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Resource Use and Plant Interactions in a Rice-Mungbean Intercrop

P.K. Aggarwal, D.P. Garrity,* S.P. Liboon, and R.A. Morris

ABSTRACT

Intercropping of upland rice (*Oryza sativa* L.) with short-duration grain legumes has shown promising productivity and resource use efficiency. To better understand intercrop relationships, we used above- and underground partitions, residue removal, and plant removal to investigate the interactions between upland rice (120-d crop duration) and mungbean [*Vigna radiata* (L) Wilczek, 65-d crop duration]. Treatments were evaluated during two rainy seasons on an unfertilized Typic Tropudalf at Los Baños, Philippines. Nitrogen uptake by intercropped rice (33.4 and 41.1 kg N ha^{-1}) approximated that of sole rice (35.4 and 38.1 kg N ha^{-1}). Intercropped rice yielded 73 to 87% of sole rice and intercropped mungbeans yielded 59 to 99% of sole mungbean. Root barriers did not affect rice N uptake or dry matter accumulation prior to the maturity of the mungbean, but reduced N uptake, dry matter, and grain yields substantially by the time of rice harvest. Sole rice with every third row removed at mungbean harvest had N, grain, and dry matter yields similar to the intercropped rice with every third row occupied by the legume. Sole rice with every third row vacant during the entire growing season yielded similarly (2.6 Mg h^{-1}) to sole rice (2.3 Mg h^{-1}) and intercropped rice (2.0 Mg h^{-1}). There was no evidence that N transfer from the legume to the rice increased N availability to rice above that expected with a sole rice crop with the same planting scheme. Rice yield compensation in the intercrop was apparently due to the increased soil volume for N extraction and increased aerial space available after mungbean harvest.

In most parts of southeast Asia, upland rice is grown by subsistence farmers with little or no application of inorganic fertilizers. Since the soils are generally of low inherent fertility and rainfall is variable, rice yields are modest (usually about 1.0 Mg ha^{-1}). Many farmers intercrop rice with maize (*Zea mays* L.) or cassava (*Manihot esculenta* Crantz) [Int. Rice Research Inst., 1974 (p. 16–24), 1975 (p. 324–326); McIntosh et al., 1984]. Such intercropping generally ensures production stability but reduces rice yield because of intercrop competition for light and soil N. Intercropping of rice with determinate, short-duration legumes is now being explored as a system to intensify and sustain production through efficient use of available nutrients, water, and radiation during the wet season [IRRI 1984 (p. 421–424), 1986 (p. 408–410), 1987 (p. 483–486); Torres et al., 1989]. The intercrops exhibited higher total yields and greater stability of production in these studies, presumably due to more efficient resource use.

When legumes and non-legumes are intercropped, the non-legume species sometimes performs better than it would in monoculture (Agboola and Fayemi, 1972; Burton et al., 1983; Wilson and Wyss, 1937, Willey, 1979b) possibly because of the additional N supplied by the legume. The processes by which the non-legume obtains extra N, however, are not well understood.

Nitrogen transfer from legumes to associated non-legumes is often mentioned as a potential benefit of cereal-legume intercrops. Eaglesham et al. (1981) and Patra et al. (1986), using ^{15}N-labeled fertilizer, presented evidence that N transfer occurred in a cereal-legume intercrop. Nitrogenous compounds may be excreted from the nodulated root systems of intercropped legumes (Virtanen et al., 1937; Butler and Bathurst, 1956). Soluble N may be leached from attached legume leaves, or released by the decay of fallen leaves (Whitney and Kanehiro, 1967; Whitney et al., 1967).

The yield advantage of any intercrop is attributed to below- and above-ground plant interactions. These interactions may be competitive, neutral, or complementary (Willey, 1979b). Snaydon and Harris (1979) pointed out that below-ground interaction is more important than above-ground interaction in achieving intercrop yield advantages. Below-ground interaction is more intense than that above ground (Donald, 1958; Aspinall, 1960; Snaydon, 1971; Newberry and Newman, 1978). However, Willey and Reddy (1981) observed an intercrop yield advantage to pearl millet [Pennissetum americanum (L.) Leeke] and groundnut (*Arochis hypogaea* L.) due to above-ground interaction between the respective canopies.

