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Research article

Effect of Zinc application on growth and nutritional composition of sorghum fodder varieties

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Abstract

An experiment was carried out during the *Kharif* season of 2023 in the sub- tropical climate of Jammu in the Siwalik foothills of north-west Himalaya. The soil was sandy clay loam, slightly alkaline, low in organic carbon, available nitrogen, zinc and medium in accessible potassium and phosphorus. A factorial randomized block design with three replications was used with two factors, *i.e,* Factor A, which included two varieties, *viz.,* V_1- SSG and V_2- CSV 33 MF and Factor B consisting of eight zinc fertilization treatments. $N:P_2O_5:K_2O$ @ 60:40:20 kg ha^{-1} was applied uniformly to all the treatments. CSV 33 MF (V_2) variety had the noticeably greatest crop growth metrics and crude protein at all the harvesting intervals. However, RDF + soil application of $ZnSO_4$ @ 20 kg $ha^{-1}$and foliar application of $ZnSO_4$ at 0.5% at 40 DAS and 80 DAS (F_8) proved superior in terms of growth parameters and crude protein which was statistically at par with F_6 at first cut and F_7 at second and third cut. With regard to quality traits, numerically lowest NDF, ADF, hemicellulose, crude fibre and highest values of ether extract, ash content, DDM, DMI, RFV, RFQ and TDN was recorded under CSV 33 MF (V_2) and RDF + soil application of $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of $ZnSO_4$ at 0.5% at 40 DAS and 80DAS (F_8). The findings indicate that variety CSV 33 MF with RDF + soil application of $ZnSO_4$ @ 20 kg ha^{-1} + foliar application of $ZnSO_4$ at 0.5% at 40 DAS and 80 DAS is more suitable for increased fodder quality.

Keywords: Crude protein, Fodder, Nutritive profile, Sorghum, Zinc fertilization

Introduction

Forage cultivation plays a pivotal role in sustaining the livestock sector, which is integral to India's agricultural economy. As per the 20th Livestock Census (2019), India harbors 536.76 million livestock, constituting 11.54% of the global population. However, the country faces a substantial deficit in green fodder (35.6%), dry crop residues (11%), and concentrate feed (44%) (Makhdoomi, 2022), leading to chronic nutritional stress among livestock and reduced productivity. This deficiency is particularly evident in regions like Jammu & Kashmir, where the scarcity of nutrient-rich forages and limited grazing resources constrain dairy production. In this context, improving green fodder availability, especially during lean periods, is vital for maintaining animal health, enhancing productivity, and ensuring the profitability of dairy enterprises.

Sorghum (*Sorghum bicolor* L. Moench) stands as a leading *kharif* fodder crop owing to its high biomass yield, good palatability, and rich nutritional composition, containing 4 to 5% protein, 58% total digestible nutrients (TDN), and essential minerals like Calcium and Phosphorus. At present, sorghum is cultivated in 100 countries on all continents, covering about 40.88 million hectares with a grain production of 61.46 million metric tons and a productivity of 1.50 metric tons per hectare (USDA, 2025). However, suboptimal nutrient management, particularly micronutrient deficiencies, hampers its potential. Zinc, the fourth most limiting nutrient in Indian agriculture after N, P, and K, is deficient in over 50% of soils and expected to affect 63% by 2025 (AICRP, 2021). Zinc plays a crucial role in enzymatic activities, protein synthesis, nitrogen metabolism, and photosynthesis in plants (Alloway, 2008), and is equally essential for animal health, influencing immune function, reproduction, and growth (Rajesh *et al*., 2020). Recent studies have shown that soil and foliar zinc applications can significantly enhance zinc content in fodder, thereby improving its nutritional value and contributing to animal performance (Muthusamy *et al*., 2022; Giridhar *et al*., 2021).

Moreover, understanding the nutritive profile, including crude protein, ether extract, fiber fractions (NDF, ADF, hemicellulose), and digestibility indices (DDM, RFV, RFQ) is critical for evaluating fodder quality and meeting the nutritional demands of ruminants (Bhat *et al*., 2021). Variations in sorghum genotypes also influence these quality traits, highlighting the importance of varietal selection in fodder improvement strategies (Singh *et al*., 2017). Therefore, the present study was undertaken to assess the effect of zinc fertilization on growth, yield, nutritive value, and economics of multicut sorghum varieties under the agro-climatic conditions of Jammu, with the aim of identifying the most suitable combination for enhanced fodder productivity and profitability.

