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Nitrogen Leaching Losses and Plant Response to Nitrogen Fertilizers as Influenced by Application of *Neem* (*Azadirachta indica* A. juss) Materials

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ABSTRACT. Leaching of nitrate-N, reduces N fertilizer efficiency, and increases pollution of surface and ground water. Use of nitrification inhibitors is one measure of reducing nitrate leaching. Neem (Azadirachta indica A. juss) cake and its extract have been identified as locally available materials with nitrification inhibitory properties. Leaching experiments were conducted using undisturbed soil columns under laboratory conditions to investigate whether blending neem cake with nitrogen fertilizer reduces leaching losses in Reddish Brown Latosolic (Rhodudults) soils of Sri Lanka. The treatments used were urea/ammonium sulphate at the rate of 250 kg N/ha, urea/ammonium sulphate + 20% neem cake (w/w), urea/ammonium sulphate + 30% neem cake (w/w), and a control, without neem or fertilizer. Greenhouse pot experiments were also conducted with radish (Raphanus sativus) to examine whether neem materials when blended with N fertilizer influence the response to nitrogen fertilizer. Treatments in pot experiments were urea/ammonium sulphate at recommended level, urea/ammonium sulphate + 20% neem cake (w/w), urea/ammonium sulphate + 20% neem extract (w/w) and control, without neem or fertilizer.

Neem cake treatments, at both 20% and 30% levels, significantly reduced leaching losses of nitrate with both urea and ammonium sulphate. Application of neem cake and extract with N fertilizer gave significantly higher yield of radish compared to the fertilizer alone treatments. Possibility of using neem materials to increase the agronomic efficiency of N fertilizer and to reduce pollution caused by nitrate leaching is discussed.

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INTRODUCTION

Leaching is often the most important channel of N loss from field soils (Allison, 1973; McNeal and Pratt, 1978). In humid areas, nitrate can be almost completely removed from the soil profile and moved downward into ground water depending on the soil, climate, fertilization and management practices (Legg and Meisinger, 1982). Nitrate is the form of N that is most mobile and therefore is subjected to leaching, resulting in reduced fertilizer efficiency and nitrate pollution of surface and ground waters.

There is enough evidence worldwide, that fertilizer N pollute ground waters (Embleton and Jones, 1978; Wendland *et al.*, 1996; Demissie *et al.*, 1997; Nolan *et al.*, 1997; Levallois *et al.*, 1998). In Sri Lanka, hazardous levels of nitrate contents have been reported in well waters of different areas, which has been attributed to excessive fertilizer application (Foster, 1976; Dissanayake *et al.*, 1984; Nagarajah *et al.*, 1988; Kuruppuarachchi *et al.*, 1995). The nitrate N content of well waters used for drinking purpose has been found to increase over time, possibly due to heavy fertilizer application (Mageswaran and Mahalingam, 1983; Kuruppuarachchi *et al.*, 1995).

Since leaching losses of fertilizer N occur mainly after the conversion of ammonium or amide N to nitrate form, inhibition of nitrification of applied ammonium and amide N can reduce these losses and increase efficiency of applied N. However, commercially available nitrification inhibitors are expensive. Therefore, the use of nitrification inhibitors, which do not require factory processing and can be prepared by farmers themselves using locally available ingredients, may be a more realistic approach, than importing the costly technology.

Neem has been identified as a nitrification inhibitor in India (Mishra *et al.*, 1975; Sahrawat and Parmer, 1975; Hari Shankar and Rathi, 1976; Khandelwal *et al.*, 1977; Mishra and Chonkar, 1978; Sahrawat, 1982; Bhardwaj and Singh, 1992; Geethalakshmi and Palaniappan, 1992; Joseph and Prasad, 1993). Reduction of nitrate leaching by application of *neem* cake blended urea, compared to urea alone also has been reported (Prakasa Rao and Prasad, 1980; Singh and Singh, 1986). In Sri Lanka, inhibition of nitrification, when urea was blended with *neem* in Reddish Brown Earth (RBE - *Rhodustalf*) and Reddish Brown Latosol (RBL - Rhududults) soils has already been reported (Gnanavelrajah and Kumaragamage, 1998). Inhibition of nitrification, when ammonium sulphate was blended with *neem* in a Reddish Brown Latosolic soils has also been observed (Gnanavelrajah, 1999).