The relative importance of below- and above-ground intercrop interactions is likely to vary depending upon the temporal and spatial differences in resource use by component crops. The objective of this study was to compare above- and below-ground interactions between intercropped upland rice and mungbean, and to examine their effect on N uptake and crop productivity.

MATERIALS AND METHODS

Two field experiments were conducted at the International Rice Research Institute (IRRI) experimental farm, Los Baños, Laguna, Philippines (mean annual rainfall 1892 mm) during the rainy seasons of June to September 1986 and 1987. The soil at the experimental site was an isohyperthermic Typic Tropudalf of silty clay texture. Chemical properties of the soil before planting in 1986 were pH, 6.0; Organic C, 15.0 g kg^{-1}; total N, 1.18 g kg^{-1}; available P (Bray 2), 41 g Mg^{-1}; exchangeable K, 1.07 cmol kg^{-1}; and cation exchange capacity, 20.0 cmol kg^{-1}.

Experiment 1. The nine cropping treatments (Table 1) used in Exp. 1 and their planting scheme appear in Fig. 1. In intercrop treatment (T1), the mungbean residues were left on the soil surface at mungbean harvest. In Treatment 4 the abscised leaves were removed repeatedly from the soil surface as they dropped to the surface. Abscised leaf removal was initiated 40 d after sowing and continued through mungbean harvest. Below-ground interaction between intercropped rice and mungbean roots (T1) was prevented in (T2) by placing sheets of galvanized iron vertically between rows of the two crops to a depth of 50 cm. Root interaction

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P.K. Aggarwal, Water Technology Centre, Indian Agric. Res. Inst., New Delhi—110012, India; D.P. Garrity and S.P. Liboon, Agronomy, Physiology and Agroecology Division, International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines; and R.A. Morris, Department of Soil Science, Strand Agric. Hall 202, Oregon State University, Corvallis, OR 97331. Received 13 Aug. 1990. *Corresponding author.

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Abbreviation: LER, land equivalent ratio.

Table 1. Total above-ground dry matter accumulation and grain yields of intercropped rice and mungbean as affected by plant interactions in 1986.

	Treatment	Rice dry matter yield			Grain yield		
		Prior to mung maturity	After mung maturity	Total	Rice	Mung	Total
		Mg ha^{-1}					
T1	Intercrop	1.0	2.9	3.9	1.4	0.8	2.2
T2	Intercrop with no below-ground interaction†	1.6	1.6	3.2	1.0	0.8	1.8
T3	Intercrop with slots prepared‡ (control for T2)	1.4	2.5	3.9	1.3	0.7	2.0
T4	Intercrop with abscised leaves removed	1.2	2.4	3.6	1.3	0.7	2.0
T5	Sole rice	1.8	4.0	5.8	1.8	—	1.8
T6	Sole rice with 3rd row removed§	1.8	2.2	4.0	1.3	—	1.3
T7	Intercrop, shading reduced	1.2	2.8	4.0	1.4	0.7	2.1
T8	Sole mungbean, shading reduced	—	—	—	—	0.9	0.9
T9	Sole mungbean	—	—	—	—	0.8	0.8
	SE	0.2	0.4	0.4	0.1	0.1	
	LSD (0.05)	0.5	0.8	0.8	0.2	0.1	
	CV (%)	22.4	20.8	12.6	12.2	8.5	

†Galvanized iron sheets placed between rows in slots to 50-cm depth.
‡Slots prepared for galvanized iron sheets as in T2 but sheets not inserted.
§Rice rows removed at the time mungbeans were harvested in the intercrop treatments.

below 50 cm was presumed to be minimal since rice roots were confined predominantly to the 0- to 50-cm zone (Hasagawa and Yoshida, 1982). A control for treatment (T2) was included (T3) by preparing vertical openings 50 cm deep before planting, but no root barriers were inserted. The openings were made by using a 2.54-cm wide subsoiler for strip tillage driven by a four-wheel tractor. The T3 treatment isolated possible crop performance effects due to soil disturbance that occurred during preparation of the 50-cm deep vertical openings. To determine the advantage of increased soil volume for rice after the mungbean harvest, we removed every third row of rice above-ground biomass from sole rice (T6) when the intercropped mungbean was harvested. Shading effects of early maturing mungbean on intercropped rice were minimized by a nylon net that restricted mungbean foliage to a maximum of 10 cm on either side of the mungbean (T7). A sole mungbean treatment (T8) with a similar net barrier served as a control to isolate the possible nylon net effects on mungbean (T9).

