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Jayshri D. Chaudhary
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

RP Pavaya
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

JK Malav
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

Goradara Dipika
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

Neha Chaudhary
Cental Instrumentation laboratory, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

NK Kuniya
College of Horticulture, S.D. Agricultural University, Gujarat, India.

Al Vina
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

IM Patel
Cental Instrumentation laboratory, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

JR Jat
Agroforesrty Research Center, S.D. Agricultural University, Sardarkrushinagar, India

Correspondence
JK Malav
Dept. of Agricultural Chemistry & Soil Science, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat, India

Effect of nitrogen and potassium on yield, nutrient content and uptake by forage sorghum (*Sorghum bicolor* (L.) Moench) on loamy sand

Jayshri D Chaudhary, RP Pavaya, JK Malav, Goradara Dipika, Neha Chaudhary, NK Kuniya, Al Vina, IM Patel and JR Jat

Abstract
A field trial was conducted during summer season of 2014-15 at Agronomy Instructional Farm, Department of Agronomy, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat (India), to assess the effect of nitrogen and potassium on yield, nutrient content and uptake by forage sorghum [*Sorghum bicolor* (L.) Moench] on loamy sand. The experiment encompassed three levels of nitrogen *viz.*, 60, 80 and 100 kg N ha^{-1} and three levels of potassium *viz.*, 0, 25 and 50 kg K_2O ha^{-1}. The experiment was laid out in randomized block design (Factorial) with four replications. Results revealed that individual application of nitrogen @ 100 kg ha^{-1} and potassium @ 50 kg ha^{-1} produced the significantly maximum plant height (173.98 cm), leaf area per plant (224.63), stem diameter (1.85 cm), number of leaves per plant (8.19), green leaf weight per plant (52.82 g), dry leaf weight per plant (21.95 g), green stem weight per plant (132.90 g), dry stem weight per plant (62.78 g), green (244.81 q ha^{-1}) and dry fodder (122.14 q ha^{-1}) yields were recorded due to application of 100 kg N ha^{-1}**.** Application of potassium @ 50 kg ha significantly influenced the number of leaves per plant, green leaf weight (g/plant), dry leaf weight (g/plant), green stem weight (g/plant), green fodder yield (q ha^{-1}) and dry fodder yield (q ha^{-1}). Effect of different levels of nitrogen and potassium application on forage sorghum influence by the nitrogen content and nitrogen, phosphorus and potassium uptake. Application of nitrogen significantly influenced the quality parameters like crude protein content, crude fiber content and chlorophyll content in forage sorghum.

Keywords: Sorghum, nitrogen, potassium, yield, nutrient content and uptake

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is the king of millets and third important cereal crop in the country after rice and wheat. Sorghum is not only staple food but it is also required to fulfill fodder requirement in order to make animal husbandry sector more viable. There is a need to supply regularly well balanced feed and fodder to the animals in the state. The crop is popularly known as "Jowar" also and is important food crop for human and feed fodder crops for livestock including poultry. Its grains contains 10-12% protein, 3% fat and 70% carbohydrate. At present, in India only 4.4 per cent of the cultivated area is under fodder crops with annual total forage production of 866 million tones. Whereas, the annual green fodder requirement is 1097 million tones and dry fodder is 609 million tones. (Source: X^{th} Five year Plan Document, Government of India). The main sorghum growing states in India are Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Gujarat, Tamilnadu, Rajasthan and Uttar Pradesh.

Gujarat has total animal population of 18.44 million heads and their optimum fodder requirement worked out is 42.2 million tonnes, whereas only 20.0 million tonnes of fodder is made available in normal year. Thus, the state is not only had shortage of fodder but its quality is also poor. As a result, livestock suffers with malnutrition resulting into decline in production even though they have capacity. Therefore, to increase the milk production in the country we have to increase the fodder production by increasing the area and productivity of the crop. Cereal fodder and crop residues are major sources of fodder, but the nutritive value of these fodders is not adequate to achieve higher milk production.

