AATCC Review

22 July 2025: Received
12 September 2025: Revised
19 September 2025: Accepted
18 October 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Performance of single-cut forage sorghum varieties under varying fertility levels during summer season in semi-arid conditions

Kanika*[1], Suresh Kumar[2], Satpal[3], V. S. Hooda[1], Aarzoo[1], Khushkarandeep Singh[4], Nitish Balhara[1] and Monika[1]

[1]Department of Agronomy, CCS Haryana Agricultural University, Hisar-125001, Haryana, India
[2]Directorate of Research, CCS Haryana Agricultural University, Hisar-125001, Haryana, India
[3]Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar-125001, Haryana, India
[4]Department of Agronomy, Punjab Agricultural University, Ludhiana-141001, Punjab, India

ABSTRACT

A field experiment was conducted during summer season of 2023 to evaluate the performance of fodder sorghum varieties under different fertility levels at Research Farm, Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, which is located at 29° 10' N latitude and 75° 46' E longitude with an elevation of 215.2 m above mean sea level in semi-arid conditions of Haryana state of India. Sixteen treatment combinations consisted of four varieties viz. CSV 53F, HJ 541, HJ 513 and HC 308 and four fertility levels viz. control, 75%, 100% (75 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1}) and 125% RDF and were laid out in factorial RBD with three replications. Results revealed that sorghum variety CSV 53F performed best in terms of growth and quality parameters and as well as in terms of yield with green fodder and dry fodder yield of 524.43 and 134.57 q ha^{-1}, respectively, which was statistically at par with variety HJ 541. Also, the highest crude protein and digestible crude protein content (8.17% and 4.66%, respectively) at harvest and the lowest HCN content (92.78, 88.96 and 37.10 µg/g at 30, 45 and 60 DAS, respectively) were observed in CSV 53F. The maximum HUE for green fodder yield was recorded from HJ 541 (29.02 kg ha^{-1} °C^{-1} day^{-1}) and was statistically at par with CSV 53F. The most economical variety was found to be CSV 53F, as it recorded the maximum benefit-cost ratio (2.05) being statistically at par with HJ 541. Among fertility levels, fodder sorghum responded upto 100% RDF, being at par with 125% RDF. Application of 125% RDF gave higher green and dry fodder yield (564.05 and 146.94 q ha^{-1}, respectively) which were 2.9 and 2.3 % higher over 100% RDF, respectively. With the increase in fertility levels from control to 125% RDF, though HCN (at 30, 45 and 60 DAS) have also increased, but it was found below the critical limit (200 µg/g) at all the stages. The maximum HUE for green and dry fodder yield was recorded with 125% RDF (32.36 and 8.43 kg ha^{-1} °C^{-1} day^{-1}) over rest of the fertility levels.

Keywords: *Fertility levels, green and dry fodder yield, HCN content, heat use efficiency (HUE), varieties, RDF, crude protein.*

INTRODUCTION

Agriculture forms the backbone of the Indian economy and within this sector, livestock plays a crucial role. India is home to approximately 536 million livestock heads, accounting for nearly 15% of the world's domesticated animal population, making it one of the largest livestock-holding countries globally [1]. With the livestock population steadily increasing, the demand for quality feed and fodder is also rising. However, fodder crops are cultivated on only about 8.6 million hectares, which constitutes merely 4.89% of the total cultivated area, often on marginal and sub-optimal lands. The annual fodder production in the country stands at about 866.6 million tonnes (400.6 million tonnes green fodder and 466 million tonnes dry fodder). Currently, India faces a shortage of green fodder, dry fodder and feed concentrates by 11.23%, 23.40% and 28.90%, respectively [2]. Therefore, enhancing fodder production is essential for sustaining livestock productivity.

*Corresponding Author: **Kanika***

DOI: https://doi.org/10.21276/AATCCReview.2025.13.04.847

A major challenge occurs during the lean period (May–June), when fodder availability declines drastically. Summer-sown forage sorghum has emerged as a viable option to address this seasonal scarcity by providing fresh green fodder during the lean period.

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crops globally, ranking fifth after wheat, rice, maize and barley. It is a versatile crop valued for its use as food, feed, fodder and biofuel. Owing to its remarkable drought tolerance, sorghum is often referred to as the "camel crop". In North India, it is a preferred fodder crop during the summer and *kharif* seasons due to its adaptability to diverse agro-climatic conditions and relatively low water requirement. Forage sorghum genotypes exhibit rapid growth, producing highly palatable and nutritious green fodder suitable for use as silage, hay or fresh fodder [3].

