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Quantifying the response of *rabi* sorghum (*Sorghum bicolor* L.) to nano urea

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Abstract
A field experiment was carried out during the *rabi* season of the year 2023-24 at College Farm, N. M. College of Agriculture, NAU, Navsari, Gujarat for "Quantifying the response of rabi sorghum [*Sorghum bicolor* L.] to nano urea". The experiment was laid out in Randomized Block Design having ten treatments comprising of T_1: Absolute control (0% N), T_2: 80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS, T_3: 80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS, T_4: 60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS, T_5: 60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS, T_6: 80% RDN + spray of urea (2%) at 30 DAS, T_7: 80% RDN + spray of urea (2%) at 30 and 45 DAS, T_8: 60% RDN + spray of urea (2%) at 30 DAS, T_9: 60% RDN + spray of urea (2%) at 30 and 45 DAS and T_{10}: 100% RDN through Urea with three replications. Among the different treatments, application of 80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS (T_3) recorded a significantly higher plant height, panicle length, number of grains per panicle, grain yield and straw yield but it was statistically at par with treatment T_{10} (100% RDN through Urea) except plant height at 30 DAS. Whereas, significantly lower higher plant height, panicle length, number of grains per panicle, grain yield and straw yield was recorded under treatment T_1 (Absolute control (0% N)). The maximum net return of 91009 ₹/ha was obtained under the treatment of 80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS (T_3) followed by treatment T_{10} (100% RDN through Urea). Maximum BCR of 2.34 was obtained under the treatment of 100% RDN through Urea (T_{10}) followed by treatment T_3(80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS).

Keywords: Sorghum, grain sorghum, millet, urea, nano urea, nitrogen, fertilizer, fertilization, RDN, GJ-101, grain, straw, stover, Gujarat

1. Introduction
India, now the most populous nation, faces rising food demand while cultivable land remains limited. Improving productivity through efficient agricultural practices is therefore essential. Grain sorghum (*Sorghum bicolor* L.), a major dryland cereal, ranks fifth globally after wheat, rice, maize and barley and serves as a staple food for millions in the semi-arid tropics of Asia and Africa. India is among the leading producers, with major contributions from Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh and Tamil Nadu.

Sorghum belongs to the family *Poaceae* and comprises about 25 species, of which *S. bicolor* is cultivated worldwide for grain and fodder. Sorghum is valued for its drought tolerance, efficient C_4 photosynthesis and stable grain and fodder yield under low-input conditions. Nutritionally, it contains 72.6% carbohydrates, 10-12% protein and significant dietary fibre (7.6-9.2%), along with essential amino acids, B-vitamins and minerals (Ahari *et al*., 2024) [1].

Nitrogen is the most limiting nutrient in Indian soils. It is essential for chlorophyll formation, protein synthesis, shoot growth and nutrient utilization. Sorghum responds strongly to nitrogen application, improving growth parameters and enhancing both green and dry fodder yields (Meena *et al*., 2012) [7]. However, the efficiency of conventional nitrogen fertilizers is low due to losses through volatilization, leaching and denitrification. This has raised the need for more efficient and environmentally safer nutrient technologies.

Nanotechnology offers a promising alternative. Nano fertilizers, particularly nano urea, improve nutrient-use efficiency by delivering nitrogen in ultra-small particles (18-30 nm) that are more

readily absorbed through the leaf surface. Urea is the most widely used nitrogen fertilizer, but its efficiency is limited due to losses through mineralization, immobilization, nitrification, denitrification and volatilization. Improving nitrogen-use efficiency has therefore been a major focus in recent decades (Sharma *et al*., 2022) [13]. Nanotechnology provides a promising solution, as nanoscale nutrients penetrate leaf tissues more effectively and enhance nutrient uptake pathways, leading to higher efficiency and reduced environmental losses.

The nano urea formulation contains 4% nitrogen with particle sizes <100 nm, a stable zeta potential (>30) and a shelf life of two years. Nano urea is applied as a foliar spray at

2-4 ml/l, synchronized with crop nitrogen demand. Typically, the first spray is given at 30-35 days after germination (or 20-25 days after transplanting) and the second about one week before flowering, with adjustments based on crop requirements. With a significantly larger surface area and higher particle density than conventional urea, nano urea applied at 2-4 ml/l during critical growth stages can enhance crop performance while reducing fertilizer losses (Kumar *et al*., 2021) [6].

