

Nano urea-mediated improvement in yield, nutrient uptake and economics of maize

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ABSTRACT

A field experiment was conducted during *khari*, 2023 at ANGRAU-Agricultural Research Station, Vizianagaram to assess the impact of nano urea on growth, yield, economics and nutrient uptake of maize and also to explore the possibility of reducing the conventional nitrogen fertilizer dose. This study was conducted in a Randomized Block Design with three replications. The soil of the experimental field was sandy loam in texture, neutral in reaction, low in nitrogen, organic carbon, medium in phosphorus and potassium. The experimental results revealed that, T₅:100% RDN through urea in three splits (33% basal + 33 % KH+ 33% at TS) + nano urea sprays at KH and TS resulted in higher growth and yield attributes, grain yield, stover yield and plant nutrient uptake. However, it remained on par with T₃:100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS), T₆:75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and T₇:75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. Economic parameters viz., gross returns, net returns and BCR also did not vary significantly among T₅, T₃, T₆ and T₇. Hence, 75% RDN + nano urea foliar sprays at Knee-high (KH) and Tasselling(TS) stages can be recommended to increase the yield, economic returns and nutrient uptake with an additional saving of conventional urea fertilizers.

Keywords: *Economics, Maize, Nano Urea, Nutrient Uptake and Productivity*

Maize (*Zea mays L.*) is one of the most important cereal crops serving as a staple food, animal feed, and industrial raw material. Ensuring its optimal growth and yield is crucial for global food security, particularly in the face of increasing population pressure and diminishing arable land. Among the critical factors influencing maize productivity, nutrient management plays a pivotal role. Nitrogen continues to be the “kingpin” of the nutrient management as it is the key constituent of proteins, nucleic acids, vitamins and chlorophyll. Traditionally, urea has been widely used as a nitrogen source to support vegetative and reproductive growth in maize. However, the conventional use of urea is often associated with low nitrogen use efficiency (NUE), leading to significant nitrogen losses through leaching, volatilization, and denitrification (Ladha *et al.*, 2005), which not only reduce crop productivity but also pose environmental hazards (Singh, 2018).

In recent years, the advancement of nanotechnology in agriculture has opened new avenues for enhancing nutrient delivery and uptake efficiency. Nano urea, a novel fertilizer formulation,

contains nitrogen in nano-sized particles that offer higher surface area, increased solubility and targeted delivery (DeRosa *et al.*, 2010 and Rameshaiah *et al.*, 2015). When applied as a foliar spray, nano urea has the potential to be rapidly absorbed by plant leaves, thereby reducing nutrient losses and improving nitrogen assimilation. This precision in nutrient application not only enhances plant metabolic activity but also positively influences growth parameters, yield attributes, and overall crop productivity.

The foliar application of nano urea presents a promising alternative to conventional urea, especially under conditions where soil-based nitrogen applications are inefficient or environmentally unsustainable. Several preliminary studies have indicated that nano urea can significantly boost growth traits such as plant height, leaf area index, and chlorophyll content, as well as yield components including cob weight, kernel number, and grain yield. However, comprehensive evaluations under different agro-climatic conditions and maize genotypes are essential to validate these benefits. This study aims to assess the influence of nano urea foliar application on

the growth and yield of maize, with a focus on reducing the conventional urea usage, optimizing nitrogen use efficiency, while ensuring sustainable agricultural productivity.

MATERIAL AND METHODS

The experiment was conducted during *kharif*, 2023 at Agricultural Research Station, Vizianagaram located at 18°07' N latitude, 83°25' E longitude and 63 m above MSL in the Coastal Agro-climatic Zone of Andhra Pradesh. The total rainfall received during *kharif*, 2023 was 797mm in 24 rainy days. The soil of the experimental field was sandy loam in texture, neutral in pH (6.93), non-saline (0.23 dS m⁻¹), low in organic carbon (0.45%) and soil available nitrogen (222 kg ha⁻¹) and medium levels of available phosphorus (24.5 kg ha⁻¹) and potassium (312.5 kg ha⁻¹).

