AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 68

1. SUBJECT CLASSIFICATION

A. PRIMARY: Food production and nutrition — AF25-0150-0000

B. SECONDARY: Soil fertility,fertilizers and plant nutrition--Cereals--Rice

2. TITLE AND SUBTITLE

The implication of the world fertilizer situation for new rice technology

3. AUTHOR(S)

(101) IRRI

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	23p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

IRRI

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER
PN-AAE-428

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Fertilizers
Research
Rice
Shortages

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/ta-G-1074 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

PN-AAE-428

The Implications of the World Fertilizer Situation for New Rice Technology *

The advent of the new seed-fertilizer technology has led to a rapid growth in fertilizer use on Asian rice farms over the past decade. Although fertilizer input per hectare is still very low, higher yields due to increased fertilizer use account for an increasingly larger share of the annual additions to Asian food grain production. This growing dependence on fertilizer causes many to view with alarm the impact of the energy crisis and other recent events on the availability of fertilizer supplies.

In this paper we consider the effect of the fertilizer situation on rice production and technological developments in both the short (2-3 years) and intermediate (5-10 years) time periods. On the basis of the evidence available, we conclude that the impact of the fertilizer shortage on production in the near future is potentially serious. In the intermediate run, however, we anticipate that adequate fertilizer supplies are likely to be available and that the major task will be to encourage increased use of fertilizer other than through higher food grain prices. The redirection of rice research toward the goal of greater efficiency in fertilizer use, and the continued emphasis on research in areas such as pest and disease resistance, water management, and drought tolerance will lead to more efficient use of available supplies and enhance the demand for fertilizer.

* Prepared by staff members of the International Rice Research Institute in response to request from TAC for a statement indicating "the extent to which the shortage and high price of fertilizer and other inputs based on fossil fuels would affect the spread and effectiveness of the technology being developed and recommended" by IRRI, June 1974.

The Fertilizer Problem

There are two sides to the fertilizer issue - the availability of supplies and producer demand. These must be viewed simultaneously and in time perspective. It seems most appropriate to divide our time horizon into three periods - short, intermediate, and long run. Of the three major soil nutrients (nitrogen, phosphorous, and potassium) nitrogen is pethaps the most critical element and the one most seriously affected by the current shortage.

In the short run - the next two to three years - Asia will experience a critical shortage of nitrogen fertilizer. In the intermediate period - 5 to 15 years in the future - we will continue to be very dependent on nitrogen fertilizer to meet added food grain requirements, and fertilizer will continue to be produced largely through conversion of fossil fuels. But whether the lack of fertilizer supply or the lack of producer demand will be the major constraint to food production in this period is open to question, and is likely to be first one and then the other. In order to feed the increased population, it will be necessary to increase the demand and hence the use of fertilizer through measures other than higher food prices.

Fifteen to 20 years from now we may begin to see either a shift away from the use of fossil fuels for nitrogen production, or a major breakthrough in nitrogen fixation research which enables plants to assimilate a higher level of nitrogen through natural processes. These long run changes are mere speculation at this stage, however. Hence, we will focus our remarks on the short and intermediate run issues.

The Current Situation

Deteriorating fertilizer conditions[1/]

Between 1965 and 1971 consumption of fertilizer nutrients grew by 16.6 percent annually in Asia, while worldwide consumption grew 8.8 percent annually. But world production capacity grew at an even more rapid rate with the result that prices for most types of fertilizer declined steadily throughout the period. In the developing world, particularly Asia, new nitrogen plant capacity outpaced demand. But because plants operated at only 60 percent of capacity, developing countries in Asia imported 40 percent of their nitrogen requirements from the developed countries. Japan became the major supplier of nitrogen fertilizers to the rice growing countries of South and Southeast Asia.

Declining prices for fertilizer, the increasing costs for pollution control, feedstock, and freight rates, reduced profit margins and caused Japan and most other developed countries to curtain their expansion in nitrogen plant capacity in the late 1960's and early 1970's. The realignment of world currencies also affected the competitive position of the Japanese fertilizer industry in the world market and led to an initial rise of about 30 percent in Asian nitrogen prices in 1972.

