2-72

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Evaluation of Nitrogen Leaching in a Non-calcic Brown Soil under Irrigated Rice

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ABSTRACT. A lysimeter experiment was conducted in a wet (Maha) and a dry (Yala) season to evaluate nitrogen leaching in a non-calcic brown soil under irrigated rice. Nitrogen gains over rain, irrigation water and fertilizers were also considered for the evaluation.

A natural split-plot design with upper and middle catenal positions as main plots was adopted. Subplot treatments were soil alone, soil with crop without fertilizer, and soil with crop plus fertilizers.

Nitrogen gain by rain and irrigation water and removal through runoff and leaching were determined considering different forms of nitrogen. Rain water supplied 1.3 and 0.3 kg.N/ha during Maha and Yala respectively. Dominant form of nitrogen in different kinds of water was nitrate-N which contributed almost more than 50% of the total N followed by ammonium-N, nitrate-N and organic N. N supply by irrigation water was 4.7 and 1.6 kg/ha during Maha and Yala respectively.

Runoff losses were very low ranging from 0.2-1.9 kg.N/ha per season. Nitrogen leaching was reduced from 11 to 8 kg/ha per season in the presence of a crop but increased dramatically with an application of N fertilizers to around 16 kg. Leaching losses were positively correlated to the depth of water percolated.

INTRODUCTION

Soil fertility problems often limit agricultural productivity. Nutrient retention of a soil is one of the important aspects pertaining to the fertility of a soil. Mahaweli development programme in eastern Sri Lanka aims to bring more land under crop production, mainly under irrigated paddy. However, there is very little information available with regards to fertility characteristics of Non-calcic brown soils (NCBs) in the area which covers about 35% of the Mahaweli system B (Acres

International, 1980). As this particular soil is coarse textured, and has very low cation exchange capacities, usually less than 10 me/100 g soil, and high infiltration rate as well as high hydraulic conductivities (De Alwis and Panabokke, 1972; Mapa and Bodhinayake, 1988), it is justifiable to anticipate nitrogen leaching losses, especially under irrigation.

The recovery of fertilizer N by rice is generally low. Mitsui (1954) estimated that a rice crop usually recovers only 30 - 40% of applied nitrogen. The rest is lost in water by leaching and runoff and by transformations to gases (Craswell and Vlek, 1979). Koshino (1975) reported that leaching losses of 3 - 25% of applied nitrogen depend on water percolation as influenced by soil texture. Such losses affect not only the economy of farmers and the country but also lead to pollution of domestic water supplies.

The objective of this study was thus to quantify the leaching losses of nitrogen from a NCBs in relation to gains over rain water, irrigation water and fertilizers, and removals over plant uptake and runoff.

MATERIALS AND METHODS

This study was conducted at Aralaganwila in the Pimburettewa colonization scheme of Mahaweli System B, Sri Lanka. The NCBs in the area has been utilized for irrigated rice for about 20 years. The soil has high sand and low silt and clay content (Figure 1). Some important chemical properties are given in Table 1.

A lysimeter procedure was adopted for the experimentation and it consisted of a split-plot design with catenal upper and middle slopes as main plots and three fertilizer crop combinations as subplot treatments. Each subplot factor was triplicated. Following treatments were assigned randomly in each main plot:

1. Without crop and fertilizer (control)
2. With crop without fertilizer and
3. With crop and recommended amount of fertilizer for the area.

Ordinary oil drums coated with anticorrosive paint were used for the construction of lysimeters. Figure 2 illustrates the construction and