In India, sorghum is cultivated on approximately 7.38 million hectares, with an annual production of about 8.71 million tonnes [4]. Sorghum fodder contains more than 50% digestible nutrients, including 8–10% crude protein, 2.5% fat, 45% nitrogen-free extract (NFE), 70% carbohydrates and essential minerals such as calcium and phosphorus. Single-cut forage sorghum varieties generally yield about 400–500 q/ha of green fodder and 100–150 q/ha of dry fodder.

Additionally, sorghum exhibits moderate tolerance to salinity, making it suitable for cultivation in stress-prone areas [5].

Despite having one of the largest livestock populations in the world, India's milk production remains lower than that of many leading countries. This is primarily due to the low productivity of milch animals, which is largely attributed to the inadequate and poor-quality feed and fodder supplied to them. Therefore, there is an urgent need to enhance the production of good-quality fodder to support better animal health and improve overall livestock productivity.

One of the major constraints to fodder production in the country is the limited availability of improved forage crop varieties that offer higher fodder yield and superior nutritional quality. In addition, the lack of improved genotypes, appropriate fertiliser application and irrigation management leads to significant yield losses. For instance, the absence of improved genotypes, recommended fertiliser doses and proper irrigation has been shown to result in 39%, 30% and 22% reductions in fodder sorghum productivity, respectively, when compared to the adoption of full recommended production practices [6]. Thus, the identification and promotion of location-specific forage sorghum genotypes with high fodder yield and better nutritive value are essential for achieving sustainable livestock productivity. Fertilisation also plays a crucial role in plant growth, development and disease resistance. Moreover, summer-sown sorghum can be particularly advantageous under irrigated conditions, as the hot and dry climate reduces the incidence of pests and diseases, thereby improving both yield and fodder quality.

Since different sorghum genotypes respond variably to fertility levels, it is important to optimise nutrient application to maximise yield and quality while minimising environmental impacts. Therefore, selecting suitable varieties along with appropriate fertility management practices ensures better adaptation to local growing conditions and improves nutrient availability to the crop [7].

Keeping this in view, the present field investigation was undertaken to evaluate the growth, productivity and quality of single-cut forage sorghum varieties under different fertility levels.

MATERIALS AND METHODS

The field experiment was conducted during the summer season of 2023 at the Research Farm of the Department of Agronomy, CCS Haryana Agricultural University, Hisar (29°10′ N, 75°46′ E, with an average elevation of 215.2 m above mean sea level). The region is characterized by a semi-arid, sub-tropical climate with hot, dry summers and cold winters. The average annual rainfall is approximately 450 mm. Weekly meteorological data recorded during the crop growth period are presented in figure 1.

The experimental soil was sandy loam in texture with a pH of 7.8 and available nutrient status of 132 kg N/ha, 12 kg P/ha and 280 kg K/ha. The experiment comprised of 16 treatment combinations involving four single-cut forage sorghum genotypes (CSV 53F, HJ 541, HJ 513 and HC 308) and four fertiliser levels (control, 75%, 100% and 125% of the recommended dose of fertiliser). The treatments were evaluated in a factorial randomized block design (RBD) with three replications. The recommended dose of fertiliser (RDF) for sorghum is 75 kg N + 30 kg P_2O_5 + 30 kg K_2O/ha.

Full doses of phosphorus and potassium along with 50 kg N/ha were applied at sowing, while the remaining 25 kg N/ha was top-dressed at 30 days after sowing (DAS).

Sowing was done manually on 10 April 2023 (Standard Week 15) at a row spacing of 25 cm. All other standard agronomic practices were followed uniformly across treatments as per the CCS HAU, Hisar package of practices for *kharif* crops [8]. The crop was harvested at 50% flowering.

For estimation of hydrocyanic acid (HCN) content, plant samples were collected at 30, 45 and 60 DAS from the portion immediately below the uppermost leaf collar. HCN content (µg/g fresh weight) was determined using the method described by Hogg and Ahlgren [9] and calculated using a standard curve prepared from known concentrations of KCN, with absorbance recorded at 515 nm using a spectrophotometer.

Crude protein content (CPC) was estimated from dried and ground plant samples (2 mm sieve size) collected at 50% flowering. Nitrogen content was determined using the micro-Kjeldahl method [10] and CPC was calculated by multiplying nitrogen (%) by 6.25. Digestible crude protein (DCP) percentage was computed using the formula: DCP (%) = (CPC – 3.09) × 0.916 [11]. *In-vitro* dry matter digestibility (IVDMD) was determined using the method proposed by Barnes [12].

