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Research article

Effect of fertilizer levels on yield and biochemical analysis of forage sorghum genotypes

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Abstract
A field experiment was conducted during the *kharif* season of 2022 to evaluate the effect of fertilizer levels on the fodder yield and quality of sorghum genotypes in a randomized block design. Treatments consisted of two single-cut forage sorghum cultivars (HJ 541 and *Duggi*) and seven different fertilizer treatments comprising control, 50% recommended dose of fertilizer (RDF), 100% RDF, 150% RDF, RDF minus N, RDF minus P, and RDF minus K. Sorghum variety HJ 541 demonstrated superior characteristics for parameters like green fodder yield (GFY), crude protein (CP), crude fat, Neutral detergent fibre (NDF), Acid detergent fibre (ADF), crude fibre (CF), hemicellulose, cellulose, lignin, phosphorus, potassium, iron and calcium. Fertilizer levels also played a crucial role, with higher CP and crude fat and lower NDF, ADF, and CF recorded at 150% RDF, on par with 100% RDF. The variety HJ 541 performed better than *Duggi* (a local cultivar) in yield and quality parameters under the experimental conditions studied. The present study provides better insights into their performance and enables the effective utilization of the outcome, contributing to the ongoing research in this area.

Keywords: Crude protein, HCN, Hemicellulose, RDF, Sorghum

Introduction
India is home to 536.7 million livestock, including 36% cattle, 27.7% goats, and 20% buffalo (DAHD, 2023). Although India has one of the largest cattle populations, productivity remains low mainly due to feed and fodder shortages. Present green and dry fodder availability is 734.2 million tonnes and 326.4 million tonnes, respectively; however, the 827.19 million tonnes of green and 426.1 million tonnes of dry fodder shall be required to meet the demands (Arora *et al*., 2024). The area under green fodder cultivation has remained nearly stagnant at about 8–9 million hectares, accounting for only 4 to 5% of the total gross cropped area. Therefore, improving both productivity and nutritional quality of green fodder requires promoting the cultivation of high-yielding, multi-cut forage crops. Important examples include berseem, lucerne, oats, forage sorghum hybrids, and Bajra Napier (BN) hybrid grass (Singh and Roy, 2026). Sorghum [*Sorghum bicolor* (L.) Moench], belonging to the Poaceae family, is a drought-tolerant crop commonly known as *Jowar*. It is widely grown for grain, fodder, and bioethanol production and is considered the fourth most important cereal crop after wheat, rice, and maize (Devi *et al*., 2018). As a major staple crop in semi-arid regions, sorghum was originally domesticated in Northeastern Africa. Today, it is widely cultivated across 100 countries spanning every continent, with extensive production centered in Africa, China, the United States, Mexico, and India (Santhiya *et al*., 2025). Sorghum is more commonly grown than other forage crops because of its exceptional tolerance and adaptability to a wide range of soil and climate conditions, as well as having numerous benefits like rapid growth, high biomass accumulation, high dry matter content, and broad adaptability to abiotic stresses, particularly to drought stress (Kumawat *et al*., 2021). Fertilizer management in fodder crops aims to increase forage yield, improve quality, and maintain soil fertility

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(Pathan and Kamble, 2012). Nutrient management, especially nitrogen (N), phosphorus (P), and potassium (K), plays a crucial role in enhancing crop productivity (Bapurayagouda *et al.,* 2018). Fertilizer application significantly influenced forage yield and quality, with nitrogen and phosphorus playing distinct roles. Nitrogen fertilization substantially increased crude protein (CP) content and slightly decreased acid detergent fiber (ADF), though it had no noticeable effect on neutral detergent fiber (NDF). Conversely, phosphorus exerted only a slight impact on NDF and did not significantly alter ADF. Overall, the strategic application of both nutrients successfully enhanced both the yield and nutritional value of the forage (Sahin *et al*., 2024). Genotype selection also plays a key role in improving fodder yield. Therefore, evaluating newly developed sorghum genotypes under different fertility levels is essential to optimize production and provide quality fodder for livestock (Aruna *et al.,* 2015). Considering these aspects, the present study was conducted to evaluate the effect of different fertilizer levels on the growth of forage sorghum.