There was still no immediate sign of a shortage in nitrogen supplies although it was pointed out that the world could be facing

- - - -

1/ One of the major sources of information on world fertilizer is the Tennessee Valley Authority. Much of the data contained in this section is based on the reports of this organization and its staff (c.f. Stangel 1973, TVA, 1972).

a worldwide shortage by 1976 if investment was not made immediately in new plant capacity (Stangel 1972).

The sharp rise in food and feed grain prices in 1973 led to an increased demand for fertilizer and by midyear Asian prices of urea and ammonium sulphate had doubled over the previous year (Figure 1). At the same time the energy crisis reduced the availability and raised the price of the feedstock that is the basic ingredients of nitrogen fertilizer. As a result many fertilizer plants were forced to reduce their output. By the second quarter of 1974 the price of urea was at $220 per metric ton and Asian importers were having difficulty finding supplies.

Tracing through these events, we can conclude that the energy crisis was only one of several events leading to the fertilizer shortage. Furthermore, the fertilizer industry appears to be highly cyclical, experiencing periods of both over and cruder production. But for the immediate future, as developed countries protect their own supplies and exporters sell to the highest bidder, the developing Asian countries will have difficulty securing adequate amounts of feedstock and fertilizer. In light of the uncertain situation our estimate of the shortfall in fertilizer production and imports to Asia is highly tentative. But it may reach as high as 1 million tons or 25 percent of Asia's estimated 1973/74 use.

Effects of the fertilizer shortage on Asian rice production

Given a reduction of this magnitude in fertilizer availability, its impact can be traced by estimating the agronomic response under farm conditions and the present level of use of fertilizer on rice.

Considerable data are available describing the response of modern rice varieties to fertilizer under experimental conditions. Extreme year-to-year variability and distinct seasonal differences with greater response during the dry season are apparent from these data.

Response to fertilizer under farmers' conditions is more difficult to obtain, but we have analyzed some data from a cooperative study involving economists from 14 different rice growing areas in Asia. Response data from that study are summarized in Table 1. The villages are grouped into three sets on the basis of the range in application rates of nitrogen within the village: 0 to 60; 30 to 90 and 50 to 190 kg/ha of nitrogen.

An examination of these sets of experimental and farm survey suggests that data response curves appropriate to a number of situations may be approximated by those shown in Figure 2. Dry season response is steeper and continues to higher rates of fertilizer than in the wet season. Advanced farmers cannot match the experiment station yield response, but they can get substantially better performance than average farmers. The latter group get good enough performance from the modern varieties to induce them to use substantially higher rates of fertilizer than on traditional varieties.

The explanation for these differences lies in the environment, cultural practices and complementary inputs that are very different for the three situations. High response to fertilizer is observed on experiment stations because the complementary inputs and practices are supplied at yield maximizing rates. Under farm conditions, however, we do not observe such high fertilizer response rates because control over water, weeds, insects, diseases, rodents, and cultural practices are not at the high level demanded for maximum yields. It is also likely that experiment stations are located on land well suited to rice production, while rice farmers have widely variable land qualities.

On the basis of this evidence, we conclude that the average yield response to fertilizer applied to modern varieties of rice by farmers in Asia is highly variable, but that it probably is between 10 and 15 kg of grain per kg of fertilizer. Theoretically, the marginal yield response is lower than the average at near optimal use and higher than the average at low rates of use, but we believe that the marginal and average responses are similar enough under current Asian conditions that we need not distinguish between the two.

There are no firm statistics on the amount of fertilizer currently applied to rice in Asia. Before 1966, almost none was used on rice but the new varieties have changed that. Rates of application are still relatively low on traditional varieties while on the average modern varieties receive substantial amounts. In order to estimate the effect of a reduction in fertilizer on rice production we need some estimate of current use so we have made two alternative assumptions to derive such an estimate.

Assumption 1 is that all of the increased fertilizer used in Asia between 1960-66 and 1970-71 is allocated to the land planted to modern fertilizer responsive cereals.[1/] This sets an upper limit on the current rate of use. Assumption 2 is that 40 kg/ha of N is applied to modern varieties of cereals. This follows from the Philippine national data and our guesses of what average farmers are doing.