The present experiment was laid out with nine treatments in a Randomized Block Design with three replications. The treatments include T₁: Control (no application of N); T₂: Application of nano urea alone twice at Knee high (KH) and Tasseling (TS) stage @ 4ml/L; T₃: 100% RDN through urea in three splits (33% basal+ 33% KH+ 33%TS); T₄: 33% RDN as basal + Two sprays Nano urea at KH and TS; T₅: 50% RDN only basal + Two sprays Nano urea at KH and TS; T₆: 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS; T₇: 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS; T₈: 50% RDN (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS and T₉: 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS. Recommended dose of N was 200 kg ha⁻¹ applied in the form of urea as per treatments. Recommended dose of P (60 kg ha⁻¹) and K (50 kg ha⁻¹) were commonly applied to all the treatments as basal in the form of Di-ammonium phosphate and Murate of Potash. IFFCO Nano urea was applied as foliar spray @ 0.4% at Knee-high (KH) stage and Tasseling(TS) stages.

Maize hybrid NK6668⁺ was sown in plots with 4.8 m × 4.0 m size at 60 cm × 20 cm spacing on 28.07.2023. Pre emergence herbicide Atrazine was applied @ 1.0 kg a.i. ha⁻¹ immediately after sowing. Intercultivation was done with human labour at 25 DAS. Necessary plant protection measures were

taken from time to time to keep the pest and disease problems under control. Pre harvest (Plant height, days to reproductive stage) and post-harvest (Cob length, cob girth, test weight, grain yield and stover yield) observations were recorded. Economics of various treatments were worked out by considering the prevailing input costs and output market prices. The Nitrogen, phosphorus and potassium contents of both grain and stover were estimated by Modified Micro Kjeldahl's method, Vanadomolybdo phosphoric yellow colour method and Flame photometer method (Jackson, 1973) respectively. Statistical analysis of the data was done by using ANOVA as outlined by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Effect On Growth Attributes

Nano urea application had a significant influence on crop duration and plant height of maize. Days to reproductive stage and days to maturity were extended with increased nitrogen application. 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS showed longer days to tasseling and maturity (57.7 days & 117.3 days respectively). The treatment with no nitrogen application had the minimum days to reproductive stage and days to maturity. Lower nitrogen promotes flowering, while the optimal nitrogen doses delays flowering until the plants are sufficiently large and healthy enough to enter into reproductive stage.

Plant height of maize was higher with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS (198.9cm), however it was found on par with 100% RDN through urea in three splits (33% basal+ 33% KH + 33%TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. No nitrogen application significantly reduced the plant height of maize (124.9cm). The taller plant height of maize in 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS might be due to adequate availability nitrogen, a key element in plant growth which stimulates the cell division, cell elongation, protein synthesis, chlorophyll formation and photosynthesis. Further, the nano urea application in this treatment might have

Table 1: Effect of nano urea on growth and yield attributes of maize

Treatments	Days to reproductive stage	Days to maturity	Plant height (cm)	100 seed wt (g)	Cob length (cm)	Cob girth (cm)
T ₁ : Control (no application of N)	52.7	114.7	128.9	23.2	9.3	8.9
T ₂ : Application of nano urea alone twice at KH and TS stage @ 4ml L ⁻¹	54	119	167	23.5	12.4	10.8
T ₃ : 100% RDN through urea in three splits (33% basal + 33% KH + 33% TS)	56.7	112.3	200.7	26.2	15.5	14.1
T ₄ : 33% RDN as basal + Two sprays of nano urea at KH and TS	54.3	113.7	172.6	23.6	12.6	11.6
T ₅ : 50% RDN only basal + Two sprays of nano urea at KH and TS	55	112	180.3	24.1	13.5	12.1
T ₆ : 75% RDN (33% basal+ 33% KH+33% at TS) + Two sprays of nano urea at KH and TS	56.7	109	194.9	26.1	15.3	13.3
T ₇ : 75% RDN (66% basal + 17% KH+17% at TS) + Two sprays of nano urea at KH and TS	56	112.3	192.8	25.7	15	12.6
T ₈ : 50% RDN (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	55.3	114	183.1	24	13.7	12.3
T ₉ : 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	57.7	115.3	204.4	26.7	15.9	14.8
S.Em±	0.67	1.35	8.35	0.35	0.66	0.59
CD (0.05)	1.99	4.05	25.04	1.05	1.97	1.76
CV (%)	2.08	2.06	8.02	2.45	8.32	8.3

stimulated more physiological and enzymatic activities. Similar observations were reported by Chavan *et al.* (2023) and Dokhe *et al.* (2024).

