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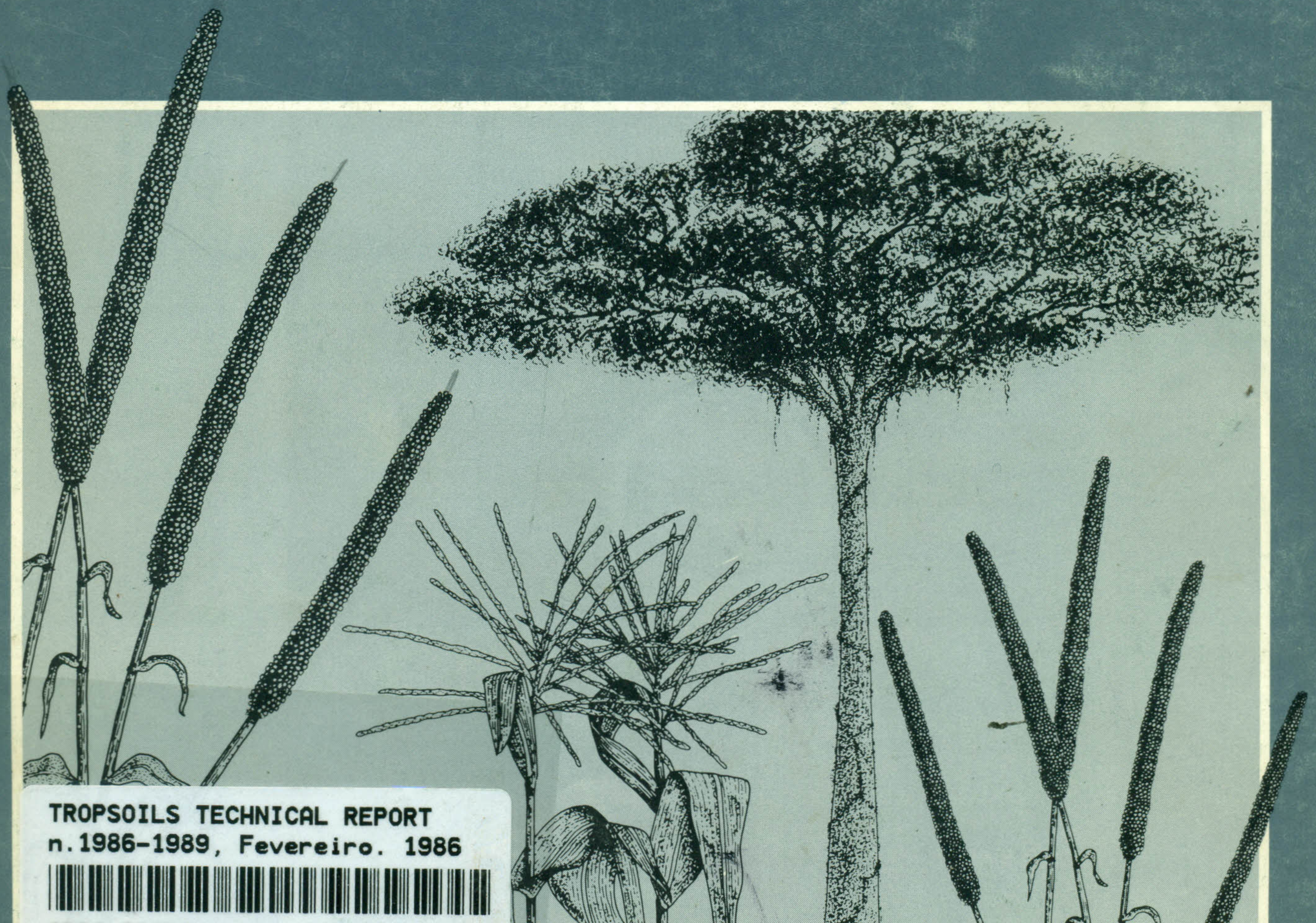

Nitrogen Management

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Preliminary evaluations for N fertilizer requirements entailed three N treatments in the nutrient dynamics study. Urea-N was applied to these treatments in three equal split applications to each crop of rice and corn. Yield data are shown in Table 1. Upland rice yields declined with 90 kg N/ha due to lodging by the tall-statured local cultivar.