The present experiment was conducted to investigate the effect of blending *neem* cake with urea or ammonium sulphate on leaching losses of N in a Reddish Brown Latosolic soil, and to evaluate the nitrogen response of radish to urea or ammonium sulphate blended with *neem* materials.

MATERIALS AND METHODS

Leaching experiment

The objective of this experiment was to assess the effect of blending *neem* cake with urea or ammonium sulphate on potential leaching loss of N in a Reddish Brown Latasolic (Rhodudults) soil. Twenty four undisturbed soil columns were collected using PVC pipes from Dodangolla University farm. The internal diameter and the height of the tubes were 14 cm and 60 cm respectively. The tubes were driven into soil using a hammer, and by removing the adjoining soils by a spade, undisturbed soil columns were taken. The treatments; urea/ammonium sulphate (T1), urea/ammonium sulphate + 20% *neem* cake (w/w) (T2), urea/ammonium sulphate + 30% *neem* cake (w/w) (T3), and control without *neem* or fertilizer (T4), were arranged in a Complete Randomized Design with three replicates. Initially, the columns were saturated with distilled water and allowed to drain to reach field capacity. *Neem* cake was mixed at the respective rates 2 days prior to application of fertilizer to the columns. N fertilizers were added at the rate of 250 kg N/ha for each column and mixed thoroughly with soil up to 10 cm. At two weeks intervals, leachates were collected, by applying 500 ml distilled water to each column. Ammonium (Keeney and Nelson, 1982), nitrate (Vendrell and Zupanic, 1990), and nitrite (Norwitz and Keliher, 1984) nitrogen contents in leachates were analyzed colourimetrically. The experiment was conducted for a period of twelve weeks.

Pot experiment

Disturbed, surface soil samples (Reddish Brown Latasolic - Rhodudults) were collected up to a depth of 20 cm from the Dodangolla University farm. Samples were air dried and passed through a 2 mm sieve prior to experiments. Some selected properties of the soil were measured (Table 1). Soil (2.5 kg) was filled into plastic pots having holes for drainage at bottom. The treatments; urea/ammonium sulphate at recommended level (T1), urea/ammonium sulphate + 20% (w/w) *neem* cake (T2), urea/ammonium sulphate + 20% (w/w of N) *neem* extract (T3), and control (T4), without *neem* or fertilizer, were arranged in a Complete Randomized Design with three replicates. *Neem* cake/extract were mixed thoroughly 2 days prior to fertilizer application. Fertilizers were applied according to the recommendation made by the Department of Agriculture (Basal dress: Urea-125 kg/ha or ammonium sulphate-250 kg/ha, TSP-200 kg/ha and MOP-75 kg/ha; Top dress: Urea-125 kg/ha or ammonium sulphate-250 kg/ha and MOP-75 kg/ha). The variety *Beeralu Rabu* of radish was used for this study. Initially 2 seeds were planted in each pot, and after germination, one plant was allowed to grow in each pot. All other cultural practices were done according to Department of Agriculture recommendations. No other agro chemicals were used for any purpose. After 60 days radish was harvested and fresh weights were recorded for whole plant.

Table 1. Selected characteristics of soil used in this study.

Property		
Texture :	Sand (%)	60.00
	Silt (%)	14.20
	Clay (%)	25.80
pH (1 : 2.5 soil : water)		7.10
CEC (cmol (+) / kg)		19.20
Organic matter		1.45
Total N (%)		0.09
Nitrate N (mg/kg)		15.30
Ammonium N (mg/kg)		10.30

RESULTS AND DISCUSSION

Leaching of nitrate N

Over 99% of the total nitrogen leached was in the nitrate form in both urea and ammonium sulphate treated columns. Mixing *neem* cake with urea significantly reduced leaching of nitrate N up to eight weeks after application.

