PB-219 713

AGRONOMIC PRACTICES FOR OPTIMIZING THE YIELD POTENTIAL OF SHORT-STATURED RICE VARIETIES IN LATIN AMERICA

Pedro A. Sanches

North Carolina State University

Prepared for:

Agency for International Development

October 1971

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PB 219 713

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BIBLIOGRAPHIC DATA SHEET	1. Report No. LAT-633.18-S211	2.	3. Recipient's Accession No. PB-219 713
4. Title and Subtitle "Agronomic Practices for Optimizing the Yield Potential of Short-Statured Rice Varieties in Latin America".			5. Report Date October [redacted], 1971
			6.
7. Author(s) Pedro A. Sanchez.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address North Carolina State Univ~~ersity~~. Soil Science Department. ~~Raleigh, N.C. 27607~~			10. Project/Task/Work Unit No. Proj. 931-17-120-525
			11. Contract/Grant No. AID/CSD-2806
12. Sponsoring Organization Name and Address Department of State Agency for International Development Washington, D.C. 20523			13. Type of Report & Period Covered Research paper 6/70-11/71
			14.

15. Supplementary Notes

Presented at the Seminar on Rice Policies in Latin America, Cali, Columbia, Oct.11, 1971.

16. Abstracts

The purpose of this paper is to illustrate the varietal response to specific cultural practices as examples of the kind of information needed for optimizing yields in each rice growing area in Latin American countries. Time of planting in relation to weather patterns is discussed for upland rice and irrigated rice. Planting systems, seed density and spacing are explained for upland rice systems, direct seeded-irrigated systems, and transplanted systems. Nitrogen response and response to other nutrients are described under rice fertilization. Weed control and harvest timing are included as important cultural practices. Examples of cultural practices interactions, total production costs and revenues and the effects of nitrogen levels are provided under economic considerations. The author concludes that the possibility of increasing rice yields throughout the different cropping systems in Latin America seem excellent if proper agronomic practices are adopted.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

*Rice, *Crop yields

17c. COSATI Field/Group 633

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 47
	20. Security Class (This Page UNCLASSIFIED	22. Price $5.00

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

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Presented at the Seminar on Rice Policies for Latin America

Centro Internacional de Agricultura Tropical

Cali, Colombia

October 11, 1971

Pedro A. Sanchez

Soil Science Department

North Carolina State University

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AGRONOMIC PRACTICES FOR OPTIMIZING THE YIELD POTENTIAL OF SHORT-STATURED RICE VARIETIES IN LATIN AMERICA [1/]

Pedro A. Sanchez [2/]

The drastic change in the architecture of the rice plant accomplished by the International Rice Research Institute in 1966 revolutionized rice production all over the world. In the Latin American tropics, several short-statured rice varieties are now extensively cultivated in several countries. The change from tall, lodging susceptible, low grain:straw ratio varieties to short, lodging resistant, high grain:straw ratio types such as IR8 has increased rice yields substantially at the farm level. When farmers manage the new varieties as the old ones, sometimes they get very limited yield increases or none at all. In order to maximize yields and profits of the new varieties, different cultural practices must be applied, some of which require further investments and more precise timing. The purpose of this paper is to illustrate the varietal response to specific cultural practices as examples of the kind of information needed for optimizing yields in each rice growing area.

[1/] Paper presented at the Seminar on Rice Policies in Latin America, Centro Internacional de Agricultura Tropical, Cali, Colombia, October 11, 1971.

[2/] Assistant Professor, Soil Science Department, North Carolina State University at Raleigh and former Coleader, National Rice Program of Peru.

In tropical Latin America, rice is the third food crop consumed in larger quantities after yuca and corn, according to calculations from an FAO report (FAO, 1965). Over 75 percent of Latin America's rice is produced under upland (secano) conditions characterized by direct seeding and rainfall dependency (Brown, 1969). About 21 percent of the total rice area is direct seeded and irrigated (Table 1). Transplanting is practiced on the remaining 4 percent (about 235,000 ha.) including over 60 percent of Peru, the Dominican Republic and Surinam, and significant proportions of Ecuador and Venezuela. With over 5 million hectares in production, Latin America's average rice yields are 1.72 tons/ha or slightly below the world average of 2 tons/ha. National average yields range from 1.1 to 4.1 tons/ha.

1. TIME OF PLANTING IN RELATION TO WEATHER PATTERNS

Rice is very sensitive to mositure stress, solar radiation and low temperatures. While there is very little man can do to modify climate, he can subject his rice crop to the best probable weather pattern by planting at the optimum time for a particular area.

1.1 Upland rice and rainfall distribution.

Total rainfall and its distribution during crop growth is probably the most important limiting factor affecting upland rice production. For reasons which are not yet understood, it is known that rice plants suffer from moisture stress at higher soil moisture contents than other crops (Jana and DeDatta, 1971). Upland rice is grown in areas and during seasons of high rainfall since the crop is completely rainfall dependent. These areas usually have at least 200 mm. of monthly rainfall during the growing season (Brown, 1969; Kawano, et al., 1971). The performance of IR4-2, a short-statured variety and Carolino, a tall

local, variety are compared during a two year period under upland conditions in Yurimaguas, Peru (Fig. 1). This figure shows that when the monthly rainfall distribution was adequate, such as in the September and November plantings,IR4-2 produced between 4 and 6 tons/ha while Carolino produced between 2 and 3 tons/ha. During periods of worse rainfall distribution (May and June plantings), IR4-2 yielded about 1 ton/ha and Carolino about 0.5. This figure shows how closely upland rice yields follow the rainfall pattern and that in all cases, the yield of the improved plant type was about double that of the conventional variety. Both varieties were grown under identical conditions but the short-statured plants produced more tillers, more grain in relation to straw and resisted lodging. It is interesting to note that although the short-statured plant types were developed under irrigated, transplanted conditions, they are also superior under upland conditions (Nureña et al., 1970; DeDatta and Beachell, 1971). The new varieties, however, must have at least moderate tolerance to the rice blast disease and other important pests before they can successfully compete with the traditional plant types.

1.2 Irrigated rice and solar radiation.

In hot, tropical areas the main climatic factor associated with flooded rice performance is the amount of solar energy received during the reproductive phase of rice growth (DeDatta and Zarate, 1970). Solar radiation levels approach their maximum during clear cloudless days, and are directly related with photosynthetic activity and nitrogen response. Figure 2 shows the performance of IR8 and H4, a tall, lodging-susceptible variety at different planting dates and at two levels of nitrogen application in an experiment conducted in the Philippines under constantly flooded conditions. As in the previous case, the yields of the short-statured plant type were substantially superior to H4's. Under these conditions,

maximum yields were obtained when solar radiation values during the reproductive period were highest, which occurred when the crops flowered during the peak of the dry season. At low levels of nitrogen fertilization (30 kg N/ha), H4 produced higher yields than at 120 kg N/ha, because this type of plant responds to added N by increasing its foliar area, causing mutual shading of leaves, eventually lodging and subsequent yield losses. Lodging-resistant varieties like IR8 can effectively combine the added nitrogen with the increased photosynthates produced under high solar radiation, resulting in tillering, more panicles and therefore higher yields. This figure also indicated that in order to obtain maximum yields with the new varieties, they should be fertilized at higher rates.

1.3 Growth duration and low temperatures.

It has been recently recognized that low temperatures can be limiting to rice growth in the tropics as this crop usually suffers when the mean monthly temperatures fall below 20-21°C. In the Coast of Peru, the nearby Humboldt Current causes temperature decreases sufficient to produce spiklet sterility at the flowering stage. The traditional tall-statured varieties like Minabir and Mochica, although higher yielding than other similar plant types, have the disadvantage of being very late maturing. A trial consisting of two planting dates was conducted for two years at Lambayeque, Peru (Fig. 3). The 1966-67 growing season had a normal temperature regime during which the Mochica variety produced 7.16 tons/ha when it flowered in late April, but when flowering was delayed by about 3 weeks and the temperatures dropped, the yield was reduced by 3.55 ton/ha. The following year, 1967-68, temperatures began to drop earlier. The first planting date of Mochica flowered at almost the same date as in the previous year but produced 3.50 tons/ha; the second planting data flowered at extremely low temperatures and produced 0.47

tons/ha. The IR8 variety, introduced during that year, was planted at the same time as Mochica. Being earlier maturing, IR8 flowered 30 to 45 days before Mochica, avoiding the low temperature periods and producing 5.9 and 5.4 tons/ha at the two planting dates. The advantage of the new plant types in this situation is earlier maturity in relation to the conventional varieties, since IR8 is not resistant to low temperatures. The new varieties are not necessarily earlier maturing but when they are, they possess an additional advantage which has proven to be crucial and partially responsible for attaining rice self sufficiency in the case of Peru.

The new short-statured plant types, just like the old ones, must be synchronized with the weather through proper planting dates as much as possible. Unlike the traditional plant types, the new ones can maximize the climate advantages or reduce risks of weather-induced production decreases.

2. PLANTING SYSTEMS, SEED DENSITY AND SPACING.

2.1 Upland rice systems.

In the most primitive upland rice areas, the crop is planted with a stick, dropping several seeds in holes irregularily spaced at an average of 50 cms between holes. The use of machinery is limited by the abundant tree stumps and fallen branches. Experiments have shown that closing the spacing between holes to 25 x 25 cms, increased yields substantially (Fig. 4). Although this effect was beneficial in both the short-statured IR578-8 and the tall-statured Carolino varieties, the combination of closer spacing and a short-statured variety quadrupled yields obtained by the conventional variety and cultural practice (Nureña, 1971).

In upland rice areas where mechanized planting is possible, most of the fields observed by this writer are drilled in very widely spaced rows (40-70 cms apart). Figure 4 also shows that closing the spacing from 50 to 25 cms is highly beneficial for this planting system. Closer spacing also decreases weed competition and increases harvest uniformity. In some areas, however, it is believed that closer spacing increases the incidence of the rice blast disease caused by Pyricularia oryzae, because of a more humid microclimate. Two uniform seed density-spacing experiments conducted at Yurimaguas in the presence and absence of blast disease attacks showed that these factors had no effect on the intensity of attack (Sanchez and Nureña, 1970).

Several seeding density experiments conducted on upland rice in Peru, (Salhuana and Sanchez, 1969; Sanchez and Nureña, 1970; Velez, 1970; Nureña, 1971; Zumaeta and Barba, 1971) show very little effects of seed density on yields within a range of 25 to 100 kg/ha. Local experience is usually the best guideline. Tillering ability tends to compensate initial seed density effects. Excessive amounts of seeds per hole in the primitive upland areas definitely decreases yields being 5 to 10 seeds the optimum for conditions at Yurimaguas, Peru (Nureña, 1971).

2.2 Direct seeded-irrigated systems.

Direct seeded-irrigated rice is planted in various ways in Latin America: it is drilled in rows by hand or by tractor; dry seeds are broadcast incorporated in dry soil; and pregerminated seeds are broadcast on flooded soils, usually by airplane. In all cases, the objectives are the same: to produce an optimum number of panicles/m^2 and avoid mutual shading. The tillering ability of the variety, its height, nitrogen and solar radiation levels are the main factors affecting this optimum.

Seed density experiments conducted in Brazil, Peru and Colombia have shown little influence of this variable on yields within a wide range of 60 to 200 kg/ha, both for tall varieties (Gomes and Miranda, 1963; Salhuana and Sanchez, 1969) and short varieties (Caballero and Paredes, 1971; Cheney, 1971; Sanchez and Larrea, 1971). Known adverse conditions such as poor land leveling, seedbed preparation or germination percentage or excessive soil salinity or acidity usually require higher seeding rates. Under most circumstances, tillering ability can compensate for low initial stands, especially with short-statured plant types.