Materials and Methods

Experimental site and climatic conditions: The experiment was conducted during the *Kharif* season of 2023 at the Research Farm of the Division of Agronomy, SKUAST-Jammu. The experimental site is located in the subtropical Shiwalik foothills of the north-western Himalayas at 32°40′ N latitude, 74°82′ E longitude, with an elevation of 332 meters above mean sea level. The experimental area experiences a subtropical climate characterized by hot and dry early summers, a warm and humid monsoon period, and cold winters. During the cropping period, the mean weekly maximum temperature reached 37.9°C in June, while the lowest minimum temperature of 14.2°C was recorded in October. Relative humidity ranged from 44.6 to 94.7%, with the highest in August and the lowest in October. Rainfall is predominantly received during the southwest monsoon (June-September), accounting for 75% of the annual total, with the remaining 25% contributed by western disturbances (December-March). The site received approximately 1115 mm of rainfall during the cropping period, with considerable variability in distribution and intensity (range: 0.0–174.8 mm).

Table 1. Treatment details (zinc fertilization levels)

F_1	Recommended dose of fertilizers (RDF: $N:P_2O_5:K_2O$ @ 60:40:20 kg ha^{-1})
F_2	RDF + soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} at sowing
F_3	RDF + foliar application of $ZnSO_4.7H_2O$ @ 0.5% at 40 DAS
F_4	RDF + foliar application of $ZnSO_4.7H_2O$ @ 0.5% at 80 DAS
F_5	RDF + foliar application of $ZnSO_4.7H_2O$ @ 0.5% at both 40 and 80 DAS
F_6	RDF + soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} at sowing + foliar spray @ 0.5% at 40 DAS
F_7	RDF + soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} at sowing + foliar spray @ 0.5% at 80 DAS
F_8	RDF + soil application of $ZnSO_4.7H_2O$ @ 20 kg ha^{-1} at sowing + foliar spray @ 0.5% at 40 and 80 DAS

Experimental design and treatments: The experiment was laid out in a factorial randomized block design (FRBD) with three replications. The treatments consisted of two sorghum fodder varieties (SSG and CSV 33 MF) and eight zinc fertilization levels (Table 1), resulting in 16 treatment combinations.

The recommended dose of fertilizers, i.e., N:P:K:Zn was 60:40:20:20 kg ha^{-1}. Urea, diammonium phosphate, muriate of potash, and zinc sulphate heptahydrate were used as sources of nitrogen, phosphorus, potassium, and zinc, respectively. As basal doses, half of the nitrogen was applied with the full dose of phosphorus, potassium and zinc at the time of sowing and the remaining nitrogen was applied in two splits; the first at 30 days after sowing (DAS) and the second immediately after the first cut as top dressing. For foliar spray, 0.5% zinc sulphate heptahydrate was sprayed with the help of a knapsack sprayer at 40 and 80 DAS.

Soil characteristics and crop management practices: The soil was sandy clay loam, slightly alkaline, low in organic carbon, available nitrogen, zinc, and medium in accessible potassium and phosphorus. Land preparation included two cross-harrowings followed by planking. Sowing was done using the *kera* method at a row spacing of 30 cm. The crop received uniform agronomic practices across all treatments, including irrigation and pest management, as per recommendations.

Growth parameters: The crop was harvested three times during the growing period to assess multi-cut performance; first cut at 60 days after sowing (DAS), second cut at 100 DAS and third cut at 130 DAS. At each cut, data on plant height, fresh weight, and dry weight were recorded. Plant heights of five plants were measured with the help of a meter scale from the ground surface to the tip of the uppermost fully opened leaf at each cut and the mean value was used for analysis. Fresh forage yield was recorded by harvesting plants from one square meter area at three random locations within each net plot at every cut and the average fresh weight of the plants harvested from these spots expressed in kg m^{-2} was taken at each cut. The fresh weight of the sample was recorded and shade-dry for one day, then the next day, dried in a hot air oven at 60-65°C for 48-72 hours till a constant dry weight was obtained.

Quality parameters: Plant sample from each net plot was sun-dried, followed by its oven drying at a temperature of 60-65° C for 36-48 hours to a constant weight and was subsequently ground in a hammer mill for proximate composition and fiber fractions analysis. Different quality parameters, viz., Fiber fractions including acid detergent fiber (ADF), neutral detergent fiber (NDF), and hemicellulose, were measured, while crude fiber, ether extract, and ash content were determined using the Van Soest *et al*. 1991 method.

