanese farmers fundamentally differ from ones in their foreign counter parts. The foregoing statistic statement centers on rice cropping in this country. However, farm mechanization here is confronted with a new challenge, a situation which requires the development of new types of farm machinery and implements.

Future Trend of Farm Mechanization in Japan

Rice cropping machines for a small scale farming have been developed almost to a satisfactory level in Japan. Waht is highly needed in the very near future will be the mechanization for vegetable growing. Engineers and scientists have started their research and development on mechanization system for various species of vegetables. They must be undoubtedly requested to make more assiduous efforts for this mechanization; mechanization for vegetable growing in this country is placed in a more disadvantageous position than one for rice cropping, because there are a lot of vegetable species and yet cropping acreage income from vegetable growing is more than fourtimes that from rice cropping, a situation which may permit the farmer larger investment than the latter.

Since Japan has a very small land on which the most intersive industries have been run, she is suffering a wide range of land devastatiton and the environmental pollution. Among them, especially devastated are the slopes of mountains and forests. Insufficient mechanization for afforestation is preventing reforestation, which has caused a terrible result that as many as 30,000,000 seedlings had a sad fate of having been burnt down owing to the lack of reforestation facilities.

In order to supply as much food as possible, it is essential to utilize slopes in full. For this purpose, it is urgently required that machinery for use in slopes for reforestation and fruit-trees should be developed as soon as possible. The exploitation of pastures and grass lands are also needed. Japan now depends too much on imported raw materials. This does not always make a sense, in view of more and more tightening export policy employed by foreign countries which are supplying Japan with their natural resources.

Under such circumstances, the most important things are to use minimum resources, to recycle maximum ones and to prevent public accompanied with the development of industries. Japanese agriculture has many things to do with them, too.

For instance, Japanese farmers heavily relyed on chemical fertilizers, which have weakened soil preservation power. On the other hand, large cities have a serious problem of how to despose of a huge quantity of garbage and wastes coming out from kitchens daily. (In pre-chemical-fertilizer days in Japan, all rubbish and trash were used as fertilizers. The Tokyo metropolitan area alone is discharging about 15,000,000 kilo grams of garbage and wastes.) If we succeed in the fertilization of these wastes, we shall be able to have and use large quantity of resources.

A splendid and wonderful idea is now emerging. That is to make compost from these wastes in order to strengthen soil preservation power and to prevent public pollution. It is not merely a machine with which to make compost, but a machine on a plant to make compost from wastes. This concept is advocated by a number of engineers. Rural areas must establish a self-supply system of fertilizers in cooperation with local cities. For this, the development of this kind of machinery is urgently required. In parallel with the world tendency, Japan has almost completed the introduction of farm machinery and implements. More and more improvements on farm machinery will continously made towards the future. In this case, improvement centering on automated machines will play an important role. Along with this automation, the following steps will also be vital for use in farm machinery:

1. To prevent hazards and dangers
2. To ensure safety
3. To simplify the use of machinry and implments

Simultaneously, the introduction of an unmanned machine is also an important challenge to engineers and scientist. They have begun tackling this task, although it is highly difficult for them to automate a small machine.

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How to Develop The Harvesting Mechanization

by
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Harvesting Mechanization in Japan

As harvesting machines, small binder and small combine are popular and have been widely distributed in Japan, the former cuts and makes a small bundle of crops while the latter not only harvests but also threshes simultaneously.

The large binder imported from foreign countries, does not give high efficiency to the lodged plants or at paddy fields where soil pan is not hard enough to support this machine. Due to the unfavorable paddy field, it is not suitable for utilization in Japan. About 1100 units of large combine were imported into Japan from 1962 to 1973. These imported ones are called Direct-flow type combines for the convenience of distinguishing them from the small ones made in Japan. Its cutter bar width ranges from 2 to 5 meters. Anyway it's a huge machine for small Japanese paddy fields. The farmer is not willing to use the large combine because it causes grain losses and damage to crops as shown in **Table 1.** In addition a small plot offers another obstacle for further utilization of the combine which is not suitable in such a place. The farmers themselves do not like their field to be destroyed by a giant machine. Due to the above mentioned reasons, Direct-flow type combine are shunned by the farmers.

Due to this fact, what the farmer wanted most or the aim of mechanization lies not in the higher capacity of the machines but in accuracy of work. The majority of the harvesting machines they need are therefore, of the small type, mini-combine or small binder with the length of the cutter bar ranging from 0.3m to 1.5m.

Harvesting and post-harvesting work of paddy rice traditionally consists of harvesting rice plants with sickle, making smaller rice bundles and drying them in the sun. This is followed by threshing and drying the threshed grains in the grain driers. The dried grains are feed to the huller and the hulled rice or brown rice is sold to Government. **Table 2.** shows the percentages of acreage by each drying method to the total acreage of rice field.

Table 2. The method of rice drying
(Food Agency of Ministry of Agr. and Forestry. 1970)

Drying before threshing			Drying after threshing	
Natural Drying	Drying on rack	48%	Natural Drying (on mat)	11%
	Windrowing	17	Without drying	29
	Drying on pole	12	Artificial drying	45
	Drying in standing bundle	5		
	Other methods of natural drying	3		
Without drying (Threshing immediately after harvesting)		15	Artificial drying	15

(1973, Iam)

Table 1. Quality and quantity of direct flow type combine

Cutterbar width (m)	Rice: Capacity (ha/hr)	Rice: Grain output (t/hr)	Rice: Grain loss (%)	Rice: Domage (%)	Wheat: Capacity (ha/hr)	Wheat: Grain output (t/hr)	Wheat: Grain loss (%)	Wheat: Damage (%)
2.6-3.0	0.1-0.25	0.7-1.7	≒6	≒3	0.3-0.6	0.9-1.5	1.0-3.0	0.5-1.0
3.5-4.5	0.2-0.3	1.4-2.1	≒6	≒3	0.5-0.9	1.5-2.7	1.0-3.0	0.5-1.0

What a Japanese farmer needs most is to see that the conventional process is maintained. It is the binder for smaller bundle size and the circumference is from 20 to 30 cm. It is estimated that more than one million sets of binders will be used on farm in 1973. So rapid was the increase of sales witnessed in the span of short years that only 1,000 sets were sold in 1966, 10,000 in 1967, 80,000 in 1968, 240,000 in 1969, 320,000 in 1970, 250,000 in 1971 and 160,000 in 1972. As for the distribution of small combine in Japan, 1,000 sets were distributed in 1967, 10,000 in 1968, 40,000 in 1969, 45,000 in 1970, 40,000 in 1971 and 50,000 in 1972. And it is estimated that more than 250,000 sets of small combine were used of farm in 1973.

A small binder is made up of a pick-up device with fingered chain for the lodged plants, 50 mm pitched cutter bar ranged from 30cm to 75cm in width, conveying apparatus of stems, binding mechanism and travelling parts. Concerning travelling parts, a pair of pneumatic tyre is fixed at the rear portion of the cutting device. The binder is a walking type machine travelling within a range of 0.3-0.8m/s. Travelling speed on the road becomes a little faster 1.3-1.8m/s. The knife bar has 50mm knife sections and the majority of its stroke is 50mm. Dividers are set in front of the cutter bar every 20 or 30cm of the cutter width. As for the frontal processing apparatus which has dual function, picking up the lodged plants and supporting the upper portion of plants when they are cut, it is fixed behind the divider with a certain angle. This apparatus is a pick-up device with the chain, fingered by nylon tines. Plants, being lifted by the pick-up device, are cut by cutter bar and forwarded to the conveyor and conveyed to the side or rearportion of the binder. When plants, transported and gathered in a pocket, reach a given volume enough to make a small bundle, press the clutch door with the aid of a packer arm, then the binding mechanism is put in motion which requires 0.2-0.3 seconds, and the discharge arm throws out the bundle to one side of the binder, some 1,500 to 1,800 bundles are made up per 0.1ha.

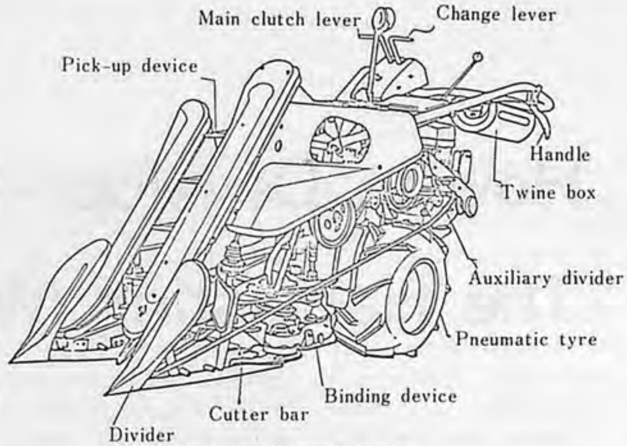

Fig.1. Small bundle binder

Concerning this type of binder, those equipped with 30-50cm cutter bar are distributed most popularly. The small bundle binder also gives good performance even in harvesting lodged rice or wheat whose standing angle is 20-30 degrees. The grain loss is minimized below 2 per cent. However accurate work becomes aggravated when the standing angle drops as low as 20 degrees or below, and in proportion to the worse condition of lodgeing, grain losses increase. The size of the bundle is also adjustable to a certain extent within the range of 1.2-1.6 kg. The efficiency of work of binder is 6-13 a/hr.

The combine which is now in the developing stage in Japan is equipped with an axial-type threshing drum which is different functionally from foreign-make one. In case of the latter all of the harvested crops are fed to the rotating drum. On the other hand, in a Japanese combine, not all of the plant but the panicle is fed to the threshing chamber in the rotating direction of the threshing drum while the whole plant is conveyed in parallel with the direction of the axis of the rotating threshing drum. The Japanese small combine is constructed with engine, travelling device, cutting apparatus, pick-up apparatus, threshing and sieving section and straw disposing section.

