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Effect of Nitrogen Rates and Foliar Spray of Urea Application and Nano Urea on Yield and Economics of *rabi* Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) to study the "Effect of Nitrogen Rates and Foliar Spray of Urea Application and Nano Urea on Yield and Economics of *rabi* Maize (*Zea mays* L.)"effect of three nitrogen rates (50%, 75% and 100% RDN) and three foliar spray of urea *viz* 20000 PPM (2%) and nano urea *viz* 2000 PPM (2 ml/L) and 4000 PPM (4ml/L) application on yield and economics of *rabi* maize (*Zea mays* L.). The soil of experimental plot was sandy loam texture,

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nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.28%), available N (225kg/ha), available P (19.50) kg/ha) and available K (92 kg/ha). The experiment consists of 10 treatment, each being replicated thrice and laid out in Randomized Block Design. The results of present investigation revealed that the highest Grain yield (6.41 t/ha), Stover yield (8.65 t/ha), Harvest Index (42.58), Maximum gross return (INR 1,28266.67), Net return (81,682.75) and B:C ration (1.75) under 100% RDN +4000ppm (4 ml/l) spray of nano urea.

Keywords: Nitrogen; foliar spray; urea; nano urea; yield, economics.

1. INTRODUCTION

Maize (*Zea mays* L.) is considered as one of the most important food grains in India after the main cereals rice and wheat. Over other cereal crops and members of the Gramineae family, India comes in third in production and fifth overall. It is also known as the "Queen of Cereals" and is the third most significant crop in Uttar Pradesh. It has the potential to significantly increase our ability to meet the food needs of all living things, including both people and animals. The nutrients in maize are crude protein 7.6%, crude fibre 2.3%, crude fat 3.6%, starch 63.8%, total sugar 1.7%, and gross energy 3840 kcal/kg. In India, maize cultivates over an area of 8.49 million hectares with a yield of 2057 kg/ha and a production of 21.28 million tonnes. Considering Uttar Pradesh has reported 8.33% of the nation's total maize area and 9.65% of its total production, the world's average yield of maize is reported to be 27.8 q/ha. It almost makes up 9% of the total national food basket. Most of the year, maize is grown in every state for a variety of purposes, including grains, fodder, green cobs, baby corn, sweet corn, and popcorn in various regions. Andhra Pradesh (21%), Karnataka (17%), Rajasthan (10%), Bihar (9%), Maharashtra (8%), Uttar Pradesh (7%), Madhya Pradesh (6%) and Himachal Pradesh (4.4%) are the states that grow the most maize and account for more than 80% of the nation's total production. Jammu & Kashmir and a few North-East states also contribute in some measure. In addition to being utilised for human consumption and animal feed, it can also be used in businesses that make corn starch, corn oil, baby corn, etc. In every Indian home, maize starch, which has been extracted, is regarded as one of the primary ingredients. Many by-products from maize starch, such as corn syrups and alcoholic drinks like beer and whisky, are also produced. About 28% of the maize grown in India is used for food, 11% for animal feed, 48% for poultry feed, 12% for milling, and 1% for the production of seeds. Maize's demand is improved by its several uses as food, feed, and fodder, giving it a strong advantage over low demand conditions. The normal 65-75% of acres of hybrid maize are used for animal feed, while the majority of the remaining acres are used for industrial purposes, where food-grade maize is grown using conventional cultivars. These types of characteristics of maize contribute to an increase in farmer revenue. Nowadays, farmers are gradually replacing old, low-yielding cultivars with new, high-yielding hybrids.

Balanced use of nitrogen (N), phosphorus (P) and potassium (K) fertilizers could play a pivotal role in increasing the yields of cereals under moisture stress condition. Among the limiting factors; proper level and ratio of NPK are of prime importance [1]. Foliar application of NPK could increase crop productivity many fold under moisture stress condition. Foliar spray not only provides the nutrients but can also provide a significant amount of water in the time of water stress. In addition to supplying a nutrient for plant growth, N application could enhance drought tolerance of plant to increase yield under water deficit [2]. Research shows that N-application during grain filling could enhance the remobilization from stored carbohydrates in vegetative organs to grain under moderate water stress (WS), which might benefit starch synthesis and grain yield formation under post-anthesis drought. Foliar- applied N can be up to seven times more efficient than soil applied N [3]. Other benefits of foliar applied N include lower application rates (higher efficiency), plus the relative ease of obtaining timely, uniform applications. A combination of soil-applied and foliar applied N is the best management practice to reduce the efficient alternative for feeding N to plants.

A new agricultural input based on nanotechnology, Nano Urea supplies nitrogen to plants. Nano urea is a sustainable choice for farmers to practise smart agriculture and stop climate change. These act as fertiliser by providing the nutrients that plants need. Additionally, Nano urea reduces the loss of nutrients from agricultural areas in the form of

leaching and gaseous emissions, which previously resulted in environmental damage and climate change.

