**Effect of different levels of Nano Urea on growth and yield of Maize (*Zea mays* L.)**

**ABSTRACT:**

A field experiment was conducted during the *kharif* season of 2023 at the Zonal Agricultural Research Station, V.C. Farm, Mandya, to investigates the effects of nano urea and conventional urea doses through foliar spraying at different growth stages of the maize crop by establishing a comparative analysis between both treatments. The experiment was followed a Randomized Complete Block Design with ten treatments, replicated thrice. The treatments consisted of 75% and 100% of the recommended nitrogen dose (RDN), supplemented with foliar applications of nano urea (2, 4, and 6 ml l⁻¹) and urea (2%) at 25 and 50 days after sowing. These were compared with the recommended dose of fertilizer (RDF) alone and a control (RDF without nitrogen). Theresults revealed that the highest plant height (220.33 cm), SPAD readings (48.97 at 90 DAS and 35.97 at harvest), and total dry weight of leaf (55.86 g plant⁻¹) and stem (160.73 g plant⁻¹) were recorded with 100% RDN + nano urea @ 4 ml l⁻¹ foliar spray. This treatment was statistically on par with 75% RDN + nano urea @ 4 ml l⁻¹. Similarly, the highest grain yield (9256 kg ha⁻¹) and stover yield (11474 kg ha⁻¹) were obtained under 100% RDN + nano urea @ 4 ml l⁻¹, with comparable results in the 75% RDN + nano urea @ 4 ml l⁻¹ treatment. These findings suggest that nano urea application allows a reduction in nitrogen fertilizer use without compromising maize productivity, offering a sustainable alternative for nutrient management.

**Keywords:** Nano urea, Foliar spray,Plant height, SPAD Readings, Total dry weight, maize

**1. INTRODUCTION**

Maize is one of the most important cereal crops in the global agricultural economy, ranking alongside rice and wheat as a vital source of food for humans and feed for livestock. With its exceptional yield potential, maize is unmatched by any other crop, earning it the title of 'Queen of Cereals' Siatwiinda *et al.* (2021) [14]. Its botanical name is *Zea mays* L., and it belongs to the family Gramineae, subfamily Poaceae, with a chromosome number of 20 (2n). Nutrient composition of maize includes crude protein 7.6%, crude fiber 2.3%, crude fat 3.6% and starch 63.8% and total sugar 1.7%, Gross energy 3840 kcal kg-1 Langyan *et al*. (2022) [9]. In India, it occupies an area of 10.74 M ha with a production of 38.08 M t with an average productivity of 35.45 q ha-1 (Anon., 2023) [3]. Karnataka holds first rank in area (1.91 M ha) and production (5.91 M t) among the maize growing states in India, with average productivity of 3.09 t ha-1 (Anon., 2023) [4].

A balanced use of nitrogen (N), phosphorus (P), and potassium (K) fertilizers is crucial for enhancing cereal yields, especially even under moisture-stress conditions. Among various growth-limiting factors, the correct levels and ratios of NPK are of prime importance. Among the all nutrients nitrogen play a vital nutrient for healthy plant growth and development and it available in liquid form nano urea. This nutrient is essential for the synthesis of amino acids, enzymes, genetic material, photosynthetic pigments, and energy transfer molecules in plants. Foliar application of nitrogen, particularly under moisture stress, can significantly increase crop productivity.

A sufficient amount of nitrogen stands essential for cultivating crops to their peak outcomes along with superior yield production. Standard urea remains popular yet struggles to achieve satisfactory use efficiency and causes large environmental losses. Soil degradation plus environmental imbalances emerge when fertilizers are excessively applied. Nano urea, with its ultrafine particles and higher bioavailability, offers a promising alternative. The efficient nutrient uptake enabled by nano urea enables the use of lower application rates according to research by hoque *et al.* (2024) [8].