Almost all of these combine are adopted a crawler to their travelling device aiming at higher workability and adaptability in paddy field than crossing over the levee or field work on the upland condition. Ground contact pressure of the travelling device is from 0.1-0.3 kg/cm^2. Body weight of the combine is from 500-2,000 kg at its net weight and it is too light to destroy the soil structure of paddy plot and also harmless for land tillage work which is usually put into practice after harvesting rice. Plants sometimes lodge due to various kinds of natural or conditions of cultivation. So these plants have to be arranged in a clean and neat condition before cutting. This sorting work is perform by the divider and pick-up apparatus. The cut and neatly arranged plants are to be threshed by the thresher mounted on the combine. The threshing device of the combine consists of the threshing drum, wire teeth planted spirally on it and a concave sieve with 8-15 mm mesh. In addition to the above structure, as for some kinds of model, a small rethreshing drum is installed.

Suction blower or oscillating sieve is the functional element in the cleaning section of the combine. Harvested plants are held at the basal portion by the feeding chain running in front of the threshing section at the velocity of 0.2-0.4m/s and while travelling

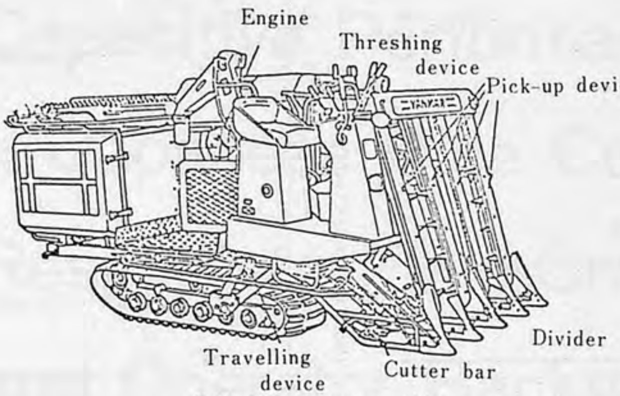

Fig.2. Japanese type combine

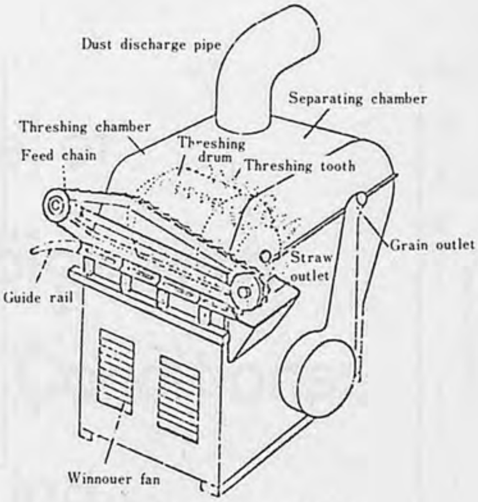

Fig.3. Japanese type thresher

Table 3. Quality and quantity of Japanese type combine for harvesting rice (1972. Iam)

Cutterbar width (m)	Capacity (ha/hr)	Grain output (ton/hr)	Grain losses (%)	Damage (%)	Kind of fuel	Fuel consumption (l/hr)
0.6-0.7	0.07-0.12	0.4-1.0	0.6-2.0	0.0-0.5	kerosene	3-5
0.8-1.0	0.13-0.16	0.9-1.3	0.4-2.3	0.0-0.5	kerosene	5-7
1.2-1.4	0.20-0.26	1.4-1.8	0.6-2.7	0.0-0.5	diesel oil	3.5-4.1

inside of the threshing chamber in 1 or 2 seconds, they are to be threshed completely. The cutter bar is attached in front of those combines on market. Two or three years ago, this cutterbar was attached to one side of the combine, thus some stretch of paddy field had to be harvested by hand or any other means before combining. In the paddy plot of 0.1ha, 1.2a was the minimum space to be disposed of before start of combining. But front cutterbar type combine needs only 0.2a for turning space. In case the paddy plot is nearly 10a, harvesting capacity is 7-12 a/hr for 50cm cutterbar combine and 20-26 a/hr for 1.3m cutterbar combine.

The larger the area of paddy plot, the more increase the capacity of work of combine as shown in **Fig.5**.

Still Japanese combine do not have so much capacity as shown in **Table 3**. Japanese farmers have shown a keen interest in this machine. The reason is ascribable to the low ratio of grain losses under 3 %, and grain damage 0.1-0.9% irrespective of timing when harvesting is done under such various conditions that color of stems is still pale green indicating a high moisture content, or hard-to-thresh varieties occupy the majority of the rice planted area in Japan.

The Co-Operative Reseach Project of Mada Malaysia and Japan to Develop A Combine Harvester

In order to develop a suitable combine harvester for Muda Irrigation Scheme, Malaysia a reseach project was organized between MADA and Tropical Agricultural Reseach Center of Japan. This Project started in 1973 and will be continued for five years. In 1973 a test was conducted using several types of combine in August, rainy season. This repot is a summary of the data obtained in the paddy field test in Malysia.

At present there are eleven combines. These were manufac-

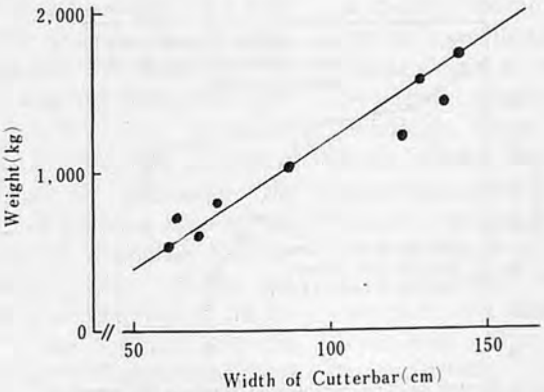

Fig.4. Weight of the Japanese combine

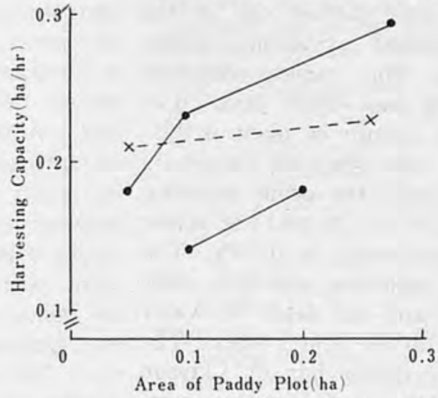

Fig.5. Relation between the area of paddy plot and harvesting capacity

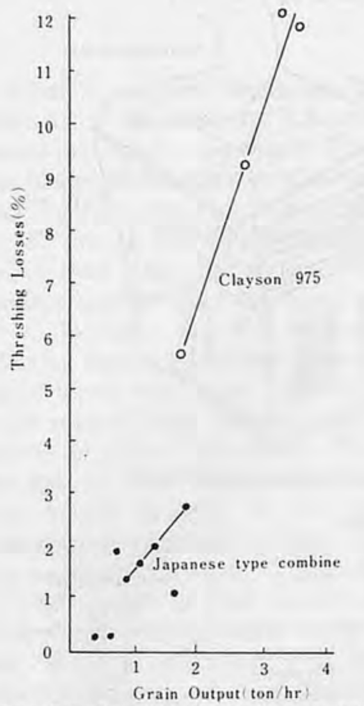

Fig.6. Relation between grain output and threshing losses (Kedah, Malaysia, 1973)

tured in Belgium and West Germany, working on Muda Scheme and were utilized by contractors as well as farmers' associations. The area of this place is approximately 110,000ha, and about 1.2% is covered by these large combines. During the short period a preliminary survey was conducted on the large combine (Clayson 975) as well as the smaller combines developed in Japan (Iseki HD50, Suzue 730, Kubota HT 90T, Yanmer TC1300LA). In order to observe the performance of these combines, we studied the quality of work, rate of work and trafficability of the machines. These studies was carried out in the Experimental Station Keda, Malysia. The variety of rice harvested was "Padi Jaya" (C4-63), the stature of plant is 105-110cm, the standing angle is 65-78 degree, the grain moisture content is 16-21% and the straw moisture content is 70-80%. The ground condition was faily soft, but flat and the depth of water covered on the field is 0-5cm. The width of cutter bar of Clayson 975 is 4.0m and Japanese combines range 0.5-1.3m.

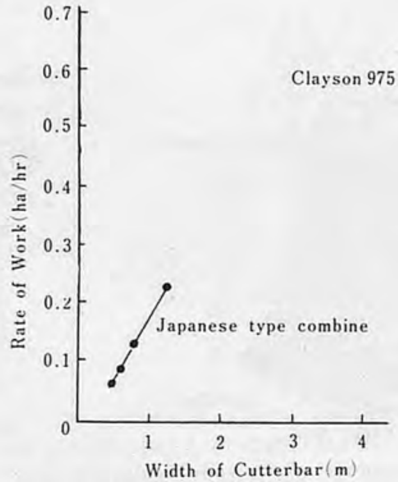

Fig.7. Relation between width of cutterbar and rate of work of harvesting rice (Kedah, Malaysia, 1973)

For the study in the observation of quality of work, we changed travelling speed from the lowest to the highest speed untill any trouble occurred with the testing combine.

