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Assessment of nano urea based N application on the performance of quality protein maize (QPM) in sub-tropical condition of Punjab

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Abstract
Aims: To study the impact of different dosage of nanourea on the growth and yield of quality protein maize in Punjab, India.
Study design: The study design was randomized block design (RBD) with 3 replication and 10 treatments.
Place and Duration of Study: A research trial was conducted during Rabi season at Agricultural Research Farm of Lovely Professional University during 2022-2024. 9 treatment combinations of nano urea based nitrogen application were utilized for the present study on maize crop. The different growth, yield, quality and economic parameters were studied.
Methodology: The land was prepared and intercultural operation was done and maize varirt name LQH-1 was sown in 5X4m^2 area plot with 8 treatments having different dosage of nanourea.
Results: The plant height was more in treatment T_6 (50% RDN basal + Two FSNU@4ml/Lt. at 35 DAS & 65DAS) followed by treatments T_5 (50% RDN basal + One FSNU @ 4ml/Lt. at 35 DAS) and T_4 (50% RDN basal + Two FSNU @ 2ml/Lt. at 35 DAS & 65 DAS). The maximum number of leaf area index was observed at harvest as 263.78 at T_6 (50% RDN basal + Two FSNU@4ml/lt. at 35 DAS & 65 DAS) treatment. The maximum dry matter accumulation was recorded in T_6 (50% RDN basal + Two FSNU @ 4ml/Lt. at 35 DAS & 65 DAS) followed by T_5 (50% RDN basal + One FSNU @ 4ml/Lt. at 35 DAS) and lowest was observed in T_0 (control). The highest crop and relative growth rate was observed in T_6 (50% RDN basal + Two FSNU @4 ml/Lt. at 35 DAS & 65 DAS) at 90 days and start decreasing at harvest. The yield parameters including number of cobs/plant (1.75±0.03), number of grains/cob (358.61±0.14), seed index (38.20±0.07 g), seed yield (5.14±0.02 t/ha), Stover yield (7.26±0.02 t/ha) and Harvest index (25.48±0.04%) was recorded more in treatment T_6 (50% RDN basal + Two FSNU@4ml/Lt. at 35 DAS & 65DAS) and lowest was observed in T_0 (control) at harvest. The quality parameters including protein, nitrogen content and nitrogen uptake was observed more in treatment T_6 and lowest was observed in T_0 (control).
Conclusion: Overall, our study suggests that use of nanourea in maize can be a better and sustainable approach

Keywords: Nanourea, maize, nitrogen, nutrient management

1. Introduction
Human beings utilized crops for their survival to having good nutrition, health, medical, economic, and industrial outcomes from different crops. Maize is such a useful crop utilized for sustenance by humans. Maize scientifically known as *Zea mays* belongs to the family Poaceae is an important cereal crop. It is also known as the queen of cereals (Bassu *et al*., 2014) [5]. It is not only cultivated for human consumption but also for feeding livestock and poultry. Maize achieved third place in cultivation over the world followed by rice and wheat. Maize is widely produced in cultivated and has around 21% of production in Andhra Pradesh, 16% in Karnataka, 10% in Rajasthan, and 9% reported from Bihar and Maharashtra (Abedinpour *et al*., 2012) [1]. It is reported that, In India, maize is grown in more than 9.23 Mha area with an overall production of approximately 25.6 t/ha and average productivity of around 2.56 t/ha (Igbadun *et al*., 2007) [8]. It is grown over an area of approximately 177mha throughout the world with a total production of around 967 m tonnes. It is a kharif crop and covers 85% of the total cultivated area.