Evaluation of Agro Meteorological Indices

(A) Growing degree days (GDD), °C day

The cumulative growing degree days were determined by summing the daily mean temperature above the base temperature (T_b =10°C). This was calculated by using the following formula:

$$GDD = \Sigma\{(Tmax + Tmin) / 2\} - Tb$$

Where,

T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

(B) Helio thermal units (HTU), °C day hour

The cumulative HTU was calculated by multiplying GDD with actual or bright sunshine hours (BSS).

$$HTU = \Sigma\{GDD \text{ X } BSS\}$$

(C) Photo thermal units (PTU), °C day hour

Photothermal units was calculated as the cumulative value of growing degree days multiplied by the day length or maximum possible sunshine hours (N).

$$PTU = \Sigma (GDD \text{ X } N)$$

(D) Heat use efficiency (HUE), kg/ha °C^{-1} day^{-1}

It was calculated by dividing the yield with GDD, for both green and dry fodder yield.

$$HUE = \frac{Yield}{GDD}$$

Data was analyzed by using OPSTAT software available at CCS Haryana Agricultural University website [13]. The results are presented at five per cent level of significance (P=0.05) for making comparison between the treatments.

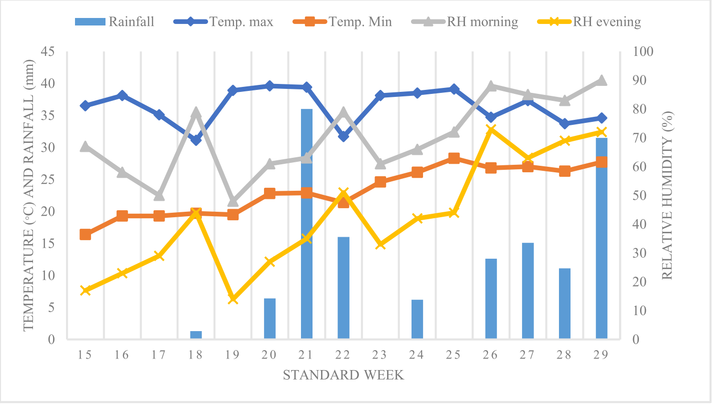

Fig.1. Mean weekly meteorological parameters during the experimental period (summer, 2023)

RESULTS AND DISCUSSION

Varieties

Data presented in Table 1 indicate that among the varieties, CSV 53F produced the highest number of leaves per plant (12.80) at harvest, though it remained statistically at par with HJ 541. The maximum plant height at harvest was also recorded in CSV 53F (2.61 m), which was significantly superior to the remaining varieties except HJ 541. CSV 53F recorded the highest leaf stem ratio (L:S) of 0.36, which was statistically at par with HJ 541. The days taken to attain 50% flowering were significantly higher in CSV 53F (92.08 days), whereas HJ 513 reached 50% flowering earliest (88.58 days). The maximum benefit cost ratio (B:C) of 2.05 was also observed in CSV 53F, though it did not differ significantly from HJ 541.

From figures 2 and 3, it is evident that CSV 53F produced the maximum green fodder yield (524.43 q ha^{-1}) and dry fodder yield (134.57 q ha^{-1}) and these yields were statistically at par with HJ 541. Both these varieties were markedly superior to the remaining varieties.

The observed differences in growth and yield attributes among the sorghum varieties may be attributed to their inherent genetic potential [14, 15].

Data presented in Table 2 show the quality parameters of forage sorghum. The HCN content recorded at 30, 45 and 60 DAS (figure 4) revealed that HC 308 exhibited the highest HCN content at all the stages (105.70, 99.97 and 49.69 µg g^{-1} fresh weight, respectively). In contrast, CSV 53F consistently recorded the lowest HCN content (92.78, 88.96 and 37.10 µg g^{-1} at the three respective stages), which was significantly lower than that of the other varieties. However, the HCN range (37.10–105.70 µg g^{-1}) remained well below the critical toxicity threshold of 200 µg g^{-1} across all varieties and sampling stages. A consistent decline in HCN content was also observed with advancement in crop age. Variety CSV 53F recorded the highest crude protein (CP) content (8.17%), which was statistically at par with HJ 541. The highest digestible crude protein (DCP) content (4.66%) was also recorded in CSV 53F and was statistically similar to HJ 541. Likewise, the highest *in-vitro* dry matter digestibility (IVDMD) (50.84%) was observed in CSV 53F, which remained statistically comparable with HJ 541.

