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Influence of nano nitrogen on growth and yield of finger millet under rainfed condition

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Abstract
The experiment was carried out at the Zonal Agricultural Research Station, Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Bangalore with the aim of assessing the impact of nano urea on the growth and yield of finger millet under rainfed condition. The study employed a Randomized Complete Block Design encompassing eight distinct treatments. These treatments comprised of varying nitrogen levels, specifically 50%, 75% and 100% of Recommended Dose of Nitrogen (RDN) and the application of nano urea in different ways including seed treatment, foliar spray and combination of both the methods. Each treatment was replicated thrice to ensure robust and reliable results. Among the different treatments, application of 75% RDN + seed treatment with nano urea + foliar spray of nano urea at 30 and 50 DAS recorded significantly higher growth and yield parameters *viz*., plant height (79.52 cm), number of tillers hill^{-1} (5.56), total dry matter accumulation (48.84 g hill^{-1}), productive tillers hill^{-1} (5.20), ear head length (7.13 cm), grain yield (3397 kg ha^{-1}) and straw yield (6015 kg ha^{-1}) of finger millet over absolute control. Notably, this particular treatment also proved to be the most financially rewarding, generating higher gross returns (₹ 1,04,139 ha^{-1}), net returns (₹ 65,591 ha^{-1}) and benefit cost ratio of 2.70, outperforming all other treatment options. These findings underscore the potential of nano urea in improving finger millet growth and yield, particularly in rainfed agricultural system and highlight its economic benefits for farmers.

Keywords: Nano nutrient, seed treatment, foliar spray, productive tillers and BC ratio

Introduction
Among the several small millets, finger millet (*Eleusine coracana* L. Gaertn.) also known as ragi, is the most important crop in terms of production, adaptability and productive potential especially in regions characterized by limited resources and reliance on rainfed agriculture (Prasanna Kumar *et al*., 2019) [13]. In India, 1.98 million tonnes of finger millet were produced from a total area of 1.19 million hectares under finger millet cultivation, yielding an average productivity of 1661 kg ha^{-1} (Anon., 2022) [1].
Boosting production can be achieved through the provision of essential nutrients from a dependable source, presenting a highly effective strategy. Nutrients play a pivotal role in fostering crop growth and sustaining yields. Among the array of essential nutrient elements, nitrogen (N) stands out as one of the most vital element for plants. This distinction arises from its primary role in chlorophyll synthesis, a crucial process for photosynthesis. Additionally, nitrogen serves as a constituent in numerous enzyme proteins, exerting control over and facilitating various aspects of plant development (Samanta *et al*., 2022) [17]. When nutrient application is not synchronized with crop needs, soil-plant system losses are high, resulting in low fertilizer use efficiency.
To address these issues, one of the cutting-edge technologies such as 'Nanotechnology' must be considered. Nano-fertilizers are a new class of synthetic fertilizers that contain easily accessible nutrients on a nano scale result in increasing crop yield, nutrient content in edible portions and nutrient uptake efficiency (Alshaal and El-Ramady, 2017) [2]. Nano-fertilizers prove to be highly effective in the realm of precision agriculture, as they facilitate precise nutrient management by synchronizing nutrient supply with the varying demands of crop growth stages throughout the entire growth period. The conventional method of applying fertilizers to the soil, while widely practiced comes with several limitations, primarily related to nutrient accessibility to plants. Inorganic nutrients tend to accumulate in the soil in insoluble forms, making them vulnerable to leaching due to rainfall or irrigation. These constraints are circumvented through seed treatment and foliar application by nano urea.

In this instance, nitrogen supplementation by seed treatment and foliar spray may be the most efficient and appropriate technique (Liu and Lal, 2015) [10]. Research on nano urea application on finger millet was scarce hence present investigation was carried out to evaluate the influence of nano nitrogen on growth and yield of finger millet crop.

