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RESEARCH ARTICLE

Effect of foliar nitrogen application on leaf chlorophyll content and grain yield in maize (*Zea mays* L.)

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Abstract

Applying urea is becoming more and more rapidly rising worldwide; nonetheless, the present study aimed to investigate the influence of using nitrogen fertilizer in the soil application in conjunction with foliar spraying of urea and nano-urea, the study was carried out to explore the effects of nitrogen (N) fertilizer on chlorophyll content in maize, during the rabi season of 2024, aiming to compare chlorophyll concentration at different growth stages and its influence on grain yield. The experiment was conducted using a randomized block design with seven treatments and three replications. The research was conducted in the SRM College of Agricultural Science farm, Baburayanpettai, Chengalpattu, Tamil Nadu, India. Results showed that the interaction of N with treatment T_4 recorded the highest total chlorophyll content, leaf area index, stover yield and grain yield. This indicates that structuring N fertilizer application using this combination can enhance uptake efficiency, minimize leaching losses and improve crop performance.

Keywords: chlorophyll content; grain yield; leaf area index; nano-urea; urea

Introduction

Nitrogen (N) levels applied through foliar methods significantly influence leaf chlorophyll and grain yield in maize (*Zea mays* L.), highlighting nitrogen's critical role in agricultural productivity. Maize is one of the most important crop species worldwide, serving as a staple food source and a key component in various industries, including livestock feed, biofuel production and industrial applications (1). Given its significance, optimizing maize yield through effective management of macro nutrients is essential for ensuring food security and sustainability.

Nitrogen (N), being a vital macronutrient, is fundamental for plant growth and development. It is an integral part of amino acids, proteins, nucleic acids and chlorophyll (2). Adequate N availability directly influences the synthesis of chlorophyll, which in turn affects the photosynthetic efficiency of maize plants. Increased chlorophyll content typically leads to enhanced photosynthetic rates, which contributes to improved biomass accumulation and grain yield (3, 4). Conversely, N deficiency can lead to chlorosis, reduced photosynthesis and ultimately lower yields.

The complexity of N dynamics in soils, combined with varying environmental conditions, makes the effective application of N fertilizer a challenging task for farmers (5). Foliar applications of N, in contrast to soil application, has gained attention due to its potential to augment chlorophyll levels and improve crop yield more efficiently. N fertilizer application generally has positive and significant impacts on crop growth and yield (6, 7). The foliar method can allow for quicker nutrient uptake, mitigating the effects of soil-related limitations, such as poor N availability or immobilization caused by soil microbes. Leaves can absorb nutrients directly, resulting in immediate physiological responses that enhance chlorophyll production and overall plant health.

Several studies have indicated that varying N application rates achieve higher yield performance of maize hybrids by alternating the expensive N fertilizer, to construct a more efficient farming cycling with an environmentally friendly or more sustainable system, can have differential effects on both chlorophyll content and grain yield (8). Understanding these relationships is crucial for formulating precise fertilization strategies that maximize yield while minimizing environmental impacts, such as N leaching and greenhouse gas emissions. Some researchers have identified optimal N rates that improve chlorophyll content and grain yield in maize, but the findings can vary widely based on factors such as cultivar, soil type and climatic conditions (9).

In addition to N levels, the interactive effects of other agronomic practices, such as planting density and water availability, can further complicate these relationships (10, 11). For instance, high planting densities may increase competition for N, potentially leading to diminished returns on N inputs. Therefore, a comprehensive understanding of these interactive

effects is necessary to optimize both nitrogen-use efficiency (NUE) and yield. Increasing N rate results optimal NUE and timings, particularly in modern hybrids (12). Field experiments, N treatments (levels and splits) increase the production and quality of the hybrid maize and vice versa, in addition to an increase in leaf area per plant, plant height and biomass.

