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Influence of foliar application of nano urea and nano diammonium Phosphate combined with growth regulators on growth of maize (*Zea mays*)

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Abstract
A field experiment entitled "Influence of foliar application of nano urea and nano diammonium phosphate combined with growth regulators on growth, yield and quality of maize (*Zea mays*)". Was carried out at experimental farm, department of Soil Science, College of Agriculture, Parbhani during *kharif* 2024-25. The field trial was conducted in randomized block design (RBD) with ten treatments T_1 - Control, T_2 - 100% RDF, T_3 - 100% RDF + nano urea + GA_3 50 ppm (25 and 50 DAS), T_4 - 100% RDF + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_5 - 100% RDF + nano urea + nano DAP (25 and 50 DAS), T_6 - 100% RDF + nano urea + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_7 - 75% RDF + nano urea + GA_3 50 ppm (25 and 50 DAS), T_8 - 75% RDF + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_9 - 75% RDF + nano urea + nano DAP (25 and 50 DAS), T_{10} - 75% RDF + nano urea + nano DAP GA_3 50 ppm (25 and 50 DAS) with three replications. Result obtained clearly indicated that the growth, yield and quality was significantly impacted due to foliar spray of nano urea, nano DAP and growth regulator along with 100% RDF. The significantly highest plant height at harvest (208.56 cm) compared with control (179.86 cm), leaf length at harvest was 128.35 cm compared with the control 103.60 cm, maximum grain (89.39 q ha^{-1}) at harvest were recorded in treatment (T_6) 100%RDF + nano urea + nano DAP + GA_3 50 ppm 25 and 50 DAS.

Keywords: Foliar application, nano urea, nano DAP, growth regulator

Introduction
Maize (*Zea mays* L.) a member of the family Poaceae, is the world's third most important cereal crop after rice and wheat, cultivated extensively across the globe (Sandhu *et al*., 2007) [14]. The term "maize" is derived from the Spanish language and it is also known by names such as zea, silk maize and Makka (Kumar *et al*., 2013) [7]. Owing to its remarkable genetic yield potential, maize is often referred to as the "queen of cereals". It is unique among cereal crops as it can be grown in diverse seasons and ecological conditions. Nutritionally, maize contains about 72% starch, 10% protein, 9.5% fiber, 4.8% oil, 3.0% sugar and 1.7% ash. In India, its usage is distributed as follows: 23% for human consumption, 51% for poultry feed, 12% for animal feed, 12% for industrial starch products and 1% each for beverages and seed purposes (Parihar *et al*., 2011) [10].

India ranks fourth in maize cultivation area and seventh in production globally, contributing around 4% of the world's cultivated area and 2% of global output. Within the country, maize is cultivated over 97.9 lakh hectares, making it the third most produced cereal after rice and wheat, with an annual output of 314.47 lakh tones and a productivity of 30.99 q/ha (Anonymous, 2023). In Maharashtra, maize occupies 12.26 lakh hectares and produces about 20.60 lakh tones annually, ranking third in area and fifth in production among Indian states, with a productivity of 3,000 kg/ha. However, the Marathwada region records a lower productivity of around 1,983 kg/ha (Anonymous, 2022).

Nanotechnology, a modern innovation that has emerged in recent years, is making significant contributions across various agricultural domains. Among its applications, nano fertilizers stand out for their high efficiency, multifunctionality and ease of use.

The adoption of nano-fertilizers is steadily increasing due to their proven positive effects on crop growth and productivity. These fertilizers are derived from bulk materials or biological sources such as plant, microbial or animal extracts processed through chemical, physical, mechanical or biological methods using either top-down or bottom-up manufacturing approaches.

Nanomaterials are defined as materials with at least one dimension between 1 nm and 100 nm. They are valued for being environmentally friendly and for promoting sustainable agriculture (Kantwa & Yadav, 2022) [5]. Nano urea, a liquid nitrogen-based nutrient, serves as an alternative to conventional urea, effectively meeting plants nitrogen requirements when applied at critical growth stages. It has been developed indigenously by the Nano Biotechnology Research Center in Kalol, Gujarat, as part of the Atmanirbhar Bharat and Atmanirbhar Krishi initiatives. Similarly, nano DAP liquid is an efficient nitrogen and phosphorus source, addressing nutrient deficiencies in plants. Developed by the Indian Farmers Fertilizer Cooperative (IFFCO) the country's largest cooperative it was officially approved by the Ministry of Agriculture and Farmers' Welfare under the Fertilizer Control Order on March 2, 2023. This eco-friendly, biologically safe formulation supports residue free, sustainable farming.

