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Effect of integrated nitrogen management on growth, yield and quality of sorghum

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Abstract
In the *kharif* seasons of 2022 and 2023, a field experiment titled "Effect of integrated nitrogen management on growth, yield and quality of sorghum" was conducted at the Agronomy Instructional Farm of the Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha, Gujarat. The experiment was laid out in a randomized block design with ten treatments and four replications. The pooled results indicated that application of 50% RDN through castor shell compost + 50% RDN through urea to sorghum crop recorded significantly higher growth parameters, yield attributes, yield and quality parameters *viz*., plant height at 30,60 DAS and harvest (52.55, 187.66 and 249.46 cm, respectively), dry matter accumulation per plant at 30, 60 and 90 DAS and at harvest (13.01, 84.36, 175.68 and 199.58 g, respectively), stem girth (33.72 mm), higher length of earhead (25.40 cm), grain weight per earhead (50.10 g), test weight (21.99 g), grain (2166 kg/ha) and fodder yield (14059 kg/ha), chlorophyll content (53.95 SPAD value at 60 DAS) protein content (10.49%) in sorghum grain. However, application of RDF (80:40:00 kg N: P_2O_5:K_2O/ha) to sorghum crop recorded significantly higher harvest index (13.55%) and HCN content (30.20 ppm) during pooled result.

Keywords: INM, sorghum, yield, quality, castor shell compost, FYM, *Azotobacter*

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench], the king of millets holds promise for food, feed, fodder and ration for human, cattle and poultry. Amongst cereals, sorghum is the fourth most important crop after rice, wheat and maize. In India, it is popularly known as "*Jowar*". Sorghum is a genus of about 25 species of flowering plants in the grass family *Poaceae*. Its grains have about 10-12% protein, 3% fat and 70% carbohydrate. India ranked 6th in jowar production in the world during 2023. India occupies an area of 3.5 million hectares and production of 3.81 million tons with productivity of 1079.10 kg/ha during the year 2022-23 (Anonymous, 2023^{b}) [2]. In Gujarat, sorghum occupies an area of about 31.6 thousand ha with annual production of 40100 MT and productivity of 1459 kg/ha (Anonymous, 2023^{a}) [1]. The sorghum crop exhausts more nutrients than other forage crops and being cereal crop, requires higher amount of nutrients for higher productivity. Ill effects of chemical fertilizers on soil health, and prohibitive cost of chemical fertilizers and poor purchasing power of small and marginal farmers restrict the use of this vital input. Therefore, it is time to develop a strategy for integrated use of organic manures in conjunction with chemical fertilizer to boost crop production. Among the essential nutrients, nitrogen is universally deficient in Indian soils. Nitrogen is a major input in sorghum production, affecting both yield and quality through influencing those components which have increasing grain yield of sorghum. The organic manures like FYM and castor shell compost are natural sources of slow release nutrients and inclusion in nutrient management has become necessity to improve the soil fertility and to sustain the productivity. Biofertilizers are microorganisms which have the ability to mobilize plant nutrients in the soil and are cost effective, eco-friendly source to boost productivity. Keeping these points in view, the present experiment was conducted to study effect of integrated nitrogen management on growth, yield and quality of sorghum.

Materials and Methods

An experiment was conducted during rainy (*kharif*) season of 2022 and 2023 at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (24° -19' North and 72° -19' East with an elevation of 154.52-meter alms), Gujarat. The climate of Sardarkrushinagar is subtropical monsoon type and comes under semi-arid region. The soil was low in organic carbon (0.25%) and available nitrogen (149.65 kg/ha) estimated by Alkaline permanganate method; medium in available phosphorus (35.90 kg/ha by Olsen's method) and potassium (261.65 kg/ha, by Flame photometer method).

The experiment was laid out in a randomized block design comprising of 10 treatments *viz*., T_1: absolute control, T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha), T_3: 25% RDN through FYM + 75% RDN through urea, T_4: 50% RDN through FYM + 50% RDN through urea, T_5: 25% RDN through castor shell compost + 75% RDN through urea, T_6: 50% RDN through castor shell compost + 50% RDN through urea, T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*, T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*, T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea, T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* to sorghum replicated four times in a gross plot size of 6.0 m × 9.0 m. Sorghum crop variety 'GJ 43' was sown in June with recommended package of practices during both the years. Sowing of sorghum was done with recommended seed rate of 12 kg/ha by maintaining 45 cm distance between the rows. The application of fertilizer for sorghum was applied as per fertilizer treatment. According to content of nutrient, FYM and castor shell compost were applied to sorghum crop as per treatments at least 13 days before sowing and incorporated into the soil. Recommended dose of fertilizers (80: 40: 00: kg N: P_2O_5: K_2O ha^{-1}) were applied through urea and SSP as per the treatments. 25% inorganic N was applied at basal and remaining 75% as three equal splits at 20, 40 and 60 DAS. Seeds of sorghum were treated 10 ml *Azotobacter* per kg seed in specific treatments at the time of sowing. The 1st irrigation was given immediately after sowing and remaining irrigations were given as per requirement of the crop. During the entire crop season experimental area was kept weed free and clean. Sorghum was harvested in the 1st week of October during both the years.

