Nutrient Management with Nitrogen Based Formulations for Enhanc~~ed~~ingGrowth ~~and Yield~~and Yieldin Fodder Sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT

Fertilizers play a ~~crucial~~vital role in agricultural practices by boosting crop yield. Among various nutrient application methods, foliar application is one of the ~~effective~~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, 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 andyield of fodder sorghum. The study was conducted at Instructional Farm, Vellayani, Thiruvananthapuram, Kerala during December 2023-February 2024. The field experimentwas laid out in randomized block design with 13 treatments, replicated thrice. The treatments were T_1:75% recommended dose of nitrogen (RDN) + nano urea (0.2%);T_2:75% RDN+ nano urea (0.4%);T_3:75% RDN + nano urea (0.6%);T_4:100% RDN + nano urea (0.2%);T_5:100% RDN + nano urea (0.4%);T_6:100% RDN + nano urea (0.6%);T_7:75% RDN + urea spray (2%); T_8:100% RDN + urea spray (2%);T_9: nano urea alone (0.2%); T_{10}:nano urea alone (0.4%); T_{11}:nano urea alone (0.6%); T_{12}:KAU POP and T_{13}: Control (withoutnitrogen). Both nano urea and urea spray were applied at 20 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. Thestudyrevealedthatcombined application of RDN along with nano urea 0.4% proved its superiority by registering higher growth and yield attributes such as plant height,stem girth, leaf: stem ratio, green fodder yield and dry fodder yield.

1. INTRODUCTION

The total livestock population of India is 535.6 million (cattle-192.5 million,buffalo-109.8million,sheep–74.3million,goat–148.8million,others-10.2million) (Livestock census, 2019).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 (Vijay *et al*., 2018). 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 (Singh *et al*., 2022)

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_4 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 (Bhakar *et al*., 2020). 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 (Tokas *et al*., 2021). Consequently, developing location-specific production strategies to supply high quality fodder for improving nutrition offers an excellent opportunity to providegood 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 (Alam *et al*., 2010). Foliar feeding allows rapid and efficient nutrient absorption, minimizes losses from leaching and soil fixation and regulates nutrient uptake by plants (Rahman *et al*., 2014). The application of essential nutrients through foliar spray at the critical growth stages is crucial for enhancing their effectiveness and improving crop yield (Anandhakrishnaveni*et al*., 2004). 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 (Samui *et al*., 2022). 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 (Naderi and Danesh-Shahraki, 2013). 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 (Mahil and Kumar, 2019).

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 (Pitambara *et al*.,2019). 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*., 2009). Moreover, nano fertilizers can enhance soil fertility, improvecrop yield and quality, increase disease resistance, strengthen plant stability and reduce harm to humans and the environment (Kumar *et al*., 2023). Today, nano fertilizers are emerging as a viable alternative to conventional fertilizers (Veronica *et al*., 2015).

Kantwa and Yadav (2022) 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 (IFFCO, 2021). 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 (Sadhukan *et al*., 2021).

MATERIALSANDMETHODS

1.1 ExperimentalSite

Thefieldexperiment was toevaluatetheeffect of different concentrations of nano urea on growth and yield of fodder sorghum and wasconductedat College of Agriculture, Vellayani,Kerala Agricultural University, India during December 2023 - February 2024.Theexperimentwaslaidoutinrandomizedblockdesignwith13treatmentsreplicatedthrice,asfollows: T_1:75% recommended dose of nitrogen (RDN) + nano urea (0.2%); T_2:75% RDN+ nano urea (0.4%); T_3:75% RDN + nano urea (0.6%);T_4:100% RDN + nano urea (0.2%); T_5:100% RDN + nano urea (0.4%); T_6:100% RDN + nano urea (0.6%); T_7:75% RDN + urea spray (2%); T_8:100% RDN + urea spray (2%); T_9: nano urea alone (0.2%); T_{10}: nano urea alone (0.4%); T_{11}: nano urea alone (0.6%); T_{12}: KAU POP (60:40:20 NPK kg ha^{-1}) T_{13}: Control (withoutnitrogen). Both the nano urea and urea spray were applied at 20 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^{-1}) and available potassium (278.38 kg ha^{-1}) and high in available phosphorus (62.44 kg ha^{-1}).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^{-1}). 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 $plot^{-1}$) and converted into kg ha^{-1}. 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 $\pm$ 5 ^{0}C. The dry fodder yield was worked out and expressed in t ha^{-1}.

