LEACHING IN SANDS AND ITS EFFECT ON NITROGEN RECOVERY BY YOUNG CANE *

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Introduction

It is probable that one of the main causes of reduced fertilizer N efficiency, especially on sandy soils, is the loss of nitrogen through leaching, usually in the form of nitrate—N (NO_3-N). Lysimeter studies [2, 3, 6] have shown that varying amounts of NO_3-N may be removed, potential losses depending on time, method, and rate of N application, and the presence or absence of a growing crop. Soil texture also has a noticeable effect on the distance to which a given quantity of water will move nitrates, being largely associated with differences in water holding capacity and porosity. This has been well illustrated by Bates and Tisdale[1] and Maud[7].

Where precipitation exceeds evapotranspiration over long periods, nitrates may link up with ground water and be lost to the plant. Usually however movement down the profile is limited by insufficient rainfall, or physically due to textural changes, so that eventually some of the leached NO_3-N can be utilized, particularly by deep rooted crops such as cane and maize. Upward movement of nitrate has been noted when evapotranspiration exceeds precipitation[11]. Mineral N moving down the profile may also be temporarily immobilized by microbial action and become available subsequently to a future crop, this residual N effect having been demonstrated on cane by Takahashi[10].

Generally however it would appear that it is only in the lighter soils that serious leaching losses may occur, particularly where fertilizer N is applied at planting or the early stages of growth. This might deprive young cane of much of its N supply before this can be properly utilized, especially if added in the nitrate form, or where nitrification readily occurs on addition of an ammonium carrier to the soil. These losses can probably be reduced when applied N is retained by the soil in the NH_4-N form, nitrification being partially delayed either naturally due to acid conditions or artificially by the addition of an inhibitor to the soil via the fertilizer.

A greenhouse experiment to study the effects of leaching and delayed nitrification on N uptake by young cane on two coastal sands was therefore undertaken, details of which are now reported.

Procedure

Fertilizer treatments: 1500 g air dry samples of two sands (Clansthal and Lytton series, pH 6.15 and 4.60 respectively) were weighed into polystyrene pots and the following fertilizer treatments applied to each of 16 replicates of the Clansthal, and 12 replicates of the Lytton sand.

1. 150 mg N as $(NH_4)_2SO_4$ — 100 ppm
2. 150 mg N as $(NH_4)_2SO_4$ — 100 ppm treated with 2% N - Serve†: 2 - chloro - 6 - (trichloro methyl) - pyridine.
3. 150 mg N as $NaNO_3$ — 100 ppm

The fertilizers were uniformly mixed with the soils beforehand after which they were moistened to 50% WHC (water holding capacity) with a basic nutrient solution supplying 100 ppm K and 80 ppm P. As in previous greenhouse experiments all solutions were applied down a perforated nylon tube situated in each pot, the latter having a plastic seal at the base to eliminate drainage losses.

Ten of the Clansthal and six of the Lytton replicates were planted with previously germinated single-eyed cane setts (Variety N:Co.310) of uniform weight, while the remaining pots in each treatment were left unplanted. Apart from the time when leaching treatments were imposed, all pots were weighed daily, being maintained at 50% WHC. After eight weeks tops and roots were harvested and prepared for total N analysis as described elsewhere[12] while the soils were rapidly air dried before being analysed for NH_4-N and NO_3-N.

Leaching treatments: The following treatments were imposed on duplicate pots of all fertilizer treatments both cropped and uncropped, except where stated.

Clansthal

1. Control—no leaching.
2. 1 in. water applied 1 week after fertilization (cropped only).
3. 2 in. water applied 1 week after fertilization.
4. 1 in. water applied 3 weeks after fertilization (cropped only).
5. 2 in water applied 3 weeks after fertilization.

Lytton

1. Control—no leaching.
2. 2 in. water applied 1 week after fertilization.
3. 2 in. water applied 5 weeks after fertilization.

During leaching the required amount of water was applied dropwise to the surface of the pots, the soils having first been brought to 50% WHC, and the plastic seals removed. After drainage was complete the pots were resealed and the leachate from each pot made up to a fixed volume, from which aliquots were taken for inorganic N determination.

* Post-graduate material by the author for submission to the University of Natal, Soil Science Department.

† Registered trade mark of Dow Chemical Co.