For instance, the travelling speed of Yanmer TC1300LA of Japanese and that of Clayson 975 were from 0.2 to 0.6 m/s, and the output of grain varied from 0.5 to 1.8 ton/hr for Yanmer and from 1.6 to 3.7 ton/hr for Clayson. **Fig.6.** shows the relation between grain out put and threshing loss. It is noted that the more the grain output the more the grain losses. The rate of work was measured for about an hour on each combine working continuously within one hectre field in a squre run. **Fig. 7.** indicates the result obtained. The main problem on using combine harvester in muddy paddy field is

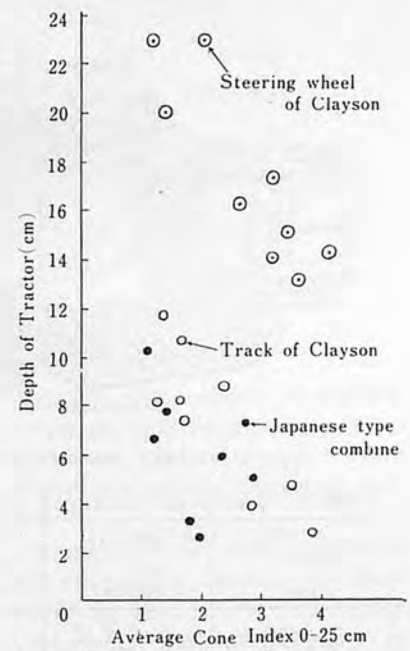

Fig.8. Relation between depth of trace and ground bearing (cone penetration index)-(Kedah, Malaysia, 8. 1973)

the trafficability. The unloaded weight of Clayson is approximately 7tons. This combine is only applicable to the areas with a high ground bearing pressure. The reseach result in **Fig.9.** shows the relation between the ground bearing and the capacity of combine. **Fig.8** shows the relation between the depth of trace and. the ground bearing. The depth of trace of the track of large heavy combine is similar to that of the small and light combine, but the steering wheel of Clyson sinks twice to the depth of the trace of track, and this would be a problem where the hard pan of the soil breaks. ■ ■

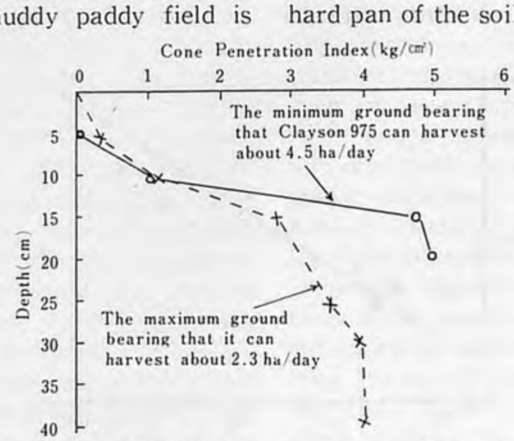

Fig.9. Ground bearing comparison between the areas of different capacity of combining (Kedah, Malaysia, 1973)···Mr. S. Yasima

Capacitive Performance of a Japanese Rice Combine with Respect to Field-Crop Conditions and Operator Background

by
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Introduction

Traditional studies of the field capacity of agricultural machinery have concerned themselves primarily with the effects of easily quantified variables such as field size or crop yield, and, in general, to a rather limited subset of those variables. Occasional mention is made about the importance of evaluating the total man-machine combination with respect to its effect upon the performance of a given piece of farm equipment but other than subjective observations and subjective evaluations of the operator's effect upon field capacity, little work has been done to more adequately describe the relationship between the operator, the machine, and the field crop condition.

This paper describes a preliminary effort to determine the feasibility of utilizing some of the techniques of Response Surface Methodology to derive a quantitative description of the influence of the operator and the influence of field-crop conditions upon the field capacity of a particular farm machine. Research objectives were defined to be (1) to examine the nature and distribution of field capacity variations, and (2) to examine the relative contributions of field conditions, crop conditions, and operator background to the variations in machine field capacity.

Most of the variation in the performance of agricultural machines can be described as variation due to (1) MACHINE parameters, (2) the OPERATOR, and (3) FIELD and CROP CONDITIONS. Venn diagrams as shown in FIGURES 1 and 2 can be used to illustrate the complex, interactive nature of such a set of factors and to illustrate their relative contributions towards an "explanation" of the variations in performance encountered in real situations. These variations can be attributed as being due to each respective factor (main effects), to the intersection between factors (two-way, or even greater, interactions), or to even more complex and higher order interactions. The residual or "unexplained variation" is generally attributed to experimental or measurement error.

The study was restricted to a single make and model of machine in order to minimize variations in field capacity due to variations in machines. Thus all physical machine parameters (cutting width, horsepower, etc.) were essentially constant and any variations due to such factors were attributed to random error.

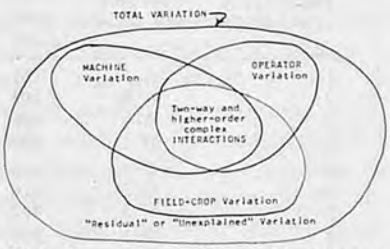


Fig.1. Venn diagram illustrating the interactions between the MACHINE, the OPERATOR, and FIELD-CROP conditions.

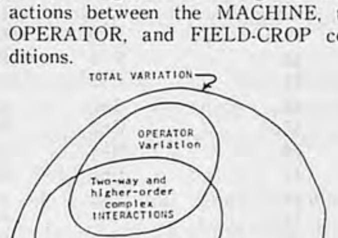


Fig.2. Simplification is achieved by restricting the study to a single make and model of MACHINE. Variation due to differences in MACHINES is minimized.

Variables, Symbols and Units

FIELD CAPACITY--Field area divided by the sum of the productive time, turning time, and non-productive time. Break times were excluded. In Japanese rice fields, some hand-cutting of rice at field curners is necessary to allow the combine to enter the field. This hand-cut rice must be run through the combine to be threshed. These times were not utilized in the calculation of field capacity as they did not offer consistent basis of comparison.

ARES--One are=100 square-meters. 100ares equals one hectare.

AGE--Age of operator in years.

R/T--The ratio of each operator's income from the sale of rice to his total income. Used as an indicator of the intensity of commitment to rice farming. Alternatively, it indicates the degree of part-time or full-time farming.

FMI--Renoll's (4) FIELD MACHINE INDEX. Used as indicator of the suitability of a specific field for machine use. Differs from field efficiency in that non-productive time is not used in its calculation and is thus more indicative of the influence of field size, shape, and dimensions upon the performance of machinery in that specific field. Renoll showed that the FMI was little influenced by the specific machine operation and that it remained relatively constant for different machine operations on the same field. It was quite applicable to this situation because Japanese rice is planted in rows and the Japanese type rice combine is operated as a row-crop machine.

STAND--Proportion of the rice field which is not badly lodged.

NYIELD--Net yield of the rice crop, paddy.

Table 1. Operator background

Operator	Age (years)	Farm experience (years)	Education (years)	Annual income* (millions of yen) rice	farm	total	Ratio of rice income to total income	Acreage (hectares) rice	total
A	29	10	12	2.4	2.4	2.4	1.0	2.98	3.98
B	36	18	12	3.0	3.0	3.0	1.0	3.97	3.97
C	30	12	12	2.0	2.0	2.0	1.0	1.98	1.98
D	47	24	12	1.1	1.1	1.1	1.0	1.98	2.48
E	38	20	8	2.0	2.0	2.0	1.0	1.98	1.98
F	43	23	12	0.5	1.0	1.0	0.5	1.29	1.29
G	20	2	12	0	0	1.0	0	0	0
H	46	12	12	0	0	2.0	0	0.54	0.54
I	34	16	12	0.52	0.52	1.34	0.39	0.79	0.99
J	32	14	12	0. 7	2. 1	2.1	0.33	0.99	1.39
Average	35.3	15.1	11.6	1.22	1.33	1.75	0.63	1 61	1.81
Range	20-47	2-24	8-12	0-3.0	0-3.0	1.0-3.0	0-1.0	0-3.97	0-3.98

*One million yen equaled approximately US $3,300(Fall, 1972).

Table 2. Field and crop date

Observation number	Operator and field	Field area (sq.m.)	Net yield (kg/hect) paddy	Stand (proportion)	Field machine index
1	A-1	381	5400	1.0	0.789
2	A-2	608	5740	1.0	0.647
3	B-1	507	7792	1.0	0.744
4	B-2	492	7790*	1.0	0.740
5	C-1	496	7795	1.0	0.604
6	C-2	476	7847	1.0	0.633
7	C-3	492	8982	1.0	0.706
8	D-1	670	6057	0.95	0.808
9	D-2	513	7174	0.7	0.805
10	E-1	1166	7590	0.2	0.854
11	E-2	440	9250	0	0.736
12	F-1	974	6448	0.8	0.897
13	F-2	1056	7121	0.9	0.911
14	G-1	514	5498	1.0	0.677
15	G-2	963	5757	0.8	0.735
16	H-1	368	4538	0.05	0.680
17	H-2	445	4756	0.5	0.648
18	I-1	552	4917	1.0	0.544
19	I-2	863	6512	1.0	0.706
20	I-3	967	4841	1.0	0.716
21	I-4	440	4852	1.0	0.705
22	J-1	1885	6669	0.99	0.703
Average		694	6515	0.81	0.727
Range		381-1885	4538-9250	0-1.0	0.544-0.911

* Substitution for missing data. This estimate was made by simply substituting similar values from the same farmer's other fields.

General Background Data

Table 1. gives the background data on each of the operators studied. All of them had gone through the standard compulsory period of education (8-12 years). The average amount of farm experience was 15.1 years and their average age of 35.3 years was considerably younger than the median age of 47 years for all male farmers in Japan (2).

Most of the farmer-operators' farms were larger than the national average of 1.1 hectares (1). And reflecting a national trend, many obtained substantial portions of their income from part-time work off the farm.

Table 2. summarizes the field and crop data. The average net yields of paddy rice were higher than the 1970 national average of 5640kg/hectare (1). Field sizes varied considerably from 0.038 hectares to 0.188 hectares--an indication of the difficulty of operating larger farm machines efficiently in these fields. But this is a common problem. According to Tsutomu Mukumoto, "...the

Table 3.
Performance data

Observation number	Field capacity (ares/hr)	Field efficiency (percent)
1	8.91	76.9
2	7.71	64.3
3	5.53	73.0
4	5.37	67.1
5	6.99	54.5
6	5.98	63.3
7	5.89	65.0
8	6.00	76.9
9	4.34	73.5
10	4.78	81.9
11	2.86	59.1
12	7.26	88.5
13	5.61	84.6
14	4.97	65.6
15	4.81	72.4
16	2.40	64.0
17	1.46	35.1
18	4.15	48.1
19	6.31	70.0
20	7.95	71.6
21	6.00	62.8
22	5.63	67.2
Average	5.496	67.52
Range	1.46−8.91	35.1−88.5

area of paddyfield over 0.1 ha,whose partitions have been realigned is only 20% of the total rice area..." (2). Under such conditions, one would expect the low FIELD MACHINE INDEXES shown in **Table 2.** Poor stands are also a problem due to lodging of the rice.

Capacitive Performance Results

Table 3. Shows the response variables, field capacity and for comparison, field efficiency, for all operators and fields observed. Field capacities ranged from 1.46 ares per hour to 8.91 a/hr and the vargation coefficient (σ/mean × 100) was 32.2 percent.