Foliar spraying not only supplies essential nutrients directly to plants but also provides a supplemental water source during water-stress periods. In addition to promoting growth, nitrogen application can enhance a plant’s drought tolerance, leading to improved yields under water-deficit conditions. Research shows that nitrogen applied at different growth stages can benefit starch synthesis and grain formation during post-anthesis drought. Foliar-applied nitrogen is also up to seven times more efficient than soil-applied nitrogen, requiring lower application rates and allowing for timely, uniform distribution Hong *et al.* (2021) [7]. A best practice is to combine soil and foliar nitrogen applications to optimize nutrient use efficiency, making it a highly effective method for delivering nitrogen to plants.

Nano Urea (Liquid) contains nitrogen particles at the nanoscale, providing an exceptionally high surface area and particle density up to 10,000 times greater than conventional 1 mm urea prills, which typically contain around 55,000 nitrogen particles. With an uptake efficiency of over 80%, nano urea offers a distinct advantage over traditional granular urea. Rather than being soil-applied, nano urea is directly sprayed onto crop leaves during two key growth stages, allowing for precise nutrient delivery. Remarkably, a single 500 ml vial of nano urea can replace a traditional 45 kg bag of granular urea, demonstrating its high efficiency and potential to improve sustainability Naveen *et al*. (2021) [11].

Nanotechnology applications in fertilizers, such as nano urea, show great promise for advancing sustainable agriculture. By enhancing soil health and optimizing nutrient use, these innovations support increased crop yields. Recently, researchers have focused on modern agricultural techniques, including the use of nanotechnology to improve fertilizer efficiency. The development of nano fertilizers, with specialized formulations and delivery systems, is poised to enhance nutrient uptake and support the demands of modern agriculture. Foliar spray of nano urea at knee stage and tasselling stage could be an ideal technological alternative to achieve sustainability in irrigated maize Samui *et al.* (2021) [13] and significantly increased the growth parameter and yield parameter of the crop.

# **2. MATERIALS AND METHODS**

A field trial was conducted at Zonal Agricultural Research Station (ZARS) V. C. Farm, Mandya University of Agricultural Sciences, Bengaluru (Karnataka) in 2023. Geographically, the experimental site is situated at 12°18’ and 13°04’ North latitude and 76°19’ and 77°20’ East longitude and at an altitude of 697 m above mean sea level in the southern dry zone. The soil at the experimental site was neutral in pH (6.6), sandy loam in texture, low in organic carbon (0.58%), medium in available N (287 kg ha-1), medium in available P (53.59 kg ha-1) and high in available K (287 kg ha-1).

The actual rainfall received during the crop growing period was 257.40 mm. The major part of the rainfall was received in the month of October (89.50 mm). The mean maximum air temperature varied from 28.2 °C to 32.3 °C. The highest mean maximum air temperature was noticed during August (32.3 °C). The mean minimum air temperature ranged from 18.0 °C to 20.6 °C. The lowest mean minimum temperature recorded during December (18.0 °C). The mean bright sunshine hours varied from 6.4 to 7.2 hours during July to December. The relative humidity varied from 82 to 85.8 % and 57.8 to 60 % in morning and afternoon hours, respectively during the crop growing period of 2023.