In the first two corn crops, yields with N rates of 40-120 kg N/ha were not significantly different. These data suggest that native soil N, and perhaps applied N, carried over in residues of soybean and/or cowpea, were sufficient to limit yield response of corn to less than 40 kg N/ha. Nitrogen rates for the third corn crop, therefore, were reduced to 20-80 kg N/ha. Corn yields significantly increased in 1986 only with applications of 80 kg N. Although the 1984-1985 results suggest that N fertilizer inputs would be minimal in these Oxisols, 1986 data

Table 1. Effect of N fertilization on rice and corn yield during four years of cultivation. Manaus Oxisol.

	Grain yield			
		Corn		
Applied N	Rice '82	'84	'85	'86
kg/ha	t/ha			
20				1.5
30	2.9			
40		2.7	2.2	1.6
60	3.0			
80		2.5	1.8	2.7
90	2.1			
120		2.9	2.3	
$LSD_{0.05}$	ns	ns	ns	0.6

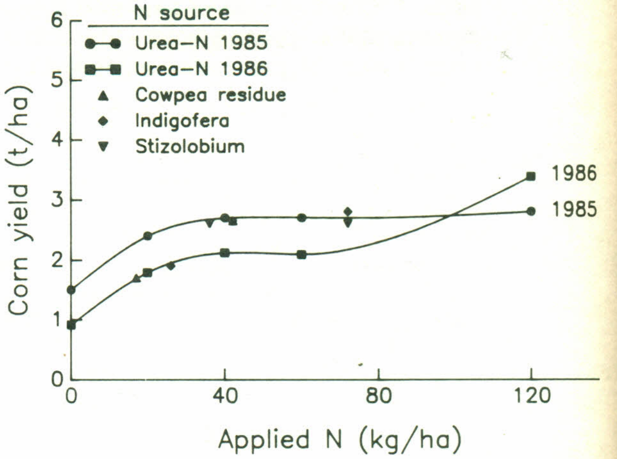

Figure 1. Effect of nitrogen application on corn yield and equivalent yields produced by green manure crops. Manaus, 1985-1986.

suggest reduction in native-soil as well as residue-N supply to corn after five years of continuous cultivation.

Nitrogen fertilization was further investigated in an experiment initiated in 1985 on land cultivated for two years after a four-year fallow. Treatments included five rates of urea-N (0, 20, 40, 60 and 120 kg N/ha), applied annually to corn in three equal amounts between planting and tasseling. Legume crops were not grown in rotation with these treatments. Nitrogen contribution from legumes, grown *in situ*, were compared in three additional treatments: cowpea residues (after grain harvest), and two green manures, *Indigofera tinctoria* and *Mucuna preta* (*Stizolobium aterrimum*). Residual N was evaluated with a rice crop after the first corn crop. Urea-N and legume treatments were repeated for the 1986 corn crop.

Corn-yield response curves to fertilizer N are shown in Figure 1. Corn yields for legume treatments are compared to urea-N treatments on a yield-equivalency basis. Yield and total N uptake by rice were not significantly affected by residual N treatments. Two management factors may have contributed to the increased response to N fertilization in 1986: decreased native soil N supply and improved placement of fertilizer N.

Nitrogen uptake in three consecutive crops is shown in Table 2. During 1985, aboveground corn and rice N accumulation on the treatment without fertilizer N or legumes totaled 88 kg/ha. The fraction of fertilizer N applied at planting was banded below the seed in 1986, as opposed to broadcast incorporated in 1985. This change in fertilizer placement may have promoted early corn growth and increased the overall yield response to urea-N in 1986.

Corn yields among the green manure treatments also varied with years of cultivation (Figure 2). Grain yields with cowpea residue, *Indigofera* and *Stizolobium* were equivalent to yields obtainable with 42, 72 and 36 kg N/ha of urea in 1985 and to 17, 26 and 72 kg N/ha of urea in 1986. These differences in legume performance between years are in agreement with changes in N additions (Table 2). Whereas biomass for *Indigofera* and cowpea residues declined from 6.2 and 1.4 t/ha in 1985 to 3.2 and 0.3 t/ha in 1986, biomass for *Stizolobium* remained constant (7.1 vs. 7.0 t/ha in 1985 and 1986). Reductions in biomass production for the two former legumes may have been associated with a decline in available soil P. Mehlich-1 extractable soil P declined from 14 to 9 mg/kg between the corn and rice crops in 1985. The latter level is below the established critical P level for cowpea in this Oxisol. Additional reductions in soil P could also have occurred before P fertilizer was reapplied to corn in 1986, raising extractable P levels to 15 mg/kg. Differences between years in the performance of these two green manures would indicate a preference for *Stizolobium* in conditions of low nutrient availability.

