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Potassium Dynamics Under Exhaustive Cropping of Sudan Grass (*Sorghum vulgare*) in Some Indian Soils

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Abstract. In order to study the effect of different levels of K exhaustion on potassium dynamics, Sudan grass was grown in clay pots containing 5 kg of three types of soils each namely Alfisol, Vertisol, and Inceptisol from India. Potassium was applied at the rate of 0, 50, 100, and 200 mg/kg before starting the experiment and after each of the first three cuttings. Seven cuts of Sudan grass were taken over a period of 280 days, at 4-6 week intervals. Potassium content of Sudan grass increased with increased amounts of K applied as fertilizer. The highest values for K concentration in Sudan grass were recorded in the 1st and the 2nd cuts and gradually decreased up to the last cut, but the rate of decrease was much lower in moderately exhausted soils (AK_{200}, BK_{200}, and RK_{200}). In Inceptisol and Vertisol as the intensity of exhaustion increased the contribution of non-exchangeable K (NE-K) to meet the plant demand also increased, but in Alfisol a reverse trend was noticed (decrease in replenishment rate). Total amount of NE-K utilized by crop was high in K_0 and low in K_{200} treatment in all the soils, but the proportion of percent share of K_0/K_{200} was the highest in Inceptisol (4.5), medium in Vertisol (3.50) and the lowest in Alfisol (2.29).

Keywords: K dynamics, K depletion, exhaustive cropping, Sudan grass, Indian soils, *Sorghum vulgare*

Introduction

Agricultural soils are always in a state of disequilibrium with regard to K transformations. Soils that have been intensively cropped and fertilized with optimum K fertilizer for many years fall in this group, because equilibrium is precluded by periodic addition of fertilizers (Sparks, 1985).

Martin and Sparks (1985) stated that exhaustive cropping method has helped to define K supplying power of soils and K depleting abilities and depletion tolerances of various crop species of regional interest. Fox and Kacar (1965) studied the mobilization of non-exchangeable K (NE-K) and reported that K is released by two mechanisms: one involving depletion of K in the exchange complex and a shift in equilibrium with non-exchangeable form and the other, involving weathering of primary minerals by acid roots.

Mutscher and Tu (1988) reported that biological depletion of potassium decreases the K concentration in the soil solution and induces the release of inter-layer potassium (K_i). Due to massive decrease of K concentration directly near the active roots, easily releasable K_i takes part in the K supply even if the K concentration of bulk soil solution and the average contents of exchangeable K are still high.

Oliveira *et al*. (1971) reported that the quantities of K absorbed from each soil by 7 cuttings of perennial rye grass in the greenhouse ranged upto 13 times that of exchangeable K and upto 5 times that of HNO_3 extractable K. Total plant uptake represented 3.5 to 29.7% of total soil K. Chakravorti and Patnaik (1990) reported that release of NE-K was higher from the alluvial and red soils than lateritic and black soils.

According to Deshmukh and Khera (1990), an average of 85% of total K uptake occurred through the release of NE-K sources of the soils. When K was added at 100 and 300 ppm, NE-K contributed 55-76% and 20-57% of the total potassium uptake, respectively. The residual exchangeable potassium showed a close correlation with the potassium supplying power of the soil.

The potassium supplying power of eleven Ustochrepts of Delhi territory was determined by exhaustive cropping with Sudan grass (*Sorghum vulgare* var. Sudanense) in pots treated with 3 levels of potassium (0, 100, and 300 ppm). The exchangeable K content in the soil and the total potassium content in the plants after each crop were calculated. The residual exchangeable potassium showed a close correlation with the potassium supplying power of the soil (Deshmukh and Khera, 1990).

Srinivasarao (1996) reported that on account of huge removal of K from soil in harvested crops, continuous cropping without the use of K fertilizer caused a decline in available K content. An imbalanced use of fertilizers, either without K or

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*Author for correspondence; E-mail: gh_roshani@yahoo.com with lower amount of K, may lead to depletion of available K to such an extent that the crop response to normal doses of applied K may not be observed on account of very high K fixation in such soils. With potassium depletion, the fixation further increased up to 90 % of the added K.

Materials and Methods

Sudan grass (*Sorghum vulgare* var. *sudanensis*) was grown in 8/kg capacity sealed clay pots containing 5 kg of three types of air dried soils: Alfisol (Bangalore), Vertisol (Bhopal), and Inceptisol (Delhi) from India and placed randomly in a greenhouse. Seven cuts of biomass were periodically harvested. Measured quantity of deionized water was applied to the pots depending on the amount of evapotranspiration which was calculated by daily weighing method. Twenty seeds of Sudan grass were sown in each pot. Twelve days after sowing, eight healthy plants per pot were retained to ensure enough dry matter production and potassium removal from the soil.

