Response of Stargrass to K fertilization as affected by liming, N and K sources[1,2]

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ABSTRACT

The effect of liming and sources of K and N on the response of Stargrass to potassium fertilization was studied on a Typic Tropohumults. Stargrass responded with up to 1,500 kg/ha of K with or without liming, when $(NH_4)_2SO_4$ was the source of N, but responded only to 500 kg of K/ha when urea was the source of N. Liming increased the response of Stargrass to K fertilization when $(NH_4)_2SO_4$ was the source of N, but only at the highest rate when urea was used. The source of K had no significant effect on yields of Stargrass. More K accumulated in the soil but percentage recovery of applied K decreased as the rate of application increased. More K accumulated in the soil when KCl was the source of K. Marked changes in soil acidity factors occurred as a result of heavy fertilization with $(NH_4)_2SO_4$.

INTRODUCTION

This paper presents the results of an experiment conducted to determine the yield response of Stargrass (*Cynodon nlemfuensis*) on an Ultisol to K levels and K uptake as affected by liming and N and K sources.

Potassium is adsorbed by plants in larger amounts than any other cation. Coffee, plantains and grasses absorb more K than any other nutrient and respond strongly to high applications of this element under humid, tropical conditions (2, 10, 20). Vicente-Chandler et al. (20) found that K recovered by grasses decreased in an Alfisol even though more K accumulated in available form as rate of application increased. Jordan et al. (11) reported that a K content of around 1% was associated with maximum forage yields of Bermuda grass.

Reports on the effect of liming on K availability has been inconsistent for many years. Peech and Bradfield (15) showed that liming reduced the amount of K in the soil solution and thus interfered with this nutrient uptake. Powell and Hutchinson (16), working with a micaceous soil, found that lime applications resulted in lower exchangeable K levels, although liming effects on K were not associated with crop response. Liming soils with a high Al saturation percentage tends to increase exchangeable K and decrease K in the soil solution (18).

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Ayers and Hagihara (6), working with acid soils from Hawaii, found that K from KCl was more easily leached out than K from K_2SO_4 or K_3PO_4. They concluded that K retention from K_2SO_4 without measurable quantities of displaced cations indicated that both K and SO_4 were sorbed simultaneously. On the other hand, Pearson et al. (14) found that 90% of the water soluble bases moving throughout the profile of Ultisols from Puerto Rico were sulfates. Aylmore et al. (7) found that sulfates adsorbed on the kaolinite clay edges are weakly held and easily removed, whereas those which sorb Al and Fe oxides are highly susceptible to leaching.

The effect of the nitrogen source and pH on K uptake was investigated by Murdock and Rich (13). They found that K uptake at high soil pH was significantly higher when the N source was NH_4NO_3 than when the N source was $Mg(NO_3)_2$. Figarella et al. (9) and Vicente-Chandler and Figarella (19) found that N source had little effect on K uptake by Pangola or Napier grass when the soil was limed.

MATERIALS AND METHODS

The experiment was conducted over 3 consecutive years near Orocovis in the uplands of Puerto Rico, at an elevation of 600 m above mean sea level. Annual rainfall varied from 1,500 to 2,500 mm with an average of 2,070 mm/year. Mean annual temperature was 24° C with seasonal variations of 5° C.

The soil was an eroded Humatas clay, Typic Tropohumults, clayey, kaolinitic, isohyperthermic. The cation exchange capacity of the upper 15 cm of soil (by sum of cations) was of 6.5 me/100 g of soil with about 40% aluminium saturation. The soil contained 2.2% organic matter. The predominating clay mineral is kaolinite with a high content of free oxides of Fe and Al.

A randomized block design was used with treatments replicated 4 times. Plots were 4x4 m surrounded by ditches to prevent fertilizer from washing into adjoining plots. Treatments consisted of 3 rates of K (0,500 and 1,500 kg/ha/yr) from 2 sources, (KCl and K_2SO_4); 2 sources of N, $(NH_4)_2SO_4$ and urea at a rate of 700 kg/ha/yr with 4.5 t/ha of $Ca(OH)_2$ or without liming.

All plots received 50 kg/ha/yr of P from triple superphosphate, and 700 kg/ha/yr of N from either urea or $(NH_4)_2SO_4$, and K from either KCl or K_2SO_4 at the indicated rate. The fertilizer was divided in six equal applications during the year and applied after each cutting. Lime was applied to the corresponding plots prior to planting sprigs of Stargrass (*Cynodon nlemfuensis*), 0.8 m apart.

