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Foliar spray of urea and nano-urea on the growth and yield of maize (*Zea mays* L.)

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Abstract
The application of urea is tremendously increasing globally, which leads to higher nitrous oxide emissions. Hence, the researchers suggest applying nitrogen through foliar spray to improve efficiency and loss and avoid excess emission. However, the effect of nitrogen fertilization of soil application combined with foliar spray of maize crop in this field investigation was conducted at the research field, Department of Agronomy, SRM College of Agricultural Sciences, Chengalpattu, India during the rabi season of 2024, to study the "Effect of foliar spray of urea and nano-urea on the growth and yield of maize (*Zea mays* L.)". The Experiment was laid out in a Randomized Block Design with seven treatments replicated thrice. Hybrid NK 6802 maize seed was selected for this experiment. The study revealed that the treatment T_4: 75% RDF foliar spray of urea @ 1% at knee height and tasselling stage, recorded significantly highest Plant height (139.83 cm), Leaf Area Index (3.707), Total Dry Matter Production (94.32 g), SPAD value (38.74), Total Chlorophyll Content (1.34), Cob length (19 cm), Number of grains per row (24.67), Number of rows per cob (14.43), Grain yield (6415 kg/ha), as well as improving nitrogen content, nutrient uptake and its efficiency. Therefore, for improved phenology, growth, yield and yield attributes and profitability of maize, nitrogen fertilizer applied as soil and foliar application has been structured as per this pattern of uptake to avoid losses by leaching and the crop response absorbs the higher amount of nutrients.

Keywords: Foliar spray, grain yield, nano-urea and urea

Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under changing agro-climatic conditions. It is popularly known as the queen of cereals because it has the highest genetic yield potential among cereals. Every part of the maize plant is primarily to feed livestock, corn is a versatile grain with a wealth of uses. Maize is grown in more than 166 global countries, including tropical, sub-tropical and temperate regions. Globally, it is cultivated in an area of nearly 205 mha with a production of 1210 metric tons and productivity of 5878 kg/ha. The rapidly growing population creates a demand for food and a need to minimize the yield gap of maize crops (Nduwimana, 2020) [5]. Farmers affected by the price volatility of sugarcane, turmeric and vegetables were shifting to maize cultivation (Rajalakshmi *et al*., 2020) [7]. The post-green revolution era faces a challenge due to the excessive utilization of fertilizers and is complicated by the growing global population, emphasizing the need for increased quantities of chemical fertilizers, particularly nitrogen fertilizer in maize crops. The application of nutrients at the right time from the right concentration is the most important strategy for achieving the potential yield of maize crops. As a primary source of plant nutrients, nitrogen is a vitally important component of the protein, chlorophyll content enzyme content and enzyme activity in the plant system (Pan *et al*., 2021) [6]. In urea, nitrogen use efficiency generally ranges from 30 to 50% in moist soil (Singh, 2016) [10]. Urea is the most nutrient used as a commercial nitrogen fertilizer for increasing crop productivity. However, their imbalanced application has environmental and ecological consequences. When applied at the right time, split doses of urea application can reduce environmental pollution and improve yield by increasing nutrient usage efficiency. To optimize nutrient utilization, especially nitrogen, contain neem-coated urea in conventional form. Losses of nitrogen by soil application in maize through leaching (NO_3) and gas emissions (NH_4 and N_2O) leading causes of environmental pollution and climate changes.

Therefore, the present investigation was undertaken to appraise the foliar spray of urea and nano-urea on the growth and yield of maize (*Zea mays* L.) at two stages, *viz.,* knee height and tasselling stage.

Materials and Methods

Field and Experimental details

The research study was investigated during the *rabi* season of the year 2024 at the research field of SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Tamil Nadu, India (12º 23'22" N latitude 79º 44' 36" E longitude). The soil texture of the field was clay in nature with neutral soil reaction (pH 7.5), high in organic carbon (1.2%), low in available nitrogen (138 kg/ha), medium in available phosphorous (10 kg/ha) and low in available potassium (120 kg/ha). The Maize hybrid Syngenta NK 6802 seeds were sown on 4th March 2024 with a recommended seed rate of 25 kg/ha at spacing (60cm × 25cm). The various agronomic practices and other management practices apart from the treatment were performed according to the package and practices of Crop Production Guide (CPG) 2022, Tamil Nadu Agricultural University, Coimbatore, India.