Between 1960-66 and 1970-71 nitrogen fertilizer use increased by 1.6 million metric tons in the 11 major non-communist Asian rice growing countries (Table 2). In 1970-71, those countries had 23 million has. planted to MV cereals, and 10 million has in MV rice, all of which represented an increase since 1966. Under assumption 1, an equal per hectare distribution of the increased fertilizer on the MV area implies a rate of 70 kg/ha of N. However, for several individual countries, especially Malaysia, Sri Lanka, and Thailand, this procedure results in rates of N which are obviously too high, clearly overestimating the rate of application. Hence, the estimated impact of the fertilizer reduction based on this assumption is overstated.

If the fertilizer export reduction to Asia is indeed 1 million tons of N, the most pessimistic view, and if all this is absorbed in the cereals sector, again the most pessimistic view, rates of use on modern rice varieties would drop from 70 kg/ha of N (under assumption 1) to 50 kg/ha of N. At a response rate of 15 kg grain

---

1/ Because modern varieties of wheat, maize, sorghum and millets also are being increasingly grown in Asia with fertilizer, we have taken these into account in countries where they are important.

per kg of N, this implies a reduction in rice yields of 300 kg/ha, or a total reduction of 4.5 million m.t. (Table 3). Smaller reductions in fertilizer exports would result in smaller production losses. Under assumption 2, roughly half as much fertilizer is currently being used on rice, so the impact of a given shortfall would be proportionately less as shown in the last section of the table.

Under the most pessimistic combination of assumptions, a reduction of 25% in nitrogen availability would lead to a 2.2 percent reduction in rice production. Less pessimistic assumptions imply a smaller shortage. For example, if present rates of use are 40 kg/ha of N a 1 million ton cutback amounting to a 25 percent in use rates implies a 1.1 percent reduction in rice output. Lower response rates would imply an even smaller reduction.

It should be stressed however, that a 2.2 percent reduction in Asian rice output would have serious implications for many people, especially the very poor. In fact, in order to completely fill the distribution channels depleted in 1972 and 1973, production in 1974 will have to increase by about 5 percent over the 1973 production level. The likelihood of that increase depends as much on the weather being "normal" as on the availability of fertilizer.

Differential effect by region or size

The above analysis considers only the aggregate production effect, and assumes a constant rate of response under all conditions. The likely reduction in output will also vary by country. Burma, Thailand, Bangladesh, and other areas where modern varieties have not been widely grown will not be much affected, while the Philippines ,

parts of India and Indonesia and other areas where modern varieties have been increasingly used could suffer more. In addition, there will be differences between locations and farmers partly dependent on their present levels of use. In the context of Figure 2, one can differentiate between farmers operating at low levels with rather high marginal rates of response from farmers operating at high levels of input with low marginal rates of response. If both high use and low use areas (farmers) suffer the same absolute reduction in fertilizer available, then the reduction in grain output will be greater for those beginning from a lower level, because they are operating where the response is steeper.

Commenting on this Timmer says, "wealthier farmers (and countries) are higher up their response functions than are their poorer counterparts and will be better able to maintain their fertilization levels at higher prices. The fertilizer shortage will thus hit the poor farmer and nations with high physical response rates relatively harder. The resulting grain deficit will be greater than it would be under arrangements for more equitable distribution of available fertilizer supplies." (Timmer, 1974) Within countries governments may take some action to insure greater equity, but such actions are unlikely to change the estimates made above.

The spread of new rice technology

While the evidence is clear that modern rice varieties are highly responsive to fertilizer application, it seems equally clear that the acute reversal in fertilizer price and availability is likely to have relatively little effect on the spread of new rice varieties. This

follows from three observations: (1) the modern varieties that embody the new technology give at least the same yield as previously used varieties even without fertilizer; (2) present fertilizer levels used on the modern varieties are relatively low, although in most areas they are higher than levels used on traditional varieties; and (3) the major factors restricting the further spread of the available new varieties are their adaptability to various environmental factors and their resistance to important insects and diseases.

