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PRESENT AND FUTURE DEVELOPMENT OF THE MECHANIZATION OF RICE PRODUCTION

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SUMMARY

Mechanization of rice production in the tropics has many problems which still remain unsolved. Attempts to transfer the highly advanced western and Japanese mechanization technologies have not produced effective results for the small farm holdings in the tropical regions. The overwhelming need today is to develop an intermediate mechanization technology to suit the prevailing set of agricultural, socio-economic and industrial conditions of the tropical regions.

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OF THE MECHANIZATION OF RICE PRODUCTION

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More than half of the world population depend on rice for their basic food supply. Rice is grown on 1.29 billion hectares with an estimated annual production of 2.76 billion metric tons per year. Table 1 includes some basic information on the major rice-producing countries of the world. Approximately 90 percent of rice production is concentrated in South, South East, and Far East Asia where population density is high and rice is primarily produced with traditional non-mechanized methods. The mechanization of rice cultivation with power equipment is therefore a vital question which will affect millions of people who depend on this crop for food and livelihood.

Mechanization of rice production in the tropics not only presents the usual non-technological dryland farming problems related to equipment size, economics of use and ownership, but also many technological problems which still remain unsolved. In recent years some of these problems of mechanization have been further intensified due to the spectacular developments in the rice seed-fertilizer technology. The changing agro-economic climate in the tropical regions is making it increasingly difficult to follow the traditional rice production practices. Agricultural mechanization is therefore becoming an important issue in many countries. Questions pertaining to mechanization are being vigorously debated by various authorities, but there is no clear-cut agreement on either the necessity or the type of mechanization that should be promoted in the developing regions.

Two somewhat opposed premises are often put forward for the mechanization of agriculture in the tropical world: (1) That mechanization of agriculture would displace labor and create adverse socio-economic problems, hence, mechanization is both unnecessary and harmful. (2) That mechanization of agriculture with large tractors and equipment is desirable since shortage of power is the essence of the mechanization problem and large equipment can provide this power in the most economical manner. Proponents of these two points of view have often argued strongly and have seemingly put forward substantially convincing data to support their hypotheses.

An unusual characteristic of the first hypothesis is that it is invariably based on the amount of direct agricultural labor that may be displaced by the machines and does not take into consideration the employment generation and labor intensification aspects of agricultural mechanization. Past experience indicates that seed and fertilizer technologies have generally preceded the mechanization of agriculture in the agriculturally mechanized countries. There is no reason to believe that it would be otherwise in the tropical regions. Recent studies in the Philippines indicate that the progressive farmers who adopt the new rice seed-fertilizer technology are more inclined toward mechanization. Tables 2 and 3 are the results of two

studies in the Philippines which show increased labor utilization in rice production on more mechanized farms. The case of Japan is perhaps a classical example which indicates a very high labor utilization (1400 man-hr/ha) in spite of a highly mechanized agriculture (2.664 hp/ha; Tables 4 and 5). It seems highly doubtful that the mechanization of agriculture in the tropics with smaller machines when coupled with the appropriate seed-fertilizer technology would reduce labor utilization.

An unusual aspect of the second hypothesis is the contention that adequate equipment to mechanize rice production is already available from the temperate regions and that the problem lies primarily in the proper selection of equipment. Such a premise is based on a limited knowledge of the requirement of the tropical regions, for there is a wide range of operations which cannot be satisfactorily performed with the existing array of equipment available from the temperate regions. Some examples of the unsolved problems of wetland paddy cultivation equipment are concerned with mechanical tillage of soft soils, mobility of tractors, seeding of pregerminated paddy on puddled soils, application of plant nutrients in puddled soils, harvesting and threshing of high-moisture paddy, small-scale rapid drying, parboiling and milling of paddy.

Another unusual aspect of the two hypotheses is that they are primarily concerned with only the utilization aspects of the agricultural machines and do not consider the various implications of manufacture, sales and service of the tools necessary for mechanization. It is taken for granted that agricultural mechanization in the tropical countries will be based on a non - indigenous technology, and that equipment to mechanize will primarily come from the industrialized regions. The history of agricultural mechanization of even the smaller countries of Europe reveals that widespread agricultural mechanization was only possible with the indigenous production of farm equipment.