Materials and Methods

Field experiment and treatments: The experiment was conducted during the *kharif* season of 2022 at CCS Haryana Agricultural University, Hisar, India (29° 10′N of 75° 46′ E, at an average elevation of 215.2 m above sea level). The experiment consisted of 14 treatment combinations comprising two single-cut forage sorghum genotypes (HJ 541 – a popular state variety released in 2014 by CCSHAU, Hisar and *Duggi* (Popular land race local variety) and seven fertility levels *viz.,* Control; 50% RDF; 100% RDF; 150% RDF; 100% RDF minus N; 100% RDF minus P; and 100% RDF minus K. The recommended dose of fertilizer for sorghum was 75 kg N+30 kg P_2O_5+30 kg K_2O ha^{-1}. These treatments were tested in a randomized block design with three replications. The crop was raised on standard recommended practices and harvested at 50% flowering stage.

Biochemical Analysis**:** The biochemical composition of forage sorghum was analyzed following standard analytical procedures. Hydrocyanic acid (HCN) was estimated using the picrate paper method as described by Hogg and Ahlgren (1942). Total nitrogen content was determined according to the Kjeldahl method (FOSS Kjeltec 8100). The CP content was based on total nitrogen (N) multiplied by 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations were determined using a FOSS Fibertech 8000, whereas crude fat was determined using BUCHI FatExtractor E-500 according to Van Soest *et al.* (1991). Cellulose and hemicellulose contents were calculated based on detergent fiber fractions as described by Yang (1993). Crude fiber was determined according to ISO 6865:2000 AOAC 973.10 (AOAC, 2016). Phosphorus was determined by the vanadomolybdophosphoric yellow color method as described by Koenig and Johnson (1942), while potassium content was estimated using the flame photometric method described by Richards (1954). Calcium and iron contents were estimated using the atomic absorption spectrophotometric method described by Isaac and Kerber (1971).

Statistical analysis**:** The data recorded during this study were statistically analyzed using analysis of variance (ANOVA), as described by Panse and Sukhatme (1985), using statistical software OPSTAT developed by Sheoran *et al.* (1998).

Results and Discussion

Green fodder yield: The maximum GFY (33.3 t ha^{-1}) was recorded in HJ 541 compared with *Duggi* (Table 1). Since both genotypes were grown under identical agronomic and environmental conditions, the variation in growth was mainly due to genetic potential and genotype–environment interactions (Satpal *et al.,* 2020). Among fertilizer levels, the highest GFY (35.8 t ha^{-1}) was obtained with 150% RDF, which was at par with 100% RDF. Improved varieties and recommended fertilizer doses play a major role in sorghum productivity (Satpal *et al*., 2021), and increasing fertilizer levels can significantly improve fodder yield (Kanika *et al*., 2025).

Crude protein: The highest crude protein content was recorded in HJ 541 (9.03% at 60 DAS and 8.45% at harvest). Among fertilizer levels, the maximum crude protein (9.72% at 60 DAS and 9.05% at harvest) was observed with 150% RDF, comparable to 100% RDF at harvest (Table 1). Increased fertilizer levels, particularly nitrogen, enhance amino acid formation and protein synthesis (Patel *et al*., 2010). Furthermore, nitrogen plays an essential role in photosynthesis and serves as an indispensable structural component of proteins, directly influencing both forage yield and nutritional quality (Divakaran *et al.,* 2024)

HCN content: HCN content at 30 DAS was lower in HJ 541 (61.99 ppm) than in the *Duggi* variety (Table 1). Among fertilizer levels, the highest HCN (120.54 ppm) was observed with 150% RDF. HCN content was maximum at germination and then continuously decreased with age (Busk and Moller, 2002). Such differences in HCN content throughout the growth period might be due to the genetic makeup of the sorghum genotypes (Oberoi *et al*., 2020).