TABLE I

The effect of leaching on N recovery by cane grown on Clansthal sand

Treatment	Inches of water applied per pot at leaching				
	Nil	1 in. after 1 week	2 in. after 1 week	1 in. after 3 weeks	2 in. after 3 weeks
150 mg N as $(NH_4)_2SO_4$			*Tops*		
Yield g	16·8	12·7	9·9	11·0	12·2
N content mg/g	11·3	9·7	7·2	8·8	6·9
N in tops mg	189·8	123·2	71·3	96·8	84·2
			Roots		
Yield g	7·6	4·5	3·9	3·8	7·2
N content mg/g	8·0	8·9	7·6	7·9	8·0
N in roots mg	60·8	40·1	29·6	30·0	57·6
Total plant recovery mg N	**250·6**	**163·3**	**100·9**	**126·8**	**141·8**
150 mg N as $(NH_4)_2SO_4$ *+ 2% N—Serve*			*Tops*		
Yield g	15·0	11·7	12·1	10·0	10·9
N content mg/g	12·9	11·3	7·7	11·9	9·1
N in tops mg	193·5	132·2	93·2	119·0	99·2
			Roots		
Yield g	5·8	4·9	6·4	3·8	5·7
N content mg/g	8·8	10·6	8·4	10·0	8·4
N in roots mg	51·0	51·9	53·8	38·0	47·9
Total plant recovery mg N	**244·5**	**184·1**	**147·0**	**157·0**	**147·1**
150 mg N as $NaNO_3$			*Tops*		
Yield g	11·0	10·2	6·1	10·1	7·0
N content mg/g	12·6	10·4	6·6	10·5	6·8
N in tops mg	138·6	111·2	40·3	106·1	47·6
			Roots		
Yield g	5·1	3·6	2·6	4·0	3·5
N content mg/g	9·8	9·6	7·9	9·9	8·0
N in roots mg	50·0	34·6	20·5	39·6	28·0
Total plant recovery mg N	**188·6**	**145·8**	**60·8**	**145·7**	**75·6**

TABLE II

The effect of leaching on N recovery by cane grown on Lytton sand.

Treatment	Inches water applied per pot at leaching		
	Nil	2 in. after 1 week	2 in. after 5 weeks
150 mg N as $(NH_4)_2SO_4$		*Tops*	
Yield g	12·2	9·9	11·5
N content mg/g	11·0	8·7	9·2
N in tops mg	134·2	86·1	105·8
		Roots	
Yield g	3·7	3·4	4·7
N content mg/g	8·6	7·1	6·7
N in roots mg	31·8	24·1	31·5
Total plant recovery mg N	**166·0**	**110·2**	**137·3**
150 mg N as $(NH_4)_2SO_4$ *+2% N—Serve*		*Tops*	
Yield g	12·5	11·1	13·4
N content mg/g	14·4	10·2	8·1
N in tops mg	180·0	113·2	108·5
		Roots	
Yield g	4·7	4·0	5·9
N content mg/g	8·7	6·6	6·0
N in roots mg	40·9	26·4	35·4
Total plant recovery mg N	**220·9**	**139·6**	**143·9**
150 mg N as $NaNO_3$		*Tops*	
Yield g	11·8	8·8	9·9
N content mg/g	11·8	7·6	8·4
N in tops mg	139·2	66·9	83·2
		Roots	
Yield g	3·3	2·5	3·5
N content mg/g	7·3	5·3	7·2
N in roots mg	24·1	13·3	25·2
Total plant recovery mg N	**163·3**	**80·2**	**108·4**