Material and Methods

The experiment was conducted at Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vigyan Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The center is situated in the Vth agro-climatic zone under Eastern Dry Zone of Karnataka at 13º 05' N latitude and 77º 34' E longitude and at an altitude of 924 m above mean sea level. The soil of the experimental site was red sandy loam in texture, classified under the order *Alfisols*. The composite soil samples from 0 to 20 cm depth were collected randomly in experimental area before sowing from each replication. The moisture content at field capacity was 18.63 per cent with a bulk density of 1.43 g cc^{-1}. The soil of the experimental site is slightly acidic in reaction (6.22) with lower electrical conductivity (0.24 dS m^{-1}) and organic carbon content (0.38%). It has low available nitrogen (266.80 kg ha^{-1}), medium phosphorus (28.50 kg ha^{-1}) and potassium (278.60 kg ha^{-1}) status.

The experiment comprised of eight treatments laid out in Randomized Complete Block Design with three replications. Treatments intricate application of varied levels of recommended dose of nitrogen (RDN) and nano urea as either seed treatment (ST: Seed treatment with 80 ml nano nutrient kg^{-1} seed) or foliar spray (FS: Foliar spray at 0.4% solution at 30 and 50 DAS) or as both. T_1: Absolute control, T_2: 100% RDF, T_3: 50% RDN + ST, T_4: 50% RDN + FS, T_5: 50% RDN + ST + FS, T_6: 75% RDN + ST, T_7: 75% RDN + FS, T_8: 75% RDN + ST + FS. The finger millet variety GPU-66 seeds were sown in lines (drill sowing) at the rate of 12.5 kg ha^{-1} at a depth of 2-3 cm, maintaining 30 cm row to row and 10 cm plant to plant spacing. The crop was fertilized with 50 kg N, 40 kg P_2O_5 and 37.5 kg K_2O through urea, single super phosphate and muriate of potash respectively. According to the treatments, seeds were treated with nano urea before 2 hours of sowing and foliar application of nano urea at 30 and 50 days after sowing. Individual gross plot size was 3.9 m × 3.0 m (11.7 m^2). All sorts of plant protection measures along with water and weed management practices were followed in all the treatments as and when needed.

Observations recorded

Growth parameters

From the experimental plot, five plants from each net plot were tagged to record observation on growth and yield parameters. At harvest stage, plant height was measured from base of the plant to base of the ear head and expressed in centimetre (cm). Similarly, number of tillers were counted, recorded and expressed as number of tillers hill^{-1}. Five plants from the destructive sampling area of a plot were collected and samples were dried at 70 °C until they attained constant dry weight. Total dry matter was recorded and expressed as g hill^{-1}.

Yield attributing parameters

At harvest stage, the number of ear head bearing tillers per hill were counted and recorded from randomly selected five hills from the net plot area and expressed as number of productive tillers hill^{-1}. Correspondingly, length of the ear head was measured from the base to the tip of the ear head and expressed in centimetre. Random samples of grains were collected from grain yield of each net plot and 1000 grains were counted and their weight was recorded and expressed in gram.

Yield

The grain yield obtained from each net plot area was sun dried for 4-6 days in the threshing yard. When the moisture per cent brings down to 10-12 per cent, threshing was carried out, grains were separated, cleaned and weighed. Later the grain yield per net plot was computed on hectare basis and expressed in kilogram per hectare. Likewise, straw yield from the net plot area was recorded after sun drying for 8-10 days and expressed in kilogram per hectare. Harvest index was calculated by dividing economic yield by biological yield (Grain yield + straw yield) (Donald, 1962).

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$$

Economics

The cost of cultivation (₹ ha^{-1}) of each treatment was worked out by considering the price of inputs, charges for cultivation, labour, land and other charges. The gross returns (₹ ha^{-1}) occurred due to different treatments in the present study were worked out by considering market prices of economic product, by product and crop residues. The net returns (₹ ha^{-1}) of each treatment were worked out by deducting the mean cost of cultivation (₹ ha^{-1}) of each treatment from the gross returns (₹ ha^{-1}) gained from the respective treatments. The benefit cost ratio of each treatment was calculated by dividing the gross returns with the mean cost of cultivation.