Calculation of nutritional indices: Derived nutritional indices, i.e., digestibility dry matter, dry matter intake, relative feed value, relative forage quality and total digestible nutrients were calculated as follows:

- DDM (%)= 88.9 – (0.779 × %ADF)
- DMI (% body weight) = 120 / %NDF
- RFV (%) = DDM × DMI / 1.29
- TDN (%) = 96.35 – (1.15 × %ADF)
- RFQ (%) = DMI × TDN / 1.23

Where DDM- Digestibility dry matter, DMI- Dry matter intake, RFV- Relative feed value, TDN- Total digestible nutrients, RFQ- Relative forage quality, ADF- Acid detergent fiber, and NDF- Neutral detergent fiber

Statistical analysis: Data were analyzed using analysis of variance (ANOVA) appropriate for FRBD as described by Cochran and Cox (1963). Treatment means were compared using the F-test at 5% level of significance. Critical differences (CD) were calculated where applicable.

Results and Discussion

Growth parameters: The growth performance of multicut fodder sorghum varieties and zinc fertilization treatments showed significant variation in plant height, fresh weight, and dry weight across all three harvests (cut) (Table 2). Among the two varieties, CSV 33MF consistently recorded superior growth attributes. The tallest plants (165.92, 157.92, and 94.21 cm), maximum fresh biomass (3.29, 1.99, and 1.09 kg m^{-2}), and highest dry biomass (0.48, 0.44, and 0.39 kg m^{-2}) were observed in CSV 33 MF at the first, second, and third cuts, respectively.

The superior performance of CSV 33 MF can be attributed to its inherent genetic vigor for rapid regrowth, greater tillering ability, and efficient partitioning of assimilates and morphological traits that support greater chlorophyll production, enhanced photosynthesis, and overall biomass accumulation. The sustained dry matter production across cuts suggests better carbohydrate reserves in the basal portions of the plant, which support regrowth after cutting. Similar regrowth behavior in multicut sorghum has been reported by Bharti *et al*. (2023), who observed significantly higher plant height and green fodder yield in CSV 33 MF due to improved tiller production and regrowth ability, and by Patil *et al*. (2023) who documented enhanced dry matter accumulation in multicut sorghum varieties associated with efficient

Table 2. Effect of zinc application on plant height of multicut sorghum varieties

Treatment	Plant height (cm)			Fresh weight (kg m^{-2})			Dry weight (kg m^{-2})		
	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut
Variety									
V_1: SSG	158.25	140.88	87.71	2.33	1.59	0.79	0.43	0.41	0.36
V_2: CSV 33MF	165.92	157.92	94.21	3.29	1.99	1.09	0.48	0.44	0.39
SEM (±)	1.30	1.16	1.36	0.06	0.06	0.04	0.01	0.01	0.01
CD (P<0.05)	3.75	3.35	3.93	0.17	0.17	0.11	0.02	0.02	0.02
Zinc fertilization									
F_1	153.83	137.33	80.83	2.26	1.34	0.71	0.39	0.37	0.32
F_2	160.33	141.67	82.83	2.71	1.49	0.77	0.44	0.39	0.34
F_3	161.17	142.67	85.33	2.96	1.56	0.80	0.47	0.40	0.35
F_4	154.00	146.50	90.67	2.35	1.80	0.86	0.40	0.42	0.37
F_5	167.00	149.83	93.00	2.99	1.85	0.90	0.48	0.43	0.38
F_6	170.17	151.83	93.83	3.25	1.87	1.01	0.49	0.45	0.40
F_7	156.50	160.00	99.17	2.65	2.12	1.23	0.44	0.46	0.41
F_8	173.67	165.33	102.00	3.30	2.29	1.26	0.52	0.49	0.44
SEM (±)	2.12	1.90	2.22	0.10	0.09	0.06	0.01	0.01	0.01
CD (P<0.05)	6.12	5.47	6.41	0.28	0.27	0.17	0.03	0.03	0.03
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

For details of zinc fertilization treatment, please refer to Table 1

Table 3. Effect of zinc application on neutral detergent fibre, acid detergent fibre and hemicellulose of multicut sorghum varieties

Treatment	NDF (%)			ADF (%)			Hemicellulose (%)		
	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut
Variety									
V_1: SSG	66.02	64.71	65.63	35.00	33.88	32.05	31.03	30.91	33.87
V_2: CSV 33MF	65.26	63.59	64.57	34.19	32.48	30.27	30.98	30.78	33.76
SEM (±)	0.66	0.51	0.66	0.81	0.67	0.77	1.06	0.78	1.02
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc fertilization									
F_1	66.82	66.33	65.98	34.60	35.50	33.33	32.22	31.50	33.82
F_2	65.68	64.45	66.05	34.83	34.12	32.62	30.85	30.33	33.43
F_3	65.62	64.00	65.95	34.77	33.03	31.20	30.85	30.97	34.75
F_4	65.87	64.30	65.87	35.28	33.13	31.13	30.58	31.17	34.40
F_5	65.43	63.93	65.25	34.30	32.58	30.75	30.80	30.68	34.17
F_6	65.35	64.20	64.92	34.25	32.27	30.93	31.10	30.93	33.82
F_7	65.78	63.28	64.87	34.62	32.40	29.73	31.17	30.88	33.80
F_8	64.57	62.70	61.90	34.10	31.38	29.55	30.47	30.32	32.35
SEM (±)	1.07	0.83	1.08	1.32	1.09	1.26	1.74	1.27	1.67
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

