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Response of Sweet Sudan Grass to Graded Levels of Phosphorus and Potassium Fertilization

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ABSTRACT

Background: Green fodder yield potential of the landmark multi-cut sweet sudan grass (SSG) variety SSG 59-3 was influenced due to the poor fertility status at many places in Haryana. The performance of sweet sudan grass under different P and K treatments was assessed by measuring fodder yield, agronomic efficiency, physiological efficiency and net income.

Methods: A two-year (2018 and 2019) field study was conducted at Hisar, Haryana to assess the effect of four P levels (0, 6.6, 13.2 and 19.8 kg/ha P) and four K levels (0, 12.5, 25.0 and 37.5 kg/ha K) on growth, yield and quality of sweet sudan grass (SSG-59-3). The sixteen treatment combinations were replicated thrice in a factorial RBD. The sandy-loam soils of the experimental field was low in organic carbon (0.47%) and available nitrogen (141 kg/ha) and medium in available P (12.9 kg/ha) and K (225 kg/ha). The nutrients P and K were applied through di-ammonium phosphate and muriate of potash just before sowing.

Result: The graded levels of P and K gave significantly better results up to 13.2 kg/ha P and 37.5 kg/ha K. The agronomic efficiency, physiological effeciency and apparent nutrient recovery (%) of nutrients were highest with lower levels of P and K (6.6 and 12.5 kg). The application of K had complementary effect on the uptake of P as appropriate ratios of N, P and K fertilizer improved absorption and utilization of nutrients.Therefore, farmers can apply 13.2 kg P/ha plus 37.5 kg K/ha along with recommend N for increased dry fodder yield and net income in sweet sudan grass.

Key words: Fodder yield, Multicut, Phosphorus, Potassium, Sweet sudan grass.

INTRODUCTION

Fodder sorghum cultivars derived from sorghum [*Sorghum bicolor* (L.) Moench] and sudan grass (*Sorghum sudanense* Piper) are considered superior in terms of fodder yields because of their multicut nature and longer duration of fodder availability over single cut forage sorghum (Kumari *et al*., 2020). Hence, multi-cut sorghum varieties have gained prominence under irrigated conditions all over the world. In India too, a Sweet Sudan grass (SSG) cultivar SSG-59-3 (cross between Sudan grass and the sweet sorghum variety JS 263) released in 1977 (Paroda and Lodhi, 1978) for North India was popularly cultivated till now. Of the total forage sorghum area in the country (2.6 m ha), multi-cut sorghums account for 2.0 m ha (Prabhakar Babu, 2018). Saberi and Siti Aishah (2013) have reported that perennial forage sorghums are rich in phosphorus (0.104% in whole plant root and shoot at 38 days age) and potassium (1.007% in shoots) indicates their uptake potential. Deficiencies of P (Werner, 1986) and K (Sharma and Kumari, 1996) affected metabolic processes and development of grasses which resulted into slower growth, low number of tillering and decreased productivity. Most of the soils of Haryana are low to medium in phosphorus and if the required amount of phosphorus of any forage crop is not supplied in sufficient amount then the deficiency is reflected in green and dry fodder (Satpal *et al*., 2020). Lack or excess or inappropriate ratios of N, P and K fertilizer can affect the absorption and utilization of nutrients and reduce yield and quality (Li *et al*., 2019). Presence of K in exchangeable and non-exchangeable fractions in soil and their interchange mechanism decides the availability to crops. Though soils of sorghum region have sufficient K reserves in soil, in continuously sorghum cropped regions, K fertilization was recommended. As per Mulder's chart, P and K nutrients in soil have antagonistic effects, with high soil P reducing the K uptake, however, studies in upland rice have shown synergism between P and K fertilization (Fageria and Oliveira, 2014) while in soybean no additive effects of P and K fertilization (Abbasi *et al*., 2012) were reported. So,