Table 4 shows comparable yields of new and old varieties grown without nitrogen fertilizer in experiments carried out over a number of years at 4 locations in the Philippines. In all locations the modern varieties gave higher yields than the traditional variety even with no added nitrogen. In the Philippines one-third of the farmers growing modern varieties in 1969-1970 used no fertilizer in the wet season and obtained slightly higher yields than farmers who grew traditional varieties. In the dry season over two-fifths of those growing modern varieties used no fertilizer and obtained yields .26 t/ha higher than farmers growing traditional varieties (Atkinson, 1973).

In the study of 36 "progressive" Asian rice villages that had over 90 percent of their riceland in modern varieties, farmers used an average 75 kg/ha of nitrogen on modern varieties and 50 to 80 percent as much fertilizer on traditional varieties. But as shown earlier, if even 10 kg/ha of nitrogen fertilizer is applied on traditional rice varieties throughout Asia, then the maximum amount available for the modern varieties is only 40 kg/ha of nitrogen.

We believe that the average rate actually used is somewhat lower than that.

From this evidence it is apparent that farmers do not consider fertilizer a necessary input to be used with modern varieties. In fact over the next 5 to 10 years the problem will likely be one of encouraging farmers to use more fertilizer on their rice in order to keep production increasing as rapidly as population.

It has often been observed that the modern varieties of rice have been more rapidly accepted where irrigation is available than where it is not. In fact, quality of irrigation was found to be a major factor affecting both the proportion of land devoted to modern varieties and the level of fertilizer applied in the 36 village study. Farmers were also asked to identify the main factors preventing them from obtaining higher yields with the modern varieties. The results, reported in Table 5, show that diseases, insects and pests are the major problem perceived by those farmers, and that these were considered serious more than twice as often on modern varieties than on traditional varieties. We believe these factors are more influential than fertilizer in the adoption of modern varieties, and these factors are receiving increasing attention from IRRI.

Implications for the Future

Fertilizer and Food in the late '70s

What can we expect in four or five years? Will fertilizer continue to be in short supply? Will the demand picture change? The critical issue here is that both the supply of and demand for fertilizer must expand if we are to produce the abundant food supplies needed for economic development.

The supply picture for the intermediate period is somewhat confused and in a state of flux. At a recent conference on fertilizer sponsored by the World Bank and the Agricultural Development Council participants differed widely in their view with respect to the elasticity of expansion in fertilizer supply. While many anticipate that new fertilizer plants will spring up in the Middle East at the source of surplus natural gas, the Middle East countries have to date shown very little interest. However, the Canadians have within the last few months committed a major expansion in nitrogen plant capacity.

It is our view that the fertilizer industry is fairly elastic in the intermediate run, and that there will be adequate supplies of nitrogen available in the late 1970s, although not at the extremely low prices experienced in 1970.

What is of equal if not more pressing concern is the demand picture for fertilizer. Many observers tend to feel that Green Revolution is loosing some of its steam and that we are reaching the limits in terms of the spread of new varieties of rice and wheat.

Taken together, the supply and demand issues with respect to fertilizer have important implications for the direction of rice research.

Changes in Rice Research

The shortage of fertilizer supply at present (and possibly in the more distant future) dictates that rice scientists turn more attention to the efficiency of fertilizer use. As indicated above, research results show that the present use of fertilizer and yield

response to fertilizer on farmers' fields is frequently disappointing and considerably below experimental results. The opportunity for more efficient use of fertilizer through measures such as better weed control, better water management, and better cultural practices is very great.

While yield response to fertilizer within a village is often disappointingly small, the aggregate close linkage between high yields and high levels of fertilizer input has been established by national statistics and by surveys in agricultural economics. Economists and agronomists are working to identify more clearly the factors that limit yields and the use of fertilizer on farmers fields.

Agricultural scientists at IRRI have turned their attention to other ways in which fertilizer can be used more efficiently. Agronomists are working on ways to place fertilizer so that less will be required to achieve the same yield level. Soil scientists are examining the varietal difference in tolerance to low levels of nitrogen and phosphorous. In total, there is greater focus on the low and of the fertilizer response function where most Asian farmers now operate.

The above measures will help to achieve a more efficient use of limited supplies of fertilizer. Realistically speaking, however, this research will have an impact, not immediately, but over the intermediate period. If our prognostication is correct, in this period the world will: (1) continue to depend upon nitrogen

fertilizer as a major input for added food production, (2) be able to obtain adequate supplies of fertilizer. Therefore, we must continue a focus on research that achieves a higher efficiency in the use of fertilizer and as a result enhances the rice farmers' demand for fertilizer.