There was no significant difference observed between *neem* treatments in this regard. Within the experimental period of 12 weeks, *neem* cake treatments, on an average, reduced leaching of nitrate N by 19% compared to urea alone treatment (Figure 1). In ammonium sulphate treated columns, a similar trend was observed. Both *neem* cake treatments reduced nitrate leaching significantly up to eight weeks after application. Within the experimental period, *neem* treatments, on average, reduced nitrate leaching by 18%, compared to that observed when ammonium sulphate was applied alone (Figure 2).

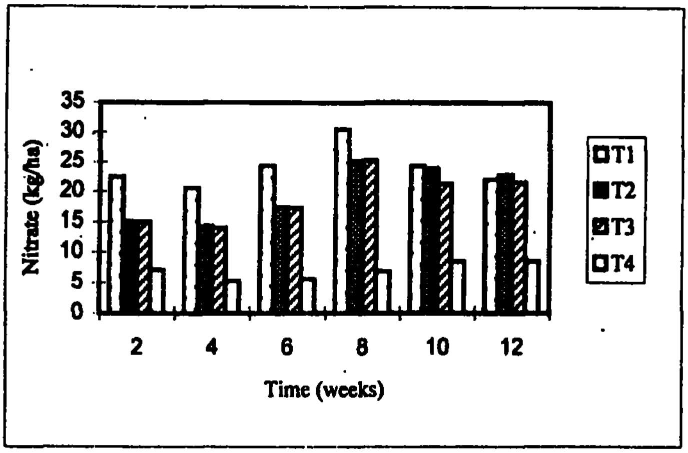

Figure 1. Effect of blending neem cake with urea on leaching losses of nitrate N.
[Note: T1 - urea, T2 - urea+20% *neem* cake, T3 - urea+30% *neem* cake, T4 - Control]

Leaching of ammonium N

At 2 weeks after application, leaching of ammonium was significantly higher in columns treated with *neem* cake blended urea, compared to columns treated with urea alone (Figure 3). A similar effect was observed with ammonium sulphate treated columns, during 2 weeks as well as 4 weeks after application (Figure 4). Thereafter, blending *neem* cake did not have any significant effect on leaching of ammonium N. Even though the

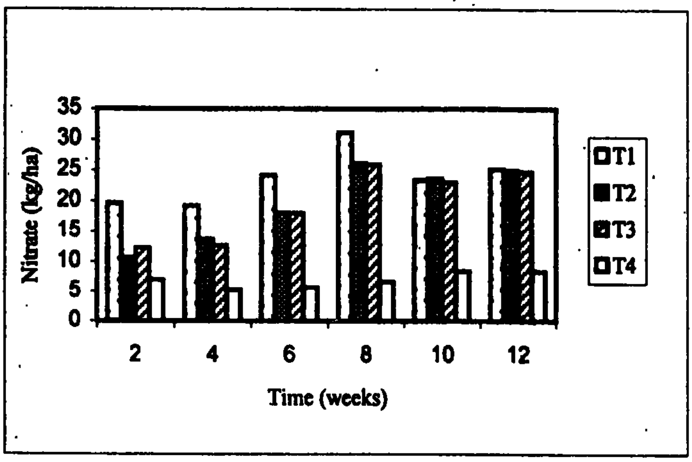

Figure 2. Effect of blending neem cake with ammonium sulphate on leaching losses of nitrate N.
[Note: T1 - ammonium sulphate, T2 - ammonium sulphate+20% *neem* cake, T3 - ammonium sulphate+30% *neem* cake, T4 - Control]

