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Soil microbial and enzymatic responses to various sources of potassium in fodder maize and sugargraze

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ABSTRACT

The field experiment was conducted during Kharif season of 2018 at NDRI, Karnal to study the influence of various sources of potassium on soil microbial population, enzymatic activities and yield of fodder crops. The experiment was laid out in the split-plot design with 16 treatment combinations and replicated thrice. In the main plot treatment, two fodder crops, viz., maize (Zea mays) and sugargraze (Sorghum bicolor L. × Sweet sorghum × Sorghum sudanese L.), were included while potassium treatments were executed under subplot treatment. The results revealed that, application of K_{50} + KSB + 2% KNO_3 had a significant influence on biomass production and 30.3 and 22.4% green and dry fodder yield, enhancement was recorded over control. Soil microbial biomass carbon (MBC) was not significantly affected by fodder maize and sugargraze crops at 30 DAS and harvest. However, potassium application had significant influence on soil MBC and a higher values (167 and 185 µg/g dry soil) were recorded with K_{25} + KSB + 2% KNO_3 treatment at 30 DAS and harvest over control, respectively. The soil enzymatic activities dehydrogenase (17.4 and 21.9 µg TPF/g soil/day) and phosphatase (55.4 and 72.8 µg PNP/g soil/hr.) and microbial population counts viz., bacteria (17.12 × 10^6 and 27.45 × 10^6 CFU/g soil), actinomycetes (28.2 × 10^5 and 36.2 × 10^5 CFU/g soil) and fungi (12.8 × 10^5 and 18.3 × 10^5 CFU/g soil) were also remarkably influenced with potassium treatments and found significantly higher at 30 DAS and harvest respectively over control under application of K_{25} + KSB + 2%.

Keywords: Enzymatic activities, maize, microbial counts, potassium, sugargraze

INTRODUCTION

Livestock is the backbone of India's economy in terms of income, employment, equity, and sustainability. It plays a vital role in the rural economy by providing employment, uniformly supplementing the family income. The scarcity of feed and forage resources in the country has made the livestock suffer continuously with malnutrition, resulting in low production potential as compared to many developed nations. The various challenges faced in current agriculture are to produce more food and fodder to feed the large population and equal importance to be given to maintain the soil health status and quality of produce. Like nitrogen and phosphorus, potassium is an essential macronutrient and a key factor controlling crop productivity. Its role is well documented in different physiological processes like photosynthesis, enzyme Catalysis, respiration, protein, and carbohydrates synthesis, translocation of photosynthetic, enabling their ability to resist environmental stress, pests, and diseases. The misconception of potassium richness in soil and faulty agronomical practices adopted by Indian farmers are the main reason for the continuous decline in the potassium status of the soil.

Maize (*Zea mays* L.) is one of the important fodder crop as well as third most growing cereal crop with zero anti-nutritional factors. Sugargraze (*Sorghum bicolor* L. × Sweet sorghum × *Sorghum sudanese* L.) is a top-quality three-way cross of sorghum × sorgho × sudangrass hybrid developed for quality green fodder or hay making. A primary characteristic of sugargraze has very high sugar content which helps to improves feed quality and palatability resulted significantly reduced feed wastage. A study on the effect of potassium application on fodder crops performance mainly on maize and sugargraze is less investigated and therefore, an experiment was carried out to study the soil microbial and enzymatic responses under fodder maize and sugargraze as influenced by varying potassium management options to obtain higher productivity and improved soil properties.

