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Effect of foliar application of nano DAP on yield and yield attributes of finger millet

V Pushpalatha, U Triveni, M M V Srinivasa Rao and Y Sandhya rani
Department of Agronomy, Acharya N G Ranga Agricultural University,
Agricultural College, Bapatla-522101, Andhra Pradesh, India

ABSTRACT

A field experiment was carried out during *rabi*, 2023-24 at Agricultural Research Station, Vizianagaram. The experiment was laid out in Randomized Complete Block Design with ten treatments *viz.,* T_1 : 100 % NPK, T_2 : 100 % NPK + foliar spray of nano DAP at Tillering stage, T_3 : 100 % NPK + foliar spray of nano DAP at PI stage, T_4 : 100 % NPK + foliar spray of nano DAP each at Tillering and PI stage, T_5 : 100 % NK only, T_6 : T_5 + foliar spray of nano DAP each at Tillering and PI stage, T_7 : T_5 + 50 % P + foliar spray of nano DAP each at Tillering and PI stage, T_8 : T_5 + 75 % P + foliar spray of nano DAP each at Tillering and PI stage, T_9 : T_5 + 75 % P + foliar spray of nano DAP at Tillering stage and T_{10} : T_5 + 75 % P + foliar spray of nano DAP at PI stage. Results revealed that 100 % NPK + foliar spray of nano DAP @ 2.5 ml L^{-1} at Tillering and PI stage (T_4) significantly enhanced growth and yield attributing characters of finger millet, however it was found on par with 100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage (T_8). Hence, 100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage (T_8) can be regarded as the best treatment as it saves 25 % of conventional phosphorus fertilizers in addition to environmental safety.

Keywords:*Finger millet, Foliar spray and Nano DAP.*

Finger millet (*Eleusine coracana* L.) is an important food crop of semi-arid tropics particularly in India and East Africa. It is a drought-resistant crop and can be adaptable to all types of soils and climatic conditions. The major finger millet growing states in India are Karnataka, Uttarakhand, Tamil Nadu, Andhra Pradesh, Odisha, Jharkhand and Maharashtra. In India, finger millet is cultivated over an area of 10.37 lakh ha with a total production of about 13.86 lakh tonnes and with productivity of 1336 kg ha^{-1}. Andhra Pradesh produces nearly 0.33 lakh tones of finger millet in an area of 0.27 lakh ha with a productivity of 1222 kg ha^{-1} (Agricultural and Processed Food Products Export Development Authority, 2023-24). Finger millet is mostly grown in poor and marginal soils under low or no input supply conditions. Adequate plant nutrient supply is required to explore the full yield potential of improved varieties. Phosphorus is the second most important element next to nitrogen and is particularly important for stimulation of the root development, increased stalk and stem strength, improved flower formation, seed production, grain filling and also improved crop quality. However, only 15-30 % of applied fertilizer phosphorus is taken up by crops in the year of its application Syers *et al.,* 2008 and the remaining P becomes part of the soil P pool, which subsequently released to the crop over the following months and years Roberts and Johnston, 2015. The P fertilizer prices are more than doubled in recent years and further increases in prices seems inevitable in the future by considering the non-renewable nature of rock-P resources Cordell *et al.,* 2009. Urea and Di-Ammonium Phosphate (DAP) are widely used conventional fertilizers in India, but their nutrient use efficiency is relatively low, with only 30-40 per cent efficiency for nitrogen fertilizers and 18-20 per cent for phosphorus-based fertilizers Tiwari *et al.,* 2022.

Nano fertilizers deal with the elements in nanometer dimensions (1 -100 nm) and at nanoscale, these fertilizers release the nutrients at a slower rate for a longer period, consequently, limiting nutrient loss from the soil and reducing soil groundwater pollution Meena *et al.,* 2017. Nano-fertilizers have an important role in the physiological and biochemical processes of crops by increasing the availability of nutrients, which help in enhancing metabolic processes and promoting meristematic activities causing higher apical growth and photosynthetic area DeRosa *et al.,* 2010. Nanoparticles have unique physico-chemical properties and key potential to boost the plant metabolism Zulfiqar *et al.,* 2019; Raliya *et al.,* 2018

