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Fallow and Sesbania Effects on Soil Nitrogen Dynamics in Lowland Rice-Based Cropping Systems

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ABSTRACT

Vast areas of rice-growing (*Oryza sativa* L.) lowlands in Asia are fallowed or cropped with non-rice crops for part of the year. Nitrate can accumulate during the fallow or non-rice crop, but this nitrate can be lost upon flooding for rice production. To determine fallow and green manure crop effects on soil nitrate and ammonium dynamics in lowland riceland, a 2-yr field study was conducted in the Philippines. Treatments before wet season rice were (i) *Sesbania rostrata* grown for either 45 or 60 d, (ii) weedy fallow, and (iii) weed-free fallow. *Sesbania rostrata* was sown with irrigation in late April-early May, rains started in early (1989) or mid-May (1990). Weeds and *S. rostrata* were incorporated after soil flooding on 23 June. Rains increased soil water-filled pore space to above 0.75 mL mL^{-1} between mid-May and soil flooding. Weeds and *S. rostrata* assimilated soil nitrate, as evidenced by lower ($P < 0.05$) nitrate in those treatments than in the weed-free fallow. The decrease in soil nitrate in the weed-free fallow from 24 April to before soil flooding (15 kg N ha^{-1}) was apparently due to denitrification or leaching; additional nitrate (19 kg N ha^{-1} in 1990) disappeared after soil flooding. Ammonium-N was rapidly released from incorporated weeds and *S. rostrata*. It reached a maximum by 36 d after incorporation, which correlated ($r = 0.95$) with N accumulation by rice at 45 d after transplanting. Results suggest that weeds and crops before rice can reduce soil N loss by assimilating nitrate-N and then cycling this N through incorporated plant residues back to the soil where it is rapidly mineralized and used by rice.

RICE IS THE STAPLE FOOD for the majority of people in Asia. Approximately 80% of the rice-growing areas in Asia is irrigated and rainfed lowlands (IRRI, 1989). In lowlands with adequate year-round water supply and favorable temperatures, rice can be grown continuously on flooded soils. In vast areas of Asia, however, insufficient water supply and cold temperature prevent continuous rice cropping. In such areas, the ricelands are fallowed or cropped to upland crops, such as legumes, wheat, or green manure, between rice crops.

Soils are typically saturated for at least part of the time during the rice crop. In the interval between rice crops, the soil dries and becomes aerobic. Ammonium in aerobic soils is normally oxidized to nitrate, which can accumulate in the soil or be utilized by plants. When aerobic soils are flooded for rice production, soil oxygen is rapidly depleted and nitrate may be lost by denitrification or leaching (Ponnamperuma, 1985; Buresh and De Datta, 1991).

Buresh et al. (1989) observed between 39 and 91 kg nitrate-N ha^{-1} in the top 60-cm soil layer following a dry season mungbean [*Vigna radiata* (L.) Wilczek]-weedy fallow sequence at three sites in the Philippines. The nitrate rapidly disappeared after flooding. Denitrification and leaching, but not dissimilatory nitrate reduction to ammonium, were possible mechanisms for nitrate disappearance.

The accumulation of nitrate in aerobic soil is influenced by soil water status (Linn and Doran, 1984; Doran et al., 1990) and inversely correlated with weed growth (Buresh et al., 1989). Singh (1984) speculated that legumes grown between lowland rice crops can scavenge soil nitrate, which might otherwise be lost after the soil was flooded for rice production. Yield and N accumulation of lowland rice, as affected by prior soil flooding during either a fallow or growth of *Sesbania* sp. (Furoc and Morris, 1989; Morris et al.,1989), suggested that *Sesbania* accumulated soil nitrate before soil flooding, thereby preventing N loss and cycling soil N through green manure N back to the soil for use by rice (Buresh and De Datta, 1991). However, Furoc and Morris (1989) and Morris et al. (1989) did not monitor soil nitrate and ammonium dynamics to substantiate this speculation.

The objectives of this study were (i) to determine the effect of weeds and *Sesbania rostrata*, a stem-nodulating aquatic legume (Ladha et al., 1990), on soil nitrate dynamics and (ii) to measure the release of ammonium from weeds and *S. rostrata* green manure incorporated during land preparation for rice.

MATERIALS AND METHODS

A field experiment was conducted in 1989 and 1990 at the International Rice Research Institute, Los Baños, Philippines on a silty clay (Typic Tropaquept). The top 30-cm layer of the soil had the following characteristics: air-dried pH (1:1 wt/vol water) = 5.8, organic C = 11 g kg^{-1}, total N = 1.1 g kg^{-1}, CEC = 30 cmol$_c$ kg^{-1}, clay = 43%, and sand = 12%. The site had been cropped to lowland rice in the 1988 wet season and to soybean in the 1989 dry season. The experiment was initiated immediately after soybean harvest in March 1989.