The enhancing demand of feed for poultry the dependency and demand of maize are also showing a steep increase which is indicated from the fact that presently it is being cultivated in more than 150 countries around the world (Abedinpour *et al.*, 2012) [1]. It has also been observed that in Asia the demand for maize will increase rapidly in the next 20 years which may be due to the growing livestock population and increasing poultry feed industry. Therefore, it has been observed that the increasing demand for maize is rapidly transforming the cropping systems and cropping patterns throughout the globe. The increasing dependency on maize as the substitute of rice and wheat crop to fulfill the dietary requirement makes the replacement of common maize with quality protein maize (QPM) very effective and one of the most attractive major to meet the quality protein needs for providing good nutritional requirement for the ever-increasing human population (Tokatlidis, 2013; Abedinpour *et al.*, 2012) [23, 1]. Further, it has been reported that QPM production under zero tillage cultivated techniques will be beneficial for India to meet food security with nutrition security. Generally, a large number of quality protein maize hybrids are available for cultivation under the prevailing environmental conditions in Punjab. However, their suitability for different cultivation practices and weed management may vary (Ciampitti *et al.*, 2021) [6]. Therefore, there is a need to evaluate the performance of such hybrids for different weed management practices to obtain a good and healthy economic and sustained yield. Maize is also used in industries for the production of different food products like pizzas, bread, cakes, muffins, besides this maize is also used as raw material for several industrial products such as protein, beverages, food sweetener, cosmetics, starch, oil. etc. (Sachan *et al*., 2023; Gou *et al*., 2021) [19, 7]. Even with the best efforts and intensive research, maize yield in India is considered much lower as compared to its potential yield which may be due to a decrease in modern technology. Nitrogen is one of the essential nutrients that significantly influence the vegetative growth of plants and is widely adopted due to its easy availability and cost-effectiveness (Peddapuli *et al.*, 2021) [15]. However, the heavy supply of nitrogen does not guarantee its availability, as it is susceptible to various losses such as leaching, volatilization, and denitrification, leading to poor availability. Over time, the application of nitrogen-based fertilizers with low efficiency may lead to the deterioration of maize quality and environmental pollution. Thus, the adoption of slow-release nitrogen fertilizers with comparatively higher efficiency is urgently needed to achieve agricultural sustainability. Mainly the nano-based technology ranges in nanoscale and improved the characteristics of crops by applying the nano-based fertilizers (Abednego *et al.*, 2023) [2]. The nanoparticles-based fertilizers have different compositions and their compositions are subjected to a significant role in their application and functioning. The zinc-based nanoparticles have a diameter of less than 100 nm. The other factor known as plant density is the main factor that causes growth and yield to the field crop. The nano fertilizers and densities provide maize a stable yield and growth and improve its height also. Mainly the nano fertilizers avoid minerals losses and thus raises the yield and supporting agriculture development (Rawat *et al*., 2024) [17]. The nano fertilizers are important as they enhance the crop yield and nutrient use efficiency, decrease chemical fertilizers. The nano formulation-based fertilizers are used in the fields to avoid diseases to crops, by replacing the application of fertilizers and pesticides used on crops, for the detection of diseases and other agrochemicals (Barlow *et al.*, 2015) [4].

Nitrogen is one of the essential nutrients that significantly influence the vegetative growth of plants and is widely adopted due to its easy availability and cost-effectiveness However, the heavy supply of nitrogen does not guarantee its availability, as it is susceptible to various losses such as leaching, volatilization, and denitrification, leading to poor availability (Meena *et al.*, 2021) [12]. Over time, the application of nitrogen-based fertilizers with low efficiency may lead to the deterioration of maize quality and environmental pollution. Thus, the adoption of slow-release nitrogen fertilizers with comparatively higher efficiency is urgently needed to achieve agricultural sustainability. Nanotechnology has been suggested as a potential alternative to traditional nitrogen fertilizers on a large scale, due to its higher surface to volume ratio and ability to optimize fertilizer usage However, there is limited data on the relative performance of nano urea versus traditional urea fertilizers on maize. To address this gap in knowledge, a study was conducted to evaluate the impact of foliar spraying of nano urea versus urea at two stages of growth (knee height and tasseling) and two different levels of nitrogen application (Magodia *et al.*, 2024) [11]. Lysine and tryptophan are two important amino acids that are deficient in maize grain, causing nutritional deficits in consumers. Lysine and tryptophan shortage is connected with a wide range of deficiency symptoms such as cognitive dysfunction, kwashiorkor disease, decreased appetite, impaired skeletal development, delayed growth, and abnormal behaviour. These amino acids are also necessary for the treatment of Pellagra illness. Researchers discovered numerous mutants in maize, including opaque-2, that are responsible for elevated lysine and tryptophan levels. It was discovered a few years later that the opaque-2 mutant exhibits various pleiotropic impacts on maize grain and plant. Researchers have been working for four decades to develop quality protein maize (QPM).