Figure 3 is a cumulative probability plot of field capacity for the conditions of "badly lodged" rice and for the condition of "no lodging". A comparison curve for "all observations" is included. Tabulation of the data shows;

	mean a/hr	variance a/hr	variation coefficient percent
No lodging	6.3	1.35	21.5
Badly lodged	4.19	1.87	44.8
All observations	5.5	1.78	32.4

The obvious effect of a good

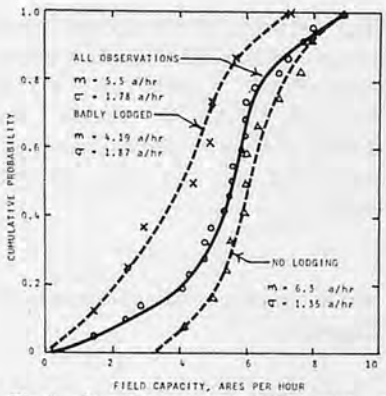
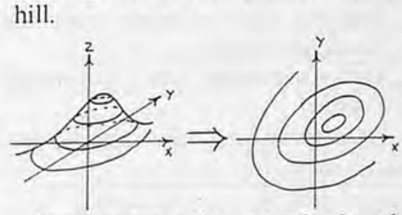


Fig.3. Cumulative probability plot of FIELD CAPACITY for (1) all observations, (2) hadly lodged, and (3) no lodging condition.

stand (i.e. no lodging) is to increase the field capacity but a more significant characteristic seems to be the decrease in variance with improvement in field condition.

The Response Surface

In the following analysis, the underlying conceptualization will be that of a "response surface" which represents the locus of points whose position, in any arbitrary n-dimensional space, is uniquely determined by the values of the respective n-coordinate axes. A typical physical analogy is a topographical land feature such as a hill. Given an adequate contour map, one can determine from the X and Y map coordinates, the elevation of any given point on the surface of the hill.



In our case, the magnitude of the rice combine field capacity represents our elevation and our "n" independent variables represent the coordinates of our location in the n-dimensional space. But the difficulty that we face (very much analogous to the problem of representing a three dimensional hill surface upon a two dimensional piece of paper) is how does one represent and visualize an n-dimensional space in a three dimensional world in such a manner that it is comprehensible to the three dimensionally oriented mind?

It is possible to derive a multi--variable regression equation whose coefficients represent the least-squares solution to the socalled "normal equations" but with more than two or three terms in the equation, visualization becomes difficult. The usual solution to this dilemma is to limit the number variables considered. The approach followed here was to consider a relatively large set of variables of possible significance and to then run a regression analysis on those variables. The criteria for choosing which variables to retain in our final regression model was to select those variables which appeared to be highly influential with regard to the response variable rather than seeking a regression equation with high predictability. Although the preceding statement may seem rather contradictory on its face, what it implies is that (in statistical terms) we seek variables which have high F-values rather than seeking to obtain a small residual mean square. A highly predictive regression equation with many non-significant parameters will not help us to understand the nature of the interactions between those variables which have the largest influence upon the response variable.

After selection of a regression equation, the response surface that it represents was explored in three ways.

(1) A canonical analysis was conducted to determine the general shape of the surface, whether either a maximum or a minimum existed, and if so, where?

(2) Gradient equations were derived from the regression

equation. These were analyzed to determine the magnitude and dirrection of maximum field capacity increase with respect to each of the independent variables.

(3) The overall effect of proportionate canges in the independent variables upon the change in field capacity were examined.

Derivation of the Regression Model

In order to reduce the original set of twenty measured variables to a manageable number, a regression was first run using only main effects. The most significant main effects were retained and the corresponding second-order effects and interaction terms were a added to the analysis. The ten percent level of significance was taken as the criterion for acceptance of any given variable into the regression model. It was felt that such a level was low enough to recognize most variables of influence, and yet high enough to reject most spurious variables.

This procedure yielded the following regression equation:

(1) FIELD CAPACITY (ares/hour) = 1.93303 + 13.78588(R/T) − 5.5772(R/T)^2 − 0.15809(AGE)(STAND) − 0.73888(NYIELD)(R/T) + 9.61555(FMI)(STAND)

The predominance of interaction terms is indicative of the complex nature of the relationship between the response variable, FIELD CAPACITY, and the independent variables. The ANOVA TABLE (**Table 4.**) shows that all parameters are significant at the one percent level.

Interpretation of Regression Equation

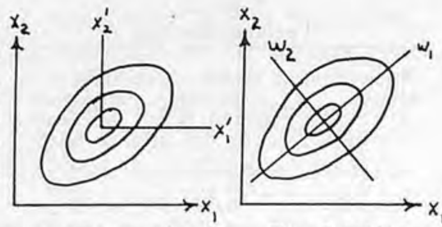
Canonical analysis can be used as an aid to visualization of the five variable response surface which eq. (1) represents. The first step is to determine the coordinates of the stationary point--the point at which all the partial derivatives of the response equation go to zero, which many be a point of maximum or minimum response, or a saddle point. The response fuction is then subjected to a translation of coordinates from the origin of its original coordinate system to the stationary point where it is then expressed in terms of new variables, w_1, w_2,...w_k. This "canonical form" is written:

(2) $\hat{y} = \hat{y}_0 + \lambda_1 w_1^2 + \lambda_2 w_2^2 + \cdots + \lambda_k w_k^2$

Where y_0 is the predicted response at the stationary point and the λ_i are the eigenvalues. (See reference (3) for details.) In geometric terms, the response function undergoes a linear translation of its origin to the stationary point and is then rotated so that its axes coincide with the "principal axes".

Transformation to Canonical Form :

Carrying out the above procedure, we find that a stationary point exists at:



Linear Translation... Then Rotation to Principal Axes

1. AGE = 60.823(FMI)
2. FMI = 0.01644(AGE)
3. STAND = 0
4. R/T = 0
5. NYIELD = 18.66

The corresponding eigenvaluse are:

$\lambda_i = -5.594, -4.82, 0, 0.024, 4.808$
$i = 1.5$

The presence of both positive and negative values indicate a saddle point for this response function and rule out the existence of a maximum peak or minimum depression. However, local maxima or minima can still be located within the experimental region.

The presence of an eigenvalue which is equal to zero indicates that in the canonical form, our response fuction of five variables can be represented by only four variables. Reference to the stationary point coordinates shows a stationary ridge condition exists for all values of AGE/FMI = 60.823--an indication that the two variables corld be collapsed into a single, new variable. Since no reasonable physical interpretation could be attached to this "new" variable, the previously derived five variable model was retained.

Gradient Equations

Partial differentiation of eq. (1) yields the following gradient equations:

(3) ∂(FC)/∂(AGE) = −0.15809(STAND)

(4) ∂(FC)/∂(R/T) = 13.78588 − 2(5.5772)(R/T) − 0.73888(NYIELD)

Table 4. Anova table

Source	dof	SS	MS	F Ratio
Regression	5	58.260	11.652	22.037*
Residual	16	5.460	0.529	
Total	21	66.720		

Variable	Coefficient	Standard Error	F to Remove
CONSTANT	1.93303		
R/T	13.78588	2.58329	28.4787*
(R/T)	−5.57720	1.81357	9.4572*
AGE-STAND	−0.15809	0.03388	21.7732*
NYIELD-R/T	−0.73888	0.19854	13.8503*
FMI-STAND	9.61555	1.50216	40.9748*

R=0.9345　R=0.8732
Standard Error of Estimate=0.7271

*Significant at 1% level

Table 5. Rate of change of field capacity with respect to independent variables

Gradient equations	Regin of greatest rate of change	approximate rate of change (ares/hour)	Region of least rate of change	Approximate rate of change (ares/hour)
$\Delta FC=-0.15809(STAND)\cdot\Delta AGE$ $[\Delta AGE=27]$	$STAND=1$ No lodging	−4.3	$STAND=0$ Badly lodged	0
$\Delta FC=13.78555$ $-2(5.5772)(R/T).\Delta R/T$ $-0.73888(NYIELD)\cdot\Delta R/T$ $[\Delta R/T=1.0]$	$R/T\to0$ $NYIELD\to4.54$ Low R/T and Low net net yield	10.4	$R/T\to1$ $NYIELD\to9.25$ High R/T and High net yield	−4.2
$\Delta FC=9.615(STAND)\cdot\Delta FMI$ $[\Delta FMI=0.367]$	$STAND=1$ No lodging	9.6	$STAND=0$ Badly lodged	0
$\Delta FC=-0.15809(AGE)\cdot\Delta STAND$ $+0.616(FMI)\cdot\Delta STAND$ $[\Delta STAND=1.0]$	$AGE\to20$ $FMI\to1.0$ Young operator and high FMI	6.5	$AGE\to47$ $FMI\to0.544$ Old operator and low FMI	−2.2
$\Delta FC=-0.73888(R/T)\cdot\Delta NYIELD$ $[\Delta NYIELD=4.71]$	$R/T=1.0$ High R/T	−3.5	$R/T=0$ Low R/T	0

(5) $\partial(FC)/\partial(FMI)$
$=9.61555(STAND)$

(6) $\partial(FC)/\partial(STAND)$
$=-0.15809(AGE)+9.61555(FMI)$

(7) $\partial(FC)/\partial(NYIELD)$
$=-0.73888(R/T)$

where FC is the FIELD CAPACITY.

These equations give the rate of change of FIELD CAPACITY with respect to changes in each of the independent variables. Substitution of specific values will give the slope estimates at any particular point on the response surface. Because of their scale dependent nature, each slope estimate was multiplied by the full experimental range of each independent variable to allow proportionate comparisons to be made. The del (Δ) symbol was substituted for the partial (∂) to represent the variable increments. For example, eq. (3) was transformed to read:

$$\frac{\Delta FC}{\Delta AGE}=-0.15809(STAND)$$

$$\Delta FC=-0.15809(STAND)\cdot\Delta AGE$$

Results are given in **Table 5.**

Table 5. gives the rate of change of FIELD CAPACITY with respect to changes in the five independent variables for (1) the condition of greatest rate of change and (2) the condition of least rate of change. The first row of TABLE 5 indicates the rate of change of FIELD CAPACITY to be expected with changes in the AGE of the machine operator. For a rice field with no lodging (STAND=1), our responses function predicts a moderate decrease in FIELD CAPACITY with increase in operator AGE. For operation in badly lodged fields (STAND=0), the expected rate of change is zero, i.e. the effect of a change in AGE is negligible compared to the detrimental influence of poor crop conditions. The remainder of **Table 5.** can be analyzed in a simllar manner and can be summarised as:

(a) Effect of change in AGE upon FIELD CAPACITY...
Increase in AGE of operator is detrimental in fields with no lodging (STAND=1).
In badly lodged fields (STAND=0), the effect of AGE is negligible compared to the influence of the crop condition.

