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A MAXIMUM ANNUAL RICE PRODUCTION TRIAL IN THE TROPICS

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Usually, rice cultivation in the tropics is limited to the rainy season, so yield per crop is important. But at low altitudes in the tropics where temperatures are favorable for rice growth throughout the year, three or four crops a year are possible, provided irrigation is available. In such conditions, total annual production per unit land area is more important than yield per crop. In the future, increased production per unit land area per year will be necessary because arable land area is limited. For this reason, it is important to know production potential of tropical environment for rice.

Maximum possible dry matter production has received a considerable attention from physiologists (Eastin 1966, Loomis and Williams 1963). Such attempts are based on quantum yield in photosynthesis and also on various assumptions. These studies may reveal an ultimate limit in dry matter production under a given amount of sunlight. They do not, however, indicate how much grain production is possible, because grain is a part of the total dry matter and many things other than photosynthesis are involved in determining the proportion of dry matter that turns into grain.

Some rice scientists confined their estimates of energy conversion efficiency to the ripening period when most of the grain starch is produced, thus estimating the theoretical maximum for grain yield (Tsunoda 1966). Estimated maximum yields vary from 16 t/ha to 42 t/ha per crop without husks and moisture, depending on assumptions made. If husks (20% of grain dry matter) and moisture (14% of grains) are taken into consideration, the estimates would range from 23 to 61 t/ha of rough rice per crop.

An agronomic attempt to produce maximum yields depends on the yield potential of existing varieties, and it is hindered by disease and pests in the field. For these reasons, an agronomic attempt does not give an estimate for maximum production under a given physical environment. But it does give an estimate of possible annual production that might be achieved under specified conditions.

In this paper, we report the results of maximum annual rice production trial we conducted at Los Baños, Philippines in 1972. This experiment demonstrates that the tropics have a greater potential for rice production than the temperate regions.

MATERIALS AND METHODS

The experiment was conducted in an experimental field of the Institute at Los Baños, Philippines (14°N). The environment of this location is described elsewhere (Moomaw and Vergara 1965).

The soil of the field is Maahas clay. Typical Maahas clay has a pH of 6.0 at

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1 : 1 soil-to-water ratio. The cation exchange capacity of the soil is 45 meg/100 g soil. Montmorillonite is the dominant clay mineral (IRRI 1966). The field has been used for continuous cropping experiments for several years. Perhaps, for that reason, the soil properties have been slightly changed. At the start of the present trial, the pH of the air-dried soil was 6.9 at 1 : 1 soil-to-water ratio and soil organic matter content was 2.2%. In addition, zinc deficiency occurred in the 1970 crops, and hence 50 kg/ha Zn as zinc chloride was applied to the field before the first crop of the present trial started.

To grow four crops a year, we used three crops of early maturing lines and one crop of a medium maturing variety. IR 8 was chosen for the medium maturing variety because of its high yield potential. It matures in about 130 days at Los Baños. IR 747 B2 and IR 667-98 were selected for early maturing varieties. Both varieties mature in about 100 days at Los Baños. IR 747 B2 has a wide spectrum of disease and insect resistance but it is susceptible to low temperature. Yield of this variety, when expressed as grain production per day in the main field, is greater than that of IR 8 (IRRI 1971). Despite its weak culms, and hence its susceptibility to lodging, its filled-grain percentage is very high. IR 667-98 has a high yield potential and is resistant to lodging and low temperature. This variety is, however, susceptible to tungro virus and bacterial leaf blight.

In a previous study on early maturing varieties, we found that close spacings are indispensable for high yields of early maturing varieties but not for medium maturing varieties like IR 8 (IRRI 1971). Based on the above, the following was planned (Table 1).

Table 1 shows the planting density and nitrogen application for each crop. Nitrogen was applied as ammonium sulfate. In addition, we applied superphosphate (30 kg P_2O_5/ha) and potassium as muriate of potash (30 kg K_2O/ha).

The experimental plots measured 6 × 14 m and were replicated two times. For collecting grain yield data, two 10 sq m areas were selected from each plot. Therefore, the grain yield figure is the mean value of four harvests. The grain yield was measured as rough rice at 14% moisture.

We transplanted 20-day-old seedlings at one plant per hill. We flooded the field about 5 to 10 cm deep from transplanting to harvest. Periodical application of insecticides and frequent hand-weeding were practiced.