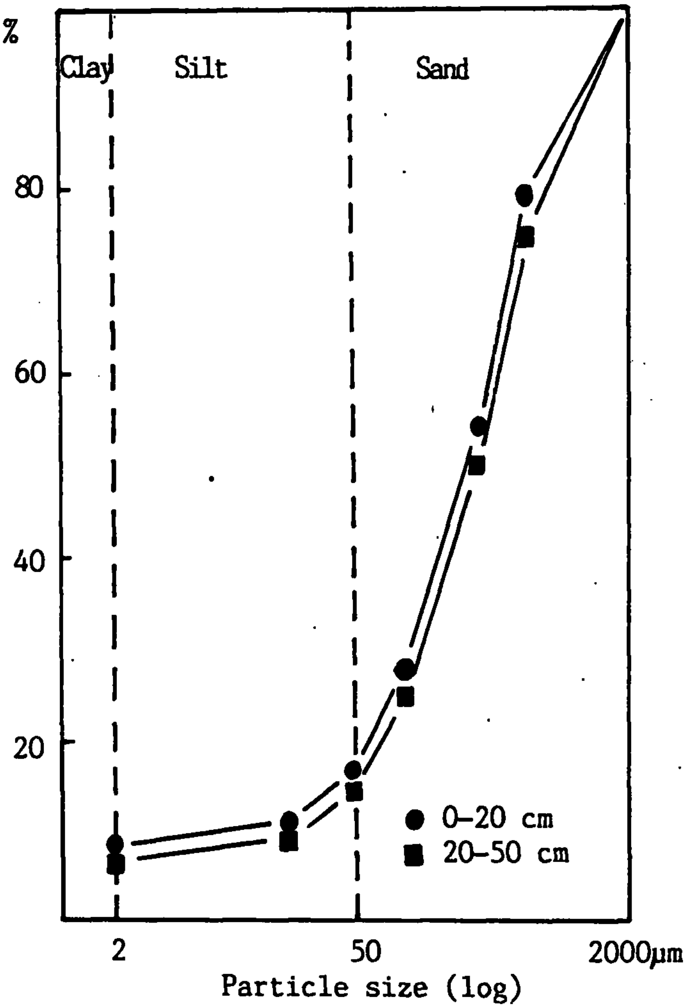

Fig.1. Cumulative partical size distribution for surface (0-20 cm) and subsurface (20-50cm) soil.