The high cost of imported machinery has always been a serious, limiting factor in the mechanization of tropical agriculture. Farmers in the developing regions pay considerably higher (Table 5) for machines than their counterparts in the industrialized countries, whereas the returns from agriculture are usually much lower in the less developed regions. Most developing countries are undergoing balance of payment problems of varying degrees. It is doubtful that these problems will improve enough to permit a large-scale import of farm equipment in the foreseeable future. Figure 1 indicates an estimate of the number of tractors that would be required in three Asian countries to raise their power level to a conservative 2.0 hp/ha in a period of 20 years. The compound rate of tractor population growth necessary to achieve such a level will be 27.5 percent for Pakistan, 21 percent for the Philippines, and 15 percent for Ceylon. The foreign exchange required, if tractors are to be obtained from non-indigenous sources, would be of staggering proportions and is clearly impossible to contemplate in consideration of the present foreign exchange allocations for importation of agricultural machinery.

The question of agricultural mechanization is therefore very closely related to the indigenous manufacture of agricultural equipment in most developing countries. It is somewhat unrealistic to look at agricultural mechanization without considering the indigenous production of the tools that are necessary for mechanization. Unfortunately, however, almost all national and international efforts toward agricultural mechanization in the tropical regions are primarily directed to the utilization aspects of agricultural machines.

Quite often an argument is put forward that economical manufacture is only possible when a mass demand exists. There is no doubt that economies of scale in manufacturing are extremely important in the industrialized countries where the cost of labor is very high. Understandably, farm machinery manufacturers from the industrialized countries have tended to overemphasize this aspect when considering the feasibility of manufacture in the developing regions. It is often unrealistic to apply the highly capital-intensive manufacturing techniques in regions where labor costs are only a fraction of those in the industrialized countries.

Many interesting examples of economic short-run production are found today in Asia. These examples indicate that it is possible to manufacture relatively complex products provided such products are suitably modified and adapted for low-volume production. Two interesting examples of low-volume production in the Philippines are the manufacture of the jeepney and the McCormick threshers. A major portion of the jeepney vehicle, a locally adapted version of the jeep, is manufactured by small fabricating shops all over the Philippines. The vehicle chassis, complete sheet metal body, and many other components are fabricated with labor-intensive techniques in small shops. The jeep is the lowest priced vehicle available in the country, and twice as many jeepneys are sold every year as all the imported passenger cars put together. Another interesting example is the local manufacture by small fabricators of the old McCormick type threshers in the Philippines. These machines are sold at economical prices and are very popular for custom threshing of paddy in the Central Luzon region of the Philippines.

In Thailand, numerous fabricators are manufacturing small walking tractors of relatively simple but indigenous designs in small volumes for paddy cultivation. These machines are quite economical and can adequately meet most of the requirements of the Thai farmers. Similarly, many small machine shops are successfully fabricating small power tillers and farm trucks in Taiwan in small quantities with simple production techniques.

A closer examination of the past achievements in agricultural mechanization in the tropical regions indicates that the real and overwhelming need is not just to transfer the highly advanced mechanization technologies from the developed countries but rather to create an intermediate level of mechanization technology tailored specifically for the developing countries. This new technology must fit well with the prevailing set of agricultural, socio-economic and industrial conditions in the tropical regions.

There are two distinct agricultural mechanization technologies which have evolved in the industrialized regions of the world. The western approach emphasizes dryland farming using large, high-powered equipment with greater emphasis on labor saving. The use of large machines, either on large farms or in custom operation, has but limited application for paddy cultivation. In certain areas such as Thailand, Malaysia, Philippines, and Ceylon, custom operation with large equipment has gained some degree of acceptance for either land preparation or for threshing. It is doubtful, however, that in the long run the tropical farmer would accept only a selective mechanization of his operations. The other crop production operations along with the transport of farm produce and personnel, will continue to favor individual ownership of smaller equipment. Chancellor's study[1/] in Malaysia indicates a rapid increase in the sales of two-wheel tractors even in the face of the availability of economical large tractor hire services. The introduction of custom operation services for every operation of rice production may also have some serious economic limitations. A survey of ten "special projects" in Ceylon[2/] indicated that up to 50 percent of the cost of rice production consisted of the two custom operations of tillage and threshing.