Soil samples were taken at 0-45 cm depth in all plots at the beginning and at the end of the experiment, and analyzed for pH, exchangeable Al, Ca + Mg, and K, SO_4 and HNO_3-soluble K. Exchangeable Ca + Mg were extracted with *N* ammonium acetate and determined by the Versenate titration method (8). Exchangeable Al was extracted with *N* KCl and determined by the double titration method (12). Potassium was determined by flame photometry.

The grass was cut every 60 days and the forage weighed and removed from the plots. Forage samples were taken from each plot and analyzed for dry matter and K content.

RESULTS AND DISCUSSION

Table 1 shows the effect of treatments on Stargrass forage yields. Dry matter yields increased up to 1,500 kg/ha/yr of K with or without liming when $(NH_4)_2SO_4$ was the source of N and K_2SO_4 the source of K. However, Stargrass responded only to 500 kg/ha/yr of K when urea was the source of N.

Liming increased forage yields at all K rates when $(NH_4)_2SO_4$ was the source of N, but only at the 1,500 kg/ha-K rate when urea was the source of N.

Table 1 shows the K content of the forage increased significantly with increasing K rates but was not affected by N source, K source, or liming. Potassium extracted by Stargrass increased with increasing K rates with both N or K source, and with or without liming. Liming increased K uptake at all rates when $(NH_4)_2SO_4$ was the source of N, but only at the 1,500 kg/ha/yr rate when urea was the N source.

Table 1 shows that K source had no effect on K uptake or percent recovery of applied fertilizer, with or without liming. Liming increased percent recovery of applied K at all K rates when $(NH_4)_2SO_4$ was the source of N, but only at the 1,500 kg/ha/yr rate when urea was the source of N. Percent recovery of applied K decreased as the rate of K application increased, irrespective of K or N sources and liming.

Accumulation of K in the soil increased with increasing rate of application, irrespective of K or N sources and liming (table 1). More K accumulated in the soil when it was applied as KCl than as K_2SO_4, irrespective of liming. However, liming increased the percentage of K accumulated in the soil when K was applied as KCl rather than K_2SO_4.

A higher percent of the applied K was either recovered or accumulated in the soil when applied as KCl than as K_2SO_4, with or without liming. More K was recovered or accumulated in the soil when urea was the source of N instead of $(NH_4)_2SO_4$, with or without liming.

Table 2 shows that the use of high rates of residually acid N sources caused marked changes in the soil. The use of $(NH_4)_2SO_4$ during a 3-year period without liming lowered soil pH by a full unit, reduced the exchangeable Ca + Mg to 1/3 its original content, and increased the Al saturation from 40 to 81%. Similar results have been reported elsewhere (1, 4, 5). The use of urea as the source of N had a less detrimental effect on soil properties than $(NH_4)_2SO_4$ with or without liming. However, lim-

TABLE 1.—*Effect of two N sources, liming and three K rates from two sources on dry matter yields and utilization of applied K by Stargrass grown on a typic Tropohumults from the uplands of Puerto Rico*[1]

Nitrogen		Potassium		Lime	Yearly average dry matter yields	K content in forage	K extracted by grass	Applied K recovered in forage	Applied K accumulated in soil	Applied K recovered or accumulated in soil
yearly application as										
NH_4SO_4	Urea	KCl	K_2SO_4							
kg/ha				*t/ha*	*kg/ha*	*%*	*kg/ha*	*%*	*%*	*%*
700	—	—	0	0	11941 g[2]	1.9 c	130 f	—	—	—
700	—	—	500	0	18478 e	1.80 b	332 e	40.3 bc	18.4 d	58.7 d
700	—	—	1500	0	29015 bc	2.40 a	693 bc	37.7 c	20.0 d	57.7 d
700	—	—	0	4.5	15917 ef	.79 c	126 f	—	—	—
700	—	—	500	4.5	25338 cd	1.77 b	448 d	64.4 a	2.1 f	66.5 c
700	—	—	1500	4.5	31966 a	2.44 a	779 a	43.5 b	14.0 cd	57.5 d
—	700	0	—	0	13946 fg	.98 c	136 f	—	—	—
—	700	500	—	0	24794 d	1.84 b	455 d	63.9 a	10.5 e	74.4 b
—	700	1500	—	0	27039 bcd	2.58 a	697 bc	37.4 c	41.2 b	78.6 b
—	700	—	500	0	24186 d	1.88 b	454 d	62.7 a	1.9 f	64.6 c
—	700	—	1500	0	25960 cd	2.51 a	652 c	34.4 c	34.4 c	68.8 c
—	700	0	—	4.5	15788 efg	.86 c	135 f	—	—	—
—	700	500	—	4.5	26895 bcd	1.81 b	486 d	70.3 a	1.4 f	71.7 bc
—	700	1500	—	4.5	30019 ab	2.46 a	738 ab	40.2 bc	51.4 a	91.6 a
—	700	—	500	4.5	26891 bcd	1.73 b	465 d	65.9 a	3.2 f	69.1 bc
—	700	—	1500	4.5	30592 ab	2.53 a	774 a	42.6 b	36.1 bc	78.7 b