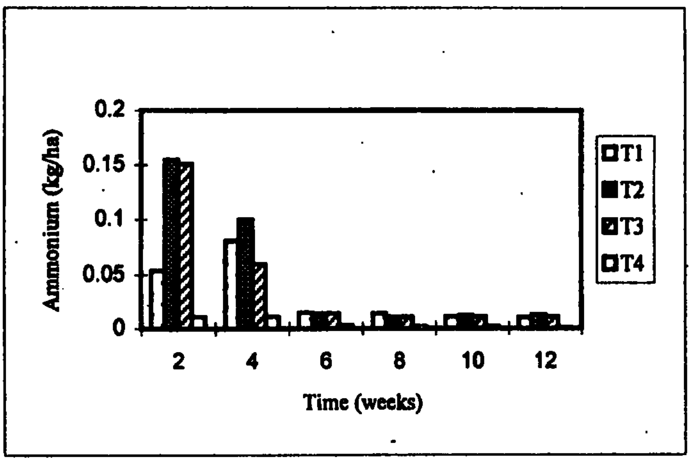

Figure 3. Effect of blending *neem* cake with urea on leaching losses of ammonium N.
[Note: T1 - urea, T2 - urea+20% *neem* cake, T3 - urea+30% *neem* cake, T4 - Control]

ammonium N leached was higher in *neem* cake treated columns compared to the non *neem* treated columns, the percentage of ammonium lost was very low, being 0.3% of the total loss. The increase in leaching losses of ammonium N on application of *neem* cake blended fertilizers may be attributed to the high concentration of ammonium in soil due to *neem* treatments. Similar observations were made by Singh and Singh (1986) in lysimeter studies.

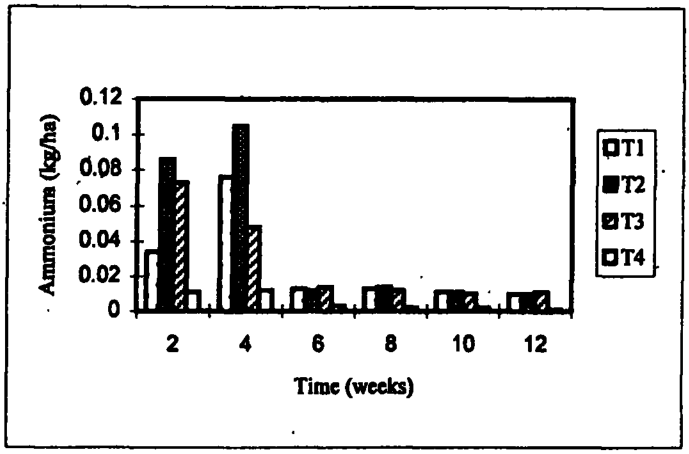

Figure 4. Effect of blending neem cake with ammonium sulphate on leaching losses of ammonium N.

[Note: T1 - ammonium sulphate, T2 - ammonium sulphate+20% *neem* cake, T3 -ammonium sulphate+30% *neem* cake, T4 - Control]

Leaching of Nitrite N

Neither fertilizers, nor *neem* treatments had any effect on leaching of nitrite N. Moreover, the leaching loss of nitrite N was less than 0.1% of the total N loss, hence it needs no emphasis.

Leaching of total (ammonium + nitrate + nitrite) N

Mixing *neem* cake with N fertilizers, at both 20% and 30% levels significantly reduced total nitrogen leaching losses from applied urea and ammonium sulphate. During the experimental period of 12 weeks, *neem* cake treatments reduced total N leaching by about 19% (Table 2), and 18% (Table 3), in urea treated and ammonium sulphate treated columns, respectively. However, no significant differences in total nitrogen leaching losses were observed between 20% and 30% levels of mixing *neem* cake with both urea and ammonium sulphate, indicating that mixing at 20% level is sufficient to achieve a significant reduction in nitrogen leaching.

Table 2. Effect of blending *neem* cake with urea on leaching loss of N (ammonium + nitrate + nitrite) - kg/ha.

Treatment	Incubation Period (weeks)					
	2	4	6	8	10	12
T1	22.60 a	20.69 a	24.32 a	30.52 a	24.32 a	22.11 a
T2	15.23 b	14.41 b	17.42 b	25.21 b	23.92 a	22.92 a
T3	15.13 b	14.07 b	17.32 b	25.41 b	21.32 a	21.61 a
T4	7.14 c	5.32 c	5.61 c	6.80 c	8.50 b	8.50 b

T1 - urea, T2 - urea+20% *neem* cake, T3 - urea+30% *neem* cake, T4 – control.
Values denoted by the same letter within a column are not significantly different by the Duncan's New Multiple Range Test at P = 0.05.