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MATERIALS AND METHODS

A field experiment was carried out during *kharif* season of 2018 at Research Farm of Agronomy Section, ICAR-National Dairy Research Institute, Karnal, India (29º45’ N latitude, 76º58’ E longitude and an altitude of 245 m above mean sea level). The mean annual rainfall was about 766 mm, of which a significant portion (about 574 mm) was received during the southwest monsoon season (July to September) and rest during the winter and spring season. The soil was sandy clay loam in texture having pH 7.5, 6.9 g organic carbon kg^{-1} soil, 221.7 kg ($KMNO_4$ oxidizable N ha^{-1}), 34.8 kg (0.5 N $NaHCO_3$ extractable) P ha^{-1} soil and 240 kg (1.0 N NH_4OAc exchangeable K ha^{-1} soil). The initial bacterial, fungal and actinomycetes counts recorded in the soil were 9.2, 8.3 and 9.8 CFU/g soil, respectively. The experiment was conducted in *split plot design* with two crops in main plot *viz*., maize and sugargraze and eight potassium treatments in subplot *viz*., K_0- control, K_1- KSB, K_2- 40 kg K_2O, K_3- 60 kg K_2O, K_4- 25 kg K_2O + KSB + 2% K_2SO_4 foliar spray, K_5- 25 kg K_2O + KSB + 2% KNO_3 foliar spray, K_6- 50 kg K_2O + KSB + 2% K_2SO_4 foliar spray and K_7- 50 kg K_2O + KSB + 2% KNO_3 foliar spray with three replications. In this experiment, KSB (potassium solubilizing bacteria) was applied to 50 ml inoculants/acre through the seed treatment method. It contained 10^9 cfu/ml counts of potassium solubilizing bacteria. Nitrogen was applied in the form of urea in two splits. Phosphorus was applied in the form of DAP as a basal dose. Potassium was applied as per treatments through basal as well as a foliar application. Foliar spray of 2% K_2SO_4 and KNO_3 was applied at 25 DAS. The seeds of sugargraze @ 12 kg ha^{-1} and fodder maize cv. J-1006 @ 50 kg ha^{-1} were used for sowing. The green fodder yield of crops was recorded at maturity stage. The dry matter yield was estimated by drying fresh material in hot air oven at 60ºC till it attains a constant weight. Organic carbon was estimated by Walkley and Black method and available nitrogen by alkaline $KMnO_4$ method.The MBC (µg/g dry soil) content was determined by the chloroform fumigation-extraction method as described by Nunan *et al.* (1998). Alkaline phosphatase was determined by Tabatabai and Bermner (1969) and dehydrogenase by triphenyl formazan reduction method of Casida *et al.* (1964). The population of different microorganisms’ viz., bacterial count (Gordon *et al.* (1973), fungi (Martin (1950) and actinomycetes (Ken-Knight and Muncie (1939) were computed by using standard serial dilution plating techniques. The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for split-plot design using SAS 9.1 software (SAS Institute, Cary, NC). The least significant difference test was used to decipher the effect of treatments at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Green and dry fodder yield

Results (Table 1) noticed that significantly higher green and dry fodder yields were recorded in sugargraze (57.6 and 13.3 t ha^{-1}) over maize (44.3 and 9.45 t ha^{-1}), respectively. Sugargraze produced 28.5 and 40.4% higher green and dry fodder yield, respectively over fodder maize. The higher fodder yield of sugargraze crop might be due to comparatively higher genetic growth potential and respond to applied input over maize crop. Application of potassium made significant differences in green as well as dry fodder yield. Application of K_{50}+KSB+2% KNO_3 had produced significantly higher green and dry fodder yield (57.4 and 12.4 t ha^{-1}) respectively, which was at par with treatments K_{25} + KSB + 2% KNO_3, K_{50} + KSB + 2% K_2SO_4 and significantly higher over rest of the treatments. The application of K_{50} + KSB + 2% KNO_3 gave 30.3 and 22.4% higher green and dry fodder yield, respectively over control. Potassium fertilization + KSB+ foliar spray increased the green fodder yield as it enhances chlorophyll content which is undoubtedly determines the photosynthetic efficiency and productivity of plants (Wang *et al.* 2013).

Organic carbon and available N

Results (Table 2) revealed that both the crops (maize and sugargraze) and potassium management failed to exhibit any significant effect on organic carbon content of the soil after harvest of crops. However, the available nitrogen status of soil was significantly influenced by the crops and potassium treatments. Significantly

Table 1: Effect of potassium management on green and dry fodder yield of maize and sugargraze