For details of zinc fertilization treatment, please refer Table 1

Table 4. Effect of zinc application on crude fibre, ether extract and ash content of multicut sorghum varieties

Treatment	Crude fibre (%)			Ether extract (%)			Ash content (%)		
	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut
Variety									
V_1: SSG	30.57	28.24	24.12	2.31	2.25	2.13	5.49	5.35	5.24
V_2: CSV 33MF	29.16	27.11	24.07	2.63	2.28	2.25	6.27	6.10	6.04
SEM (±)	0.64	0.63	0.68	0.14	0.10	0.17	0.78	0.46	0.68
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc fertilization									
F_1	29.30	27.30	23.80	2.17	2.09	1.85	3.17	4.27	2.65
F_2	30.60	29.37	25.20	2.28	2.11	1.86	5.77	4.38	4.28
F_3	29.67	28.53	25.03	2.57	2.18	2.00	5.63	5.21	4.89
F_4	33.03	28.60	25.10	2.17	2.20	2.13	4.31	5.44	5.20
F_5	29.49	27.67	24.17	2.73	2.27	2.23	7.31	5.77	6.68
F_6	28.33	27.49	23.99	2.78	2.31	2.35	8.10	6.70	6.85
F_7	30.53	26.33	22.83	2.18	2.39	2.46	4.53	6.87	6.89
F_8	27.96	26.13	22.67	2.92	2.57	2.64	8.22	7.16	7.67
SEM (±)	1.04	1.03	1.12	0.24	0.17	0.28	1.28	0.75	1.11
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

For details of zinc fertilization treatment, please refer to Table 1

photosynthetic activity and sustained meristematic growth following repeated harvests.

In terms of zinc fertilization, the treatment F8 (RDF + Soil application of $ZnSO_4$ @ 20 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at 40 and 80 DAS) consistently performed best. At the first harvest, F8 resulted in significantly higher plant height (173.67 cm), fresh weight (3.30 kg m^{-2}), and dry weight (0.52 kg m^{-2}), statistically at par with F6. At the second and third cuts, F8 again recorded the tallest plants (165.33 cm and 102.00 cm), along with maximum fresh (2.29 and 1.26 kg m^{-2}) and dry weights (0.49 and 0.44 kg m^{-2}), followed closely by F7.

The improvement in growth parameters under zinc application may be primarily due to the role of zinc in promoting Auxin synthesis, enhancing cell division and enhancing zinc availability, which promotes stronger stem elongation and leaf development, resulting in taller plants and higher fresh biomass (Akhila *et al*., 2021). Additionally, zinc improves nitrogen metabolism and photosynthetic efficiency, leading to greater dry matter accumulation (Kumar and Ram 2021). The sustained superiority of F8 across second and third cuts suggests that zinc application helped replenish nutrient reserves depleted during earlier harvests, thereby supporting successive regrowth cycles. Overall, the results clearly demonstrate that the superior growth of CSV 33 MF, combined with integrated soil and foliar zinc application, is a consequence of synergistic effects between genetic potential and enhanced nutrient-mediated physiological processes, ultimately leading to improved growth performance across successive harvests. Dhaliwal *et al.* (2020) also reported a similar kind of synergistic effect for these growth parameters.

Quality Parameters

Proximate and fibre composition: The chemical composition of fodder was not significantly influenced by either variety or zinc treatment for most quality parameters, including NDF, ADF, hemicellulose (Table 3), crude fibre, ether extract, and ash content (Table 4). This lack of significant variation indicates that fibre synthesis and cell wall composition in sorghum are largely governed by crop maturity stage and structural carbohydrate deposition rather than by micronutrient supply alone.