Effect on Yield Attributes and Yield

Cob parameters like cob length and cob girth were increased significantly with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS as compared to other treatments but remained on par with 100% RDN through urea in three splits (33% basal+ 33% KH + 33%TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. Substantial reduction in cob parameters were recorded with no nitrogen application. Test weight was also influenced by the plant nutrition. Many studies have proven that even lower or higher plant nutrition may negatively correlate with test weight. In this study, the higher test weight of maize was recorded with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS (26.7

g), however, it was found on par with 100% RDN through urea in three splits (33% basal+ 33% KH + 33%TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS.

Superior growth and yield attributes ultimately contributed to higher grain and stover yields of maize where, 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS (7859 & 9500 kg ha⁻¹ respectively) was applied as compared to other treatments except 100% RDN through urea in three splits (33% basal+ 33% KH + 33%TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. The improvement in grain and stover yields were 5.73% and 5.99% respectively with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS as compared to 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS). Application of nano urea alone

Table 2. Effect of nano urea on yield and economics of maize

Treatments	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Gross income (Rs/ha)	Net income (Rs/ha)	BCR
T ₁ : Control (no application of N)	3508	4762	82834	43087	2.08
T ₂ : Application of nano urea alone twice at KH and TS stage @ 4ml L ⁻¹	3878	5221	91500	48953	2.15
T ₃ : 100% RDN through urea in three splits (33% basal + 33% KH + 33% TS)	7433	8963	173282	130031	4.01
T ₄ : 33% RDN as basal + Two sprays of nano urea at KH and TS	5603	7025	131157	87451	3
T ₅ : 50% RDN only basal + Two sprays of nano urea at KH and TS	6205	7647	144973	100824	3.28
T ₆ : 75% RDN (33% basal+ 33% KH+33% at TS) + Two sprays of nano urea at KH and TS	7304	8802	170256	124856	3.75
T ₇ : 75% RDN (66% basal + 17% KH+17% at TS) + Two sprays of nano urea at KH and TS	7116	8595	165912	120512	3.65
T ₈ : 50% RDN (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	6384	7827	149082	104333	3.33
T ₉ : 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	7859	9500	183247	137196	3.98
S.Em±	268.1	323.5	5880.4	5880.4	0.13
CD (0.05)	803.6	969.7	17626.7	17626.7	0.4
CV(%)	7.6	7.4	7.1	10.2	7.1

Table 3: Effect of nano urea on nutrient uptake of maize grain and stover

Treatments	Nutrient uptake in grain (kg ha ⁻¹)			Nutrient uptake in stover (kg ha ⁻¹)		
	N	P	K	N	P	K
T ₁ : Control (no application of N)	50.2	7.3	10.7	19.1	7.5	28.9
T ₂ : Application of nano urea alone twice at KH and TS stage @ 4ml L ⁻¹	55.3	8.7	11.5	20.7	8	32.3
T ₃ : 100% RDN through urea in three splits (33% basal + 33% KH + 33% TS)	101.9	17.6	25.7	30.2	13.7	58.5
T ₄ : 33% RDN as basal + Two sprays of nano urea at KH and TS	79	12.5	17.4	25.3	10.1	43.5
T ₅ : 50% RDN only basal + Two sprays of nano urea at KH and TS	87.3	13.8	19.7	26.3	11.2	47.7
T ₆ : 75% RDN (33% basal+ 33% KH+33% at TS) + Two sprays of nano urea at KH and TS	100.7	16.6	25.5	29.9	13.1	56.6
T ₇ : 75% RDN (66% basal + 17% KH+17% at TS) + Two sprays of nano urea at KH and TS	99.2	16.2	23.9	29.5	12.9	54.7
T ₈ : 50% RDN (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	90.3	13.8	20.6	27.2	12.7	48.7
T ₉ : 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + Two sprays of nano urea at KH and TS	109.2	18.8	27.7	34.5	14.9	62.7
S.Em±	4.04	0.85	0.79	1.59	0.62	1.77
CD (0.05)	12.11	2.54	2.38	4.77	1.87	5.3
CV(%)	8.14	10.54	6.76	10.22	9.36	6.35