K management	Green fodder yield (t ha^{-1})			Dry fodder yield (t ha^{-1})		
	Maize	Sugargraze	Mean	Maize	Sugargraze	Mean
K_0	37.3	50.9	44.1	7.9	12.4	10.2
K_1	39.5	52.2	45.8	9.0	12.9	10.9
K_2	41.4	54.4	47.9	9.1	12.8	11.0
K_3	45.4	58.7	52.1	9.3	12.7	11.0
K_4	45.6	58.2	51.9	9.9	13.5	11.7
K_5	47.4	59.5	53.5	9.7	13.5	11.6
K_6	47.5	62.1	54.8	10.1	14.0	12.0
K_7	50.3	64.5	57.4	10.6	14.3	12.4
Mean	44.3	57.6		9.5	13.2	
LSD (P=0.05)	Crop 3.04	K 4.37	Crop × K NS	Crop 1.09	K 1.14	Crop × K NS

Note: K_0 - Control, K_1 - KSB, K_2 - K_{40}, K_3 - K_{60}, K_4 - K_{25} + KSB + 2% K_2SO_4, K_5 - K_{25} + KSB + 2% KNO_3, K_6 - K_{50} + KSB + 2% K_2SO_4, K_7 - K_{50} + KSB + 2% KNO_3,

higher available nitrogen status of soil was recorded from maize (204.9 kg ha^{-1}) compared with sugargraze (198.1 kg ha^{-1}). The control (218.5 kg ha^{-1}) remained at par with KSB (215.1 kg ha^{-1}) and significantly higher over rest of the treatments. Similar findings were also reported by Brar *et al.* (2015). The lower available nitrogen in the soil may be due to intensive exhausting of nutrient compared to inadequate replenishment and higher dependency on chemical fertilizers reduced the mineralization process in all the treatments. These observations corroborate with those of Parikh and James (2012).

Table 2: Effect of potassium management on organic carbon and available nitrogen of post harvest soil

K management	Organic Carbon (g kg^{-1})			Available N (kg ha^{-1})		
	Maize	Sugargraze	Mean	Maize	Sugargraze	Mean
K_0	6.7	6.4	6.6	214.0	223.1	218.6
K_1	6.9	6.5	6.7	217.3	213.1	215.3
K_2	6.6	6.6	6.6	207.7	206.1	206.9
K_3	6.6	6.7	6.7	217.1	193.8	205.5
K_4	6.9	6.7	6.8	215.0	190.8	202.9
K_5	6.7	7.1	6.9	189.9	183.4	186.7
K_6	6.7	7.0	6.8	193.3	192.9	193.1
K_7	6.6	7.3	6.9	184.4	181.1	182.8
Mean	6.7	6.8		204.9	198.1	
LSD (P=0.05)	Crop NS,	K NS,	Crop × K NS	Crop 6.22	K 10.82	Crop × K NS

Microbial biomass carbon of soil

Results (Table 3) on MBC exhibited that growing of maize and sugargraze had a non-significant effect on soil MBC at 30 DAS and harvest. However, potassium management had significant influence on soil MBC at 30 DAS and harvest. Significantly higher MBC values were obtained with application of K_{25} + KSB + 2% KNO_3 (167.2 and 184.4 µg/g dry soil) at 30 DAS and harvest, respectively. It was significantly higher over rest of the treatments except K_{25} + KSB + 2% K_2SO_4 and K_{50} + KSB + 2% KNO_3. Potassium is the major intracellular cation in all kinds of organisms and the concentration inside cells is generally maintained higher than outside. Bacteria and fungi also accumulate K inside the cells with a greater concentration. Thus, it may be indicated that soil microbial biomass is a significant potassium pool in soil (Yamashita *et al.* 2014).

Bacterial, Actinomycetes and Fungal count in soil

The microflora count (bacteria, actinomycetes and fungal populations) were reported higher at harvest over 30 DAS with all the treatments. Sugargraze and fodder maize had no significant effect on microflora population

Table 3: Effect of potassium management on microbial biomass carbon of soil and bacterial count at 30 DAS and harvest of maize and sugargraze