Sole rice (upland cultivar UPL Ri7, 115–120-d crop duration) was drilled in rows 20 cm apart using a seed rate of 100 kg seed ha^{-1}. Sole mungbean (cultivar EG MG 174-3, 55–65 d crop duration) was seeded in rows 40 cm apart and thinned to 12 to 15 plants per linear m after emergence. In the intercrop treatments, two rice rows alternated with one row of mungbean, with all rows 20 cm apart. The experiment was laid out in a randomized complete block design with four replicates and was sown on 3 June 1986. Plot size was 4 by 5 m. No inorganic fertilizer was applied. The 1986 wet season rainfall was 1270 mm, 29% higher than the 20-yr average for the June to September period, and was sufficient to maintain a relatively water stress-free environment during the experiment. Pests and diseases were controlled, but the incidence of leaf spot (*Cercospora* spp.) on mungbean at flowering stage could not be fully suppressed. At both mungbean maturity and at rice maturity, crop cuts for grain yield and total dry matter were taken from 1.2- by 3-m sample areas, and consisted of four rice rows and two mungbean rows. Mungbeans were harvested on 31 July and rice on 29 Sept. 1986. Samples were oven-dried at 80°C. Total N in grains and above-ground vegetative plant matter was determined by the Kjeldahl method (Varley, 1966).

Experiment 2. In the second year the two netting treatments for minimizing shading effects (T7 and T8; Table 1) were eliminated and two treatments added (T7 and T8). New treatment T7 evaluated the response of intercrop rice to mungbean vine incorporation within the row after mungbean harvest. The second additional treatment (T8) determined the response of monocrop rice with the third row vacant during the entire rice-growing period. Experimental design, crop management, and sampling procedures were the same as in the first experiment. Both crops were sown on 2 June 1987. Mungbean was harvested on 31 July and rice on 11 Sept. 1987. The rainfall during the growing season was 825 mm (35% lower than the 1986 wet season and 16% lower than the 20-yr average). Supplemental irrigation was applied to minimize drought stress.

RESULTS AND DISCUSSION

Grain yield and N uptake of monocrop rice and mungbean were higher in 1987 when lower rainfall and fewer cloudy days favored crop growth and reduced the incidence of leaf spot (*Cercospora* spp.) compared to 1986. Grain yield of intercropped rice (1.4 Mg h^{-1}) was 22% lower than that of sole rice (1.8 Mg h^{-1}) in 1986 (Table 3). However, the total N uptake of intercropped rice was similar to that of sole rice in both years (Tables 2 and 4). Nitrogen uptake of intercropped rice was less than that of sole rice at the time of mungbean maturity in both years. After mungbean harvest, N uptake by intercropped rice continued to be similar to that of sole rice in 1986 (Table 2). However, in 1987 N uptake in the intercropped rice continued after mungbean harvest but ceased entirely in sole rice (compare T1 and T5 in Table 4). In 1987, initial N uptake was very rapid in