2. Material and Methods

The research work was carried at the farm of Lovely Professional University, Phagwara, Punjab during summer season 2023-24. The farm is geographically situated at an altitude of 5423 m above mean sea level at 17° 19 N latitude and 78° 28 E. The climate of Phagwara has a semi-arid & sub-tropical climate with severs cold and hot during winters and summers respectively. The pH of soil was 8.4 in clayey loamy texture with alkaline in nature. The soil samples have low nitrogen and have medium organic carbon, phosphorus, and potassium present. The availability of low nitrogen in the soil represents that soil has low nutrients present for crop growth.

2.1 Experimental design and crop management

The study used the LQMH-1 variety of maize with the application of fertilizer dosage recommendations of 120:60:40 kg/ha (N: P: K). The field experiment used a randomized block design with three replicate (plot size of 5m x 4m) and 9 treatments *viz*., Control (T_0), 100% RDN (Recommended dose of nitrogen) (T_1), 50% RDN Basal + One FSNU @ 2ml/Lt. at 35 DAS (T_2), 50% RDN Basal + Two FSNU @ 2ml/Lt. at 35 DAS (T_3), 50% RDN basal + Two FSNU @ 2ml/Lt. at 35 DAS & 65 DAS (T_4), 50% RDN basal + One FSNU @ 4ml/Lt. at 35 DAS (T_5), 50% RDN basal + Two FSNU @ 4ml/Lt. at 35 DAS & 65DAS (T_6), 25% RDN basal + One FSNU @ 4ml/Lt. at 35 DAS (T_7), 25% RDN basal + Two FSNU @ 4ml/Lt. at 35 DAS & 65 DAS (T_8).

The seedbed was prepared after pre-sowing irrigation depending on the main plot treatments with seed drill at the spacing of 60 x 20 cm. maize crop was sowed at one row per bed on the tops of beds. Fertilizers were applied in form of urea, di-ammonium phosphate (DAP), and potash. 50% of nitrogen was applied to maize at the sowing time and DAP and potash were applied as basal dose. The remaining 50% of nitrogen was supplied as 25, 45 DAS. The seeds of maize were treated with carbendazim @ 2 g/kg seed before sowing. Total four irrigations with check basin method were provided to maize crop to provide growth, good development, and yield to maize. Harvesting of maize was done manually and separately. Total five cobs from each plot were selected and used for observations for the evaluation of treatments as per the plan of the experiment. The measured plant growth metrics encompassed plant height, leaf area index, dry matter accumulation, crop growth rate, and relative growth rate and yield parameters.

2.2 Statistical analysis

A two-way analysis of variance (ANOVA) was conducted at a significance level of 5% to investigate the assessment of Nano Urea based N application on the performance of QPM in Sub-tropical condition of Punjab. The significance of the difference between treatment means was assessed using an 'F' test. The critical difference (CD) was calculated when the 'F' value indicated a significant treatment impact.

3. Results and Discussion

3.1 Effect of Nano urea based N application on Growth parameters of QPM

3.1.1Plant height (cm)

Effect of different increased doses of nano urea based nitrogen application on plant height (cm) was studied in maize. Data were recorded at 30, 60, 90 days and at harvest after sowing (DAS) increased successively with increasing the nano urea levels significantly as presented in (Tables 1). At 30 DAS, plant height was found highest in T_6 (50% RDN basal + Two FSNU@4ml/Lt. at 35 DAS & 65DAS) was recorded as 26.84 cm and the lowest was observed in T_0 (control) as 18.52 cm. The treatment T_6 was found statistically at par with the treatments T_5 (50% RDN basal + One FSNU@4ml/Lt. at 35 DAS) and T_4 (50%RDN basal + Two FSNU @2ml/Lt. at 35 DAS & 65 DAS). At 60 DAS, the highest plant height was found as 94.59 cm in the T_6 followed by T_5 and T_4 and the lowest as 76.52 cm in T_0 (control). Treatment T_6 was found statistically at par with the treatments T_5 and T_4. At 90DAS the highest and lowest plant height were found as 181.17 cm and 124.61 cm in T_6 (50% RDN basal + Two FSNU@4ml/Lt. at 35 DAS & 65DAS) and T_0 (Control) respectively. At harvest maximum plant height was observed as 234.64 cm in T_6 treatment. Plant height may have increased as a result of increased cell multiplications, cell elongation, and cell expression in the plant body, which were all enhanced by adequate nano urea availability, which was linked to a better nutritional environment for plant growth during active vegetative stages (Yahya and Dawod, 2022) [25]. The positive impact of these nutrients on metabolism and biological activity, as well as their stimulatory effect on photosynthetic pigments and enzymatic activity, which in turn stimulate plant vegetative growth, may also be responsible for this enhancing effect (Kumar *et al*. 2024; Alzreejawi and Juthery, 2020) [10, 3].