Table 2. Annual additions and total N uptake by aboveground biomass in three consecutive crops.

N additions			N uptake		
	Amount		1985		1986
Source	'85	'86	Corn	Rice	Corn
	kg/ha				
None	0	0	44.8	43.0	25.9
Urea	20	20	63.2	37.3	44.8
	40	40	66.9	41.4	50.2
	60	60	79.6	49.0	51.7
	120	120	80.8	47.9	81.0
Cowpea residue	32	7	68.0	39.4	45.4
Indigofera	152	91	72.8	49.4	48.3
Stizolobium	168	254	72.6	52.1	60.4
$LSD_{0.05}$			17.2	ns	18.9

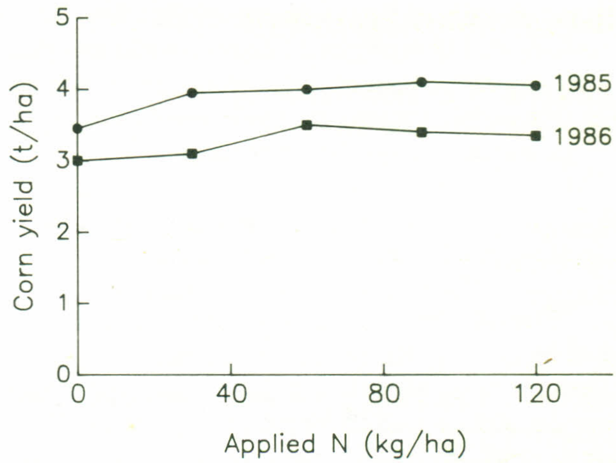

Figure 2. Effects of nitrogen application in an alluvial (*várzea*) soil at Caldeirao, Amazonas.

Additional advantages to including green-manure cover crops in annual crop rotations are the suppression of weeds and recycling of nutrients other than N. Total ground cover under *Stizolobium* was achieved within 30 days after planting this legume. Weed incidence for this treatment, in both corn crops, was less than for treatments without green manures. Significant amounts of K were also measured in the green-manure biomass. Biomass K for *Stizolobium* and *Indigofera* were 63 and 68 kg/ha in 1985, and 90 and 39 kg/ha in 1986. In the absence of green manures, significant K movement had been detected to a soil depth of 75 cm with K fertilizer rates of 50 kg/ha/crop during continuous cultivation. Biomass K levels for these legumes are compatible with the recommended K fertilization rates for this soil.

Corn fertilizer N requirements in the Oxisol can be compared to similar data for the fertile lowland alluvial (*várzea*) soils along the Amazon River at Caldeirao (Figure 2). The high fertility of these soils is evident from the surface soil chemical characteristics of the experimental site: pH in water of 5.6, 18 cmol/L of Ca + Mg, 0.4 cmol/L of K, 118 mg/kg of Mehlich-1 P and less than 5% Al saturation. Farmers often plant corn during the five- to six-month period each year when the river recedes and there is no risk of flooding.

Although corn yields are favorable (4-5 t/ha) in the first year of cultivation, yields often decline in successive years when visible symptoms of N deficiency develop. The site for this study was cleared in 1982 but had not been cultivated. Submergence by flooding has not occurred since 1983. Across the range of N rates studied, maximum yields were approached with the application of 60 kg N/ha in both years. With this N rate, yields were increased by 0.7 t/ha in 1985 and 1.0 t/ha in 1986. These data indicate the potential yield levels that may be achieved with available corn germ plasm, under nonlimiting nutrient conditions in the Manaus ecosystem.

Implications

A major implication of the Manaus work is the recognition of N as a major limiting factor, with N response varying with time. Green manures are a good source of N, but there is considerable variability from year to year in the amounts of N supplied by different green manure species due to variations in dry-matter production and N content.

Research has also been initiated in the alluvial soils (*várzeas*) where N is also a major limiting factor in annual crop production.