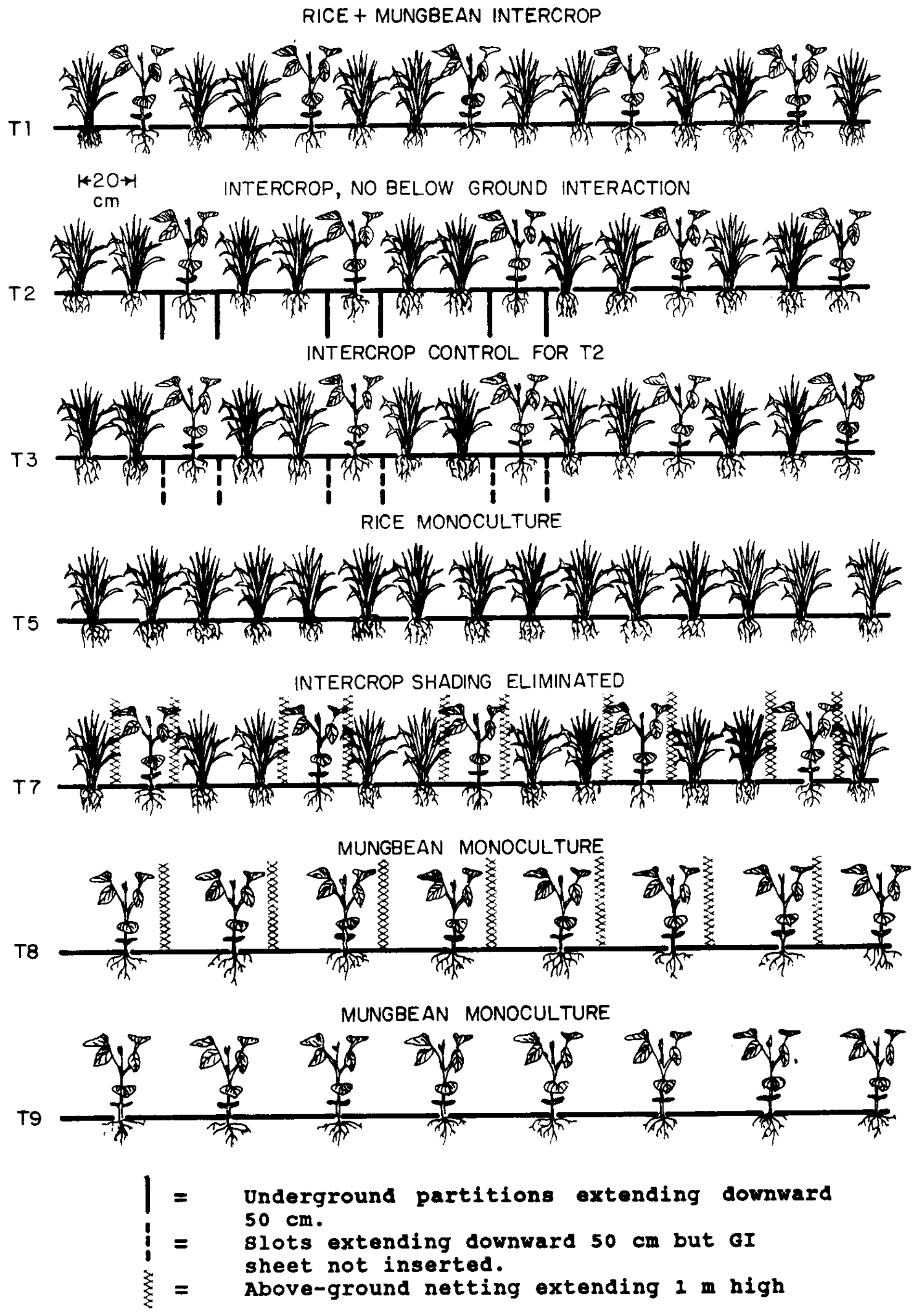

Fig. 1. Diagram of the rice and mungbean intercropping and monoculture treatments in 1986. (Exp. 1). Treatments 4 and 6 are not illustrated.

all three sole rice treatments (T5, T6, and T8) but during the later phases of rice growth mineralized soil N was apparently exhausted and no longer available for uptake (Table 4).

When rice and mungbean were intercropped but separated by an underground partition (T2), rice dry matter and N uptake were not significantly affected up to the time of mungbean harvest in both years (Tables 1–4, T2 vs. T3). However, subsequent to mungbean harvest, rice dry matter and N uptake were strongly reduced, compared to the intercrops without root barriers (T2 vs. T1 and T3, Tables 1–4). Consequently, rice grain and final N uptake were significantly reduced in the presence of the barriers. The process of underground partition installation had no effect on rice or mungbean as evidenced by the similarity between grain yield and N uptake of intercropped rice and mungbean in T3 and T1 (Tables 1–4). Root barriers did not affect the ability of rice to exploit the above-ground space vacated after mungbean harvest. Therefore, rice productivity was negatively affected by the root barriers because of the inability of the rice to utilize the below ground space vacated by mungbean.

Table 2. Nitrogen uptake† by intercropped rice and mungbean and N concentration in rice grain yield as affected by plant interaction in 1986.

