Forage Res., **51**(3) : pp. 310-314 (2025) **http://forageresearch.in**

NANO UREA FERTILISATION ON PRODUCTIVITY AND PROFITABILITY OF FORAGE SORGHUM

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(Received: 5 December 2025; Accepted: 25 December 2025)

SUMMARY

The aim of this experiment was to study the effect of foliar application of nano urea and nano zinc on growth and yield of single cut forage sorghum. The experiment was laid out during *kharif* season, June, 2022 at Instructional Dairy Farm, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The field was designed in a randomized block design having eleven treatments which were replicated thrice. The available treatments consist of different combinations of RDF and nano fertilizers containing nano urea and nano zinc. The implementation of treatment, T_5 has significantly effect on plant height, leaf: stem ratio, SPAD value, mean CGR, mean RGR over other treatment combinations. Green and dry fodder yield were noted highest under T_5 (75.3 t/ha) and (16.6 t/ha) over other treatments. T_5 incurred the highest cost of cultivation (Rs. 37,821/ha), whereas T_1 had the lowest (Rs. 34,495/ha). Despite its higher cost, T_5-60 kg N/ha as basal + NU & NZn spray at 30 and 60 DAS, yielded the highest net return (Rs. 112,779/ha), while T_1- T_1: 60 kg N/ha as basal + top dressing of 30 kg N/ha at 30 DAS (RDF) recorded the highest benefit-cost (B:C) ratio of 3.2 among all treatments. Foliar application of nano urea and nano zinc at 30 and 60 days after sowing (DAS), in combination with a basal application of 60 kg N/ha, significantly enhances the yield and net returns of single-cut forage sorghum.

Key words: Economic, fodder yields, foliar spray, forage sorghum and nano fertilization

Sorghum is an important forage crop in India, valued for its rapid growth, palatability, and nutritional content, making it ideal for livestock feed. It is the fifth most significant cereal globally, after maize, rice, wheat, and barley. Known for its high yield potential and drought tolerance, sorghum provides 400-500 quintals of green fodder and 100-150 quintals of dry fodder per hectare (Mace *et al.*, 2009; Venkateswaran *et al.*, 2014). Despite low production, it remains a crucial source of nutritious feed for India's 536.76 million livestock. It contains 8-10% crude protein, 60-65% neutral detergent fiber, 37-42% acid detergent fiber, 32% cellulose, and 21-23% hemi-cellulose when harvested at 50% flowering (Kumar *et al.,* 2012; Satpal *et al.*, 2020). Sorghum is cultivated on approximately 41.64 million hectares globally, yielding 62.17 million metric tonnes (USDA, 2022). Major producers include Argentina, Ethiopia, India, Mexico, Nigeria, and the U.S. In India, key producing states are Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh, Gujarat, Rajasthan, and Uttar Pradesh. Currently, India faces a shortage of 44% in concentrate feed, 11.95% in dry fodder, and 35.6% in green fodder (IGFRI Vision, 2050). Only 4% (8.4 million ha) of India's cultivated land is used for fodder, a figure unchanged in recent years (Meena *et al.*, 2018). To meet cattle fodder demands, it's essential to increase yields on existing land (Singh *et al.*, 2021). Nitrogen fertilizer plays a key role in enhancing dry matter and forage yield of sorghum in irrigated areas due to its high solubility and mobility in soil (Afzal *et al.*, 2012).

Sorghum, often used as pasture, needs high nitrogen input for optimal growth. Nitrogen, along with phosphorus and potassium, is essential for boosting shoot growth, tillering, leaf-to-stem ratio, succulence, and palatability (Satpal *et al.*, 2020; Karthika *et al.*, 2017). Zinc is regarded as the fourth most yield limiting nutrient after nitrogen, phosphorus and potassium in both global and Indian soils (Arunachalam *et al.*, 2013). Zinc is crucial for crop nutrition, supporting metabolic processes such as glucose, nucleic acid, lipid, and protein synthesis. It enhances indole acetic acid (IAA)