Nutrient content: Nitrogen content was highest in HJ 541 (1.44% at 60 DAS and 1.35% at harvest), and the maximum values (1.56% at 60 DAS and 1.45% at harvest) were recorded at 150% RDF, comparable to 100% RDF (Table 1). These results align with earlier studies (Gurjar

Table 1. Effect of fertilizer levels on green fodder yield (GFY), HCN Content (30DAS), nutrients content in sorghum varieties at 60 DAS and at harvest

Treatment	GFY (t ha^{-1})	Crude protein (%)		HCN (ppm)	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Iron (ppm)		Calcium (ppm)	
		60 DAS	At harvest	30 DAS	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Varieties														
HJ 541	33.3	9.03	8.45	61.99	1.44	1.35	0.24	0.23	1.75	1.53	242	218	6171	6950
Duggi	23.6	8.41	8.00	102.47	1.35	1.28	0.22	0.17	1.45	1.19	220	190	5592	6835
SEM	0.4	0.02	0.03	0.76	0	0	0.01	0.01	0.03	0.02	0.18	0.36	236	207
CD (P<0.05)	1.1	0.05	0.10	2.22	0	0.01	NS	0.04	0.1	0.06	0.52	1.05	NS	NS
Fertilizer levels														
Control	17.5	8.03	7.51	46.92	1.28	1.2	0.17	0.14	1.25	1.07	194	174	6268	6886
50% RDF	27.1	8.49	8.27	71.5	1.36	1.32	0.23	0.19	1.63	1.35	226	195	5573	7058
100% RDF	33.9	9.43	8.86	97.52	1.51	1.42	0.28	0.24	1.86	1.59	262	236	7126	7894
150% RDF	35.8	9.72	9.05	120.54	1.56	1.45	0.32	0.29	2.01	1.74	263	238	7475	7817
100% RDF-N	26.9	8.16	7.62	59.06	1.31	1.22	0.23	0.19	1.55	1.32	199	179	5466	7101
100% RDF-P	28.2	8.55	8.09	69.43	1.37	1.29	0.19	0.15	1.49	1.2	234	199	4158	6010
100% RDF-K	29.7	8.68	8.20	110.64	1.39	1.31	0.21	0.19	1.42	1.25	239	205	5104	6484
SEM	0.7	0.03	0.06	1.42	0	0.01	0.02	0.02	0.06	0.04	0.33	0.67	442	389
CD (P<0.05)	2.0	0.10	0.19	4.16	0.01	0.03	0.08	0.07	0.19	0.12	0.98	1.96	1292	1137

Table 2. Effect of fertilizer levels on fibre fraction and crude fat of sorghum varieties at 60 DAS and at harvest

Treatment	Crude fibre (%)		NDF (%)		ADF (%)		Lignin (%)		Hemicellulose (%)		Cellulose (%)		Crude fat (%)	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Varieties														
HJ 541	27.89	32.79	54.6	60.63	32.41	36.84	5.58	5.99	22.19	23.79	26.83	30.85	1.38	1.53
Duggi	31.32	37.05	58.08	65.04	34.57	38.24	5.9	6.28	23.51	26.8	28.67	31.96	1.3	1.44
SEM	0.08	0.05	0.07	0.08	0.07	0.05	0.01	0.01	0.102	0.101	0.07	0.05	0.01	0.0
CD (P<0.05)	0.23	0.16	0.19	0.24	0.2	0.15	0.04	0.02	0.3	0.29	0.19	0.15	0.01	0.01
Fertilizer levels														
Control	34.39	41.47	63.17	68.42	35.91	39.47	6.35	6.697	27.26	28.95	29.56	32.77	1.13	1.27
50% RDF	30.41	35.88	57.88	63.511	34.1	37.99	5.82	6.28	23.78	25.53	28.28	31.71	1.24	1.41
100% RDF	26.3	31.49	52.69	59.04	31.65	35.66	5.43	5.82	21.04	23.38	26.21	29.84	1.48	1.62
150% RDF	24.94	29.8	51.1	57.41	31.38	35.48	5.28	5.66	19.73	21.93	26.1	29.82	1.52	1.65
100% RDF-N	33.25	39.78	61.49	66.51	35.09	38.89	6.14	6.52	26.4	27.62	28.95	32.37	1.23	1.34
100% RDF-P	29.5	33.26	54.53	63.07	33.06	37.55	5.62	6.05	21.47	25.52	27.44	31.5	1.39	1.54
100% RDF-K	28.44	32.75	53.51	61.87	33.25	37.75	5.53	5.95	20.27	24.11	27.72	31.8	1.41	1.56
SEM	0.15	0.1	0.12	0.15	0.13	0.10	0.02	0.07	0.19	0.19	0.12	0.1	0.01	0.01
CD (P<0.05)	0.43	0.29	0.36	0.45	0.37	0.29	0.07	0.05	0.56	0.55	0.36	0.29	0.03	0.02