2. Materials and Methods

A field experiment was carried out during *rabi* season of the year 2023-24 at College Farm, N. M. College of Agriculture, NAU, Navsari, Gujarat. Geographically, the campus of Navsari Agricultural University is located at 20°57´N latitude and 72°54´E longitude at an altitude of 10 m above the mean sea level. The soil of experiment field was clayey in texture with medium in organic carbon (0.49%), low in available nitrogen (246.98 kg/ha), medium in available phosphorus (35.33 kg/ha) and fairly high in available potassium (302.60 kg/ha). The soil has normal electric conductivity (0.36 dS/m) with normal in soil reaction (pH 7.32).

The climate of this region is characterized by three well defined seasons: a fairly hot summer, moderately cold winter and warm humid monsoon with annual rainfall of about 1854.20 mm. During the crop period, the maximum and minimum temperature ranged between 29.2 °C to 39.0 °C and 11.6 °C to 23.8 °C, respectively. The maximum and minimum relative humidity ranged between 59 to 96 per cent and 25 to 60 per cent, respectively.

The experiment was laid out in Randomized Block Design (RBD) having ten treatments comprising of T_1: Absolute control (0% N), T_2: 80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS, T_3: 80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS, T_4: 60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS, T_5: 60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS, T_6: 80% RDN + spray of urea (2%) at 30 DAS, T_7: 80% RDN + spray of urea (2%) at 30 and 45 DAS, T_8: 60% RDN + spray of urea (2%) at 30 DAS, T_9: 60% RDN + spray of urea (2%) at 30 and 45 DAS and T_{10}: 100% RDN through Urea with three replications.

Sorghum variety GJ-101 was sowed at a seed rate of 10 kg/ha after the experimental area was cleaned, stubbles were eliminated and clods were broken. The seeds were covered with soil after being sowed two to three cm deep with a 45 x 15 cm spacing. Fertilizer application in accordance with the approved procedures. The required dosage of fertilizers was 80:40:00 kg N: P_2O_5: K_2O per hectare. As baseline fertilizer, 50% of the required nitrogen dose and the recommended phosphorus dose (*via* SSP) were administered. For sorghum crop, the remaining 50% of N was applied as urea at 30 DAS. Furthermore, in accordance with the recommended treatments at 30 and 45 DAS, a foliar spray of 4 ml/l nano urea and 2% urea was sprayed. The gross plot size of each experimental unit was 4.5 m x 5.1 m and net plot size was 3.6 m x 4.5 m.

Growth and yield attributes of sorghum *viz*., plant height, panicle length and number of grains per panicle were recorded from five observational plants in each plot and the average was worked out. The plant height was measured in centimetres using a meter scale from the base of the plant to the growing tip of the stem at 30, 45 and 60 DAS and at harvest.

The panicle length was measured in centimetres using a meter scale from the base of the panicle to the top at harvest. Seed index was measure by combined sample of grains was gathered from the yield of each net plot and 100 grains were calculated and weighed in grams (g) using an electronic digital balance. The panicle from each net plot were cut off, sun dried and individually threshed., Following the threshing process which included cleaning and winnowing, the grains were weighed and documented as the grain yield per net plot in kilograms and grain yield was converted to a hectare basis and expressed in kilograms per hectare. The net plot was harvested and left in its respective plot for approximately 8-10 days for sun drying. Subsequently entire yield was weighed in kilograms. Plot-wise straw yield was determined by subtracting the grain yield from the biological yield and result was then converted to kilograms per hectare. The harvest index is the ratio of economic yield to the biological yield. It was calculated by using the formula (Donald and Hamblin 1976) [5].

$$\text{Harvest index (\%)} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

The cost of cultivation and the gross returns were calculated using the straw yield of sorghum and the market price of the produce at the time of marketing. The net returns per hectare were calculated by deducting the cost of cultivation per hectare from the gross returns per hectare.

Net monetary returns = Gross monetary returns - Total cost of cultivation

Benefit cost ratio was worked out for each treatment by using following formula.

$$\text{B:C} = \frac{\text{Net returns (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

Data analysis was conducted following the standard procedure for analysis of variance (ANOVA) as described by (Panse and Sukhatme, 1954) [10] and differences in treatment means were tested using the critical difference (CD) at a 5% level of probability.

3. Results and Discussion

Growth parameters

Plant population: On examination of data presented in Table 1 clearly shows that the different treatments did not manifest their significant effect on initial and final plant population of *rabi* sorghum. Thus, whatever variation observed in the investigation is likely to be attributed to different treatments applied in the experiment. This suggests that none of the treatments had a detrimental impact on the germination, emergence, or survival rates of the plants.