This study aims to investigate the foliar effects of different N levels on both leaf chlorophyll content and grain yield of maize. It will focus on assessing the physiological responses of maize plants to varying N treatments, providing valuable insights into how farmers can better manage N resources in their cropping systems. By elucidating the complex interactions between N levels, chlorophyll synthesis and yield potential, the findings will contribute to the ongoing discourse on sustainable agricultural practices. Ultimately, the knowledge gained from this research will not only inform the best practices for maize cultivation but also assist in the development of strategies that mitigate the environmental impacts associated with N fertilization. As global food demands continue to rise, refining our understanding of nutrient management in crops like maize is paramount in achieving high productivity and sustainability in agriculture.

Materials and Methods

This experiment was conducted in the research field of SRMCAS farm, Baburayanpettai, Chengalpattu, Tamil Nadu, during the *Rabi* season 2024. The experimental site has a tropical hot and humid climate and is located at an elevation of 60 m above sea level. The soil was clayey in nature, pH was about 7.5-8.5, organic carbon (12) (< 1 %), available N (138 kg/ha), available phosphorus (10 kg/ha) and available potassium (120 kg/ha) (13-15). The experiment focused on a widely used maize hybrid variety, Syngenta NK 6802 seeds were sown on 4th March 2024 with a recommended seed rate of 25 kg/ha at a spacing of 60 cm × 25 cm, to dissect the productivity response to N management. The various agronomic practices and other management practices apart from the treatment were performed according to the package and practices of the crop production guide (CPG), Tamil Nadu Agricultural University (TNAU), Coimbatore, India. The experiment was designed in a randomized block design (RBD), with seven treatments with three replications.

The treatments are T_1: 100 % recommended dose of nitrogen (RDN), T_2: 75 % RDN, T_3: 75 % RDN + foliar spray of urea at 0.5 % at knee height and tasselling stage, T_4: 75 % RDN + foliar spray of urea at 1 % at knee height and tasselling stage, T_5: 75 % RDN + foliar spray of nano-urea at 0.2 % at knee height and tasselling stage, T_6: 75 % RDN + foliar spray of nano-urea at 0.3 % at knee height and tasselling stage, T_7: 75 % RDN + foliar spray of nano-urea at 0.4 % at knee height and tasselling stage.

Growth and yield parameters such as leaf area index, total chlorophyll content, total dry matter production, grain and straw yield of the maize plant were recorded at every 30, 60 DAS and harvest stage because, the treatments were fixed based on the crop growth critical stages (knee height and tasseling stage). The recorded data were analyzed statistically by using statistical software using R (version 4.2.2) with R-Studio (version 2022.12.0 + 353) and the Agricole package was utilized. Overall differences were tested by the F-test of significance at a 5 % ($p \leq 0.05$) level (16).

Results and Discussion

The treatment T_4: 75 % recommended dose of nitrogen + foliar spray of urea at 1 % at knee height and tasselling stage of maize significantly enhanced total chlorophyll content, leaf area index, total dry matter production and overall crop productivity. In this study, it was observed that plants treated with foliar spray of urea as well as soil application of a recommended dose of fertilizer. Showed remarkable increase in chlorophyll content, which is crucial for photosynthesis and overall plant vitality. This N delivery method not only optimizes nutrient uptake but also reduces N loss a common issue in traditional soil applications. Adequate N is crucial for achieving maximum leaf expansion, which directly affects the leaf area index (Table 1).

The recorded chlorophyll content reached an impressive value indicating enhanced photosynthetic efficiency (Table 2). The concentration of leaf chlorophyll is significantly influenced by N levels in maize. Numerous studies have shown that increased N fertilizer rates lead to significant increases in leaf chlorophyll content, particularly at critical growth stages (17). The correlation between N levels and chlorophyll concentration is often positive, indicating that higher N fertilization results in more robust chlorophyll production, which in turn enhances photosynthetic efficiency and plant vigour (18-21). Additionally, chlorophyll concentration acts as a reliable predictor of plant productivity, allowing farmers to assess N fertilizer needs better based on chlorophyll measurements at early reproductive stages (22). Similarly, researchers have found that N application increases leaf chlorophyll content, net photosynthesi and maximum quantum yield of photosystem system II (PSII), favouring dry matter accumulation and grain formation in super high-yield maize (22).