		Rice					
	Treatment	Prior to mung maturity	After mung maturity	Total	Nitrogen in grain	Mungbean Total	Both Crops (Total)
		kg ha^{-1}			%	kg ha^{-1}	
T1	Intercrop	12.0	21.4	33.4	1.2	50.7	84.1
T2	Intercrop with no below-ground interaction‡	16.0	8.9	24.9	1.2	51.9	76.8
T3	Intercrop with slots prepared§ (control for T2)	15.4	17.7	33.1	1.2	47.4	80.5
T4	Intercrop with abscised leaves removed	14.0	13.9	27.9	1.2	45.3	73.2
T5	Sole rice	17.4	18.0	35.4	1.0	—	35.4
T6	Sole rice with 3rd row removed¶	17.4	11.2	28.6	1.1	—	28.6
T7	Intercrop, shading reduced	14.0	16.7	30.7	1.2	43.4	74.1
T8	Sole mungbean, shading reduced	—	—	—	—	57.5	57.5
T9	Sole mungbean	—	—	—	—	51.8	51.8
	SE	2.1	1.5	3.1	0.1	2.7	3.8
	LSD (0.05)	4.5	7.3	6.7	0.1	6.3	7.8
	CV (%)	20.2	32.1	14.7	5.4	8.6	8.4

†N in total above-ground dry matter.
‡Galvanized iron sheets placed between rows in slots to 50-cm depth.
§Slots prepared for galvanized iron sheets as in T2 but sheets not inserted.
¶Rice rows removed at the time mungbeans were harvested in the intercrop treatments.

Intercropped mungbean grain and N uptake were similar to that of sole mungbean crops in 1986 (T1 vs. T9) (Tables 1 and 2). In contrast, in 1987, intercropped mungbean grain yields and N uptake (N yield) were reduced (41 and 35%, respectively) compared to those in monoculture. Elimination of the interaction between roots of the two crops had no effect on mungbean grain yield and N uptake except in 1987, when N uptake as significantly reduced (T2 vs. T1; Tables 1–4).

The apparent absence of competition between rice and mungbean in 1986 was probably due to the dif-

Table 3. Total above-ground dry matter and grain yields of intercropped rice and mungbean as affected by plant interactions in 1987.

		Rice dry matter yield			Grain yield		
	Treatment	Prior to mung maturity	After mung maturity	Total	Rice	Mung-bean	Total
		Mg ha^{-1}					
T1	Intercrop	2.6	2.8	5.3	2.0	1.0	3.0
T2	Intercrop with no below-ground interaction†	2.1	1.9	4.0	0.7	0.8	1.5
T3	Intercrop with slot prepared‡ (control for T2)	2.6	3.4	6.0	1.7	1.1	2.8
T4	Intercrop with abscised leaves removed	2.6	3.0	5.5	1.9	1.2	3.1
T5	Sole rice	4.4	2.5	6.8	2.3	—	2.3
T6	Sole rice with 3rd row removed§	3.9	1.7	5.6	1.7	—	1.7
T7	Intercrop, mungbean incorporated at harvest	2.6	2.5	5.0	1.7	1.2	2.9
T8	Sole rice—every 3rd row vacant	4.0	3.6	7.6	2.6	—	2.6
T9	Sole mungbean	—	—	—	—	1.7	1.7
	SE	0.4	0.5	0.7	0.3	0.1	
	LSD (0.05)	0.9	1.0	1.4	0.6	0.3	
	CV (%)	18.5	24.8	16.6	20.5	14.6	

†Galvanized iron sheets placed between rows in slots to 50-cm depth.
‡Slots prepared for galvanized iron sheets as in T2 but sheets not inserted.
§Rice rows removed at the time mungbeans were harvested in the intercrop treatments.

Table 4. Nitrogen uptake† by intercropped rice and mungbean as affected by Plant interactions and N concentration in rice grain in 1987.

		Rice					
	Treatment	Prior to mung maturity	After mung maturity	Total	Nitrogen in grain	Mung total	Both crops (Total)
		kg ha^{-1}	kg ha^{-1}	%	kg ha^{-1}	kg ha^{-1}	
T1	Intercrop	26.4	14.7	41.1	1.0	72.5	113.6
T2	Intercrop with no below-ground interaction‡	20.9	5.9	26.8	1.1	49.3	76.1
T3	Intercrop with slots prepared;§ (control for T2)	26.9	17.0	43.9	1.1	75.6	119.5
T4	Intercrop with abscised leaves removed	28.5	12.3	40.8	1.1	62.1	102.9
T5	Sole rice	38.4	−0.3	38.1	0.9	—	38.1
T6	Sole rice with 3rd row removed¶	33.1	−1.2	31.9	0.9	—	31.9
T7	Intercrop, mungbean incorporated at harvest	27.3	13.3	40.6	1.1	56.8	97.4
T8	Sole rice—every 3rd row vacant	40.4	3.1	43.5	0.9	—	43.5
T9	Sole mungbean	—	—	—	—	111.2	111.2
	SE	4.8	4.0	4.3	0.1	10.8	7.6
	LSD (0.05)	10.0	8.2	9.0	0.1	23.1	15.7
	CV (%)	22.5	28.3	15.9	7.1	21.5	13.2