Plant height at 30 DAS: The result sown in Table 1 indicated that significantly higher plant height at 30 DAS was reported in T_{10} (100% RDN through Urea) which was statistically at par with the treatments T_3. Whereas significantly lower plant height

was recorded with the control treatment. The per cent increase of plant height at 30 DAS of treatment T_{10} was 31.77% over control.

Plant height at 45 DAS: The finding was sown in Table 1, indicate that the different treatments had a significant effect on the plant height. Significantly maximum plant height was obtained with the application of 80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS (T_3) at 45 DAS and it was statistically at par with treatment T_{10} (100% RDN through urea). Whereas, the treatment T_1 (Absolute control (0% N)) recorded significantly lower plant height at 45 DAS. The per cent increase of plant height at 45 DAS of treatment T_3 was 29.94% over control.

Table 1: Effect of different treatments on growth parameters of sorghum

Treatments		Plant population per net plot		Plant height (cm)				Days to 50% flowering	Days to physiological maturity
		20 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest		
T_1	Absolute control (0% N)	235	213	23.6	69.8	109.9	158.9	72	113
T_2	80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS	238	219	29.2	85.4	134.9	186.9	77	116
T_3	80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS	239	220	30.3	90.7	142.6	196.0	77	117
T_4	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS	237	214	28.2	81.2	127.3	161.9	76	115
T_5	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS	238	219	27.9	79.3	125.8	160.9	75	115
T_6	80% RDN + spray of urea (2%) at 30 DAS	238	219	29.5	84.1	127.5	168.2	77	116
T_7	80% RDN + spray of urea (2%) at 30 and 45 DAS	238	217	29.4	82.3	128.1	170.4	76	116
T_8	60% RDN + spray of urea (2%) at 30 DAS	237	216	27.7	78.6	120.7	160.3	72	114
T_9	60% RDN + spray of urea (2%) at 30 and 45 DAS	238	219	27.8	79.1	121.4	160.9	73	115
T_{10}	100% RDN through Urea	239	224	31.1	87.1	137.4	195.8	77	117
S.Em±		10.35	11.73	1.31	3.61	5.82	8.78	3.57	5.71
CD at 5%		NS	NS	3.90	10.74	17.30	26.07	NS	NS
CV (%)		7.54	9.32	7.99	7.66	7.90	8.84	8.23	8.57

Note: 100% RDN: 80 kg N/ha, 80% RDN: 64 kg N/ha, 60% RDN: 48 kg N/ha

Plant height at 60 DAS and at harvest: The mean data summarized in Table 1 indicated that plant height at 60 DAS was significantly influenced by the different nutrient management treatments. The treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) recorded significantly higher plant height at 60 DAS and at harvest but it was statistically at par with the treatment T_{10} (100% RDN through Urea). Whereas, the treatment T_1 (absolute control) recorded significantly lowest plant height. The per cent increase of plant height of treatment T_3 at 60 DAS is 29.75% and at harvest is 23.35% over control.

The significant increase in plant height may be attributed to the basal application of conventional fertilizers combined with foliar spraying of nano fertilizers. This combination likely enhanced enzyme activity and auxin metabolism within the plant, promoting cell enlargement and elongation, which ultimately led to taller plant growth. Similar results of increase in plant height were also reported by Sharma *et al.* (2022) [13], Chinnappa *et al.* (2023) [4], Udapudi *et al.* (2023) [14] and Meena *et al.* (2024) [8].

Days to 50% flowering: A critical examination of the data revealed that the differences among treatments were not statistically significant. This indicates that the application of different nitrogen levels and foliar sprays, whether through nano urea or conventional urea, did not have a marked influence on the flowering time of rabi sorghum. Hence, the variations observed in days to 50% flowering may be attributed to the treatments applied, but they were not significant enough to establish a consistent trend.

Days to physiological maturity: Upon detailed analysis, it was found that the differences among treatments were not statistically significant. This implies that the use of different nitrogen levels and foliar applications, whether with nano urea or conventional urea, did not significantly influence the duration required for the crop to reach physiological maturity. As a result, while some variation was observed among treatments, these differences couldn't be confidently linked to the treatment effects due to the absence of statistical significance.

Yield attributes and yield: The data on different yield attributes *viz*., panicle length, number of grains per panicle, seed index, grain yield, straw yield and harvest index are presented in Table 2.