(b) Effect of change of R/T upon FIELD CAPACITY...
An increase in R/T is most beneficial for part-time farmers (low R/T) working in fields with low yields. The effects of the added experience seem to be most helpful under these circumstances.
For full-time farmers (high R/T) working in fields with high yields, an increase in R/T is detrimental. Such operators seem to slow their pace under such conditions.

(c) Effect of change of FMI upon FIELD CAPACITY...
The effects of improved field layout (indicated by higher FMI) are most evident in fields with no lodging (STAND=1).
The effects of higher FMI become negligible in badly lodged fields (STAND=0). Crop condition becomes the significant factor.

(d) Effect of change of STAND upon FIELD CAPACITY...
Improvement in crop STAND has most noticeable effect for young operators in fields with high FMI.
Improvement in crop STAND becomes detrimental for older operators in poorly laid-out fields (low FMI).

(e) Effect of change of NYIELD upon FIELD CAPACITY...
Increased yield (NYIELD) results in lower FIELD CAPACITY for full-time farmers (high R/T) who seem to pace themselves to the work.
Increase in NYIELD has negligible effect for parttime farmers (low R/T) whose working time is limited by their job schedules and who do not appear to adjust their working rate to the crop conditions.

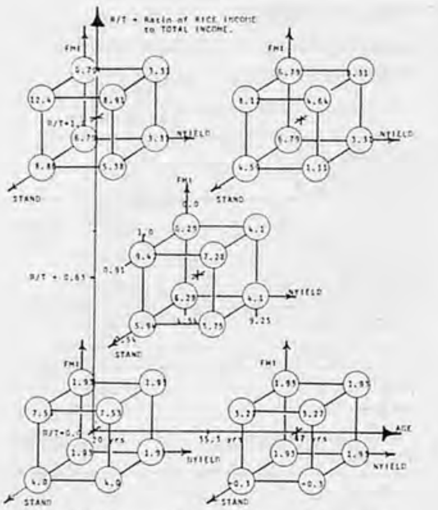


Fig.4. Field capacities estimated from response function in ares per hour.

Table 6. Independent and response variables

Operator	Field	Age	R/T	FMI	Stand	NYIELD ×10 KG/Are	Actual field capacity a/hr	Predicted field capacity a/hr	Residual a/hr
A	A-1	29	1.0	0.79	1.0	5.40	8.91	9.17	−0.26
	A-2			0.65	1.0	5.74	7.71	7.57	0.14
B	B-1	36	1.0	0.74	1.0	7.79	5.53	5.81	−0.28
	B-2			0.74	1.0	7.79	5.37	5.81	−0.44
C	C-1	30	1.0	0.60	1.0	7.80	6.99	5.41	1.57
	C-2			0.63	1.0	7.85	5.98	5.66	0.32
	C-3			0.71	1.0	8.98	5.89	5.59	0.30
D	D-1	47	1.0	0.81	0.95	6.06	6.00	6.01	−0.01
	D-2			0.81	0.7	7.17	4.34	5.09	−0.75
E	E-1	38	1.0	0.85	0.2	7.59	4.78	4.97	−0.19
	E-2			0.74	0	9.25	2.86	3.31	−0.45
F	F-1	43	0.5	0.90	0.8	6.45	7.26	6.54	0.72
	F-2			0.91	0.9	7.12	5.61	6.56	−0.95
G	G-1	20	0	0.68	1.0	5.50	4.97	5.31	−0.34
	G-2			0.74	0.8	5.76	4.81	5.10	−0.29
H	H-1	46	0	0.68	0.05	4.54	2.40	1.90	0.50
	H-2			0.65	0.5	4.76	1.46	1.42	0.04
I	I-1	34	0.39	0.54	1.0	4.92	4.15	4.86	−0.71
	I-2			0.71	1.0	6.51	6.31	6.04	0.27
	I-3			0.72	1.0	4.84	7.95	6.62	1.33
	I-4			0.71	1.0	4.85	6.00	6.52	−0.52
J	J-1	32	0.33	0.70	0.99	6.67	5.63	5.91	−0.28

Overall View of the Response Surface

The actual observations for the five independent variables and the response variable are tabulated in TABLE 6. The field capacity as predicted by the response function is also tabulated for comparison. The column titled "Residual" is the difference between the predicted field capacity and the actual field capacity and illustrates how well the model fits the data. The regression accounts for roughly 87 percent of the variation in field capacity (Recall TABLE 4). The standard error of the estimated FIELD CAPACITY is 0.7271 a/hr (A variation coefficient of 13.2 percent). Since two standard errors represent the approximate 95 percent confidence limits, we expect roughly 95 percent of field capacity observations to fall within ±1.45 a/hr of our estimates.

Figure 4. gives an overall view of the predicted field capacity as estimated from the response function, eq. (1). The two large axes are AGE and R/T whose coordinates represent the data in the experimental region. At each corner of the region defined by the high and low values of AGE and R/T and the point representing the average AGE and the average R/T, cubes are superimposed. Each cube represents the estimated field capacities for all combinations of the high and low values of the three variables, STAND, NYIELD, and FMI, at that particular combination of AGE and R/T.

Summary

The performance of a farm machine and its operator as measured by FIELD CAPACITY can be characterised by two parameters, its mean and its variance. Unfavorable field conditions result not only in lowered field capacity but also in increased variance. The large variances encountered, typical of agricultural operations, make accurate prediction of field capacity difficult.

Canonical analysis can be useful as an aid to visualization of the nature of a multi-variate response surface. The signs and magnitudes of the eigenvalues of the canonical form of the response function indicate the general shape of the response surface.

A complex response function with many interaction terms can be further analyzed by differentiating the function with respect to each of the independent variables. The resulting gradients show the rate of change of field capacity with respect to each individual independent variable and how it may be affected by changes in the other independent variables.

Field capacity measurements taken over a wide range of conditions yielded a highly significant six parameter response function consisting of five independent variables. The five variables which accounted for 87 percent of the variation in field capacity were 1) AGE, 2) R/T, 3) FMI, 4) STAND, and 5) NYIELD. AGE and R/T relate to the operator, FMI relates to field size and layout, and STAND and NYIELD relate to crop conditions. The derived response function shows the great influence of interactions between the indepedent variables upon the response variable, FIELD CAPACITY.

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ACKNOWLEDGEMENTS

The author gratefully acknowledges the many individuals and organizations who made this research possible: The YANMAR Agricultural Equipment Co., Ltd. of Osaka, Japan, and its affiliated dealers for their denerous assistance and support during the conduct of the field research; Mr. Yosisuke Kishida, Director, and Mr. Yoshikuni Kishida, Chairman, Shin-Norinsha Co., Ltd. of Tokyo, Japan, and Dr. William Chancellor, Professor of Agricultural Engineering, Universtity of California at Davis, for their help in initiating research arrangements in Japan; The East-west Center, Open Grants, Honolulu, Hawaii, for their financial support; Dr. Jaw-Kai Wang, chairman, Agricultural Engineering Dept., University of Hawaii, Dr. Elgin B. Hundtoft, Associate professor of Agricultural Engineering, University of Hawaii, and Dr. Nicolass Luykx, Director, East-west Center Food Institute, Honolulu, Hawaii, for their ideas, criticisms, and comments; Loren D. Gautz, Agricultural Engineer, University of Hawaii, for providing a critical soundigboard.

And particular thanks to Mr. Kansyo kunishi of YANMAR's Gakuin Department. Without his extraordinary efforts, the field research could not have been accomplished.

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Historical Development of Agricultural Machinery and Implement in Japan

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Head director of International Farm Mechanization Information Service

Introduction

Up the last quater of the 16th century Agricultural implements and machinery were quite primitive both in its design and usage. However the influence made by inflow of the Chinese and Korean civilization around last half of the 17th century, they began to make more effective agricultural implemnts to be used for both man-power and animal power.

No doubt that there were skilled workers making iron utensils and other various hand-tools which earned our fame as metallurgist.

There have been the records of having workers contested for their excellence in working with tools and the quality of their products with both foreign and domestic manufacturing technique. Plows are the one of the best invention which Japan has make as well as harvesters and descriminator paddy-cleaner though the rice-huller and water mill were originally came from China and korea.

Revolutionary change occured when Japan shifted from feudalism to democracy in 1866 through the influence of European world, and having exchange trade and informations. Though they only improved existed hoes and plows untill beginning of the 20th. Making gradual progress in such as thresher, operating them by pedals, they went into the period of automation for manufacturing agicultural machinery and implements after the World War II.

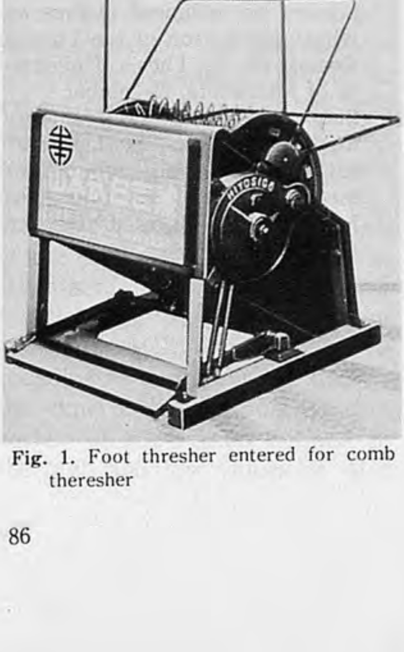

Fig. 1. Foot thresher entered for comb theresher

In this first phase of automation, there were 2—3 horse power engine of kerosene, was started to produce. But for only experimental basis power thresher, rice-huller, rice-refiner, and small-scale tiller were imported from Europe.

After the World War II, the various research and studies foe further development have been tried and produced the light weight engine with high speed for the tiller which made them so popular in its use and they were widely spead. These tiller were improved then became planters and harvesters. By the time of last half of 20th, almost every kind of agricultural machinery and implements were avairable in Japan.