Foliar application of nutrients enables rapid nutrient uptake by plants, reducing losses through leaching and fixation and enhancing crop yields with lower environmental impact. This method is particularly useful for efficiently correcting nutrient deficiencies, as nutrients are absorbed directly by plant leaves and transported (Elayaraja and Angayarkanni, 2005). Nano DAP improves nutrient absorption efficiency and availability throughout the crop cycle. This higher efficiency can reduce the need for conventional fertilizers by up to 50 per cent, potentially increasing crop yields by 15 - 30 per cent, conserving soil health, and lowering greenhouse gas emissions. Developed by IFFCO Ltd., nano DAP is anticipated to save approximately 25 per cent of traditional fertilizer use. Despite these promising claims, research on nano DAP's specific effects on crop productivity remains limited, highlighting the need for further studies to verify its full potential.

MATERIAL AND METHODS

The experiment was conducted at Agricultural Research Station, Gajularega, Vizianagaram, Acharya N.G Ranga Agricultural University, Andhra Pradesh, India, during *rabi* season 2023-2024. The experimental site is located at 180 º 07' N latitude and 83º 26' E longitude, with an altitude of 58.2 m above mean sea level in North Coastal Agroclimatic Zone of Andhra Pradesh. The initial soil had a pH (1:2.5 in water) 7.20, EC of 0.53 ds m^{-1}, organic carbon (OC) of 0.40 %, available N_2 (201.05 Kg ha^{-1}), available P_2O_5 (21.8 kg ha^{-1}) and available K_2O (205.4 kg ha^{-1}). The soil of the experimental field had sandy loam texture, corresponding to the USDA soil taxonomy.

The field experiment was carried out in Randomized Block Design (RBD), taking ten treatments with three replications in the plot size of 4.5 m * 3.6 m (19.8 m^2). The experiment consisted of treatments comprising NPK or NK, along with foliar spray of nano DAP combinations (Table1), applied to VR 929 variety of finger millet. The sowing of finger millet was done in the first week of January, with a spacing of 30 cm × 10 cm, and was harvested in the third week of April the following year. The Recommended Dose of Fertilizer (RDF) for finger millet was 60:40:30 kg N: P_2O_5:K_2O ha^{-1}. N (at half dose) and P_2O_5 and K_2O (at their full) were applied at the time of sowing by the means of urea, di-ammonium phosphate, and muriate of potash, respectively. The remaining half dose of N was applied as split application at tillering stage of the crop. The application of foliar sprays of nano DAP @500 ml acx^{-1} was given at the tillering stage and second application at the panicle initiation stage in selected treatments.

Straw yield from each plot was recorded after sun drying for 8-10 days. Later the yields per plot was computed on hectare basis and expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

Plant height (cm)

A significant difference in plant height was observed among the treatments at harvest. The highest plant height was recorded with T_4 (94.00 cm); however, it was on par with T_8 and T_3 but significantly superior over T_5, T_6, T_7, T_1, T_9, T_{10} and T_2. As compared to 100 % NPK, significant improvement in plant height was observed with T_4 (13.80 %) and T_8 (9.07 %) and lowest plant stature was observed with T_5 (77.93 cm).

Application of 100 % P + two foliar sprays of nano DAP at Tillering and PI stage might be the reason for superior plant height in T_4, T_8 and T_3. Conventional DAP as basal and nano DAP as a foliar spray facilitated the increased availability of phosphorus throughout the crop growth period. Further, the smaller particle size of nano phosphorus allows it to penetrate the leaf tissues more effectively, reaching chloroplasts. The enhanced accessibility of phosphorus further boosts chlorophyll production and photosynthetic activity, which in turn contributes to greater plant height and overall plant growth. At all the stages, the lowest plant height was recorded with T_5, where phosphorus was not applied. Similar findings were reported by Karmegam *et al.,* 2023 in groundnut, who observed the highest plant height with 100 % RDF + foliar spray of nano phosphorus @ 1000 ppm at pre flowering and flowering stages +

