Potential Productivity and Nitrogen-Use Efficiency of Corn and Rice in Várzeas: M-910C

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Alluvial soils along the white water rivers, locally known as *várzeas*, are a major land resource in the Amazon basin. The state of Amazonas in Brazil has about 25 million hectares of such soils. Their high base status, adequate water supply, and eight-month flood-free period provide appropriate conditions for intensive food production in a region dominated by low fertility Oxisols and Ultisols. Total soil N is low in many of these soils, suggesting a potential nutrient deficiency. Yield response to N has been noted to increase during successive corn crops in *várzea* soils. This response would be magnified with the use of improved, high yielding varieties.

Despite the high native fertility and adequate water supply in this environment, yields for locally selected corn have seldom exceeded 5.0 t/ha when N was applied. These yields are similar to yields reported in the Peruvian Amazon but 1 to 2 t/ha less than yield maxima reported in the humid tropical lowlands of Sumatra, Indonesia, and Kenya.

Rice is also grown extensivly in the Amazon. Because of the soil's high water-holding capacity and the absence of severe drought stress periods, the *várzea* ecosystem is a favored upland rice condition. In the top 30 cm of soil, approximately 120 mm of available water are retained in the 0.01 to 1.0 MPa tension range. Although a limited number of rice trials in the Amazon have included N fertilization, results showed a relatively high grain yield potential, on the order of 6 to 7 t/ha for improved varieties. Results from irrigated rice in the Peruvian Amazon also showed grain yields in the same range.

Yield differences between corn (C4) and rice (C3) may be related to differences in N-use efficiency by their photosynthetic pathways and could result in contrasting N responses.

Objective

The purpose of this study was to assess the potential nitrogen-use efficiency of corn and rice in *várzeas*.

Procedures

Two experiments were conducted at the Caldeirao research field of the EMBRAPA/UEPAE Experiment Station, located 50 km west of Manaus, Amazonas, Brazil. The site is an alluvial cuaternary terrace on the Amazonas River, which is occasionally flooded during the periods of May to August. The soil in the corn experiment is a fine-loamy, mixed, nonacid, isohyperthermic Typic Tropofluvent. The soil in the rice experiment is a coarse-loamy, mixed, nonacid, isohyperthermic Aquic Tropofluvent. The two experiments were 200 m apart but the same distance from the river bank. Although the site for the rice experiment had more mottles in the subsoil, both sites were otherwise morphologically similar.

Initial soil (0 to 20 cm) characteristics for the corn experiment were as follows: 118 mg/kg of P (Mehlich 1); 1.7 and 14.1 g/kg of organic N and C; and 14.9, 2.9, 0.3, and 0.2 $cmol_c/kg$ of exchangeable Ca, Mg, and Al, respectively. The nitrogen availability index, as evaluated by net anaerobic incubation during one week, gave 3 and 9 mg/kg of NH_4 production for soil samples of the corn and rice experiments, respectively. These soil test values determined that no fertilizer, other than N, was applied to the experiment. Weather data are shown in Figure 1.

Grain Yields

Grain yield responses to applied N in the two corn crops and rice varieties are shown in Figure 2. Grain yields for both corn crops were increased by fertilizer N up to the 60 kg/ha rate. This N rate produced yield maxima of 4.4 t/ha, in the first crop, and 3.9 t/ha in the second crop. Differences among years may have resulted from weather or N contribution from mineralized organic matter.

Yield plateaus for both rice varieties were achieved with 20 kg N/ha, but maximum yields of CICA 8 exceeded that of BR-1 by 0.9 t/ha. Differences in grain yield between varieties were attributed to differences in grain weight for CICA 8, although there was no N-rate effect on grain weight in either variety (Table 1).

Maximum grain yield for the first corn crop was representative of the potential yield for this species at this location. Yield maxima of CICA 8 rice variety approached the potential yield of this species under favored upland conditions. Crops were grown under near-average weather conditions with no nutrient limitations. Nitrogen uptake continued to increase beyond N rates that resulted in maximum grain yields. The N rates associated with maximum grain yields were low and suggested other limitations for grain production.

Low solar radiation may account for the lack of response to applied N above the lowest rate in rice. In the absence of a water deficit, solar radiation received during the 45-day period before harvest is the foremost climatic variable affecting rice response to N. IRRI scientists related grain N responses at several planting dates to four categories of solar energy. The category with the highest solar energy (> 489 $mWh/cm^2/day$) contained linear yield responses up to 120 kg N/ha with progressive declines of optimum N rates with lower solar energy levels. Our solar radiation values averaged 330 $mWh/cm^2/day$ during the 45 days prior to harvest. Low solar-energy levels, maximum yields, and N responses for improved rice varieties grown under favored upland conditions in the Peruvian Amazon are similar to those reported herein.