Similarly, the non-significant effect of zinc on crude fibre, ether extract, and ash content can be attributed to the role of zinc as a catalytic micronutrient involved mainly in enzymatic activity, hormone synthesis, and metabolic regulation rather than in the direct formation of fibre or mineral constituents (Mehta *et al*., 2025). The absence

Table 5. Effect of zinc application on DDM, DMI, RFV, RFQ and TDN of multicut sorghum varieties

Treatment	DDM %			DMI %			RFV %			RFQ %			TDN %		
	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut
Variety															
V_1: SSG	61.64	62.51	63.94	1.82	1.86	1.83	86.91	89.94	90.72	82.98	86.61	88.55	56.10	57.39	59.50
V_2: CSV 33MF	62.26	63.60	65.32	1.84	1.89	1.86	88.88	93.20	94.30	85.36	90.68	92.96	57.03	59.00	61.54
SEM (±)	0.63	0.52	0.60	0.02	0.02	0.02	1.23	1.40	1.52	1.58	1.76	1.88	0.93	0.77	0.89
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc fertilization															
F_1	61.95	61.25	62.93	1.80	1.81	1.83	86.29	85.88	89.09	82.63	81.65	86.08	56.56	55.53	58.02
F_2	61.76	62.32	63.49	1.83	1.86	1.82	87.49	90.05	89.48	83.63	86.55	86.97	56.29	57.12	58.84
F_3	61.82	63.17	64.60	1.83	1.88	1.82	87.65	91.94	91.18	83.82	89.11	89.53	56.37	58.36	60.47
F_4	61.41	63.09	64.65	1.82	1.87	1.82	86.77	91.41	91.31	82.65	88.53	89.68	55.77	58.25	60.55
F_5	62.18	63.52	64.95	1.83	1.88	1.84	88.42	92.49	92.69	84.88	89.91	91.32	56.91	58.88	60.99
F_6	62.22	63.67	64.80	1.84	1.87	1.85	88.57	92.58	92.91	85.04	90.19	90.57	56.96	59.11	60.78
F_7	61.93	63.66	65.74	1.82	1.90	1.85	87.61	93.60	94.32	83.89	91.12	93.55	56.54	59.09	62.16
F_8	62.34	63.76	65.88	1.87	1.92	1.94	90.38	94.59	99.07	86.80	92.12	98.35	57.14	59.24	62.37
SEM (±)	1.03	0.85	0.98	0.03	0.03	0.03	2.01	2.29	2.49	2.58	2.87	3.07	1.51	1.26	1.45
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

For details of zinc fertilization treatment, please refer to Table 1

of varietal effects further suggests that both sorghum genotypes possess comparable inherent capacity for fibre deposition under identical management and environmental conditions.

Digestibility metrics: The calculated feed quality parameters, such as digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), relative feed quality (RFQ), and total digestible nutrients (TDN) (Table 5), did not show statistically significant variation due to either sorghum variety or zinc treatments. However, numerically higher values for these parameters were recorded in CSV 33MF and the F8 treatment at all harvests.

Higher values of DDM, DMI, and TDN indicate enhanced energy availability and digestibility of the forage. As fibre fractions did not vary significantly across treatments, derived digestibility parameters also remained statistically unchanged, indicating that zinc application improved plant growth and biomass accumulation without modifying the intrinsic digestibility characteristics of the forage. Similarly, Relative feed value (RFV) and relative feed quality (RFQ) are composite indices derived from DDM and DMI, likewise did not differ significantly with zinc fertilization, suggesting that yield improvement was achieved without compromising forage quality. Comparable results were reported by Kumar *et al*. (2016), who observed no significant changes in NDF and ADF content of fodder sorghum under different zinc levels, and by Dhaliwal *et al*. (2020), who similarly reported negligible variation in fibre fractions and digestibility parameters with zinc application despite increased biomass yield.

Conclusion

The study clearly demonstrated that the performance of multicut fodder sorghum is significantly influenced by variety selection and zinc fertilization strategies. Variety CSV 33MF consistently outperformed in terms of plant height, biomass yield (fresh and dry), across all three cuts, highlighting its superior genetic potential and adaptability. Zinc fertilization, particularly the combined application of soil-applied $ZnSO_4$ @ 20 kg ha^{-1} and foliar sprays of 0.5% $ZnSO_4$ at 40 and 80 DAS (F8), significantly enhanced growth and quality attributes. Although other proximate and fiber quality parameters, such as NDF, ADF, hemicellulose, ether extract, ash content, DDM, DMI, RFV, RFQ, and TDN, were not statistically influenced, numerically higher values were observed with CSV 33MF and F8 treatment, suggesting positive but subtle trends. Overall, CSV 33MF, along with F8 zinc fertilization treatment, can be recommended for maximizing both the yield and nutritive value of multicut sorghum fodder. Adoption of these practices can substantially contribute to improved forage availability and better livestock productivity in sustainable fodder production systems.

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