Statistical analysis

The experimental data pertaining to each character were analyzed statistically by using the technique of Analysis of Variance (Gomez and Gomez, 1984) [7] for Randomized Complete Block Design. The significance was tested by "Variance ratio" (F), standard error of mean (S.Em.±) and critical difference (CD) were worked out for each character studied to evaluate differences between the treatments and interaction effect at 5 per cent level.

Results and Discussion

Crop growth

Among the different treatments, application of 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS, recorded significantly higher plant height (79.52 cm), higher number of leaves hill^{-1} (36.73), number of tillers hill^{-1} (5.56) and total dry matter accumulation (48.84 g hill^{-1}) at harvest stage (Table 01).

The observed enhancement in growth parameters can be attributed to the foliar application of nano nitrogen on finger millet crop. Nitrogen holds immense significance in the realm of plant biology as it serves as a fundamental component of amino acids, proteins, vitamins, hormones and enzymes, all of which exert an immediate influence on the stimulation of cell division and enlargement. This effect manifests both longitudinally and transversely, leading to an amplified meristematic activity, subsequently resulting in increased internodal length and overall plant height (Samui *et al*., 2022)

[18]. The combined availability of nitrogen from conventional soil applied urea and foliar applied nano nitrogen contributes to the accelerated shoot development and heightened stature of finger millet plant. These results were in conformity with the findings of Reddy *et al*. (2022) [16].

The increased proliferation of number of leaves and tillers can be attributed to the stimulatory effects of nano nitrogen on various physiological mechanisms. Notably, nano nitrogen has been observed to enhance the activity of chloroplasts, bolster antioxidant enzyme systems and augment nitrate reductase activity (Rajesh, 2021) [14]. These factors collectively contribute to accelerated growth processes, ultimately leading to a higher number of tillers in the plant. The findings have also been reported by Singh and Shivay (2003) [19].

The presence of nano sized nitrogen particles which provide more sites to facilitate different metabolic processes in plant system results in production of more photosynthesis and in turn more growth and yield (Yasser *et al*. 2020) [20]. The application of nano nitrogen has been shown to elevate chlorophyll content and stimulate the synthesis of vital components such as amino acids, proteins and protoplasm. Consequently, this promotes an increase in plant height, the number of tillers and total dry matter. The results were in conformity with the findings of Kumar *et al.* (2014) [8] in finger millet crop.

Yield attributing parameters

Among the different treatments, application of 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS, recorded significantly higher productive tillers hill^{-1} (5.20), ear head length (7.13 cm), number of ear heads hill^{-1} (6.31) and finger number per ear head (6.78) compared to other treatments (Table 02).

The attainment of maximal yield can be largely ascribed to the strategic combination of conventional fertilizer with nano fertilizer, which has yielded significant benefits in terms of the number of effective tillers and the length of ear head. Nano fertilizer in particular demonstrates a synergistic effect when used alongside conventional fertilizer, enhancing the plant cells capacity for nutrient absorption (Benzon *et al*. 2015) [4]. This in turn promotes optimal growth of various plant components and vital metabolic processes like photosynthesis, leading to an accumulation of higher levels of photosynthates. Subsequently, the translocation of these photosynthates to economically vital plant parts results in a notable improvement in yield attributing parameters. The results are also in conformity with the findings of El-Gizawy *et al*., 2020 and Samui *et al*., 2022 [6, 18].

Yield

Among the different treatments, application of 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS, recorded significantly higher grain yield (3,397 kg ha^{-1}) and straw yield (6,015 kg ha^{-1}) compared to other treatments (Fig. 01).