Growth, yield attributes, yield and quality parameters were recorded from randomly selected and previously tagged 5 plants in each net plot at different stages of sorghum. The grain yield was calculated from each net plot after threshing, winnowing and cleaning, and expressed in kg per ha. Straw yield was calculated by subtracting the grain yield from total dry matter of each net plot. The pooled analysis of the 2-years data was carried out as per procedure suggested by Cochran and Cox (1967) [4]. The data recorded for various parameters were statistically analyzed using Analysis of Variance Test (ANOVA) as applicable to randomized block design and the comparison of treatment means was made by least significant difference (LSD) at P=0.05.

Results and Discussion

Growth attributes

Integrated nitrogen management treatments exhibited significant effect on various growth attributes of sorghum during pooled results (Table 1). Among different treatments, application of 50% RDN through castor shell compost + 50% RDN through urea (T_6) recorded significantly higher plant height at 30 and 60 DAS and at harvest (52.55, 187.66 and 249.46 cm, respectively), dry matter accumulation per plant at 30, 60 and 90 DAS and at harvest (13.01, 84.36, 175.68 and 199.58 g, respectively) and stem girth (33.72 mm) of sorghum at harvest. While in case of plant height and dry matter accumulation per plant treatment T_6 was statistically at par with 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea (T_9), 50% RDN through FYM + 50% RDN through urea (T_4), 25% RDN through castor shell compost + 75% RDN through urea (T_5), 25% RDN through FYM + 75% RDN through urea (T_3) and RDF (80:40:00 kg N:P_2O_5:K_2O/ha) (T_2). In stem girth treatment T_6 being at par with 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea (T_9) and 50% RDN through FYM + 50% RDN through urea (T_4). The enhancement in growth parameters attributed to adequate nitrogen supply by castor shell compost to growing plants, it might be due to favorable function of nitrogen being a major structural constituent of cell helps in stimulating the cell division and cell enlargement, improvement in photosynthetic parameters due to fertilizer application might have resulted in better interception and utilization of radiant energy leading towards higher photosynthesis and finally more accumulation of dry matter by plant. These findings are in close conformity with Javiya (2019) [6] in groundnut as well as Khushbu (2021) [7] in castor. The minimum plant height (180.53 cm) at harvest, dry matter accumulation per plant at 30, 60 and 90 DAS and at harvest (8.55, 60.74, 127.08 and 144.44 g, respectively) and stem girth (21.73 mm) of sorghum were recorded with absolute control (T_1).

Yield attributes and yield

An appraisal of data (Table 2) revealed that application of 50% RDN through castor shell compost + 50% RDN through urea (T_6) recorded significantly higher length of earhead (25.40 cm), grain weight per earhead (50.10 g) and test weight (21.99 g) during pooled result. Further, it remained at par with 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea (T_9), 50% RDN through FYM + 50% RDN through urea (T_4) and 25% RDN through castor shell compost + 75% RDN through urea (T_5). This might be due to castor shell compost rich source of macro and micro nutrients, improve physical, chemical and biological property of soil, make favorable environment for crop growth resulting increase growth attributes of plant like plant height, dry matter accumulation, green biomass of plant which captured more solar radiation and increased photosynthetic capacity of crop and there by more production of photosynthates resulted in better plant growth in terms of yield attributing characters (Singh *et al.*, 2013; Pushpa 2014; Khushbu 2021; Tudu *et al*., 2023) [12, 9, 7, 13]. Nitrogen and phosphorus enhanced strong cell wall and therefore better earhead length which might be resulted into profuse earhead of sorghum (Nemade *et al*. 2017 in sorghum-chickpea cropping sequence) [8]. Whereas, lower length of earhead (20.00 cm), grain weight per earhead (42.04 g) and test weight (19.63 g) was recorded under treatment absolute control (T_1) on pooled basis.