In order to study the effect of different levels of K exhaustion on potassium dynamics, pots were divided into four sets, receiving different potassium doses as fertilizer. Before sowing the crop, optimum doses of nitrogen (50 mg/kg), phosphorous (30 mg/kg), copper (2 mg/kg), manganese (5 mg/kg), iron (10 mg/kg) and zinc (5 mg/kg) were applied as basal and these nutrients were also supplied at the same rate after the 1st, the 2nd, and the 3rd cutting. Potassium was applied at the rate of 0, 50, 100, and 200 mg/kg before starting the experiment and after each of the first three cuts. Urea, di-ammonium phosphate and potassium chloride served as sources of N, P and K, respectively, while micronutrients were applied in their sulphate form.

Sudan grass was harvested 7 times over a period of 280 days at a height of about three centimetres above the soil level at 4-6 weeks intervals. The first sown grass was harvested three times and the subsequent resown crop was harvested thrice and the second resown crop was also harvested twice. Before any resowing, soil of each pot was removed and mixed after carefully removing the roots. To avoid any loss of K, such root mass separated from each pot was kept at the bottom of the same pot before refilling with soil.

The above ground plants harvested at each cut were dried at 60 °C in oven for 72 h and weighed. The oven dried plant samples were ground and stored properly for further chemical analysis. After each cut, a small quantity of soil was collected from each pot with a tube auger. After air drying, the soil samples were crushed using a wooden mortar and pestle and passed through a 2 mm round hole sieve and kept for chemical analysis. The dry matter production, total K uptake by the crop (Jackson, 1967) and exchangeable K content of soil (Page *et al.*, 1982) were measured.

Results and Discussion

The dry matter yield, potassium concentration, potassium uptake by Sudan grass and potassium supplying power of three types of soils at different cuts, are presented in Tables 1 and 2.

Table 1. Dry matter yield (g/pot) of Sudan grass in seven cuttings in differentially K treated soils

Treatment	Dry matter yield (g/pot) at cuttings 1-7							Cumulative dry matter yield (g/pot)
	1st	2nd	3rd	4th	5th	6th	7th	
AK_0*	6.4	15.5	17.4	19.3	28.4	15.8	15.0	117.8
AK_{50}	6.8	16.5	15.9	16.5	34.5	20.5	18.2	128.9
AK_{100}	6.9	16.1	15.9	16.1	34.8	20.3	16.5	126.6
AK_{200}	6.1	12.9	15.6	18.7	31.1	23.0	23.4	130.8
BK_0	7.3	14.4	15.6	21.4	41.0	11.8	21.1	132.6
BK_{50}	5.8	13.0	14.4	18.6	34.9	12.5	25.3	124.5
BK_{100}	5.1	12.5	16.5	19.0	34.6	14.8	20.7	123.2
BK_{200}	4.9	11.7	16.4	20.9	46.3	16.7	23.1	140.0
RK_0	5.5	12.5	14.2	20.6	33.5	11.9	20.9	119.1
RK_{50}	5.7	13.6	14.4	19.3	32.9	18.2	21.1	125.2
RK_{100}	5.5	15.8	13.6	19.5	35.6	20.1	29.0	139.1
RK_{200}	5.8	16.5	15.3	18.8	36.8	20.0	32.1	145.3
CD 1%	1.69	3.47	3.21	3.91	7.44	3.09	4.49	
CD 5%	1.27	2.61	2.42	2.94	5.59	2.32	3.38	

A = Inceptisol (Alluvial); B = Vertisol (Black); R = Alfisol (Red); K_0, K_{50}, K_{100}, and K_{200} levels of potassium applied @ 0,50,100 and 200 mg/kg of soil, respectively.

The cumulative dry matter production of Sudan grass increased in Inceptisol, Vertisol and Alfisol with increased K application. The largest and the lowest increases were recorded in Alfisol (26 g/pot) and Vertisol (7.4 g/pot), respectively (Table 1).

Potassium content of Sudan grass increased drastically with increased K application as fertilizer (Table 2). The highest values for K concentration in Sudan grass were recorded in the 1st and the 2nd cuts which gradually decreased to the last 7th cut, but the rate of decrease was much lower in moderately exhausted soils (AK_{200}, BK_{200}, and RK_{200}).