2. RESULTSANDDISCUSSION

2.1 PlantHeight

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_5) and was on par with T_6. While, foliar application of nano urea 0.6 per cent + 100 per cent RDN (T_6) at both 45 DAS and at harvest, resulted in taller plants (132.41 cm and 226.62 cm)which was comparable with T_5.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(Midde *et al*., 2021).

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 (Asha Kiran, 2022).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*. (2018) in wheatPrakasha *et al*. (2020) in maize Samui *et al*. (2022)in maize.

2.2 Stem Diameter

At 30, 45 DAS and at harvest stem diameter was observed higher with T_6 and was comparable with T_5. 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 (Abu Dahi, 1997). The increase in stem diameter is associated with increased number of leaves, which resulted in enhanced biomass production and higher photosynthetic rate in maizeSudha *et al*. (2023).Also, adequate nitrogen supply promoted greater absorption of nutrients and resulted in rapid expansion of plant parts, including stem girth. These results are in close conformity with Raliya *et al*. (2012), Juthery *et al*. (2018) in wheatandSalama and Badri (2020) in teosinte.

2.2Leaf: Stem Ratio

Data revealed that T_5 recorded higher leaf: stem ratio (0.39) which was comparable with T_6.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 (Somashekar *et al*., 2014). Similar results are also reported byYadav *et al*. (2019) in multi-cut sorghum and Satpal *et al*. (2020) in fodder sorghum.

2.3 Green Fodder Yield

The treatment (T_5) exhibited higher green fodder yield (32.03 t ha^{-1}) and was 43.43 per cent higher compared to T_{12}. 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. These are in fodder sorghum, Bochare*et al*. (2015) in fodder maize, Meena *et al*. (2021) in fodder maize and Samui *et al*. (2022) in maize.

2.4 Dry Fodder Yield

Dry fodder yield was observed higher with T_5(5.81 t ha^{-1}) and was 38.00 per cent higher compared to T_{12}. 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 and dry fodder yield in sorghum. The results are in corroborate with the findings ofSingh *et al*. (2012) in fodder sorghum and Meena *et al*. (2021) in fodder maize.

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^{-1}) along with foliar spray of nano urea, 0.4 per cent at both 20 and 40 DAS is beneficial for growing fodder sorghum in terms of growth and yield under Kerala conditions during rabi season.

Table1.Chemicalpropertiesofsoil before the experiment

Soiltext ure	Soil pH	Electricalcon ductivity (dSm^{-1})	Organic carbon (%)	AvailableN(kgha^{-1})	Available P(P (kgha^{-1})	Available K(K (kgha^{-1})
Sandy clayloam	5.63	0.21	0.56	413.95	62.44	278.38

Table2.Effectof nitrogen management and foliar nutrition onplantheightof fodder sorghum atvariousstagesofcropgrowth, cm

Treatment	15 DAS	30 DAS	45 DAS	AtHarvest
T_1 - 75% RDN +nano urea (0.2%)	24.87	60.12	87.22	174.52
T_2 - 75% RDN + nano urea (0.4%)	24.99	60.17	87.52	175.17
T_3 - 75% RDN + nano urea (0.6%)	26.04	60.38	101.23	181.57
T_4 - 100% RDN + nano urea (0.2%)	30.43	60.40	93.98	191.48
T_5 - 100% RDN + nano urea (0.4%)	31.30	75.52	116.61	208.58
T_6 - 100% RDN + nano urea (0.4%)	30.71	74.95	132.41	226.62
T_7 - 75% RDN + urea spray (2%)	27.68	60.09	78.04	171.56
T_8 - 100% RDN + urea spray (2%)	28.04	63.29	90.10	181.55
T_9 - Nano urea alone (0.2%)	22.94	57.82	73.82	166.71
T_{10} - Nano urea alone (0.4%)	23.16	58.73	76.70	167.33
T_{11} - Nano urea alone (0.6%)	23.15	59.64	78.71	170.15
T_{12} - KAU POP (60:40:20 kg NPK ha^{-1})	31.36	60.29	95.62	180.69
T_{13}- Control (without nitrogen)	22.48	47.69	57.67	136.30
SEm ($\pm$)	2.43	4.22	6.57	11.39
CD (P=0.05)	NS	12.312	19.189	33.237