The loftier grain and straw yield observed in finger millet crop with application of nano nitrogen can be attributed to the remarkable enhancements induced by nanoparticle action on photosynthesis and nutrient utilization efficiency resulting in a substantial increase in overall yield. The increased production of straw can be largely attributed to the foliar application of nano nitrogen where the rapid absorption of these nanoparticles by the plants facilitates ease of translocation, thereby expediting the rate of photosynthesis and leading to greater accumulation of dry matter, ultimately resulting in a more substantial straw yield (Kumar *et al*. 2020) [9]. Furthermore, the nano fertilizer augments nutrient uptake by the plant, fostering optimal growth of plant parts and key metabolic processes such as photosynthesis. This in turn leads to the maximal accumulation and translocation of photosynthates to the economically significant plant parts ensuring a higher yield, which can be linked to increased source (leaves) and sink (economic parts) strength. Similar results were reported by Morsy *et al*. (2021) [12].

Influence of nano nitrogen on test weight and harvest index of finger millet was found to be non-significant. As test weight being a genetical character of the plant because of which did not get influenced by the different treatments of the nano nitrogen whereas, proportional increase in both grain and straw yields observed with foliar application of nano nitrogen leads to a non-significant effect on the harvest index. Similar results were obtained in foxtail millet and pearl millet by Basavarajappa *et al.* (2002) [3] and Rajesh (2012) [15] respectively.

Production economics

Application of 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS fetched higher gross returns (₹ 1,04,139 ha^{-1}), net returns (₹ 65,591 ha^{-1}) and profit per rupee invested (2.70) compared to all other treatments (Table 03).

Despite the observed increase in the cost of cultivation associated with the approach involving 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS, this higher cost was offset by the substantial gains in grain and straw yields, ultimately resulting in higher returns and a more favourable benefit-cost (BC) ratio. These results are in conformity with the findings of Manikandan and Subramanian (2016) [11] and Kumar *et al*. (2020) [9].

Table 1: Growth parameters of finger millet at harvest as influenced by nano nitrogen under rainfed condition

Treatment		Plant height (cm)	Number of leaves hill^{-1} (At 90 DAS)	Number of tillers hill^{-1}	Total dry matter (g hill^{-1})
T_1	Absolute control	56.79	27.18	3.80	34.47
T_2	100% RDF	70.05	30.97	5.18	42.92
T_3	50% RDN + ST	59.94	28.31	4.51	37.84
T_4	50% RDN + FS	63.33	29.41	4.54	38.64
T_5	50% RDN + ST + FS	68.76	31.25	4.65	41.84
T_6	75% RDN + ST	65.17	30.56	4.60	39.34
T_7	75% RDN + FS	73.62	33.85	5.12	43.34
T_8	75% RDN + ST + FS	79.52	36.73	5.56	48.84
F-test		*	*	*	*
S.Em.±		1.69	0.84	0.12	1.12
CD (p=0.05)		5.13	2.55	0.37	3.40

Table 2: Yield attributing parameters of finger millet as influenced by nano nitrogen under rainfed condition

Treatment		Productive tillers hill^{-1}	Ear head length (cm)	Number of ear heads hill^{-1}	Finger number per ear head	Test weight (g)
T_1	Absolute control	2.88	4.17	5.28	5.41	2.92
T_2	100% RDF	4.78	6.12	5.55	5.78	3.72
T_3	50% RDN + ST	3.54	5.81	5.61	5.68	3.10
T_4	50% RDN + FS	4.20	5.62	5.63	5.90	3.40
T_5	50% RDN + ST + FS	4.62	6.18	6.02	5.98	3.34
T_6	75% RDN + ST	4.54	5.84	5.72	6.01	3.33
T_7	75% RDN + FS	4.85	6.17	6.12	6.51	3.67
T_8	75% RDN + ST + FS	5.20	7.13	6.31	6.78	3.88
F-test		*	*	*	*	NS
S.Em.±		0.11	0.15	0.08	0.05	0.12
CD (p=0.05)		0.34	0.47	0.24	0.16	-