The experimental design was a randomized complete block with four replications and four pre-rice treatments in factorial combination with four rates of urea applied to rice. The pre-rice treatments were (i) *Sesbania rostrata* grown for 45 d, (ii) *S. rostrata* grown for 60 d, (iii) weedy fallow, and (iv) weed-free fallow. All measurements in this study were made in the four pre-rice treatments receiving no added urea. Plot size was 20 m^2, and all plots were surrounded by 20-cm-high soil levees.

All plots were rototilled without prior irrigation in early April 1989. *Sesbania rostrata* seeds were germinated, sown at 30 kg ha^{-1}, and then incorporated by harrowing. *S. rostrata* grown for 60 d (SR60) and 45 d (SR45) were sown on 17 April and 5 May, respectively. All plots were irrigated with 24 mm of water on 17 April and 39 mm of water on 24 April to facilitate emergence of early sown *S. rostrata*. Weed growth was not controlled in the two *S. rostrata* treatments and the weedy fallow. In the weed-free fallow, aboveground weed biomass was removed by hand at 7-d intervals.

On 22 June, *S. rostrata* was cut at ground level, chopped, and placed on the soil surface. Plots were flooded on 23 June

Abbreviations: DT, days after transplanting; PN, plant N; and WFPS, water filled pore space.

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and then wet plowed and harrowed. *S. rostrata* and weed residues were further incorporated with a hydrotiller on 26 and 27 June. On 30 June, 22-d-old seedlings of 'IR72' were transplanted at 20- by 20-cm hill spacing. Soil analyses indicated sufficient P, K, and Zn; therefore, these nutrients were not added to rice. Rice was harvested between 25 September and 6 OctoberPlots were then flooded, plowed, and harrowed without removing rice stubble. A second crop of 'IR72' rice with 60 kg urea-N ha^{-1} applied to all plots was transplanted on 31 October and harvested in February 1990.

In 1990, treatments were repeated in the same plots. SR60 and SR45 were sown on 17 April and 4 May, respectively. All plots were irrigated with 20 mm water on 17 April, 20 mm on 25 April, and 20 mm on 4 May to facilitate emergence of *S. rostrata*. Management practices in 1990 were identical to those in 1989 except that rice transplanting was delayed by 4 d until 4 July.

Immediately before incorporation, the total aboveground *S. rostrata* biomass in each plot was weighed. A subsample was then collected, dried to constant weight at 70 °C, and analyzed for total N by the micro-Kjeldahl method. Dry and wet weights of the subsample were used to convert the total fresh weight of *S. rostrata* to a dry weight basis. An aboveground weed sample was collected from a 0.5-m^2 area in each *S. rostrata* and weedy fallow plot, dried to constant weight at 70 °C, and analyzed for total N by the micro-Kjeldahl method. The dominant weed in the weedy fallow was *Echinochloa colona* (L.) Link. *Portulaca oleracea* L., *Ipomoea triloba* L., *Paspalum distichum* L., and *Digitaria ciliaris* (Retz.) Koel. were also present.

Before transplanting in each year, soil samples were periodically collected from 0- to 10-, 10- to 30-, and 30- to 60-cm depths with a 3-cm-diam auger. After transplanting, samples were periodically collected from 0 to 10 cm with a 7-cm-diam core and 10 to 20 and 20 to 30 cm with a 3-cm-diam auger. Each sample was a mixed composite collected from four locations in each plot. Soil was refrigerated or frozen without drying; within 7 d a 40-g wet soil subsample was extracted with 100 mL 2 *M* KCl. The extract was analyzed for ammonium-N by steam distillation (Bremner and Keeney, 1965) and for (nitrate + nitrite)-N by cadmium reduction (Dorich and Nelson, 1984) with subsequent colorimetric determination of nitrite (Hilsheimer and Harwig, 1976). No effort was made to separate nitrate and nitrite. Because nitrite is likely to be small relative to nitrate, the values will be reported as nitrate-N for the sake of simplification. Ammonium and nitrate values were converted to kg N ha^{-1}, using soil bulk density periodically determined with soil cores at each depth. The soil water-filled pore space (WFPS) was calculated as described by Doran et al. (1990) using gravimetric water content for each soil sample, experimentally determined bulk densities, and an assumed particle density of 2.65 Mg m^{-3}.