twice at KH and TS stage @ 4ml/L showed 10.5% and 9.64% higher grain and stover yields as compared to control (no nitrogen application). These results are similar to the results reported by Rathour (2023), Bhukya *et al.*, (2024), Raj *et al.*, (2024), Parameshnaik *et al.*, (2024) and Pathak *et al.*, (2024).

Nano urea increases the nitrogen uptake, utilization, releases nitrogen based on plant's demand and minimizes losses from volatilization and leaching. Nano-urea can improve a number of physiological functions in plants, including enzyme activity, photosynthesis, and nutrient uptake (Dokhe *et al.*, 2024). Balanced supply of conventional urea in combination with nano urea might have contributed to the higher yield attributes and yield of maize.

Economics

Considering the economics, the highest gross returns (Rs.1,83,247.00) and net returns (Rs.1,37,196.00) were recorded with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS, however, it was found on par with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. The lowest gross and net returns were observed in the no-nitrogen application. Benefit cost ratio was not significantly varied among 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS), 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS, 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS.

Insufficient nitrogen led to the lower growth, yield and economic returns in absolute control plot. Higher grain and stover yields in T₉, T₃, T₆ and T₇ might be the reason for higher gross returns, net returns and benefit cost ratio. These results are analogous to the results reported by Rathour (2023).

Effect on Nutrient Uptake

The nitrogen uptake in grain was significantly higher with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea

sprays at KH and TS (109.2 kg ha⁻¹) among all the treatments, except 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS), 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS and 75% RDN (66% basal+ 17% KH+17% at TS) + nano urea sprays at KH and TS. The grain phosphorus and potassium uptakes were also found to be higher with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS (18.8 & 27.7 kg ha⁻¹), however, it was found on par with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) and 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS. The lowest grain nitrogen, phosphorus and potassium uptakes were found in the no-nitrogen application.

The straw nitrogen and phosphorus uptakes in 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS were found higher (34.5 & 14.9 kg ha⁻¹), however, it was found on par with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) and 75% RDN (33% basal+ 33% KH+33% at TS) + nano urea sprays at KH and TS. Potassium uptake in straw was also higher with T₉ and T₃. The lowest nitrogen, phosphorus and potassium uptakes were found in no-nitrogen treatment.

Nitrogen is the major essential element required by the plants in adequate quantities. The nitrogen applied through conventional sources is subjected to various losses, including volatilization, leaching, and denitrification, resulting in lower nutrient use efficiency. In contrast, due to its smaller particle size, higher surface area and activity, nano urea readily penetrated through stomata, absorbed by the plants and thereby improves the nutrient use efficiency. Moreover, nano urea releases nitrogen over an extended period, which matches the plant's growth stages and minimizes losses from volatilization and leaching [DeRosa *et al.* (2010); Lv *et al.* (2019)]. Conventional urea in combination with nano urea supplies the nitrogen in adequate quantities based on the crop nutrient demand.

Adequate nitrogen supply in the form of nano urea and conventional urea stimulates the cell division and cell elongation in the root tips, leading to higher root biomass and increased rhizosphere microbial

population, which ultimately results in more nutrient uptake and overall improvement in the nutrient use efficiency. Similar results were reported by Sriram *et al.* (2025), Bhukya *et al.* (2024), Rathour (2023) and Adhikari *et al.* (2014).

CONCLUSION

Based on the findings, it can be concluded that applying 75% RDN along with two sprays of nano urea at KH and TS stages resulted in higher yield, economic returns and nutrient uptake. These outcomes were comparable to those obtained with 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) and 100% RDN through urea in three splits (33% basal+ 33 % KH+ 33% at TS) + nano urea sprays at KH and TS. Moreover, this approach saves 25% of the conventional urea, without any yield reduction, thereby contributing to enhanced nutrient use efficiency and environmental sustainability.

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