Table 2. Potassium concentration (%) of Sudan grass in differently K-treated soils

Treatment	K concentration (%) at different cuttings						
	1st	2nd	3rd	4th	5th	6th	7th
AK_0	2.7	1.7	1.7	1.6	0.9	0.9	1.4
AK_{50}	3.3	2.7	2.4	2.5	1.3	1.1	1.6
AK_{100}	3.8	3.4	2.7	2.6	1.6	1.2	2.3
AK_{200}	4.6	4.2	2.8	3.3	2.3	1.5	2.5
BK_0	4.6	3.0	2.0	1.7	1.0	1.7	1.2
BK_{50}	4.7	3.5	2.3	2.3	1.6	1.8	1.7
BK_{100}	4.7	3.3	2.6	2.6	2.0	1.9	2.2
BK_{200}	4.8	3.3	2.6	2.9	2.4	2.2	2.6
RK_0	2.4	1.3	1.0	0.6	0.5	0.7	0.6
RK_{50}	3.9	2.9	2.1	1.8	0.9	1.0	1.1
RK_{100}	4.6	3.7	2.6	2.6	1.5	1.4	1.5
RK_{200}	5.0	4.5	3.2	3.2	2.8	2.0	2.5

A, = Inceptisol (alluvial); B = Vertisol (black); R = Alfisol (Red); K_0, K_{50}, K_{100}, and K_{200} levels of potassium applied @ 0,50,100 and 200 mg/kg of soil.

The difference between different levels of K-application, as fertilizer, and total potassium uptake by Sudan grass during the exhaustive cropping was significant in all soils but the ratio of total K uptake in control treatment (AK_0 BK_0 and RK_0) to moderately exhausted soils ($AK_{40,}$ BK_{40} and RK_{40}) was high (4.81) in Alfisol, medium (2.14) in Inceptisol and low (1.67) in Vertisol (Fig.1). The share of non-exchangeable K and replenishment rate (R.R.) was calculated by employing the following formula:

Share (%) = (Total removal-decrease in exchangeable K ´ 100)/Total K removal

R.R. = (Total K removal-decrease in exchangeable K)/Number of days of cropping

Thus, in calculating the non-exchangeable K removed by Sudan grass during the exhaustive experiment, the exchangeable level of K before the 1st cut was considered as initial exchangeable K and the exchangeable K after the 7th cut was considered as final exchangeable K. The amount of potassium added by fertilizer was added to the initial exchangeable K. Percent contribution of nonexchangeable K varied between 92.7 in AK_0 to 20.6 in AK_{200}. The results indicated that the amount of non-exchangeable K-contribution decreased significantly from K_0 to K_{200} (Fig. 2). Total amount of non-exchangeable K utilized by crop was high in K_0 and it was low in K_{200} treatment in all the soils, but the proportion of per cent share of K_0/K_{200} was the highest in Inceptisol (4.5), medium in Vertisol (3.50) and the lowest in Alfisol (2.29).

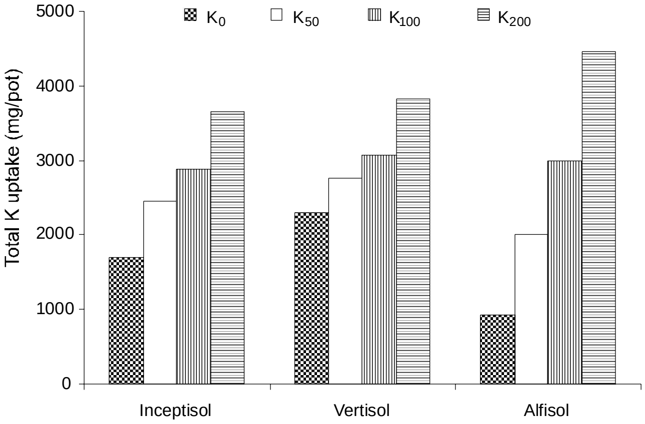

Fig. 1. Potassium uptake (mg/pot) of Sudan grass in differentially K treated soils.

As it is evident from the data presented in Fig. 2, the percent contribution of NE-K to the nutrition of plants followed similar trend in Inceptisol and Vertisol. In these two soils, as the intensity of exhaustion increased the contribution of NE-K to meet the plant demand also increased, but in Alfisol a reverse trend was noticed (decrease in replenishment rate). This may have happened because the quantum of NE-K in Alfisol is much less as compared to other two soils and, there-

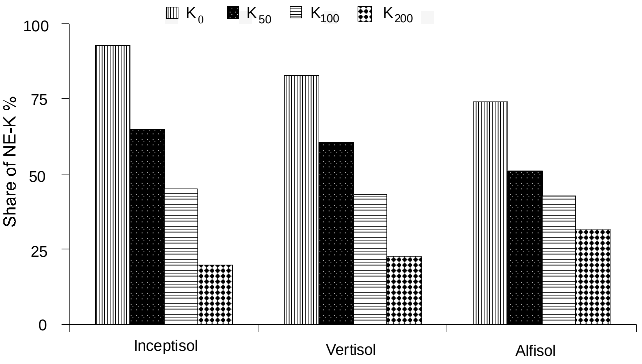

Fig. 2. Percent share of non-exchangeable K in differentially K treated soils.

fore, as the withdrawal from this limited non-exchangeable pool proceeded, the rate of such withdrawal came down sharply.

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