



# Nutrient Management with Nitrogen Based Formulations for Enhancing Growth and Yield in Fodder Sorghum [Sorghum bicolor (L.) Moench]

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Fertilizers play a vital role in agricultural practices by boosting crop yield. Among various nutrient application methods, foliar application is one of the cost-effective method which allow rapid and efficient nutrient absorption through the stomata or cuticle, and subsequently into the cells. Applying nutrients through foliage offers several benefits, such as rapid nutrient absorption by plant tissues, improved transport to developing plant parts, elimination of leaching and fixation losses,

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regulated nutrient uptake by crops and enhanced nutrient utilization. Timely foliar application of nano fertilizers enhances crop output while reducing environmental risks. The current study aimed to evaluate the different concentrations of nano urea on growth and yield of fodder sorghum. The study was conducted at Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during December 2023- February 2024. The field experiment was laid out in randomized block design with 13 treatments, replicated thrice. The treatments were T<sub>1</sub>:75% recommended dose of nitrogen (RDN) + nano urea (0.2%); T<sub>2</sub>:75% RDN+ nano urea (0.4%); T<sub>3</sub>:75% RDN + nano urea (0.6%); T<sub>4</sub>:100% RDN + nano urea (0.2%); T<sub>5</sub>:100% RDN + nano urea (0.4%); T<sub>6</sub>:100% RDN + nano urea (0.6%); T<sub>7</sub>:75% RDN + urea spray (2%); T<sub>8</sub>:100% RDN + urea spray (2%); T<sub>9</sub>: nano urea alone (0.2%); T<sub>10</sub>: nano urea alone (0.4%); T<sub>11</sub>: nano urea alone (0.6%); T<sub>12</sub>: KAU POP and T<sub>13</sub>: Control (without nitrogen). Both nano urea and urea spray were applied at 20 DAS and 40 DAS. Soil application of nitrogen was applied in three splits - 50% as basal, 25% at 20 DAS and 25% at 40 DAS. Full P and K were applied as basal. The study revealed that application of 100% RDN along with nano urea 0.4% proved its superiority by registering higher growth and yield attributes such as plant height, stem diameter, leaf: stem ratio, green fodder yield and dry fodder yield.

**Keywords:** Sorghum; fertilizers; nutrient; nitrogen; urea.

## 1. INTRODUCTION

The total livestock population of India is 535.6 million (cattle-192.5 million, buffalo- 109.8 million, sheep-74.3 million, goat-148.8 million, others-10.2 million) [1]. Approximately 20.5 million people in the country depend on livestock for their livelihood. Though India is having the highest livestock population (535.78 M) and milk production (221.06 Mt) productivity per animal is far below compared to the developing countries [2]. In Kerala, the livestock population is about 29.08 lakh which is 6.32 per cent higher than the previous census (2012). India has a supply of green fodder and dry fodder of 590.4 Mt and 467.6 Mt whereas, the demand for both is 530.5 Mt and 851.3 Mt respectively (IGFRI, Vision 2050). However, the country has only 4 per cent of the cultivated area under fodder crops. The country faces net deficit of 35.6 per cent in green fodder and 10.95 per cent in dry fodder and 44 per cent in concentrate feed ingredients [3].

Sorghum is often referred to as the "camel crop" because of its resilience to drought, waterlogging and saline-alkaline conditions. It is one of the most efficient C<sub>4</sub> plants for photosynthesis. Sorghum contains 6.10-7.37 per cent crude protein, 66.76-67.94 per cent neutral detergent fibre, 35.79-36.97 per cent acid detergent fibre, 4.58-4.79 per cent acid detergent lignin, 1.61-1.98 per cent ether extract and 9.15-9.59 per cent total ash content on dry matter basis [4]. In addition to its grains, it provides fodder which is nutritious and palatable. It can also be preserved as silage or hay for future use. Imbalanced use of fertilizer is a key factor restricting the fodder productivity and quality across various climatic

regions in the country [5]. Consequently, developing location-specific production strategies to supply high quality fodder for improving nutrition offers an excellent opportunity to provide good quality fodder for ever-increasing livestock population.