Table 1. Treatment details

S.No	Treatments
T_1	100 % NPK
T_2	100 % NPK + foliar spray of nano DAP at Tillering stage
T_3	100 % NPK+ foliar spray of nano DAP at PI stage
T_4	100 % NPK + foliar spray of nano DAP each at Tillering and PI stage
T_5	100 % NK only
T_6	T_5 + foliar spray of nano DAP each at Tillering and PI stage
T_7	T_5 + 50 % P + foliar spray of nano DAP each at Tillering and PI stage
T_8	T_5 + 75 % P + foliar of nano DAP each at Tillering and PI stage
T_9	T_5 + 75 % P + foliar spray of nano DAP at Tillering stage
T_{10}	T_5 + 75 % P + foliar spray of nano DAP at PI stage

Table 2. Growth and yield attributes of finger millet influenced by various treatments of nano DAP

Treatments	Plant height (cm)	Drymatter accumulation (kg ha^{-1})
T_1	82.60	8643.00
T_2	85.70	9384.00
T_3	87.20	9682.00
T_4	94.00	10249.00
T_5	77.90	7299.00
T_6	82.10	7989.00
T_7	82.50	8472.00
T_8	90.10	9540.00
T_9	84.20	9056.00
T_{10}	84.90	9261.00
S.Em ±	2.60	276.60
CD (P=0.05)	7.90	821.80
CV (%)	5.40	5.30

Arbuscular mycorrhiza. Sharma *et al*. (2022) also reported similar result with 100 % RDN + two sprays of nano urea @ 4 ml L^{-1} at 30 and 45 DAS in pearl millet.

Drymatter accumulation (kg ha^{-1})

Over the stages of crop growth, the drymatter accumulation was highest during harvest, due to higher production and translocation of photosynthates for plant development. Among the different treatments, T_4 registered the maximum drymatter accumulation (10249 kg ha^{-1}), however it was on par with T_8 and T_3. As compared to 100 % NPK, the increment in drymatter accumulation was 18.58 %, 12.02 % and 10.38 % respectively, in T_4, T_3 and T_8. The lowest drymatter accumulation (7299 kg ha^{-1}) was observed with T_5, where no phosphorus was applied. The drymatter accumulation with T_6 (T_5 + foliar spray of nano DAP each at Tillering and PI stage) was 9.45 % higher as compared to T_5 but 7.57 % lower as compared to 100 % NPK. These results are in line with the findings of Singh *et al.* (2023) in wheat and Bhargavi and Sundari (2023) in rice and Pal *et al.* (2023) in wheat. Based on the above results, it can be inferred that the combined application of conventional and nano DAP resulted in better vegetative and root growth.

These improvements were likely to have contributed to an increased photosynthesis. Moreover,

Table 3. Grain yield (kg ha^{-1}) and Straw yield (kg ha^{-1}) of finger millet as influenced by various treatments of nano DAP

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	2370.00	5314.00
T_2	2785.00	6007.00
T_3	2838.00	6118.00
T_4	3076.00	6481.00
T_5	1872.00	4601.00
T_6	2218.00	5279.00
T_7	2354.00	5492.00
T_8	2978.00	6303.00
T_9	2603.00	5694.00
T_{10}	2645.00	5790.00
S. Em±	138.20	263.90
CD (P=0.05)	410.00	783.00
CV (%)	9.30	8.10

T_1 : 100 % NPK, T_2 : 100 % NPK + foliar spray of nano DAP at Tillering stage, T_3 : 100 % NPK + foliar spray of nano DAP at PI stage, T_4 : 100 % NPK + foliar spray of nano DAP each at Tillering and PI stage, T_5 : 100 % NK only , T_6 : T_5 + foliar spray of nano DAP each at Tillering and PI stage, T_7 : T_5 + 50 % P + foliar spray of nano DAP each at Tillering and PI stage, T_8 : T_5 + 75 % P + foliar spray of nano DAP each at Tillering and PI stage, T_9 : T_5 + 75 % P + foliar spray of nano DAP at Tillering stage and T_{10} : T_5 + 75 % P + foliar spray of nano DAP at PI stage.

the effective translocation of these photosynthates might be the key reason for the higher drymatter accumulation observed under the combined application of conventional and nano DAP. The enhanced availability and uptake of phosphorus and nitrogen from conventional and nano DAP sources possibly played significant role in promoting plant growth and overall biomass accumulation.