Nitrogen is the most mobile element and required throughout the crop growth period. Better utilization of applied nitrogen can be achieved by supplying it at a time when the crop needs. Nitrogen is usually supplied in split to majority of the crops.

The soils of North Gujarat are loamy sand in texture, so they are prone to leaching of nitrogen with irrigation water. More over the soils of North Gujarat are having a high infiltration and percolation rate which leads to leaching of nitrogen beyond the root zone of crops. So it is very essential to apply the nitrogen to forage sorghum coincide with the growth period of the sorghum crop.

Potassium is also one of the three major nutrients needed by the plant. It has an important role to play in physiological processes, such as root growth, water uptake and utilization efficiency, production and translocation of carbohydrates, synthesis of protein and amino acids, enzyme activation and yield determining processes *viz*., drought, pest and disease tolerance. The loss of water through transpiration can be minimized by potassium application. When it is not available in adequate quantities, it limits crop production. Response of crops to potassium are limited owing to the presence of illite clay minerals in alluvial soil of Gujarat, which may release sufficient amount of K during crop growth to meet its requirement (Kanwar, 1959) [8]. However, the introduction of high yielding varieties and intensive cropping system has shown positive response to potassium application. Therefore, the research work carried out to access the effect of nitrogen and potassium application on yield, nutrient content and uptake by forage sorghum [*Sorghum bicolor* (L.) Moench] grown during summer on loamy sand.

Materials and Methods

In order to achieve the pre-set objectives of the present investigation, a field experiment was conducted during the *summer* season of 2014-15 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat (India), is situated at 24º -19' North latitude and 72º – 10' East longitude with an altitude of 154.52 meter from the mean sea level. It represents the North Gujarat Agro-climatic Zone IV. This zone is characterized by semi-arid climate. The weather conditions are quite favourable for normal growth and development of the crop. In general, monsoon is warm and moderately humid; winter is fairly cold and dry while summer is quite hot and dry. The monsoon commences by the last week of June and retreats by the end of September with an average rainfall of 622.9 mm received in about 24 rainy days.

The experiment was based on a Randomized Block Design with factorial concept encompassing four replications and nine combined treatments. The plot size was 6.0 m X 3.6 m and the total numbers of unit plots were 36 (9×4), GFS-5 variety was used in this experiment. The entire dose of phosphorus as per recommendation was applied through DAP. Three levels of nitrogen *viz.,* 60, 80 and 100 kg N ha^{-1} from urea and DAP, while three levels of potassium *viz.,* 0, 25 and 50 kg K_2O ha^{-1} were applied through murate of potash at the time of sowing.

The experimental site had an even topography with a gentle slope and good drainage. It is suitable to variety of crops of tropical and sub-tropical region. To find out physico-chemical properties of soil, soil samples were taken randomly before the commencement of experiment from different spots in the field to a depth of 0-15 cm. The composite sample was prepared and analyzed for physical and chemical properties of the soil. The values of soil analysis along with methods followed are given in Table 1. It is evident from the data (Table 1) that the soil of the experimental field was loamy sand in texture, low in organic carbon (0.23%) and available nitrogen (158 kg/ha), medium in available phosphorous (30.22 kg P_2O_5/ha) and potassium (151 kg K_2O/ha). Electrical conductivity was very low showing that the soil was free from salinity hazard.

Results and Discussion

Growth, yield attributes and yield

All growth and yield attributing characters and yield like plant height, leaf area per plant, stem diameter, number of leaves per plant, leaf weight per plant (green and dry), stem weight per plant, total chlorophyll content, green and dry fodder yields were significantly influenced due to nitrogen application (Table 2). Application of different levels of potassium had no significant influence on some growth parameters like plant height, leaf area per plant, stem diameter (Table 2), total chlorophyll content and leaf: stem ratio (Table 3). Significantly maximum plant height (173.98 cm), leaf area per plant (224.63 cm^2), stem diameter (1.85 cm), number of leaves per plant (8.19), green leaf weight per plant (52.82 g), dry leaf weight per plant (21.95 g), green stem weight per plant (132.90 g), dry stem weight per plant (62.78 g), green (244.81 q ha^{-1}) and dry fodder (122.14 q ha^{-1}) yields were recorded due to application of 100 kg N ha^{-1} (Table 2**).** Application of potassium @ 50 kg ha significantly influenced the number of leaves per plant, green leaf weight (g/plant), dry leaf weight (g/plant), green stem weight (g/plant), green fodder yield and dry fodder yield (Table 2).