Data presented in Table 3 depict the influence of accumulated heat units on crop phenology and yield. Variety CSV 53F recorded the maximum growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) (1846 °C day, 13437 °C day hour and 24230 °C day hour, respectively), though these values were statistically at par with HC 308. The highest heat use efficiency (HUE) for green fodder yield was observed in HJ 541 (29.02 kg ha^{-1} $°C^{-1}$ day^{-1}), being statistically at par with CSV 53F, whereas CSV 53F recorded the highest HUE for dry fodder yield (7.39 kg ha^{-1} $°C^{-1}$ day^{-1}), remaining statistically comparable with HJ 541. Plants require a definite amount of accumulated heat units to complete different phenophases and any deviation may affect phenological progression as well as yield realization.

Table 1: Performance of forage sorghum varieties at different fertility levels

Treatments	Number of leaves per plant at harvest	Leaf stem ratio at harvest	Plant height (m) at harvest	Days to 50% flowering	B:C
(A) **Varieties**					
CSV 53F	12.80	0.36	2.61	92.08	2.05
HJ 541	12.52	0.35	2.53	89.42	2.01
HJ 513	11.79	0.31	2.38	88.58	1.84
HC 308	12.05	0.32	2.42	92.00	1.86
Sem	0.18	0.01	0.04	0.54	0.02
CD at 5%	0.52	0.03	0.11	1.57	0.06
(B) **Fertility levels**					
Control	9.62	0.29	2.16	97.08	1.56
75% RDF	12.31	0.32	2.50	89.83	1.94
100%RDF	13.24	0.36	2.62	88.00	2.11
125%RDF	14.00	0.38	2.66	87.17	2.14
Sem	0.18	0.01	0.04	0.54	0.02
CD at 5%	0.52	0.03	0.11	1.57	0.06

100% RDF is 75:30:30 :: N:P_2O_5:K_2O kg/ha

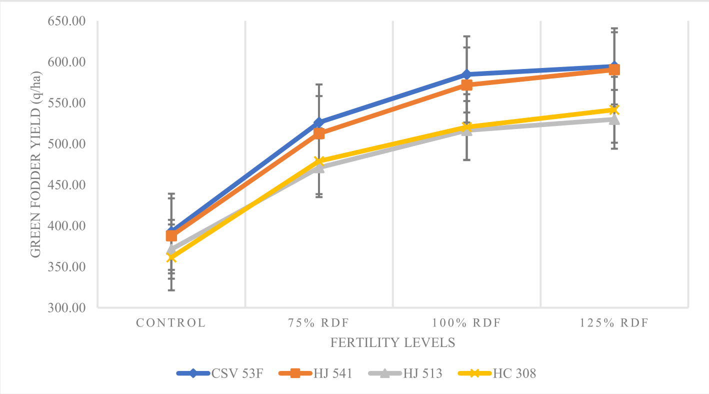

Fig.2. Effect of fertility levels on green fodder yield as influenced by different forage sorghum varieties

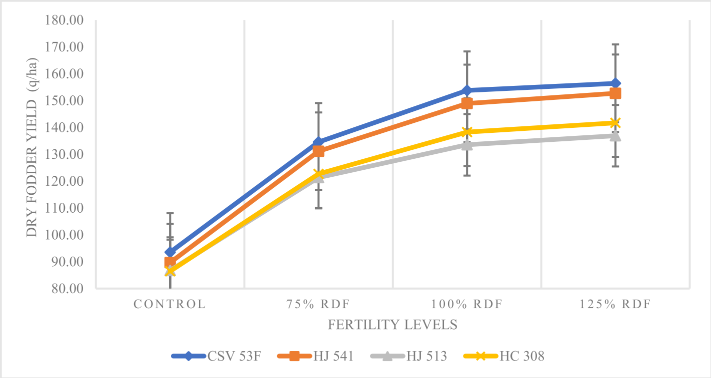

Fig.3. Effect of fertility levels on dry fodder yield as influenced by different forage sorghum varieties