In nearly all nitrate and ammonium data sets, the mean correlated positively with the variance as frequently observed by other researchers (Buresh et al., 1989; White et al., 1987). Therefore, nitrate and ammonium data were transformed to log (X + 1) before analysis of variance. All reported means were calculated using untransformed data.

Rice plants from two predetermined 0.32-m^2 areas in each plot were collected at ground level at 21 and 45 d after transplanting (DT). They were dried at 70 °C and analyzed for total N by the micro-Kjeldahl method.

RESULTS AND DISCUSSION

Nitrogen accumulation by *S. rostrata* was much greater at 60 d (161 and 227 kg N ha^{-1}) than at 45 d (83 and 45 kg N ha^{-1}) (Table 1). In 1989, the N accumulations by *S. rostrata* (83 and 161 kg N ha^{-1}) were representative of previously observed levels in the Philippines (Buresh and De Datta, 1991). In 1990, the N accumulation of 45 kg N ha^{-1} at 45 d was lower and the N accumulation of 227 kg N ha^{-1} at 60 d was higher than typically observed in the Philippines (Buresh and De Datta, 1991).

Sesbania rostrata suppressed weed growth, but the N concentration of weeds tended to be higher in *S. rostrata* plots than in weedy fallow (Table 1). With SR45 treatment, weed N represented 27 (1989) and 46% (1990) of the total aboveground plant N incorporated during land preparation for rice. The N accumulated by weeds in this study (22—42 kg N ha^{-1}) was higher than the range (11—25 kg N ha^{-1}) previously reported in unweeded fallow plots before wet season rice at nearby experimental sites (Buresh and De Datta, 1991).

Soil Water and Nitrate before Flooding

In both years, the WFPS before rice transplanting was strongly affected ($P < 0.01$) by soil depth and sampling time, but not by pre-rice treatment (Table 2). Before the first sowing of *S. rostrata* on 17 April, mean WFPS for the four pre-rice treatments was much lower at 0 to 10 cm and 10 to 30 cm than at 30 to 60 cm in both 1989 (Fig. 1) and in 1990 (Fig. 2). Irrigation and rainfall increased WFPS in the top two soil layers, and WFPS at 0 to 10 cm eventually matched or exceeded WFPS at 30 to 60 cm (Fig. 1, 2).

On 10 April, mean nitrate-N in the top 60-cm-soil layer for the four pre-rice treatments was 27 kg N ha^{-1} in 1989 and 34 kg N ha^{-1} in 1990. In both years, nitrate increased rapidly after the first irrigation to a maximum on 24 April (Fig. 1, 2). On 24 April, nitrate levels were not significantly different ($P < 0.05$) among pre-rice treatments and averaged 37 kg N ha^{-1} in 1989 and 58 kg N ha^{-1} in 1990. The mean increase in nitrate between 10 and 24 April (10 kg N ha^{-1} in 1989 and 22 kg N

Table 1. Dry weight and N accumulation for aboveground biomass of *Sesbania rostrata* and weeds before incorporation.

Year	Pre-rice treatment	*S. rostrata* Dry weight	*S. rostrata* N concentration	*S. rostrata* N accumulation	Weeds Dry weight	Weeds N concentration	Weeds N accumulation	Total N added
		Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	kg ha^{-1}
1989	*S. rostrata*, 45 d (SR45)	2.2	37	83	2.1	15	30	113
	S. rostrata, 60 d (SR60)	4.8	34	161	1.8	17	30	191
	Weedy fallow (WF)	—	—	—	2.5	11	29	29
SE		0.2	2	8	0.2	1	2	7
1990	*S. rostrata*, 45 d (SR45)	1.7	27	45	3.1	12	37	82
	S. rostrata, 60 d (SR60)	10.4	22	227	1.3	17	22	249
	Weedy fallow (WF)	—	—	—	5.1	8	42	42
SE		0.3	2	12	0.3	1	4	11

SE = standard error of the mean.

Table 2. Analysis of variance for soil water-filled pore space (WFPS), expressed in milliliters per milliliter, and soil nitrate, expressed in kilogram N per hectare, before rice transplanting.

