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ABSTRACT

Over a 4-yr period fertilizers having three N and five K levels in a factorial arrangement were applied in a replicated, randomized complete block design to coastal bermudagrass (**Cynodon dactylon** L.) growing on a Pembroke silt loam just north of Fayetteville. In the spring of the fifth year (1972) soil samples were taken from a 3.67-m profile of each plot. Nine depth samples from the profile of each plot were analyzed for exchangeable K and Ca. Potassium fertilizer, especially at the higher rates, and where no N was applied, greatly increased exchangeable K levels only in the top 45 cm of the profile; however, exchangeable Ca levels were decreased markedly in these same upper soil layers, and increased greatly at lower levels in the profile. The first increment of N reduced this effect of K fertilizer on exchangeable Ca, probably because of increased plant growth that resulted from N fertilization; this increased growth removed a larger portion of the fertilizer K. At the higher N rate the net change in exchangeable Ca was greater, but more varied between K treatments, with the highest level of N and K resulting in a net loss of Ca from the 3.67-m profile sampled.

INTRODUCTION

During the summer of 1968 a nitrogen-potassium soil fertility experiment was initiated to study the effect of fertilization on winter hardiness of coastal bermudagrass (*Cynodon dactylon* L.). Fifteen different fertilizer treatments were used, ranging from no fertilizer to very high rates of both N and K. Early in the fifth year the question arose of the effects of these treatments, especially the higher fertilizer rates, on the environment of the soil profile; therefore, a chemical analysis of the soil profile under each fertilizer treatment was undertaken.

Changes in the chemical environment of a soil profile as a result of the addition of salts have been reported by several workers. Hileman (1972) of the University of Arkansas conducted a laboratory leaching experiment using 2-ft (60-cm) undisturbed soil columns. Chicken litter was applied at rates ranging from 2 to 40 tons per acre. He reported that very high concentrations of K remained in the soil column and amounts of Ca in excess of 800 ppm were found in the leachate. Hileman stated that ammoniacal N released from the chicken litter, as well as the K, "was probably strongly involved" in this Ca leaching. The data obtained for total N in the leachate tended to verify his hypothesis, because the nitrate concentration in the leachate was fairly constant whereas the total N in the leachate varied greatly with rate of litter application. Mathers et al. (1973), of the USDA Southwestern Great Plains Research Center, added feedlot manure containing 1,500 lb of K at a rate of 50 tons per acre yearly to a sorghum field during a 3-yr period. He found that most of the salts from the manure, as measured by electrical conductance, remained in the upper 18 in. (45 cm) of the profile. Cooke (1967) stated that N fertilizer applied to a permanent grass sward reduced exchangeable soil K in the A horizons and increased it in the B horizons, resulting in no net K change within the profile. Cooke also stated that ammonium salts displaced exchangeable Ca from soil colloids, and that this Ca was lost in percolating water. He believes it is likely that high rates of K must increase losses of Ca, though there is no recent literature on this phenomenon. Munson and Nelson (1963) reported that on silt loams and heavier soils K leaching losses are normally negligible.

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MATERIALS AND METHODS

Fifteen fertilizer treatments were applied to a coastal bermudagrass sod growing on a Pembroke silt loam during a 4-yr period. Three nitrogen rates of 0, 336, and 672 kg N (NO, N1, N2) and five potassium rates of 0, 84, 168, 336, and 672 kg K (KO, K1, K2, K3, K4) per hectare annually, composing a 3x5 factorial arrangement, were used in a randomized and replicated complete block design. All N was applied as NH_4NO_3 and all K was applied as KCl.

In the spring of the fifth year each plot was sampled to a depth of 3.67 m with a 76-mm power-driven core sampling device. Samples from nine soil horizons within each profile were collected and analyzed for exchangeable cations, principally K and Ca, by S-52 Technical Committee Procedures (1965). These data were analyzed statistically by the analysis of variance procedure to determine the effect, if any, the treatments had on the chemistry of the soil profile. In this paper the term significant(ly) implies statistical significance at or beyond the 5% level of probability.

RESULTS

The effects of fertilizer applications on exchangeable soil K levels in the top four horizons sampled are given in Table I. The values show the deviation from the NO-KO treatment for each soil horizon. Potassium fertilizer increased exchangeable soil K levels only in the top 45 cm. Increasing rates of K generally increased the amount of K accumulation, especially in the NO treatments where plant growth was sparse and K removal was minimal, but even in the NO-K4 treatment there was no potassium accumulation below the 45-cm depth.