Material and Method

A field experiment was conducted during *kharif,* 2024-2025 at research farm of the Department of Soil Science, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) on vertisols, having pH (7.8), EC (0.16 dSm^{-1}), organic carbon content (2.26 g kg^{-1}) and calcium carbonate (2.6 g kg^{-1}). Experimental site was located at 410 m above mean sea level at between 76°46' East longitude and 19°16' North latitude. The area experiences a semi-arid climate, with an average annual rainfall of 869.7 mm, falling within an agro-climatic zone that benefits from reliable monsoon rains. The mean daily maximum temperature ranges between 27.6°C to 34.5°C, while the mean daily minimum temperature varies from 8.1°C to 24.2°C. The mean daily maximum relative humidity varied between 79% and 94%, whereas the mean daily minimum relative humidity ranges from 25% to 81%.

The research was arranged in Completely Randomized Block Design, there were ten treatments with three replications consisting of T_1 - Control, T_2 - 100% RDF, T_3 - 100% RDF + nano urea + GA_3 50 ppm (25 and 50 DAS), T_4 - 100% RDF + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_5 - 100% RDF + nano urea + nano DAP (25 and 50 DAS), T_6 - 100% RDF + nano urea + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_7 - 75% RDF + nano urea + GA_3 50 ppm (25 and 50 DAS), T_8 - 75% RDF + nano DAP + GA_3 50 ppm (25 and 50 DAS), T_9 - 75% RDF + nano urea + nano DAP (25 and 50 DAS), T_{10} - 75% RDF + nano urea + nano DAP GA_3 50 ppm (25 and 50 DAS). After the previous crop was harvested, the field was ploughed once again, followed by one harrowing. The basal application of fertilizers in the form of urea, SSP were applied as per treatments with recommended dose of (120:60:40- N: P_2O_5:K_2O kg ha^{-1}) all treatment except absolute control. In each net plot five plants were tagged randomly for periodic observation. The height was recorded at maturity in all the plots. Height of each selected plant was measured in centimeters with the help of meter scale from the ground surface level to the tassel. The observations were recorded at tasseling, silking and harvest stage. Five plants were randomly selected from each net plot and recorded the leaf length at 30, 60, 90 and at harvest. The number of cob per plant were counted in each plot from five tagged plants and thus mean per plant was calculated for analysis. The observations were recorded from all the plots. The seed yield per net plot was recorded after drying the seed. The plot yield was later on converted into kg ha^{-1} by multiplying it by conversion factor. The stover yield per plot was obtained by subtracting grain yield from bundle weight of each plot. This was later on converted into kg ha^{-1}. Nitrogen content in the plant and seed samples was determined by the micro kjeldhal method after digestion as suggested by A.O.A.C. (1975). This seed nitrogen percent was multiplied by the factor of 6.25 to get the percentage of protein in maize seed.

Result and Discussion

Growth parameter

Plant height (cm)

The data on plant height of maize crop as influenced by foliar application of nano urea, nano DAP and growth regulator are presented in Table 1. The height of maize plant was significantly increased due to foliar application of nano urea, nano DAP and growth regulator at 120 DAS (at harvest), the significantly highest plant height (208.56 cm) was observed with the treatment T_6 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) + GA3 50 ppm at 25 and 50 DAS which was significantly at par with the treatment T_5 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) at 25 and 50 DAS (205.22 cm). Multiple studies have reported consistent benefits of foliar nano fertilizer applications combined with basal nutrient management on maize plant height. Ajithkumar *et al*. (2021) [1] observed the tallest maize plants (226 cm) under a treatment with 50% nitrogen, full phosphorus and potassium, no zinc, plus two foliar sprays of IFFCO nano-N and IFFCO Sagarika representing a 25% increase over control plots. Similarly, Samui *et al.* (2022) [13] found that foliar application of nano-urea (FSNU) at 4 mL/L twice at knee height and tasseling together with 100% recommended nitrogen significantly boosted plant height while slightly reducing dry matter accumulation, confirming findings across studies. Abdullah *et al.* (2024) also reported notable height increases at 90 and 120 DAS as well as at harvest under a treatment combining 75% NP basal dose with seed treatment and foliar spray of nano DAP these results were statistically comparable to those with full RDF treatment.

Leaf length (cm)

The data on leaf length of maize crop as influenced by foliar application of nano urea, nano DAP and growth regulator are presented in Table 1. The significant difference in leaf length was observed at 120 (at harvest) DAS. The significantly highest leaf length (128.35 cm) was recorded with the treatment T_6 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS which was significantly at par with the treatment T_5 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) at 25 and 50 DAS (127.25 cm), T_{10} - 75% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (126.87 cm), T_9 – 75% RDF + foliar spray of nano urea (4ml L^{-1}) +

nano DAP (4ml L^{-1}) at 25 and 50 DAS (125.53 cm), T_4 - 100% RDF + foliar spray of nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (123.36 cm), T_3 - 100% RDF + foliar spray of nano urea (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (122.59 cm), T_8 -75% RDF + foliar spray of nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (121.86 cm), T_7 -75% RDF +foliar spray of nano urea (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (120.57 cm).