[1] All figures are 3-year average.

[2] Values followed by one or more letters in common do not differ significantly (Duncan multiple range).

TABLE 2.—*Effect of two N sources, liming, and three K rates from two sources on soil properties of the upper 45 cm of a Typic Tropohumults from the uplands of P.R.*

Treatments					Soil data at the beginning of the experiment						Soil data at the end of the experiment				
Nitrogen (Yearly application as)		Potassium (Yearly application as)		Lime	pH	Ca + Mg	Al saturation	Exchangeable K	HNO_3 soluble K	SO_4	pH	Ca + Mg	Al saturation	Exchangeable K	HNO_3 soluble K
$(NH_4)SO_4$	Urea	KCl	K_2SO_4												
kg/ha				t/ha		me/100 g	%		kg/ha	kg/ha		me/100 g	%	kg/ha	
700	—	—	0	0	4.70	3.14	40	257	340	823	3.65	1.07	81	254	240
700	—	—	500	0	4.85	3.62	42	276	281	877	3.85	1.22	78	559	272
700	—	—	1500	0	4.85	3.70	38	411	300	724	4.05	1.41	67	1158	453
700	—	—	0	4.5	5.30	6.67	5	313	304	823	4.20	2.78	54	128	215
700	—	—	500	4.5	5.35	5.60	8	246	274	689	4.30	3.33	53	235	318
700	—	—	1500	4.5	5.25	5.65	10	220	334	847	4.40	2.68	45	778	425
—	700	0	—	0	4.85	3.37	40	289	195	692	4.05	1.50	71	113	236
—	700	500	—	0	4.90	3.06	43	262	253	712	4.55	1.63	57	446	226
—	700	1500	—	0	4.85	3.57	41	248	283	672	4.35	1.13	57	1853	512
—	700	—	500	0	4.85	3.48	40	251	251	840	4.70	2.02	56	235	273
—	700	—	1500	0	4.85	3.57	40	248	248	756	4.40	1.77	51	1485	653
—	700	0	—	4.5	5.30	6.42	2	232	232	875	4.70	3.47	38	121	215
—	700	500	—	4.5	5.25	6.03	6	247	247	664	4.85	3.33	34	323	221
—	700	1500	—	4.5	5.25	5.87	8	225	225	995	4.70	2.43	29	2207	442
—	700	—	500	4.5	5.30	6.04	2	236	236	687	5.00	4.41	23	218	253
—	700	—	1500	4.5	5.20	5.35	5	300	300	732	4.75	3.34	26	1764	442

ing had a significant ameliorating effect when used with either N source. The lime-urea combination had a more lasting beneficial effect than the lime-ammonium sulfate combination.

The use of K_2SO_4 as K source had a light ameliorating effect on soil acidity, both with and without lime.

Exchangeable K content of the soil increased with rates of K application, irrespective of K and N sources or liming. Liming in combination with $(NH_4)_2SO_4$ resulted in the accumulation of less exchangeable K in the soil than when lime was not applied. Forage production increased and, therefore, a higher K uptake by the grass was measured. Moreover, the total available K accumulated in the soil (exchangeable + HNO_3 soluble K) was much less when $(NH_4)_2SO_4$ was the source of N rather than urea, irrespective of the lime treatment. The use of urea in combination with liming had no clear effect on K accumulation in the soil.

The HNO_3 soluble K also increased with rates, although to a lesser extent than exchangeable K. This increase suggests that there was a temporary fixation of K possibly by dioctahedral vermiculite, since this soil contains around 8% of this mineral (3). Simultaneous adsorption of both K cations and SO_4 ions as suggested by Ayers and Hagihara (6) is another possibility. Swindale and Uehara (17) postulated that plants could recycle K to the soil surface in sufficient quantitites to form micas.

