



RESEARCH ARTICLE

Evaluating combined nano and conventional urea on yield, quality and economics in maize

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Abstract

The study was conducted at Regional Research Station, Karnal during 2022 in kharif season. Nine treatments- T₁: control (no recommended dose of nitrogen (RDN)), T₂: 100 % RDN through urea (150-60-60 kg ha⁻¹), T₃: 100 % RDN (three foliar spray of nano-urea at 15, 30 and 45 days after sowing (DAS)), T₄: 100 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS), T₅: 100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS), T₆: 75 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS), T₇: 75 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS), T₈: 50 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS) and T₉: 50 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS) were laid out in randomised block design (RBD) with 3 replications. Highest number of cobs/meter row length (4.7 cm), number of cobs (000 ha⁻¹) (63.0), number of grains/cob (453.3) and 1000-grains weight (32.0) was recorded by 100 % RDN through urea. Highest grain yield (76.5 q ha⁻¹) was recorded by 100 % RDN through urea which was statistically on par with 100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS). Highest protein content (11.4 %) was recorded with 100 % RDN through urea. Maximum gross returns (₹ 146899 ha⁻¹), net returns (₹ 78450 ha⁻¹) and benefit : cost (B : C) (2.08) were recorded with 100 % RDN through urea. This study recommends combined application of urea and nano urea for better productivity and profitability.

Keywords: conventional urea; economics; grain yield; maize; nano urea; protein

Introduction

Maize is one of the world's most important crops which serves both as food and fodder. In terms of area and production, India ranks as the 4th and 6th respectively among maize-growing countries. The United States records about 31.7 % of world production and has the highest productivity (over 11.3 t ha⁻¹), which is almost double than the global average (5.9 t ha⁻¹). Maize is cultivated across 9.9 m ha in India, yielding 40 million metric tonnes with an average yield of 3.57 t ha⁻¹ (1). Market growth is anticipated to be fuelled by factors such as the growing population, a rising demand for animal fodder and industrial use and increasing corn starch use. Because of the highest yield potential among all the cereal crops, it is known as the "queen of cereals". While rice and wheat are the top two cereals, maize holds the third position in India. This versatile crop can be grown in all seasons, making it a globally cultivated crop. It is one of the principal fodder crops in north-west India during summer season (2). However, as an intensive crop, maize requires significant nutrients for optimal growth with nitrogen (N) being one of the most important for maximising production. Nitrogen plays a key function

in formation of DNA, which is essential for cell division, growth and development.

Excessive N application, however, can have negative impacts on the environment, such as leaching of N to the groundwater. When conventional urea is applied as basal fertiliser, a considerable amount of N is lost through leaching, ammonia volatilisation, runoff, gaseous emissions and immobilisation. These losses on one hand contribute to environmental pollution but on other hand it reduces the available amount of N to the crops which limits the maize growth and yield. Nanotechnology offers a sustainable solution to tackle this issue under field conditions. Nano fertilisers are designed to release nutrients in a controlled manner making them more accessible to the plants. Nano-urea is a type of nano fertiliser that contains 4 % total N. It is often applied through foliar spray on crops. The smaller size of nanoparticles increases their penetration capacity through the leaf stomata and ensures rapid absorption of nanoparticles by the plant. This study explored the effect of combined application of nano urea and conventional urea on yield, quality and economics in maize.

Materials and Methods

The experiment was carried out at the Regional Research Station, Karnal, Chaudhary Charan Singh Haryana Agricultural University, during the kharif season of 2022. The maize hybrid HQPM 1 was sown with spacing of $75 \times 20 \text{ cm}^2$ with plot size of $4.5 \times 3.0 \text{ m}^2$. The soil of the experimental field was sandy clay loam in texture, non-saline, low in organic carbon (0.40 %), low in available N (164 kg ha^{-1}), low in available phosphorus (P) (160 kg ha^{-1}), high in available sulphur (S) (17 kg ha^{-1}) and medium in available potassium (K) (160 kg ha^{-1}). The mean weekly values of weather parameters during cropping season have been depicted at Fig. 1. A randomised block design (RBD) with 3 replications was adopted, including 9 treatments. T_1 served as the control (no recommended dose of nitrogen (RDN)). In T_2 , 100 % of RDN was applied through conventional urea ($150\text{-}60\text{-}60 \text{ kg /ha}^{-1}$, $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$). T_3 consisted of 100 % RDN through three foliar sprays of nano-urea applied at 15, 30 and 45 days after sowing (DAS). T_4 consisted of 100 % RDN with 50 % applied as a basal dose through urea and one foliar spray of nano-urea at 45 DAS. T_5 included 100 % RDN with 50 % basal application through urea along with two foliar sprays of nano-urea at 30 and 45 DAS. T_6 consisted of 75 % RDN with 50 % applied as basal through urea and one foliar spray of nano-urea at 45 DAS, while T_7 involved 75 % RDN with 50 % basal urea application and two foliar sprays of nano-urea at 30 and 45 DAS. T_8 comprised 50 % RDN with 50 % basal urea application and one foliar spray of nano-urea at 45 DAS. Finally, T_9 received 50 % RDN with 50 % basal urea application along with two foliar sprays of nano-urea at 30 and 45 DAS. The treatments were allocated to different plots at randomly

