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Effects of Sul-Po-Mag and Kieserite Incorporated to a Tea Fertiliser Mixture on (i) Leaching of Soil Nitrogen

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Mg fertilisers such as kieserite ($MgSO_4.H_2O$) and Epsom salt ($MgSO_4.7H_2O$,) are generally not included into common urea based formulations due to poor storing and handling qualities. Sul-Po-Mag (Sulphate of potash magnesia or SPM; $K_2SO_4 .2MgSO_4$) is an imported fertiliser to the Sri Lankan market. Hence, there is a concern whether SPM could be used as a Mg fertiliser instead of kieserite, in the mixtures containing urea, Eppawela rock phosphate (ERP) and muriate of potash (MOP) for mature tea. The chloride (Cl^-) based compounds are said to be restricting nitrification. Therefore, it is possible that the added N fertiliser stay in soil longer, making it available for plants to utilise for an extended period when combined with a chloride containing fertiliser such as MOP. Hence a glasshouse study was carried out to investigate the effect of either total or partial replacement of MOP fertiliser present in commonly used U709 mixture on the leaching of N through 45 cm deep undisturbed soil columns, over a period of 12 months following fertilisation.

There were 12 treatments of 04 fertiliser mixtures UEM, UES, UEMK and UEMSulPo, (see, Footnote for Abbreviations) with 03 N levels namely 240, 360 and 480kg $ha^{-1}yr^{-1}$. Pattern of NO_3^--N percolated down the profile after fertilisation of all the mixtures was that NO_3^--N quantity decreased with increasing levels of N, while NH_4^+-N quantity increased with it both linearly.

Nitrate-N quantities percolated following the application of UEMSulPo mixture were higher compared to UEM and UEMK but lower compared to UES, although quantities of NH_4^+-N in the increasing patterns in the percolate were similar in UES and UEMSulPo. However, quantities of NH_4^+-N percolated following UEMSulPo and UES fertilisations were considerably lower than that of UEM and UEMK. Therefore, it can be concluded that even the partial replacement of commercial MOP, in the mixtures containing urea, ERP and MOP, with SPM having little or no Cl^- yet contributes to greater quantity of NO_3^--N leaching from soil.

Abbreviations: U = Urea; M= Muriate of potash; E = Eppawala rock phosphate;
S = Sulphate of potash; K = kieserite; SulPo = Sulphate of potash magnesia

INTRODUCTION

Nitrification could be important for the efficient utilisation of N fertiliser in agriculture because N is taken up by plants as NH_4^+ and NO_3^- ions. The nitrification process occurring in soils converts ammonium formed by applied urea into nitrate (Sandanam *et al.*, 1978). Nitrification is prominent in tea soils as well and the formed nitrate can be leached beyond the root zone (Wickremasinghe *et al.*, 1985). Though nitrification is purely a biological process, the amount and the rate of nitrification could be influenced by climatic and soil factors. Temperature in the immediate environment (Krishnapillai and Pethiyagoda 1980), pH (Hayatsu and Kosuge, 1993) and moisture content in soil (Wild 1988) and redox potential (Mengel and Kirkby 1987), contribute significantly in changing nitrification. Since NO_3^--N is very vulnerable for losses through leaching, the factors that slow down the conversion of NH_4^+ to NO_3^- will undoubtedly reduce the amounts of such losses (Sandanam *et al.*, 1978 and Walker and Wickremasinghe 1978).

Chloride ions (Cl^-) are considered to be inhibiting nitrification through an interaction with ammonium ions (Prasad *et al.*, 1970; Golden *et al.*, 1984; Koeing and Pan 1996). Therefore, it is hypothesised that the inhibition of nitrification could be achieved by combining N fertilisers with a chloride containing fertiliser such as MOP (Golden *et al.*, 1984). This strategy may help the added N fertiliser to retain in the soil for a longer period in the ammonium form, making it available for the plants for an extended period.