Table 1: Effect of different treatments of Nano urea based N application on plant height (cm) of maize crop

Treatments	Plant Height (Cm)			
	30 Das	60 Das	90 Das	At Harvest
T_0	18.52	76.54	124.61	196.49
T_1	22.38	78.36	136.05	206.54
T_2	22.42	82.15	141.04	216.45
T_3	25.57	84.38	156.55	227.57
T_4	26.50	86.38	165.43	232.37
T_5	29.69	92.29	178.16	233.59
T_6	32.28	94.59	181.17	234.64
T_7	24.59	79.48	132.45	215.28
T_8	25.20	81.24	152.48	225.37
CD	0.20	1.88	3.03	0.09
CV	0.58	1.80	1.43	0.03
SE(m±)	0.07	0.63	1.03	0.03
SE(d±)	0.09	0.90	1.45	0.04

Data are presented in the form of mean ± SD, CD: Critical difference, CV: Critical variance, SE: Standard error

3.1.2 Leaf area index

Data were recorded at 30, 60, 90 days and at harvest increased successively with increasing the nano urea levels significantly as presented in (Figure 1). At 30 DAS, the maximum leaf area index was recorded as 61.53 in T_6 followed by T_5 as 48.56 and lowest was observed as 33.17 in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5 and T_4. At 60 DAS, the highest leaf area index was observed as 94.58 in T_6 and the lowest was recorded as 76.52 in T_0 (control). At 90 DAS, the highest leaf area index was investigated as 186.48 in T_6 and the lowest was recorded in T_0 (control). This increase in the leaf area index contributed to the accumulation of dry matter in plants at higher nano urea levels. The genetic makeup of the cultivar with a sufficient quantity of nutrients may have improved the physical and chemical properties of the soil, allowing the plants to uptake the nutrients and potentially promoting maximum plant volume and leaf area index. An improved environment for maize growth and development may be the cause of the overall increase in crop growth under the impact of the suggested dose of NPK and nano urea application. Similar, findings are revealed by Singh *et al.* (2023) [22] and Morsy and Ahmed (2021) [13] in maize crop.