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there was need to verify these facts in multi-cut forage sorghum. Although, studies were conducted to assess the response of multi-cut forage sorghums to graded levels of P (Patel and Kotecha, 2008; Roy *et al*., 2015), K (Khanum Al Akbari and Umar, 2014) and NPK fertilizers (Satpal *et al*., 2017; Yadav *et al*., 2019 and Shanti *et al*., 2019), studies assessing the interactive impacts of phosphorus and potassium fertilizers were meagre. Proper and appropriate fertilization and correct genotypes are one of the major limiting factors for the cultivation of sorghum, otherwise it can provide substantial quantity of forage to livestock (Tokas *et al*., 2021). Hence, the present studywas undertaken with an objective of assessing the interactive influence of P and K fertilization on quantity and quality of fodder produced from multicut fodder sorghum and finally to work out the economics of its cultivation.

MATERIALS AND METHODS

Field experiments were conducted for two years (2018 and 2019) at All India Coordinated Research Project on Sorghum center, Hisar (Haryana) situated at 29°1′N Latitude, 75°46′ E Longitude at an altitude of 215.2 meters above mean sea level. The soils of the experimental field was sandy loam in texture with pH values of 7.8-7.9, EC 0.32-0.39 dS/m, low in organic carbon (0.46-0.48%) and available nitrogen (138 -145 kg/ha) and medium in available phosphorus (12.6- 13.2 kg/ha) and potassium (222-228 kg/ha). The experiment comprising of sixteen treatments; four levels of phosphorus (0, 6.6, 13.2 and 19.8 kg P/ha) and four levels of potassium (0, 12.5, 25.0 and 37.5 kg K/ha). Each treatment was replicated thrice in a factorial randomized block design (FRBD). Multi-cut forage sorghum cultivar SSG 59-3 was used for the experimentation. Seeds were sown in rows at 25 cm apart on 20th and 1st April during 2018 and 2019, respectively. Entire P and K fertilizers were applied through DAP and muriate of potash as basal just before sowing. Nitrogen (150 kg/ha) was applied uniformly to all treatments with 50 kg N at sowing (after balancing N contribution of DAP), 25 kg/ha at 30 days after sowing (DAS) and remaining 75 kg was top dressed after first, second and third cut. A rainfall of 349.7 and 429.4 mm was received during 2018 and 2019, respectively. During summer (April to June) irrigation was given just after sowing and thereafter at 15 days interval. Crop was grown as rainfed during rainy season (July to September) and whenever dry spell prevailed supplemental irrigation was given to avoid moisture stress. Pre-emergence application of atrazine at 500 g/ha was used for weed control along with one hand weeding at 25 days after sowing (DAS). Four fodder cuts were taken in both the years of study. First cut was taken at 60 DAS and subsequent (second, third and fourth) cuts were at 45 days' interval after the preceding cuts. Five random plants were selected from each plot for recording of plant height and leaf:stem. Green fodder yield from net plot in kg/ha was recorded and converted into t/ha. A known quantiy of green fodder samples were kept in an oven for drying at 63°C for 72 h and final weight was recorded to calculate dry fodder yield. Phosphorus (P) and potassium (K) contents were estimated using colorimetrically (Fiske and Subbarow, 1925) and digital flame photometer (Model CL-22D), respecively. Economics were also worked out based on input and out prices (Rs.1250/t green fodder). A fertilizer price (Rs./kg) of 12.83 for N, 117.51 for P and 38.24 for K were used. Various nutrient efficiency indices are workedout as per Fageria *et al*. (2010). Agronomic effcicency (AE) was estimated as ratio of dry fodder yield (kg/ha) in fertilized plot-dry fodder yield in control plot/ fertilizer applied (kg/ha) and reported as kg DFY/kg nutrient applied. Physilogical efficiency (kg DFY/kg nutrient uptake) was estimated as ratio of (DFY (t/ha) in fertilized-unfertilzed control)/ nutrient uptake (kg/ha) in fertilized-nutrient uptake (kg/ha) unfertilized control). Apparent nutrient recovery efficiency (ANR) was estimated as:

$$\frac{\text{Nutrient uptake (kg/ha) in fertilized plot} \\ \text{-Nutrient uptake (kg/ha) in control plot}}{\text{Quantity of nutrient applied (kg)}} \times 100$$

Data were analyzed as per Gomez and Gomez (1984). All the results significance were tested at p = 0.05.