REFERENCES

Atkinson, 1973: L.J. Atkinson and David E. Kunkel, Some Exploratory Notes on the Nature of the Green Revolution in the Philippines, Project ADAM working paper No. 2, BAEcon-DANR, UPCA and ERS-USDA.

Anden, 1973: Teresa Anden and Randolph Barker, Changes in Rice Farming in Selected Areas of Asia, IRRI Saturday Seminar, December 1.

Dalrymple, 1972: Dana G. Dalrymple, Imports and Plantings of High-yielding Varieties of Wheat and Rice in the Less Developed Nations. USDA Foreign Economic Development Report 14.

FAO, 1970: Food and Agricultural Organization of the United Nations, Trade Yearbook.

FAO, 1971: Agricultural Commodity Projections, 1970-1 80, Volume 2.

FAO, 1972: Production Yearbook

IRRI, 1973: International Rice Research Institute, Annual Report for 1972, Los Baños, Philippines

Stangel, 1972: Paul J. Stangel, "Fertilizer Industry Development Policy," consultant reports to the Philippine Government (mimeo), Report No. 1

Stangel, 1973: Paul J. Stangel, "Summary, World Fertilizer Situation and Its Effects on Indonesia," USAID/TVA, Djakarta.

Timmer, 1974: C. Peter Timmer, "The Demand for Fertilizer in Developing Countries," Stanford Rice Project Working Paper No. 5, April, 1974. Food Research Institute, Stanford University.

TVA, 1972: Tennessee Valley Authority, "Estimated World Fertilizer Production Capacity," Muscle Shaoals.

Table 1. Yield increase from nitrogen calculated from response curves fitted to farm date, selected Asian rice growing villages, 1971/72

	Wet Season			Dry Season		
	No. of villages	Range of N	kg grain/ kg N	No. of villages	Range of N	kg grain/ kg N
Low N (0-60)						
High response	3	0-60	25	2	0.60	35
Low response	2	0-60	10	1	0.40	12
Moderate N (30-100)						
High response	0	-	-	0	-	-
Low response	3	30-70	14	2	30-80	10
High N (50-190)						
High response	1	50-130	16	2	50-150	25
Low response	3	50-130	4	2	50-150	9

Table 2. Fertilizer consumption and area planted to modern rice varieties (MV) in Asia, selected years.

	Nitrogen fertilizer consumed ('000 m.t.) 1960-66	1970-71	Rate of N per ha if all increase used on MV cereals	Area in MV 1970/71 ('000 ha)
		(kg/ha)		
Bangladesh	30	63	72	460
Burma	5	21	80	200
India-rice[a/]				5500[c/]
all cereals[a/]	480	1497	66	(15387)
Indonesia	75	181	113	932
Malaysia (W)	28	61	250	132
Nepal	b/	5	73	68
Pakistan - rice[a/]				626
all cereals[a/]	75	299	63	(3575)
Philippines	53	104	32	1565
Sri Lanka	38	60	733	30
Thailand	17	51	209	162
Vietnam (S)	31	97	131	502
Total	832	2439	70	10231[c/] (23067)

Sources: Fertilizer use data from FAO Production Yearbooks, various years, Area in MV 1970/71 from (Dalrymple, 1972), others as noted in footnotes.

a/ For columns referring to crops.
b/ Less than 1.0
c/ Rice total

Table 3. Impact of alternative fertilizer projections on Asian rice production in 1974/74 a/

	Assumed reduction in N available (million m.t.)	Percentage reduction in N	New rate of N kg/ha	Reduction in rice	
				(million m.t.)	(%)
If 1970/71 rate of N on modern varieties was 70 kg/ha	1.0	25.6	50	4.50	2.2
	0.5	16.8	60	2.25	1.1
	0.3	7.6	65	1.35	0.7
If 1970/71 rate of N on modern varieties was 45 kg/ha	1.0	25.6	30	2.25	1.1
	0.5	12.8	35	-1.13	0.6
	0.3	7.6	37	0.70	0.3

Table 4. Yields of a traditional variety and two modern varieti grown without nitrogen fertilizer at IRRI and three Philippine government rice stations.