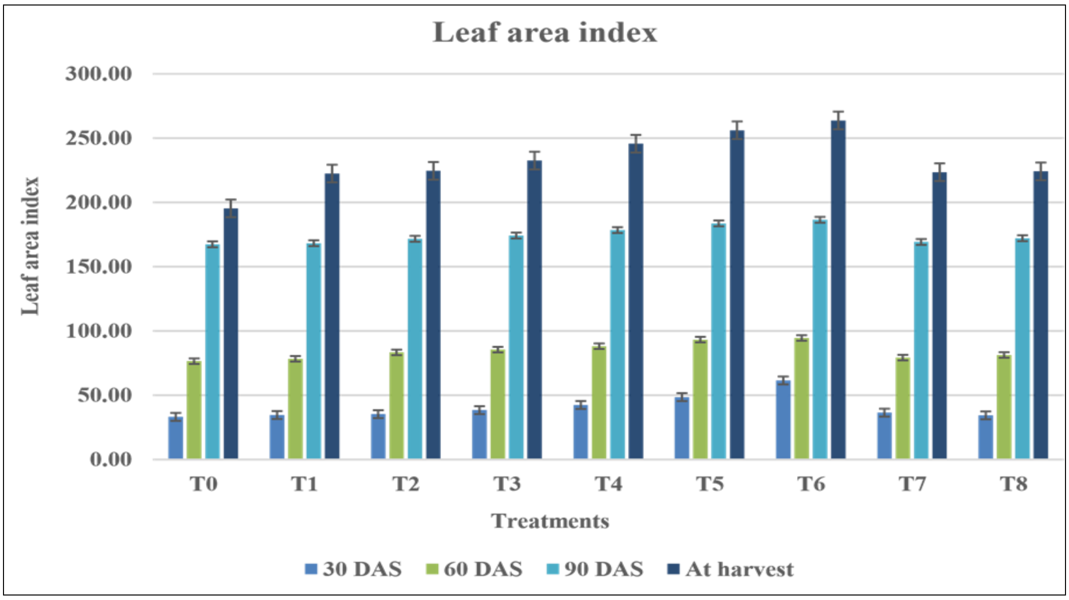

Fig 1: Influence of different treatments of nano urea based N application on leaf area index of maize crop

3.1.3 Dry matter accumulation

Increased doses of nano urea effect the dry matter accumulation was studied in maize. Data were recorded at 30, 60, 90 days and at harvest increased successively with increasing the nano urea levels significantly as presented in (Figure 2.). At 30 DAS, the maximum dry matter accumulation was recorded as 68.38 g/m2 in T_6 followed by T_5 as 65.51 g/m2 and lowest was observed as 62.22 g/m2 in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5 and T_4. At 60 DAS, the maximum dry matter accumulation was recorded as 88.19 g/m2 in T_6 followed by 65.51 g/m2 in T5 and lowest was observed as 82.43 g/m2 in T_0 (control). At 90 DAS and at harvest, the highest dry matter accumulation was observed as 169.37 and 182.31 g/m2 in T_6 respectively and the lowest was recorded as 163.65 g/m2 in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5 and T_4. This increase in the levels of nano urea based nitrogen levels contributed to the accumulation of dry matter in plants. The genetic makeup of the cultivar with a sufficient quantity of nutrients may have improved the physical and chemical properties of the soil, allowing the plants to uptake the nutrients and potentially promoting maximum dry matter accumulation. Similar, results are reported by Kumar *et al.* (2024) [10] and Yadav *et al.* (2017) [24] in maize crop.

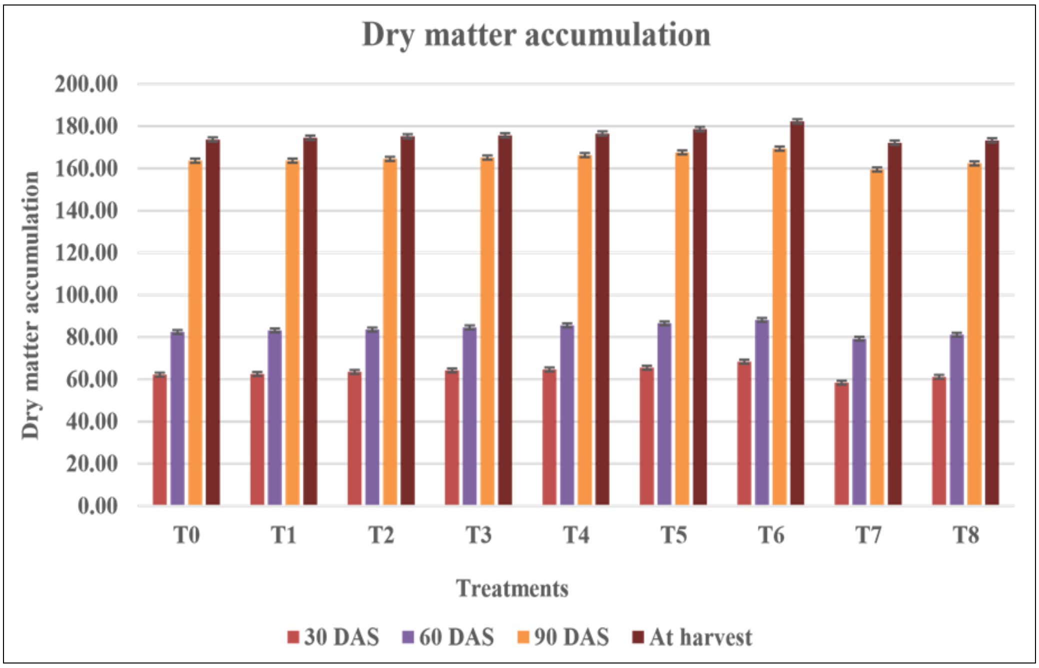

Fig 2: Influence of different treatments of nano urea based N application on dry matter accumulation (g/m^2) of maize crop