An imported fertiliser to Sri Lanka, namely sul-po-mag (SPM; $K_2SO_4.2MgSO_4$) is now available in the market. This contains mainly K and Mg and some amount of sulphur (S) as well. Generally, Mg fertilisers such as kieserite ($MgSO_4.H_2O$), Epsom salt ($MgSO_4.7H_2O$) are not mixed to urea based fertiliser formulations due to poor storage and handling qualities. It is attributed to the hygroscopic nature of urea and degree of hydration in Mg containing fertilisers. There is a concern among growers whether SPM could be used as a source of Mg in commonly used mixtures, as there is no hydration and also as it partly substitutes K of MOP which may be economical. In the event of using SPM for formulating Mg containing fertiliser mixtures that contain urea, ERP and MOP (e.g. U709). The use of a fertiliser mixture containing SPM may have a better nutritional value than U709 because it supplies Mg as well as S. This may be particularly important for soils depleted in Mg. However reduced supply of chloride through partial substitutes of MOP with SPM could favour the nitrification.

Therefore, objective of this study was to investigate the effect on N-leaching due to incorporation of SPM as a Mg source to the most commonly used mature tea fertiliser mixture U709 replacing some amount of MOP along with kieserite and the complete replacement of KCl from the fertiliser grade SOP, using undisturbed soil columns, adopting a glass house technique.

MATERIALS AND METHODS

The soil selected for this study was from the St. Coombs Estate, Talawakelle, Sri Lanka. This location was an abandoned tea land under mana grass (*Cymbopogan confertiflorus*) and scrubs. The soil type is Red yellow podzolic. During the last six years, no mineral fertilisers were added to this field. Seventy-four undisturbed soil profile columns were drawn using PVC tubes of gauge 3mm from an area of 3m x 2m. The dimensions of the PVC tubes were 14 cm in diameter, 45 cm in depth and surface area of the soil column in 154 cm^2. The soil had 03 distinct horizons at the depths of 0 - 10/12 ($A_{1.1}$), 10/12 - 26/28 ($A_{1.2}$) and 26/28 - 39/45(B) cm.

Soil columns were kept vertically in three metal racks carrying 24 each in the glasshouse situated at Hantane station of the Tea Research Institute of Sri Lanka. There were 12 treatments and each treatment had six replicates. The treatments were imposed over the soil surface of the columns. The columns were arranged in a randomized complete block design (RCBD). In addition, 02 control columns were also investigated. Under each soil column, a Whatman 42 filter paper along with a nylon mesh was tied up, as shown in Fig. 1. Of the 12 treatments, there were 04 fertiliser mixtures abbreviated as UEM, UES, UEMK and UEMSulPO, and each mixture had 03 N levels (L), simulated from the field-applied rates of 240, 360 and 480 kg $ha^{-1}year^{-1}$ and frequency. Hence, in this study a basal fertilisations was carried out on the soil surface representing at 60, 90 and 120 kg·N·ha^{-1}. The compositions of 04 fertiliser mixtures are given in Table1.

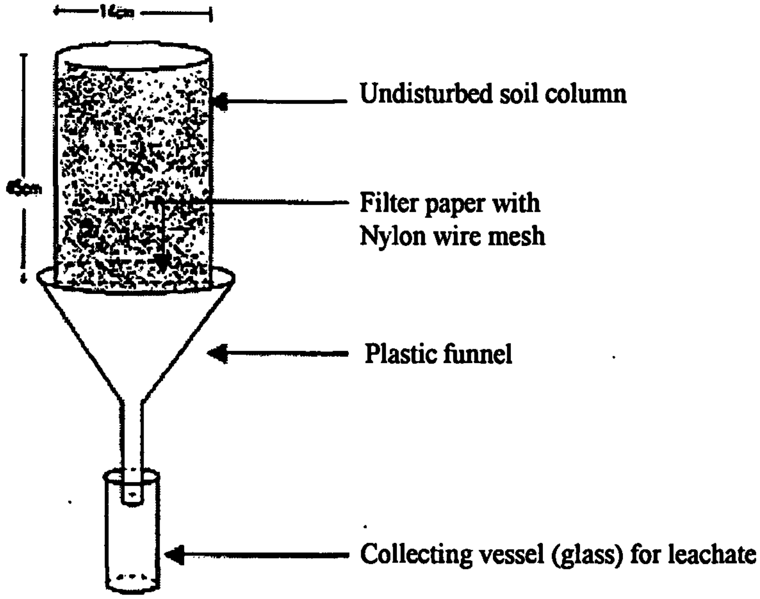

Fig.1 Schematic diagram of complete set up of the soil column in the glasshouse

Table 1 - The compositions of fertiliser mixtures and quantities added per column