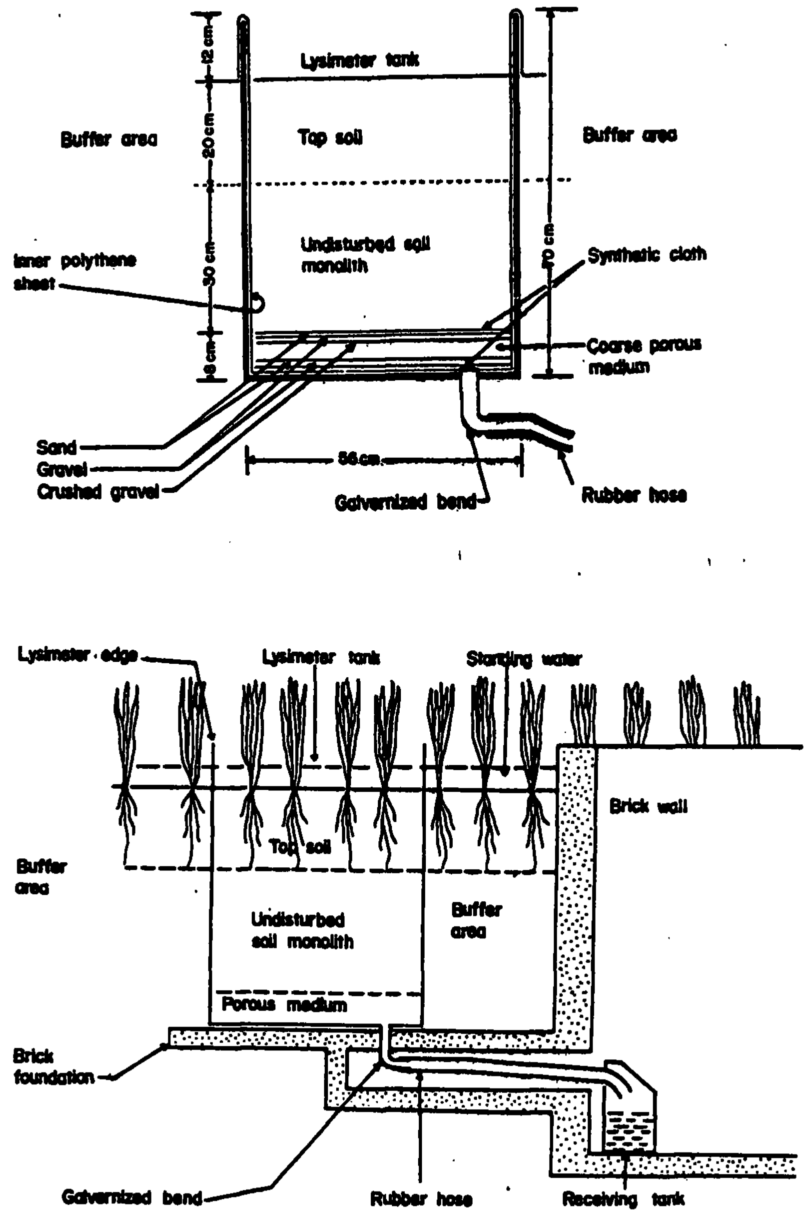

Fig.2. Construction and installation of a lysimeter.

Table 1. Chemical characteristics of the surface (0 – 20 cm) and subsurface (20 – 50 cm) soil.

Soil characteristic	Soil depth			
	0 - 20 cm		20 - 50 cm	
	Mean+	SD	Mean	SD
pH (1:5 H_2O)	6.40	0.54	7.00	0.50
CEC (me 100_g^{-1} soil)	4.08	0.83	3.64	1.64
Total N (%)	0.08	0.01	0.03	0.01
Organic matter (%)	1.10	0.18	0.29	0.14
C : N ratio	8.30	0.84	5.60	1.59
Exchangeable K (me 100_g^{-1} soil)	0.07	0.05	0.02	0.04
Total K (ppm)	311.00	67.64	297.00	73.71

\+ = means of 18 composite samples from each depth.

the installation of lysimeters in each subplot. An undisturbed subsoil 20 – 50 cm) monolith was taken using a steel cylindrical core cutter of 54 cm diameter. Topsoil was removed from the location upto 20 cm depth and the core cutter was gently driven into the subsoil. A steel blade was driven horizontally just at the lower brim of the core cutter to separate the soil core. The core was then gently lowered on to the porous medium in the lysimeter with core cutter and subsequently the cutter was raised leaving the monolith in the drum. To prevent edge effects, the thin space between the soil monolith and the lysimeter wall was packed carefully with soil from the respective depths to a higher degree. The upper 20 cm of each lysimeter was filled with puddled topsoil taken from the surrounding plot.

A randomly selected subplot received a basal application of chemical fertilizer as recommended by the Department of Agriculture, Sri Lanka (Nagarajah, 1986). Twelve days old seedlings of varieties BG 94-1 and BG 34-8 were planted in the lysimeters in *Maha* and *Yala* respectively with the spacing 15 x 15 cm and three plants per hill. Each lysimeter received 22.48 g N, 6.08 g P and 11.66 g K which represented 91.4 kg N, 22.4 kg P and 47.4 kg K per hectare.

Considering the climate and the crop requirement, the lysimeters were irrigated to a depth of not more than 3 cm at a time. Standing water of the immediate upper field of each major plot was used for irrigation. Soils were sampled from the depths 0 - 20 and 20 - 50 cm at the filling of lysimeters.

Continuously collected rain, irrigation, percolation and run-off water were measured and aliquotes of 200 ml were taken for determinations of nitrate-N, ammonium-N, nitrite-N and organic-N. The standing water levels of the lysimeters were adjusted to the level of farmer's fields by siphoning out water which was considered as runoff. Water samples were treated with 1% mercuric chloride at 2 ml per litre and stored frozen at $-14^{o}C$ until analysis. Seedling samples as well as straw and grain samples at the harvest were also analysed for nitrogen content. The total N of the soil was determined by micro Kjeldahl digestion and ammonium in the digest was determined by the indo phenol blue method which was also used for the ammonium-N determination in the water samples. (Hins and Lowe, 1980). Nitrate-N in the water samples were determined colorimetrically by using sodium salicylate method (Husemann, 1955). Greiss-Ilosva method was adopted to determine nitrate-N (Bremmner, 1965). Organic N in water samples were determined by micro Kjeldahl digestion (Bremmner, 1960).