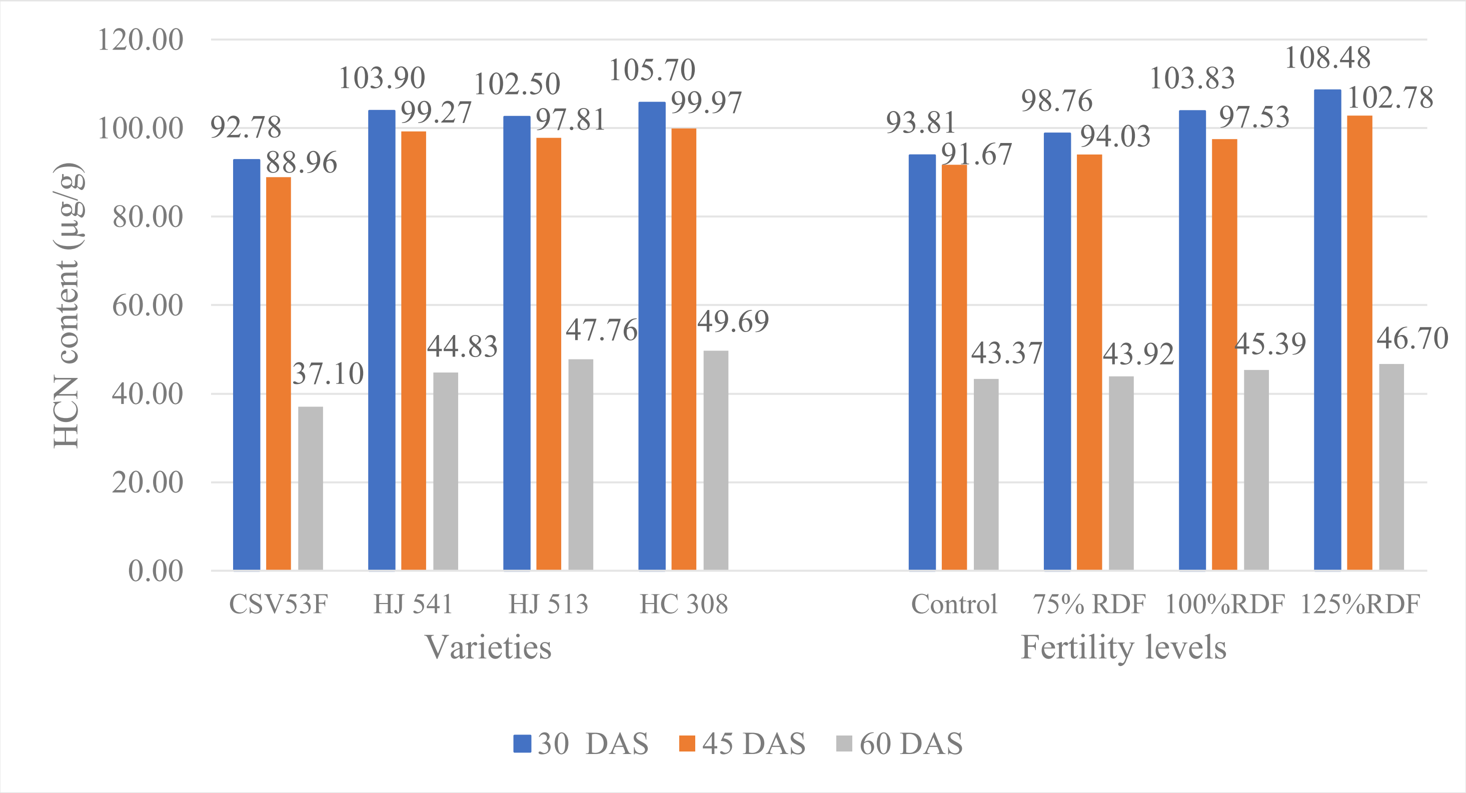

Fig.4. Effect of varieties and fertility levels on HCN content at different growth stages

Table 2: Quality parameters of forage sorghum varieties at different fertility levels

Treatments	HCN at 30 DAS (µg/g)	HCN at 45 DAS (µg/g)	HCN at 60 DAS (µg/g)	CP% at harvest	DCP (%)	IVDMD (%)
(A) **Varieties**						
CSV 53F	92.78	88.96	37.1	8.17	4.66	50.84
HJ 541	103.9	99.27	44.83	8.11	4.6	50.37
HJ 513	102.5	97.81	47.76	7.85	4.36	49.45
HC 308	105.7	99.97	49.69	7.64	4.17	50.22
Sem	1.65	1.16	0.63	0.08	0.07	0.21
CD at 5%	4.79	3.36	1.83	0.22	0.2	0.61
(B) **Fertility levels**						
Control	93.81	91.67	43.37	6.48	3.1	46.81
75% RDF	98.76	94.03	43.92	7.54	4.08	49.49
100%RDF	103.83	97.53	45.39	8.79	5.22	52.18
125%RDF	108.48	102.78	46.7	8.97	5.38	52.4
Sem	1.65	1.16	0.63	0.08	0.07	0.21
CD at 5%	4.79	3.36	1.83	0.22	0.2	0.61