N level (kg ha^{-1})	g^{-1} column^{-1} application^{-1}					
UEM	Urea	ERP	MOP	SOP	Kieserite	SPM
60	10.4	2.45	4.00	-	-	-
120	15.7	3.68	6.00	-	-	-
180	20.9	4.91	8.00	-	-	-
UES						
60	10.4	2.45	-	5.00	-	-
120	15.7	3.68	-	7.50	-	-
180	20.9	4.91	-	10.00	-	-
UEMK						
60	10.4	2.45	4.00	-	2.84	-
120	15.7	3.68	6.00	-	4.25	-
180	20.9	4.91	8.00	-	5.67	-
UEMSulPo						
60	10.4	2.45	2.84	-	-	3.17
120	15.7	3.68	4.25	-	-	4.76
180	20.9	4.91	5.67	-	-	6.35

U = Urea; M = Muriate of potash; E = Eppawala rock phosphate; S = Sulphate of potash;
K = Kieserite; SulPo = Sulphate of potash magnesia

From the 1st day after fertilisation onwards, 100 cm^3 of distilled water was poured daily over the soil surface of each column and the leachate was daily collected into glass bottles. The volumes of the daily leachate of each column were measured and transferred into separate plastic containers and stored in a refrigerator at 4°C. At each 05th day, the total volumes of the leachates were composited separately for each column. This sample was used for chemical analysis. Accordingly, after each fertilisation, a total number of 15 samples of leachates were collected and analyzed for NH_4^+-N, NO_3^--N, SO_4^{2-}-S and Cl^- contents.

Analytical procedure

The pH values in leachates and soils (1:2.5 soil: water) were measured potentiometricaly using a pH meter. The available NH_4^+-N and NO_3^--N in leachates were determined colourimetricaly by following the procedures described by Hinda and Lowe (1980) and Keeney and Nelson (1982) respectively. Chloride and SO_4^{2-}-S contents in leachates, were determined by colourimetric methods following the procedures described by Canelli and Fuge (1976) and Tabatabai (1982) by respectively.

Data interpretation

The data were subjected to an analysis of variance for a RCBD experiment. The statistical analyses were carried out with the aid of the Statistical Analysis System package.

RESULTS AND DISCUSSION

The soil of the site was Red Yellow Podzolic. The texture was sandy clay loam and the soil was well drained. Bulk densiy of the soil was 1.01g cm^{-3}. Some important chemical properties of the soil horizons are given in Table 2. The levels of NH_4^+-N, NO_3^--N, SO_4^{2-}-S and Cl^- were considerably low compared with cultivated tea soils.

Table 2 - Selected chemical properties of the soil profile

Depth	pH	Exchangeable cations and anion				$CH_3COO(NH4)$ extrac		Water soluble
		K	Mg	Ca	NH_4^+-N	NO_3^--N	SO_4^{2-}-S	Cl^-
cm		(mg kg^{-1})						
$A_{1.1; 0-12}$	4.86	45	3.7	75.8	4.08	2.84	4.21	14.3
$A_{1.2; 12-28}$	4.41	50	1.4	13.0	6.24	5.68	6.01	17.9
B; 28–45	4.41	45	0.9	7.0	3.20	4.97	7.98	26.8

Ammonium-N in leachate at 5 days intervals following fertilisation

The cumulative NH_4^+-N content (mg per column) in the leachate at 5 day intervals following fertilisation is presented in Fig. 2 and Table 3. Irrespective of the mixtures and the level of N, no significant content of NH_4^+-N was found in the leachate until 35 days following fertilisation. There was a mild increase up to 45 days, and there after a rapidly increase up to 75 day indicating the direct effect of N application. Wickremasinghe *et al* (1985) studied transformation of N fertilisers in soil and found that the urea added to soil was hydrolysed to NH_4^+ within 7 days. Therefore, it is presumed that the hydrolysis may have commenced and taken place to a considerable extent although the NH_4^+-N was not found in the percolated solutions up to 35 days. Hence, it appeared that the release of NH_4^+-N from the bottom of the profile column to be commenced, an approximate period of 35 days was required.