NS-Not Significant, RDN-Recommended dose of nitrogen

Table3.Effectof nitrogen management and foliar nutrition onstem diameter of fodder sorghum atvariousstagesofcropgrowth, mm

Treatment	15 DAS	30 DAS	45 DAS	At Harvest
T_1 - 75% RDN +nano urea (0.2%)	3.79	9.44	9.95	10.37
T_2 - 75% RDN + nano urea (0.4%)	3.92	8.85	10.14	11.01
T_3 - 75% RDN + nano urea (0.6%)	4.38	9.46	12.31	13.08
T_4 - 100% RDN + nano urea (0.2%)	406	8.89	10.59	11.04
T_5 - 100% RDN + nano urea (0.4%)	4.70	10.55	12.36	13.16
T_6 - 100% RDN + nano urea (0.4%)	4.42	11.06	12.94	15.19
T_7 - 75% RDN + urea spray (2%)	3.87	8.81	9.42	10.15
T_8 - 100% RDN + urea spray (2%)	4.42	10.07	11.90	11.7
T_9 - Nano urea alone (0.2%)	3.70	7.52	8.36	9.00
T_{10} - Nano urea alone (0.4%)	3.66	7.57	8.71	9.20
T_{11} - Nano urea alone (0.6%)	3.77	7.95	8.99	9.59
T_{12} - KAU POP (60:40:20 kg NPK ha^{-1})	4.53	8.48	9.91	10.66
T_{13}- Control (without nitrogen)	3.57	6.48	7.00	7.27
SEm (±)	0.26	0.68	0.98	1.04
CD (P=0.05)	NS	1.995	2.849	3.02

NS-Not Significant, RDN-Recommended dose of nitrogen

Table4.Effectof nitrogen management and foliar nutrition onleaf: stem ratio, Green fodder yield and Dry fodder yield of fodder sorghum

Treatment	Leaf: Stem Ratio	Green Fodder Yield (t ha^{-1})	Dry Fodder Yield (t ha^{-1})
T_1 - 75% RDN +nano urea (0.2%)	0.29	20.33	3.40
T_2 - 75% RDN + nano urea (0.4%)	0.30	21.95	4.14
T_3 - 75% RDN + nano urea (0.6%)	0.32	24.33	4.53
T_4 - 100% RDN + nano urea (0.2%)	0.30	23.17	4.40
T_5 - 100% RDN + nano urea (0.4%)	0.39	32.03	5.81
T_6 - 100% RDN + nano urea (0.4%)	0.37	30.00	5.51
T_7 - 75% RDN + urea spray (2%)	0.28	21.00	3.92
T_8 - 100% RDN + urea spray (2%)	0.30	23.00	4.22
T_9 - Nano urea alone (0.2%)	0.24	19.33	2.00
T_{10} - Nano urea alone (0.4%)	0.25	19.50	3.08
T_{11} - Nano urea alone (0.6%)	0.26	20.00	3.13
T_{12} - KAU POP (60:40:20 kg NPK ha^{-1})	0.30	22.33	2.21
T_{13}- Control (without nitrogen)	0.20	14.00	1.77
SEm (±)	0.02	2.08	0.38
CD (P=0.05)	0.055	6.055	1.110

NS-Not Significant, RDN-Recommended dose of nitrogen

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