RESULTS AND DISCUSSION

The input of nitrogen by rain fall, irrigation water, planting material and fertilizers were considered as gains. Nitrogen in the runoff water and in the leachates as well as in grain and straw were considered as nitrogen removals from the soil.

Nitrogen gains are given in Table 2 and the removals are given in Table 3.

Table 2. Nitrogen gains in kg ha^{-1}.

Season	Catenal position	Treatment	Rain water	Irrig. water	Planting material	Fertilizer
Maha	Upper	Soil	1.3	4.7	0.0	0.0
		Soil + crop	1.3	4.7	0.7	0.0
		Soil + crop + fert.	1.3	4.7	0.7	91.4
	Middle	Soil	1.3	4.9	0.0	0.0
		Soil + crop	1.3	4.9	0.7	0.0
		Soil + crop + fert.	1.3	4.9	0.7	91.4
Yala	Upper	Soil	0.3	1.6	0.0	0.0
		Soil + crop	0.3	1.6	0.8	0.0
		Soil + crop + fert.	0.3	1.6	0.8	91.4
	Middle	Soil	0.3	1.9	0.0	0.0
		Soil + crop	0.3	1.9	0.8	0.0
		Soil + crop + fert.	0.3	1.9	0.8	91.4

Table 3. Nitrogen removals from the soil in kg ha^{-1}.

Season	Catenal position	Treatment	Runoff	Leaching	Uptake
Maha	Upper	Soil	1.2	9.0	0
		Soil + crop	0.8	6.9	64.7
		Soil + crop + fert.	1.2	13.8	75.3
	Middle	Soil	0.9	12.0	0
		Soil + crop	1.3	8.9	70.7
		Soil + crop + fert.	1.0	18.7	83.3
Yala	Upper	Soil	0.8	10.1	0
		Soil + crop	1.9	8.9	39.9
		Soil + crop + fert.	1.1	14.9	58.3
	Middle	Soil	0.3	13.1	0
		Soil + crop	1.0	8.5	39.7
		Soil + crop + fert.	0.8	15.3	63.6

Nitrogen gains from rain water in *Maha* was about four times higher than that in the *Yala* which may attributed to the greater intensity of rain fall and thunderstorms during *Maha* (Table 2). The dominant form of nitrogen in rain water was nitrate which contributed 82 and 78% of the total N during *Maha* and *Yala* respectively (Table 4). The supply of nitrogen over irrigation water was not so high. However, inspite of greater depth of irrigation water in *Yala* (972 mm), the nitrogen supply was about one third that in *Maha* (663 mm) which indicated a lower content of nitrogen in *Yala* irrigation water (Table 2). The shares of nitrate – N were about 50 and 75% of the total N during *Maha* and *Yala* respectively (Table 4). This is acceptable as the conditions for nitrification in a dry season is better than in a wet season. Considerably high percentage of nitrate – N may be attributed to the retarded process of nitrification and an increase in denitrification in *Maha* (Table 4). Shares in ammonium – N in *Maha* confirms the above explanation to a certain extent. Thenabadu and Ekanayake (1985) also observed relatively high nitrate contents in Mahaweli river water.

Table 4. Nitrogen forms in rain and irrigation water.

Source	Season	Catenal position	Composition (%) Nitrate N	Ammonium N	Nitrite N	Org.N
Rain water	*Maha*		82.1	17.4	0.1	0.4
	Yala		78.2	16.4	5.2	0.4
Irrigation	*Maha*	Upper	50.8	35.1	8.2	5.9
		Middle	51.2	37.7	8.0	3.1
	Yala	Upper	78.6	17.0	0.4	4.0
		Middle	70.0	22.0	2.8	5.2

Nitrogen removal over runoff was comparatively very low (Table 3). However, in farmers' fields, N loss could be little higher than in our experiment as a result of continuous outflow of water to maintain the standing water level. Distribution of nitrogen forms in runoff water was almost similar to that of rain and irrigation water (Table 5).