 The experiment was conducted in a Randomized Complete Block Design (RCBD) consisting of ten treatments and replicated three times. The treatments include RDF (N: P: K @ 150:75:40 kg ha-1) (T1), Control (RDF without N) (T2), 75% recommended dose of N + 2 foliar applications of 2% urea (T3), 100% recommended dose of N + 2 foliar applications of 2% urea (T4), 75% recommended dose of N + 2 foliar applications of nano urea @ 2 ml l-1 (T5), 100% recommended dose of N + 2 foliar applications of nano urea @ 2 ml l-1 (T6), 75% recommended dose of N + 2 foliar applications of nano urea @ 4 ml l-1 (T7), 100% recommended dose of N + 2 foliar applications of nano urea @ 4 ml l-1 (T8), 75% recommended dose of N + 2 foliar applications of nano urea @ 6 ml l-1 (T9), 100% recommended dose of N + 2 foliar applications of nano urea @ 6 ml l-1 (T10). Nitrogen was applied through urea in two splits, that is half the nitrogen was applied at the time of sowing as the basal dose, and the remaining 50% N was applied at two splits at 30 DAS and at the time of final earthing up.  Nano urea and urea was sprayed at 25 and 50 days after sowing. The recommended doses of phosphorus and K were applied basally for all treatments. Maize was sown at a seed rate of 15 kg ha-1 with a spacing of 60 cm × 30 cm. The observations were recorded for plant height (cm), Number of green leaves plant-1, SPAD readings, leaf & stem dry weight (g plant-1), Cob length, Cob girth, Number of rows per cob, kernel weight per cob, test weight (g), grain yield (kg/ha) and stover yield (kg/ha) & Harvest Index (%). The observed data obtained on various parameters were subjected to statistical analysis by adopting Fisher’s method of analysis of variance (ANOVA) as given by Gomez and Gomez (1984) [6]. The results have been discussed at the probability level of five per cent. The level of significance used in “F” test was p = 0.05. Critical difference values were calculated wherever the “F” test was found significant. Otherwise, against CD values abbreviation NS (Non-significant) was indicated.

**3. RESULTS AND DISCUSSION**

**3.1 Growth parameters**

*Plant height (cm)*: Significantly higher plant height (220.33 cm) was recorded in the treatment with the application of 100 per cent RDN + 2 foliar application of nano urea at 4 ml l-1 at 25 and 50 DAS, which was on par with the 75 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS (217.67 cm) compared with other treatments. However, significantly lower plant height (167.33 cm) was recorded in the 100 per cent RDP and K + no nitrogen treatments. Application of 100 per cent RDN + 2 foliar application of nano urea at 4 ml l-1 at 25 and 50 DAS was found to be beneficial in increasing the plant height of maize up to harvest compared to the application of the recommended dose of fertilizer alone, and was followed by 75 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS. This is due to the application of nano-urea, which stimulates and increases amino acid synthesis, which in turn increases the production of growth hormones, thereby increasing cell growth and cell elongation in plants, leading to an increase in plant height (Table 1). Ahmed *et al.* (2019) [1] revealed that the application of N through both sources (urea and nano-urea), either individually or in combination, significantly increased plant height compared to the control. The results obtained showed the greatest plant height with urea and nano-urea spray treatments, which is supported by the findings of Reddy *et al*. (2022) [12].

*SPAD reading:* SPAD readings at 90 DAS and harvest showed significant differences across treatments. Significantly higher SPAD values were recorded in the treatment with 100 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS (48.97 and 35.97 at 90 DAS and at harvest, respectively) than 100 per cent RDP and K + no nitrogen (33.06 and 28.75 at 90 DAS and at harvest, respectively). However, the treatment with 75 per cent RDN + 2 foliar application of nano urea at 4 ml l-1 at 25 and 50 DAS) recorded in higher SPAD readings (48.29 and 35.27 at 90 DAS and at harvest, respectively). Lower SPAD readings (33.06 and 28.75, respectively) were recorded in the 100 per cent RDP & K + no-nitrogen treatment. SPAD readings (chlorophyll content) were indicators of good photosynthesis (Table 1).

Two foliar sprays of nano urea at 4 ml l-1 can enhance leaf chlorophyll content in maize when combined with 100 per cent recommended nitrogen dose better than at higher concentrations of 2 foliar application of nano urea at 6 ml l-1 combined with 100 per cent recommended nitrogen dose. Crop efficiency requires finding the perfect nano urea dosage because wrong application rates might harm plants through phytotoxic effects. Nano urea being Nano-sized nanoparticles depend on the availability of leaf surface area on different days of growth for better absorption, permeability, and penetration into plant leaves. The chlorophyll content in plant leaves is closely related to the nutritional status of plants, as the chlorophyll content increases linearly with the amount of nitrogen in the leaf up to a certain point. Therefore, increased N content may lead to increased chlorophyll content up to a certain point, after which high nitrogen levels can be toxic to plants, leading to oxidative stress, which can degrade chlorophyll and damage cell structures. Thus, the increase in the SPAD value and leaf N content might help in the continuous supply of sufficient nitrogen throughout the crop growth period. This result agrees with the findings of Zhai *et al.* (2022) [17], Das *et al.* (2022) [5], and Aljuthery and Almaamouri (2020) [2].