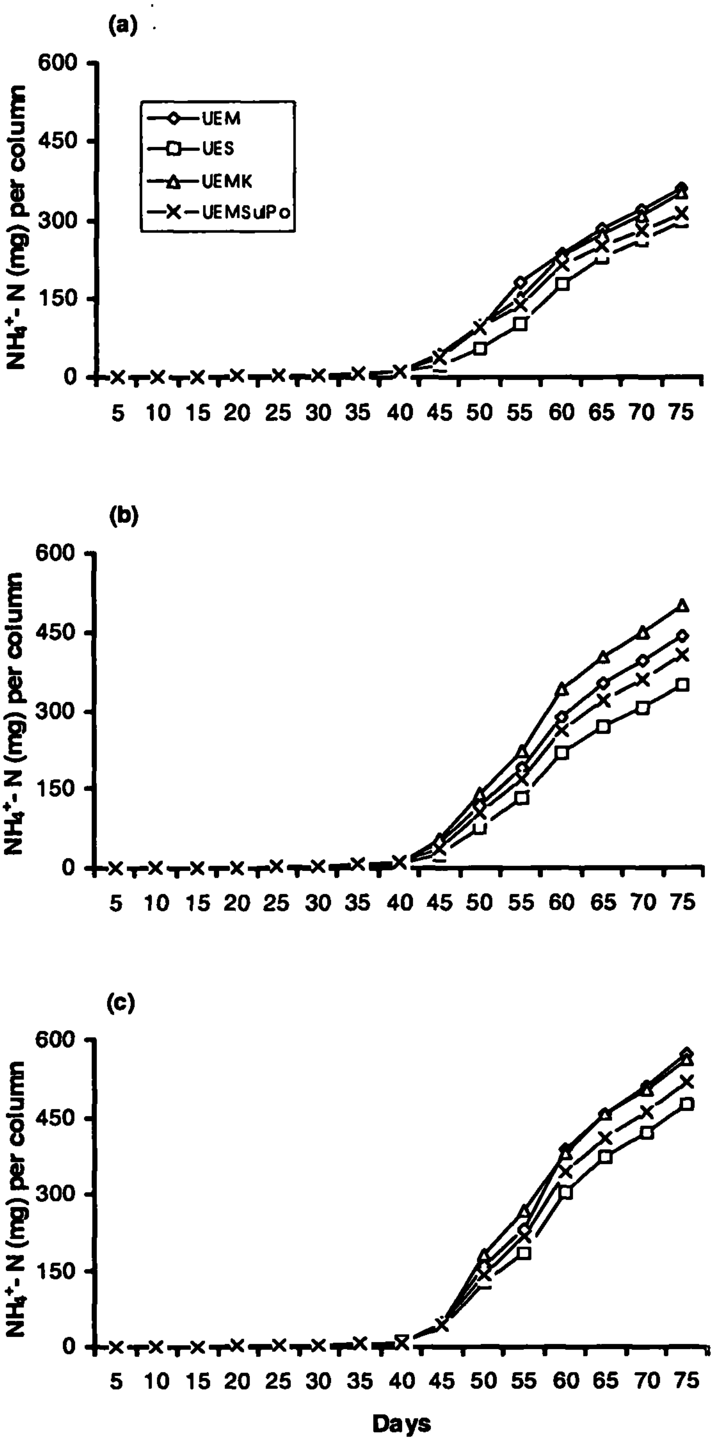

Fig. 2 The cumulative NH$_4^+$-N (mg) content in the leachate after fertilisation of N (kg ha^{-1}) levels at (a) 60, (b) 90 and (c)120

Table 3 - The cumulative NH_4^+-N (mg) content in the leachate after fertilisation of N (kg ha^{-1}) levels at 60, 90 and 120