2. MATERIALS AND METHODS

A field trial was conducted during *Rabi,* 2022 at Crop Research Farm (CRF), Department of Agronomy, SHUATS, Prayagraj (U.P.), India which is located at 25.40˚ N latitude, 81.85 ˚ E longitude, and 98 m altitude above the mean sea level (MSL). Nutrient sources were Urea, SSP, MOP and Nano urea to fulfil the requirement of N, Ps, and K. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. The treatments were 1. 50% RDN + 2000 PPM (2 ml/L) spray of Nano Urea, 2. 50% RDN+4000PPM (4 ml/L) spray of Nano Urea, 3. 50% RDN + 20000 PPM (2%) spray of Urea , 4.75% RDN + 2000 PPM (2 ml/L) spray of Nano Urea, 5. 75% RDN + 4000 PPM (4 ml/L) spray of Nano Urea, 6. 75% RDN + 20000 PPM (2%) spray of Urea, 7. 100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea, 8. 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea, 9. 100% RDN + 20000 PPM (2%) spray of Urea, 10. Control Plot (RDF N: P: K-120:60:60 kg/ha). The yield parameters of the plants were recorded after harvest. These parameters were statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen Rates and Foliar Spray of Urea and Nano Urea on Yield

3.1.1 Yield attributes

Number of Cobs per Plant: Treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea recorded significantly highest Number of cobs per plant (1.60). However, treatments with 100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea, 100% RDN + 20000 PPM (2%) spray of Urea, and 75% RDN + 4000 PPM (4 ml/L) spray of Nano Urea were statistically at par with the treatment 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea.

Nitrogen is an essential ingredient for robust vegetative growth in maize. A sufficient nitrogen supply promotes the growth of a robust and healthy plant canopy, which creates an ideal environment for the production of multiple cobs per plant. Nitrogen boosts leaf area development, tillering, and overall plant biomass, all of which contribute to the formation of more cobs (Lauer *et al*., 2019; Basso *et al*., 2012). Nano urea has the potential to improve nutrient availability and uptake in plants. It enhances nutrient use efficiency, which can contribute to better crop growth and development, including the formation of more cobs per maize plant [4,5]. Nano urea has the potential to enhance photosynthetic efficiency in plants. Improved photosynthesis can lead to increased carbohydrate production, which is essential for reproductive development and the formation of cobs [6].

Number of Grains/Pod: Treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea recorded significantly highest Number of grains per cobs (249.67). However, treatments with 100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea and 100% RDN + 20000 PPM (2%) spray of Urea were statistically at par with the treatment 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea.

Nitrogen availability effects carbohydrate allocation within the plant. A sufficient supply of nitrogen ensures an appropriate supply of assimilates to growing grains. Nitrogen deficit can cause resource constraints as well as lower carbohydrate availability for grain loading. In contrast, optimal nitrogen levels facilitate carbohydrate transport and accumulation in developing grains, promoting the formation of a higher number of grains per cob [7,8]. Nano urea has been reported to influence hormonal regulation in plants, including the synthesis and transport of growth-promoting hormones such as auxins and cytokinins. These hormones play a crucial role in reproductive processes, including grain development. Nano urea application may positively affect hormonal balance, leading to an increased number of grains per cob [9,10]

Seed Index (g): Highest seed index (23.55 g) was recorded in Treatment 8 with application of 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea, though there was significant difference among the treatments.

Study by Sharma *et al*. [11]: This study investigated the effect of nitrogen levels on maize growth and yield in India. It found that increasing nitrogen application significantly increased grain yield and biomass production of maize. While the study did not specifically focus on seed index, the positive impact of nitrogen on overall yield suggests the potential for an indirect

effect on seed characteristics. Nano urea has the potential to increase maize pollination and fertilization. It can promote pollen viability, germination, and pollen tube expansion, resulting in more efficient fertilization and potentially enhanced seed set and seed index [12].

3.1.2 Yield

Grain Yield (t/ha): The highest grain yield of 6.41 t/ha recorded under Treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea recorded the highest grain yield (6.41 t/ha). However, treatment with 100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea was statistically at par with the treatment 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea.

The increase in grain output may be attributable to nitrogen's beneficial effects on expanding the size of the source and creating an optimal source to sink connection, respectively. Rathnayaka et al. [13] reported similar findings. Comparatively to regular urea, nano urea particles are smaller, which may increase their solubility and increase nutritional availability. This increased nutrient uptake, particularly nitrogen, can contribute to improved plant growth, development, and ultimately, higher maize yields [14,15]. Nano urea has been reported to enhance plant growth parameters such as plant height, leaf area, and chlorophyll content. Improved photosynthetic efficiency can contribute to increased biomass accumulation and grain yield in maize [16].

Stover Yield (kg/ha): Treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea recorded the highest stover yield (8.65 t/ha). However, treatments with 100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea, 100% RDN + 20000 PPM (2%) spray of Urea, and 75% RDN + 4000 PPM (4 ml/L) spray of Nano Urea were statistically at par with the treatment 100% RDN + 4000 PPM(4 ml/L) spray of Nano Urea.