K management	MBC (µg/g dry soil)						Bacterial count (x 10^6 CFU/g soil)					
	30 DAS			Harvest			30 DAS			Harvest		
	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean
K_0	134.2	147.8	141.0	154.4	166.9	160.7	13.9	14.4	14.2	20.2	20.8	20.5
K_1	149.6	155.3	152.5	171.3	178.6	175.0	15.0	15.8	15.4	24.1	25.0	24.6
K_2	134.3	150.2	142.3	158.5	167.3	162.9	14.0	15.2	14.6	23.0	24.2	23.6
K_3	135.3	149.2	142.3	156.0	166.0	161.0	14.5	15.4	14.9	23.5	24.4	23.9
K_4	160.1	170.1	165.1	177.8	192.0	184.9	16.0	16.7	16.3	27.0	27.7	27.3
K_5	161.2	173.2	167.2	179.5	191.3	185.4	16.9	17.3	17.1	27.6	27.3	27.5
K_6	150.5	162.0	156.3	169.5	183.8	176.6	15.5	16.1	15.8	24.3	25.1	24.7
K_7	155.7	167.7	161.7	170.9	181.3	176.1	16.1	16.4	16.3	24.5	25.3	24.9
Mean	147.6	159.5		167.2	178.4		15.2	15.9		24.3	25.0	
LSD (P=0.05)	Crop NS K 8.87 Crop × K NS			Crop NS K 11.97 C × K NS			Crop NS K 1.58 Crop × K NS			Crop NS K 2.10 Crop ×K NS		

at different stages (Table 3 and 4). A strong relationship was found between the studied microflora and the potassium management. The soils of K_{25} + KSB + 2% KNO_3 applied treatment showed the highest count of microflora (bacteria, actinomycetes and fungal populations), whereas the lowest count of these microflora were found in the control. As regards all the microflora population, the K_{25} + KSB + 2% KNO_3 treatment resulted in a significant rise in the soil bacteria count (about 34.1%), actinomycetes (about 15.5%) and fungal counts (about 16.6%) over control at harvesting stage. The microbial population counts viz., bacteria (17.12 × 10^6 and 27.45 × 10^6 CFU/g soil), actinomycetes (28.2 × 10^5 and 36.2 × 10^5 CFU/g soil) and fungi (12.8 × 10^5 and 18.3 × 10^5 CFU/g soil) were also remarkably influenced with potassium treatments and found significantly higher at 30 DAS and harvest, respectively over control under application of K_{25} + KSB + 2%. Application of K_{25} + KSB + 2% KNO_3 remained at par with K_{25} + KSB + 2% K_2SO_4, K_{50} + KSB + 2% K_2SO_4 and K_{50} + KSB + 2% KNO_3 in respect of these counts. The population of microbe's viz., bacteria, actinomycetes and fungi increased with the advancing crop stages and after the crop maturity further it decreased. It may be due to increased in total root biomass with time which might support a higher microbial population (Meena *et al.* 2014).

Table 4: Effect of potassium management on actinomycetes and fungal count at 30 DAS and harvest of maize and sugargraze

K management	Actinomycetes count(x 10^5 CFU/g soil)						Fungal count (x 10^4 CFU/g soil)					
	30 DAS			Harvest			30 DAS			Harvest		
	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maiz e	Sugar-graze	Mean
K_0	20.4	22.2	21.3	29.6	31.4	30.5	8.7	10.0	9.4	15.9	15.5	15.7
K_1	23.9	24.0	24.0	32.5	31.9	32.2	9.7	11.1	10.4	16.3	17.8	17.1
K_2	22.5	23.3	22.9	31.7	32.5	32.1	9.2	10.3	9.7	16.1	17.4	16.8
K_3	22.2	23.7	22.9	32.6	33.5	33.1	9.4	10.6	10.0	16.1	17.0	16.6
K_4	27.0	26.1	26.6	34.1	36.3	35.3	11.9	13.2	12.6	17.1	18.5	17.8
K_5	25.9	30.5	28.2	34.7	35.8	35.3	12.1	13.6	12.8	17.1	19.5	18.3
K_6	23.1	24.6	23.9	34.1	34.0	34.1	10.4	11.9	11.2	17.1	16.9	17.0
K_7	25.3	24.7	25.0	34.5	34.8	34.7	10.3	12.4	11.3	17.6	17.0	17.3
Mean	23.8	24.9		33.0	33.8		10.2	11.6		16.7	17.5	
LSD (P=0.05)	Crop NS K 2.30 Crop × K NS			Crop NS K 3.28 Crop× K NS			Crop NS K 1.24 Crop × K NS			Crop NS K 1.47 Crop × K NS		