Source of variation	1989			1990		
		Mean squares			Mean squares	
	df	WFPS	Nitrate†	df	WFPS	Nitrate†
		× 10⁻⁴			× 10⁻⁴	
Pre-rice treatment (*P*)‡	3	530	0.232	3	539	0.183
Among SR45, SR60, WF (*P′*)	2	651	0.152	2	618	0.006
SR45, SR60, WF vs WFF (*P″*)	1	288	0.392	1	380	0.537*
Soil depth (*D*)	2	4196**	3.567**	2	10066**	1.788**
P × *D*	6	89	0.045	6	454	0.006
P′ × *D*	4	86	0.036	4	254	0.008
P″ × *D*	2	96	0.064*	2	853	0.003
Sampling time (S)	5	2860**	2.267**	7	8020**	2.875**
P × *S*	15	68**	0.131**	21	76*	0.159**
P′ × *S*	10	61*	0.055**	14	104**	0.045**
P″ × *S*	5	80*	0.283**	7	19	0.388**
D × *S*	10	881**	0.625**	14	1640**	0.625**
P × *D* × *S*	30	30	0.035*	42	47	0.021*
P′ × *D* × *S*	20	22	0.019	28	55	0.019
P″ × *D* × *S*	10	47	0.069**	14	32	0.025*

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† Analysis of variance conducted on data transformed to log $(X + 1)$.
‡ SR45 = *Sesbania rostrata* grown for 45 d, SR60 = *S. rostrata* grown for 60 d, WF = weedy fallow, and WFF = weed-free fallow.

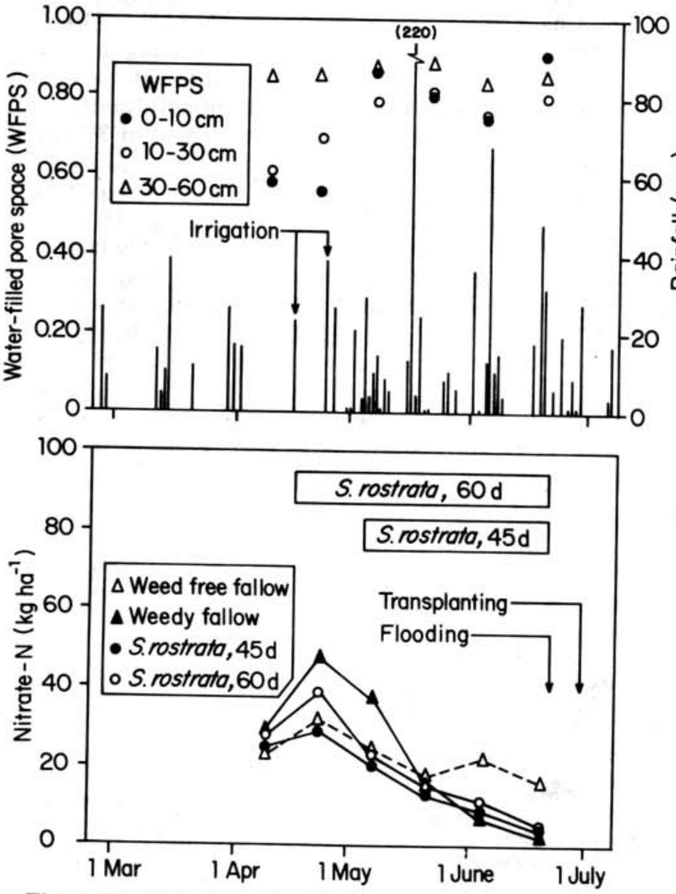

Fig. 1. Rainfall, soil water-filled pore space, and nitrate in the top 60-cm soil layer during the period before rice (1989 experiment).

ha⁻¹ in 1990) corresponded to a net decrease in ammonium (5 kg N ha⁻¹ in 1989 and 22 kg N ha⁻¹ in 1990)