Fertiliser mixtures	60 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	0.21	0.36	0.52	0.88	1.75	2.59	6.44	12.1	35.5	95.7	182	236	282	318	361
UES	0.14	0.28	0.48	0.95	1.61	2.29	5.22	9.72	22.6	53.7	101	178	227	262	298
UEMK	0.17	0.48	0.69	1.29	1.87	2.46	5.24	11.3	44.9	99.5	153	233	273	309	351
UEMSulPo	0.19	0.33	0.43	2.35	2.81	3.27	6.35	12.2	35.5	93.2	139	216	249	280	314
	120 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	0.15	0.23	0.50	0.74	1.30	1.44	6.74	10.3	46.1	120	190	288	350	393	442
UES	0.19	0.37	0.61	1.06	1.43	1.82	3.60	8.52	25.5	76.2	131	220	269	304	347
UEMK	0.17	0.41	0.61	1.79	2.50	2.76	5.01	8.96	54.5	140	224	339	403	447	500
UEMSulPo	0.18	0.31	0.76	1.43	2.21	2.88	6.24	11.4	35.9	102	170	262	320	360	406
	180 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	0.22	0.45	1.07	1.73	3.10	3.34	5.40	7.88	45.3	157	231	388	454	509	571
UES	0.10	0.20	0.30	0.60	1.39	2.16	5.35	9.91	37.4	126	183	302	370	420	475
UEMK	0.13	0.35	1.68	3.08	3.85	4.05	5.76	8.38	43.0	180	267	380	455	503	559
UEMSulPo	0.19	0.29	1.22	2.28	2.98	3.67	5.92	7.81	43.2	141	215	343	407	460	517

The levels of significance for NH_4^+-N contents due to sources of variation are given in Table 4. No significant content of NH_4^+-N was found in the leachate, until 35 days following treatment application. At the out set, NH_4^+-N contents determined particularly after 35 days following fertilisation, significantly ($P \leq 0.05$) varied mostly due to N level and certainly due to fertilisation treatment.

Table 4 - Levels of significance for NH_4^+-N content in leachate at 5 days intervals due to fertiliser mixtures (F), and nitrogen levels (L)

Source	5 days intervals following fertilisaion							
	40	45	50	55	60	65	70	75
F	NS	**	***	**	*	NS	NS	*
L	**	*	***	***	***	***	***	***
F.L	NS	NS	NS	NS	NS	*	NS	NS

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, NS - not significant

As far as NH_4^+-N contents after 45 days are concerned, the lowest contents were found from the UES mixture up to 75 days, compared to UEM, UEMK and UEMSulPo (Figs 2a to c). In a lysimeter study, Golden *et al* (1981) pointed out that the Cl^- in MOP fertiliser inhibited the nitrification under field conditions where tea was grown. It is therefore possible that the total replacement of MOP fertiliser, with SOP in the UES mixture, allowed the nitrification to take place with out inhibition. As far as UEM and UEMK mixtures are concerned it appeared that the NH_4^+-N contents were similar in leachates, at 60 and 120 N levels where the contents were some what different (Fig 2 a and c). Schroeder (1984) explained that the replacing power of Mg^{2+} was higher than that of NH_4^+. Hence it is possible that NH_4^+ in the cation exchange complex of soils may have been replaced by Mg^{2+} ions additionally, and as a result the content of it was finally increased. However, it appears that this replacement was not significant, because the differences in the NH_4^+-N contents were marginal.

It was also found that the NH_4^+-N contents in the leachates were lower at all levels of N of UEMSulPo mixture compared to both UEM and UEMK (Fig 2a to c). The equal quantities of Mg supplied for UEMK and UEMSulPo mixtures from kieserite and SPM respectively, and the quantities of K present in UEM, UEMK and UEMSulPo were also equal. The Cl^- contents present in UEM, UEMK and UEMSulPo mixtures were in the order of UEM = UEMK > UEMSulPo. It is therefore possible that even the partial replacement of MOP fertiliser with SPM in the UEMSulPo mixture, that resulted in from the supply of Mg while keeping the K content same, also allowed the nitrification to be taken place fairly freely. Although it is possible to replace NH_4^+-N in the cation complex by Mg^{2+}, it is unlikely that this replacement had taken place significantly because, on one hand NH_4^+-N contents in UEM and UEMK fertilisation treatments at 60 and 120 N levels were similar. On the other hand, NH_4^+-N content in UEMSulPo treatment in general was lower than that of UEMK despite the presence of similar levels of Mg in UEMK and UEMSulPo. However, it is to be assumed that the solubility factor remained fairly constant.

Nitrate-N in leachate at 5 days interval following fertilisation

The cumulative NO_3^--N contents (mg per column) in the leachates at 5 day intervals following fertilisation are presented in Fig. 3 and Table 5.