Glucose-equivalent yield for the two rice varieties and the corn corps are presented in Table 2. To compare yields of crops grown under different years, we assumed that weather effect was constant across years. Corn yields simulated with the CERES-Maize program under no water or N limitations averaged 4 t/ha using several planting dates of the 1986 weather data. Differences in maximum grain yield between corn and rice remained when glucose equivalent yields were considered. Equivalent yields from unfertilized treatments appeared higher for rice than for both corn corps even with a lower soil-N availability index. Maximum equivalent yields did not differ between corn and BR-1 rice, but corn required three times as much N as rice to produce the maximum equivalent yield.

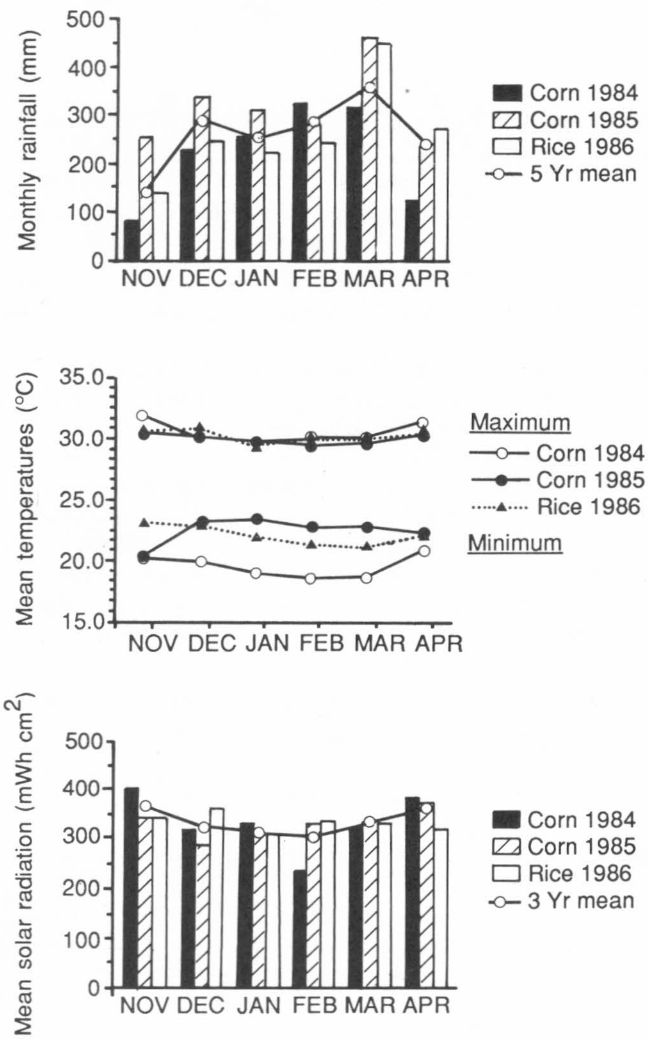

Figure 1. Monthly rainfall, maximum and minimum air temperatures, and solar radiation during the crop-growth cycles.

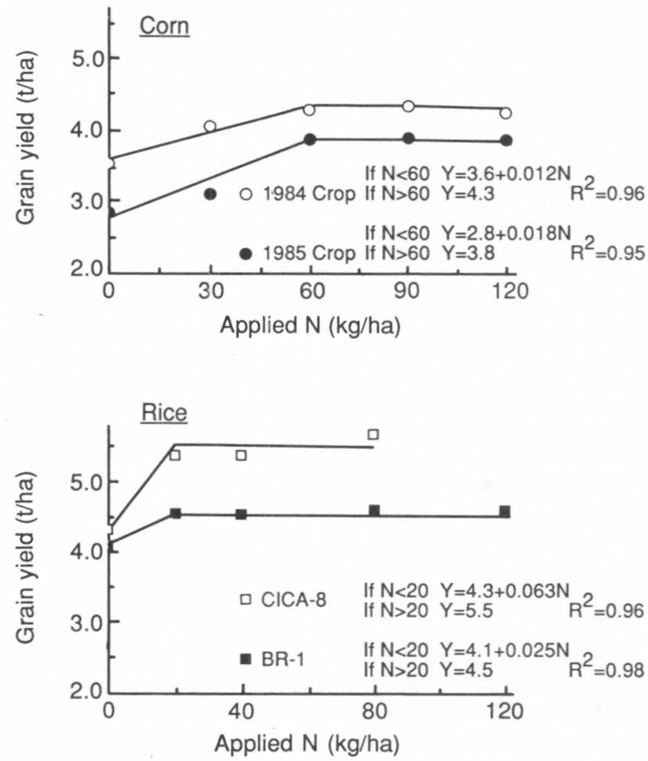

Figure 2. Grain yield response to N fertilization in two consecutive corn crops and two rice varieties.