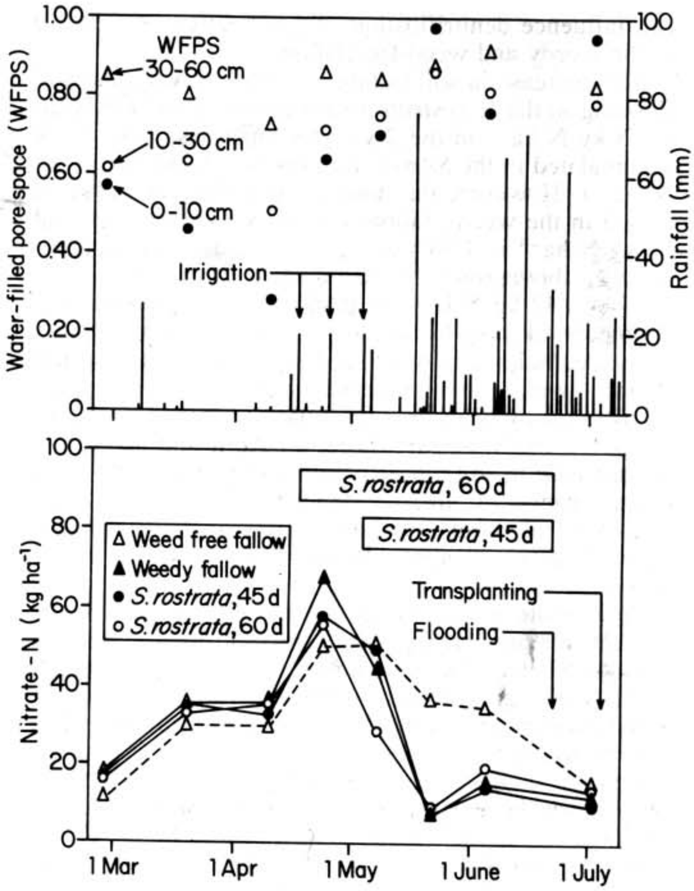

Fig. 2. Rainfall, soil water-filled pore space, and nitrate in the top 60-cm soil layer during the period before rice (1990 experiment).

(data not shown). The increase presumably resulted from ammonification and nitrification following soil wetting. The WFPS in the top two soil layers was near 0.6 mL mL⁻¹ (Fig. 1,2), the level at which ammonification and nitrification reportedly proceed rapidly (Linn and Doran, 1984; Doran et al., 1990).

The WFPS in the top two soil layers exceeded 0.75 mL mL⁻¹ by early May in 1989 (Fig. 1) and by mid-May in 1990 (Fig. 2); then it remained above 0.75 mL mL⁻¹ in all soil layers until flooding on 23 June. A WFPS value above 0.75 mL mL⁻¹ reportedly can result in N loss by denitrification (Linn and Doran, 1984; Rolston et al., 1984; Doran et al., 1990). Therefore, a decrease in soil nitrate after 24 April in both years (Fig. 1,2) could have resulted from denitrification, particularly in the weed-free fallow where no plants were present to assimilate soil nitrate.

During the two June samplings in 1989, soil nitrate was higher ($P < 0.05$) for weed-free fallow than for the three other treatments (Fig. 1). Similarly in 1990, soil nitrate was higher for the weed-free fallow than for the other treatments during the 22 May and 5 June samplings (Fig. 2). Lower soil nitrate in the *S. rostrata* and weedy fallow treatments was attributed to nitrate uptake by *S. rostrata* and weeds. The maximum differences in nitrate between weedy and weed-free fallow treatments (14 kg N ha⁻¹ on 5 June in 1989 and 29 kg N ha⁻¹ on 22 May in 1990) was less than the total N accumulated by weeds during the pre-rice period (Table 1). The WFPS, which can influence denitrification, did not differ ($P < 0.05$) in the weedy and weed-free fallow.

The decrease in soil nitrate between 24 April and soil flooding in the *S. rostrata* treatments (approximately 26 to 48 kg N ha^{-1} in the 2 yr) was much less than the N accumulated in the *S. rostrata* plus weeds (82 to 249 kg N ha^{-1}). However, the decrease in nitrate in the same period in the weedy fallow (44 kg N ha^{-1} in 1989 and 53 kg N ha^{-1} in 1990) was greater than the N accumulated in aboveground weed biomass (29 kg N ha^{-1} in 1989 and 42 kg N ha^{-1} in 1990). Some nitrate was undoubtedly taken up by weed roots and some nitrate might have accumulated in weed seeds and plant parts that fell before sampling and hence were not included in the determination of weed N accumulation. Nonetheless, nitrification likely occurred after 24 April and hence this net decrease in soil nitrate would underestimate the total disappearance of nitrate. Denitrification and leaching cannot be ruled out as possible processes for disappearance of some soil nitrate before flooding in the weedy fallow.

Soil nitrate in the weedy fallow on 5 June (8 kg N ha^{-1} in 1989 and 15 kg N ha^{-1} in 1990) was much less than the 52 and 77 kg nitrate-N ha^{-1} observed by Buresh et al. (1989) in early June 1986 and 1987, following a mungbean-weedy fallow sequence at a nearby site. The WFPS was much higher in this study than in that of Buresh et al. (1989). In Buresh et al. (1989), WFPS before early June was conducive for ammonification and nitrification but too low for denitrification. In this study, WFPS for the 4 wk before early June was suitable for nitrate loss by denitrification but was more than the optimal for nitrate formation.