Irrespective of the fertiliser mixtures and the level of N, no significant content of NO_3^--N was found in the leachate until 35 days following fertilisation. However, from Figs. 3a to c, it is observed that NO_3^--N appears in the leachate even after 20 days period. Cumulative content of NO_3^--N in the leachates, following fertilisation with UES and UESulPO mixtures, rapidly increased compared to UEM and UEMK mixtures, except at 60 N kg ha^{-1} level. However, at 60 N kg ha^{-1} level, the content in UESulPO fertilisation was not as contrast as other levels but yet higher. After the hydrolysis, the nitrification may have commenced in the presence of required conditions and percolation down the profile has taken place. It was observed that NO_3^--N appears in the leachate even after 20 days period (Figs.3a to c), although no significant content of NH_4^+-N was found in the leachate until 35 days following fertilisation. It is likely due to faster rate of percolation of NO_3^--N down the profile compared to NH_4^+-N because it is heavier and is a cation.

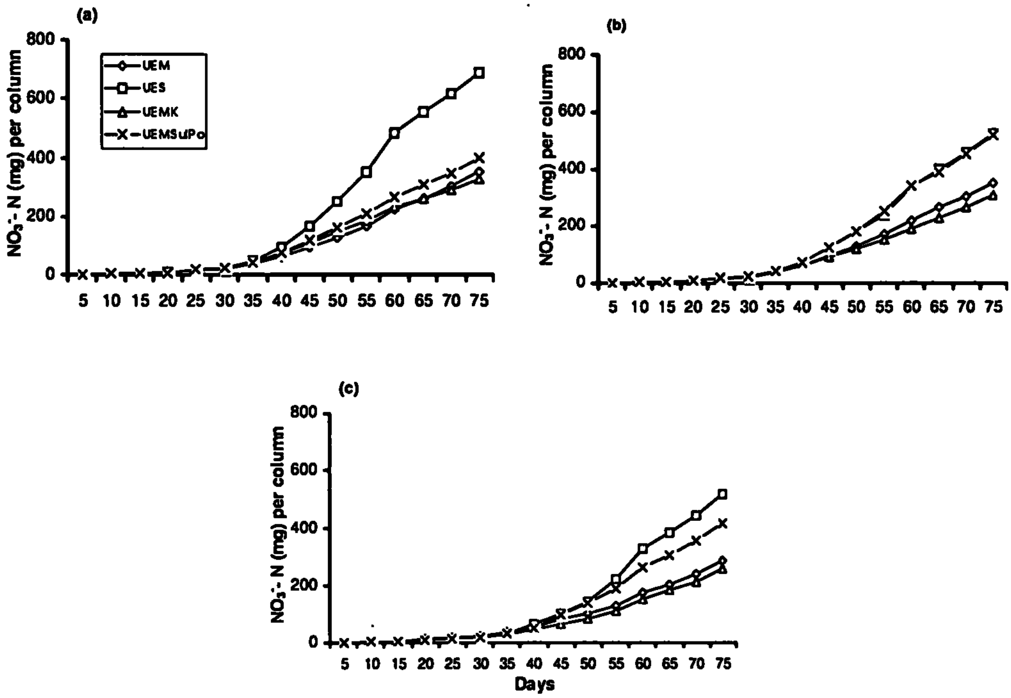

Fig. 3 The cumulative NO_3^--N (mg) content in the leachate after fertilisation of N (kg ha^{-1}) levels at (a) 60, (b) 90 and (c)120

Table 5 - The cumulative NO_3^--N (mg) content in the leachate after fertilisation of N (kg ha^{-1}) levels at 60, 90 and 120