†N in total above-ground parts only.
‡Galvanized iron sheets placed between rows in slots to 50-cm depth.
§Slots prepared for galvanized iron sheets as in T2 but sheets not inserted.
¶Rice rows removed at the time mungbeans were harvested in the intercrop treatments.

ferent growth durations of the two species, as well as their different rooting depths. The initial growth and height increments of rice were less than those for mungbean, and rice rooting patterns are known to be shallower [Angus et al., 1983; IRRI, 1973 (p. 21–34); Trenbath, 1976]. The environment in 1987 was more favorable for growth, as is evident by the higher dry matter and grain yields of the rice and mungbean monocultures (Table 3). This altered the competitive balance between the two crop species, leading to decreased grain yield and N uptake in the intercropped mungbeans (T1 vs. T9; Tables 3 and 4).

Abscised mungbean leaves in T4 added 15.5 kg N ha^{-1} to the soil during the interval of 43 to 60 d after sowing in 1986. Removal of leaves as they senesced significantly reduced the N uptake of intercropped rice (T4) relative to the control intercrop (T1—no leaf removal), during the rice growth period following mungbean harvest in 1986 (Table 2). In 1987 the removal of mungbean leaves did not affect rice N uptake (Table 4). However, in both years the final dry matter, grain yield and N uptake of rice were not significantly different when abscised mungbean leaves were removed (T4 vs. T1 Tables 1–4). The incorporation of mungbean residue contributed 17.6 kg N h^{-1}. Thus, the mungbean residues did not positively influence the nutrition of the associated cereal crop within the concurrent growing season. The residual effects of these residues on subsequent rice crops were not investigated.

Removal of every third row of sole rice (T6) at mungbean maturity reduced rice grain yield and total dry matter yield to levels similar to those observed in the intercrop (T1) in both years (Table 1 and 3). However, the total N uptake of rice with third rice row removal (T6) was lower than that of intercropped rice (T1), although the differences were significant only in 1987. The similarity of grain yields in T6 and T1 suggests that the major factor causing the compensatory effect of the intercrop was the increased space available after the mungbean intercrop was harvested, i.e., greater aerial space for more solar radiation interception per rice plant, and greater available root volume. Grain and dry matter yields of T6 were higher than T2 (Tables 1 and 3), suggesting that the 60-d rice growth period after the mungbean harvest was a significant factor in creating yield compensation in the intercropped rice. Chareon (1985) and Liboon et al. (1986) also reported higher intercropped rice yield per unit area of rice.

In the skip row treatment (T8) in which every third rice row was kept vacant throughout the growing season in 1987, rice grain yield and N uptake were 13 and 14% higher, respectively (although not significantly), than sole rice, and 30% (significantly) higher than in intercropped rice (Table 3 and 4). The field area occupied by rice in the skip row (T8) and intercrop (T1) treatments was identical (two-thirds of the total area). Therefore, the results suggest that yield increases in the remaining rows in a skip row configuration may fully compensate for the lost production of the plants absent in the missing rows, as has been reported by Rathi and Verma (1974) and Willey (1979a, b).

There was no evidence that shading by mungbean affected intercropped rice yield and N uptake in the intercrop (T7 vs. T1) (Tables 1 and 2). However, it must be noted that the netting treatment (T7) eliminated competition between the canopies of the two species for direct solar radiation only at the high sun portions of the day.

Based on the proportional field area occupied by rice (67%) in the intercrop, the grain yield and N uptake of intercropped rice was predicted to be 1.2 Mg h^{-1} and 23.7 kg h^{-1}, respectively, on the basis of 1986 sole rice yield and N uptake. Since intercropped rice yield and N uptake were higher than that predicted on the basis of actual ground area occupied (1.4 Mg h^{-1} and 33.4 kg h^{-1}, respectively), there was a compensation of 0.2 Mg h^{-1} (19%) in grain yield and 9.7 kg h^{-1} (41%) in N uptake. The yield compensation of intercropped rice in 1987 was a 0.4 Mg h^{-1} (30%) increase in rice grain yield and a 15.6 kg h^{-1} (61%) increase in rice N uptake.