Wet Season	All Stations		
	Peta a/	IR8	IR20
1968	3.6	4.0	3.8
1969	3.6	4.8	4.7
1970	2.3	3.5	3.7
1971	3.0	3.3	3.4
1972	3.3	3.6	3.7
Avg	3.2	3.8	3.9

a/ Representative of the best of the varieties available before 1965.

Table 5. Proportion of farmers reporting various factors as major constraints to yields, 31 Asian rice growing villages, 1971/72

Constraint	Before the introduction of modern varieties	During the survey year
Irrigation	23	26
Obtaining fertilizer/ chemicals	24	30
Obtaining credit	19	25
Obtaining modern variety seed	14	15
Diseases, insects, pests		
MV, wet season	na	71
TV, wet season	51	33
MV, dry season	na	61
TV, dry season	na	33

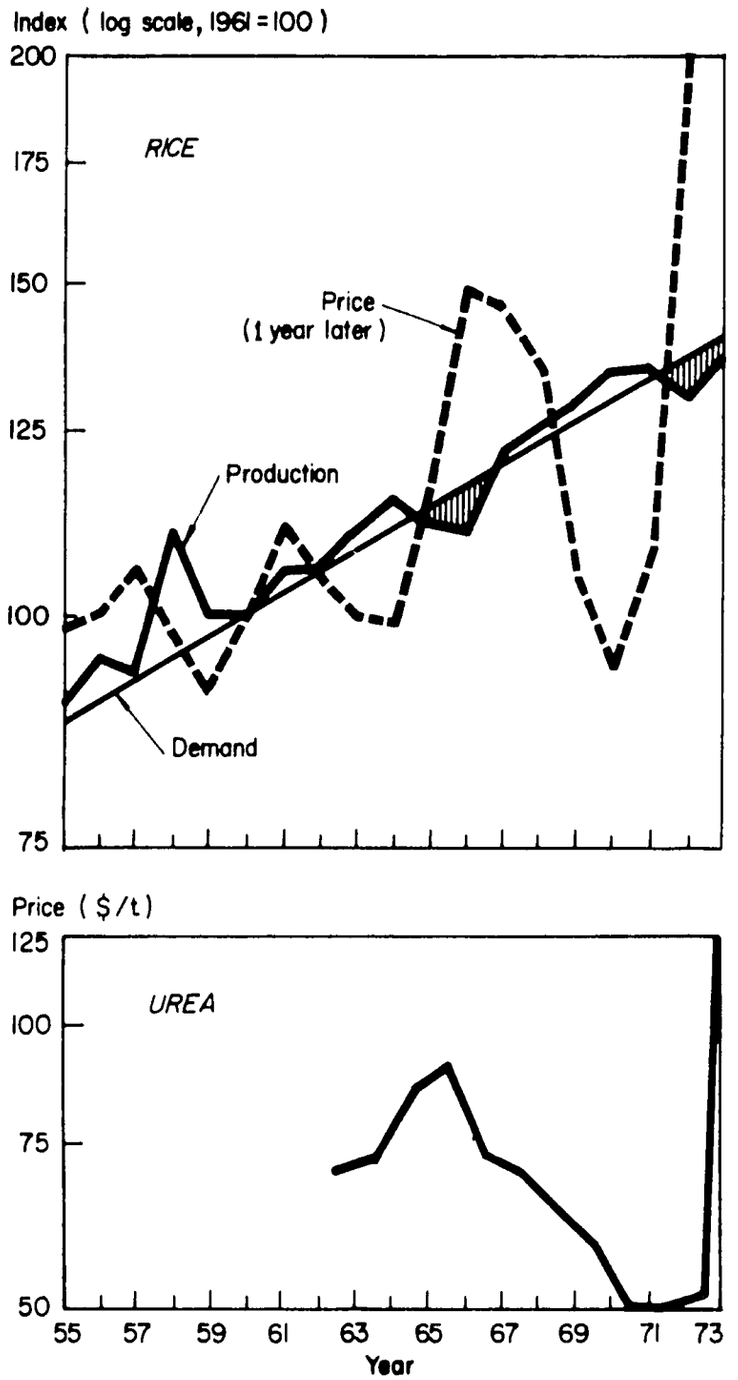

Fig. 1. World demand, production, and lagged price of rice.