Panicle length at harvest (cm): Among various treatments, treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) were recorded significantly higher panicle length over control, which was statistically at par with the treatments T_{10} (100% RDN through Urea). However, significantly lower panicle length was recorded with the control treatment. Foliar application of nano nitrogen enhanced nitrogen absorption through both leaves and roots, potentially increasing the conversion of synthesized carbohydrates into amino acids and proteins, thereby promoting accelerated cell division and elongation. Furthermore, as the nitrogen dose increased, the plant obtained more nourishment for development and growth, resulting in a healthier panicle length. The results were similar to the findings of Arya *et al.* (2022) [2], Sharma *et al.* (2022) [13] and Meena *et al.* (2024) [8].

Number of grains per panicle: Data revealed that significantly higher number of grains per panicle were reported in T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) which was statistically at par with the treatments T_{10} (100% RDN through Urea). Whereas significantly lowest no. of grains per panicle were recorded with the control treatment. The significant rise in the number of grains per panicle might be due to enhanced overall plant growth resulting from improved nutrient availability through foliar fertilizer application. Moreover, the timely supply of nitrogen promotes the initiation of grain development by boosting the absorption and movement of

photosynthates from the source to the sink. These results conform with findings of Arya *et al.* (2022) [2].

Seed index (g): From the data presented in Table 2, it is observed that seed index of sorghum was not remarkably influenced due to the different treatments.

Grain yield (kg/ha): It can be observed that different treatments showed significant impact on grain yield of sorghum. Significantly higher grain yield was recorded with the treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS), which was statistically at par with the treatments T_{10} (100% RDN through Urea). While significantly lower grain yield was recorded with the treatment T_1 (absolute control). The extended presence of nanomaterials in the plants, which increased productivity, is linked to the yield increase. Furthermore, the combination of nano fertilizers increased the efficiency of traditional fertilizers, most likely improving plant cell's ability to absorb nutrients. Because of this optimization, plant structures and metabolic activities like photosynthesis grew more effectively, increasing the accumulation and movement of photosynthetic products to the economic parts of plants and ultimately increasing yields. The similar findings were reported by Arya *et al.* (2022) [2], Rajput *et al.* (2022) [11], Chinnappa *et al.* (2023) [4], Ojha *et al.* (2023) [9] and Meena *et al.* (2024) [8].

Straw yield (kg/ha): It can be observed from the data presented in Table 2 that different treatments showed a significant impact on straw yield. Significantly higher straw yield was recorded with the treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) which was statistically at par with the treatments T_{10} (100% RDN through Urea). While significantly lower straw yield was recorded with the treatment T_1 (absolute control). The increase in the straw yield with the foliar spray of higher dose of Nano-urea might be due to their rapid uptake by plants and ease of translocation at a faster pace, that aided in higher rate of photosynthesis and more dry matter accumulation which resulted in higher straw yield. These findings were in agreement with the reports of Sahu *et al.* (2022) [12], Rajput *et al.* (2022) [11], Chavan *et al.* (2023) [3], Chinnappa *et al.* (2023) [4] and Meena *et al.* (2024) [8].

Table 2: Effect of different treatments on yield attributes and yield of sorghum

Treatments		Panicle length (cm)	No. of grains/ panicle	Seed index (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
T_1	Absolute control (0% N)	14.1	532	2.90	1624	5514	22.69
T_2	80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS	19.5	584	3.04	2079	6561	24.10
T_3	80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS	20.9	735	3.07	2241	7034	24.16
T_4	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS	16.0	572	2.96	1801	5752	23.85
T_5	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS	16.8	566	2.94	1873	5813	24.45
T_6	80% RDN + spray of urea (2%) at 30 DAS	17.3	583	3.01	1901	5885	24.56
T_7	80% RDN + spray of urea (2%) at 30 and 45 DAS	18.2	619	3.02	1927	6010	24.23
T_8	60% RDN + spray of urea (2%) at 30 DAS	15.9	544	2.98	1708	5640	23.30
T_9	60% RDN + spray of urea (2%) at 30 and 45 DAS	16.0	550	3.00	1779	5654	23.80
T_{10}	100% RDN through Urea	20.3	718	3.04	2181	6790	24.38
SEm±		0.88	28.69	0.14	104.95	287.14	1.14
CD at 5%		2.62	85.24	NS	311.82	853.13	NS
CV (%)		8.72	8.28	7.99	9.51	8.2	8.25

Harvest index (%): Data presented in Table 2 reveals that the effect of different treatments on harvest index was found non-significant. However, numerically higher harvest index (24.56%) was found under the treatments T_6 and lower (22.69%) under the treatment T_1.