More than 70 percent of the conventional urea applied to soil is not taken up by plants, and is lost. It can lead to soil acidification and water pollution. Furthermore, adverse soil conditions like low moisture, pH imbalances, and salinity can hinder nutrient absorption by plants. To enhance crop production, applying nutrients through foliar spray as a supplement to soil application is considered as an effective practice [6]. Foliar feeding allows rapid and efficient nutrient absorption, minimizes losses from leaching and soil fixation and regulates nutrient uptake by plants [7]. The application of essential nutrients through foliar spray at the critical growth stages is crucial for enhancing their effectiveness and improving crop yield [8]. Additionally, foliar application of nutrients can be an environment friendly fertilization method, as they deliver nutrients directly to the plant in controlled amounts, reducing the ecological impact associated with soil fertilization.

The use of nanotechnology as a fertilizer source could serve as a viable alternative to traditional fertilizers on a larger scale. The nanoscale size contributes to a higher surface-to-volume ratio, optimizing fertilizer requirement more efficiently [9]. Nano fertilizer technology is designed to deliver nutrients in a controlled way that aligns with crop requirements, thereby improving nutrient use efficiency without adverse

effects [10]. Additionally, nano fertilizers play a crucial role in the physiological and biochemical processes of crops by enhancing nutrient availability, boosting metabolic activities and promoting meristematic functions, which leads to increased apical growth and larger photosynthetic area [11].

Nano fertilizers enter plants through the xylem, with irrigation water being the most effective delivery method. Foliar application is also recommended and has been shown to be effective when nano fertilizers move through the phloem [12]. The movement and storage of nutrients released by nano fertilizers in plants are influenced by the content and size of the nanoparticles, plant physiology and the pore size of cell walls Corredor et al., [13]. Moreover, nano fertilizers can enhance soil fertility, improve crop yield and quality, increase disease resistance, strengthen plant stability and reduce harm to humans and the environment [14]. Today, nano fertilizers are emerging as a viable alternative to conventional fertilizers [15].

Kantwa et al. [16] found that nano urea contains 4 per cent nitrogen by weight in its nano form, effectively meets the crop nitrogen requirement. It has a nitrogen use efficiency of over 80 per cent, which is higher than that of conventional urea [17]. Nano urea have a particle size less than 50 nm and found ideal for foliar nutrition due to its better penetration in the plant system. Due to their high surface area, nano urea release nutrients slowly and steadily, aligning with crop demand [18].

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The field experiment was to evaluate the effect of different concentrations of nano urea on growth and yield of fodder sorghum and was conducted at College of Agriculture, Vellayani, Kerala Agricultural University, India during December 2023 - February 2024. The experiment was laid out in randomized block design with 13 treatments replicated thrice, as follows: T<sub>1</sub>:75% recommended dose of nitrogen (RDN) + nano urea (0.2%); T<sub>2</sub>:75% RDN+ nano urea (0.4%); T<sub>3</sub>:75% RDN + nano urea (0.6%);T<sub>4</sub>:100% RDN + nano urea (0.2%); T<sub>5</sub>:100% RDN + nano urea (0.4%); T<sub>6</sub>:100% RDN + nano urea (0.6%); T<sub>7</sub>:75% RDN + urea spray (2%); T<sub>8</sub>:100% RDN + urea spray (2%); T<sub>9</sub>: nano urea alone (0.2%); T<sub>10</sub>: nano urea alone (0.4%); T<sub>11</sub>: nano urea alone (0.6%); T<sub>12</sub>: KAU POP (60:40:20 NPK kg ha<sup>-1</sup>) T<sub>13</sub>: Control

(without nitrogen). Both the nano urea and urea spray were applied at 20 DAS and 40 DAS. Nitrogen was applied in three splits -50% as basal and 25% each at 20 DAS and 40 DAS. Full P and K were applied as basal.