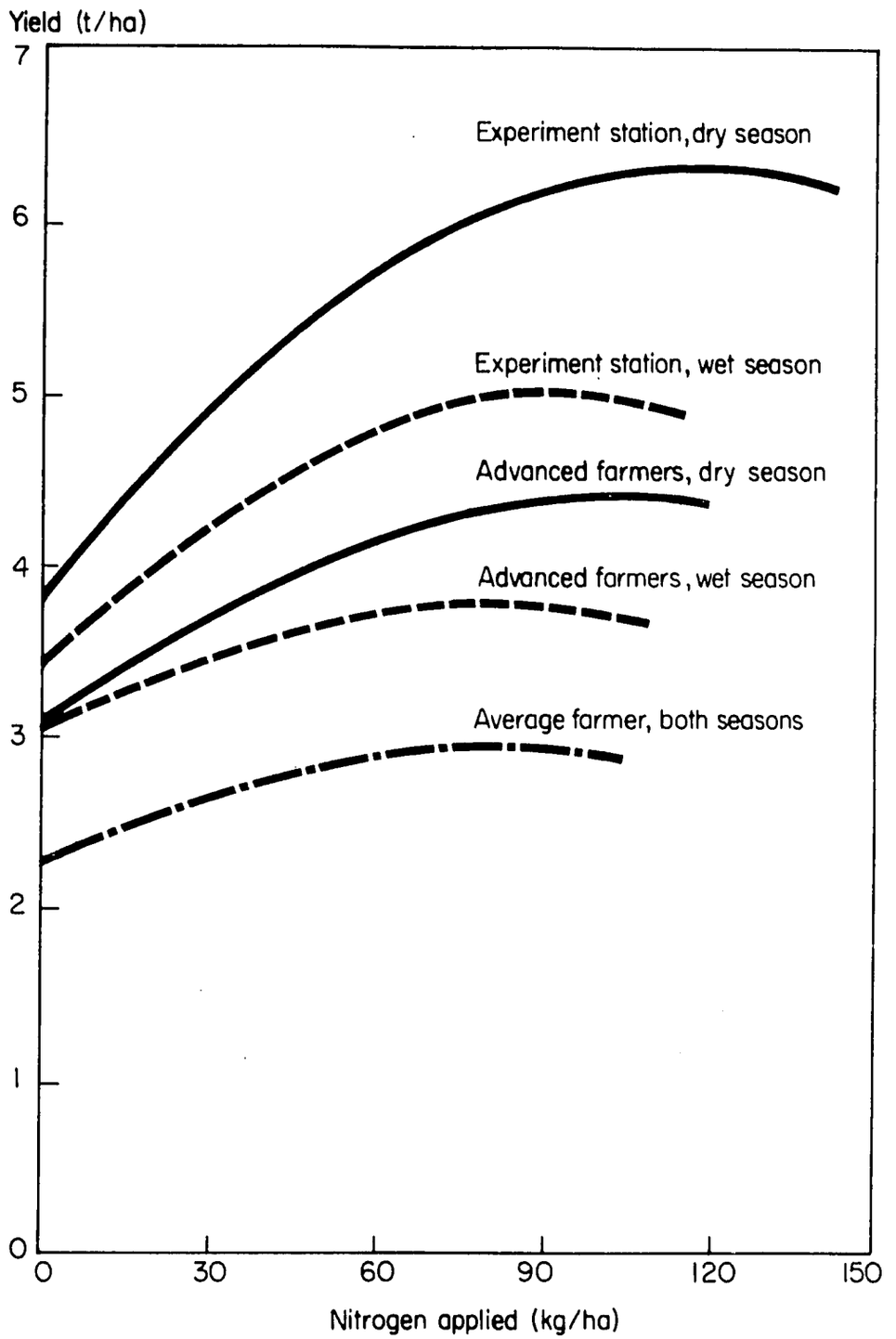

Figure 2. Representative nitrogen response curves for modern varieties of rice in the Philippines.