When soil nitrate before transplanting was analyzed by soil layer, the pre-rice treatment-by-soil-depth- by-sampling-time interaction was significant (Table 2). Soil nitrate differed less among the two *S. rostrata* and the weedy fallow treatments than between these three treatments and the weed-free fallow. In 1989, soil nitrate in the three soil layers was little affected by pre-rice treatment before 5 June (Fig. 3). The decrease in nitrate at 0 to 10 cm between 24 April and 8 May for all treatments (Fig. 3) corresponded to an increase in WFPS above 0.85 mL mL^{-1} (Fig. 1). This decrease in nitrate might be due to denitrification or leaching because plant growth at this time was small or negligible in all treatments. In 1990, the large decrease in nitrate at 0 to 10 cm between 8 and 22 May for all treatments (Fig. 4) also corresponded to an increase in WFPS above 0.85 mL mL^{-1} (Fig. 2).

In 1990, nitrate at 30 to 60 cm for the weed-free fallow increased ($P < 0.05$) between 24 April and 8 May, perhaps because of downward movement of nitrate or nitrification. At soil flooding (23 June), nitrate at 0 to 10 cm was small for all treatments in both years (Fig. 3, 4); most nitrate was below 10 cm.

In the weed-free fallow, with no plants to assimilate soil nitrate, some soil nitrate was lost before soil flooding (Fig. 1,2) through denitrification and possibly leaching. Weeds and *S. rostrata* competed with denitrification and leaching for nitrate, but some nitrate-N may still have been lost before soil flooding in the *S. rostrata* and weedy fallow treatments.

Soil Nitrate after Flooding

After soil flooding on 23 June, soil nitrate in the weed-free fallow decreased, but did not totally disappear. In 1989, soil nitrate in the weed-free fallow on 20 June was 6.2 kg N ha^{-1} at 0 to 30 cm and 10 kg N ha^{-1} at 30 to 60 cm (Fig 3). By 3 August (41 d after flooding and 34 DT) soil nitrate was 1.2 kg N ha^{-1} at 0 to 30 cm and 1.7 kg N ha^{-1} at 30 to 60 cm (data not shown). In 1990, soil nitrate on 5 June was 19 kg N ha^{-1} at 0 to 30 cm and 16 kg N ha^{-1} at 30 to 60 cm (Fig. 4). By 2 July (9 d after flooding), soil nitrate was 8.6 kg N ha^{-1} at 0 to 30 cm and 7.6 kg N ha^{-1} at 30 to 60 cm (Fig. 4).

Soil nitrate in the two *S. rostrata* and the weedy fallow treatments was small at the time of flooding (Fig. 1,2), and flooding on 23 June had little effect on nitrate in those treatments. In 1989, mean soil nitrate for these three treatments on 20 June was 2.7 kg N ha^{-1} at 0 to 30 cm and 1.7 kg N ha^{-1} at 30 to 60 cm. On 3 August (41 d after flooding), mean soil nitrate was 2.1 kg N ha^{-1} at 0 to 30 cm and 1.9 kg N ha^{-1} at 30 to 60 cm

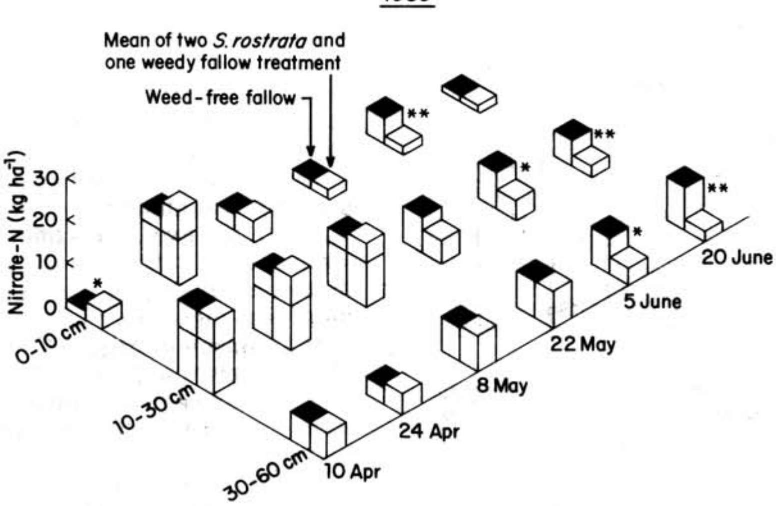

Fig. 3. Effect of pre-rice treatment on nitrate in three soil layers during the period before rice (1989 experiment). (* and ** designate that two treatment means for a day and depth differ significantly at the 0.05 and 0.01 probability levels, respectively.)