In Japan, agricultural mechanization has not followed the western pattern. Rice is a major crop in Japan which is grown under wetland conditions on small farm holdings. The high price support for rice and the rapid industrial growth have helped in the mechanization of Japanese agriculture with individually owned, small, low-powered machines. The last five years have resulted in a tremendous sophistication in the design of farm equipment originating from Japan. Such equipment is basically developed to suit the requirements of the Japanese farmer and is often too complex and uneconomical for the tropical farmers. The Japanese combine harvesters and paddy transplanters are excellent examples of functionally suitable but economically unacceptable machines for the tropical regions.

Recent trends reflect a widening gap between the available mechanization technologies from the industrialized countries and the requirements of the less developed regions. Mechanization in the western countries is decidedly moving towards larger and larger sized equipment. To some extent, developments in Japan indicate a similar trend, along with an increasing complexity in their farm equipment. These developments will no doubt further hamper the introduction of these agricultural machines in the developing regions. The inadequacy of the available mechanization technologies, and the lack of an appropriate alternative to satisfactorily meet the overall requirements of the tropical regions, has been the most important reason for the slow and spotty progress in the mechanization of tropical agriculture.

Mechanization of tropical agriculture at the present time is primarily limited to the larger farm holdings which constitute an insignificantly small segment of the total agricultural land. Table 6 shows that about 95 percent of the farm holdings in the ten rice-growing Asian countries are below 10 hectares. If mechanization is to be a reality in the tropical regions, it must be considered in this particular frame of reference.

In all of Asia, only Japan stands out as a developed country, both agriculturally and industrially. The Japanese experience indicates that rapid agricultural mechanization can be achieved within the framework of small family farms. The landholding pattern and other agricultural and labor indicators of Japan are relatively closer to the developing regions than those of the western countries. For this reason many lessons learnt from the Japanese experience can be applied to the mechanization of tropical agriculture.

A look at Table 5, which includes data on eleven rice-growing Asian countries, indicate that except for Korea, Japan has the smallest arable land area per holding. In the same group of countries, except for Nepal, Japan has the highest agricultural working population per hectare. Even though a large percentage of the agricultural population in Japan derives part of their income from non-agricultural sources, the absolute number of man-hours in rice production is still very high. Table 4 lists the number of man-hours required per hectare in Japan and some other Asian countries in rice production. In spite of the small arable land per holding, the high number of agricultural workers per hectare, and a very high labor requirement per hectare, the Japanese farmer is able to obtain the highest productivity, both per person and per hectare. This level of productivity would not have been possible without the availability of the high level of power, about 1.34 hp for every agricultural worker, in Japan.

One important characteristic in the mechanization of Japanese agriculture is that agricultural mechanization and industrial development proceeded together in a process of "concurrent" growth. "The Meiji technology decision that showed impressive foresight has been described as a 'combination of indigenous know-how and very selective borrowing from the West'."[3/] These principles established early were still in force when mechanization in Japan "took off" after World War II.

Just after World War II, numerous small shops mushroomed all over Japan and started producing simple mechanized farm equipment. At that stage, Japanese farm equipment was primarily designed as a replacement of animal power and usually matched the working capacity of animal-drawn implements. Japan was in effect developing an intermediate agricultural mechanization technology to suit its postwar needs. The last twenty years have resulted in the transformation of this intermediate technology into the highly advanced agricultural mechanization technology which we see today in Japan.

The initial steps towards the development of an intermediate mechanization technology for the less developed regions involve the design and development of relatively labor-intensive but simple, mechanically powered equipment which can be produced with the production methods that are currently available in the developing regions. Fortunately, we are seeing some encouraging signs towards the development of such a technology in a few Asian countries. Production of farm implements, pumps, stationary farm machines and, in some cases, diesel engines and walking tractors have been started by small machine shops in Taiwan, Korea, Thailand, India, Pakistan and the Philippines. These indigenously produced agricultural equipment are either adapted from imported equipment or developed locally by machine shop operators who usually

have had no formal engineering training. There is little doubt that some of these entrepreneurs who have started with humble beginnings would be the leaders of agricultural mechanization in their own countries. To accelerate the process of mechanization, every assistance must be provided to such entrepreneurs in the design and development of new equipment and in the establishment of new farm equipment industries in the tropical countries.