Table 1: Effect of foliar application of nano urea and nano DAP with growth regulators on growth and yield parameter

Tr. No.	Treatments	Plant height at harvest (cm)	Leaf length at harvest (cm)	Grain Yield (q ha-1)
T_1	Control	179.89	103.60	41.98
T_2	100% RDF	186.79	114.43	71.32
T_3	100% RDF + nano urea + GA3 50 ppm (25 and 50 DAS)	195.15	122.59	81.39
T_4	100% RDF + nano DAP + GA3 50 ppm (25 and 50 DAS)	197.82	123.36	81.78
T_5	100% RDF + nano urea + nano DAP (25 and 50 DAS)	205.22	127.25	86.61
T_6	100% RDF + nano urea + nano DAP + GA3 50 ppm (25 and 50 DAS)	208.56	128.35	89.39
T_7	75% RDF + nano urea + GA3 50 ppm (25 and 50 DAS)	193.01	120.57	78.79
T_8	75% RDF + nano DAP + GA3 50 ppm (25 and 50 DAS)	194.85	121.86	79.73
T_9	75% RDF + nano urea + nano DAP (25 and 50 DAS)	202.19	125.53	82.47
T_{10}	75% RDF + nano urea + nano DAP GA3 50 ppm (25 and 50 DAS)	205.11	126.87	84.84
	SEm±	1.13	2.89	2.03
	CD at 5%	3.60	9.25	6.03

Similar findings were reported by Subrahmanya *et al.* (2019) [15] that fodder maize cultivated at a seed rate of 60 kg/ha produced significantly longer leaves averaging 101.60 cm a result further enhanced by applying 125% of the recommended dose of fertilizers (RDF) which increased leaf length by 65.96% compared to control plots. Similarly, Kashyap *et al.* (2022) [6] demonstrated that foliar treatments guided by a leaf color chart (LCC) significantly influenced maize leaf length the LCC threshold-5 treatment combined with nano urea spray at 6 mL/L yielded leaf length increases statistically equivalent to those at thresholds 4 and 3 measured consistently at 30, 60, 90 DAS and harvest. The observed enhancements in leaf length and breadth are likely linked to nitrogen critical role in metabolic processes, driving cell division, expansion, chlorophyll synthesis, and overall plant growth effects particularly pronounced when nitrogen is supplied through efficiently absorbed nano urea.

Grain and stover yield

The data on yield of maize crop as influenced by foliar application of nano urea, nano DAP and growth regulator are presented in Table 1. The significantly highest grain yield (89.39 q ha^{-1}) was observed with the treatment T_6 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS which was significantly at par with the treatment T_5 – 100% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) at 25 and 50 DAS (86.61 q ha^{-1}), T_{10} - 75% RDF + foliar spray of nano urea (4ml L^{-1}) + nano DAP (4ml L^{-1}) + GA_3 50 ppm at 25 and 50 DAS (84.84 q ha^{-1}). Rajesh *et al.* (2021) [11] conducted a field trial on sweet cob and reported that foliar application of chemically synthesized nano nitrogen (4 mL L^{-1}) and nano zinc (2 mL L^{-1}) at 25 and 50 DAS, combined with 75% of RDN and full P K supply, significantly improved yield characteristics including cob length, girth, kernel count, cob weight and overall yield surpassing conventional NPK only treatments. This mirrors findings by Reddy *et al.* (2022) [12] who showed that replacing 50% of nitrogen with nano urea along with nano zinc substantially enhanced maize grain yield and stover biomass compared to conventional urea plus zinc EDTA. The study attributed these gains to the nanoscale formulation greater surface area and controlled nutrient release which improved nutrient uptake efficiency, photosynthetic activity and assimilate transport to developing grains, collectively boosting productivity. Monica *et al.* (2021) [9] similarly noted maximum stover yield using a combination of full N and P fertilization and two foliar sprays of 2% urea phosphate, attributing this to synergistic soil and foliar nutrient supply a result that aligns with findings by Kale *et al.* (2024) [4].

Conclusion

From the results summarized above following conclusion can be drawn that foliar application of nano urea, nano DAP and growth regulator improved all the growth parameters and yield attributes of maize. Application of 100% RDF + foliar spray of nano urea (4ml L^{-1}), nano DAP (4ml L^{-1}), GA_3 50 ppm at 25 and 50 DAS (T_6) significantly increases growth parameters such as cob length, no. of cob per plant, plant height and leaf length, also increases the yield and yield attributing parameters and quality parameter like grain protein also observed significant. The difference in plant height and leaf length was predominantly observed from 30 to 90 days after sowing i.e. after first- and second-time foliar application of nano urea, nano DAP, recommend dose of fertilizer (RDF) with growth regulator (GA_3). Also, the economics parameter like GMR, NMR and B:C ratio was also significantly maximum. So, it may be concluded that combined application of nano fertilizer (nano urea and nano DAP) combined with recommended dose of fertilizer (RDF) with gibberellic acid (GA_3) helpful for increasing the plant height and leaf length.

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