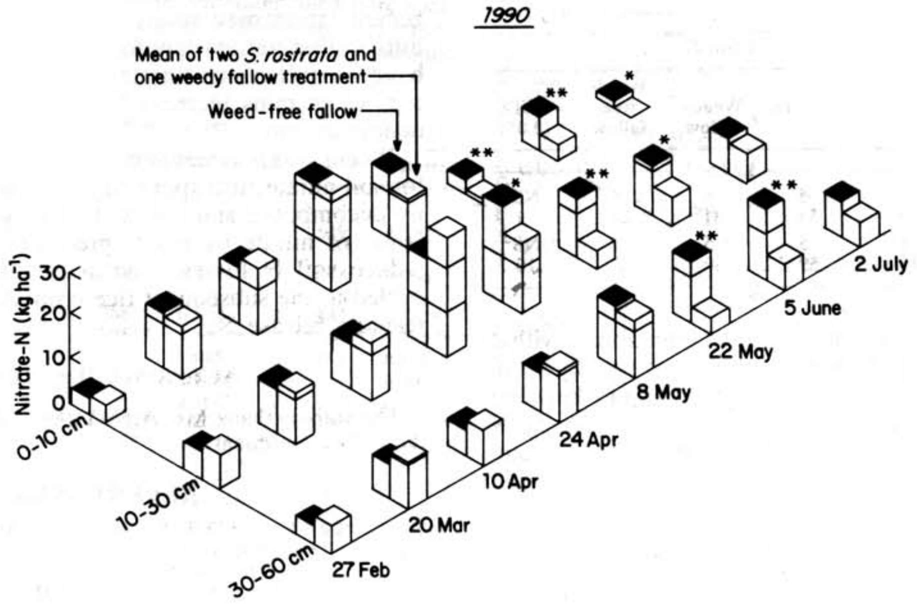

Fig. 4. Effect of pre-rice treatment on nitrate in three soil layers during the period before rice (1990 experiment). (* and ** designate that two treatment means for a day and depth differ significantly at the 0.05 and 0.01 probability levels, respectively.)

Table 3. Analysis of variance for soil ammonium in the top 30-cm layer, expressed in kilogram N per hectare.

Source of variation	1989 df	1989 Mean squares	1990 df	1990 Mean squares
Pre-rice treatment (*P*)†	3	1.173**	3	1.343**
SR45, SR60 vs WF, WFF (*P*′)	1	2.925**	1	2.648**
SR45 vs SR60 (*P*″)	1	0.313	1	0.983**
WF vs WFF (*P*‴)	1	0.282	1	0.396**
Sampling time (*S*)	10	2.373**	7	2.739**
P × *S*	30	0.104**	21	0.090**
P′ × *S*	10	0.186**	7	0.154**
P″ × *S*	10	0.033	7	0.075**
P‴ × *S*	10	0.092**	7	0.040

*,** Significant at 0.05 and 0.01 probability levels, respectively. Analysis of variance conducted on data transformed to log (X + 1).
† SR45 = *Sesbania rostrata* for 45 d, SR60 = *S. rostrata* grown for 60 d, WF = weedy fallow, and WFF = weed-free fallow.

(data not shown). In 1990, mean soil nitrate for the *S. rostrata* and weedy fallow treatments on 5 June was 11 kg N ha^{-1} at 0 to 30 cm and 5.8 kg N ha^{-1} at 30 to 60 cm (Fig. 4). On 2 July (9 d after flooding), mean soil nitrate was 6.7 kg N ha^{-1} at 0 to 30 cm and 5.7 kg N ha^{-1} at 30 to 60 cm (Fig. 4).

Soil Ammonium

Soil ammonium in the top 30-cm layer from 8 May to mid August was influenced by pre-rice cropping and sampling time in both years (Table 3). Soil ammonium was small (<10 kg N ha^{-1}) in all pre-rice treatments during the month preceding flooding and incorporation of *S. rostrata* and weed residues on 23 June (Tables 4,5), but increased in all treatments after 23 June. The increase following flooding of weed-free fallow, which contained no plant residue, resulted solely from mineralization of soil organic matter. In other treatments, the increase in ammonium resulted from mineralization of both soil organic matter and incorporated plant residues.

As reported by other researchers (Singh et al., 1991), leguminous green manures rapidly decompose in flooded

Table 4. Effect of pre-rice treatment on soil ammonium in the top 30-cm layer of plots not fertilized with urea (1989).

Day	DI†	DT†	*S. rostrata*, 45 d	*S. rostrata*, 60 d	Weedy fallow	Weed-free fallow
			kg ha^{-1}			
5 June	−18	−25	4 a	4 a	2 a	5 a
20 June	−3	−10	5 a	4 a	5 a	4 a
28 June	5	−2	17 a	25 a	7 b	8 b
5 July	12	5	28 ab	45 a	17 bc	11 c
12 July	19	12	50 a	59 a	46 a	20 b
19 July	26	19	46 a	57 a	23 b	13 c
26 July	33	26	27 b	54 a	16 c	5 d
3 August	41	34	17 b	36 a	13 b	5 c
16 August	54	47	10 b	22 a	12 ab	7 b

Analysis of variance conducted on data transformed to log (X + 1). Means in a row followed by a common letter are not significantly different by LSD (0.05).
† DI = days after incorporation of *Sesbania rostrata* and weeds, DT = days after transplanting.