Fertiliser mixtures	60 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	1.28	2.40	5.46	9.25	14.4	19.2	36.1	60.8	96.0	128	167	223	261	302	348
UES	1.61	3.00	6.54	10.3	16.4	21.8	48.9	92.3	165	253	349	481	553	616	686
UEMK	1.64	3.16	6.23	10.1	16.3	22.1	40.3	69.3	103	146	184	230	259	288	326
UEMSulPo	1.45	3.00	6.63	4.08	16.9	22.5	41.8	76.4	117	158	206	263	307	347	396
	120 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	1.43	2.89	5.36	9.40	15.0	17.9	38.9	62.7	95.0	130	172	217	264	303	353
UES	1.49	2.79	6.22	9.81	14.9	19.2	37.0	70.0	122	181	240	340	399	456	522
UEMK	1.57	2.54	5.67	9.80	14.5	18.7	36.0	61.3	91.8	120	150	191	230	264	309
UEMSulPo	1.61	3.13	5.79	10.1	18.4	25.5	43.9	71.3	123	181	251	341	391	452	521
	180 N (kg ha^{-1})														
	Intervals (days)														
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
UEM	1.52	3.06	6.72	12.8	18.5	22.5	36.4	51.8	81.6	103	131	174	204	239	285
UES	1.10	2.21	5.13	7.90	11.9	16.7	34.4	65.8	100	145	221	327	381	445	520
UEMK	1.12	2.47	5.58	9.70	14.9	18.2	29.4	44.6	64.5	83.2	110	152	184	213	258
UEMSulPo	1.22	2.45	5.39	9.53	13.9	17.6	30.8	51.0	97.4	140	191	263	306	357	416

As far as NO_3^--N contents following fertilisation after 35 days are concerned, the highest contents up to 75 days were found when UES mixture was applied, compared to UEM, UEMK and UESulPO mixtures (Figs. 3a to c). It is therefore possible that the total replacement of MOP fertiliser with SOP in the UES mixture allowed the nitrification to take place freely without any inhibitory effect by Cl^-. On the other hand, since the replacing power of SO_4^{2-} is also higher compared to NO_3^- and Cl^- (Wiklander, 1964), SO_4^{2-} adsorption by anion exchange sites also may have partly contributed to the release of NO_3^- and/or Cl^- to soil solution.

At the outset as far as UEM and UEMK mixtures are concerned, it appeared that the cumulative NO_3^--N contents percolated down the profile were somewhat similar. Therefore, it is implied that the SO_4^{2-} adsorption by anion exchange sites while releasing NO_3^- to soil solution has not taken place significantly, although theoretically possible. However, it is worthwhile to note that the SO_4^{2-} content in UES mixture was basically higher compared with other mixtures.

As far as NO_3^--N contents in UESulPO mixture treated soils are concerned, it was found that the contents were higher, compared to both UEM and UEMK mixtures (Figs. 3a to c). The Cl^- content present in UEM, UEMK, and UESulPO fertilisation treatments were in the order of UEM=UEMK>UESulPO. It is therefore possible that even the partial replacement of commercial MOP with SPM in the UESulPO mixture, also allowed more nitrification to be taken place. Although it is possible to replace NO_3^- and/or Cl^- in the anion complex by SO_4^{2-}, it is unlikely that the replacement for NO_3^--N had significantly taken place. Because even where UEM and UEMK mixtures were applied, NO_3^--N contents were similar although compositional difference between UEM and UEMK was such that UEMK consisted of kieserite in addition to urea, ERP and MOP in UEM. The levels of significance for NO_3^--N content due to sources of variation are given in Table 6. No significant content of NO_3^--N was found in the leachate, until 35 days following treatment application. At the out set, NO_3^--N contents in the leachate determined particularly after 35 days following fertilisation significantly ($P \leq 0.05$) varied mostly due to fertilisation treatment and certainly for N level for a shorter period (Table 6).

Table 6 - Levels of significance for NO_3^--N content in leachate at 5 days intervals due to fertiliser mixtures (F), and nitrogen levels (L)

Source	5 days intervals following fertilisaion							
	40	45	50	55	60	65	70	75
F	*	***	***	***	***	***	***	***
L	*	*	*	NS	NS	NS	NS	NS
F.L	NS	NS	NS	NS	NS	NS	NS	NS

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, NS - not significant,

Ammonium- and nitrate-N in leachate following fertilisation with N level

In order to find out the effects of either total or partial replacement of MOP fertiliser present in commonly used mixtures (e.g U709) on the leaching of N in soil, variations in NH_4^+-N and NO_3^--N contents percolated down the profile following fertilisation with N levels, are presented in Fig. 4. The pattern of all the mixtures was that percolated NO_3^--N quantity decreased with increasing levels of N, while NH_4^+-N quantity increased with it both linearly. The patterns and quantities of NO_3^--N and NH_4^+-N percolate following the application of UEM and UEMK mixtures were similar. The NO_3^--N quantities percolated down the profile following the application of UES mixture that contain urea, ERP and SOP, were higher compared to UEM and UEMK, whilst NH_4^+-N quantities percolated were considerably low compared to UEM and UEMK. Thus, it shows that total replacement of K fertiliser associated with Cl^-

such as MOP in mixtures containing urea, ERP and MOP, with SOP having little or no Cl^- contributes to greater quantity of NO_3^--N leaching from soil.