Pot experiment

Effect of blending *neem* with urea and ammonium sulphate on yield of radish is shown in Table 4. Both fertilizer treatments induced significantly higher yields of radish compared to the control. Both *neem* treatments increased the yield of radish significantly compared to the unblended urea or ammonium sulphate. However, there was no significant difference in yield observed between *neem* cake treatment and *neem* extract treatment. *Neem* blended urea treatments, on an average, gave 51% higher yield compared to

Table 3. Effect of blending *neem* cake with ammonium sulphate on leaching loss of N (ammonium + nitrate + nitrite) - kg/ha.

Treatment	Incubation Period (weeks)					
	2	4	6	8	10	12
T1	19.74 a	19.29 a	24.22 a	31.12 a	23.42 a	25.21 a
T2	10.74 b	13.72 b	18.12 b	27.22 b	23.72 a	24.92 a
T3	12.43 b	12.76 b	18.02 b	25.91 b	23.11 a	24.71 a
T4	7.41 c	5.32 c	5.71 c	6.60 c	8.40 b	8.40 b

T1 – ammonium sulphate, T2 – ammonium sulphate+20% *neem* cake, T3 – ammonium sulphate+30% *neem* cake, T4 – control
Values denoted by the same letter within a column are not significantly different by the Duncan's New Multiple Range Test at P = 0.05

Table 4. Effect of blending *neem* with urea/ammonium sulphate on yield of Radish (grams/pot).

Treatment	Urea	Ammonium sulphate
T1 (recommended level)	165 b	172 b
T2 („ + 20% *neem* cake)	246 a	255 a
T3 („ + 20% *neem* extract)	251 a	257 a
T4 (control)	81 c	81 c

Values denoted by the same letter within a column are not significantly different by the Duncan's New Multiple Range Test at P = 0.05

the unblended urea. The respective figure, for *neem* blended ammonium sulphate was 49%.

Even though addition of *neem* materials add organic matter to the soil, the amount added in this study was very low, compared to the normal rate of application of organic manure. Therefore, a significant effect on physical or chemical characteristics of soil, due to addition of *neem* cake is negligible. Moreover, the total N content of *neem* cake was only 4.9%. Therefore, at the rate of *neem* cake added, which was equal to 20% (w/w) of fertilizer N, the quantity of N added by *neem* cake can be considered negligible.

Nitrification inhibition in urea and ammonium sulphate blended with *neem* materials has already been reported (Gnanavelrajah and Kumaragamage, 1998; Gnanavelrajah, 1999). In the present study, nitrogen leaching was considerably reduced by *neem* treatments. Therefore, nitrification inhibition and reduced nitrogen leaching are the possible causes for the increased yield of radish in *neem* treated pots. Several other workers have reported increased yield of different crops when *neem* was blended with urea and ammonium sulphate under upland conditions due to the nitrification inhibition effect of *neem* materials. Significant increases in crop yield have been observed in wheat, with *neem* extract blended urea (Khandelwal *et al.*, 1977) and with *neem* cake blended urea (Sharma and Sinha, 1977), in sugar cane with *neem* blended urea (Bawasakar *et al.*, 1980), in upland rice, with *neem* blended urea (Singh and Vijayakumar, 1982), in *Kurakkan*, with *neem* blended urea and ammonium sulphate (Subbiah *et al.*, 1982), in cotton with *neem* blended urea (Geethalakshmi and Palaniappan, 1992) and in lemon grass with *neem* oil and *neem* cake blended urea (Rajeswar Rao and Chand, 1996).

CONCLUSIONS

Blending *neem* cake with urea and ammonium sulphate significantly reduced nitrate leaching up to eight weeks after application. Although *neem* cake increased ammonium N leaching during early stages, absolute loss of ammonium N was less than 0.3%, therefore, total N leaching was reduced by application of *neem* cake blended fertilizers. It is possible to use *neem* materials to improve the fertilizer efficiency and reduce potential pollution due to nitrate leaching.

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