in all the 3 replications using the random table. Nitrogen content in grain was estimated by the modified Kjeldahl's method (3) and then the protein content in grain was calculated by multiplying the percentage value of N content in grain by a factor of 6.25 for each treatment. Data for the various yield attributing parameters were statistically analysed using the method of analysis of variance (ANOVA) and online statistical package OPSTAT (4, 5).

Results and Discussion

Protein (%)

No significant effect was observed from various treatments on protein (%) of maize as illustrated in Table 1. Protein content is an important quality parameter in maize, which is affected by the application of N. Nitrogen is a fundamental constituent of amino acids, the building blocks of proteins and its adequate supply during critical growth stages promotes efficient protein synthesis in maize kernels (6).

Yield attributes

Table 2 showed different N management practices showed non-significant difference in terms of number of cobs/meter row length, number of grains/cob and number of cobs ha^{-1} (000 ha^{-1}). Application of different nutrients levels in maize produced significantly higher number of grains/cob compared to control treatment. Among all the treatments, T_2 recorded highest number of grains/cob (453.3) which was at par with T_5 (447.3), T_4 (440.3), T_7 (433.3), T_6 (429.7) and T_9 (425.7). Treatment T_2 recorded

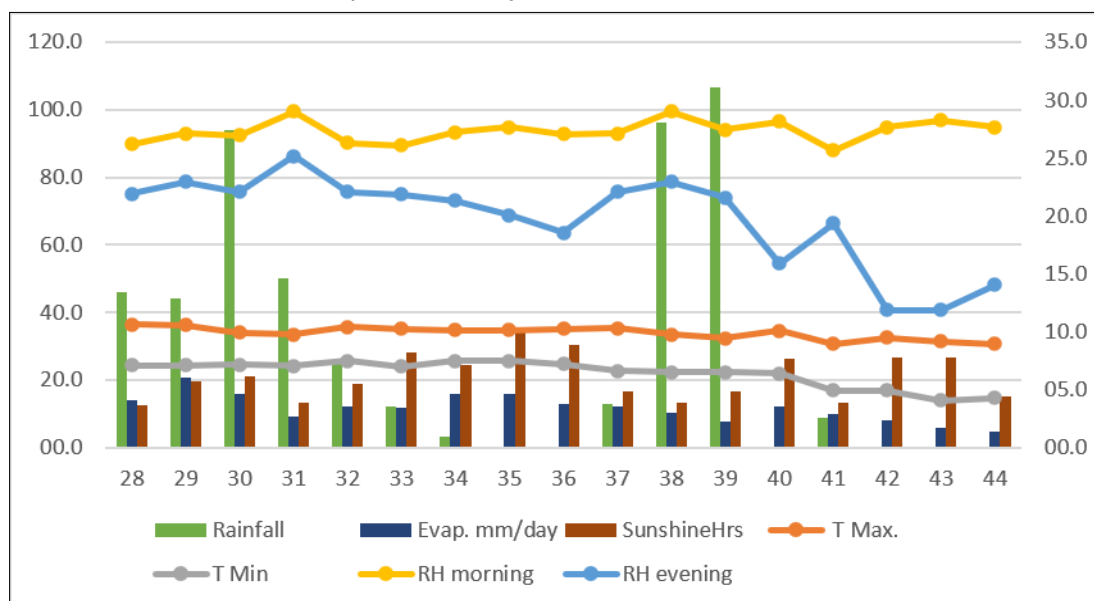


Fig. 1. Mean weekly values of weather parameters during cropping season.