Past efforts of the various national and international organizations have been primarily directed towards introducing a non-indigenous mechanization tehcnology in the developing regions. The various international aid organizations have provided considerable assistance in supporting the foreign exchange components of importing agricultural machinery but have seldom offered assistance in the development of an indigenous mechanization technology. The results obtained so far call for a reassessment of the overall strategy for the mechanization of tropical agriculture. A reorientation of the international assistance program toward the development of a new mechanization technology is imperative to accelerate agricultural mechanization in the less developed regions of the world.

The International Rice Research Institute considers the development of an appropriate technology an important area of activity. It is engaged in the development of a whole range of equipment for local production in the developing countries under a research contract from USAID. The problems are so large and diversified, however, that the Institute can only play a limited role in the process. It is hoped that this conference will devote a major attention toward deliberating the various issues of technological development and will provide some guidelines for the organizations engaged in the mechanization of tropical agriculture.

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3/ Ohkawa, Kazushi, B. F. Johnston and H. Kaneda (ed.). 1970. Agriculture and economic growth: Japan's experience. Princeton Univ. Press and Univ. of Tokyo Press. Japan 433 pp.

Table 1. Area, production and yield of paddy in various continents and selected countries of the world.

Region or country	1963			1967		
	Area x 1000 ha	Production x 1000 MT	Yield x 10 kg/ha	Area x 1000 ha	Production x 1000 MT	Yield x 100 kg/ha
Total World	122,277	253,220	20.7	128,842	275,942	21.4
Continents						
Asia	114,825	237,697	20.70	118,093	252,049	21.34
N. America	1,325	4,181	31.6	1,408	5,207	37.0
S. America	4,489	7,528	16.8	5,250	9,199	17.5
Europe (inc. USSR)	466	1,873	40.19	371	1,943	52.37
Africa	3,137	5,783	18.4	3,425	6,696	19.6
Australia-Oceania	35	158	45.1	40	284	58.5
Selected rice-growing countries						
Japan	3,272	16,639	50.9	3,263	18,770	57.5
China (Mainland)	31,500	85,000	27.0	32,000	92,000	28.75
India	35,809	55,497	15.5	36,722	56,787	15.5
Pakistan	10,294	17,724	17.2	11,309	19,005	16.8
Indonesia	6,731	11,915	17.7	7,523	13,932	18.5
Burma	4,877	7,783	16.0	4,800	7,714	16.1
Ceylon	525	1,026	19.5	546	1,169	21.4
Philippines	3,089	3,843	12.4	3,304	4,561	13.8
Thailand	5,354	10,029	15.9	5,601	9,595	17.1
N. Vietnam	1,959	4,296	21.9	2,550	4,700	18.4
S. Vietnam	2,530	5,327	21.0	2,296	4,688	20.4
United Arab Republic	403	2,219	55.1	464	2,316	49.9
Brazil	3,722	5,740	15.4	4,291	6,792	15.8
Taiwan	749	2,763	36.9	787	3,162	40.2

Source: Production Yearbook FAO 1964 and 1968.

Table 2. Man-days of labor used per hectare for specific operations on 42 farms planting high-yielding varieties (HYV) in 1969, Laguna 1966 vs 1969 wet season.

	1966 local varieties	1969 HYV	1970* HYV
Number of farms	42	42	32
Average area (ha)	2.4	2.3	2.2
	Man-days by operation		
	Total	Total	Total
Land preparation	22	16	13
Transplanting	10	10	10
Weeding	14	14	17
Other pre-harvest	10	11	15
Harvesting and threshing	23	34	36
Total	79	85	91
Percent using tractors (%)	31	62	75
Yield (metric tons/ha)	2.5	4.3	3.5
Kg/man-day	32	51	38

*Latest available data from the continuing survey for 1970 wet season.

Source: R. Barker and V. Cordova, "The Impact of New Technology on Rice Production - A study of Change in Three Philippine Municipalities from 1966 to 1969," paper presented at IRRI Saturday Seminar, December 12, 1970.