Like in upland rice, spacing is probably the dominant factor. Most direct seeded - irrigated rice fields in Latin America show evidence of wasted space. An experiment conducted in Lambayeque, Peru (Fig. 5) shows large yield increases when spacing between rows was reduced from 33 to 17 cms. in both the short, high tillering IR8 variety and the tall, low tillering SML-Apura. Optimum spacing for a given area is heavily influenced by solar radiation, nitrogen level and plant type. High solar radiation like in Lambayeque, decreases the height of all rice plants and permits maximum utilization of light by closer spacing. High nitrogen rates increase leaf area and in cases of tall statured plant types, this can cause mutual shading and lodging. In general, tall leafy varieties require wider spacing than short ones with erect leaves.

The differences between planting systems for direct seeded rice are small under controlled conditions. The choice usually depends on field and water management characteristics and available equipment. Table 2 shows the performance of a short and a tall variety subjected to seven different planting methods in Lambayeque, Peru. No yield differences were observed between drilling in 17 cm rows and broadcasting on dry or flooded soils. Yields of the short statured variety were reduced when

spacing was increased to 25 cms between rows, while this practice definitely benefited the tall variety.

2.3 Transplanted Systems.

Table 2 also shows that properly managed direct seeded systems can perform as well as transplanted rice at comparable spacings. Similar evidence has been found by Adair et al., 1943; IRRI, 1966 and Sanchez and Larrea, 1971. Nevertheless, transplanting is practiced in over 67 percent of the world's rice area and in important sections of Latin America. Several factors traditionally favor transplanting in these areas, such as a better synchronization between water supply and the growth of late maturing varieties, the need to puddle the soil to control weeds and reduce water losses, poor land leveling, salinity conditions etc... Under such conditions, direct seeding cannot outperform transplanting in spite of its lower labor costs, until these limitations are eliminated.

One of the most critical practices affecting the yields of transplanted rice is the age of seedlings at the time they are transplanted. A review of the literature by Larrea and Sanchez, (1971a) indicated that tropical rice farmers transplant traditional varieties between 25 and 120 days after seeding although experimental evidence indicates that optimum results were obtained between 30 and 45 days. The main reason for delaying transplanting is the erratic distribution of water supply in over 75 percent of the world's transplanted acreage. A series of studies conducted in Peru showed sharp yield decreases with delays beyond 30 to 45 days irrespective of seedbed management (Larrea and Sanchez, 1971a,b; Gavidia and Ventura, 1971; Vergara, 1971). Figure 6 shows the average behavior of four locations. IR8 yields decreased by an average of 92 kg/ha per day of transplanting delay while the traditional Minabir variety decreased at the rate of 52

kg/ha per day. It is significant to note that although IR8 is more sensitive to these delays, its yields were always higher than Minabir's.

The differential response to transplanting densities in contrasting plant types is illustrated in Fig. 7 adapted from unpublished data of Gavidia and Saavedra (1971). While the tall, heavy tillering Minabir variety performs best at low transplanting densities, the short, high tillering IR8 performs best at higher densities. Of the two density components, spacing between hills has greater influence than the number of seedlings per hill. The interaction between transplanting spacing and nitrogen fertilization is shown in Table 3. While very little yield differences were observed at low N levels and wide spacings, the effects of plant type are large at high N levels and close spacings.

3. RICE FERTILIZATION

3.1 Nitrogen response and management.

Probably no other cultural practice affects the performance of short-statured rice varieties more decisively than nitrogen fertilization. Since this subject has been recently reviewed (Sanchez, 1971), only the highlights will be discussed in this section. The average response in ten experiments conducted during three years under transplanted, intermittently flooded conditions at Lambayeque, Peru appear in Figure 3. While both plant types yielded similarly at zero or low N levels, IR8 responded positively to increased applications, doubling the yields of check plot at the highest level. The tall-statured Minabir variety responded positively to about 150 kg N/ha and negatively afterwards, because of lodging and increased incidence of the rice blast disease. The high yields and high nitrogen rates used in this particular location are due to the very high solar radiation levels and high nitrogen losses

caused by alternate flooding and drying. The high yields obtained with Minabir in this Figure are not representative of a farming situation, while the yields of IR8 are closer to what area farmers obtain. In the Magdalena Valley of Colombia, Rosero and Moreno (1970) compared the nitrogen response of IR8 with the tall, low tillering Bluebonnet 50 variety under direct seeded irrigated conditions (Fig. 9). While Bluebonnet showed very small responses, IR8 responded economically to 50 and 100 kg N/ha applications. Under upland conditions in Yurimaguas, Peru, Sanchez and Nureña (1970) obtained positive nitrogen responses with IR4-2 and IR8, while no responses were observed in the two tall traditional varieties (Fig. 10). The wide differences in optimum rates between these three examples are mainly due to differences in solar radiation, water management and soil characteristics. Since there are no adequate soil tests for determining optimum N rates for rice, it is recommended to establish these rates through variety - nitrogen experiments on major soils and seasons in each rice growing region or valley (Sanchez, 1971).

Several factors affect the efficiency of nitrogen fertilizer utilization and thus the economics of this crucial practice. In general, the rice plants recover from 40 to 60 percent of the applied nitrogen under constant flooding but only between 20 and 30 percent under alternate flooding and drying when management practices recommended for constant flooding are applied. Ammoniacal sources such as urea or ammonium sulfate are about equal in efficiency although urea is usually cheaper. Nitrate sources however, are extremely inefficient in rice because of large denitrification and leaching losses under constantly or intermittently flooded conditions. Research conducted in Peru by Ramirez and Sanchez (1971) indicated that 35 to 40 percent of the applied N as urea or ammonium sulfate was recovered while the figure for sodium

nitrate was 7.8 percent (Fig. 11). Experiments are in progress to evaluate the potential of slow release nitrogen fertilizers primarily sulfur-coated ureas. Evidence to date indicates that this source is no better than regular ammoniacal sources under constantly flooded conditions but seems very promising for intermittently flooded or upland conditions.

Another way of synchronizing the nitrogen needs of the plant with an available supply in the soil in the presence of high leaching and denitrification losses is through proper timing of N applications. Under the uncertain water management prevalent in Latin America, applications at seeding or transplanting are very inefficient (Sanchez and Calderon, 1971; Cheney, 1971). Figure 12 shows that when single or split applications of 180 kg N/ha were delayed, the yield response almost doubled. Nitrogen recovery and profits almost doubled also. The effects of timing are extremely influenced by local conditions, and only local research can provide practical answers to farmers.

3.2 Responses to other nutrients.

With the exception of acid, highly leached oxisols or ultisols and volcanic ash soils, rice very seldom responds to nutrients other than nitrogen. No responses to phosphorus and potassium were observed in 38 experiments conducted by Carmen (1968) throughout Peru, in 11 experimemts conducted throughout Colombia by the Programa Nacional de Arroz (ICA, 1970), and in 13 experiments on alluvial soils of the Brazilian Northeast (Vasconcelos and Almeida, 1966). Phosphorus responses are occasional in Rio Grande do Sul, Brazil (Patella, 1962).

Phosphorus responses however, are abundant on upland rice in the Campo Cerrado of Brazil (Miranda and Freire, 1962; Oliveira et al., 1964, 1965, 1966) and the Llanos Orientales of Colombia (Owen, 1970). Miranda and Freire further observed that the response of upland rice to phosphorus

was much smaller than that of corn and cotton in the same localities. Lime applications are of dubious value in flooded rice because the pH tends to increase and equilibrate between 6 and 7 due to reduction reactions. No lime response was observed by Oliveira (1964) in acid soils of Rio Grande do Sul. In the highly acid Llanos Orientales of Colombia, Spain (1971) reports that upland rice responds to moderate lime applications while flooded rice does not.

Secondary and micronutrient disturbances particularly sulfur, zinc and iron, are being increasingly recognized throughout Latin America, especially in the short statured plant types because of their higher yields and nutrient uptake.

4. WEED CONTROL

The high moisture environment of rice soils is excellent for weed development particularily in the absence of constant flooding. The short-statured rice plant types compete less successfully with weeds than the tall, traditional types. Weed competition is considered to reduce yields by 20 percent in rice fields under conventional management (Cárdenas, 1970). Table 4 shows some examples of the performance of the main post and pre-emergence herbicides presently utilized in Latin America. When properly and timely applied (ICA, 1971), weeds are satisfactorily controlled. Optimum herbicide rates for irrigated rice are higher in Latin America than in Asia, for reasons not yet understood. Table 4 also shows that weed control is more difficult in direct seeded than in transplanted systems where rice seedlings have a head start over the weeds. Significant information on weed control in upland rice is lacking in Latin America. Most of the research is limited to control of broad-leaf weeds, but no solution is available for controlling the more vigorous grassy

weeds which tend to dominate after the broadleaves disappear.

5. HARVEST TIMING

In addition to time of planting, transplanting and nitrogen applications, optimum harvest timing can have significant influence not only on yields but on milling quality. An optimum harvest time, in which grain yields are highest and the percent of broken grains lowest, generally exists for each variety under a specific environment. Premature harvests result in lower yields, poor milling recovery due to immature and irregularly shaped grains and high breakage. Overmature harvests often result in lower yields due to grain shattering and higher breakage due to cleavages formed in the endosperm by changes in relative humidity (Stout, 1966). Varieties with chalky endosperm areas like IR8 or with very long, slender grains like the Surinam types are particularily susceptible to harvest timing (Ten Have, 1967). Experiments in several areas of Peru have quantified some of these differences. The tall, high milling quality Minabir variety (Fig. 13), showed very little grain yield response when harvested between 30 and 60 days after 50% flowering. The percent breakage, however, was lowest (8%) at 40 days. In contrast, the short, chalky IR8 variety (Fig. 14) showed a well defined yield peak at 45 days after flowering which coincided with the lowest grain breakage of 22 percent. For reasons not yet understood, IR8 is more sensitive to harvest timing than Minabir. Comparing the two figures, it is worthwhile to note that the total production of head (whole, milled) rice in kg/ha was almost the same when IR8 was harvested at the optimum timing. Larrea and Sanchez (1970) also reported that the short statured variety IR4-93-2 with less chalky areas produced minimum grain breakage percentages identical to Minabir's and a significantly higher head rice yields/ha because of its

superior grain yield. Some of the new short statured plant types currently being introduced in Latin America like CICA-4, IR22 and Naylamp should perform better than IR8 due to their superior milling quality. The same investigators observed very sharp yield declines in a tall variety very susceptible to grain shattering when harvest was delayed. Optimum harvest time can be more accurately specified in terms of grain moisture contents, usually between 19 and 21 percent (Ten Have, 1967; Nangju and DeDatta, 1970; Larrea and Sanchez, 1970) but this measurement is beyond the reach of most tropical rice farmers. Environmental differences can change the optimum harvest time for the same variety. Optimum timing for IR8 is about 45 days after flowering in the cooler Lambayeque and Jequetepeque Valleys of the Peruvian Coast but drops to 25 or 30 days in the hotter Amazon Jungle areas of Iquitos and Yurimaguas (Larrea and Sanchez, 1970; Vergara, 1971; Zumaeta and Barba, 1971; Nureña and Mesía, 1971).