Table 1. Effect of nitrogen management practices on protein content of maize

Treatments		Protein (%)
T_1	Control (No RDN) ($0\text{-}60\text{-}60\text{-}\text{N-P-K kg ha}^{-1}$)	10.0
T_2	100 % RDN through urea ($150\text{-}60\text{-}60\text{-}\text{N-P-K kg ha}^{-1}$)	11.4
T_3	100 % RDN (three foliar spray of nano-urea at 15, 30 and 45 DAS)	11.0
T_4	100 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	11.2
T_5	100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	11.4
T_6	75 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	11.1
T_7	75 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	11.1
T_8	50 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	10.9
T_9	50 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	11.0
SE(m) $\pm$		0.3
CD ($p = 0.05$)		NS

RDN: recommended dose of nitrogen; N-P-K: nitrogen-phosphorus-potassium; DAS: days after sowing; SE(m): standard error of the mean; CD: critical difference; NS: non-significant.

Table 2. Effect of nitrogen management practices on number of cobs/meter row length, number of cobs/hectare, grains/cob and 100 grains weight of maize

	Treatments	Number of cobs/ meter row length	Number of cobs (000 ha ⁻¹)	Number of grains/cob	100-grains weight (g)
T ₁	Control (No RDN) (0-60-60-N-P-K kg ha ⁻¹)	3.7	61.4	370.7	21.6
T ₂	100 % RDN through urea (150-60-60-N-P-K kg ha ⁻¹)	4.7	63.0	453.3	32.0
T ₃	100 % RDN (three foliar spray of nano-urea at 15, 30 and 45 DAS)	4.0	61.9	404.7	25.3
T ₄	100 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	4.3	62.3	440.3	30.7
T ₅	100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	4.0	62.8	447.3	31.0
T ₆	75 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	4.3	62.3	429.7	29.6
T ₇	75 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	4.3	62.1	433.3	30.7
T ₈	50 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	4.0	62.8	421.3	26.5
T ₉	50 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	4.0	62.1	425.7	27.3
SE(m) ±		0.3	0.3	9.3	0.7
CD (p = 0.05)		NS	NS	28.1	2.1

RDN: recommended dose of nitrogen; N-P-K: nitrogen-phosphorus-potassium; DAS: days after sowing; SE(m): standard error of the mean; CD: critical difference; NS: non-significant.

significantly higher test weight (32.0 g) which was at par with T₅, T₄ and T₇. The minimum 100 grain weight was found in T₁ control. As the length and girth of the cob increase, the number of grains per cob also increases. This positive relationship can be attributed to the greater surface area of larger cobs. These results are in close conformity with earlier study (7).

Yield parameters

Among all the treatments, significantly higher grain yield (76.5 q ha⁻¹) was recorded in T₂ which was found statistically at par with T₅ and 119.03 % higher as compared to control as shown in Table 3. The treatment T₅ was found to be 103.2 % higher in comparison to the control. The lowest grain yield (34.95 q ha⁻¹) was observed in T₁ treatment. Nitrogen is crucial for synthesis of protein and starch during the grain filling phase in maize crop. At this stage, adequate amount of N is a key factor for transformation of photosynthates into carbohydrates which leads to better improvement in grain yield. This process results in the formation of larger and fuller kernels with increased dry weight, which ultimately enhances overall grain yield. The rise in yield can be attributed to N's ability to expand the source size and establish an optimal source-sink relationship, as reported in earlier studies (8–10). The highest stover yield (121.96 q ha⁻¹) was recorded in treatment T₂ (121.96 q ha⁻¹) which was statistically at par with T₅ (109.78 q ha⁻¹). Minimum stover yield (73.01 q ha⁻¹) was

recorded from T₁ control. The increase in stover yield was attributed to the enhanced morphological growth of the plant, which is in close agreement with the earlier finding (11). Among all the treatments, significantly higher harvest index (39.43 %) was observed in treatment T₅ which was statistically at par with treatment T₂ (38.6 %), T₄ (38.1 %) and T₆ (37.3 %), T₇ (36.9 %) and T₈ (36.8 %) whereas, minimum harvest index (32.0 %) was observed in T₃. An increased harvest index indicates greater accumulation of photosynthates in the grain rather than in the straw, which is in accordance with the earlier finding (12).