Table 3. Man, animal and tractor utilization per hectare of 100 lowland rice farms in Rizal Province, Philippines, by variety and season, 1967-68 (days per hectare).[a]

	Old varieties			New varieties		
	Man	Animal	Tractor	Man	Animal	Tractor
Wet season						
Land preparation	28.45	19.73	0.53	27.60	15.89	1.35
Transplanting	12.95			17.37		
Weeding and replanting	13.65			29.38		
Other pre-harvest	2.95			5.83		
Harvest, thresh, haul	25.86			30.72		
Total	83.86	19.73	0.53	110.90	15.89	1.35
Dry season						
Land preparation	28.84	28.08	1.13	24.48	11.24	3.02
Transplanting	18.49			18.76		
Weeding and replanting	22.71			46.28		
Other pre-harvest	5.52			6.67		
Harvest, thresh, haul	25.10			35.97		
Total	100.66	28.08	1.13	132.16	11.24	3.02

[a] Average farm size was 1.39 ha with 23% double cropped and 42% of the farmers were owners or part-owners.

Source: P. C. Manuel and M. P. Lopez, "Productivity of Farms Using Traditional and Improved Rice Varieties in Rizal and Laguna," Seminar on Economics of Rice Production in the Philippines, IRRI (December 1969).

Table 4. Labor hours for rice cultivation in some selected Asian countries.

Country	Land preparation	Transplanting	Harvesting	Total including others
Japan	50	240	220	1,400
Taiwan	60	190	220	1,300
India	170	229	227	1,000
Philippines	190	120	170	800
Nepal	240	240	240	N. A.
Korea	160	160	160	830

Source: APO Expert Group Meeting on Agricultural Mechanization, Vol. II, (APO Project SYP/III/67), October 1968.

Table 5. Some agricultural mechanization indicators on 11 selected rice-producing countries in Asia.

Country	Arable land per holding	Agricultural working population/ha	Net domestic agricultural production US$		Horsepower per hectare				HP per agricultural worker	Cost/hp of agricultural tractors US$	
			Per person	Per hectare	Human	Animal	Mechanical	Total		Small (6-8 hp)	Large (35 hp)
Ceylon	1.59	1.20	293	352	0.120	0.148	0.110	0.378	0.009	133.30	66.70
Taiwan	1.11	1.95	349	696	0.195	0.164	0.146	0.505	0.074	107.05	N.A.
India	2.62	0.90	148	133	0.037	0.204	0.008	0.249	0.009	179.48	107.69
Iran	6.17	0.37	417	154	0.90	0.048	0.154	0.292	0.418	92.85	66.85
Japan	1.06	2.16	626	1,350	0.216	0.120	2.664	3.000	1.231	77.48	59.12
Korea	0.90	1.96	244	477	0.196	0.236	0.003	0.435	0.0018	105.43	N.A.
Nepal	1.22	2.49	99	236	0.249	0.480	0.004	0.733	0.0016	N.A.	85.50
Pakistan	2.37	1.09	154	169	0.109	0.288	0.013	0.410	0.012	164.29	71.69
Philippines	3.66	0.71	242	186	0.071	0.104	0.023	0.198	0.030	219.25	146.17
Thailand	3.64	1.10	102	112	0.110	0.184	0.054	0.348	0.050	89.14	68.57
Vietnam	1.57	2.10	203	421	0.210	0.244	0.023	0.477	0.003	661.20	495.90

Source: APO Expert Group Meeting on Agricultural Mechanization, APO Project SYP/III/67, Tokyo, October 1968, Vol. II.

Table 6. Percent of farm household by size of holding.

Country	Year	No. of holdings	% of total holdings		
			0-1 ha	1-10 ha	0-10 ha
Ceylon	1961	1,119.8	65.40	33.4	98.80
Taiwan	1960	807.6	61.00	39.0	100.00
India	1954/55	-	19.42	62.39	81.81
Japan	1965	5,465.8	70.70	29.3	100.00
Korea	1965	2,506.9	67.00	33.0	100.00
Nepal	1965	-	4.90	90.50	95.40
Pakistan	1960	10,999.5	43.40	52.8	96.20
Philippines	1960	2,166.2	11.5	82.9	94.40
Thailand	1963	3,214.4	18.60	76.1	94.70
Vietnam	1960	1,893.0	43.00	54.8	97.80

Source: APO Expert Group Meeting on Agricultural Mechanization, Tokyo, October 1968, Vol. II (APO Project SYP/III/67).