The variety used for the study was CNFS-1, single cut variety released from Zonal Agricultural Research Station Mandya. The soil in the experimental site was identified as sandy clay loam in texture, moderately acidic (5.63) in reaction, low in organic carbon (0.56), medium in available nitrogen (413.95 kg ha<sup>-1</sup>) and available potassium (278.38 kg ha<sup>-1</sup>) and high in available phosphorus (62.44 kg ha<sup>-1</sup>). The seeds were sown with a spacing of 30 cm X 15 cm. RDF (Recommended dose of fertilizer) use for the study was (60:40:20 NPK kg ha<sup>-1</sup>). All other agronomic practices were followed uniformly in all the treatments as per the package of practices for Kerala Agricultural University, India (KAU POP). Five plants were randomly selected from each treatment to record the observations.

Observations on plant height and stem diameter were taken at 15, 30, 45 DAS and at harvest. Harvesting of the crop was done at 50 per cent flowering stage. After harvesting the weight of green fodder from each plot was taken (kg plot<sup>-1</sup>) and converted into t ha<sup>-1</sup>. Random sample of green fodder of 500 gm was taken separately from each net plot were sundried and then oven dried to a constant weight at 65 + 5 °C. The dry fodder yield was worked out and expressed in t ha<sup>-1</sup>.

## 3. RESULTS AND DISCUSSION

### 3.1 Plant Height

Data on plant height showed that at 30 DAS, taller plants (75.52 cm) were produced by 100 per cent RDN + nano urea 0.4 per cent (T<sub>5</sub>) and was on par with T<sub>6</sub>. While, foliar application of nano urea 0.6 per cent + 100 per cent RDN (T<sub>6</sub>) at both 45 DAS and at harvest, resulted in taller plants (132.41 cm and 226.62 cm) which was comparable with T<sub>5</sub>. The reason for increase in plant height might be due to improved nutrient uptake by the plant. This enhanced uptake supported optimal growth of plant parts and metabolic processes such as photosynthesis, led to maximum accumulation and translocation of photosynthates to economic parts of the plants. This can be attributed to increased source and sink strength [19].

Nano fertilizers are easily absorbed by the leaf epidermis and transported to the stem, which

promoted the uptake of active molecules and boost growth. It delivers nutrients directly to plants or enhanced the uptake and transport of existing nutrients, which led to better crop growth. Nano particles can move more easily within plant, enhancing nutrient distribution and promoting new cell growth, which might have led to increased plant height in maize [20]. Nano urea has shown to be more effective than conventional urea in nutrient uptake and utilization. It provides nitrogen in a controlled release manner, which reduces losses due to leaching and volatilization. This enhanced efficiency might have improved plant growth and development, potentially resulted in taller plants. Similar findings were observed by Abdel-Aziz et al. [21] in wheat Prakasha et al. [22] in maize Samui et al. [9] in maize.

### 3.2 Stem Diameter

At 30, 45 DAS and at harvest stem diameter was observed higher with T<sub>6</sub> and was comparable with T<sub>5</sub>. This might be due to foliar spray of nano urea which enhanced the photosynthetic rate by providing more space for various biochemical activities within the plant. Moreover, this increased activity leads to more dry matter accumulation and carbohydrates production, which in turn resulted in maximum stem diameter

[23]. The increase in stem diameter is associated with increased number of leaves, which resulted in enhanced biomass production and higher photosynthetic rate Sudha et al. [24] in maize. Also, adequate nitrogen supply promoted greater absorption of nutrients and resulted in rapid expansion of plant parts, including stem diameter. These results are in close conformity with Raliya et al. [25], Juthery et al. [26] in wheat and Salama and Badry [27] in teosinte.

### 3.3 Leaf: Stem Ratio

Data revealed that T<sub>5</sub> recorded higher leaf: stem ratio (0.39) which was comparable with T<sub>6</sub>. It was attributed to rapid growth of dark green foliage, which enhanced the ability of plant to capture and utilize solar radiation for photosynthesis, which led to increased meristematic activity and resulted in higher leaf: stem ratio as nitrogen levels were increased in fodder sorghum. Furthermore, this might be due to favorable effect of nitrogen on cell division and elongation and recorded higher number of leaves that sustained longer period in fodder sorghum [28]. Similar results are also reported by Yadav et al. [29] in multi-cut sorghum and Satpal et al. [30] in fodder sorghum.