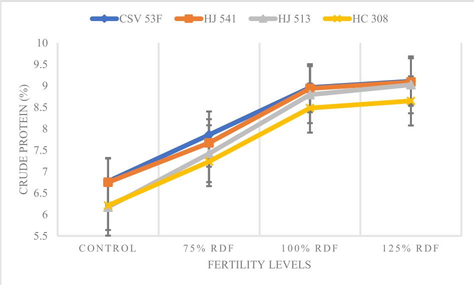

Fig.5. Effect of varieties and fertility levels on crude protein (CP) content

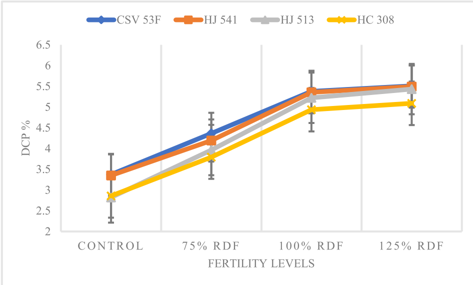

Fig.6. Effect of varieties and fertility levels on digestible crude protein (DCP) content

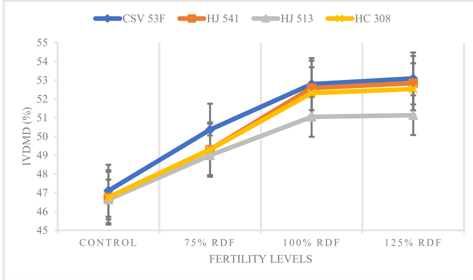

Fig.7. Effect of varieties and fertility levels on in-vitro dry matter digestibility (IVDMD)

Table 3: Agro-meteorological indices of forage sorghum varieties at different fertility levels

Treatments	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (kg ha⁻¹ °C⁻¹ day⁻¹)	
				GFY	DFY
		(A)**Varieties**			
CSV 53F	1846	13437	24230	28.77	7.39
HJ 541	1791	13227	23506	29.02	7.37
HJ 513	1773	13134	23271	26.81	6.8
HC 308	1843	13399	24202	25.95	6.68
Sem	11	44	147	0.32	0.1
CD at 5%	32	128	428	0.92	0.29
		(B)**Fertiliser levels**			
Control	1946	13768	25567	19.44	4.58
75% RDF	1799	13246	23617	27.63	7.08
100% RDF	1763	13148	23135	31.12	8.15
125% RDF	1745	13034	22891	32.36	8.43
Sem	11	44	147	0.32	0.1
CD at 5%	32	128	428	0.92	0.29

Fertility levels

Perusal of the data presented in Table 1 indicates that fertility levels exerted a significant influence on growth, yield and quality attributes of fodder sorghum. The maximum plant height (2.66 m) and L:S (0.38) were recorded with 125% RDF, which remained statistically at par with 100% RDF. A significantly higher number of leaves per plant (14.00) was also observed under 125% RDF as compared to lower fertility treatments. The maximum number of days to 50% flowering was recorded in the control plot (97.08 days), while the minimum (87.17 days) was recorded with 125% RDF. This could be attributed to favourable soil conditions and better nutrient availability, which resulted in early attainment of the reproductive phase as compared to nutrient-stressed conditions [17]. The highest B:C (2.14) was also recorded with 125% RDF, while the lowest was noted in the control plot; however, 125% and 100% RDF were found statistically comparable in terms of B:C.

The highest green and dry fodder yields (564.05 and 146.94 q ha^{-1}, respectively) were recorded with 125% RDF, which remained statistically at par with 100% RDF (figures 2 and 3). The increase in green fodder yield with 125% RDF over control, 75% and 100% RDF was 49.11, 13.50 and 2.80%, respectively, while the corresponding increases in dry fodder yield were 64.87, 15.31 and 2.30%. Similar findings have also been reported by [18] and [19]. Although plant height, number of leaves per plant and L:S increased progressively with increasing fertility levels up to 100% RDF, further increase to 125% RDF did not cause a statistically significant improvement, suggesting near-optimum growth at 100% RDF.

From figure 4, it is evident that HCN content increased with higher fertiliser levels from control to 125% RDF at 30, 45 and 60 DAS, ranging from 93.81 to 108.48, 91.67 to 102.78 and 43.37 to 46.70 μg g^{-1}, respectively. However, HCN concentration remained below the critical toxicity limit (200 μg g^{-1}) at all growth stages.

The increase in HCN may be attributed to greater nitrogen uptake under higher fertility levels. HCN content in sorghum is known to be heritable and influenced by genotype, environmental conditions, irrigation, stage of maturity, soil type and fertiliser regime [20]. Higher levels of nitrogen application have been linked to increased HCN content in forage sorghum, which aligns with the findings of [21].