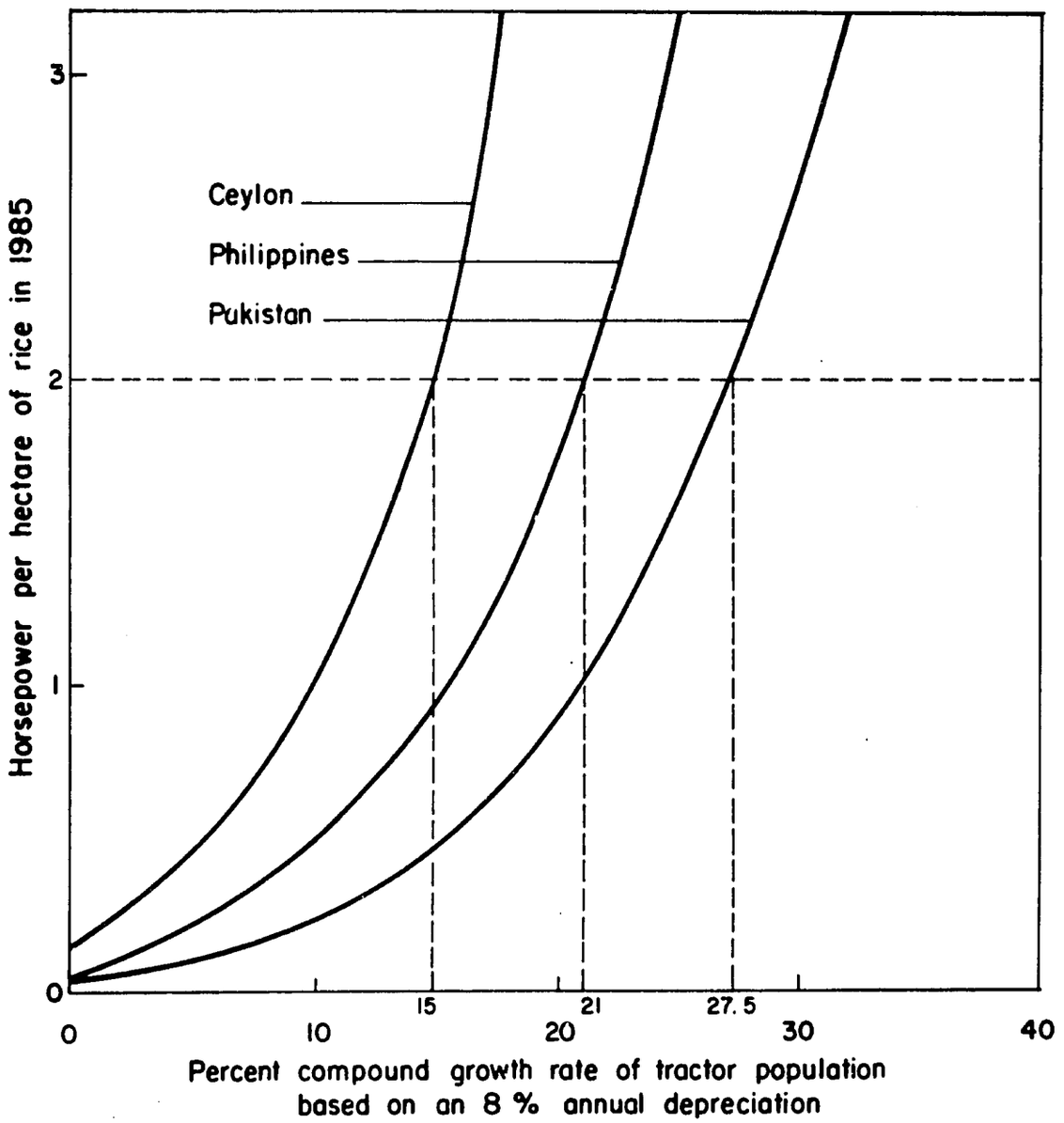

Fig. 1 . Tractor population growth rate for three countries in Asia to achieve a 2 hp/ha level in a 20-year period.