Nitrogen leaching was evaluated for the vegetation period and the relationship between water percolation and nitrogen leaching was examined. Irrespective of the season, the average percolation rates without plants and with plants were 6.3 and 5.4 mm per day respectively. The reduction of percolation of water in lysimeters with plants could be attributed to the presence of the vegetation. As a result of better crop growth in lysimeters with fertilizers, the percolation loss of water reduced further to 5 mm per day. Water percolation as a fraction of total supply was always lower in *Yala* than in *Maha* due to high rates of evaporation and transpiration. Bandara (1981) also observed a similar phenomenon.

There was a significant decrease in nitrogen leaching by having a crop; as a result of N uptake by plants. However, there was also a marked increase ($P=0.05$) in N leaching when chemical fertilizers were applied to the crop. This increase could be due to the soil being sandy; the effect of soil texture on such nitrogen leaching losses was also reported by Koshino (1975). Nitrogen leaching of the middle slope was significantly higher than that of upper slope, only during *Maha*, possibly due to observed higher nitrogen concentrations in the leachates; not due to the amount of water percolated.

Percentage composition of nitrogen forms in the leachates is given in the Table 5. Dominant N form in the leachate was nitrate. However, share of nitrate N in *Yala* was much higher than in *Maha* indicating a prevailed better nitrification. The opposite tendency of Nitrate – N confirmed the above (Table 5). Moreover, the share of ammonium – N had been also reduced in *Yala* confirming the above transformation. The mentioned phenomena were possible as a result of frequent alternate drying and wetting processes by rotational irrigation.

Irrespective of the season, all treatments showed a positive relationship ($P=.001$) between N leaching and depth of water percolated (Figures 3 and 4). Similar relationships have also been reported by

Table 5. Nitrogen forms in runoff and in the leachates.

Season	Catenal	Treatment	Composition (%)							
			Runoff				Leachate			
			NO_3^-.N	NH_4^+.N	NO_2^-.N	org. N	NO_3^-.N	NH_4^+.N	NO_2^-.N	org.N
Maha	Upper	Soil	68.2	17.1	12.6	2.1	81.7	7.0	7.4	3.0
		Soil+crop	70.7	20.2	9.1	0.1	78.7	8.3	4.1	8.9
		Soil+crop+fert.	73.2	10.3	13.6	2.9	85.1	9.4	3.8	1.7
	Middle	Soil	71.1	12.8	9.7	6.4	82.2	6.9	5.6	5.3
		Soil+crop	67.4	6.1	26.5	0.0	65.8	24.5	4.1	5.6
		Soil+crop+fert.	72.7	13.9	10.1	3.3	77.1	7.8	12.7	2.4
Yala	Upper	Soil	79.0	11.9	9.0	0.1	96.0	3.0	0.6	0.4
		Soil+crop	78.1	4.8	5.8	11.3	92.4	6.6	0.6	0.4
		Soil+crop+fert.	80.7	16.3	1.4	1.6	92.0	5.8	1.7	0.5
	Middle	Soil	63.9	24.4	3.7	8.0	95.8	3.1	0.7	0.4
		Soil+crop	83.0	13.2	3.8	0.0	95.5	3.2	0.5	0.8
		Soil+crop+fert.	73.8	18.2	4.8	3.2	91.0	4.7	2.7	1.6