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formation, promoting growth, chlorophyll production, stress tolerance, and water transport. Foliar application of liquid nano fertilizers boosts absorption in plant leaves (Nasiri *et al.*, 2010; Marzouk *et al.*, 2019). Nano fertilizers have particles that are less than 100 nm in size, allowing for greater penetration of the plant from the applied surface, such as soil or leaves (Singh *et al.*, 2017). Nano fertilizers, such as nano urea and nano zinc, offer better absorption by plants due to their small size, with a nutrient efficiency of over 80%, compared to just 30-40% for regular fertilizers. This makes nano fertilizers significant in reducing inorganic fertilizer use and minimizing environmental impacts. Therefore, this experiment was conducted to evaluate their effects on the growth, fodder yield, and economics of single-cut forage sorghum.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted during *kharif* season June, 2022 at Instructional Dairy Farm, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The place has a humid subtropical climate with frigid winters and hot, dry summers. The months of May and June have the highest temperatures at the experimental site, with the mean temperature reaching up to 43°C, while the months of December and January have the lowest temperatures which occasionally reaching 0°C. The experiment was laid out in a randomized block design with three replications. The gross plot size was 12 m^2 (4 x 3 m). The experiment consisted of eleven treatments *viz.*, T_1: 60 kg N/ha as basal + top dressing of 30 kg N/ha at 30 DAS, T_2: 60 kg N/ha as basal + NU spray at 30 DAS, T_3: 60 kg N/ha as basal + NU spray at 30 and 60 DAS, T_4: 60 kg N/ha as basal + NU & NZn spray at 30 DAS, T_5: 60 kg N/ha as basal + NU & NZn spray at 30 and 60 DAS, T_6: 45 kg N/ha as basal + NU spray at 30 DAS, T_7: 45 kg N/ha as basal + NU spray at 30 and 60 DAS, T_8: 45 kg N/ha as basal + NU & NZn spray at 30 DAS, T_9:45 kg N/ha as basal + NU & NZn spray at 30 and 60 DAS, T_{10}: NU were used for experiment spray at 30 and 60 DAS and T_{11}: Basal application of NU in furrows + NU spray at 30 DAS. The forage sorghum variety CSV 35 F was sown @ 25 kg per hectare and seeds were sown at a depth of 4 cm, with a row-to-row spacing of 25 cm and a plant-to-plant spacing of 5 cm. The soil of the experimental field was clay loam, neutral in pH, high in organic carbon content, low in available nitrogen and medium in phosphorus and potassium.

Application scheduling of foliar spray: The first foliar spray was administered 30 days after sowing, and the second spray was given 60 days after sowing, using a knapsack sprayer with a flat fan nozzle. The scheduled treatments involved applying nano urea @ 4 ml/l of water and nano zinc @ 2 ml/l of water.

Statistical analysis: The experimental data obtained for various parameters was analyzed with the help of software 'OPSTAT', an analysis of variance technique suitable for a randomized block design developed by Haryana Agriculture University, Hisar, Haryana. The analysed data was then tabulated treatment wise for each parameter.

RESULTS AND DISCUSSION

Growth attributes

Significant differences were observed among treatments for all measured parameters (Table 1). Treatment T5 recorded the highest plant height (346.0 cm), 0.64% greater than T_1 (343.8 cm), while T_{11} showed the lowest height (298.1 cm), representing a 13.3% reduction compared to T_1. T_5 also exhibited a 12.4% increase in leaf number over T_1 (16.3 vs. 14.5). The highest leaf area index (LAI) was also noted in T_5 (14.98), a 2.5% increase over T_1 (14.61). Similarly, T_5 had the highest leaf-to-stem ratio (0.27), 17.4% higher than T_1 (0.23), whereas T_{11} showed a 30.4% decrease (Fig. 1). Stem girth in T_5 (8.85 cm) was 7.1% greater than in T_1 (8.26 cm). Treatment T_5 also recorded the highest crop growth rate (CGR) at 31.59 $g/m^2/day^1$, a 15.2% increase over T1 (27.42 $g/m^2/day^1$). Although T5 excelled in most parameters, T_3 showed the highest relative growth rate (RGR) at 65.49, 2.1% higher than T_1 (64.11), while T_{11} recorded the lowest RGR (60.53), 5.6% lower than T_1. SPAD value had recorded maximum with T_5 (39.5) and lowest with T_1 (30.0) (Fig.2). Enhanced vegetative growth in this study is linked to improved nitrogen availability from conventional and nano urea fertilizers. Nano urea's smaller particle size and higher surface area enhance foliar absorption and nitrogen use efficiency, boosting photosynthesis, chlorophyll synthesis, and cell division, thereby accelerating plant growth (Afzal *et al.*, 2012). In addition to nitrogen, the application of nano zinc significantly contributed to improved root morphology and nutrient uptake. Zinc is an essential micronutrient involved in enzyme activation, protein synthesis, and auxin metabolism, all of which are fundamental to root initiation and