6. COMBINED EFFECTS AND ECONOMIC CONSIDERATIONS

6.1 Examples of cultural practices interactions.

The effects of individual cultural practices on varieties of contrasting plant types have been illustrated in the previous sections. The interaction between different cultural practices, however, are not so evident, except for the combined effects of solar radiation and nitrogen fertilization in Figure 2, transplanting spacing and nitrogen level in Table 3 and weed control-planting systems in Table 4. In certain instances one cultural practice is more limiting than another. Fig. 15 compares the performance of IR8 seeded at different dates and transplanted at different seedling ages. The interaction is present, although the detrimental effects of delaying planting dates had a more decisive influence on yields, because of low temperature induced sterility at

the flowering stage. Fig. 15 also shows that the cultural practices package developed for IR8 and responsible for producing a yield of 11 tons/ha in the November planting had a most detrimental effect when applied to the traditional Minabir variety. When Minabir was grown with its traditional practices (early planting, late transplanting age, wide spacing, 160 kg N/ha applied all at tillering and harvest data at 60 days after flowering) it yielded 6.90 tons/ha. When the recommended practices for IR8 (later planting, earlier transplanting age, close spacing, 300 kg N/ha in split applications and harvest date at 45 days after flowering) were applied on Minabir, it yielded 1.65 tons/ha.

6.2 Total production costs and revenues[1/]

The economic cost of production from an average rice farm in the Lambayeque Valley of Peru, growing the Minabir variety with conventional cultural practices is compared with the average of a 30 ha. field of IR8 in which the recommended cultural practices were applied on a commercial scale (Hernandez, 1971). Table 5 compares the production costs and revenues between the two packages. Total production cost per hectare, (excluding land rent and matching contributions to social security which could not be determined) were 32 percent higher in the IR8 package due to additional land leveling, higher labor cost of transplanting younger seedlings at closer spacing, and higher fertilizer costs. The yields, however, doubled. The cost of production per kilo of rough rice was reduced from 3.94 to 2.60 soles (US $90.62 to 59.80 per metric ton of rough rice). When no price differential between varieties was applied (4.70 soles/kg or US $108/m.t.) the net revenues were 3677 soles/ha for the traditional package and 20,270 soles/ha for the IR8 package. This situation applied up to the

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[1/] The assistance of Mr. Carlos Pomareda, Graduate Student of the Economics Department at North Carolina State University, in the preparation of this section is gratefully acknowledged.

1970 harvest for IR8 and should apply to the new high yielding, high grain quality varieties like Naylamp, CICA 4 and IR 22. For the 1971 harvest in Peru, recent rice marketing regulations with deductions for grain breakage percentage have effectively reduced the price of IR8 to 3.80 soles/kg (US $87/ton). At the stated yield and cost levels, IR8 net revenues were reduced from 20,270 to 11,576 soles/ha, (US $486 to 266/ha) which still compares favorably with the net revenue with traditional practices of 3677 soles/ha (US $84/ha).

Table 6 illustrates the total and relative proportion of the different production cost components for the same comparison. Although all components but labor for other cultural practices (dike and canal repair, weeding, irrigating, fertilizer application and bird control) increased in absolute amounts with the IR8 package, only the land preparation, fertilizer material and harvest costs increased in relative proportion. Harvest costs (hand harvesting, contract threshing and transportation) per kilo of rough rice was reduced from 0.74 soles paid for Minabir to 0.56 soles for IR8 because of labor savings when non-lodged rice is hand harvested. The total labor requirement increased from 128 to 161 man-days/ha. with the IR8 package but the proportion of labor in total production costs decreased from 57 to 51 percent.

6.3 Effects of nitrogen levels.

The average of two variety - nitrogen experiments conducted during 1971 in Lambayeque was used to make the following comparison[1/], since rising labor costs and a cooler climate impeded the realistic application of 1971 costs to the three year average response curve of Fig. 8. Gross revenues and net profits are plotted as function of N applications with and without

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[1/] IR8 yielded 4.32, 6.44, 8.14, 9.21, 9.68, 9.98 and 10.66 ton/ha. and Minabir 3.92, 4.93, 5.64, 4.97, 4.29, 3.40 and 3.10 ton/ha. from 0 to 480 kg N/ha at 80 kg intervals.

the price differential (Fig. 16). Next partial cost calculations included additional fertilizer and harvest costs. This figure shows that maximum profits are reached with about 160 kg N/ha for Minabir. Without a price differential profits continue to increase with N applications in IR8. With the price differential, the optimum level for IR8 is between 240 and 320 kg N/ha. Substantial variability is expected in the field. It is probable that the price drop of IR8 resulted in serious losses to many farmers.

The effects of these relationships on unitary production costs appear in Fig. 17. The lowest cost obtained with Minabir was 3.5 soles/kg (US $80/ton) at the optimum nitrogen rate of 160 kg N/ha. Lodging causes increased unitary costs at higher rates. With IR8, the minimum costs were about 2.6 soles/kg (US $60/ton) reached at about 240 Kg N/ha and beyond. The necessity of using high yielding varieties to significantly reduce unitary production cost is obvious from this figure.

7. SUMMARY AND CONCLUSIONS

The varietal response of rice to a series of agronomic practices was compared, mostly under Peruvian conditions. Proper date of planting under rainfall uncertainty, solar radiation levels and minimum temperatures permitted short-statured varieties to take more advantage of favorable climatic conditions than tall, traditional varieties. Regardless of rainfall patterns, upland rice yields were doubled with a short-statured variety in the Selva. Regardless of the planting system used, short-statured varieties performed better than traditional types, particularly at closer spacings. Transplanting seedlings early significantly increased IR8's yields and profits in spite of a 32 percent increase in labor costs associated with this operation. Under conditions of good land leveling, lack of soil salinity and adequate weed control, direct-seeding systems

yielded as well as transplanted when short-statured varieties with close spacing were utilized. No other cultural practice widens the performance difference between rice plant types as nitrogen fertilization. Specific rates and management of nitrogen fertilizers, however, vary widely between localities. Chemical weed control of irrigated rice is a successful practice, but absence of clear weed control research results on upland rice in Latin America represents a major limiting factor. Optimum time of harvest not only increases yields, but improves the milling quality of varieties with chalky endosperm areas.

In actual practice, many of the specific agronomic practices interact with each other and more research is needed to quantify these interactions. The economic implications of traditional and improved package of variety-cultural practices at the commercial scale was compared. Production costs of the IR8 package increased by 32 percent, yields doubled and profits increased several times with and without a 19.1 percent price differential. Data from Peru suggests that new high yielding - high grain quality rice varieties have similar agronomic potential as IR8. The possibility of increasing rice yields throughout the different cropping systems in Latin America seem excellent if proper agronomic practices are adopted.

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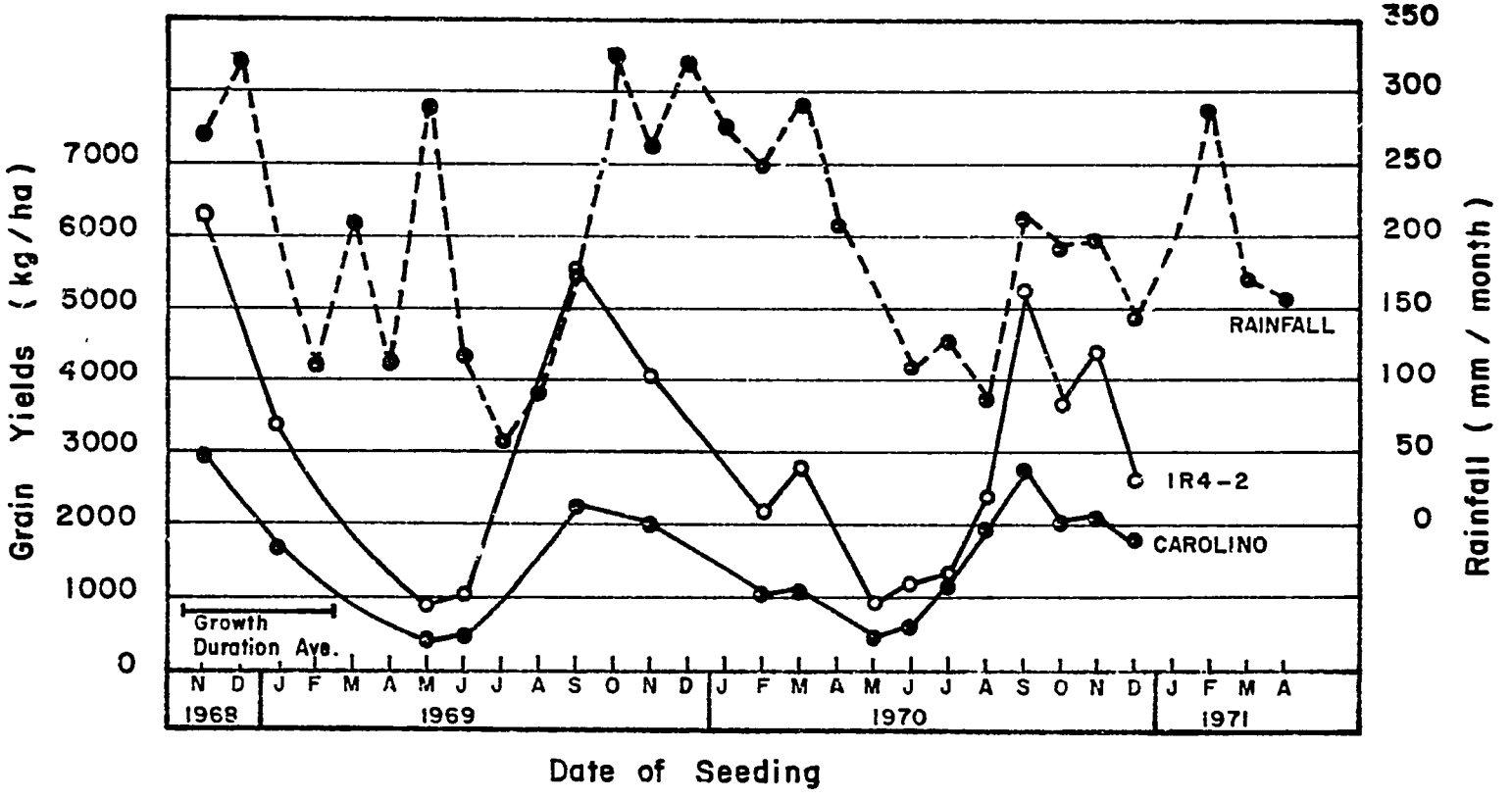

Fig. 1 Performance of IR4-2, a short statured plant type and Carolino the local variety as a function of date of planting under upland conditions and available rainfall, Yurimaguas 1968-71. (Kawano, Sanchez, Nureña and Velez, 1971).