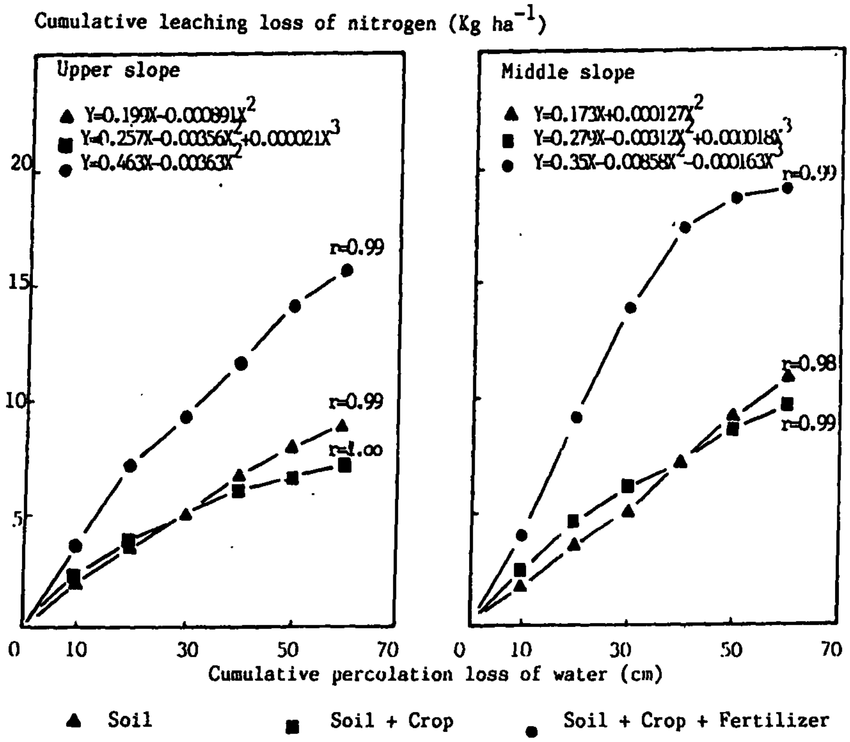

Fig.3. The relationship of nitrogen leaching loss to percolation water loss in Maha.

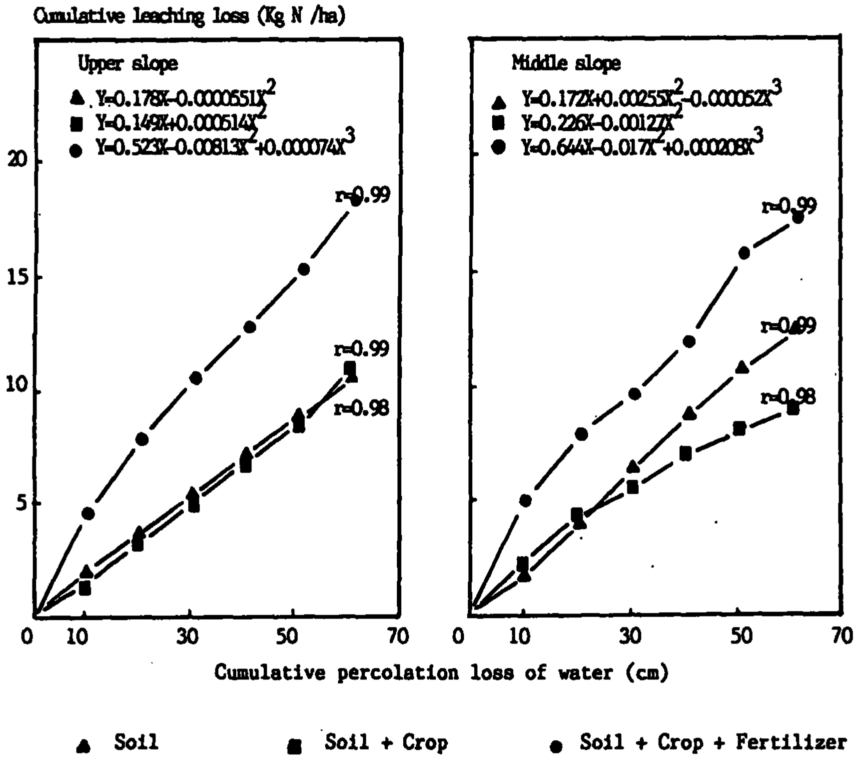

Fig.4. The relationship of nitrogen leaching loss to percolation water loss in Yalá.

Diaz–Fierros *et al.*, (1973) for a sandy soil. The nitrogen leached per unit of water percolated was clearly greater in the fertilized treatments.

The results showed that the supply of nitrogen by irrigation water was not much; 5% in *Maha* and 2% in *Yala* of the recommended amount of N fertilizer. However, the amounts leached, especially in fertilized lysimeters, was considerable (15 kg N/ha) creating a loss to the soil unless not fertilized. Introduction of a crop reduced N leaching and fertilizer application in turn increased the N leaching.

Since there was positive relationship between water percolated and nitrogen leaching, limited irrigations have to be tested to achieve a reduction of leaching losses of nitrogen. The procedures of N applications should also be reviewed to increase the efficiency use of applied N in such soils.

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