Significantly higher grain (2166 kg/ha) and fodder yield (14059 kg/ha) of sorghum were observed under application of 50% RDN through castor shell compost + 50% RDN through urea (T_6) compared to other treatments on pooled mean (Table 2) which was statically at par with 25% RDN through FYM + 25%

RDN through castor shell compost + 50% RDN through urea) (2083, 2089, 2086 kg/ha (T_9), 50% RDN through FYM + 50% RDN through urea (T_4), 25% RDN through castor shell compost + 75% RDN through urea (T_5), 25% RDN through FYM + 75% RDN through urea (T_3) and RDF (80:40:00 kg N:P_2O_5:K_2O/ha) (T_2), respectively. The extent of increase in grain yield due to T_6, T_9, T_4, T_5, T_3 and T_2 to the tunes of 83.40, 76.92, 72.90, 71.21, 69.09 and 67.48 over T_1 and 35.88, 30.86, 28.10, 26.85, 25.28 and 24.09 over T_{10} and 27.26, 22.56, 19.97, 18.80, 17.33 and 16.21 over T_7 and 25.71, 21.06, 18.51, 17.35, 15.90 and 14.79 per cent over T_8 in pooled study, respectively. The magnitude of the increase in fodder yield due to T_6, T_9, T_4, T_5, T_3 and T_2 to the tunes of 68.57, 63.05, 59.88, 58.54, 55.97 and 51.23 over T_1 and 27.54, 23.36, 20.96, 19.95, 18.00 and 14.42 percent over T_{10} in pooled study, respectively. Positive influence of these treatments through immediate supply of nutrients from inorganic sources especially at the early stage of the crop and slow and steady supply of nutrients from castor shell compost and FYM throughout the crop growth period improved adequate biomass production and improvement in growth and yield attributing characters such as plant height, dry matter accumulation per plant, length of ear head, grain weight per earhead and test weight might have contributed to higher sorghum grain and fodder yield. These results are in close vicinity with the findings of Jat *et al*., (2013) [5], Singh *et al.*, (2013) [12], Nemade *et al*., (2017) [8], Rakesh (2017) [10], Javiya (2019) [6], Khushbu (2021) [7]. While lowest grain (1181 kg/ha) and straw yield (8340 kg/ha) of sorghum were note down with treatment absolute control (T_1) in pooled study.

The data presented in Table 2 reveled that treatment T_2 (RDF (80:40:00 kg N: P_2O_5:K_2O/ha)) demonstrated a significantly superior harvest index in pooled results and it was remained at par with T_3, T_4, T_5, T_6, T_7, T_8 and T_9.

Quality parameter

Research data presented in Table 3 explicitly show that protein content (10.49%) in sorghum grain and chlorophyll content (53.95 SPAD value at 60 DAS) in sorghum was influenced significantly and recorded maximum with the application of 50% RDN through castor shell compost + 50% RDN through urea (T_6) in pooled study which remained at par with treatments T_9 (25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea), T_4 (50% RDN through FYM + 50% RDN through urea), T_5 (25% RDN through castor shell compost + 75% RDN through urea), T_2 (RDF (80:40:00 kg N:P_2O_5:K_2O/ha)) and T_3 (25% RDN through FYM + 75% RDN through urea). This might be due to better supply of nitrogen and phosphorus by castor shell compost helped in better absorption and utilization of all plant nutrients. Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. The present results are in close agreement with the results of Jat *et al*., (2013) [5], Rakesh (2017) [10], Javiya (2019) [6], Khushbu (2021) [7] Significantly lower protein (8.94%) and chlorophyll content (45.72 SPAD value at 60 DAS) in sorghum was recorded under the treatment (T_1) absolute control during pooled study.

Significantly higher HCN content (30.20 ppm) of sorghum at 45 DAS was recorded with treatment T_2 RDF [(80:40:00 kg N:P_2O_5:K_2O/ha)] in pooled study, which remained at par with treatments T_3 (25% RDN through FYM + 75% RDN through urea), T_5 (25% RDN through castor shell compost + 75% RDN through urea), T_6 (50% RDN through castor shell compost + 50% RDN through urea), T_8 (25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*), T_4 (50% RDN through FYM + 50% RDN through urea), T_1 (Absolute control) during pooled result. Higher level of nitrogen application may increase prussic acid contents of sorghum and ultimately poisoning to animals. These results are supported by Sher *et al*. (2012) [11] and Bhuriya *et al*. (2019) [3] in sorghum. Nitrogen application is essential requisite to utilize the available soil and environmental resources effectively. Hence, it was felt necessary to use of inorganic fertilizer in with integration of organic manure. Significantly lower HCN content (18.28 ppm) of sorghum was recorded under the treatment T_{10} (50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter)* in pooled study.