The NO_3^--N quantities percolated down the profile following the application of UESulPO mixture that contain urea, ERP, MOP and SPM, were higher compared to UEM and UEMK but lower compared to UES, although the quantities of NH_4^+-N in the increasing patterns of percolation were similar in UES and UESulPO. However, the quantities of NH_4^+-N percolated following UESulPO and UES fertilisations were considerably lower than that of UEM and UEMK. Therefore, it can be concluded that even the partial replacement of commercial MOP, in the mixtures containing urea, ERP and MOP, with SPM having little or no Cl^- yet contributes to greater quantity of NO_3^--N leaching from soil.

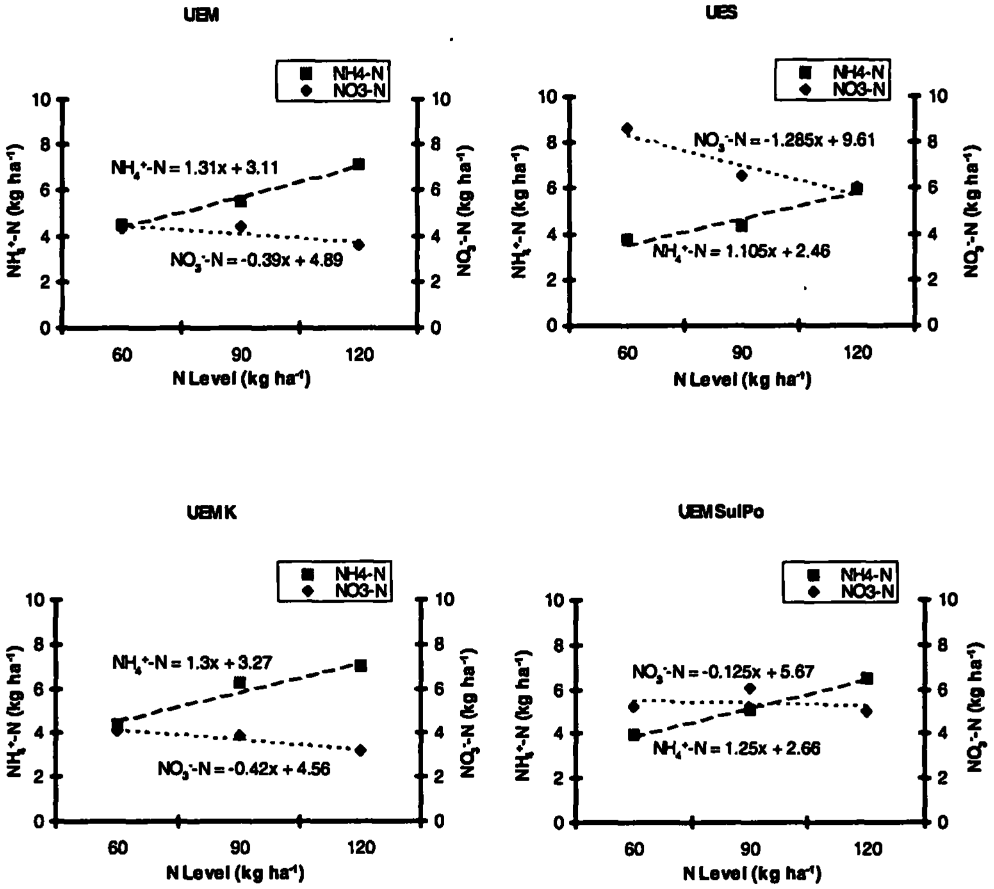

Fig 4. Ammonium-N and Nitrate-N in leachate following fertilisation with N level

CONCLUSIONS

The results of this study revealed that either total or partial replacement of K fertiliser associated with Cl^- such as MOP in the mixtures containing urea, ERP and MOP, with other K fertiliser such as SOP and SPM with inadequate Cl^- contributes towards promoting NO_3^--N leaching from soil.

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