TABLE 1

Response of nano urea and nano zinc on growth parameters of forage sorghum

Treatments	Plant height (cm)	Number of leaves	Leaf area index	Stem girth (cm)	Mean CGR	Mean RGR
T_1	343.8	14.5	14.61	8.26	27.42	64.11
T_2	336.8	13.3	13.51	7.77	26.44	64.28
T_3	344.5	14.6	14.65	8.33	28.85	65.49
T	337.7	13.2	13.72	7.80	27.84	62.33
T_5	346.0	16.3	14.98	8.85	31.59	65.19
T_6	313.3	11.6	9.67	7.03	25.66	62.11
T_7	315.6	13.3	11.91	7.33	24.48	63.67
T_8	314.0	12.9	10.74	7.17	25.45	62.07
T_9	316.1	13.3	12.48	7.40	25.82	62.72
T_{10}	307.5	11.7	8.06	6.60	24.30	61.66
T_{11}	298.1	10.6	7.74	6.13	19.31	60.53
SEm±	10.0	0.7	0.77	0.42	0.96	0.69
CD at 5 %	29.5	2.3	2.26	1.24	2.84	2.05

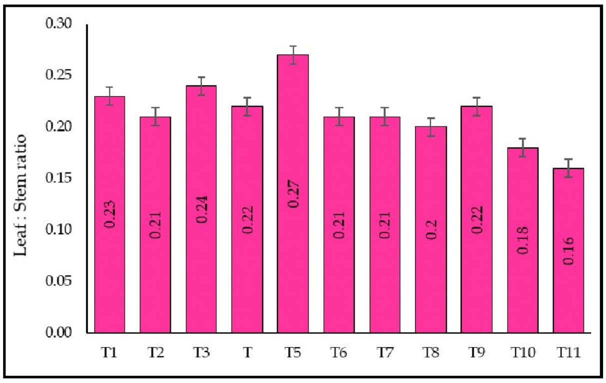

Fig. 1. Effect nano fertilizers on leaf: stem ratio of forage sorghum.

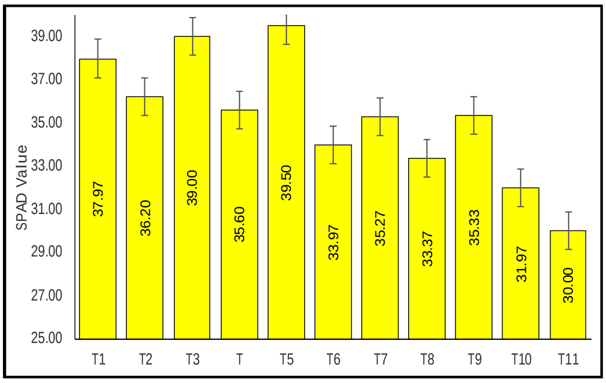

Fig. 2. Effect nano fertilizers on SPAD value of forage sorghum.

elongation (Laghari *et al.*, 2016; Tarafdar *et al.*, 2014). Enhanced root systems improve water and nutrient uptake, boosting plant growth during key stages. Foliar nano fertilizers offer fast, targeted nutrient delivery, bypassing soil issues and quickly correcting deficiencies to enhance nutrient use efficiency (Reddy *et al.*, 2022). The combined foliar application of nano urea and nano zinc significantly improved sorghum growth and forage yield, highlighting nano-fertilizers as a promising tool for sustainable nutrient management and crop productivity (Sharma *et al.*, 2022).

Fodder yield

Green and dry fodder yields were significantly influenced by the various treatments (Table 2). Green fodder yield ranged from 54.3 to 75.3 t/ha, with the highest yield observed under treatment T_5 (75.3 t/ha), which was 2.6 t/ha higher than that of T_1 (72.7 t/ha). A similar trend was observed for dry fodder yield, which varied significantly across treatments, ranging from 9.6 to 16.6 t/ha. Treatment T_5 again recorded the highest dry fodder yield (16.6 t/ha), reflecting a notable increase of 1.5 t/ha over T_1 (15.1 t/ha). Conversely, the lowest dry fodder yield was recorded under treatment T_{11} (9.6 t/ha), which was 5.5 t/ha lower than T_1. The observed improvements in plant growth can be attributed to the enhanced nutrient supply provided by nano urea, which is directly applied to the plant leaves. This mode of application facilitates quicker absorption of nutrients by the plant tissues, thereby improving nutrient use efficiency. As a result, key physiological processes such as photosynthesis, cell division, and cell elongation are optimized, leading to better overall growth. Additionally, the application of nano zinc has been shown to enhance the plant's ability to uptake more phosphorus from the soil. Phosphorus, being essential for energy transfer and metabolic processes, contributes significantly to improved physiological development. These findings are in line with the studies by Reddy *et al.* (2022) and Kumar *et al.* (2022), which also reported similar