Table 1. Effect of foliar application of urea and nano-urea on leaf area index of maize

Treatment		Leaf area index		
		30 DAS	60 DAS	Harvest
T_1	100 % RDN	0.513	2.32	1.40
T_2	75 % RDN	0.477	1.69	0.95
T_3	75 % RDN + FSU 0.5 % at knee height and tasselling stage	0.433	2.58	1.50
T_4	75 % RDN + FSU 1 % at knee height and tasselling stage	0.502	2.63	1.65
T_5	75 % RDN + FSNU 0.2 % at knee height and tasselling stage	0.442	2.13	1.22
T_6	75 % RDN + FSNU 0.3 % at knee height and tasselling stage	0.465	2.19	1.25
T_7	75 % RDN + FSNU 0.4 % at knee height and tasselling stage	0.484	2.26	1.36
SE(d)		0.03	0.11	0.11
CD ($p \leq 0.05$)		NS	0.25	0.23

RDN: recommend dose of nitrogen, DAS: days after sowing, FSU: foliar spray of urea, FSNU: foliar spray of nano-urea, SE(d): standard error deviations, CD: critical difference.

Table 2. Effect of foliar application of urea and nano-urea on total chlorophyll content (mg/g) of maize

Treatments		Total chlorophyll content (mg/g)		
		30 DAS	60 DAS	Harvest
T_1	100 % RDN	0.58	1.36	1.25
T_2	75 % RDN	0.54	1.11	1.03
T_3	75 % RDN + FSU 0.5 % at knee height and tasselling stage	0.50	1.42	1.36
T_4	75 % RDN + FSU 1 % at knee height and tasselling stage	0.54	1.49	1.38
T_5	75 % RDN + FSNU 0.2 % at knee height and tasselling stage	0.57	1.26	1.15
T_6	75 % RDN + FSNU 0.3 % at knee height and tasselling stage	0.58	1.30	1.19
T_7	75 % RDN + FSNU 0.4 % at knee height and tasselling stage	0.53	1.34	1.22
SE(d)		0.03	0.05	0.05
CD ($p \leq 0.05$)		NS	0.12	0.11

RDN: recommend dose of nitrogen, DAS: days after sowing, FSU: foliar spray of urea, FSNU: foliar spray of nano-urea, SE(d): standard error deviations, CD: critical difference.

The treatment of 75 % recommended dose of N with foliar spray at 1 % of urea showed substantial improvements in total dry matter production (Table 3). Foliar application has been linked with enhanced total dry matter accumulation owing to improved photosynthetic performance and nutrient absorption. For instance, specific experiments highlighted that optimal N levels achieved through urea foliar spray resulted in increased dry matter production, with some treatments yielding up to 6.41 t/ha of grain and enhanced stover yield due to higher nutrient transport and utilization efficiencies (23). For instance, specific treatment combinations using foliar applications of urea have recorded substantially improved dry matter yields, demonstrating the effectiveness of N supplementation through this method in optimizing maize growth and maximizing productivity (23, 24).

The crop phenology and growth notably responded to varying rates of N fertilizers. The nutrient solution, which involves applying directly to the foliage, allows for more immediate absorption compared to traditional soil applications. This treatment significantly increased chlorophyll content, which, along with improved leaf area index, contributed to higher biomass and yield (Table 4). Additional metrics such as cob length, number of grains per row and overall grain yield dramatically improved the efficacy of combining soil and foliar N applications. Therefore, the strategic use of foliar urea under these specific growth stages demonstrates a highly effective agronomic practice, leading not only to improved yield attributes but also to better nutrient uptake efficiency, thereby ensuring that maize crops are more productive and resilient in their growing environment. However, in the present experiment, the application of nano-urea did not significantly improve yield or associated parameters. Also, results differ, indicating that nano-urea spraying cannot replace the required quantity or meet the plant requirement. Other researchers have reported N uptake issues and yield loss in wheat crops due to high doses of nano-urea, also noting potential phytotoxic effects (25).