3.1.4 Crop growth rate and Relative growth rate

Data related to CGR and RGR was increased with increased in levels of nano urea based nitrogen application was studied in maize (Figure 3). Data were recorded at 30, 60, 90 days and at harvest increased successively with increasing the nano urea levels. At 30 DAS, the maximum crop growth rate was recorded as 18.21 g/m2/day in T_6 followed by T_5 and lowest was observed as 8.46 g/m2/day in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5. At 60 DAS and 90 DAS and at harvest, the highest crop growth rate was observed in T_6

and the lowest was recorded. The relative growth rate improved with an increase in nano urea levels. At 30 DAS, the maximum relative growth rate was recorded as 55.21 g.g-1/day in T_6 followed by T_5 and lowest was observed in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5 and T_4. At 60 DAS and 90 DAS, the highest relative growth rate was observed in T_6 and the lowest was recorded in T_0 (control). The maximum relative growth rate was observed at harvest as 68.34 g.g-1/day at T_6 in T_0 (control). This increase in the nano urea based nitrogen application contributed to the accumulation of crop growth rate in plants. The genetic makeup of the cultivar with a sufficient quantity of nutrients may have improved the physical and chemical properties of the soil, allowing the plants to uptake the nutrients and potentially promoting maximum crop growth rate of maize. Similar, results are investigated by (Rashmi and Prakash, 2023) [16] in maize.

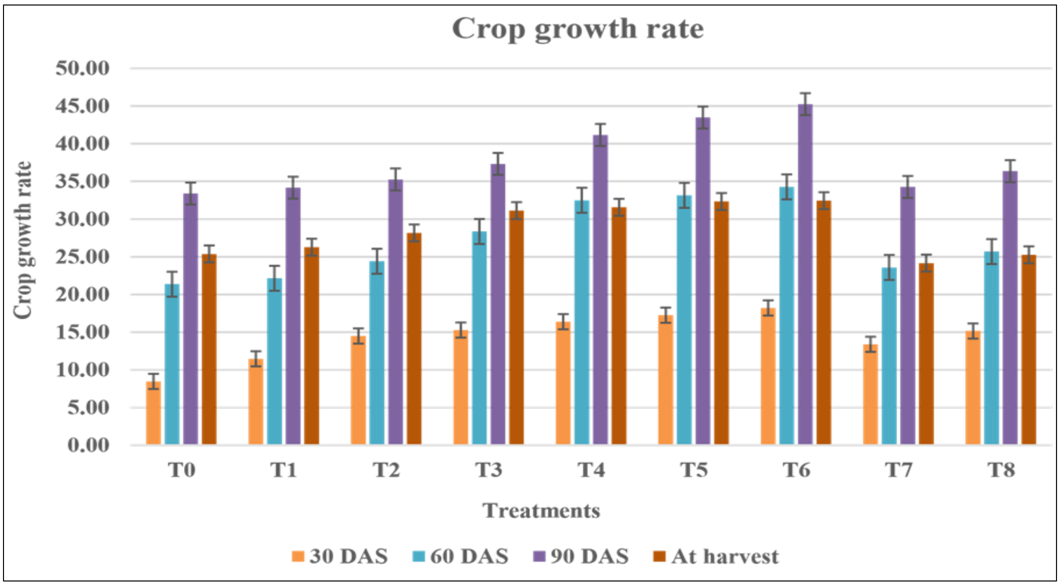

Fig 3: Influence of different treatments of nano urea based N application on crop growth rate (g/m^2/day) of maize crop