Treatment details

The experiment was designed in RBD (Randomized Block Design), with seven treatments and triplicate. The treatments are T_1: 100% RDF, T_2: 75% RDF, T_3: 75% RDF + foliar spray of urea @ 0.5% at knee height and tasselling stage, T_4: 75% RDF foliar spray of urea @ 1% at knee height and tasselling stage, T_5: 75% RDF foliar spray of nano-urea @ 0.2% at knee height and tasselling stage, T_6: 75% RDF foliar spray of nano-urea @ 0.3% at knee height and tasselling stage, T_7: 75% RDF foliar spray of nano-urea @ 0.4% at knee height and tasselling stage. Growth and yield parameters of the maize plant were recorded at regular intervals of 15, 30, 45, 60, and 75 DAS.

Statistical analysis

The data were collected from the research plot area and exposed analysed based on "Analysis of variance" (ANOVA). Overall differences were tested by the "F" test of significance at a 5% ($p \leq 0.05$) level as suggested by Gomez and Gomez (1984). The figures were constructed using the data analysis tool pack of Microsoft Excel 365. Statistical analysis was conducted by using R (version 4.2.2) with R-studio (version 2022.12.0+353) and the "Agricole" package was utilized.

Results and Discussion

Morphological parameters

During the 2024 growing *rabi* season, treatment T_4: 75% of RDF + foliar spray of urea @1% at knee height and tasselling stage significantly enhanced growth parameters of plant height (139.83 cm), Leaf Area Index (3.707), Total Dry Matter Production (94.32g), SPAD value (38.74) and Total Chlorophyll Content (1.34) compared to other nitrogen management treatments (Table 1), and lowest value recorded in the T_2: 75% of RDF. This study of foliar spray of urea indicates that nitrogen fertilizer has positively impacted the growth character by foliar spray stimulating dry mass production through enhancement of cell division and chlorophyll accumulation which leads to higher photosynthetic activity of maize crops and in turn reflected on the increase in translocation and accumulation of microelements in plant organs and these in turn on their growth characters. Also, nitrogen is a key constituent of the plant's photosynthetic organ, which helps to improve the chlorophyll content, enzyme content and enzymatic activity of plant leaves (Nasar *et al*., 2020) [4]. (Zaki *et al*., 2016) [12] Application of nitrogen fertilizers such as urea and potassium foliar spray may decrease such losses, nitrogen losses from the recommended nitrogen dose for corn as a summer crop were 50% through leaching and denitrification. However, these indices were more prominent under nitrogen fertilizer combined soil application with a foliar spray of urea when compared to soil application alone (*i.e.*, RDF) as well. Higher doses of nitrogen fertilizer can result in environmental concerns but it is crucial for maize production (Reddy *et al*., 2024) [8]. However, there were no significant changes between 100% and 50% or 75% with urea foliar treatment in several studies on aspects of growth yield and yield components, and there were significant variances due to varieties and interactions between varieties and the urea foliar spray (Afifi *et al.*, 2011*)* [1]. Through recent studies of urea, 75 experiments have been conducted to compare the performance of urea coated with neem cake (NCU) or neem oil (NOCU) in increasing the yield of rice, wheat and several other crops *viz,* uncoated urea (Singh, 2016) [10]. In addition, a comparison of soil *vs* foliar application of urea on maize was studied in Pakistan, which was reported by Ahmad (1998) [2], who mentioned that foliar spraying of urea was not superior to soil application, however, a combination of soil + foliar application treatments showed positive responses and these treatments need further examination, this means that the nitrogen applied through foliar feeding without any quantities of soil-N applied are not fairly enough.

Table 1: Effect of foliar spray of urea and nano-urea on the morphological parameters of maize at 75 DAS

Treatments		Morphological parameters				
		Plant height (cm)	LAI	TDMP(g)	SPAD value	TCC
T_1	100% RDF	135.23	3.437	91.83	37.45	1.27
T_2	75% RDF	128.40	2.950	84.45	34.89	1.08
T_3	75% RDF + FSU 0.5% at knee height and tasselling stage	139.00	3.573	93.95	38.52	1.31
T_4	75% RDF + FSU 1% at knee height and tasselling stage	139.83	3.707	94.32	38.74	1.34
T_5	75% RDF + FSNU 0.2% at knee height and tasselling stage	129.86	3.157	86.91	36.23	1.12
T_6	75% RDF + FSNU 0.3% at knee height and tasselling stage	131.40	3.270	88.19	36.93	1.17
T_7	75% RDF + FSNU 0.4% at knee height and tasselling stage	133.23	3.367	90.38	37.96	1.25
F-test		871.41^{***}	188.63^{***}	8.91^{***}	NS	3.00^{**}
S.E(m)		0.15	0.018	1.23	-	0.03
CD ($p \leq 0.05$)		0.46	0.06	3.79	-	0.04