The fact that these development of the agricutural machinery and implements in Japan were for the small-scale farms which are around 1～2 hectares, indicate that the developments of especially compact-type are needed and they were so unigue in the field of mechaization.

Let me tell you some interest-

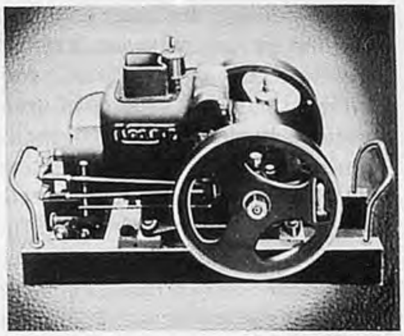

Fig. 2. Engine was imported in 1915. But home-product was developed in 1930. At present there is no imports.

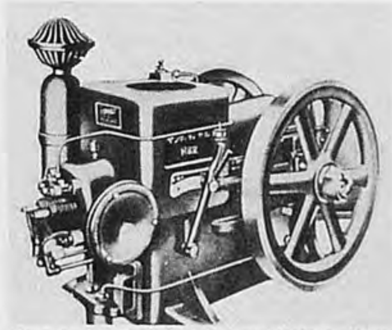

Fig. 3. A small diesel engine of the first in the world (1932)

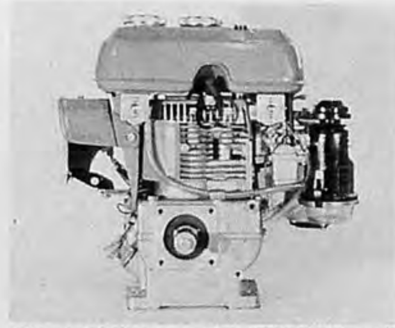

Fig. 4. Mini-type engine with high speed which became driving force of agricultural mechanization (1950).

ing episodes which happened in the course of these development of agricultural machinery and implements.

Improvement of engines and tillers (Two wheel type)

Kerosene Engines called, "International", were imported from U.S.A. in 1915, and were sold with pumps as a set, gradually were studied and progressed and finally became localized. These localized engines were, "Kubota engine" or "Yanmer Diesel engine" and other fifties of the similar kinds. Thus, in the beginning, impors were mainly from U.S.A. howerer, with the progress made by local manufactures around 1930, all these imported engines were disappeard from the market. Notably, "Yanmer Diesel" has succeeded domestic prodution of the most compact-type diesel engine in the world.

In those days, 5-horse power engine was the least compact-type engine in the West. Yet, we started as low as 2-horse power engine in Japan.

As it has been described before, the trend has gone in the direction of manufacturing compact-type such as "tractor in crank-type", cultivator whose main parts made by screw-type". The tillers in the present type were diviced and sold in 1931, however, by the improvement in the cultivating parts becomming "tine-rotary", all crank and screw types also have disapeared from the market.

After the World War II, together with the agraian reform, industrialization was stressed, causing poor situation in supplying labor force in agriculture. But, on the contray, this was

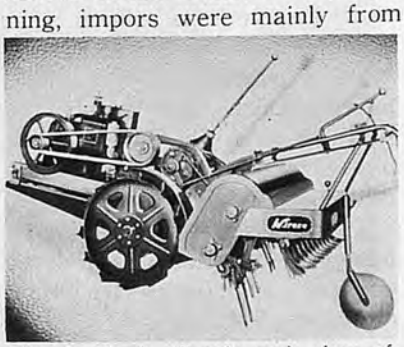

Fig. 5. Crank tiller in early days of development.

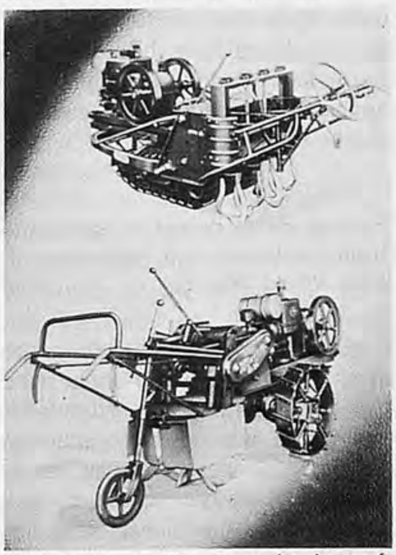

Fig. 6. Screw-tiller in early days of development.

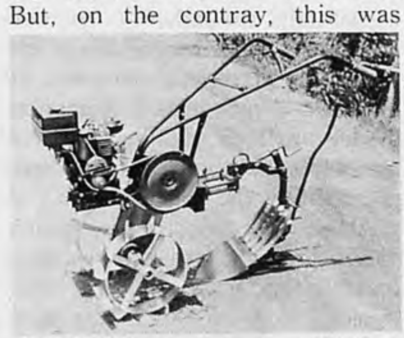

Fig. 7. Tiller in early days of import equipped a plow made in Japan (1947).

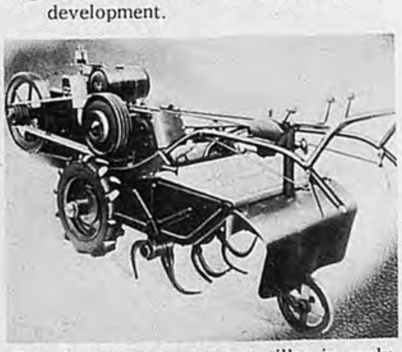

Fig. 8. Rotary type-power tiller in early days of development.

Fig. 9. Most recent tiller (a plow type).

Fig. 10. Most recent rotary tiller.

Fig. 11. Knapsack duster.

farorable factor on the side of mechanization, increasing the use of agricultural machinery, especially the use of cultivator. Other notable factor was the improvement of the small-tiller impoted from U.S.A. This was able to draw both multi-rotary, and small-plow, which was improved to 3-5 horse power "plow-drawn model" later.

These two improvements have made a big step twords agricultural mechanization in Japan. This "plow drawn model" had the output of 3,000,000 units, recently. Now Japan is promoting the production of four-wheeled tractor with 13-25 horse power. We are reaching now output of 50,000 units annually.

As it is noticed, here again, we have been stresssing the point of manufacturing the compact-models, which is suitable to agricultural condition and topograghy of the country.

About the investiment, which Japan has put into the research and investigation in this field, especially in the field of tillers, was said to be about 70 millon dollars, and there were more than 150 manufactures of tillers. When we estimate the total cost of the research and investigation expenses of the total labor cost divided by per person, we could readily estimate how much these research expenses would be needed in order to accomplish one machine.

In Japan, about fifty times more than the market price of the machine, have been used as the research and developmental expenses before their appearance on the market.

Further development of agricultural machinery and implements after World War II

Major change which took place after World War II in Japan was the disappearance of self-sufficient farms who used to manage average 1.2 hectares per farm. Though many compact-type model of the machinery were imported from various western nations, those machinery were not able to use without having them re-fixed or modified for suitable to Japan's agricultural situation, therefor through their engineering ability, they invented and improved and contributed much in further development. For example, shoulder-type duster and compact power-sprayer with the higher cycles of piston and so on. This power-sprayer was almost a half of weight of the same type produced before the War, and was produced 500,000 units in 1967, now there are almost over 2,000,000 units which would be delivered to farms.

Paddy-threshing husking machinery were also improved, thresher became automatic and rice-huller was made of steel and became compact-type. This rice--huller is the invention made by Mr. Iwata by whom the centrifugal power machine was made for husking paddy. This was very unique even in the field, being invented in 1916, became popular within five years, then was made further progress as "rubber-roller type" in that of today. Eversince, all rice-huller has changed into "rubber-roller type." The other invention was "wide-broadcaster" made of plastic pipe of about 50 meters which was capable of spraying from the holes in the pipe. This was the invention of a farm in the Niigata prefeture.

These episodes were quite remarkable invention in the development of the agricultural machinery in Japan.

Fig. 12. Self-propelled automatic thresher developed after 70 years' technical change from foot thresher.

Fig. 13. Widespread rice protecting work by utilization of vinyl hose.

Fig. 15. Development of binder begins at three row cutting in 1966, aiter being miniaturized year by year, at present the main is one row cutting binder.

Around the first quater of 20th, the improvements made for "power-thresher" was extrodinary. The fact that all these improvement were made by carpenters in the rural villages and farmer's boys, or even in blacksmith's skilled individual, would indicate that the development of those agricultural machinery was born not from fine research institution but from the people who actually in the rice-field. However lately, such as "rice-huller, roller-type;" "combine," "reapers," were born from these fine institution's laboratry.

Up to 1940, there were not any laboratries of these kind. The manufactures had a role of the designers and also inventors who were the maker of the foundation for today's success.

From these facts drawn, we would say that is not likely to produce such unique invention through specialization (or, automation) of the work, but rather the real invention which reqire the sound scientific back ground, would likely to be born from the field.

Fig. 14. Radically growing rice transplanter.

To remember all those ideas from the farms were very important for futher expansion of the agricultural mechanization.

Development of the harvester, combine, rice planter

Rice-planter has not completely accomplished yet. But, actually has been sold 130,000 units in annual basis. That is to say the rice-planter is on its way to the perfection.

Due to the short length of the young rice plant, as well as climatic condition of the North, availability of the water, and the long duration of the planting period, the rice-planter has the many future assignments to improve. Although, it requires less labor, less water than "direct seeding model," and save the extra work of weeding. In the present situation, there are some improvement in planting larger size of young rice plant. Yet to carry this out, there should be quite big steps to be taken within ten years.

It is the binder that has been progressing incredibly in last ten years. Around 1960, "binder with three-rows" were began to be sold by Kubota Tekko, then immeadiatly, "the compact-type with two-rows" was invented with the weight of 220kg, then next year, from 170kg to 80kg with one-row, were manufactured, sequently. By this production rate it is not impossible to make "binders with two-rows," with the weight of 120kg which would cost less and increase the distribution ratio.

Cause of these rapid expansion of the binder sector, many manufactures had to face the situation that they must discount the last year's stock.

About ten years ago, "combine off-set type, with two-rows," was sold by Iseki. This off-set type combine with two-rows, was actually invented by Mr. Doihara at Hokkaido Agricultural Research Laboratory in 1950. This was called "stripper head combine".