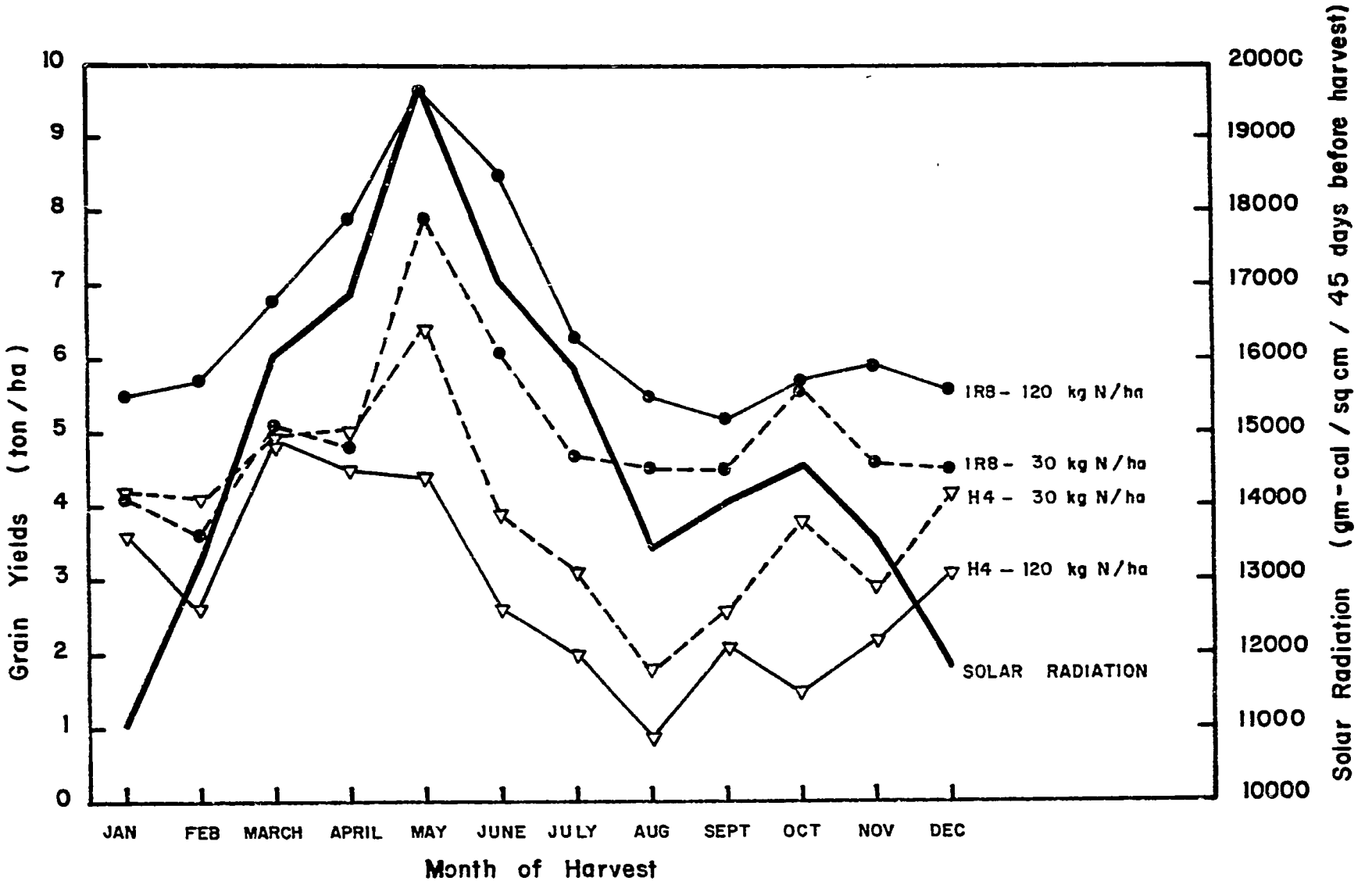

Fig. 2 The effects of solar radiation and nitrogen applications on the performance of a short (IR8) and a tall (H4) statured rice variety in Los Baños, Phillippines 1968-1969. Adapted from data presented by DeDatta and Zante (1970).

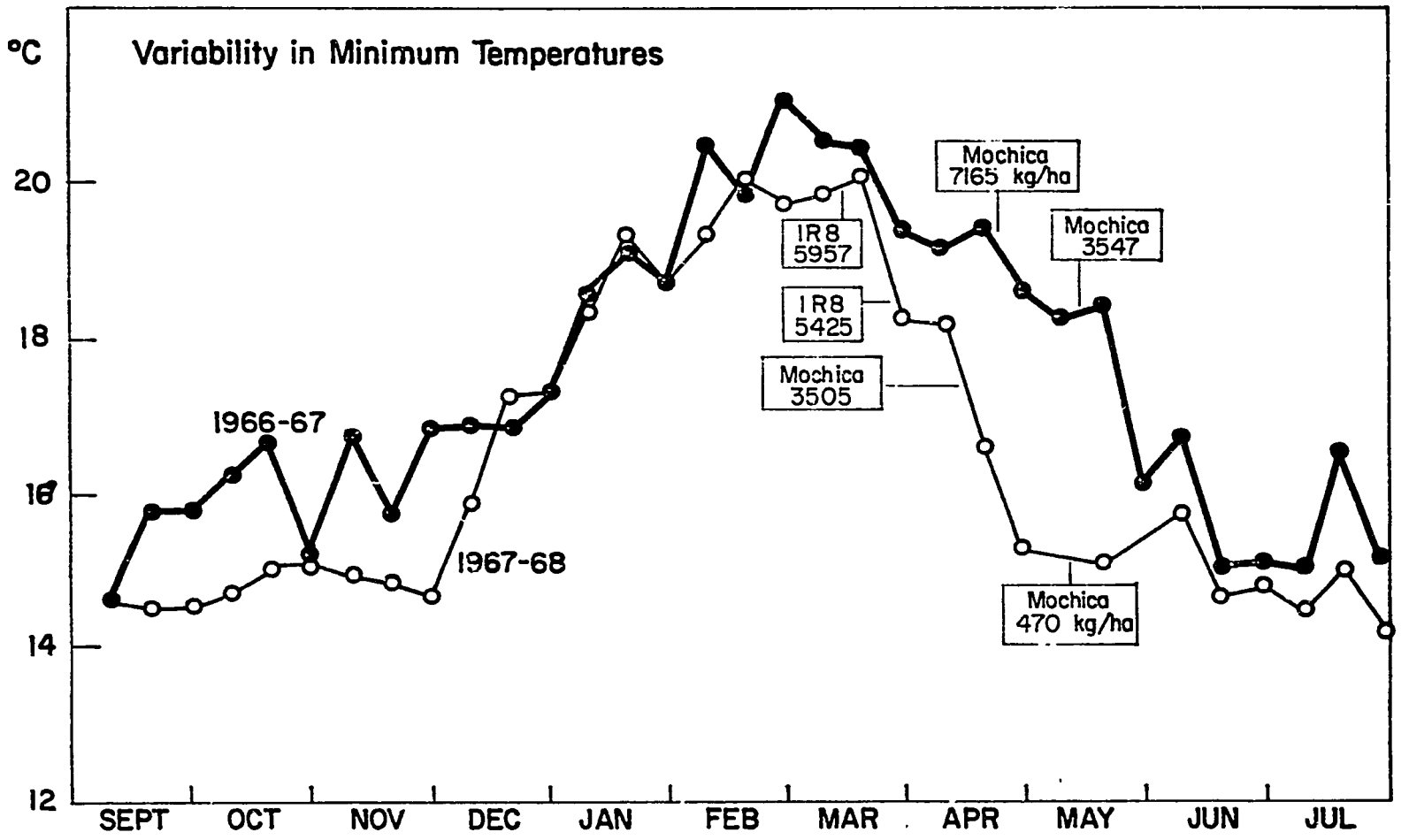

Fig. 3 The effect of minimum temperature variability and dates of flowering on rice yields in two cropping seasons at Lambayeque. Mean minimum temperatures of 10-day periods. (Sanchez, 1969).

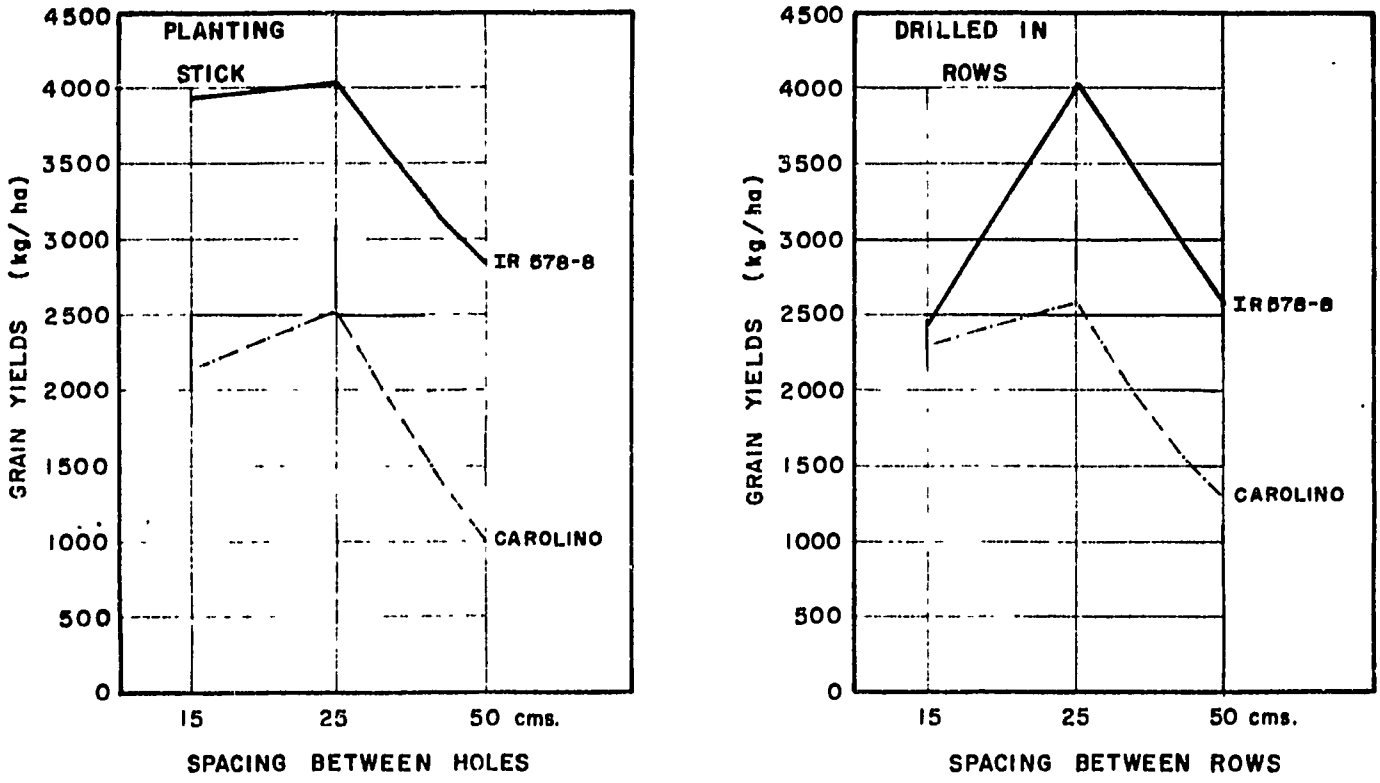

Fig. 4 Effects of spacing on upland rice yields of contrasting plant types in unmechanized and mechanizable planting systems. Yurimaguas, Peru 1970. (Nusena, 1971).