The data depicted in Table 2 indicated that the plant height recorded at harvest were significantly influenced by nitrogen application. Significantly higher plant height at harvest was recorded with 100 kg N/ha (N_3) application. The per cent increase in plant height at harvest by 100 kg N/ha (N_3) was 8.02 and 1.80 over 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. This might be due to more supply of nitrogen to crop resulting in rapid synthesis of carbohydrate and consequently converted into protoplasm and thereby smaller portion available for cell wall formation. This has served consequences one of them is increase in size of cell which is expressed morphologically through increase in plant height. These results are in close conformity with those of Patel *et al.* (2010) [16], Rana *et al.* (2012) [18], Banjare *et al.* (2014) [3], Singh *et al.* (2014) and Raval *et al.* (2015) [15].

The increase in leaf area per plant at higher nitrogen rate might be due to increase in leaf area expansion rate as a result of faster cell division and greater cell expansion and concomitantly increased in photosynthate formation that resulted in higher leaf length and leaf width which resulted in higher leaf area per plant of forage sorghum. Moreover, the higher leaf area per plant was might be due to the application of nitrogen in right quantity to forage sorghum grown on soil low in available N content. These results were in close conformity with those of Mayub *et al*. (2002) [10], Nadeem *et al*. (2009) [13] and Khan *et al*. (2014) [9]. This might be probably due to progressive increase in uptake of nitrogen by the plants with every successive level of nitrogen application increased the bio-chemical activities in plant which enhanced the cell division, consequently increased the stem diameter . These results are in line with the results reported by Mayub *et al*. (2002) [10] and Nadeem *et al.* (2009) [13]. Significantly the higher number of leaves per plant might be due to the higher plant height and due to favourable growth of summer forage sorghum by the application of nitrogen. These results are in accordance with Suneethadevi *et al*. (2007), Nadeem *et al.* (2009) [13] and Banjare *et al.* (2014) [3]. This might have resulted in better interception and utilization of radiant energy towards higher photosynthesis and finally more accumulation of dry matter of individual plants. These results are in line with the results reported by Singh *et al*. (2015) [20]. The higher stem weight (green and dry) per plant was due to higher plant height, leaf length and leaf width by virtue of increased photosynthetic efficiency. Thus, greater availability of photosynthates, metabolites and nutrient resulted in more stem weight (green and dry) per plant. These results are in accordance with those of Mayub *et al*. (2002) [10] and Aslam *et al*. (2011) [2].

The application of nitrogen significantly boosted up the green fodder and dry fodder yield of sorghum (Table 2). Application of 100 kg N/ha (N_3) achieved maximum green fodder yield which accounted 7.77 and 3.87 per cent higher over 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. The same trend as that of green forage yield was observed for dry fodder yield of sorghum. Application of 100 kg N/ha (N_3) contributed maximum dry fodder yield. The magnitude of increase in dry fodder yield with N_3 over N_1 and N_2 was 20.52 and 8.39 per cent, respectively. Application of higher rate of nitrogen met requirement of plants at different growth stages of crop resulting in higher uptake of nitrogen by plants (Table 2). This might have accelerated the meristematic activity, vegetative growth and photosynthetic activity, consequently resulting in to increased plant height (Table 2), number of leaves per plant, green and dry leaf weight per plant, green and dry stem weight per plant (Table 2) which had eventually increased green fodder and dry fodder yields. Similar trend was also observed by Mayub *et al*. (2002) [10], Dudhat *et al*. (2004) [5], Verma *et al*. (2005) [25], Suneethadevi *et al*. (2007), Trivedi *et al*. (2010) [24], Meena *et al*. (2012) [11] and Rana *et al*. (2012) [18].