Table 1: Effect of integrated nitrogen management on growth attributes of sorghum (Pooled data of 2 years)

Treatments	Plant height (cm)			Dry matter accumulation (g/plant)				Stem girth (mm)
	At 30 DAS	At 60 DAS	At harvest	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	At harvest
T_1: Absolute control	33.68	135.16	180.53	8.55	60.74	127.08	144.44	21.73
T_2: RDF (80:40:00 kg N: P_2O_5:K_2O/ha)	49.20	175.41	233.43	12.16	78.84	164.34	186.75	28.80
T_3: 25% RDN through FYM + 75% RDN through urea	49.56	176.66	235.09	12.28	79.39	165.48	188.09	29.03
T_4: 50% RDN through FYM + 50% RDN through urea	50.80	181.18	240.99	12.59	81.43	169.64	192.80	32.34
T_5: 25% RDN through castor shell compost + 75% RDN through urea	50.40	180.09	239.45	12.48	80.95	168.68	191.54	29.07
T_6: 50% RDN through castor shell compost + 50% RDN through urea	52.55	187.66	249.46	13.01	84.36	175.68	199.58	33.72
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	46.33	165.40	220.15	11.45	74.35	155.06	176.11	26.60
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	47.29	169.16	224.98	11.70	76.08	158.56	179.95	26.75
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	51.43	183.39	243.88	12.73	82.41	171.70	195.10	32.89
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	40.14	150.26	200.35	10.23	67.04	141.03	160.30	25.45
S.Em. ±	1.50	5.49	6.99	0.34	2.38	5.49	5.57	0.67
C. D. (P = 0.05)	4.24	15.52	19.74	0.96	6.74	15.57	15.75	1.89
Interaction (Y × T)	NS	NS	NS	NS	NS	NS	NS	NS
C. V.%	9.16	9.83	9.40	8.83	9.49	9.72	9.37	7.14

Table 2: Effect of integrated nitrogen management on yield attributes and yield of sorghum (Pooled data of 2 years)

Treatments	Length of earhead (cm)	Grain weight/earhead (g)	Test weight (g)	Grain yield (kg/ha)	Fodder yield (kg/ha)	Harvest index (%)
T_1: Absolute control	20.00	42.04	19.63	1181	8340	12.45
T_2: RDF (80:40:00 kg N: P_2O_5:K_2O/ha)	23.48	46.89	21.46	1978	12613	13.55
T_3: 25% RDN through FYM + 75% RDN through urea	23.63	46.91	20.74	1997	13008	13.35
T_4: 50% RDN through FYM + 50% RDN through urea	24.32	48.09	21.34	2042	13334	13.29
T_5: 25% RDN through castor shell compost + 75% RDN through urea	24.07	47.85	21.64	2022	13223	13.29
T_6: 50% RDN through castor shell compost + 50% RDN through urea	25.40	50.10	21.99	2166	14059	13.35
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	21.75	44.80	19.98	1702	11065	13.33
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	22.00	44.97	20.26	1723	11183	13.35
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	24.56	48.33	21.58	2086	13599	13.34
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	20.78	44.36	20.14	1594	11023	12.64
S.Em. ±	0.49	0.91	0.40	71.22	486.38	0.09
C. D. (P = 0.05)	1.39	2.56	1.13	201.25	1374.32	0.27
Interaction (Y × T)	NS	NS	NS	NS	NS	NS
C. V.%	6.52	5.96	5.83	11.63	12.12	2.11

Table 3: Effect of integrated nitrogen management on quality parameters of sorghum (Pooled data of 2 years)

Treatments	Protein content in grain (%)	Chlorophyll content at 60 DAS (SPAD value)	HCN (ppm) at 45 DAS
T_1: Absolute control	8.94	45.72	28.01
T_2: RDF (80:40:00 kg N: P_2O_5:K_2O/ha)	10.02	52.01	30.20
T_3: 25% RDN through FYM + 75% RDN through urea	10.03	51.67	29.77
T_4: 50% RDN through FYM + 50% RDN through urea	10.19	52.33	28.48
T_5: 25% RDN through castor shell compost + 75% RDN through urea	10.12	52.98	29.09
T_6: 50% RDN through castor shell compost + 50% RDN through urea	10.49	53.95	28.74
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	9.54	49.88	27.06
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	9.61	50.07	28.73
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	10.22	53.25	25.64
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	9.44	49.68	18.28
S.Em. ±	0.17	0.80	0.91
C. D. (P = 0.05)	0.48	2.27	2.58
Interaction (Y × T)	NS	NS	NS
C. V.%	5.22	4.73	10.16

Conclusion
Based on the two-year experimental findings, it is concluded that the application of 50% RDN through castor shell compost + 50% RDN through urea resulted in higher growth, yield and quality of sorghum. This integrated nitrogen management practice is effective for optimizing sorghum production.

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