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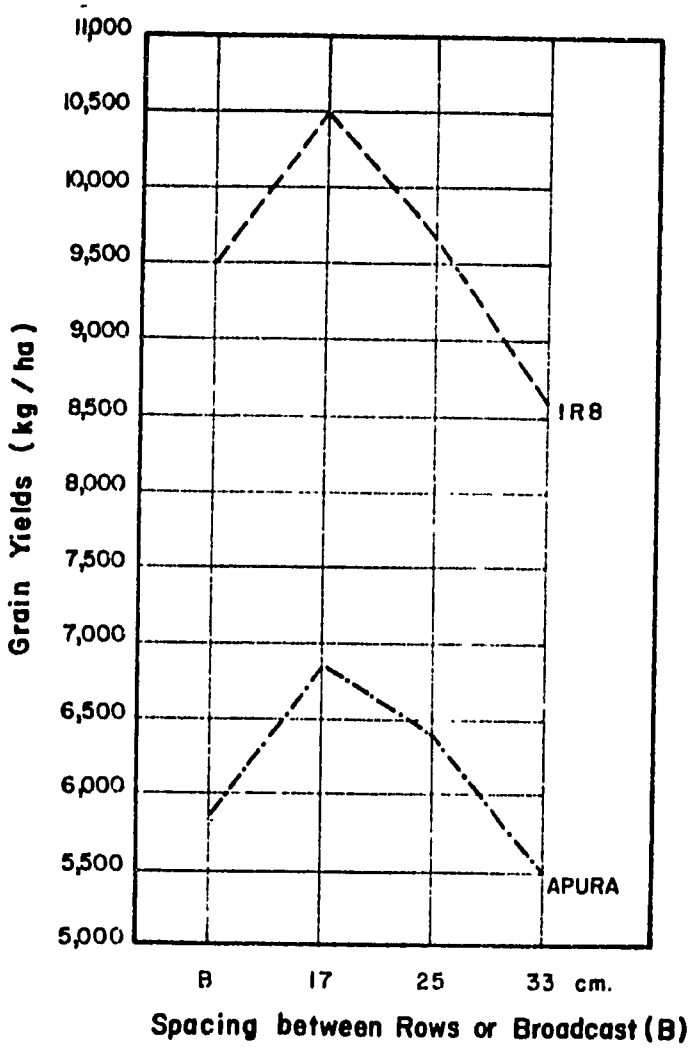

Fig. 5 The influence of spacing on the performance of varieties of contrasting plant type under direct seeded, irrigated, high solar radiation conditions. Lambayeque, Peru 1969-70. (Sanchez and Larrea, 1971)

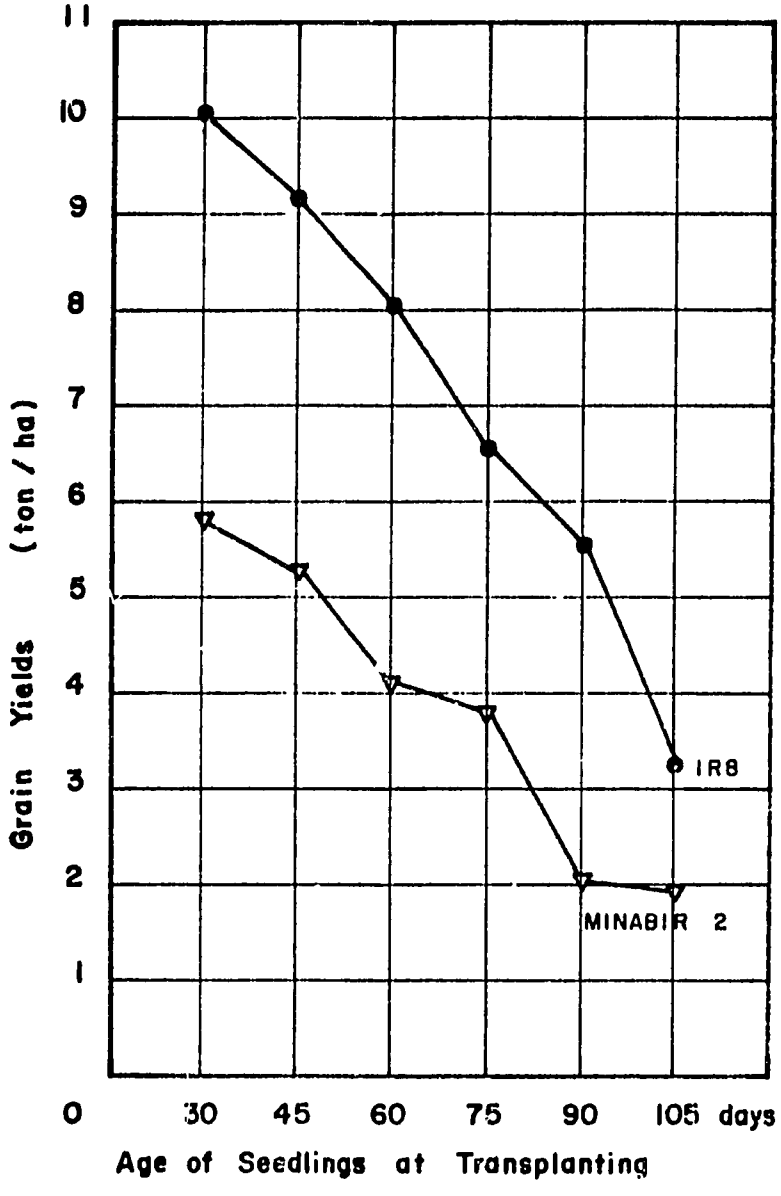

Fig. 6 Effects of seedling age on the performance of varieties of contrasting plant type. Mean of four locations in the Lambayeque and Jequetepeque Valleys of Peru.

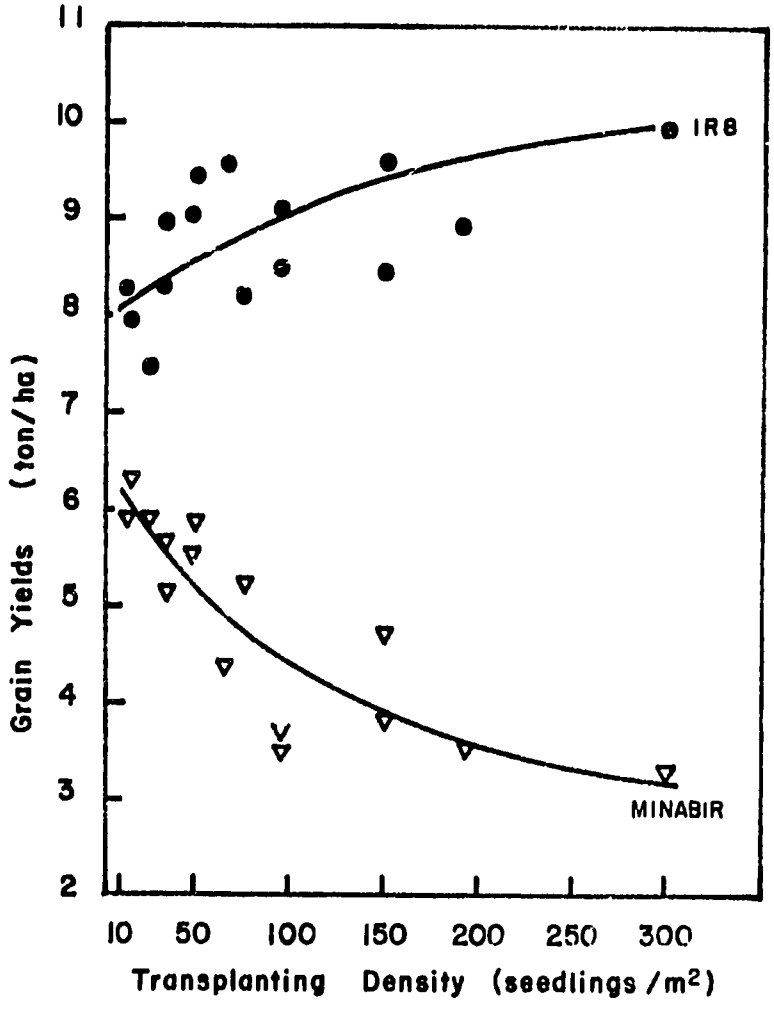

Fig. 7 The differential influence of transplanting density on rice varieties of contrasting plant types. Lambayeque, Peru 1970-71. Adapted from Gavicha and Saavedra (1971).

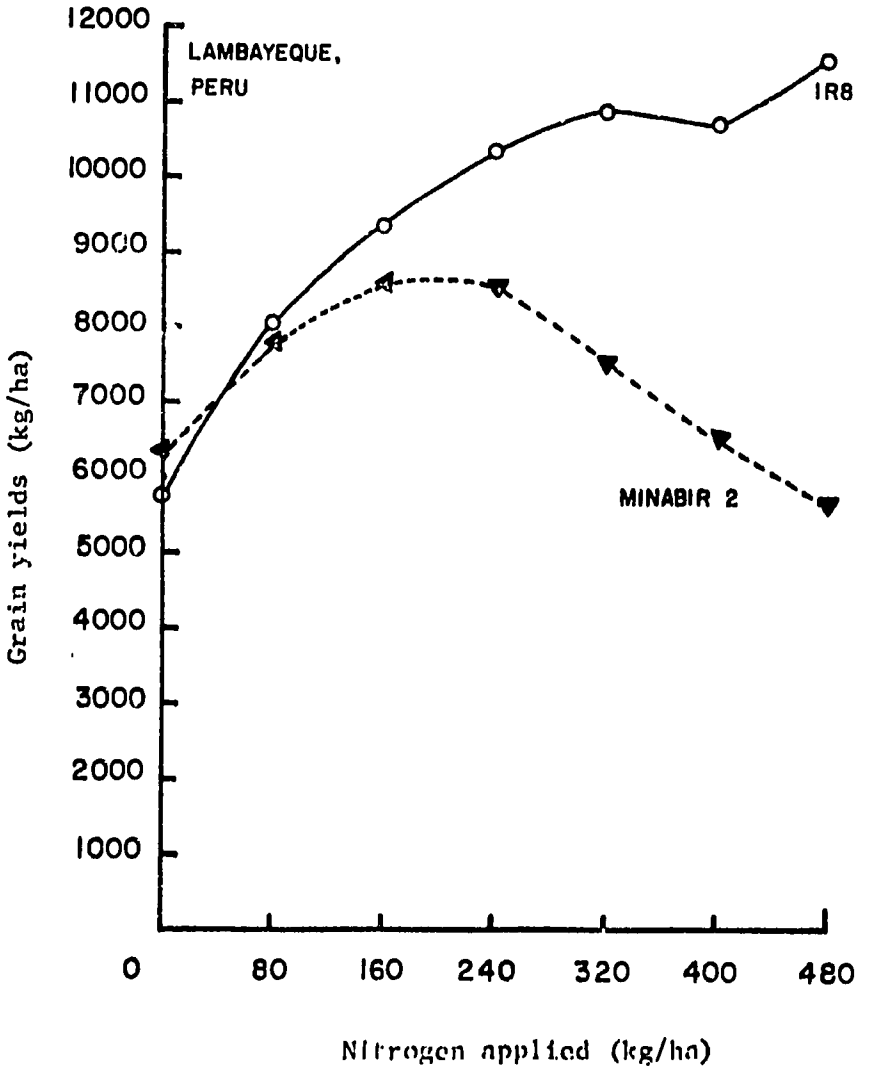

Fig. 8 Varietal response to nitrogen under high solar radiation and intermittent flooding in Lambayeque, Peru. Mean of 10 experiments during 1968-71. (Sanchez, 1971).