Table 5. Effect of pre-rice treatment on soil ammonium in the top 30-cm layer of plots not fertilized with urea (1990).

Day	DI†	DT†	*S. rostrata*, 45 d	*S. rostrata*, 60 d	Weedy fallow	Weed-free fallow
			kg ha^{-1}			
22 May	−32	−43	7 ab	9 a	4 b	4 b
5 June	−18	−29	2 a	2 a	2 a	1 a
2 July	9	−2	22 b	52 a	20 bc	13 c
11 July	18	7	32 b	71 a	16 c	8 d
18 July	25	14	21 b	59 a	20 b	8 c
31 July	38	27	45 b	73 a	31 bc	19 a
20 August	58	47	8 b	24 a	7 bc	4 c

Analysis of variance conducted on data transformed to log (X + 1). Means in a row followed by a common letter are not significantly different by LSD (0.05).
† DI = days after incorporation of *Sesbania rostrata* and weeds, DT = days after transplanting.

Table 6. Effect of pre-rice treatment on N accumulation in the aboveground rice plant.

Year	Days after trans-planting	Plant N				
		S. rostrata, 45d	*S. rostrata*, 60d	Weedy fallow	Weed-free fallow	LSD (0.05)
		kg ha^{-1}				
1989	21	5	5	6	5	NS
	45	41	53	31	21	7
1990	21	8	5	5	7	NS
	45	45	59	30	23	10

soil, leading to large accumulation of ammonium within 2 wk. In this study, N was also released rapidly from weeds. The net difference in soil ammonium between weedy and weed-free fallow treatments was 26 kg N ha^{-1} at 19 d after incorporation in 1989 (Table 4) and 12 kg N ha^{-1} at 25 d after incorporation in 1990 (Table 5).

In both years, soil ammonium tended to be greater for the two *S. rostrata* than the two fallow treatments following incorporation (Table 3). In 1989, soil ammonium tended to be similar for the two *S. rostrata* treatments (Table 3), but was greater ($P < 0.05$) for the weedy than the weed-free fallow from 19 to 41 d after incorporation (Tables 3,4). In 1990, unlike in 1989, soil ammonium after green manure incorporation was consistently higher for SR60 than for SR45 (Tables 3,5). This difference was attributed to the greater relative N accumulation of the 60- than the 45-d-old *S. rostrata* in 1990 than in 1989 (Table 1).

Pre-rice treatment had no effect on aboveground N accumulation in rice at 21 DT (5 to 8 kg N ha^{-1}) (Table 6); however, it strongly affected plant N accumulation between 21 and 45 DT (16–54 kg N ha^{-1}). The differences in plant N among treatments at 45 DT (Table 6) followed similar trends as the differences in soil ammonium after flooding and residue incorporation (Tables 4,5). Plant N at 45 DT (PN) correlated with maximum soil ammonium (N), in kg N ha^{-1}, measured during the rice crop.

$$PN = 7.79 + 0.70\ N,\ r = 0.95,\ n = 8$$

The results suggest that rice readily assimilated ammonium released from the mineralization of incorporated residues and from soil organic matter. The amount of plant N at 45 DT was higher than the difference between the measured maximum soil ammonium and the level at 47 DT (13–49 kg N ha^{-1}) in all treatments, except the 1989 weedy fallow. In this treatment, plant N at 47 DT (31 kg N ha^{-1}) was only slightly less than the difference between the maximum ammonium and that at 47 DT (34 kg N ha^{-1}).

CONCLUSIONS

The magnitude of nitrate accumulation in soil before flooding for lowland rice differed between years and from the study of Buresh et al. (1989). Soil water content is likely an important determinant of nitrate formation and simultaneous N loss before soil flooding. High nitrate accumulation may result when WFPS is favorable for nitrification but too low for denitrification. On the other hand, simultaneous nitrate formation and loss may occur, when rains increase WFPS to levels favorable for denitrification.

Weeds and *S. rostrata* competed with N loss processes for soil nitrate. Incorporated weeds and *S. rostrata* readily decomposed and released N for young rice. Assimilation of nitrate by plants preceding lowland rice may reduce soil N losses. The assimilated N can then be cycled to the subsequent rice crop as incorporated plant residues release N.

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