In an addition to this invention, Mr. Kano, the expert of agricultural research laboratory in the Ministry of Agriculture and Forestry with other specialists in the field have put their efforts to

Fig. 16. One row cutting simple binder.

Fig. 17. Off-set type self-combine developed in 1967.

improve this one-row combine, twoards overall area type. Which reap the same width of the machine. This was the beginning of Japanese type combine, which came out on the market 10 years later then within six years, they improved from off-set type" to "overall type." Besides, the weight of the machine went down from 1 ton (metric) to 650kg. Mean while, working capactity is 0.2 hectares per hour by the combine with five-rows, but they have been making research to improve further the working capacity of this comine to be 2 hectares per hour with the same light weight. In case of threshing combine being less in loss of the rice, it could be used in soft ground. (as a crawler type)

There is no doubt that in 1974, the annual output of the binder and combine were around 250,000 units and 80,000 units repsectively.

Development of agricultural machinery in Japan (general)

When one considers the development of agricultural machiney in Japan, one would see those long preparatory period, before materialization, through collecting necessary informations and data. The more information they got, the more speedy they got to

Fig. 18. Full cutting self-combine (1970).

put in to improve their own models. Within twenty-five years, after the War, the productivity of Japan has sprang up six times more than in proportion to that of before the War. But one must recognize that their inventions and progress did not come instantly but rather gradually in their sence, with the hidden foundation of metallurgical technology and wood-curving, together with the skilled handcraftmanship which was accumulated those 1500 years of their history, was sprang up and applied scintifically in specific ways.

The government in 100 years ago, not only they spent one-third of their budget for education, but they themselve had the deep-seated desire for being educated, in their mind and heart, even in the era of feudalism which continued 300 years. More over, preciseness of Japanese character shown in the development and progress they achieved for improving and modifying the existed models of machinery they always aimed the best in its quality and design. These are the indespensable factor which they systematized to carry out the mission effectively. That is to say, all requests made by the farms were gone to research laboratory and plants concernd, as quick as possible to be investigated there.

Thus, upon considering the development and improvement of

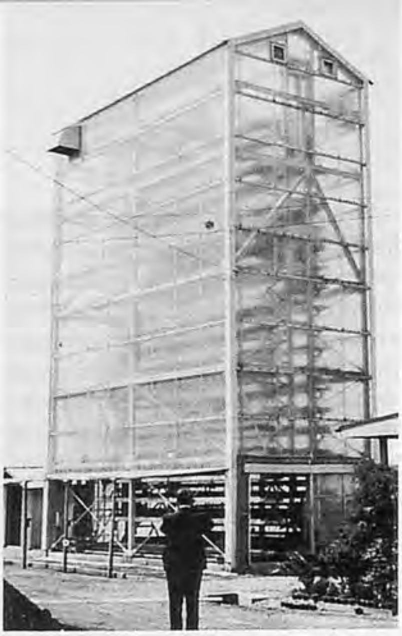

Fig. 19. Joint seedling growing facilities with enlarged supply and demand by introduction of rice transplanter

the agricultural machinery, one must always consider their latent ability and climatic condition of the county, as well as their historical back ground.

Again and again, the fine inventions and design of the machinery shown our past, was taken long way and time for their preparation before its arrival on the market. Necessary assistance from the government they had various incentives had to be planned, and above all, good cooperation made, among the organization and institution concerned with experts and specialists and various individuals in the field, were the basis of all those success to make progress of today.

Repeatedly, we must not forget that in order to encourage motive of the people, contests and exhibitions demonstrations etc, mentioned above are the factors which wa must instill to the mind of the individual so that they would also create the better foundation for all aspects of mechanization. ■ ■

Fig. 20. Tractor being expected as future main product.

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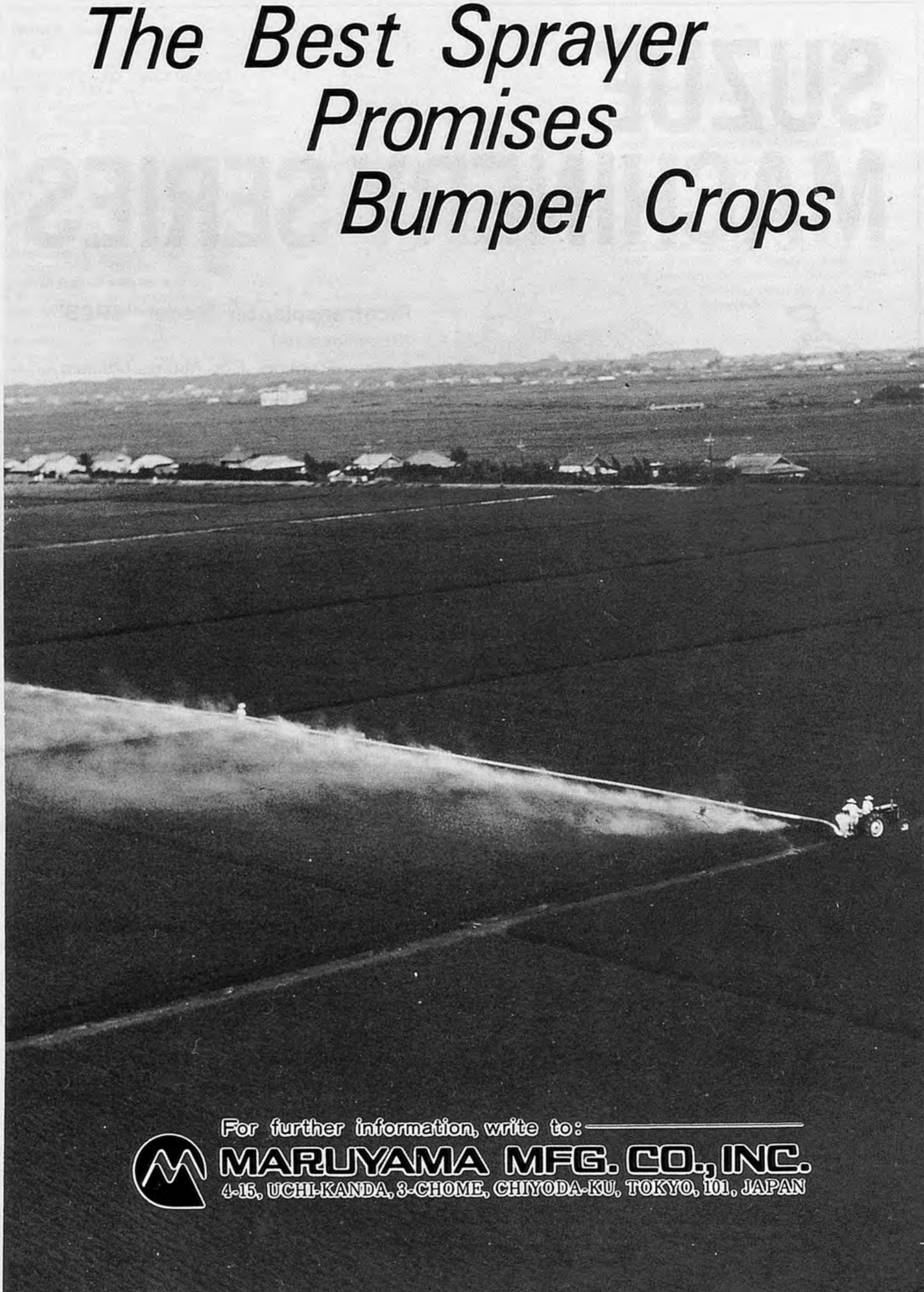
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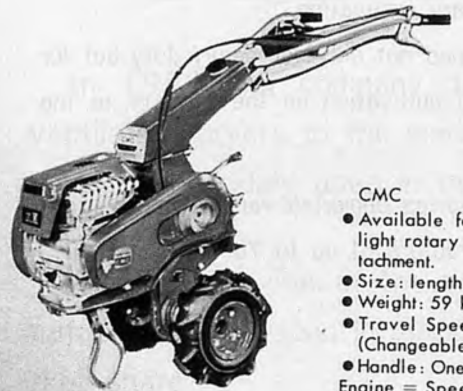

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MRD-180
- Possible to drive without hand because of self-propelled and return rotary type, also operate freely back and forth by one-touch of changeable lever.
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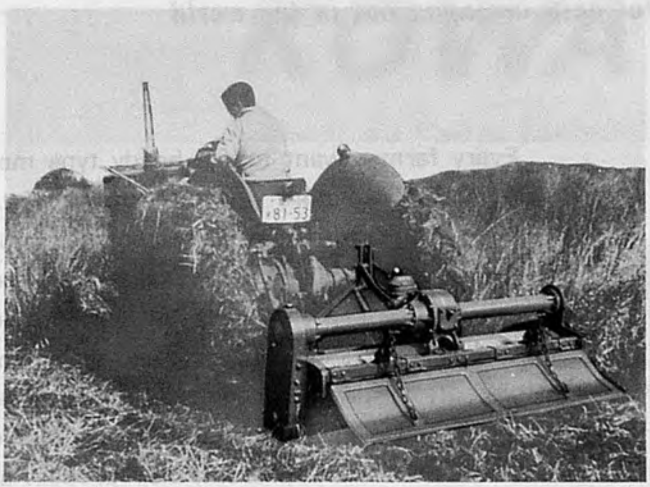

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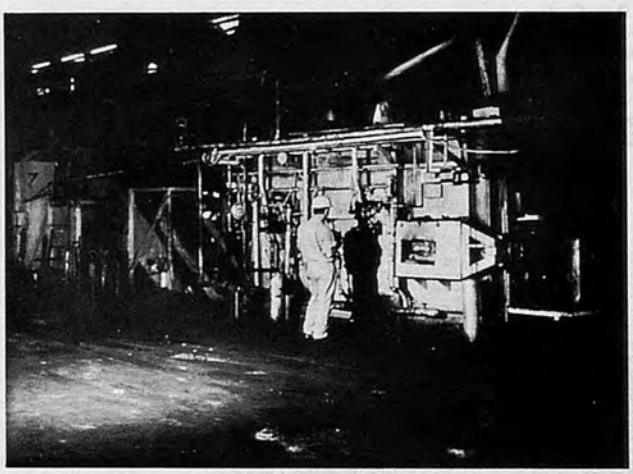