The findings support the hypothesis that compensation in rice yield in an intercrop with mungbean is due predominantly to the increased soil and aerial space available to the crop after the mungbean is removed. Since mungbean grew more vigorously in 1987 than in 1986, it is likely that the 30% reduction in grain yield of intercropped rice in T1 compared to sole rice skip row treatment (T8) was due to the shading of rice plants by mungbean, and other competitive effects of the companion crop. Skip row planting yielded as well as uniform planting, suggesting that there is potential to better utilize space and time in low-input upland rice systems by intercropping with a short duration legume.

Nitrogen Transfer. Direct N transfer from a legume to a cereal in an intercrop has been detected by several research groups (e.g. Patra et al., 1986; Eaglesham et al., 1981). However, this does not imply that the overall N availability to rice was increased by the presence of the legume. The legume also withdraws a substantial quantity of available N from the soil N pool that would have been utilized by the rice crop in the absence of the legume, i.e., if rice had been grown in monoculture with the same planting scheme. The important question relating to legume-cereal N interactions is whether there is a net positive N transfer between the legume and rice. If a net positive N transfer occurs it can be concluded that the N-fixing plant provides excess N for the cereal.

When a positive net transfer occurs, the N uptake of the cereal will exceed the level observed in monoculture skip row treatments. We found that rice N yield in the skip row treatment (T8 in 1987) was similar to that of the intercrop, and therefore concluded that a net positive N transfer did not occur. Some of the earlier intercrop studies that investigated N transfer did not provide evidence of a net positive N transfer (Wahua and Miller, 1978a; Ledgard et al., 1985). The distinction between direct N transfer from legume to cereal and the net transfer of N is important in interpreting the supposed benefits of legumes in intercropping systems.

Nitrogen Use Efficiency. In both years the percentage of N in the intercropped rice grain was significantly higher than in monoculture rice. Higher percent N in intercrop rice grain was related to lower efficiency in converting N into grain. The skiprow rice (T8) had similar total N uptake but significantly lower percent N in the grain than the intercrop treatments (T1, T3, T4). Therefore, the skip row rice had a higher N utilization efficiency, i.e. grain yield per kg of N uptake (59.8 kg kg^{-1}), compared to the intercrop rice, which produced 38.7 to 48.7 kg grain kg^{-1} N uptake (calculated from Tables 3 and 4). The other sole rice treatments (T5 and T6, Table 4) also had higher N utilization efficiencies compared to the intercrops.

When below-ground interactions were prevented (T2), intercropped rice had a high N concentration in the grain in both years but had low grain yields, low N uptake, and a lower conversion of plant N into grain yield (33.1 kg grain kg^{-1} N uptake; mean of both experiments), compared to sole crops (55.6 kg grain kg^{-1} N uptake) . The low N use efficiency and higher grain N concentration of the intercropped rice relative to that of a sole rice crop may have been due to the reduced rice proportion in the intercrop. The critical period of canopy formation i.e., tillering and leaf area development of modern rice varieties is generally up to 60 to 70 d after sowing. Intercrop mungbean reduced space and soil volume during the critical canopy formation period and thereby reduced rice dry matter per unit area. However, after mungbean harvest, rice utilized the available N in the mungbean rows, resulting in similar N uptake for intercropped and sole rice by harvest. Greater relative N availability late in the growing season resulted in higher grain N content (Turley and Ching, 1986) in the intercrop rice.

Intercrop production. The land equivalent ratio (LER) was calculated as the land area required in monoculture to equal the total yield of 1 ha of the intercrop (Willey, 1979b). The LER of the treatments in both years is shown in Fig. 2. Grain yield and N uptake of the intercrop components are plotted as a fraction of their respective monoculture checks. The LER for total grain yield was 0.77 in 1987 in treatment T2 where below-ground interactions were artificially prevented. In all other intercrops, the LER was more than 1.4, indicating a considerable superiority in resource use efficiency. Aside from treatment T2, intercropped rice yields were generally more than 70% of the sole crop, whereas mungbean grain yields were between 47 and 99% of their sole crop grain yields (Fig. 2a).

Compared to LER-grain yield, LER-N uptake was always more than 1.67 except in T2 where LER was 1.2 (Fig. 2b). In 1986, the N uptake of both mungbean and rice in the intercrop were very close to their sole crop N uptake. In 1987, although rice N uptake was comparable to the controls, N uptake of mungbean was decreased.