**Table 1. Impact of foliar application of nano urea on growth parameters in maize at harvest**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **SPAD readings** | **Plant dry weight (gm)** |
| **90 DAS** | **At harvest** | **Leaves** | **Stem** |
| **T1: RDF (POP)** | 200.67 | 36.48 | 29.97 | 42.63 | 133.13 |
| **T2: 100% RDP & K + no nitrogen** | 167.33 | 33.06 | 28.75 | 34.70 | 81.45 |
| **T3: 75% RDN + Foliar applications of 2% urea twice at 25 and 50 DAS** | 206.27 | 44.57 | 32.07 | 47.57 | 146.67 |
| **T4: 100% RDN + Foliar applications of 2% urea twice at 25 and 50 DAS** | 210.33 | 45.42 | 34.23 | 48.60 | 147.67 |
| **T5: 75% RDN + 2 Foliar applications of Nano urea @ 2 ml l-1 at 25 and 50 DAS** | 202.63 | 38.15 | 30.37 | 44.20 | 139.23 |
| **T6: 100% RDN + 2 Foliar applications of Nano urea @ 2 ml l-1 at 25 and 50 DAS** | 204.67 | 40.12 | 31.57 | 45.27 | 141.19 |
| **T7: 75% RDN + 2 Foliar applications of Nano urea @ 4 ml l-1 at 25 and 50 DAS** | 217.67 | 48.29 | 35.27 | 54.50 | 154.87 |
| **T8: 100% RDN + 2 Foliar applications of Nano urea @ 4 ml l-1 at 25 and 50 DAS** | 220.33 | 48.97 | 35.97 | 55.86 | 160.73 |
| **T9: 75% RDN + 2 Foliar applications of Nano urea @ 6 ml l-1 at 25 and 50 DAS** | 211.00 | 45.47 | 33.50 | 51.77 | 151.37 |
| **T10: 100% RDN + 2 Foliar applications of Nano urea @ 6 ml l-1 at 25 and 50 DAS** | 213.29 | 46.25 | 33.93 | 52.57 | 153.93 |
| **S.Em. ±** | **2.05** | **0.89** | **0.56** | **0.80** | **1.93** |
| **C.D. (p=0.05)** | **6.09** | **2.66** | **1.67** | **2.38** | **5.72** |

The analysis of SPAD readings at 90 DAS and harvest points in relation to plant height is displayed in SPAD Readings vs. Plant Height [Fig. 1]. The SPAD measurement reveals higher values in tall plants because they contain more chlorophyll. The SPAD readings attain their maximum values in plants T7, T8, and T10 although T2 demonstrates the minimum readings. Plant maturity during the period from 90 Days After Sowing to harvest causes a minimal decrease in the SPAD values indicating chlorophyll loss.

*Plant dry weight (g plant-1):* The data revealed that significantly higher leaf and stem dry weight (55.86 and 160.73 g plant-1) were observed in T8 -100 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS. However, T7 -75 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS was found to be statistically at par with T8 -100 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS (Table 1).

Application of nano-urea (4 ml l-1) and urea (150 kg ha-1) significantly increased plant dry weight, which may be related to the micronutrient's ability to activate the synthesis of tryptophan and a precursor to IAA, which in turn stimulates plant growth and biomass accumulation. In addition, ferredoxin and electron transport are linked to chloroplasts, which accelerate photosynthesis for improved vegetative growth. Similarly, findings were also reported by Singh *et al.* (2017) [15].

The evaluation of plant height vs Plant Dry Weight [Fig. 2]. reveals the comparison between dry weights among plant leaves and stems under different treatment conditions. A visual inspection confirms that plant stems produce greater dry components than leaves do. T8 (220.33 cm) displays maximum biomass and stands as the tallest while T2 (167.33 cm) displays minimal biomass. Plant height shows a powerful relation with the accumulation of biomass because the most vigorous plants belong to T7 T8 T9 and T10.