RESULTS AND DISCUSSION

Growth parameters

Application of P and K fertilization increased plant height (cm) and tiller number/ m row length. On pooled basis, multi-cut sorghum has recorded a plant height of 169.3, 179.6, 173.9 and 158.5 cm with 35.0, 40.7, 25.3 and 23.4 tillers/m row length in I, II, III and IVth cut, respectively indicating that plant height and tiller numbers was maximum at second cut and there after number of tillers declined drastically (37.7%) and reached the lowest values in fourth cut. Multi-cut sorghum (SSG 59-3) had a mean leaf : stem ratio (L:S) of 33.3%.

In multi-cut forage sorghum, plant height and tillers are the main growth parameters. After each cut, the regenerative capacity in response to applied nutrients form of effective tillers which plays pivotal role in deciding the fodder yield. Plant height, tiller number/m row length at each cut and mean L:S were markedly improved with successive increase of 6.6 kg P fertilization from 0 to 13.2 kg/ha. However, plant height was comparable at (first cut) of control and 6.6 kg P and tillers/ m row length (third cut) in all P fertilized treatments (6.6-19.8 kg/ha) were at par with each other. Impacts of P fertilization on plant height has shown an ascending impact after each harvest and this is evident from the fact that plant height at I, II, III and IVth cut in P fertilizerd crop was 8.7, 13.3, 17.0 and 19.1 cm higher than control treatment. Tiller number have shown a steady state improvements over cuts in P fertilized plots over control and thus P fertilized plots have 6.3, 7.8, 5.7 and 6.3 higher tillers number/m row than control plot at I, II, III and IVth cut, respectively. Role of phosphorus in cell division and cell enlargement and development of tillers explains the taller plants and more tiller production in sorghum (Saini *et al*., 2020).

In case of K, significant improvements in plant height and tillers/ m row lenegth were observed due to 12.5 kg K fertilization over control in first two cuts. In subsequent two cuts, significant improvements in plant height (tiller number in fourth cut) over control were seen with 25.0 kg K application only. In IIIrd cut, no significant changes in tiller numbers over control were obsedrved due to K fertilization. Mean leaf: stem ratio of fodder was markedly improved with 25.0 kg K application over control. All K fertilized treatments (12.5-37.5 kg K) have at par tillers/m row (in all cuts) and L:S values. The imapcts of K fertilization has shown a descending trend on plant height and tiller number. Plant height of K fertilized treatments (12.5-37.5 kg K) was 10.4, 9.2, 8.7 and 8.1 cm higher at I, II, III and IVth cut than control treatment. Tiller number of K fertilized treatments were 4.0, 3.6, 1.3 and 2.5 higher than control plot at I, II, III and IVth cut, respectively. The better growth parameters with K fertilization might be due to increase in chlorophyll content and ormoregulation during cell expansion (Asgharipour and Heidari, 2011).

Fodder yield

We have pooled the fodder yields data for better understanding and the data revealed that application of P and K fertilizer had a significant impact (Table 1). The range of green and dry fodder yield of 'SSG 59-3' was 82.0 to 101.1 t/ha and 14.36 to 20.89 t/ha. Each successive increase of 6.6 kg P fertilizer up to 13.2 kg has significantly increased total GFY and DFY of SSG-59-3. Application of 13.2 kg P have increased the GFY and DFY by 22.8 (18.7) and 43.6% (6.26) compared to without P (81.9 and 14.4 t/ha GFY and DFY) and 6.6 kg P fertilization (90.2 and 17.7 t/ha GFY and DFY). Cut wise data also shows that 6.6 and 13.2 kg/ha P treatments have produced markedly higher GFY and DFY, except GFY of IInd cut due to the quick initial response of the applied fertilizer. Data also showed that the differences in yield gains (DFY and GFY) between P fertilized (6.6 and 13.2 kg P) and control treatment got narrowed down by third and fouth cut due to reduction in number of tillers/m row length. Influence of P fertilizers on fodder yields could be ascribed to increases in soil supply and its uptake by the plants that has increased the bio-chemical activities in plant which enhanced the energy transformations, cell division, consequently increased the plant height, stem diameter and finally green and dry forage yield. These results are in line with the results reported by Mayub *et al*. (2002) and Nadeem *et al*. (2009).