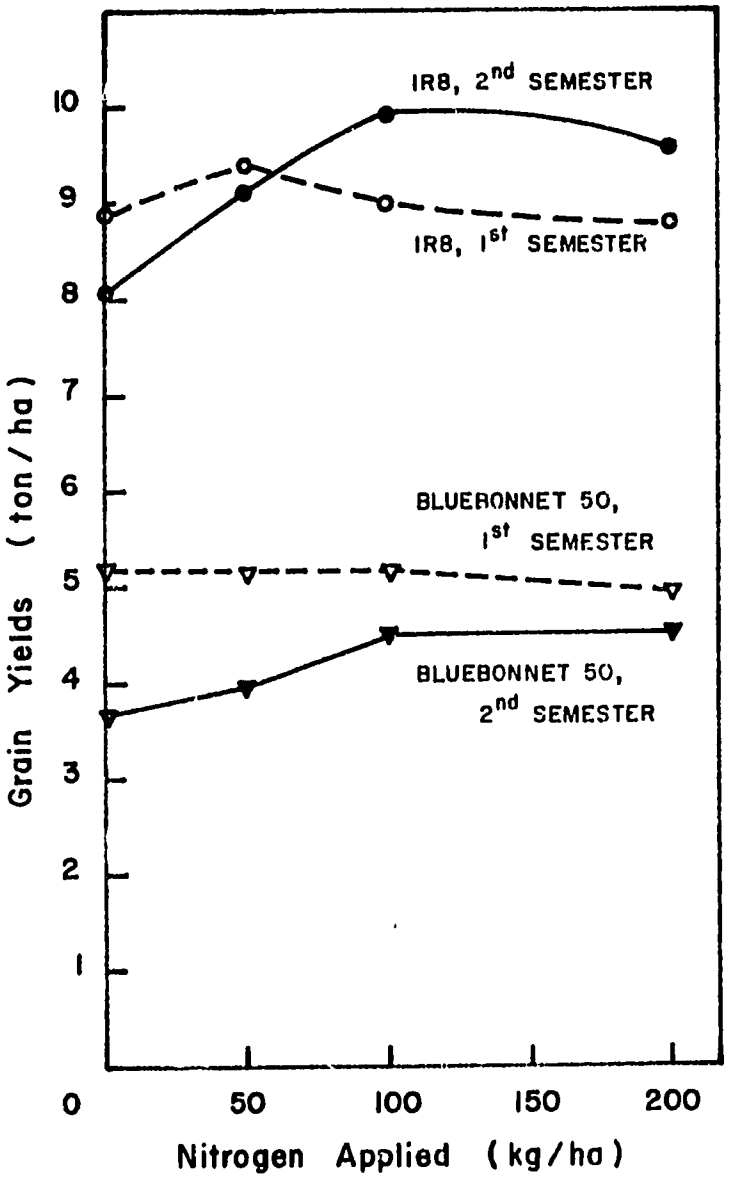

Fig. 9 Varietal response to nitrogen and season in Aracataca, Magdalena, Colombia 1968. (Rosero and Moreno, 1970)

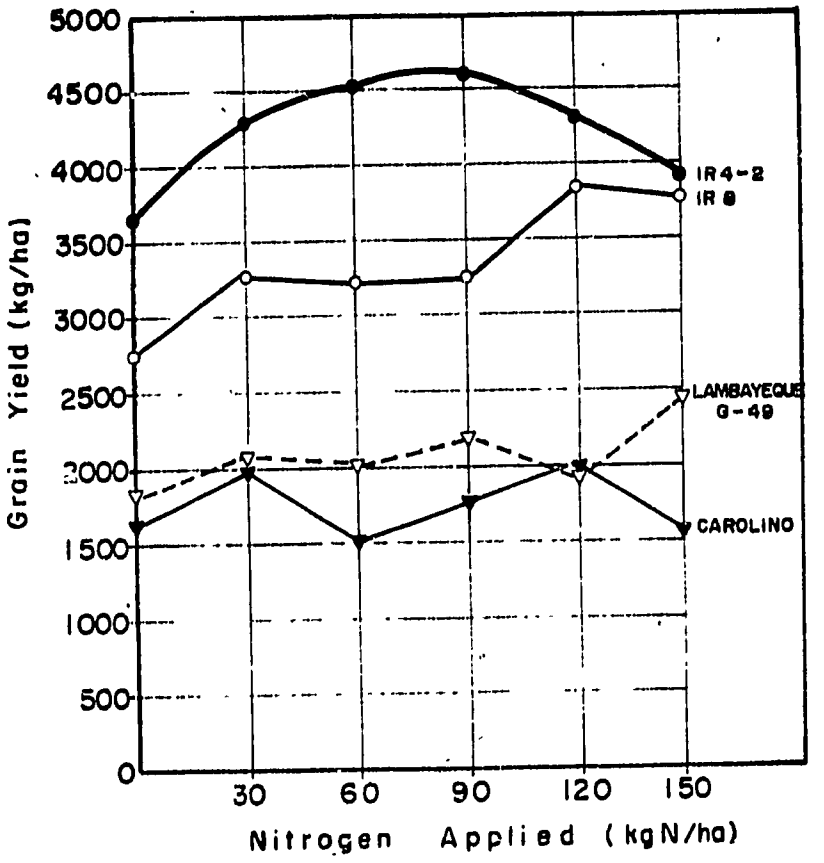

Fig. 10 Nitrogen response pattern of four rice varieties at Yurimaguas, Peru under upland conditions, 1969-70. (Sanchez and Nureña, 1970)

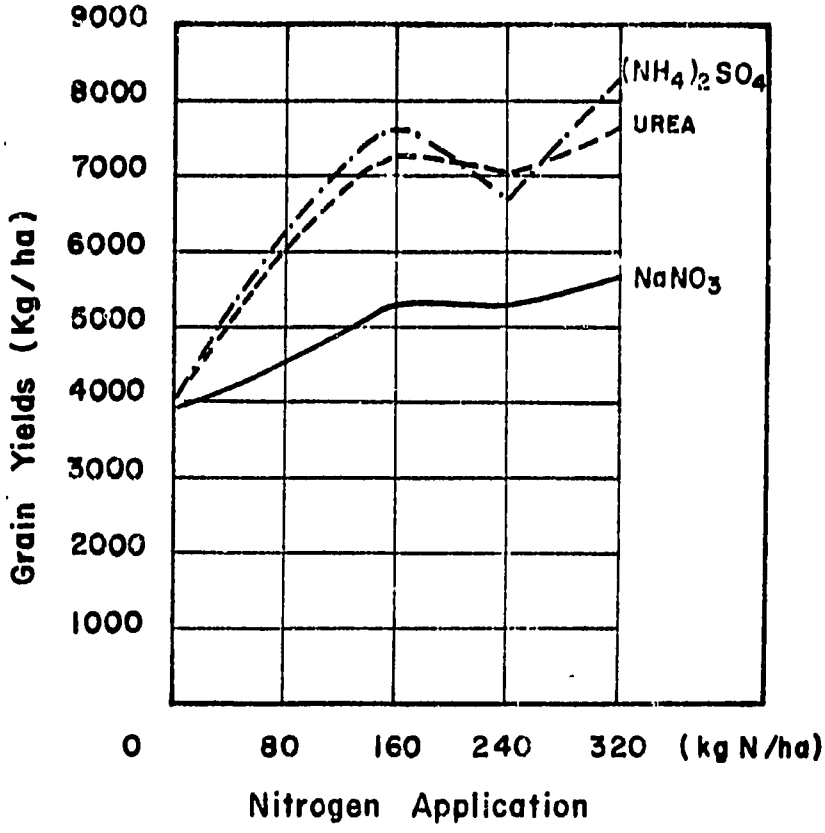

Fig. 11 The effects of nitrogen sources on rice response under intermittent flooding (Ramirez and Sanchez, 1971)

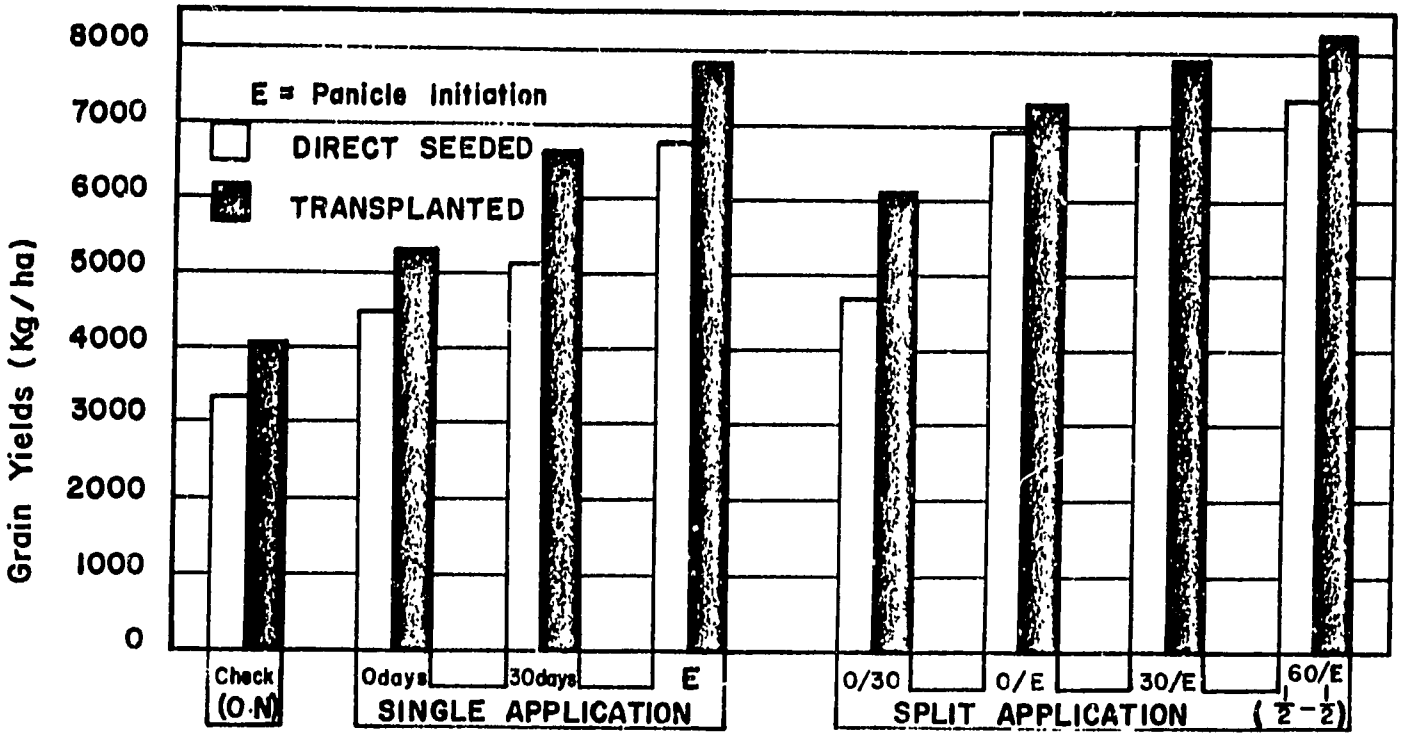

Fig. 12 Effects of timing of an application of 180 kg N/ha on rice performance under two planting systems. (Sanchez and Calderon, 1971)