Grain yield (kg ha^{-1})

Higher grain yield (3076 kg ha^{-1}) was recorded with the application of 100 % NPK + foliar spray of nano DAP each at Tillering and PI stage (T_4), which was statistically on par with T_8 (2978 kg ha^{-1}), T_3 (2838 kg ha^{-1}) and T_2 (2785 kg ha^{-1}). The grain yield recorded with T_4, T_8, T_3 and T_2 were 29.79 %, 25.65 %, 19.74 % and 17.51 % higher respectively as compared to T_1, where 100 % P was applied only as basal through conventional DAP. Among all the treatments, lowest grain yield was recorded with T_5 (1872 kg ha^{-1}), where no phosphorus was applied. Enhanced grain yield with T_4, T_8, T_3 and T_2 treatments might be attributed to their higher growth and yield contributing characters like drymatter accumulation, productive tillers per plant, earhead length, number of fingers per earhead etc. Combined application of phosphorus as basal and top dressings through conventional and nano sources of DAP might have created favourable nutritional environment below ground and above ground throughout the crop period, which in turn positively influenced other nutrients absorption from soil leading to increased photosynthetic efficiency and higher assimilates production (Choudhary *et al.,* 2019). These results are in line with the findings of Luma and Ahmed (2021), Deo *et al.* (2022), Naveen *et al.* (2021) and Poudel *et al.* (2023).

Straw yield

The highest straw yield was recorded with T_4 (100 % NPK + foliar spray of nano DAP each at Tillering and PI stage) (6481 kg ha^{-1}), however, it was found on par with T_8 (100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage), T_3 (100 % NPK + foliar spray of nano DAP at PI stage), T_2 (100 % NPK + foliar spray of nano DAP at Tillering stage) and T_{10} (100 % NK + 75 % P + foliar spray of nano DAP at PI stage). Straw yield recorded with T_9 (100 % NK + 75 % P + foliar spray of nano DAP each at Tillering stage) was found on par with T_7 (100 % NK + 50 % P + foliar spray of nano DAP each at Tillering and PI stage), T_1 (100 % NPK) and T_6 (100 % NK + foliar spray of nano DAP each at Tillering and PI stage). The lowest straw yield among all the treatments was recorded with T_5 (100 % NK) (4601 kg ha^{-1}), where no phosphorus application was done.

Higher straw yields recorded in T_4, T_8, T_3, T_2 and T_{10} might be due to abundant availability of phosphorus to the crop throughout the growing period, resulted from the periodic applications of nano DAP as foliar sprays and basal application of conventional DAP. Soil application or foliar application alone could not provide sufficient nutrients supply throughout the crop growing period. Basal + foliar application of conventional DAP and nano DAP improves nutrient absorption resulting in the optimal growth of plant parts and improved drymatter accumulation. Nano fertilizers, being quickly absorbed and easily translocated at a faster rate aided in a higher rate of photosynthesis and more drymatter accumulation, which resulted in a higher straw yield (Lahari *et al.,*2021). A similar result was seen in wheat with nano phosphorus application (Poudel *et al.*, 2023). This was concomitant with the findings of Deo *et al.* (2022) in rice and Naveen *et al*. (2021) in rice.

CONCLUSION

100 % NPK + foliar spray of nano DAP @ 2.5 ml L^{-1} at Tillering and PI stage (T_4) significantly enhanced growth and yield attributing characters, grain yield and straw yield of finger millet, however it was found on par with 100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage (T_8) and 100 % NPK + foliar spray of nano DAP at PI stage (T_3). From the above discussion, it was found that 100 % NPK + foliar spray of nano DAP @ 2.5 ml L^{-1} at Tillering and PI stage (T_4) and 100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage (T_8) showed on par performance in terms of growth and yield attributing characters, grain yield, straw yield, nutrient uptake in grain and straw and soil nutrient availability. Hence, 100 % NK + 75 % P + foliar spray of nano DAP each at Tillering and PI stage (T_8) can be regarded as the best treatment as it saves 25 % of conventional phosphorus fertilizers in addition to environmental safety.

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