In case of K, there was a significant increase in total GFY and DFY with each successive increase of 12.5 kg K from 0 to 25.0 kg/ha. There was a 8.9 (14.2), 5.5 (7.0) and 3.2% (3.8) improvement in GFY (DFY) with application of 12.5, 25.0 and 37.5 kg K when compared to their respective preceding levels. Cut wise data shows that 25.0 kg/ha K fertilization was required to bring marked impovements in GFY over control in all four cuts. Further K fertilized treatments (12.5-37.5 kg K) have at par GFY in all cuts except IInd one. In IInd cut, 37.5 kg K has significantly higher GFY than 12.5 kg. In case of DFY, 12.5 kg/ha K was sufficient to bring significant improvements in all cuts. Further gains in DFY over 12.5 kg were seen with 37.5 kg K application in Ist and IIIrd cut. In IInd cut, 25.0 kg K has higher DFY than 12.5 kg. However, in IVth cut, all K fertilized treatments have at par DFY. Marked improvement in fodder yield due to K fertilization could be ascribed to its enhnced availability in soil environment and translocation in plant system which resulted in positive impact on shoot and root growth.

Interaction effect of levels of P and K fertilization revealed that combined application of P and K was promising to either of the fertilizers applications as measured interms of GFY and DFY (Table 2). This is evident from the fact that there was a significant GFY and DFY response to 13.2 P and 12.5 kg K when applied alone. This response to K application got increased to 25.0 kg when combined with

Table 1: Green and dry fodder yield of sorghum under different P and K levels (pooled data).

Treatment	Green fodder yield (t ha^{-1})					Dry fodder yield (t ha^{-1})				
	I cut	II cut	III cut	IV cut	Total	I cut	II cut	III cut	IV cut	Total
P dose (kg ha^{-1})										
0	27.7	27.1	14.9	12.2	81.9	4.64	4.44	2.89	2.39	14.36
6.6	29.1	32.1	15.9	13.1	90.2	5.29	5.96	3.49	2.95	17.69
13.2	33.9	32.7	18.6	15.4	100.6	6.36	6.69	4.11	3.46	20.62
19.8	35.4	33.4	17.8	14.5	101.1	6.70	6.96	3.90	3.33	20.89
SEm±	1.03	1.05	0.53	0.49	2.08	0.19	0.22	0.01	0.01	0.42
CD (P=0.05)	3.00	3.05	1.55	1.43	6.04	0.55	0.64	0.29	0.31	1.21
K dose (kg ha^{-1})										
0	28.2	27.6	15.3	12.1	83.2	5.06	5.09	3.20	2.54	15.89
12.5	31.1	30.3	16.8	13.9	92.1	5.66	5.82	3.62	3.04	18.14
25.0	33.1	33.3	17.0	14.2	97.6	6.06	6.48	3.63	3.23	19.40
37.5	33.7	34.2	18.0	14.9	100.8	6.22	6.66	3.92	3.33	20.13
SEm±	1.03	1.05	0.53	0.49	2.08	0.19	0.22	0.01	0.01	0.42
CD (P=0.05)	3.00	3.05	1.55	1.43	6.04	0.55	0.64	0.29	0.31	1.21

Table 2: Green and dry fodder yields of multicut sorghum as influenced by interaction effect of P and K fertilization (pooled data).