The application of N fertilizers has been closely linked to the grain yield of maize. Research demonstrates that increasing N application generally results in higher grain yield, with optimal levels depending on specific environmental conditions and maize variety (26, 27). For instance, N levels of up to 300 kg/ha have been reported to maximize grain yield, showing a significant positive correlation between N application rates and yield outcomes (25). Correlation values between chlorophyll content and yield were also determined. Similar to the previous research (28, 29) results have shown that there was a close and linear correlation between the variables. However, excessive N application can have detrimental effects, such as reduced N use

Table 3. Effect of foliar application of urea and nano-urea on total dry matter production (kg/ha) of maize

Treatments		Total dry matter production (kg/ha)		
		30 DAS	60 DAS	Harvest
T_1	100 % RDN	1539	6113	8774
T_2	75 % RDN	1514	5298	7586
T_3	75 % RDN + FSU 0.5 % at knee height and tasselling stage	1523	6451	9103
T_4	75 % RDN + FSU 1 % at knee height and tasselling stage	1502	6512	9531
T_5	75 % RDN + FSNU 0.2 % at knee height and tasselling stage	1519	5697	8183
T_6	75 % RDN + FSNU 0.3 % at knee height and tasselling stage	1503	5814	8247
T_7	75 % RDN + FSNU 0.4 % at knee height and tasselling stage	1522	6040	8650
SE(d)		89	178	238
CD ($p \leq 0.05$)		NS	389	518

RDN: recommend dose of nitrogen, DAS: days after sowing, FSU: foliar spray of urea, FSNU: foliar spray of nano-urea, SE(d): standard error deviations, CD: critical difference.

Table 4. Effect of foliar application of urea and nano-urea on yield (kg/ha) of maize

Treatments		Stover yield (kg/ha)	Grain yield (kg/ha)
T_1	100 % RDN	8576	5771
T_2	75 % RDN	7444	3737
T_3	75 % RDN + FSU 0.5 % at knee height and tasselling stage	9018	6401
T_4	75 % RDN + FSU 1 % at knee height and tasselling stage	9228	6575
T_5	75 % RDN + FSNU 0.2 % at knee height and tasselling stage	8027	5154
T_6	75 % RDN + FSNU 0.3 % at knee height and tasselling stage	8157	5282
T_7	75 % RDN + FSNU 0.4 % at knee height and tasselling stage	8347	5503
SE (d)		244	232
CD ($p \leq 0.05$)		531	505

RDN: recommend dose of nitrogen, DAS: days after sowing, FSU: foliar spray of urea, FSNU: foliar spray of nano-urea, SE(d): standard error deviations, CD: critical difference.

efficiency and potential environmental impacts, including N runoff and greenhouse gas emissions. Therefore, balancing N application is critical for sustainable maize production practices (30). Some research indicates that adequate N availability throughout the growing season is necessary for maize to achieve its maximum yield potential. Insufficient N can lead to suboptimal plant growth and markedly reduce the grain yield (31, 32).

Conclusion

The findings of this study suggest that supplementary N applied via foliar spray in treatment T_4 plays a crucial role in enhancing crop performance, particularly during critical growth stages like knee height and tasselling, where the demand for nutrients is pronounced. The foliar effects of nitrogen on leaf chlorophyll concentration and grain yield in maize are interconnected, with nitrogen serving as a crucial determinant for plant health and productivity. Therefore, integrating both soil and foliar nutrient management strategies is recommended for optimizing maize yield and reducing nutrient losses, especially in systems where efficient nitrogen use is essential. Explore the timing and frequency of foliar N applications to further enhance NUE. Integrating precision nutrient management tools can also support site specific recommendations for maximizing maize productivity.

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Authors' contributions

VP was responsible for conceptualization, investigation and preparation of the original drafts. SK contributed to conceptualization, data curation and investigation. NS and KM handled review, editing and plagiarism checks. SE, SVR, RC, CS were involved in reviewing and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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

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