At the higher K rates nitrogen significantly reduced exchangeable soil K levels in the 0-15-cm horizon and significantly increased exchangeable soil K at the 30-45-cm depths (Table I). Exchangeable soil K was significantly lower in the K1 and K2 treatments at the 60-90, 120-180, and 180-215-cm horizons, all of which were observed to be zones of massive root development. Also, the net potassium balance in the 3.67-m profile at these two lower K rates was negative, indicating a net loss of K from the soil profile.

Nitrogen and potassium both were found to have a highly significant effect on exchangeable calcium. This is illustrated in Table II which gives the net change in exchangeable soil Ca due to N and K fertilization. All fertilizer treatments resulted in a reduction of exchangeable Ca in the 0-15-cm horizon. The N1 and N2 treatments also significantly reduced exchangeable Ca in the 15-30-cm horizon. Increasing increments of K significantly increased exchangeable soil Ca in the 60-90, 180-240, and 240-300-cm and lower horizons where no N was applied (Fig. 1). However, with the N2 fertilizer rate, Ca accumulation was significant only in the 60-90-cm horizon and the 3.67-m profile showed a net loss of more than 1,000 ppm Ca.

Table I. Net Change in Exchangeable Potassium in Four Soil Horizons from Fertilized vs. Nonfertilized Treatments

Depth (cm)	Potassium Fertilizer Treatments	Nitrogen Fertilizer Treatments		
		NO	N1	N2
			ppm Ca	
0-15	KO	0	-46	-49
	K1	40	24	1
	K2	134	52	44
	K3	295	174	122
	K4	515	292	252
15-30	KO	0	-8	-14
	K1	9	12	7
	K2	39	29	39
	K3	125	135	118
	K4	285	227	250
30-45	KO	0	9	-3
	K1	5	8	3
	K2	11	6	13
	K3	56	58	95
	K4	126	153	218
60-90	KO	0	-6	-8
	K1	-8	-13	-14
	K2	-7	-18	-8
	K3	4	-7	-2
	K4	-1	-2	-2

Table II. Net Change in Exchangeable Calcium in Four Soil Horizons from Fertilized vs. Nonfertilized Treatments

Depth (cm)	Potassium Fertilizer Treatments	Nitrogen Fertilizer Treatments		
		NO	N1	N2
			ppm Ca	
0-15	KO	0	-263	-413
	K1	-25	-304	-507
	K2	-80	-382	-441
	K3	-122	-310	-529
	K4	-207	-419	-575
15-30	KO	0	10	-253
	K1	22	-25	-341
	K2	7	-59	-316
	K3	-69	-194	-372
	K4	-234	-269	-556
30-45	KO	O	-44	22
	K1	32	-7	34
	K2	53	-4	34
	K3	44	-91	-372
	K4	-75	-125	-322
60-90	KO	0	59	234
	K1	-73	-33	-83
	K2	96	-79	325
	K3	321	317	380
	K4	613	405	134

DISCUSSION

As shown in Table I, K did not move down through the soil profile but accumulated in the top 45 cm of soil, apparently replacing Ca on the soil exchange complex in this zone. Where no N was applied the K accumulation was most evident in the top 30 cm because of minimal plant growth and K uptake. At the N1 and N2 fertilizer rates, K tended to accumulate in the 30-45-cm level, possibly because of preferential absorption of NH_4^+ by the colloids in the top 30 cm of soil. The lower exchangeable K levels observed for the K1 and K2 rates in the 60-90, 120-180, and 180-215-cm horizons (data on lower two horizons not given in Table I) where N was applied probably were due to stimulated plant root growth which allowed the plants to more efficiently mine the soil of K, because more K was removed in the forage harvested from these areas than was applied. Ca accumulated in the 60-90-cm horizon and in the lower regions of the sampled profile. At the N1 level where plant growth was vigorous the K accumulation in the upper 45 cm was somewhat reduced, as were Ca displacement and accumulation. This also is most likely attributable to increased plant growth and uptake of both K and Ca. But plant uptake and removal of K and Ca were not sufficient to account for all of the difference in Ca accumulation between the NO and N1 nitrogen levels as shown in Figure 1. This difference could have been caused by (1) the interaction of the ammonium ion with the exchange complex, and (2) the reduced K:Ca ratio in the top 45 cm of soil due to plant uptake of K. In this experiment it may have been the high K:Ca ratio which caused the replacement of Ca by K to the degree observed. At the N1 level most of the N applied was taken up by the plant, leaving very little NH_4^+ to interact in the soil. However, at the N2 rate plant growth was not significantly increased; thus less than half the applied N was removed by the plants, and large amounts of N, probably in NH_4^+ form, were left to interact with the other soil cations. In this case Ca movement was probably influenced by the NH_4^+ K:Ca ratio (or the monovalent to divalent cation ratio). At the N2 rate only the K3 and K4 treatments showed significant K accumulation in the profile, and only the KO and K2 rates showed significant Ca accumulation in the profile. The net loss of Ca observed at the N2-K4 rates probably was caused by high monovalent to divalent cation ratio which caused the Ca to be moved out of the sampled profile.