Economics

Data analysis in Table 4 indicates that the maximum cost of cultivation (₹ 71924 ha⁻¹) was recorded in T₃ followed by T₄ (₹ 70716 ha⁻¹). Nano-urea is typically applied through foliar sprays, which often require multiple applications at various growth stages of the crop to ensure adequate nutrient supply and maximum efficacy. However, each of these spray operations entails significant recurring costs, which cumulatively makes nano-urea application more expensive than conventional methods. Highest gross returns (₹ 146899 ha⁻¹) were observed in T₂. Maximum net returns (₹ 78450 ha⁻¹) were observed in 100 % RDN through urea. Highest benefit : cost (B : C) ratio (2.08) was observed in T₂ followed by T₅ (1.95) and T₄ (1.86). Lowest gross returns (₹ 69100 ha⁻¹), net returns

Table 3. Effect of nitrogen management practices on grain yield, stover yield, biological yield and harvest index (%) of maize

	Treatments	Grain yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)	Biological yield (q ha ⁻¹)	Harvest index (%)
T ₁	Control (No RDN) (0-60-60-N-P-K kg ha ⁻¹)	34.95	73.01	107.95	33.0
T ₂	100 % RDN through urea (150-60-60-N-P-K kg ha ⁻¹)	76.55	121.96	198.51	38.6
T ₃	100 % RDN (three foliar spray of nano-urea at 15, 30 and 45 DAS)	40.56	85.99	126.55	32.0
T ₄	100 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	66.14	107.48	173.62	38.1
T ₅	100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	71.02	109.78	187.80	39.4
T ₆	75 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	56.72	95.29	152.01	37.3
T ₇	75 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	59.28	101.47	160.75	36.9
T ₈	50 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	44.33	76.31	120.63	36.8
T ₉	50 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	48.27	86.20	134.47	35.8
SE(m) ±		2.28	4.51	5.87	1.1
CD (p = 0.05)		6.90	13.65	17.74	3.5

RDN: recommended dose of nitrogen; N-P-K: nitrogen-phosphorus-potassium; DAS: days after sowing; SE(m): standard error of the mean; CD: critical difference; NS: non-significant.

Table 4. Effect of nitrogen management practices on economics of maize

	Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B : C ratio
T ₁	Control (No RDN) (0-60-60-N-P-K kg ha ⁻¹)	65647	69100	3453	1.09
T ₂	100 % RDN through urea (150-60-60-N-P-K kg ha ⁻¹)	68448	146899	78450	2.08
T ₃	100 % RDN (three foliar spray of nano-urea at 15, 30 and 45 DAS)	71924	82091	10166	1.28
T ₄	100 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	69938	127432	57494	1.86
T ₅	100 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	70716	136557	65842	1.95
T ₆	75 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	69017	109823	40806	1.46
T ₇	75 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	69760	114604	44844	1.77
T ₈	50 % RDN (50 % as basal by urea + one foliar spray of nano-urea at 45 DAS)	68057	86641	18584	1.22
T ₉	50 % RDN (50 % as basal by urea + two foliar sprays of nano-urea at 30 and 45 DAS)	68821	94009	25188	1.47

RDN: recommended dose of nitrogen; N-P-K: nitrogen-phosphorus-potassium; DAS: days after sowing; SE(m): standard error of the mean; CD: critical difference; NS: non-significant B : C ratio: benefit : cost ratio.

(₹ 3453 ha⁻¹) and B : C ratio (1.09) was observed in T₁ control. The increased economic value of maize can be attributed to the successful attainment of maximum grain yield through the implementation of comprehensive and integrated N management techniques. These practices involve applying an optimum amount of basal N during the early stages of crop growth and providing foliar nutrition using nano-urea during the peak reproductive phase. These findings have been reported for maize (13), sweet corn (14) and green gram (15).

Conclusion

The study demonstrates that nitrogen (N) management significantly influences maize yield, yield attributes and economic returns. Among the various treatments, applying 100 % recommended dose of nitrogen (RDN) through conventional urea resulted in improved yield attributes, maximum grain yield, protein content and net returns. However, combination of conventional urea (50 % as basal) with two foliar sprays of nano-urea (at 30 and 45 DAS) also performed comparably considering yield and profitability. Therefore, combined application of nano and conventional urea provides an innovative alternative for sustainable maize cultivation focused on improving productivity and better input efficiency.

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Authors' contributions

A, NS, MK and DS carried out experiments and performed the statistical analysis. A, DS, AK¹, MK and RR contributed to the preparation of the manuscript, while SK, DM, and AK² assisted with editing the manuscript. All authors read and approved the final manuscript. [AK¹ stands for Arpit Kamboj and AK² for Adyant Kumar]

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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