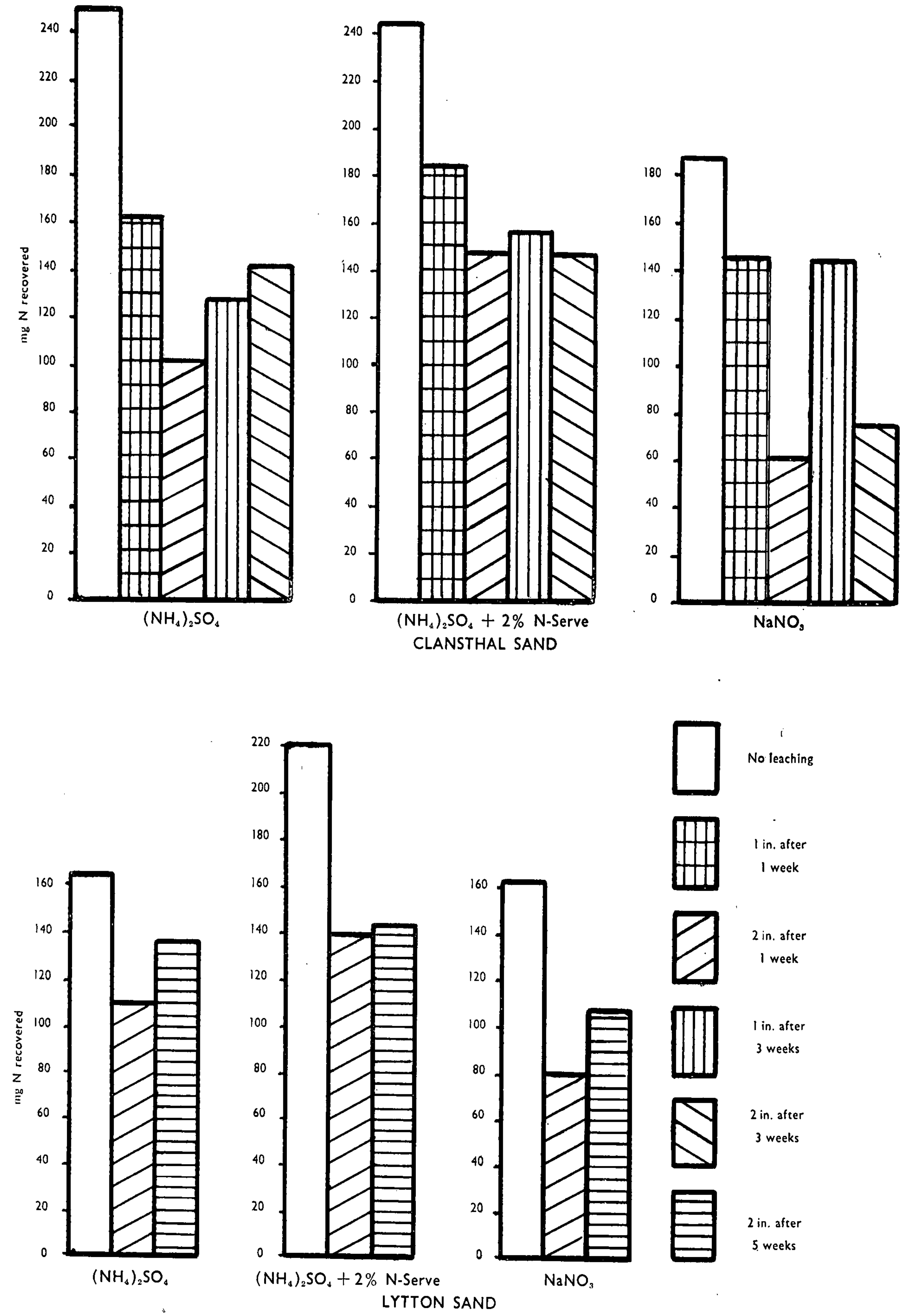

FIGURE 1. Recovery of fertilizer nitrogen by sugarcane after eight weeks under various leaching treatments.

Results and Discussion

Yield data and N recovery by cane grown under the different fertilizer and leaching treatments for a period of eight weeks are presented in Tables I and II, while Figure I illustrates the comparative uptake of N from the two sands.

As expected the effect of leaching was to reduce yield and N recovery from all fertilizer treatments on both soils. Certain factors however obviously affected the degree of leaching and these will now be briefly considered.

Amount and time of water application: Compared with a 1 inch application of water, one of 2 inches removed up to three times the amount of mineral N from the Clansthal sand. This is shown in Table III which details the amounts of NH_4-N and NO_3-N leached from the cropped pots of both soils after various periods. It is of interest to note that considerable quantities of ammonium nitrogen were leached from the soil up to three weeks after application, and smaller amounts after even longer periods. This would appear to be contrary to the

TABLE III

Relative leaching losses of NH_4—N and NO_3—N from two sands under cane at various times after N fertilization.