Potassium dose ($kg\ ha^{-1}$)	Phosphorus dose ($kg\ ha^{-1}$)				Mean	Phosphorus dose ($kg\ ha^{-1}$)				Mean
	0	6.6	13.2	19.8		0	6.6	13.2	19.8	
	Green fodder yield ($t\ ha^{-1}$)					Dry fodder yield ($t\ ha^{-1}$)				
0	69.4	82.3	87.0	89.2	82.0	11.63	14.48	15.26	16.07	14.36
12.5	79.7	89.6	96.9	94.5	90.2	14.98	17.53	19.24	19.02	17.69
25.0	93.9	96.6	102.8	108.8	100.5	18.82	19.91	21.16	22.57	20.62
37.5	89.6	100.0	103.8	110.9	101.1	18.12	20.66	21.94	22.84	20.89
Mean	83.1	92.1	97.6	100.9		15.89	18.15	19.40	20.13	
CD (P=0.05)	Phosphorus	Potassium	Interaction			Phosphorus	Potassium	Interaction		
	6.04	6.04	11.58			1.21	1.21	2.31		

Table 3: Nutrient upake and nutrient use efficiency of under different levels of P and K (pooled mean).

Treatment	Nutrient uptake ($kg\ ha^{-1}$)		Agronomic efficiency (%)	Physiological efficiency (%)	Apparent nutrient recovery efficiency (%)
	Phosphorus	Potassium			
Phosphorus Dose ($kg\ ha^{-1}$)					
0	19.45	155.8	0	α	α
6.6	30.22	200.4	0.342	0.210	163.2
13.2	40.15	239.3	0.266	0.170	156.8
19.8	41.43	242.9	0.214	0.193	111.0
SEm±	0.70	4.50	-	-	-
CD (P=0.05)	2.03	13.05	-	-	-
Potassium Dose ($kg\ ha^{-1}$)					
0	26.79	174.2	0	α	α
12.5	31.86	204.3	0.181	0.075	240.8
25.0	35.78	225.0	0.140	0.069	203.2
37.5	36.82	234.9	0.113	0.070	161.9
SEm±	0.70	4.50	-	-	-
CD (P=0.05)	2.03	13.05	-	-	

6.6 kg P application and this combination was as good as 13.2 kg P application. Over this combination, significant improvements in GFY and DFY were obtained with application $P_{13.2}K_{37.5}$ which also has indicated the positive effects of P and K fertilization.

Nutrient use efficiency

Nutrient use effcieciency data (Table 3) shows that Agronomic Efficiency (AE), Physiological Efficiency (PE) and Apparent Nutrient Recovery (ANR) are decreasing with increasing level of P / K dose and thus lowest dose has recoreded the highest AE, PE and ANR values. Mean ANR values >100 (143.7 and 202.0% for P and K fertilizer) indicate huge depletion of P and K nutrients from soil and the depletion was least (11 and 61.9%) with highest level of P and K fertilization (19.8 and 37.5 kg). Thus in absence of P and K fertilization for fodder sorghum in Haryana, there is huge depletion of P and K from soil that over years may pose huge threat to sustainable fodder yields in future.

Net income

Net income followed the trend of fodder yields. There was a significant improvement in net income with each successive increase of P dose from 0-13.2 kg/ha. Potassium fertilization too enhanced net income over control with $K_{12.5}$ and further increases in net income were obtained with $K_{37.5}$ fertilization. Interaction effects of P and K fertilization on net income showed additive effects PK fertilization with $P_{13.2}K_{37.5}$ as promising to either of nutrient application ($P_{13.2}$ or $K_{37.5}$) or combined application of $P_{6.6}$ with 12.5-37.5 kg K. Looking at 3.07 times higher cost of P fertilizers (Rs. 117.51/ kg P) when compared to K (Rs. 38.24/kg K), $P_{13.2}K_{37.5}$ proves the best combination.

CONCLUSION

From the two years field study on soils that are medium for available P and K, it is established that P and K fertilizers have additive effects on multicut forage sorghum for fodder yield and income. On net returns basis, $P_{13.2}K_{37.5}$ proves the most suitable combination considering the higher cost of P fertilizers when compared to K. Furthermore, there was a P and K nutrient mining from the soil even with highest level of their application, hence annual application of P and K is needed to maintain soil fertility .

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Conflict of interest: None.

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