As per Table 2, the highest CP content (8.97%) and DCP content (5.38%) were observed with 125% RDF, although these values were statistically at par with 100% RDF. The increase in CP content with higher nitrogen fertilisation may be due to the improved L:S, as protein content in sorghum is positively associated with leaf proportion. This trend has also been supported by earlier findings [22]. The IVDMD values increased from 46.81% in the control to 52.18% at 100% RDF; however, no significant improvement was observed beyond this level. Oberoi and Kaur [23] also reported similar enhancement in IVDMD with increased nitrogen application in fodder oats. Increased nitrogen availability enhances plant protein synthesis and reduces fibrous carbohydrate fractions (pectin, cellulose and hemicellulose), which improves digestibility.

The data in Table 3 further show that the maximum GDD (1946 °C day), HTU (13,768 °C day hour) and PTU (25,567 °C day hour) were recorded in the control plot, as plants under nutrient stress required a longer period to reach 50% flowering. The highest heat use efficiency (HUE) for green and dry fodder yields (32.36 and 8.43 kg ha^{-1} °C^{-1} day^{-1}, respectively) was obtained with 125% RDF, although the HUE for dry fodder yield with 125% RDF was statistically at par with 100% RDF.

CONCLUSION

Based on the findings of the present study, it can be concluded that the application of 100% RDF (75 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1}) along with the varieties CSV 53F and HJ 541 performed better in terms of fodder production, quality and economic returns under summer season conditions of the semi-arid region of Haryana. Among the varieties, CSV 53F exhibited superior performance with respect to growth attributes, quality parameters and green and dry fodder yields (524.43 and 134.57 q ha^{-1}, respectively), and was found statistically at par with HJ 541. A significant improvement in growth, yield and quality was observed with increased fertility levels up to 100% RDF; however, further enhancement to 125% RDF did not cause any significant increase, though the performance remained comparable to 100% RDF. Thus, 100% RDF may be recommended as the optimal fertilisation level for fodder sorghum under similar agro-climatic conditions.

FUTURE SCOPE OF STUDY

Sorghum is a climate-resilient crop and performs comparatively better during summer stress conditions. Therefore, future research should focus on developing location-specific, short-duration varieties with enhanced nutrient use efficiency and tolerance to moisture stress. Further investigations may also include evaluation of high-yielding and superior quality fodder sorghum genotypes across diverse agro-climatic zones, particularly in arid and semi-arid regions, to broaden the adaptability and production potential of the crop.

CONFLICT OF INTEREST

All the authors declare that there is no conflict of interest regarding the publication of this manuscript.

ACKNOWLEDGEMENT

The authors sincerely acknowledge the CCS Haryana Agricultural University, Hisar, and the Head, Department of Agronomy, for providing necessary facilities and support for the successful conduct of the Master's research work of the first author.

REFERENCES

1. Anonymous (2020). 20th Livestock Census - 2019, All India Report. Department of Fisheries, Animal Husbandry and Dairying, Department of Animal Husbandry & Dairying, Statistics Division, Krishi Bhawan, New Delhi. http://dadf.gov.in.

2. Roy, A. K., Agrawal, R. K., Bhardwaj, N. R., Mishra, A. K. and Mahanta, S. K. (2019). In: Indian Fodder Scenario: Redefining State Wise Status (eds. A. K. Roy, R. K. Agrawal, N. R. Bhardwaj). ICAR - AICRP on Forage Crops & Utilization, Jhansi, India, pp. 1-21.

3. Ahmed, S. E. E., Naim, A. M. E., Jabereldar A. A. and Ebrahiem, M. A. (2019). Some quality aspects of different sorghum forage (*Sorghum bicolor* L. Moench) genotypes grown under rain-fed and irrigation condition. *Advances in Plants and Agriculture Research,* 9(1): 101-104.

4. Anonymous (2022). All-India Area, Production and Yield along with coverage under Irrigation. Agricultural Statistics at a Glance 2022. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture, Government of India, New Delhi.

5. Devi, S., Satpal., Talwar, H. S., Ramprakash and Goyal, V. (2018). Performance of sorghum [*Sorghum bicolor* (L.) Moench] under salt stress. *Forage Research,* 44(2): 209-212.

6. Satpal., Kumar, S., Kumar, A., Gangaiah, B., Bhardwaj K. K. and Neelam. (2021). Evaluation of energy efficiency and optimum resource management in forage sorghum [*Sorghum bicolor* (L.) Moench] under semi-arid tropics. *Forage Research,* 47(3): 308-312.