	Leaching treatment	N Fraction	$(NH_4)_2SO_4$ 150 mg N	$(NH_4)_2SO_4$ +2%N-Serve	$NaNO_3$ 150mgN
			mg N leached*		
Clansthal sand	1 in. after 1 week	NH_4—N	18·0	16·5	Nil
		NO_3—N	10·5	7·5	46·5
		Total N	28·5	24·0	46·5
	2 in. after 1 week	NH_4—N	63·0	60·0	3·0
		NO_3—N	25·5	12·0	114·0
		Total N	88·5	72·0	117·0
	1 in. after 3 weeks	NH_4—N	12·0	12·0	Nil
		NO_3—N	19·5	7·5	52·5
		Total N	31·5	19·5	52·5
	2 in. after 3 weeks	NH_4—N	31·5	54·0	Nil
		NO_3—N	31·5	16·5	120·0
		Total N	63·0	70·5	120·0
Lytton sand	2 in. after 1 week	NH_4—N	54·0	57·0	4·5
		NO_3—N	7·5	7·5	100·5
		Total N	61·5	64·5	105·0
	2 in. after 5 weeks	NH_4—N	9·0	Nil	Nil
		NO_3—N	7·5	4·0	75·0
		Total N	16·5	4·0	75·0

*mean of duplicate pots

TABLE IV

Mineral N remaining in uncropped pots after 8 weeks (mean of duplicate pots in ppm)

Leaching treatment	N fraction	Clansthal sand			Lytton sand		
		$(NH_4)_2SO_4$	S/A+N-Serve	$NaNO_3$	$(NH_4)_2SO_4$	S/A+N-Serve	$NaNO_3$
Nil	NH_4—N	33	105	Nil	114	118	5
	NO_3—N	79	19	102	22	16	96
	Total N	112	124	102	136	134	101
2 in. after 1 week	NH_4—N	Nil	46	Nil	51	66	18
	NO_3—N	39	20	11	24	9	41
	Total N	39	66	11	75	75	59
2 in. after 3 wk. (C) 5 wk. (L)	NH_4—N	Nil	39	Nil	22	49	2
	NO_3—N	35	7	9	8	7	17
	Total N	35	46	9	30	56	19

findings of Maud[7] and others[1, 4] who state that downward movement of nitrogen takes place only in the nitrate form. Morgan and Jacobson[8] also obtained substantial amounts of ammonium salts in leachates collected from sandy soils so it is probable that lighter soils which leach rapidly should be excluded from the above observation. While much of the data in Tables I–III suggest that losses of applied N from the cropped pots were reduced the longer leaching was delayed, so increasing N recovery by the plant, this trend was not apparent in all treatments.

Type of fertilizer applied: In both soils losses of N from $(NH_4)_2SO_4$ were always much less than those from $NaNO_3$, this being reflected in yield and N recovery data. The effect of N-Serve in partially inhibiting nitrification in the Clansthal sand is apparent in the NO_3-N figures in Table III, but even more clearly demonstrated in Table IV which gives amounts of NH_4-N and NO_3-N remaining in the uncropped pots after 8 weeks.

In the slightly acid Clansthal sand in which nitrification readily occurs, no NH_4-N remained in the two leached $(NH_4)_2SO_4$ treatments without N-Serve, while substantial quantities were retained when N-Serve was present. Nitrification in the highly acid Lytton sand normally only proceeds slowly so that differences between treated and untreated soil were not as marked but obvious nonetheless. Nitrification with time probably accounts for the lower amounts of NH_4-N found in the N-Serve treated soils leached after three and five weeks, when compared with amounts found after leaching at one week.

Textural and pH differences: Although exhibiting similar moisture characteristics, the Lytton sand has a somewhat higher clay content than the Clansthal sand (15% compared with 9%). This is thought to be mainly responsible for the slower movement of water through the former soil and for the higher amounts of mineral N retained by it after leaching. Apart from texture, the difference in pH between these sands is able to affect markedly their behaviour to applied N as discussed in an earlier paper[13]. It would seem therefore that more nitrate-N is likely to be leached to greater depths more rapidly in the Clansthal sand than in the Lytton.

Leaching in the field: Evidence of rapid leaching to depth under young cane growing on Clansthal sand was obtained at the commencement of a fertilizer trial (FT 6/N) at the Central Field Station. N was applied in September 1965 as $(NH_4)_2SO_4$ in the furrow at planting, the levels being 0, 25, 50 and 100 lb. N per acre. After eight weeks three replicate profiles were sampled under each treatment at foot intervals to a depth of four feet, mineral N and moisture determinations being carried out immediately in duplicate on all samples.

The means of the results are presented in Table V, and clearly show that considerable leaching of NO_3-N had occurred to a depth of four feet at all fertilizer levels, and was related to the amount of N originally applied.