Description: RDF= Recommended dose of fertilizer, FSU= Foliar Spray of Urea, FSNU= Foliar Spray of Nano-Urea, LAI= Leaf Area Index, TDMP= Total Dry Matter Production, SPAD= Soil Plant Analysis Development, TCC= Total Chlorophyll Content, *= Significant, NS= non-significant, DAS= Days After Sowing.

Yield parameters

The yield parameters, *viz*, cob length (19 cm), number of rows per cob (14.43), number of grains per row (24.67) and grain yield (6415 kg/ha) were statistically analysed and mentioned in Table 2 and it observed that treatment T_4: 75% RDF + foliar spray of urea @1% at knee height and tasselling stage significantly highest value in the yield parameters. Then treatment T_3: 75% RDF + foliar spray of urea @0.5% at knee height and tasselling stage produced more, number of rows per cob, number of grains per row and grain yield which was at with treatment T_4. The treatment $T_{2:}$ 75% RDF with minimum yield parameters was recorded at the knee height and tasselling stage.

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. Nitrogen promotes leaf area expansion, increasing metabolic processes and enhancing overall biomass, which results in higher photosynthesis accumulation to economically valuable sections of the plants. Exiting studies have shown the relationship between nitrogen application rate on crop's photosynthetic characteristics, nitrogen utilization rate and crop yield (Shah *et al*., 2021) [9]. The foliar application of nitrogen encourages photosynthesis activities and metabolic efficiency which contributes to enhancing the accumulation of the produced metabolites of maize. However, in the context of our experiment, it is important to emphasize that the application of nano-urea significantly does not improve the higher yield and other attributes. Also, results differ, indicating that nano-urea spraying cannot replace the required quantity or meet the plant requirement. Observed nitrogen uptake and yield loss in wheat crops (Reddy *et al*., 2024) [8]. Several research studies also indicated that foliar nano-urea sprays during the critical stages have maximum yield with conventional fertilizers (Kumar *et al*., 2021) [3]. Further, research also investigates the impact of foliar spray of nano-urea at higher doses, while considering phytotoxicity (Reddy *et al*., 2024) [8].

Table 2: Effect of foliar spray of urea and nano-urea on the yield and yield parameters of maize

Treatments		Yield parameters			
		Cob length (cm)	No. of rows/cob	No. of grains/row	Grain yield (kg/ha)
T_1	100% RDF	17.4	14.22	24.00	6084
T_2	75% RDF	14.1	13.66	20.67	4502
T_3	75% RDF + FSU 0.5% at knee height and tasselling stage	18.4	14.39	24.27	6239
T_4	75% RDF + FSU 1% at knee height and tasselling stage	19	14.43	24.67	6415
T_5	75% RDF + FSNU 0.2% at knee height and tasselling stage	15.2	13.89	23.87	5783
T_6	75% RDF + FSNU 0.3% at knee height and tasselling stage	15.4	13.93	24.00	5884
T_7	75% RDF + FSNU 0.4% at knee height and tasselling stage	16.5	14.02	24.13	5978
F-test		179.24***	1870.94**	8.77***	21.36***
S.E(m)		0.13	0.01	0.45	187.94
CD ($p \leq 0.05$)		0.41	0.02	1.40	579.11

Conclusion

To address the challenges to increase the potential yield of maize for sustainability of the present-day is required that different nitrogen management of soil and foliar application of urea showed a substantial effect on various growth parameters and yield parameters of maize *viz*. Plant height, Total Chlorophyll Content, SPAD value, Leaf Area Index, and Total Dry Matter Production. In the current findings, foliar feeding of nitrogen fertilizer has the adoption of 75% RDF + foliar spray of urea @1% at knee height and the tasselling stage has significantly the highest and regimes improved the morphological and physiological parameters.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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