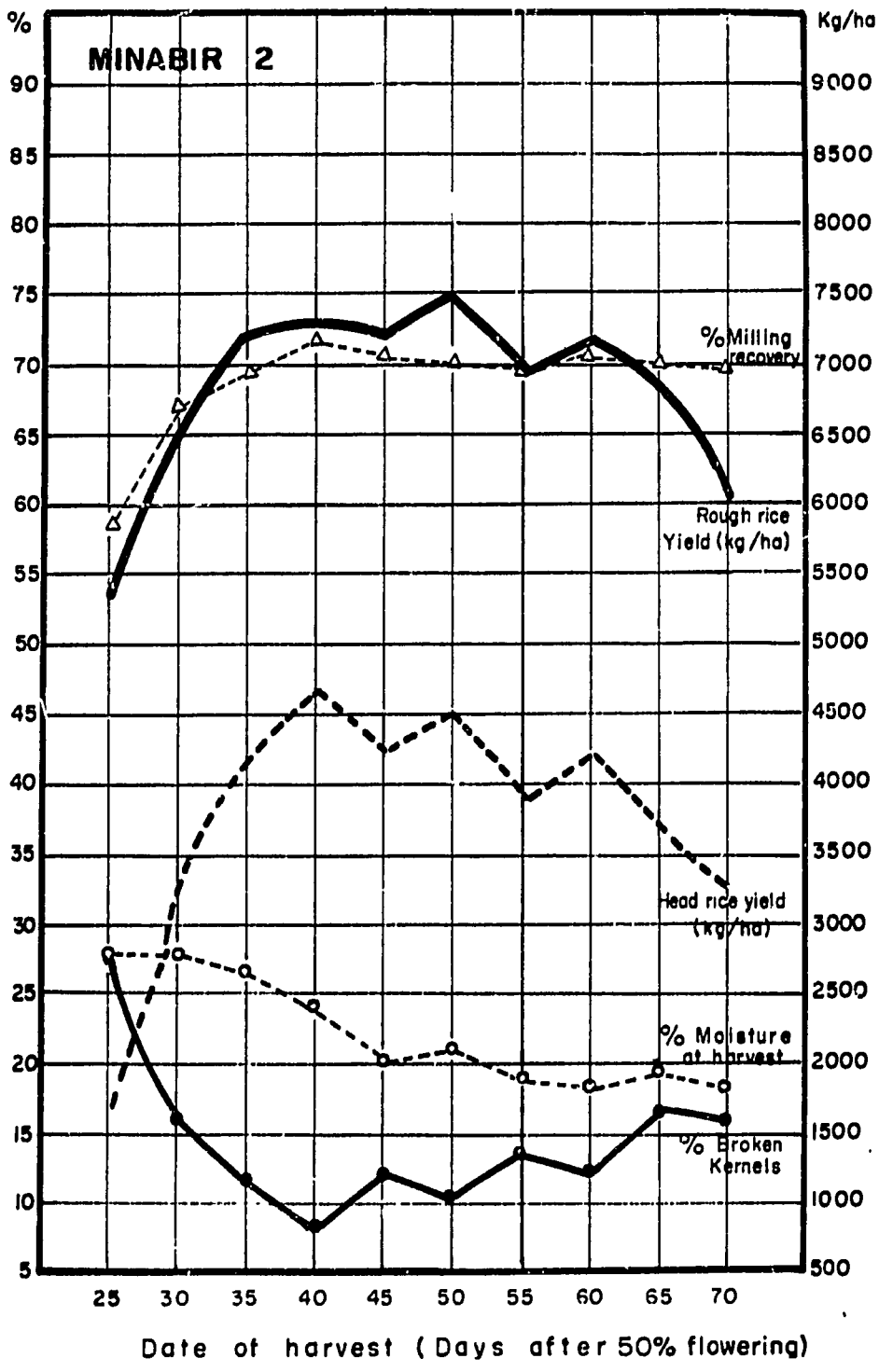

Fig. 13 Effects of date of harvest on grain yield and milling qualities of Minabir 2. (Larrea and Sanchez, 1970)

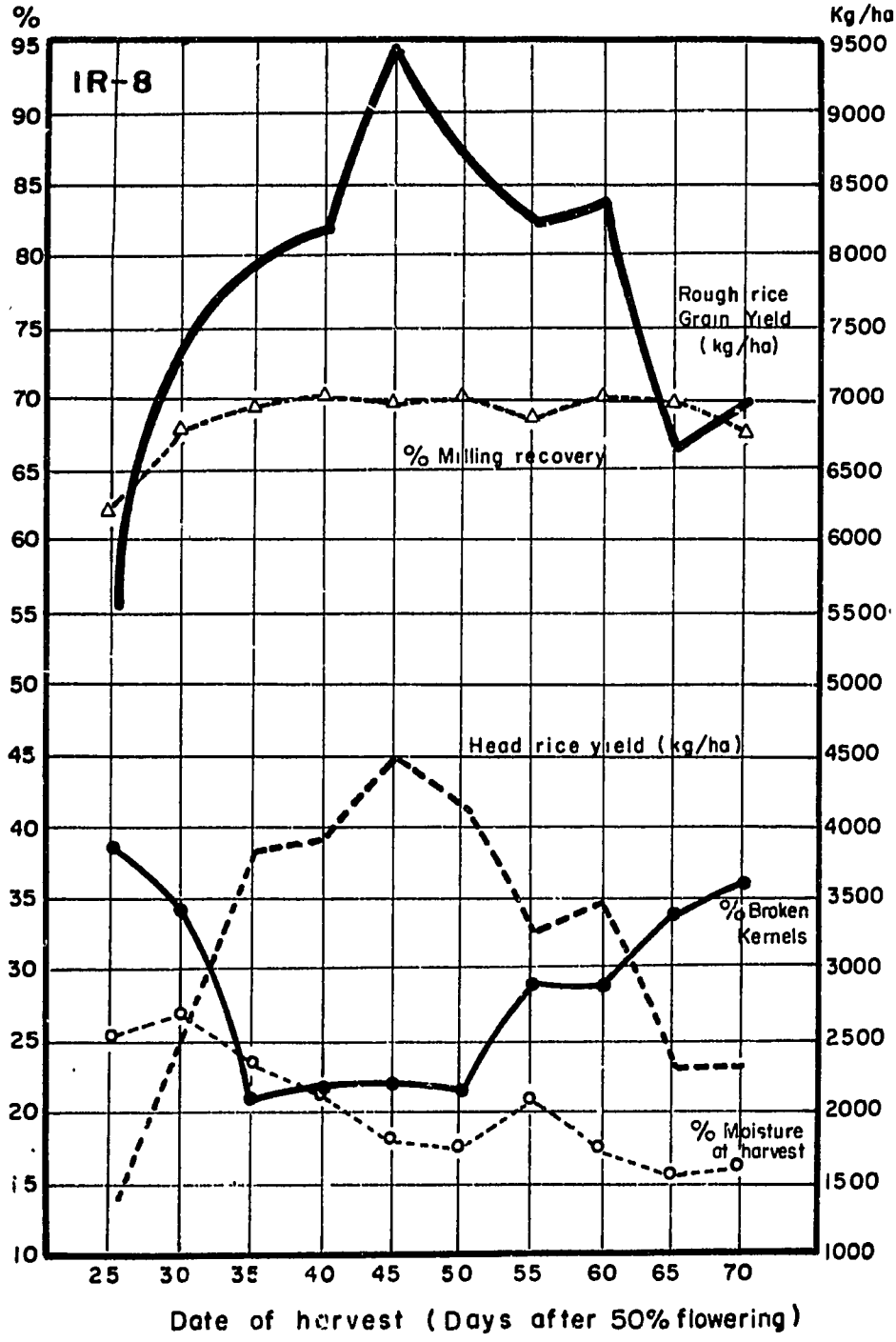

Fig. 14 Effects of date of harvest on grain yields and milling properties of IR8 (Larrea and Sanchez, 1970)

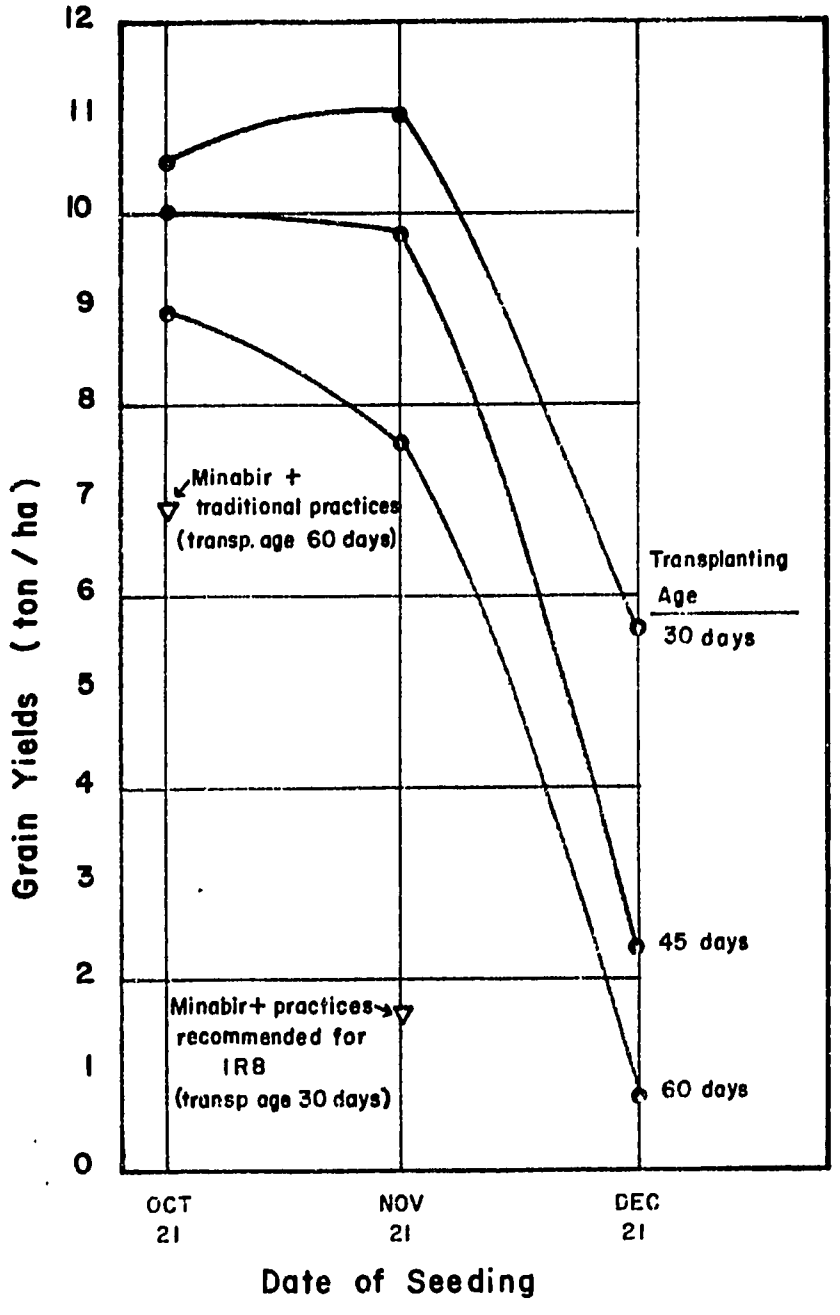

Fig. 15 Combined effects of date of seeding and transplanting age on IR8 performance in Lambayeque compared with Minabir with traditional and recommended cultural practices for IR8. (Larrea and Sanchez, 1971)