**Table 1. Chemical properties of soil before the experiment**

Soil texture	Soil pH	Electrical conductivity (dS m <sup>-1</sup> )	Organic carbon (%)	Available N (kg ha <sup>-1</sup> )	Available P (kg ha <sup>-1</sup> )	Available K (kg ha <sup>-1</sup> )
Sandy clay loam	5.63	0.21	0.56	413.95	62.44	278.38

**Table 2. Effect of nitrogen management and foliar nutrition on plant height of fodder sorghum at various stages of crop growth, cm**

Treatment	15 DAS	30 DAS	45 DAS	At Harvest
T <sub>1</sub> - 75% RDN + nano urea (0.2%)	24.87	60.12	87.22	174.52
T <sub>2</sub> - 75% RDN + nano urea (0.4%)	24.99	60.17	87.52	175.17
T <sub>3</sub> - 75% RDN + nano urea (0.6%)	26.04	60.38	101.23	181.57
T <sub>4</sub> - 100% RDN + nano urea (0.2%)	30.43	60.40	93.98	191.48
T <sub>5</sub> - 100% RDN + nano urea (0.4%)	31.30	75.52	116.61	208.58
T <sub>6</sub> - 100% RDN + nano urea (0.6%)	30.71	74.95	132.41	226.62
T <sub>7</sub> - 75% RDN + urea spray (2%)	27.68	60.09	78.04	171.56
T <sub>8</sub> - 100% RDN + urea spray (2%)	28.04	63.29	90.10	181.55
T <sub>9</sub> - Nano urea alone (0.2%)	22.94	57.82	73.82	166.71
T <sub>10</sub> - Nano urea alone (0.4%)	23.16	58.73	76.70	167.33
T <sub>11</sub> - Nano urea alone (0.6%)	23.15	59.64	78.71	170.15
T <sub>12</sub> - KAU POP (60:40:20 kg NPK ha <sup>-1</sup> )	31.36	60.29	95.62	180.69
T <sub>13</sub> - Control (without nitrogen)	22.48	47.69	57.67	136.30
<b>SEm (+)</b>	<b>2.43</b>	<b>4.22</b>	<b>6.57</b>	<b>11.39</b>
<b>CD (P=0.05)</b>	<b>NS</b>	<b>12.312</b>	<b>19.189</b>	<b>33.237</b>

NS-Not Significant, RDN-Recommended Dose of Nitrogen

**Table 3. Effect of nitrogen management and foliar nutrition on stem diameter of fodder sorghum at various stages of crop growth, mm**

Treatment	15 DAS	30 DAS	45 DAS	At Harvest
T <sub>1</sub> - 75% RDN + nano urea (0.2%)	3.79	9.44	9.95	10.37
T <sub>2</sub> - 75% RDN + nano urea (0.4%)	3.92	8.85	10.14	11.01
T <sub>3</sub> - 75% RDN + nano urea (0.6%)	4.38	9.46	12.31	13.08
T <sub>4</sub> - 100% RDN + nano urea (0.2%)	4.06	8.89	10.59	11.04
T <sub>5</sub> - 100% RDN + nano urea (0.4%)	4.70	10.55	12.36	13.16
T <sub>6</sub> - 100% RDN + nano urea (0.6%)	4.42	11.06	12.94	15.19
T <sub>7</sub> - 75% RDN + urea spray (2%)	3.87	8.81	9.42	10.15
T <sub>8</sub> - 100% RDN + urea spray (2%)	4.42	10.07	11.90	11.27
T <sub>9</sub> - Nano urea alone (0.2%)	3.70	7.52	8.36	9.00
T <sub>10</sub> - Nano urea alone (0.4%)	3.66	7.57	8.71	9.20
T <sub>11</sub> - Nano urea alone (0.6%)	3.77	7.95	8.99	9.59
T <sub>12</sub> - KAU POP (60:40:20 kg NPK ha <sup>-1</sup> )	4.53	8.48	9.91	10.66
T <sub>13</sub> - Control (without nitrogen)	3.57	6.48	7.00	7.27
<b>SEm (+)</b>	<b>0.26</b>	<b>0.68</b>	<b>0.98</b>	<b>1.04</b>
<b>CD (P=0.05)</b>	<b>NS</b>	<b>1.995</b>	<b>2.849</b>	<b>3.022</b>