Quality Parameters

Quality parameters like crude protein content and crude fiber content (Table 3) were significantly influenced due to nitrogen application. The evaluation of forage for crude protein is a matter of great importance as crude protein is essential for maintenance and production of new tissues. Crude protein content in dry fodder of sorghum was significantly increased as the rate of nitrogen application increased (Table 3). Crude protein content in dry fodder produced from plot fertilized with 100 kg N/ha (N_3) was 5.06 and 1.89 per cent more than plot fertilized with 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. This might be due to that nitrogen being on essential constituent of chlorophyll, protoplasm, protein and nucleic acids and needed for protein synthesis. These results are in accordance with Pankhaniya *et al,* (1997) [15], Dhadheech *et al.* (2000) [4] and Meena and Meena (2012) [12]. Crude fiber content in dry fodder of sorghum was increased significantly with higher dose of nitrogen (Table 3). Application of 100 kg N/ha (N_3) recorded maximum crude fiber which accounted 7.44 and 3.76 per cent higher over 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. This might be due to the fact that nitrogen application enhanced the meristematic activities of plant cells, resulting in the formation of more complex carbohydrates like crude fiber. These findings are in agreement with those of Dhadheech *et al.* (2000) [4].

Nutrient content and uptake

The N content (Table 3) in forage sorghum was significantly affected due to nitrogen application. Significantly higher N content and uptake by the crop were registered when crop was fertilized with 100 kg N/ha (N_3). Application of higher level of nitrogen tended to increase the nitrogen content and uptake by sorghum (Table 3). Significantly higher nitrogen content (0.86%) in dry fodder and uptake (105.43 kg/ha) by sorghum at harvest was recorded under 100 kg N/ha (N_3). Increase in nitrogen content under 100 kg N/ha (N_3) was 4.87 and 2.38 per cent and uptake was 26.16 and 9.95 per cent over 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. The probable reason might be that the soil was unable to supply nitrogen to the crop in sufficient quantity needed for optimum growth. Application of nitrogen fertilizer cured this deficiency and reflected in the increase in nitrogen content in plant. Similar increase in nitrogen content and uptake by sorghum due to nitrogen levels was observed by Agath *et al.* (1997) [1].

The data presented in Table 3 revealed that phosphorous and potassium content in plant was not significantly affected by nitrogen application. Nitrogen levels triggred significant variation in phosphorous and potassium uptake by forage sorghum. Significantly higher phosphorous and potassium uptake (16.09 and 130.40 kg/ha) were recorded with 100 kg N/ha (N_3). The magnitude of increase in phosphorous and potassium uptake by 100 kg N/ha (N_3) was to the tune of 23.86, 9.68 and 21.32, 9.06 per cent over 60 kg N/ha (N_1) and 80 kg N/ha (N_2), respectively. These findings are in accordance with those reported by Sonune *et al.* (2010) [21] and Jadhav *et al.* (2011) [7].

Table 1: Physico –chemical properties of the experimental plot

S. No.	Properties			Methods employed
[A]	Physical properties			
	(a)	Sand (%)	84.89	International Pipette Method (Piper, 1966)
	(b)	Silt (%)	5.53	
	(c)	Clay (%)	9.28	
	(d)	Soil texture	Loamy sand	
[B]	Chemical properties			
	(a)	Soil pH (1:2.5, Soil: Water ratio)	7.2	Potentiometric method (Jackson, 1973)
	(b)	EC (dSm^{-1} at 25 °C)	0.12	Schofield method (Jackson, 1973)
	(c)	Organic carbon (%)	0.23	Walkley and Black’s rapid titration method (Jackson, 1973)
	(d)	Available Nitrogen (kg/ha)	158	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
	(e)	Available P_2O_5 (kg/ha)	30.22	Olsen’s method (Olsen, 1954)
	(f)	Available K_2O (kg/ha)	151	Flame photometric method (Jackson, 1973)

Table 2: Effect of nitrogen and potassium application on yield and yield attributes of forage sorghum