TABLE V

ppm **NO_3—N* leached under young cane two months† after N applied in the furrow (Clansthal sand)**

Soil depth (in)	lb N applied as $(NH_4)_2SO_4$			
	0	25	50	100
0 —12	1·9	2·2	4·3	2·9
13—24	3·1	2·7	5·6	8·8
25—36	2·5	7·3	8·3	13·0
37—48	2·8	7·4	6·1	11·4
Total	10·3	19·6	24·3	36·1

* mean of 3 replicate profiles

† rainfall recorded during period = 7.92 incres

Conclusions

Where leaching of nitrates occurs under young cane particularly on sandy soils, and is sufficiently severe it can reduce N uptake considerably and may influence yield. The period of potential loss is obviously greatest before the cane rhizosphere is fully established, after which losses will normally be slight. It is often during this period however that high rainfall is experienced and substantial leaching can take place as shown. Whether the plant is ever able fully to make up for such losses from subsequent absorption of nitrates by roots at depth is not clear, though this undoubtedly occurs. Results of field trials on these soils will help to answer this question.

Application of nitrates to such soils would seem to introduce an additional unnecessary risk which is at least partially overcome by the use of ammonium carriers. If these in turn were rendered slowly nitrifiable then the most efficient use could be made of added fertilizer N.

Unfortunately only little information, of a conflicting nature, is available regarding the use of N-Serve in delaying nitrification in sandy soils under cane in the field, and this is to be further investigated. A field trial in the Philippines[5] indicated that both urea and ammonium sulphate treated with 2% N-Serve, produced higher yields than the control, but it was not clear whether the differences were economic. Parish[9] states that field trials have not shown any improvement in N fertilizer efficiency following its use, probably because the "set back" to the soil nitrifying organisms is only of a temporary nature, N-Serve being volatile.

Summary

In a greenhouse experiment cane grown on two coastal sands (Clansthal and Lytton series) was subject to various fertilizer and leaching treatments over a period of eight weeks.

The effect of leaching was to reduce yield and N recovery from all fertilizer treatments on both soils, but certain factors namely (i) amount and time of water application, (ii) type of fertilizer applied, (iii) the use of N-Serve, a nitrification inhibitor and (iv) pH and texture, were found to greatly affect the degree of leaching and N uptake by the plant.

Soil sampling on Clansthal sand under young cane, eight weeks after various N fertilizer applications, showed that considerable leaching of nitrate had occurred at all fertilizer levels to a depth of four feet, and was related to the amount of N originally applied.

It is concluded that leaching of nitrates on sandy soils under young cane if sufficiently severe, can result in reduced N uptake and may influence yield, the most critical period probably occurring between planting and the full establishment of the cane rhizosphere.

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Discussion

Mr. du Toit (in the chair): Have there been any indications, in pot work or in the fields, of a difference in the response of a sugar cane plant to the nitrate or ammoniacal form of nitrogen?

Apparently in a sandy soil such as the Clansthal leaching takes place to a marked extent. Growers who cut cane on such sands in February and March and wish to top dress the crop with a 100 lbs. of N often wonder when this dressing should be applied and whether it should be split.

Mr. R. A. Wood: From pot work observations sugar cane appears to have a preference for the ammonium form of nitrogen. Work at Rothamsted shows that grasses also prefer this form.

With a ratoon crop, that has an established root system, a full autumn application of nitrogen is in order but we have no figures to show how effective a split application would be.

Mr. Hempson: Ratoon roots die and therefore will not be effective in taking-up nitrogen.

Mr. R. A. Wood: The root mat, even though it dies eventually, remains effective for some time and will hold back nitrogen.

Dr. Thompson: Mr. Wood has indicated that a plant never fully makes up leaching losses that occur in a Clansthal sand. The neutron probe shows that the potential for recovery of nitrogen leached to a depth of seven feet is good.

Mr. Wilson: Our root laboratory has also indicated that in sands roots reach a depth of four feet in a period of eight weeks.

Mr. R. A. Wood: In sands the root system at depth is dispersed and may not be able to recover all the available nitrogen.

Mr. Moberley: In these experiments in Clansthal sands the poor growth of cane on the site was not due to lack of N but to previous heavy aplications of lime in filter press.

Mr. Cownie: Under total irrigation would you recommend a farmer to hold off irrigation for a few weeks after application of nitrogen?

Mr. R. A. Wood: The movement of water through a heavy soil should not cause much leaching but in a sandy soil it might be advisable to split the application when there is irrigation.