Economics

Cost of Cultivation (₹/ha): The summarization of data presented in Table 3 suggested that among the different treatments, treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) recorded cost of cultivation (40835 ₹/ha) followed by the treatment T_5 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS), T_2 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS), T_4 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS), T_7 (80% RDN + spray of urea (2%) at 30 and 45 DAS), T_9 (60% RDN + spray of urea (2%) at 30 and 45 DAS),T_6 (80% RDN + spray of urea (2%) at 30 DAS), T_{10} (100% RDN through Urea), T_8 (60% RDN + spray of urea (2%) at 30 DAS) and T_1 (Absolute control (0% N)) with 40614, 39451, 39230, 38916, 38694, 38492, 38289, 38270 and 36765 ₹/ha, respectively.

Table 3: Effect of different treatments on economics of sorghum

Treatments		Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
T_1	Absolute control (0% N)	98044	36765	61279	1.67
T_2	80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS	122526	39451	83075	2.11
T_3	80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS	131844	40835	91009	2.23
T_4	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS	106552	39230	67322	1.72
T_5	60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS	109798	40614	69184	1.70
T_6	80% RDN + spray of urea (2%) at 30 DAS	111350	38492	72858	1.89
T_7	80% RDN + spray of urea (2%) at 30 and 45 DAS	113140	38916	74224	1.91
T_8	60% RDN + spray of urea (2%) at 30 DAS	102160	38270	63890	1.67
T_9	60% RDN + spray of urea (2%) at 30 and 45 DAS	105084	38694	66390	1.72
T_{10}	100% RDN through Urea	127980	38289	89691	2.34
Selling price of sorghum grain @ ₹ 40/kg			Selling price of sorghum Straw @ ₹ 6/kg		

Gross Return (₹/ha): Among the different treatments, treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) recorded higher gross returns (131844 ₹/ha) followed by the treatment T_{10} (100% RDN through Urea), T_2 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS), T_7 (80% RDN + spray of urea (2%) at 30 and 45 DAS), T_6 (80% RDN + spray of urea (2%) at 30 DAS), T_5 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS), T_4 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS), T_9 (60% RDN + spray of urea (2%) at 30 and 45 DAS), T_8 (60% RDN + spray of urea (2%) at 30 DAS) and T_1 (Absolute control (0% N)) with 127980, 122526, 113140, 111350, 109798, 106552, 105084, 102160 and 98044 ₹/ha, respectively.

Net Return (₹/ha): The treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS) recorded higher net returns (91009 ₹/ha) followed by the treatment T_{10} (100% RDN through urea), T_2 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS), T_7 (80% RDN + spray of urea (2%) at 30 and 45 DAS), T_6 (80% RDN + spray of urea at 30 DAS (2%)), T_5 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS), T_4 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS), T_9 (60% RDN + spray of urea (2%) at 30 and 45 DAS), T_8 (60% RDN + spray of urea (2%) at 30 DAS) and T_1 (Absolute control (0% N)) with 89691, 83075, 74224, 72858, 69184, 67322, 66390, 63890 and 61279 ₹/ha, respectively.

B:C Ratio: Among all the treatments, higher B:C Ratio (2.34) was found under the treatment T_{10} (100% RDN through urea) followed by the treatment T_3 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 and 45 DAS), T_2 (80% RDN + spray of nano urea @ 4.0 ml/l at 30 DAS), T_7 (80% RDN + spray of urea (2%) at 30 and 45 DAS),T_6 (80% RDN + spray of urea (2%) at 30 DAS), T_9 (60% RDN + spray of urea (2%) at 30 and 45 DAS), T_4 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 DAS), T_5 (60% RDN + spray of nano urea @ 4.0 ml/l each at 30 and 45 DAS), T_1 (Absolute control (0% N)) and T_8 (60% RDN + spray of urea (2%) at 30 DAS) with 2.23, 2.11, 1.91, 1.89, 1.72, 1.72, 1.70, 1.67,1.67 respectively.

These findings are consistent with research reported by Rajput *et al.* (2022) [11], Chinnappa *et al.* (2023) [4], Udapudi *et al.* (2023) [14] and Meena *et al.* (2024) [8].

Conclusion

The findings of the present study indicate that fertilization of *rabi* sorghum with 80% RDN (64 kg N/ha) along with foliar application of nano-urea at 4.0 ml/l at 30 and 45 DAS resulted in higher yield and economic returns, and was statistically comparable to 100% RDN (80 kg N/ha) applied through urea.

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