The LER in 1986 was chiefly influenced by the mungbean component. Mungbean grain yields in the intercrops were a higher fraction of their monoculture yields in that year compared to rice. In 1987 the opposite occurred. The data suggest a considerable degree of stability in LER across growing seasons, although the relative performance of the two species in the intercrop varied.

When mungbean is intercropped with a medium duration upland rice cultivar, the legume matures before rice flowers. The period during which the two crops compete for common resources is less than one-half of the growth duration of the cereal crop. High land

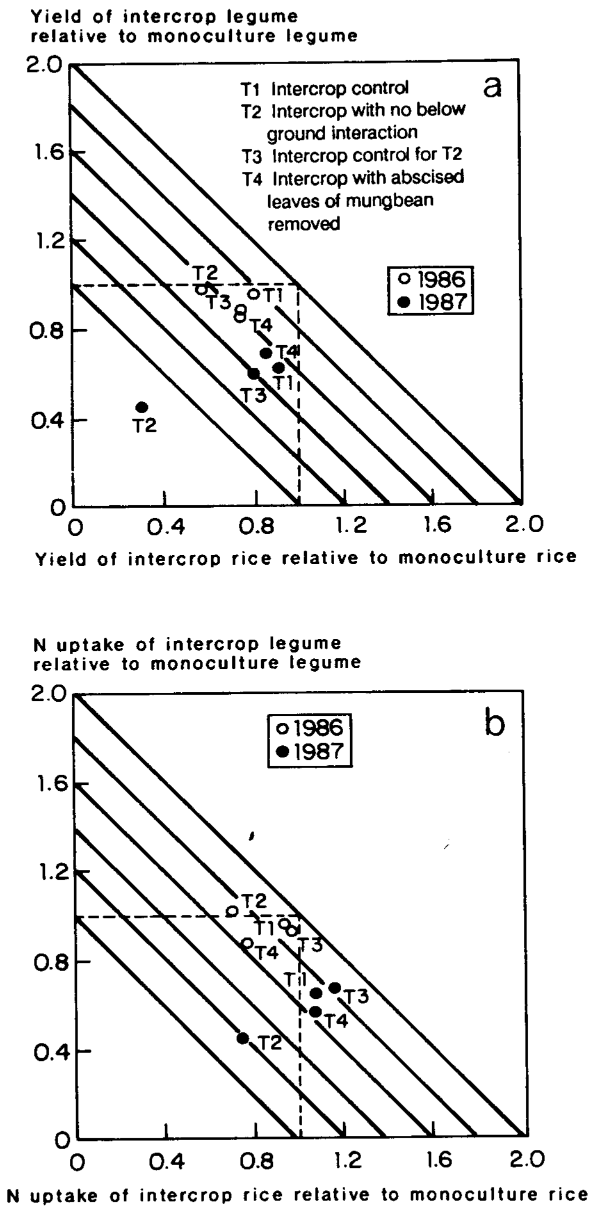

Fig. 2. Intercrop rice and legume grain yields (a) and N uptake (b) relative to the respective monoculture crops in 1986 and 1987.

productivity as measured by LER is commonly observed in these intercrops.

CONCLUSIONS

Above-ground interactions between the corp species were not important determinants of relative crop performance at row spacings used in this study. Below-ground crop interactions were found to be the dominant factors. When the root systems of the two crops were confined by root barriers, no effect was observed on mungbean yields, but rice N uptake and yield were reduced substantially.

Results from skip row and row removal treatments on sole rice crops indicated that intercropped rice benefits from the uptake of N and other nutrients in the soil volume available after harvest of early maturing intercropped mungbean.

Mungbean accumulated relatively large quantities of N but did not increase N uptake by intercrop rice. Intercrop rice and mungbean produced 0.6 to 1.0 Mg h^{-1} more total grain than an equivalent area of monoculture rice and mungbean. Rice N uptake was similar in the presence and absence of the legume intercrop. Nitrogen transfer to rice from the legume was negated by an equivalent quantity of soil N uptake by the legume. The intercropping of a 120-d rice with a 60-d duration legume offers potential to better utilize space and nutritional resources in low input cropping systems. However, the utility of intercropping depends on economic factors, the cropping system, and growing season length.

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