Table 5: Effect of potassium management on dehydrogenase and alkaline phosphatase activity of soil at 30 DAS and harvest of maize and sugargraze

K management	Dehydrogenase activity (µg TPF/g soil/day)						Alkaline phosphatase activity (µg PNP/g soil/hr)					
	30 DAS			Harvest			30 DAS			Harvest		
	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean	Maize	Sugar-graze	Mean
K_0	12.8	14.4	13.6	17.3	18.1	17.7	33.4	37.3	35.3	56.5	60.1	58.3
K_1	14.9	16.2	15.5	20.1	20.3	20.2	37.9	38.7	38.3	64.3	66.3	65.3
K_2	13.5	15.5	14.5	19.6	19.5	19.6	37.4	40.8	39.1	59.3	64.2	61.8
K_3	13.2	15.5	14.3	18.4	19.6	19.0	37.7	43.1	40.4	65.2	61.8	63.5
K_4	16.4	18.0	17.2	21.3	21.6	21.5	52.5	56.3	54.4	70.5	72.4	71.5
K_5	16.1	18.8	17.4	21.3	22.5	21.9	53.2	57.7	55.4	72.2	73.4	72.8
K_6	14.8	17.1	16.0	19.4	19.6	19.5	47.1	55.5	51.3	66.8	71.0	68.9
K_7	15.1	17.8	16.4	19.3	20.1	19.7	48.9	56.7	52.8	68.2	70.7	69.5
Mean	14.6	16.6		19.6	20.2		43.5	48.2		65.4	67.5	
LSD (P=0.05)	Crop NS K 1.97 Crop × K NS,			Crop NS K 1.09 Crop × K NS			Crop NS K 7.72 Crop× K NS			Crop NS K 7.63 Crop × K NS		

Dehydrogenase and Alkaline phosphatase enzymatic activity of soil

Dehydrogenase enzymatic activities were studied at 30 DAS and after the harvest of fodder crops (Table 5). It was observed that there was no significant difference in dehydrogenase activities with the growing of fodder maize and sugargraze. Whereas, potassium treatments had a significant effect in dehydrogenase activities and higher values were observed with application of K_{25} + KSB + 2% KNO_3 (17.4 and 21.9 µg TPF/g soil/day) at 30 DAS and harvest, respectively over control. Our results showed that application of KSB led to enhancement in dehydrogenase enzyme activity and MBC content in the soil even after harvesting of the crops. This implied that application of KSB with inorganic potassium promoted microbial activity in the soil of cultivated crops and also gives indirect evidence of higher microbial activities (Maity *et al.* 2014).

The alkaline phosphatase activity was not influenced under growing of fodder maize and sugargraze. Significantly higher activity of alkaline phosphatase was noted with application of K_{25} + KSB + 2% KNO_3 (55.4 and 72.8 µg PNP/g soil/hr.) at 30 DAS and harvest respectively over control. Whereas, K_{25} + KSB + 2% K_2SO_4, K_{50} + KSB + 2% K_2SO_4 and K_{50} + KSB + 2% KNO_3 treatments were noted at par with K_{25} + KSB + 2% KNO_3. Generally, balanced soil nutrition has stimulated the activity of the enzymes analyzed (dehydrogenase and alkaline phosphatase) in the soil under both the growing crops. The improvement in soil enzymes (phosphatase and dehydrogenase) and microbial population (bacteria, fungi, and actinomycetes) under the balanced nutrition characterized by higher accumulation of soil organic matter has been reported (Kwiatkowski *et al.* 2020).

From the present study, it may be concluded that integrated use of potassium fertilizers with potassium solubilizing bacteria significantly enhanced the fodder crop yield. The highest microbial population as well as enzymatic activities were obtained with the application of 25 kg K_2O + KSB + 2% KNO_3. Hence judicious application of 25 kg K_2O + KSB + 2% KNO_3 emerged as the best treatment for providing higher biomass yield of maize and sugargraze besides maintaining higher soil biological activities.

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