et al., 2019; Chaudhari *et al.*, 2022). The highest phosphorus content (0.24% at 60 DAS and 0.23% at harvest) was recorded in HJ 541, while 150% RDF produced the maximum values (0.32% at 60 DAS and 0.29% at harvest), at par with 100% RDF (Table 1). Increased phosphorus supplies positively influenced its concentration in plants. Likewise, potassium content was highest in HJ 541 (1.75% at 60 DAS and 1.53% at harvest), with the maximum values under 150% RDF (2.01% at 60 DAS and 1.74% at harvest). Higher N, P, and K content in fodder may be attributed to improved nutrient absorption, translocation, and utilization by the genotype (Chahal *et al.*, 2020). Nutrient content generally decreased from 60 DAS to harvest, as reported by Pal *et al.* (1982). The maximum iron content was recorded in variety HJ 541 (242 and 218 ppm at 60 DAS and at harvest, respectively), while the highest iron levels were observed with 150% RDF (263 and 238 ppm), which were at par with 100% RDF (Table 1). Fertilizer levels significantly influenced iron content, with a significant interaction between variety and fertilizer levels (Pal *et al.*, 1982). Similarly, HJ 541 recorded the highest calcium content (6171 and 6950 ppm at 60 DAS and at harvest), but fertilizer levels did not show a consistent trend or significant effect on calcium content at either stage, as reported by Pal *et al.* (1982).

Fibre fraction and crude fat content: Regarding fiber quality, HJ 541 recorded lower crude fiber, NDF and ADF contents than *Duggi* at both 60 DAS and harvest (Table 2). Similarly, 150% RDF produced the minimum crude fiber (24.94% at 60 DAS and 29.80% at harvest), NDF (51.10% at 60 DAS and 57.41% at harvest) and ADF (31.38% at 60 DAS and 35.48% at harvest), indicating better fodder quality. The reduction in fiber fractions with higher fertilizer levels may be due to increased nitrogen availability, which enhances protein synthesis and vegetative growth while reducing structural carbohydrate accumulation in cell walls (Kumar *et al.*, 2017). Similar results have been reported in earlier studies (Kushwaha *et al.*, 2018; Farhadi *et al.*, 2022). The minimum lignin, hemicellulose and cellulose contents at 60 DAS and harvest were recorded in variety HJ 541 compared to *Duggi* (Table 2), while the lowest values were observed at 150% RDF (lignin: 5.28% at 60 DAS and 5.66% at harvest; hemicellulose: 19.73% at 60 DAS and 21.93% at harvest; cellulose: 26.10% at 60 DAS and 29.82% at harvest). These reductions with higher fertilizer levels may be due to increased nitrogen supply, which enhances plant succulence and reduces lignification of cell walls (Liu *et al.*, 2021). Contrastingly, the maximum crude fat content was recorded in HJ 541 (1.38 and 1.53%) and with 150% RDF (1.52% and 1.65%) at 60 DAS and harvest, respectively (Table 2), likely due to improved nutrient availability and the synergistic effect of nitrogen and phosphorus on plant growth and dry matter accumulation (Yadav *et al.*, 2019).

Conclusion

Variety HJ 541 outperformed *Duggi* (local cultivar) in both fodder yield and quality parameters. Among fertilizer treatments, 150% RDF produced the highest fodder yield and better forage quality, though it remained at par with 100% RDF, indicating that 100% RDF is sufficient for achieving optimal yield and quality in forage sorghum. Further evaluation of additional promising sorghum genotypes under similar conditions is recommended for broader comparison and better utilization of the findings.

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