TABLE 2

Response of nano urea and nano zinc on yield and economics of forage sorghum

Treatments	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1	72.7	15.1	34495	145200	110705	3.2
T_2	71.7	12.8	35081	143200	108119	3.1
T_3	74.3	15.3	36441	148600	112159	3.1
T	72.0	12.7	35961	143800	107839	3.0
T_5	75.3	16.6	37821	150600	112779	3.0
T_6	64.7	11.4	34889	129200	94311	2.7
T_7	66.0	12.2	36249	132000	95751	2.6
T_8	65.3	11.6	35769	130600	94831	2.7
T_9	66.3	12.5	37629	132600	94971	2.5
T_{10}	60.0	10.6	35061	119800	84739	2.4
T_{11}	54.3	9.6	35061	108600	73539	2.1
SEm±	2.8	0.3	-	1346	650	0.08
CD at 5 %	8.3	1.7	-	4000	2108	0.25

benefits of nano-nutrient applications in enhancing plant growth and nutrient uptake.

ECONOMICS

The results show significant variations in cost of cultivation, gross return, net return, and B:C ratio across treatments. Treatment 5 (T_5) had the highest cost (Rs. 37,821/ha), while Treatment 1 (T_1) had the lowest (Rs. 34,495/ha). These differences are likely due to varying input costs, with T_5 possibly involving more expensive inputs or advanced practices to boost yields. In terms of gross return, T_5 also emerged as the highest, with Rs. 150,600/ha, while T_{11} had the lowest gross return (Rs. 108,600/ha). T_5's higher return likely stems from better inputs and management, while T_{11}'s lower return may reflect inefficiencies or poor environmental conditions (Afzal *et al*., 2012). Net return, which represents the profitability of the treatments after accounting for costs, was highest in T_5 at Rs. 112,779/ha, significantly higher than most other treatments. T5 had the highest profitability due to high returns offsetting its cost, while T_3 and T_1 also showed strong net returns. In contrast, T11's low returns led to lower profitability despite its lower cost (Reddy *et al*., 2022). The benefit-cost (B:C) ratio is a crucial measure of economic efficiency, and it was highest in T_1 (3.2), indicating that for every rupee invested, Rs. 3.2 was generated in return. T_1 likely used low-cost, high-efficiency practices, maximizing profitability despite lower gross returns. In contrast, T_{11} had the lowest B:C ratio (2.1), indicating poor returns relative to investment, possibly due to low returns and suboptimal cost management (Baljeet *et al.*, 2021).

CONCLUSION

The study concluded that applying 60 kg N/ ha as basal fertilizer along with nano urea and nano zinc foliar sprays at 30 and 60 DAS significantly improved growth, fodder yield, and profitability. This integrated approach is recommended for enhancing productivity, nutrient quality, and economic returns in field crop production.

FUTURE PROSPECTS

Nano fertilizers have a very interesting potential but limited published performance data at field condition, so more field studies are needed. Engagement of all stakeholders is required to acquire consumer acceptance.

REFERENCES

Afzal, M., A. Ahmad and A. H. Ahmad, 2012 : Effect of nitrogen on growth and yield of sorghum forage [*Sorghum bicolor* (L.) Moench] under three cuttings system. *Cercet. Agron. Mold.*, **45**(4): 152-156.

Anonymous, 2020 : Agricultural statistics at a glance. 2020.

Arunachalam, P., P. Kannan, G. Prabukumar and M. Govindaraj, 2013 : Zinc deficiency in Indian soils with special focus to enrich zinc in peanut. *African J. Agri. Res.*, **8**(50): 6681-6688.

Baljeet, B. L., Meena, M., Singh, S., Kumar, S. Bhattacharjee, and S. Onte, 2021 : Effect of potassium and foliar spray of zinc on yield, nutrient biofortification, economics of fodder maize (*Zea mays* L.). *Ann. Agric. Res.*, **42**(4): 382-390.

IGFRI Vision 2050 : Indian grassland and fodder research institute. IGFRI. 7-23p.

Indian Farmers Fertilizer Cooperative Limited. New Delhi, India. 2020 : Nano urea (liquid) fertilizer. Published by IFFCO, New Delhi. 1p. https:// www.iffco.in/en/ nano-urea-liquid-fertilizer.