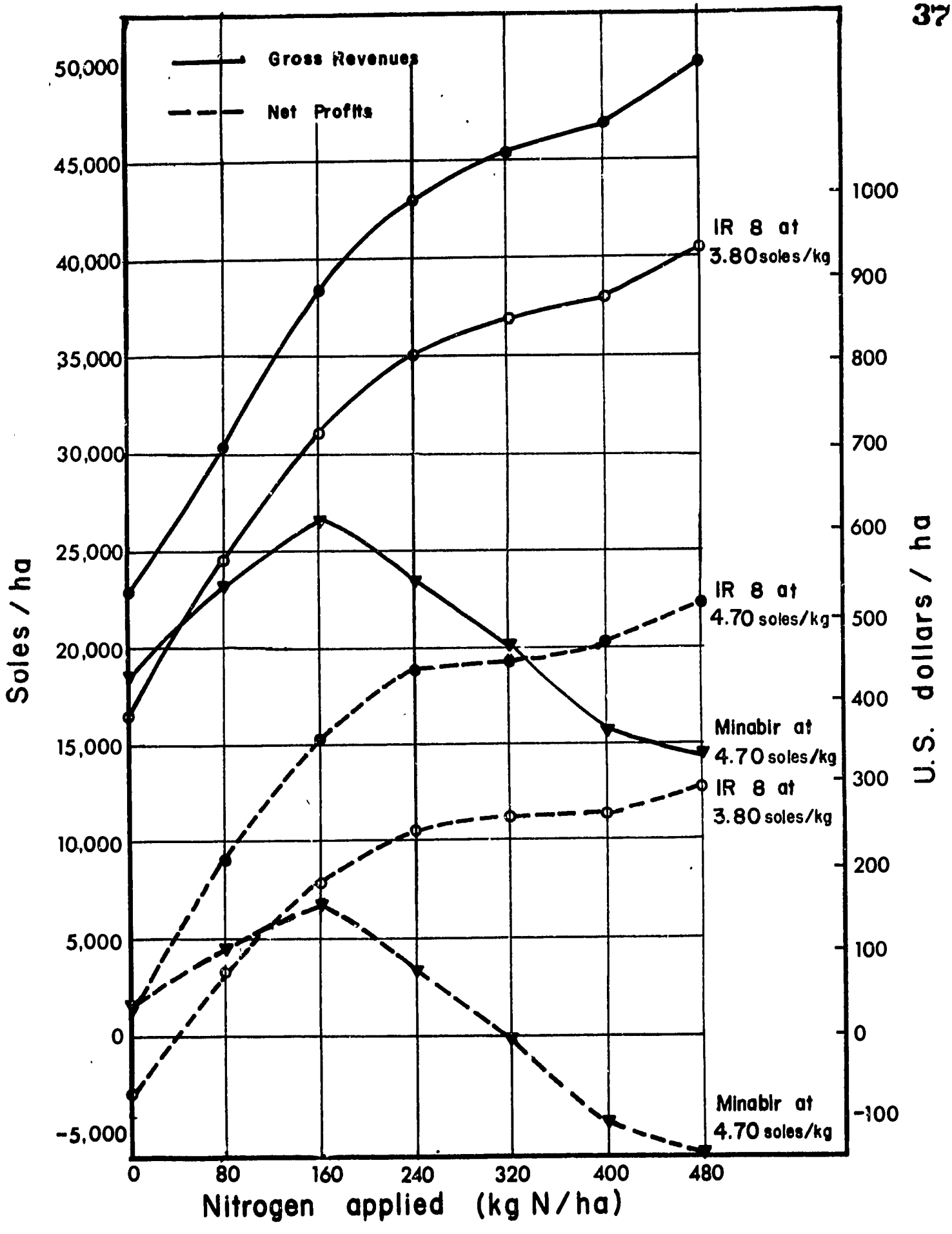

Fig. 16 Gross revenues and returns of Minabir 2 and IR8 with or without price differentials as a function of N levels in Lambayeque, Peru. Average yields of two locations in 1971.

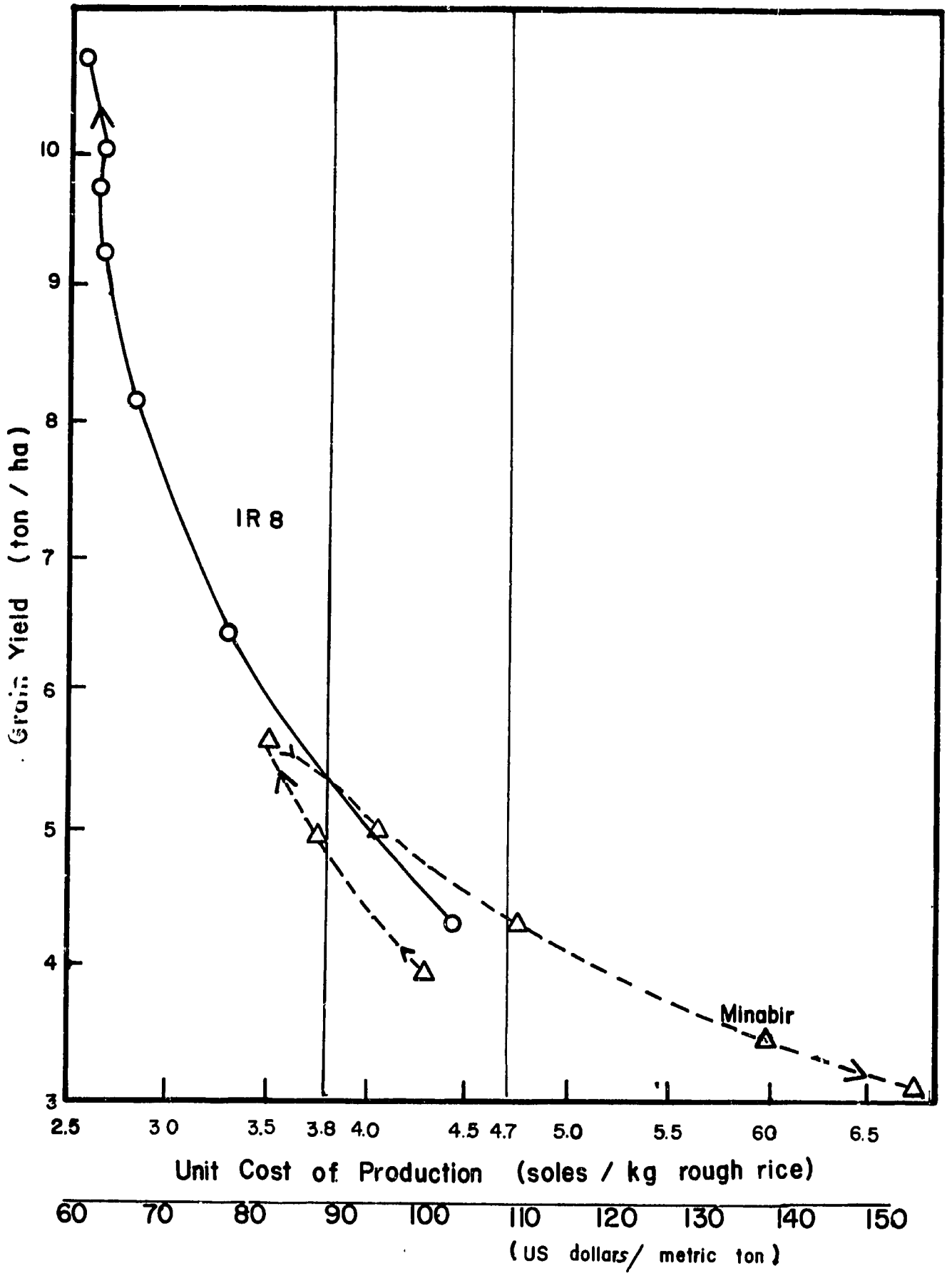

Fig. 17 Unitary production costs of IR8 and Minabir as a function of yield in Lambayeque 1971. Arrows indicate N rates increases from 0 to 480 Kg N/ha.

Table 1. Relative proportions of rice cultivation systems in the major Latin American rice producing countries or regions. (1960-64)

Country [1/]	% Upland (Direct seeded-rainfall dependent)	% Direct seeded-irrigated	% Transplanted	Average yields tons/ha
Brazil	77	22	1	1.7
Colombia	65	35	0	2.2
Guyana	55	40	5	2.1
Mexico	25	70	5	2.2
Panama	95	5	0	1.1
Ecuador	63	2	35	1.5
Peru	21	10	69	4.1
Central America	90	10	0	1.3
Venezuela	80	2	18	1.8
Total Latin America	75	21	4	1.7

1/ Listed in order of area planted to rice

Table 2. Effects of planting systems on the performance of two rice varieties of contrasting plant type in Lambayeque, Peru. Mean of 4 seeding densities. N applied: 400 kg/ha. (Larrea and Sanchez, 1971).

Planting System	IR305-3-15 (short, high tillering)	IR253-3-1-3 (tall, low tillering)
Drilled in 25 cm. rows	10.75	8.75
Drilled in 17 cm. rows	11.30	7.77
Broadcast on dry soil and covered	11.64	7.38
Broadcast 1/ on flooded, unpuddled soil	11.58	7.72
Broadcast 1/ on flooded, puddled soil	12.09	7.93
Transplanted 23 x 25 cms 2/	10.52	7.82

1/ Pregerminated seeds

2/ Adjacent experiment with identical management.

Table 3. Effects of transplanting, spacing and nitrogen fertilization on the yields of several rice varieties (ton/ha) at Lambayeque, Peru. Source: Kawano and Gonzalez (1971).

Variety	Plant type		Nitrogen application (kg N/ha)			
	Height	Tillering ability	80		320	
			25 cms	50 cms	25 cms	50 cms
IR8	Short	high	7.82	6.78	11.17	8.61
Naylamp 1/	Short	high	8.02	5.86	10.56	8.09
Minabir	Tall	high	8.22	7.37	8.40	7.97
Chiclayo	Tall	low	7.53	5.23	7.74	6.76

1/ Newly released, high grain quality in Peru from the selection IR930-2-6

Table 4. Effects of two principal herbicides on rice yields (ton/ha) in four locations in South America. Compiled from Lagos *et al*, 1970 and Lucena, 1971.

Herbicide	Active ingredient lt/ha	Colombia, direct seeded		Lambayeque, Peru	
		Turipana	Palmira	Direct-seeded	Transplanted
Propanil (Stam)[1/]	3.5	2.38	2.94	2.79	8.78
Butachlor (Machete)[2/]	3.0	1.92	3.07	3.46	7.99
Hand weeding		2.27	3.01	3.14	7.45
No weeding		1.19	1.33	0.55	2.20

1/ Postemergence, when weeds had 2-5 leaves.

2/ Pre-emergence, 4-6 days after seeding or transplanting.

Table 5. Comparative production costs and returns per hectare between traditional varieties and cultural practices, and short-statured varieties with recommended cultural practices in Lambayeque, Peru. Source: Hernandez 1971. (1 sol = US $0.023)

Cost Components	Unit Costs (soles)	Minabir variety and traditional cultural practices		Short variety and recommended cultural practices	
		Units	Cost (soles/ha)	Units	Cost (soles/ha)
Certified seed	8.7/kg	70	609	70	609
Tractor-land leveling	250/hr	0	0	4	1000
Tractor-plow & harrow	240/hr	5	1200	5	1200
Dike & canal repair	60/md 1/	12	720	12	720
Seedbed & pulling	90/md	20	1800	30	2700
Transplanting	90/md	36	3240	44	3960
Irrigation, fertilizer applic., weed and bird control	80/md	35	2800	35	2800
Fertilizer (Urea)	9.33/kg N	140	1306	275	2565
Herbicide (Stam)	500/gal.	3	1500	3	1500
Harvest by hand	90/md	25	2250	30	2700
Contract threshing	0.21/kg	4830	1050	9660	2100
Transportation	0.07/kg	4830	370	9660	700
Interests & administrative	7% + 1000	-	2179	-	2578
Total Costs/ha. 2/			19024		25132
Total Cost/kg. rice			3.94		2.60
Grain Yields kg/ha	4.70/kg 3/	4830	22701	9660	45402
Price/kg. rice					
Net Revenue/ha 2/			3677		20270
Net Revenue/kg. rice			0.76		2.10

1/ md = man-days (tarea), averaging 7 hours.

2/ Excluding land rent and matching contributions to laborers, both of which are highly variable.

3/ Assumes no price differential between varieties.

Table 6. Comparative absolute and relative production cost components between commercial production of traditional and improved variety - cultural practice packages in Lambayeque, Peru. 1971

Cost Components	Traditional variety & cultural practices		Short variety and cultural practices	
	soles/ha.	%	soles/ha.	%
Mechanized land preparation	1200	6.3	2200	8.8
Labor for seedbed & transplanting	5040	26.5	6660	26.5
Labor for other cult practices	3520	18.5	3520	14.0
Fertilizer material	1306	6.9	2565	10.2
Seed, herbicides	2109	11.0	2109	8.4
Harvest labor, threshing & transport	3670	19.3	5500	21.8
Interests and administrative	2179	11.4	2578	10.3
Total production costs	19024	100.0	25132	100.0
Total labor (man-days)	128	56.8	161	51.2