7. Kanika., Kumar, S., Satpal, Hooda, V. S., Balhara, N., Monika, Aarzoo and Ajay (2025). Effect of varieties and fertility levels on growth and yield of single-cut forage sorghum during summer season. *Forage Research,* 50(4): 412-416.

8. Anonymous (2021). Package of practices for *kharif* crops of Haryana, Directorate of Extension Education, CCS HAU, Hisar, pp. 155-160.

9. Hogg, P. G. and Ahlgren, H. L. (1942). A rapid method of determining hydrocyanic acid content of single plant of sudan grass. *Journal of the American Society of Agronomy,* 43: 199-200.

10. A.O.A.C. (2005). Official methods of analysis. 19th edition. Association of official analytical chemists, Washington D.C.

11. Sood, S., Mondal, T., Pal, R. S., Joshi, D. C., Kant, L. and Pattanayak, A. (2023). Comparison of dehulling efficiency and grain nutritional parameters of two cultivated barnyard millet species (*Echinochloa* spp.). *Heliyon,* 9(11).

12. Barnes, R. F., Muller, L. D., Bauman L. F. and Colenbrander V. F. (1971). *In vitro* dry matter disappearance of brown midrib mutants of maize (*Zea mays* L.). *Journal of Animal Science,* 33: 881-884.

13. Sheoran, O. P., Tonk, D. S., Kaushik, L. S., Hasija R. C. and Pannu R. S. (1998). Statistical software package for agricultural research workers. *Recent Advances in Information Theory, Statistics & Computer Applications* by D.S. Hooda & R.C. Hasija (Department of Mathematics Statistics, CCS HAU, Hisar), 139-143.

14. Gurjar, G. S., Choudhary, R. S., Choudhary, R., Verma, A. and Jat, G. (2019). Effects of genotypes and fertility levels on growth parameters and yield of single cut fodder sorghum [*Sorghum bicolor* (L.) Moench]. *International Journal of Current Microbiology and Applied Sciences,* 8(8): 2979-2985.

15. Kishor, K. (2017). Production potential of sorghum [*Sorghum bicolor* (L.) Moench] genotypes under different fertility levels. M.Sc. Thesis, Department of Agronomy, RCA, Udaipur, MPUAT, Udaipur.

16. Pandey, I. B., Pandey, R. K., Dwivedi D. K. and Singh R. S. (2010). Phenology, heat unit requirement and yield of wheat (*Triticum aestivum*) varieties under different crop-growing environment. *Indian Journal of Agricultural Sciences,* 80(2): 136-140.

17. Kumar, S., Arya, R. K., Singh N. and Singh S. (2024). Productivity of rainfed maize as influenced by hydrogel and mulching under conventional and zero tillage in maize–wheat cropping system. *Cereal Research Communications,* 52(2): 885-898.

18. Kubsad, V. S. (2018). Response of rabi sorghum genotypes [*Sorghum bicolor* (L.) Moench] to different fertility levels under rainfed conditions. *International Journal Current Microbiology and Applied Sciences,* 7(10): 3282-3286.

19. Satpal., Tokas, J., Bhardwaj, K. K., Devi, S., Kumari, P., Arya, S., Neelam and Kumar S. (2019). Evaluation of forage sorghum genotypes for production, productivity and quality at different fertilizer levels. *Forage Research,* 45(1): 64-68.

20. Khatri, A., Khan, I. A., Siddiqui, S. H., Ahmed, M. and Saddiqui, K. A. (1997). *In vitro* culture of indigenous and exerted banana clones for maximizing multiplication. *Pakistan Journal of Botany,* 29: 143-150.

21. Satpal., Gangaiah, B., Kumar, N., Devi, S., Kharor, N., Bhardwaj, K. K., Kumari, P., Sharma, B. L., Neelam and Kumar, S. (2021). Performance of single cut forage sorghum genotypes under graded levels of NPK fertilizers. *Forage Research,* 47(2): 180-186.

22. Joshi, U. N., Arora, R. N., Phogat, D. S., Jhorar, B. S., Avtar, R. and Sheoran R. S. (2009). Current status of crude protein and *in vitro* dry matter digestibility in forage crops. In: Emerging Trends in Forage Research and Livestock production (eds. S. K. Pahuja, U. N. Joshi, B. S. Jhorar and R. S. Sheoran). *Forage Research*, pp. 146-153.

23. Oberoi, H. K. and Kaur M. (2019). Yield, growth and proximate analysis of multi-cut fodder sorghum genotypes with different doses of nitrogen. *Forage Research,* 45: 136-139.