Rates of both N and K which were in excess of what the plants could utilize caused very significant chemical changes throughout the soil profile to the 3-m depth. These changes, especially at the N2 and K4 levels, were great enough to reduce yields significantly after only four years. This indicates that in an intensive forage management program care must be taken to apply enough fertilizer for maximum plant growth without depletion of native soil fertility, as occurred at the N1, K1, and K2 rates, but not to greatly exceed fertilizer rates which the plant can utilize. Also, more attention needs to be given to the effects of continuous intensive management on the chemcial environment of the soil profile.

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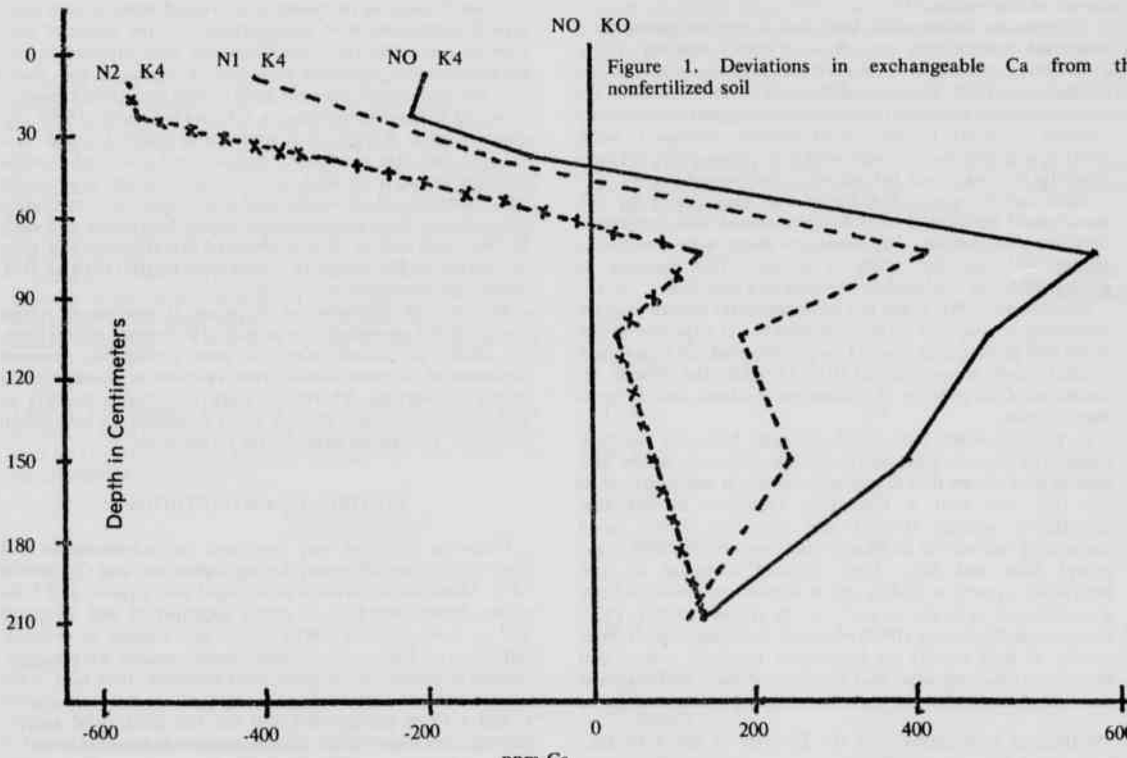

Figure 1. Deviations in exchangeable Ca from the nonfertilized soil