Table 1. Nitrogen effect on grain yield components of two rice varieties.

Rice variety	N rate	Yield components		
		Panicle density	Panicle size	Grain wt x 1000
	kg/ha	pan/m	grn/pan	— g —
BR-1	0	307	57	23.3
	20	305	63	23.8
	40	310	62	23.9
	80	317	63	23.3
	120	324	60	23.7
CICA 8	0	284	54	27.5
	20	291	65	28.6
	40	308	61	28.8
	80	324	62	28.5
	120	339	51	28.3
LSD 0.05				
Variety	—	NS	NS	0.6
Rate x Variety	—	NS	NS	NS
SE N Rate BR-1	—	29	5	0.2
CICA 8	—	34	10	0.5
CV %	—	22	28	3

Table 2. Nitrogen effect on glucose-equivalent yield and harvest index of the corn and rice experiments.

	Equivalent yield				Harvest index			
	Corn crop		Rice variety		Corn crop		Rice variety	
N Rate§	1984	1985	BR-1	CICA 8	1984	1985	BR-1	CICA 8
	t/ha				Gw/TDM			
N–0	5.0	4.0	5.6	5.8	0.46	0.35	0.52	0.57
N–1	5.7	4.4	6.2	7.3	0.43	0.32	0.50	0.59
N–2	6.1	5.5	6.2	7.3	0.48	0.38	0.48	0.56
N–3	6.2	5.5	6.2	7.7	0.47	0.36	0.50	0.53
N–4	6.1	5.5	6.2	6.6	0.44	0.38	0.47	0.49
SE	0.2**	0.4	0.2*	0.4**	0.02	0.02	0.01	0.02*
CV %	7.6	16.0	9.9	9.9	7.5	11.2	8.5	8.5

*, ** = Significant treatment effect at the 0.05 and 0.01 probability levels.

§ Nitrogen rates for the corn experiment are: 0, 30, 60, 90, and 120 kg/ha; and 0, 20, 40, 80, and 120 kg/ha for the rice experiment.

Maximum yield for CICA 8 rice was higher than for BR-1. Variations in HI's accounted for grain yield difference between species, because maximum TDM was coincident for both species. Grain equivalent yield of rice varieties and corn crops correlated (= 0.77**) with their harvest indices.

N-Use Efficiency

Lack of differences in TDM between corn and either rice variety was paralleled by a lack of differences in either N-use (Figure 3) or uptake efficiencies (Figure 4) for biomass production, indicating no differences in the amount of either absorbed N or TDM produced per unit of applied N. However, differences were observed among mean utilization efficiencies for both TDM or grain in corn and rice (Table 3). No differences were observed between corn crops or rice varieties. Overall mean efficiency of plant N in biomass and grain production for rice was 20 and 50% superior to corn, respectively. Unfertilized treatments produced 41 kg of corn grain and 65 kg of rice grain per kg of absorbed N. This relationship decreased progressively with N fertilization in rice because further uptake and accumulation of N brought no concomitant grain yield increase (Figure 2). These N-use efficiency values were lower than the average 70 kg of rice per kg of accumulated N suggested by Mori and co-workers (1986) and significantly lower than the efficiency values greater than 85 reported under irrigated conditions in the high-yielding environments of Peru and California. Fertilizer N did not affect the use efficiency for corn grain.

Part of the differences in N-use efficiency may be because rice has a lower internal N requirement than corn. Rice grain yields reached a plateau at concentrations in TDM of 8.0 and 9.5 g/kg, respectively, for BR-1 and CICA 8. These values were in close agreement with the internal requirement suggested by studies in Peru. Internal N requirements reported for corn average 12.0 g/kg, with little deviation across environments or between genotypes. Plots with maximum yields in this experiment averaged 11

Table 3. Mean nitrogen effect on N-use efficiencies (plant biomass/unit of plant N) for total dry matter and grain production of corn and rice.

	Nitrogen-use efficiency			
	Total dry matter		Grain	
N Rate§	Corn	Rice	Corn	Rice
	TDM/Nt		Gw/Nt	
N–0	100	120	41	65
N–1	100	115	37	62
N–2	85	114	37	59
N–3	95	102	40	53
N–4	91	102	38	49
Mean	94	111	39	57
SE	6 *	8 *	2	4 **
CV %	16	19	14	21

*, ** = Significant treatment effect at the 0.05 and 0.01 probability levels.

§ Nitrogen levels for the corn experiments were 0, 30, 60, 90 and 120 kg/ha; and 0, 20, 40, 80, and 120 kg/ha for the rice experiment.