NS-Not Significant, RDN-Recommended Dose of Nitrogen

**Table 4. Effect of nitrogen management and foliar nutrition on leaf: stem ratio, green fodder yield and dry fodder yield of fodder sorghum**

Treatment	Leaf: Stem Ratio	Green Fodder Yield (t ha <sup>-1</sup> )	Dry Fodder Yield (t ha <sup>-1</sup> )
T <sub>1</sub> - 75% RDN + nano urea (0.2%)	0.29	20.33	3.40
T <sub>2</sub> - 75% RDN + nano urea (0.4%)	0.30	21.95	4.14
T <sub>3</sub> - 75% RDN + nano urea (0.6%)	0.32	24.33	4.53
T <sub>4</sub> - 100% RDN + nano urea (0.2%)	0.30	23.17	4.40
T <sub>5</sub> - 100% RDN + nano urea (0.4%)	0.39	32.03	5.81
T <sub>6</sub> - 100% RDN + nano urea (0.6%)	0.37	30.00	5.51
T <sub>7</sub> - 75% RDN + urea spray (2%)	0.28	21.00	3.92
T <sub>8</sub> - 100% RDN + urea spray (2%)	0.30	23.00	4.22
T <sub>9</sub> - Nano urea alone (0.2%)	0.24	19.33	2.00
T <sub>10</sub> - Nano urea alone (0.4%)	0.25	19.50	3.08
T <sub>11</sub> - Nano urea alone (0.6%)	0.26	20.00	3.13
T <sub>12</sub> - KAU POP (60:40:20 kg NPK ha <sup>-1</sup> )	0.30	22.33	4.21
T <sub>13</sub> - Control (without nitrogen)	0.20	14.00	1.77
<b>SEm (+)</b>	<b>0.02</b>	<b>2.08</b>	<b>0.38</b>
<b>CD (P=0.05)</b>	<b>0.055</b>	<b>6.055</b>	<b>1.110</b>

### 3.4 Green Fodder Yield

The treatment (T<sub>5</sub>) exhibited higher green fodder yield (32.03 t ha<sup>-1</sup>) and was 43.43 per cent higher compared to T<sub>12</sub>. This may be attributed to rapid absorption and assimilation of nano nutrients, which led to improved growth characteristics such as increased plant height and leaf area. This increased yield could be linked to prolonged presence of nanomaterials in plants, which led to greater productivity. Moreover, combined effect of nano fertilizers enhanced

effectiveness of conventional fertilizers, which might have contributed to improved nutrient absorption by plant cells. This resulted in optimal growth of plant parts and metabolic processes like photosynthesis, which in turn increased accumulation and movement of photosynthetic products to economic plant parts and ultimately led to higher yields. This is supported by the findings of Bocharé et al. [31] in fodder maize, Meena et al. [32] in fodder maize and Samui et al. [9] in maize.

### 3.5 Dry Fodder Yield

Dry fodder yield was observed higher with T<sub>5</sub> (5.81 t ha<sup>-1</sup>) and was 38.00 per cent higher compared to T<sub>12</sub>. The increase in dry fodder yield was largely due to higher efficiency and absorption of nano urea within plant, which can be linked to its large surface area and small particle size. This might have contributed to increased biomass production and resulted in higher green fodder yield and dry fodder yield in sorghum. The results are in corroboration with the findings of Singh et al. [33] in fodder sorghum and Meena et al. [32] in fodder maize [34-36].

### 4. CONCLUSION

Based on the study it could be concluded that nitrogen management along with foliar application of nitrogen-based formulations improved the growth and yield of fodder sorghum. There was an increased yield of green fodder (39.26%) when nano urea (0.4%) was supplemented with RDF compared to urea spray (2%). When the fertilizer level was decreased to 25 percent, growth and yield attributes were also found to be reduced. Thus, the result of the research work revealed that soil application of 100 per cent recommended dose of fertilizer (60:40:20 NPK kg ha<sup>-1</sup>) along with foliar spray of nano urea, 0.4 per cent at both 20 DAS and 40 DAS is beneficial for growing fodder sorghum in terms of growth and yield in Kerala during the rabi season.

### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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