Treatments	Plant height (cm)	Leaf area (cm^2/plant)	Stem diameter (cm)	Number of leaves per plant	Green leaf weight (g/plant)	Dry leaf weight (g/plant)	Green stem weight (g/plant)	Dry stem weight (g/plant)	Green fodder yield (q/ha)	Dry fodder yield (q/ha)
[A] Levels of nitrogen (N)										
N_1 : 60 kg N/ha	161.06	200.53	1.73	7.22	44.69	16.60	123.63	50.40	227.17	101.34
N_2 : 80 kg N/ha	170.90	218.63	1.78	7.63	48.77	19.28	128.91	57.62	235.69	112.69
N_3 : 100 kg N/ha	173.98	224.63	1.85	8.19	52.82	21.95	132.90	62.78	244.81	122.14
S.Em.±	3.53	6.50	0.03	0.25	1.51	0.99	2.08	2.58	4.33	4.33
C.D.(P=0.05)	10.31	18.97	0.09	0.73	4.41	2.88	6.07	7.54	12.64	12.66
[B] Levels of potassium (K)										
K_0 : 0 kg K_2O/ha	163.71	208.14	1.77	7.25	45.40	17.56	124.03	53.75	227.03	103.20
K_1 : 25 kg K_2O/ha	169.10	215.13	1.78	7.61	49.73	19.06	130.09	57.97	237.95	113.62
K_2 : 50 kg K_2O/ha	173.13	220.52	1.79	8.17	51.16	21.21	131.33	59.07	242.69	119.35
S.Em.±	3.53	6.50	0.03	0.25	1.51	0.99	2.08	2.58	4.33	4.33
C.D.(P=0.05)	NS	NS	NS	0.73	4.41	2.88	6.07	NS	12.64	12.66
Interaction (N × K)										
S.Em.±	6.12	11.26	0.05	0.43	2.62	1.71	3.60	4.47	7.50	7.51
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	7.26	10.49	6.23	11.24	10.73	17.71	5.61	15.71	6.36	13.41

Table 3: Effect of nitrogen and potassium application on nutrient content, uptake, quality and leaf stem ratio of forage sorghum

Treatments	Nutrient content (%)			Nutrient uptake (kg ha^{-1})			Crude protein content (%)	Crude fiber content (%)	Total chlorophyll content (mg/g)	Leaf : stem ratio
	N	P	K	N	P	K				
[A] Levels of nitrogen (N)										
N_1 : 60 kg N/ha	0.82	0.128	1.058	83.57	12.99	107.48	5.14	28.78	2.43	0.33
N_2 : 80 kg N/ha	0.84	0.130	1.061	95.89	14.67	119.57	5.30	29.80	2.47	0.34
N_3 : 100 kg N/ha	0.86	0.132	1.068	105.43	16.09	130.40	5.40	30.92	2.50	0.36
S.Em. ±	0.009	0.001	0.007	4.12	0.59	4.65	0.05	0.53	0.02	0.02
C.D.(P=0.05)	0.027	NS	NS	12.03	1.73	13.58	0.16	1.55	0.05	NS
[B] Levels of potassium (K)										
K_0 : 0 kg K_2O/ha	0.82	0.129	1.047	85.70	13.36	108.28	5.17	29.40	2.45	0.33
K_1 : 25 kg K_2O/ha	0.84	0.130	1.065	96.62	14.82	121.07	5.30	29.83	2.47	0.33
K_2 : 50 kg K_2O/ha	0.85	0.131	1.074	102.58	15.58	128.10	5.36	30.27	2.48	0.36
S.Em. ±	0.009	0.001	0.007	4.12	0.59	4.65	0.05	0.53	0.02	0.02
C.D.(P=0.05)	NS	NS	0.019	12.03	1.73	13.58	NS	NS	NS	NS
Interaction (N × K)										
S.Em. ±	0.016	0.002	0.012	7.14	1.032	8.065	0.09	0.92	0.03	0.03
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	3.73	2.94	2.17	15.05	14.15	13.54	3.73	6.20	2.60	19.98

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