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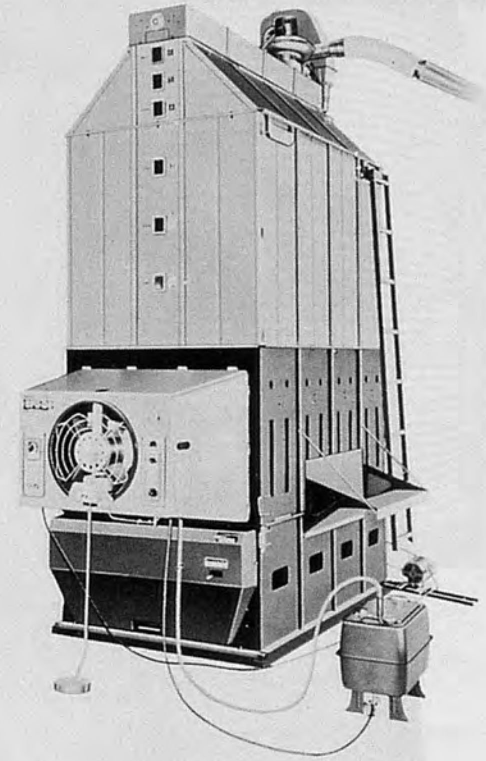

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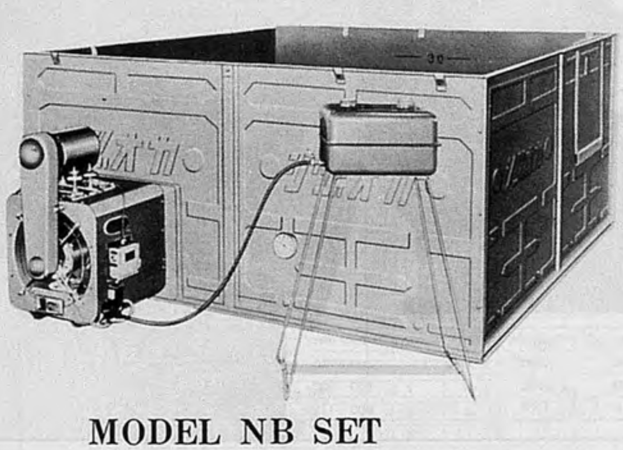

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MA-25	1210/310/880	93	1200	1/2~1	300~720
MA-30	1210/390/880	97	1200	1	600~900
MA-40	1350/460/880	117	1200	2~3	900~1150

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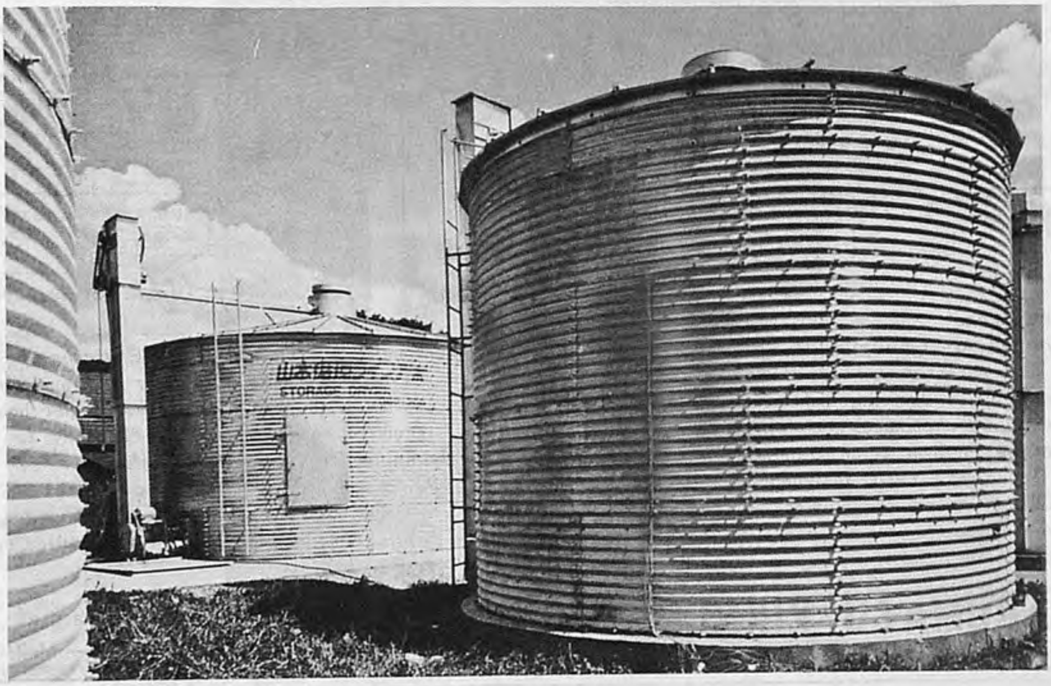

FEATURES

1. Large Capacity
   This equipment is circulating dryer of large capacity as compared with previous one's capacity. It can hold to dry wet grain, more than 20% high moisture contents, of 28 tons volume maximum. In case of dry grain, less than 20% low moisture contents, it can receive to dry grain of 46 tons maximum depending on the bin sizes.
2. Low Labor Requirement
   There is no grain handling with this continuous flow system. You place wet grain into the bin and will not touch it again. The grain is automatically dried and is transferred to storage, if you want to do so.
3. Very Little Mechanical Damage
   There is very little mechanical damage of grain by circulating for it's special mechanism of circulating device; tapered sweep auger, lower screw conveyor, bucket conveyor of large capacity, upper screw conveyor and unique grain spreader.
4. Even Circulating & Drying
   Though materials of grain contain many foreign matters, this equipment of the SBD circulate and dry evently by tapered sweep auger which is specially designed for continuous flow action and by unique grain spreader which is distributed uniformly. Drying bin is circular shape is useful for them also.
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   Special blower of large capacity is useful for aeration into grain and there is little noise for it's capacity on operation.
6. Building of Workshop Free
   There is no necessity to build workshop, because it is able to install equipment of our SBD on the outdoors.

SPECIFICATIONS

In case of low mois. cont. grain (less than 20%)

Model	SBD–4	SBD–5	SBD–6
Capacity (kg)	20,000	33,000	46,000
Loading height (m)	2.5	2.5	2.5
Floor area (m^2)	12.6	19.7	28.2
Bin diameter (m)	4.0	5.0	6.0
Overall height of bin (m)	5.0	5.1	5.2
Blower & Burner			
Air volume (m^3/min)	90	155	200
Motor (kw)	3.7	5.5	7.5
Fuel consumption (kg/hr)	4.3	7.5	9.6
Circulating volume (kg/hr)	4,000	4,500	5,000
Discharge volume (kg/hr)	10,000	13,000	15,000
Loading volume, max. (kg/hr)	15,000	15,000	15,000
Power required (kw)	5.2	7.0	9.0
Drying rate per hour (%)	0.4–0.6	0.4–0.6	0.4–0.6

SPECIFICATIONS

In case of high mois. cont. grain (more than 20%)

Model	SBD–4	SBD–5	SBD–6
Capacity (kg)	12,500	20,000	28,000
Loading height (m)	1.5	1.5	1.5
Floor area (m^2)	12.6	19.7	28.2
Bin diameter (m)	4.0	5.0	6.0
Overall height of bin (m)	5.0	5.1	5.2
Blower & Burner			
Airvolume (m^3/min)	120	190	265
Motor (kw)	3.7	5.5	7.5
Fuel consumption (kg/hr)	5.8	9.3	13.0
Circulating volume (kg/hr)	4,000	4,500	5,000
Discharge volume (kg/hr)	10,000	13,000	15,000
Loading volume, max. (kg/hr)	15,000	15,000	15,000
Power required (kw)	5.2	7.0	9.0
Drying rate per hour (%)	0.7–1.0	0.7–1.0	0.7–1.0

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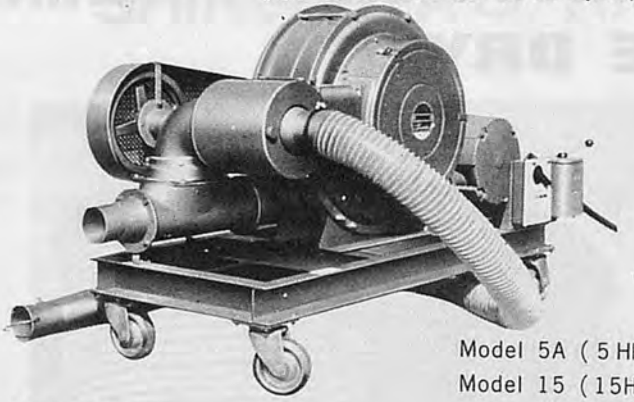

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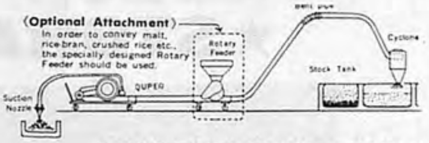
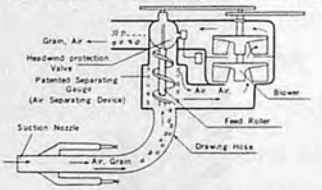


(Rough Sketch of Patented Separating Device)



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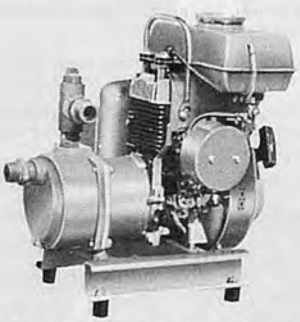

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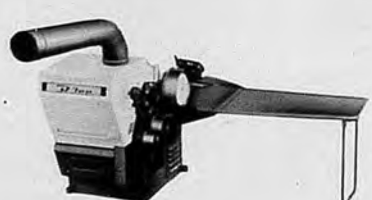

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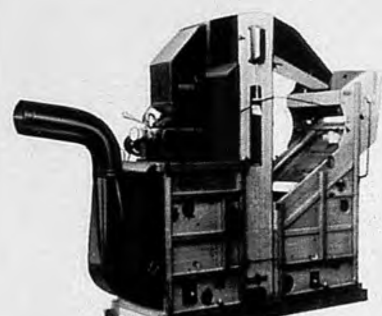

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