Table 3: Economics of finger millet as influenced by nano nitrogen under rainfed condition

Treatment		Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BC ratio
T_1	Absolute control	35421	43191	7770	1.22
T_2	100% RDF	36688	90022	53335	2.45
T_3	50% RDN + ST	36834	81707	44873	2.22
T_4	50% RDN + FS	37944	77117	39173	2.03
T_5	50% RDN + ST + FS	38394	82680	44286	2.15
T_6	75% RDN + ST	36987	80307	43320	2.17
T_7	75% RDN + FS	38097	94011	55914	2.47
T_8	75% RDN + ST + FS	38547	104139	65591	2.70

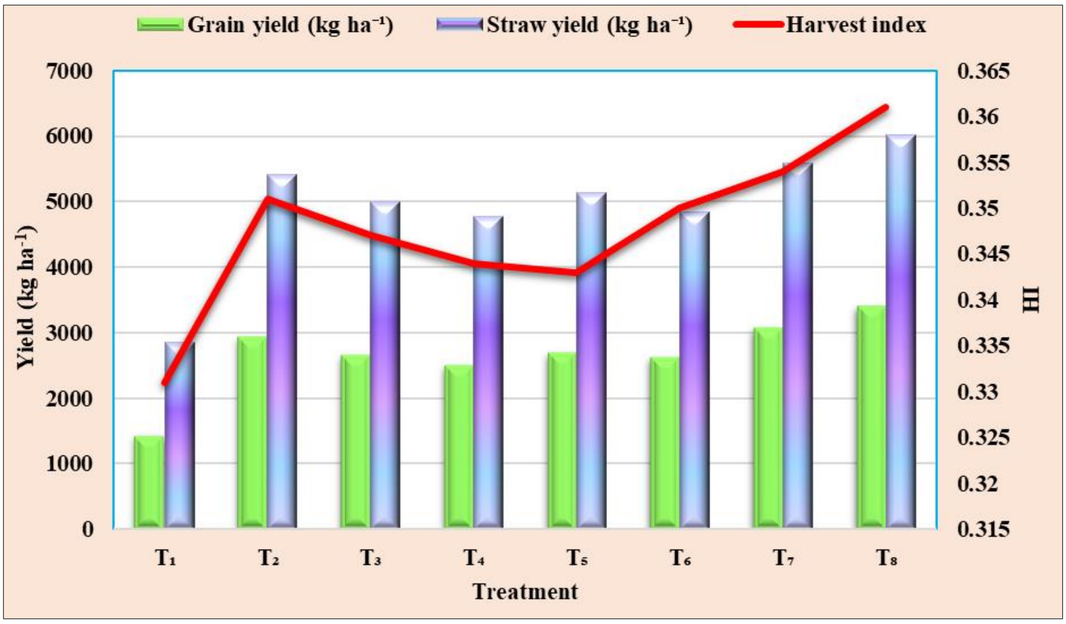

Fig 1: Grain yield, straw yield and harvest index of finger millet as influenced by nano nitrogen under rainfed condition

Conclusion

Application of 75% RDN + seed treatment with nano urea + two sprays of nano urea at 30 and 50 DAS proved to be highly effective in promoting robust growth, enhancing yield and generating favourable economic returns in finger millet. From this experiment we conclude that 75 per cent RDN with full dose of P and K along with seed treatment with nano urea (80 ml nano nutrient per kg seed) and foliar spray of nano urea at 4 ml l^{-1} at 30 and 50 DAS could be recommended as viable alternative nitrogen source and application technique for achieving superior growth and yield resulting in a remarkable 16.18% increase in yield over 100% RDF. Furthermore, it delivers the highest benefit-cost ratio (2.70), while also contributing to a substantial 24.6% reduction in nitrogen usage, making it an environmentally and economically sound choice.

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