The data here presented show that liming acid, leached, tropical soils high in sesquioxides of Al and Fe (Ultisols and Oxisols) improves the utilization of fertilizer K applied to grasses if $(NH_4)_2SO_4$ is the source of N. The beneficial effect of liming is less striking when urea is the source of N. This difference is in all probability due to the higher acid residue left by $(NH_4)_2SO_4$ as compared with urea.

The ill effect of the higher acid residue of $(NH_4)_2SO_4$ as compared with that of urea is further demonstrated by the response of Stargrass to K applications. When $(NH_4)_2SO_4$ was the source of N, Stargrass responded up to the highest rate of K tested with or without liming, but responded to the 500 kg/ha K rate only when urea was the source of N and no lime was applied. There was a positive interaction in terms of forage yields between liming and K fertilization when $(NH_4)_2SO_4$ was the source of N.

The increased recovery of applied K as a result of liming is apparently related to the displacement of active Al from exchange sites so that K can compete with Ca and Mg for exchange positions. The increase in cation exchange capacity resulting from the hydroxylation of Al polymers might also help increase K retention. It may be inferred that liming may decrease the availability of K to plants, since Ca will displace K from exchange sites making it liable to leaching especially under humid tropical conditions. Apparently, the better developed root system of the grass when the soil was limed, resulted in a higher uptake of K, hence a higher recovery of this nutrient applied as fertilizer.

More K accumulated in the soil when applied as KCl than as K_2SO_4 irrespective of lime treatment. Since forage yields and K uptake were similar with both K sources, heavier losses of K fertilizer occurred when it was applied as K_2SO_4. These findings disagree with results reported by Ayers and Hagihara (6). Apparently, the high content of Fe and Al oxides and the low exchange capacity of the soils in their report played a significant role in the retention of K_2SO_4 possibly as a salt rather than K as a cation. Under such conditions, KCl is probably more likely to be leached.

CONCLUSIONS

In acid soils high in Fe and Al oxides, liming induces a better utilization of applied K to Stargrass if $(NH_4)_2SO_4$ is used as the source of N. The response of Stargrass to liming is greatly modified by the source of N used; this grass is more responsive to lime when $(NH_4)_2SO_4$ rather than urea is the source of N. Stargrass responded only to an application of 500 kg of K/ha when urea was the source of N irrespective of liming. KCl and K_2SO_4 are equally efficient in supplying K to Stargrass. A higher percentage of the applied K is taken up by the grass or accumulates in the soil when this nutrient is applied as KCl than as K_2SO_4.

RESUMEN

La reacción de la yerba estrella al abonamiento con potasio en relación con la encaladura y las fuentas del nitrógeno y el potasio

Se estudió el efecto del encalado y de las fuentes de N y de K sobre la respuesta de la yerba Estrella a las aplicaciones de potasio en un Ultisol de la altura de Puerto Rico.

La yerba Estrella respondió a la aplicación de hasta 1,500 kg. de K/ha en ausencia o presencia de cal cuando la fuente de N fue $(NH_4)_2SO_4$. Sin embargo, sólo respondió a la aplicación de solo 500 kg. de K/ha cuando la fuente de N fue la urea. El encalado, sin embargo, incrementó la respuesta de la yerba a las aplicaciones de K. No hubo diferencias significativas entre las fuentes de K en lo que respecta a la producción de forraje.

El contenido en K en el forraje aumentó consistentemente con el aumento en el abonamiento con potasio, pero el porcentaje de recuperación en el forraje del abono aplicado disminuyó a medida que la dosis aumentó. El encalado no tuvo efecto en modificar el contenido en K del forraje, sin embargo, aumentó la cantidad de este nutrimento extraído por la yerba.

La fuente de K no tuvo efecto significativo sobre la recuperación del K aplicado, pero sí sobre la cantidad que se acumuló en el suelo en forma cambiable. Cuando el K se aplicó como KCl en vez de K_2SO_4 se acumuló una mayor cantidad del elemento en forma cambiable con encalado o sin él.

El encalado propició una mejor acumulación de K en el suelo cuando se aplicó en combinación con $(NH_4)_2SO_4$ porque hubo una mayor producción de forraje y una mayor extracción de K, por lo que hubo menos K disponible para acumularse en el suelo.

El uso de $(NH_4)_2SO_4$ como fuente de N causó cambios indeseables en el suelo, tales como un aumento en el porcentaje de saturación con Al y pérdida de Ca, Mg y del abono potásico aplicado. El efecto fue más dañino cuando no se aplicó cal.

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