However, increased stover yield was attributed due to enhanced morphological characters. Similar findings were observed by Alimohammadi *et al*. [17]. Nano urea formulations are often developed to improve nutrient uptake efficiency. By enhancing the availability and uptake of nutrients, including nitrogen, nano urea has the potential to promote plant growth, including stover biomass production [14,15].

Harvest Index (%): Treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea recorded the highest harvest index (42.58%) and there was significant difference among the treatments.

Similarly, improvement in harvest index was mainly attributed to allocation of photosynthates to grain filling rather accumulating in the straw. Similar findings were observed by Bhuiya *et al.* [18] and Mohanta *et al*. [19]. Nano urea may influence the biomass allocation pattern in maize plants. By promoting greater allocation of biomass towards grain production rather than vegetative growth, nano urea can contribute to an increased harvest index [16].

3.2 Economics

3.2.1 Effect of nitrogen rates and foliar spray of urea and nano urea on economics of maize

Cost of Cultivation: Cost of cultivation varied due to different levels of Nitrogen and Foliar spray of urea and nano urea. Highest cost of cultivation was seen in treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea (INR 46,583.92) and lowest was seen in the 50% RDN + 20000 PPM (2%) spray of Urea (INR 44,479.92).

Gross Returns: Gross returns varied due to different levels of Nitrogen and Foliar spray of urea and nano urea on Yield and Yield components of Maize. Highest Gross returns were seen in treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea (INR 1,28,266.67) and lowest Gross returns were seen in the treatment control (INR 1,12,400.00).

Net Returns: Net returns varied due to different levels of Nitrogen and Foliar spray of urea and nano urea on Yield and Yield components of Maize. Highest net returns were seen in treatment 8 with 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea (INR 81,682.75) and lowest Gross returns were seen in the treatment control (INR 66,716.08).

Benefit Cost Ratio: Highest B: C Ratio was recorded with the treatment 8, 100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea (1.75) and lowest B: C Ratio was seen in the treatment control (1.46).

Table 1. Effect of Nitrogen levels and foliar spray of urea and nano urea on Yield and Yield attributes of maize

		At Harvest					
S No	**Treatments**	**No. of cobs/plant**	**No. of Grains/ Cob**	**Seed Index(g)**	**Grain yield (t/ha)**	**Stover Yield (t/ha)**	**Harvest Index (%)**
1.	50% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	1.13	216.00	23.26	5.75	8.10	41.54
2.	50% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	1.20	217.67	23.31	5.77	8.11	41.59
3.	50% RDN + 20000 PPM (2%) spray of Urea	1.13	214.00	23.22	5.73	8.07	41.52
4.	75% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	1.33	224.00	23.38	5.90	8.24	41.72
5.	75% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	1.40	226.67	23.42	6.00	8.39	41.67
6.	75% RDN + 20000 PPM (2%) spray of Urea	1.27	219.33	23.36	5.81	8.15	41.62
7.	100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	1.53	246.00	23.53	6.21	8.55	42.08
8.	100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	1.60	249.67	23.55	6.41	8.65	42.58
9.	100% RDN + 20000 PPM (2%) spray of Urea	1.47	241.00	23.49	6.11	8.52	41.75
10.	Control (RDF N: P: K-120:60:60 kg/ha)	1.07	212.00	23.19	5.62	7.96	41.39
	F-test	S	S	NS	S	S	NS
	SE(m)±	0.07	4.94	0.10	0.08	0.10	0.47
	CD (P=0.05)	0.22	14.67	--	0.22	0.29	--

Table 2. Effect of Nitrogen levels and foliar spray of urea and nano urea on economics of maize

S No	**Treatments**	**Total cost of cultivation**	**Gross Returns**	**Net Returns**	**B:C ratio**
1.	50% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	44829.92	115066.67	70236.75	1.57
2.	50% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	45279.92	115466.67	70186.75	1.55
3.	50% RDN + 20000 PPM (2%) spray of Urea	44479.92	114666.67	70186.75	1.58
4.	75% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	45479.92	118000.00	72520.08	1.59
5.	75% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	45929.92	119933.33	74003.41	1.61
6.	75% RDN + 20000 PPM (2%) spray of Urea	45089.92	116266.67	71176.75	1.58
7.	100% RDN + 2000 PPM (2 ml/L) spray of Nano Urea	46133.92	124266.67	78132.75	1.69
8.	100% RDN + 4000 PPM (4 ml/L) spray of Nano Urea	46583.92	128266.67	81682.75	1.75
9.	100% RDN + 20000 PPM (2%) spray of Urea	45743.92	122133.33	76389.41	1.67
10.	Control (RDF N: P: K-120:60:60 kg/ha)	45683.92	112400.00	66716.08	1.46

**Data was not subjected to statistical analysis*

4. CONCLUSION

The present investigation conclude that, the treatment combination of 100% RDN along with 4000 ppm (4ml/L) of nano urea foliar spray recorded higher growth and yield parameters, grain yield in Maize crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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