Karthika, N. and R. Kalpana, 2017 : HCN content and forage yield of forage sorghum under different organic manure and nitrogen level. *Chem. Sci. Rev. Lett.*, **6**(23): 1659-1663.

Kumar, A., K. Singh, P. Verma, A. S. Panwar, T. Singh, Y. Kumar and R. Raliya, 2022 : Effect of nitrogen and zinc nanofertilizer with the organic farming practices on cereal and oil seed crops. *Scientific Rep.*, **12**(2): 1-7.

Kumar, S., Agarwal, R. K., Dixit, A. K. and Rai, S. K. 2012 : Forage crops and their management. Indian grassland and forage research institute, Jhansi Uttar Pradesh. India. 33 p.

Leghari, S. J., N. A. Wahocho, G. M. Laghari, A. H. Laghari, M. G. Bhabhan, K. H. Talpur, T. A. Bhutto, S. A. Wahocho, and A. A. Lashari, 2016 : Role of nitrogen for plant growth and development. *Advan. Environ. Biol.*, **10**(9): 209.

Mace, E. S., J. F. Rami, S. Bouchet, P. E. Klein, R. R. Klein and A. Kilian, 2009 : A consensus genetic map of sorghum that integrates multiple component maps and high-throughput diversity array technology markers. *BMC Plant Biol.*, **9**(13): 1-14.

Marzouk, N. M., H. A. Abd-Alrahman, A. M. M. EL-Tanahy and S. H. Mahmoud, 2019 : Impact of foliar spraying of nano micronutrient fertilizers on the growth, yield, physical quality, and nutritional value of two snap bean cultivars in sandy soils. *Bulletin of the National Res. Cent.*, **43**(1): 1-9.

Meena, L. R., S. A. Kochewad, V. Kumar, S. Malik, S. Kumar, L. K. Meena and A. S. Panwar, 2018 : Status of fodder production in the existing farming systems in Muzaffarnagar district of Uttar Pradesh. *Range Manag. Agrofor.*, **39**(2): 313-318.

Nasiri, Y., S. Zehtab-Salmasi, S. Nasrullahzadeh, N. Najafi and K. Ghassemi-Golezani, 2010: Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *J. Med. Plants Res.*, **4**: 1733-1737

Reddy, B. M., S. Elankavi, M. S. Kumar, M. V. Sai, B. Reddy and D. Vani, 2022 : Effects of conventional and nano fertilizers on growth and yield of Maize (*Zea mays* L.). *Bhartiya Krishi Anusandhan Patrika.*, **500***:* 1-4.

Satpal, B. Gangaiah, N. Kumar S. Devi, N. Kharor K. K. Bhardwaj, P. Kumari, D. S. Phogat and Neelam, 2020 : Performance of s ingle-cut forage sorghum cultivars at different fertilizer levels. *Forage Res.*, **46**(2): 202-207.

Sharma, K., Meena, R. H., Meena, S. C., Jain, D., Ameta, K. D., Khardia, N. and Meena, D. 2022 : Impact of foliar application of nano nitrogen and nano zinc on yield attributes and yield of Mustard (*Brassica juncea* L.). *Front. Crop Improv.*, **10**(1): 126-130.

Singh, D. N., J. S. Bohra, V. Tyagi, T. Singh, T. R. Banjara, and G. Gupta, 2021: A review of indian fodder production status and opportunities. *Grass Forage Sci.*, **77**(1): 1-10.

Singh, M. D., G. Chirag, P. O. Prakash, M. H. Mohan, G. Prakasha and Vishwajith, 2017 : Nano-fertilizers are a new way to increase nutrients use efficiency in crop production. *Int. J. Agric. Sci.*, **9**(7): 3831-3833.

Tarafdar, J. C., R. Raliya, H. Mahawar and I. Rathore, 2014: Development of zinc nano fertilizer to enhance crop production in pearl millet (*Pennisetum americanum*). *Agric. Res.*, **3**(3): 257- 262.

USDA. Washington DC, USA. 2022. World Agriculture Production. Published by USDA, Washington DC. (http://apps.fas.usda.gov/psdonline/ circulars/production. pdf).

Venkateswaran, K., M. Muraya, S. L. Dwivedi and H. D. Upadhyaya, 2014 : Wild sorghums their potential use in crop improvement. *'In: Y. Wang, H. D. Upadhyaya and K. Chittaranjan (Eds.) Genetics, genomics and breeding of sorghum'*. CRC Press, Florida, USA. pp 78-111.