Overall, Plant height directly corresponds with both chlorophyll content and biomass production according to the analysis findings. Data indicates that Treatment T8 provides optimal outcomes while the lowest performing results belong to Treatment T2 which yields the least beneficial values across all parameters. Research implies that optimizing plant height can significantly improve plant health and productivity.

**3.2 Yield Attributes**

*Cob length, cob girth:* The highest cob length and cob girth (19.42 and 16.82 cm) was recorded in 100 per cent RDN + 2 foliar application of nano urea @ 4 ml l-1 at 25 and 50 DAS.

 **Table 2.** **Impact of foliar application of nano urea on yield attributes in maize at harvest**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments**  | **Cob length** | **Cob girth** | **No of rows per cob** | **Kernal weight per cob** | **Test weight** | **Grain yield** | **Stover yield** | **Harvest index** |
| **T1** | 16.48 | 13.85 | 13.30 | 132.76 | 26.21 | 7338 | 8836 | 0.45 |
| **T2** | 11.09 | 13.05 | 12.81 | 77.67 | 23.20 | 6022 | 8110 | 0.43 |
| **T3** | 18.22 | 15.10 | 14.80 | 150.67 | 27.81 | 8270 | 9865 | 0.46 |
| **T4** | 18.52 | 15.20 | 15.00 | 154.82 | 28.60 | 8301 | 10114 | 0.45 |
| **T5** | 17.04 | 13.99 | 13.70 | 134.14 | 27.30 | 7546 | 9238 | 0.45 |
| **T6** | 17.52 | 14.20 | 13.94 | 138.43 | 27.34 | 7604 | 9520 | 0.44 |
| **T7** | 18.92 | 16.36 | 16.11 | 160.08 | 30.04 | 9196 | 11022 | 0.45 |
| **T8** | 19.42 | 16.82 | 16.19 | 161.15 | 30.78 | 9256 | 11474 | 0.45 |
| **T9** | 17.95 | 15.25 | 15.01 | 152.37 | 29.37 | 8543 | 10443 | 0.45 |
| **T10** | 18.42 | 15.79 | 15.10 | 154.03 | 29.61 | 8605 | 10893 | 0.44 |
| **S.Em. ±** | **0.28** | **0.30** | **0.33** | **2.29** | **2.21** | **215.19** | **192.66** | **0.007** |
| **C.D. (p=0.05)** | **0.85** | **0.89** | **0.99** | **6.81** | **NS** | **639.37** | **572.42** | **NS** |

However, treatments of 75 per cent RDN + 2 foliar application of nano urea @ 4 ml l-1 at 25 and 50 DAS (18.92 and 16.36 cm) were found to be at par with the treatment of 100 per cent RDN + 2 foliar application of nano urea @ 4 ml l-1 at 25 and 50 DAS. The use of nitrogen in the form of nano urea and urea helpful to increased cob length significantly which results in synergism and improvement of nutrient which leads to the formation of better cob and corn length (Table 2). These findings corroborate the results of Longchar *et al.* (2022) [10].

*Number of rows per cob:* The data on the number of rows cob-1 in maize as influenced by nano-urea application using different treatment combinations recorded at harvest are presented in Table 2. The treatment with the application of 100 per cent RDN + 2 foliar application of nano-urea at 4 ml l-1 at 25 and 50 DAS resulted in a significantly higher number of rows cob-1 (16.19), and the treatment was recorded to be on par (16.11) with the application of 75 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS compared to other treatments. In contrast, a lower number of rows of cob-1 (12.81) was identified in the 100 per cent RDP & K + no nitrogen treatment (Table 2).