RESULTS AND DISCUSSION

As shown in Table 2, a yield of 25.65 t/ha was produced in 335 days in the main field. In 1969, IRRI agronomists recorded 24.28 t/ha in 316 days in Mindanao, Philippines. The maximum annual production in that was computed from the best treatment combinations out of five variety trials (IRRI 1970). If per day production (grain yield divided by number of field days) is computed, these two experiments give almost identical efficiency, 76.6 kg ha^{-1} day^{-1} and 76 8 kg ha^{-1} day^{-1}. These two experiments. however, cannot be directly compared because of different climatic environments.

In 1971, at Baños we had an unusually low amount of solar radiation, particularly from October to December when the fourth crop was grown (Table 3). In addition, the crop was somewhat affected by tungro virus. For these reasons. the filled-grain percentage of the fourth crop was low (70%). If the normal amount of filled grains occurred, 85%, the yield of the fourth crop could have been 6.4 t/ha, and the total annual production would have been 26.8 t/ha.

Tanaka and Vergara (1967) estimated a maximum possible annual yield of 30 t/ha in 350 days after using an extremely early maturing variety which produced 85.7 kg ha^{-1} day^{-1}. In our experiments IR 747 B2 has produced 72 kg ha^{-1} day^{-1} to 106 kg ha^{-1} day^{-1}, depending on the planting season (Table 4) (IRRI 1971). Apparently, the daily production was high when solar radiation was high.

It now appears that with the existing varieties, 27 t ha^{-1} $year^{-1}$ is a quite realistic estimate of maximum yield under Los Baños conditions. Under some conditions at Los Baños IR 8 is capable of yielding 10 t/ha per crop (De Datta *et al.* 1969). If this is taken into consideration, an estimate for maximum annual production would be 28 t/ha.

In temperate regions, only one or two crops a year are possible. The maximum recorded yield per crop in Japan is 10.76 t/ha of brown rice which would be equivalent to 13.44 t/ha of rough rice (Matsuo 1966). Thus, on a yield-per-crop basis, the tropical environment is not necessarily more productive than the temperate region. But in terms of annual production, the tropics have a greater potential for rice production than temperate regions. This is because the tropical environment has a favorable temperature regime for rice growth throughout the year.

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Table 1. Variety, spacing, and nitrogen application.

Crop	Variety	Spacing (cm)	N applied (kg/ha)	
			Basal	Topdressing*
1st	IR8	20 × 20	120	30
2nd	IR747B2	5 × 5	100	25
3rd	IR747B2	5 × 5	100	25
4th	IR667-98	10 × 10	100	20+30

* First crop, 50 days after transplanting (DAT); second and third crop, 40 DAT; fourth crop, 10 and 30 DAT.

Table 2. Grain yields of four crops within 1 year at Los Baños, Philippines, 1971.

Crop no.	Period in the field from transplanting	Variety	Yield (t/ha)	Cumulative yield (t/ha)
1st	Jan. 18 - May 7	IR8	8.78	-
2nd	May 10 - July 22	IR747B2	5.35	14.13
3rd	July 26 - Oct. 6	IR747B2	6.35	20.48
4th	Oct. 11 - Dec. 27	IR667-98	5.17	25.65

Table 3. Monthly solar radiation data.

Month	Solar radiation (kcal cm^{-2} month^{-1}) 5-year average 1966–70	1971
January	10.4	10.4
February	12.2	9.5
March	14.8	13.4
April	17.0	15.5
May	15.5	13.1
June	13.2	9.8
July	12.4	11.3
August	11.6	13.5
September	11.4	11.1
October	11.2	9.1
November	9.5	8.3
December	9.1	7.7
Total	148.5	132.5

Table 4. Effect of planting season on grain production per day of IR747B2.

Year	Field period	Field duration (day)	Grain yield (t/ha)	Daily grain production (kg ha^{-1} day^{-1})	Total solar radiation during field period (kcal/cm^2)
1970	Feb. 5 – Apr. 24	78	7.92	102	33.2
	Aug. 10 – Oct. 23	75	5.62	75	26.1
1971	Feb. 5 – Apr. 19	73	7.71	106	32.4
	May 10 – July 22	74	5.35	72	27.1
	July 26 – Oct. 6	73	6.35	87	28.8