*Kernel weight per cob:* Data relevant to the kernel weight cob-1 in maize as influenced by nano-urea application using different treatment combinations recorded at harvest. Significantly higher kernel weight cob-1 (161.15 g) at harvest was recorded with the application of 100 per cent RDN **+** 2 foliar applications of 4 ml l-1 at 25 and 50 DAS, and it was on par (160.08 g) with the application of 75 per cent RDN **+** 2 foliar applications of 4 ml l-1 at 25 and 50 DAS compared to other treatments. However, the 100 per cent RDP & K **+** no nitrogen treatment resulted in a lower kernel weight cob-1 77.67 g.  The effects of various treatments on growth parameters in the previous paragraphs clearly indicated the trends wherein the nutrient-based absorption capacity also varied, causing differences in photosynthate accumulation and further transport (Table 2).

As indicated, nitrogen application mainly supported all growth parameters like cell enlargement, nutrient content, enzymatic activities, etc. Wherever there is balanced source, It is well developed with proper increased photosynthesis that leads to the accumulation of carbohydrates and proteins in the cob. The data evidenced the combination of both soil application of urea and spray of nano urea increased the yield attributes significantly.

*Test weight (g):* The data regarding the test weight of grains as influenced by nano urea application in maize in Table 2. No significant difference was observed among the various treatment combinations for test weight at harvest. However, numerically more test weight (30.78 g) was recorded in treatment with the application of 100 per cent RDN **+** 2 foliar application of nano urea @ 4 ml l-1 at 25 and 50 DAS compared to other treatments. In comparison, numerically least test weight (23.20 g) was recorded in the 100 per cent RDP & K **+** no nitrogen treatment.

The test weight remained non-significant among different treatment combinations mainly due to resource mobilization capacity to that of sink and accounted as genetic trait which doesn't vary due to other factors.

**Grain yield**

Information pertaining to grain yield as influenced by nano-urea application in maize recorded at harvest is provided in Table 2.

A significantly higher grain yield (9256 kg ha-1) was recorded in plots with the application of 100 per cent RDN + 2 foliar applications of 4 ml l-1 at 25 and 50 DAS, which was on par with the application of 75 per cent RDN + 2 foliar applications of 4 ml l-1 at 25 and 50 DAS (9196 kg ha-1) compared to other treatments. In contrast, a lower grain yield (6022 kg ha-1) was recorded in the 100 per cent RDP & K + no-nitrogen plot. Application of nano-fertilizers, which help in the activation of enzymes by fusing with the formation of chlorophyll in most plants and accelerate growth hormone formation, such as tryptophan, helps to store carbohydrates in plants, eventually leading to an increased number of seeds per plant as a source and storage of carbohydrates and increased yield.

**Stover yield**

Data pertaining to stover yield as influenced by nano-urea application in maize recorded at harvest are presented in Table 2.

Treatment with the application of 100 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS resulted in a significantly higher stover yield (11474 kg ha-1), which was statistically on par with the application of 75 per cent RDN + 2 foliar application of 4 ml l-1 at 25 and 50 DAS (11022 kg ha-1) than the other treatments. In contrast, the 100 per cent RDP & K + no-nitrogen plot recorded a lower stover yield (8110 kg ha-1).

An increase in stover yield is attributed to enhanced protein synthesis owing to the increased availability of nitrogen, which plays an important role in cell division and plant growth. These results were in agreement with those reported by Ullasa *et al.* (2016) [16].

**Harvest index**

At harvest, the highest harvest index (0.45) was recorded in T8 with the application of 100 per cent RDN and 4 ml l-1 at 25 and 50 DAS, although there was a non-significant difference among the treatments.

**Conclusion**

It may be concluded that combination of nano urea at 4 ml/L with 100% RDN applied at 25 and 50 DAS through foliar treatment demonstrates maximum positive effects on both growth and yield characteristics of maize. The application of nano urea at doses of 4 ml/L and 100% RDN produces positive effects on plant height and SPAD readings as well as plant dry weight and vegetative development. The use of nano urea brings about lengthier cob sizes together with wider girths and heavier kernels per cob that result in enhanced grain production at 9256 kg/ha. The optimized nutrient uptake capacity of nano urea produces vigorous growth patterns and enhances photosynthetic activity that results in better maize production outcomes.

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