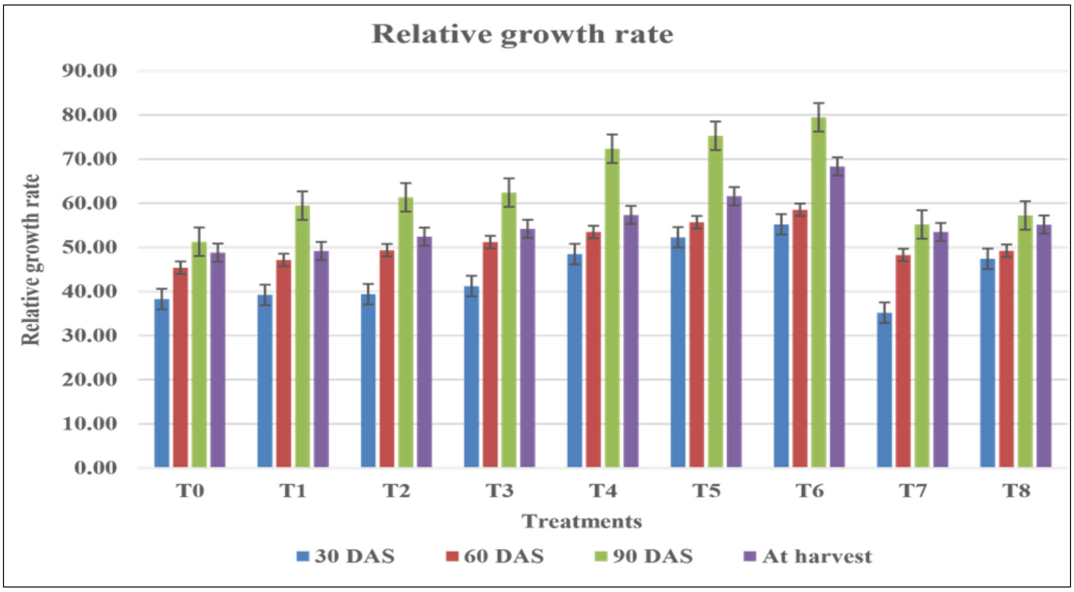

Fig 4: Influence of different treatments of nano urea based N application on relative growth rate (g.g^{-1}/day) of maize crop

3.2 Yield parameters

3.2.1 Number of cobs/plant

Number of cobs/plant increased with increased in doses of nano urea levels was studied in maize. Data were recorded at harvest after sowing (DAS) (Table 2). The number of cobs/plant was observed to increase with increase in nano urea based nitrogen application i.e. from T_0 to T_8 as comparison to control. It is evident from the observations that the average number of cobs/plant was significantly increased at T_6 treatment as 1.75 followed by 1.69 in T_5 and lowest was observed as 1.15 in T_0 (control). Treatments T_6 was found statistically at par with treatments T_6 and T_5. Different nano urea levels was applied in different treatments increased as compared to control T_0 at harvest. Similarly, when plants were exposed to a higher dose of nano urea application then a significant increase in number of cobs/plant was observed as compared to T_0. Similarly, in treatment T_6, the number of cobs/plant was observed to increase significantly in comparison to other treatments. Similar findings are reported by Rundan *et al.* (2023) [18] and Singh *et al.* (2023) [22] on the maize crop.

3.2.2 Number of grains/cob

Number of grains/cob increased with increased in doses of nano urea levels was studied in maize. Data were recorded at harvest after sowing (DAS) (Table 2). The number of grains/cob was observed to increase with increase in nano urea based. Nitrogen application i.e. from T_0 to T_8 as comparison to control. It is evident from the observations that the average number of grains/cob was significantly increased at T_6 treatment as 358.61 followed by 334.65 in T_5 and lowest was observed as 196.78 in T_0 (control). Treatments T_6 was found statistically at par with treatments T_5. Same finding was done by Srivastava *et al*. (2023) and Singh *et al*. (2023) [22] on the maize crop

3.2.3 Seed index and harvest index

Effect of different increased doses of nano urea levels on seed index and harvest index was studied in maize. Data were recorded at harvest after sowing (DAS) (Table 2). The seed index was observed to increase with increase in nano urea based nitrogen application i.e. from T_0 to T_8 as comparison to control. It is evident from the observations that the average seed index was significantly increased at T_6 treatment followed by T5and lowest was observed in T_0 (control). Similar results had been reported by Mubarok *et al*., (2022) on the maize crop.

3.2.4 Seed yield and stover yield

Effect of different increased doses of nano urea levels on seed yield and stover yield was studied in maize. Data were recorded at harvest after sowing (DAS) (Table 2). The seed yield was observed to increase with increase in concentration of nano urea based nitrogen application i.e. from T_0 to T_8 as comparison to control set at all the intervals taken under study. It is evident from the observations that the average seed yield and stover yield was significantly increased at T_6 treatment as 5.14 t/ha and 7.26 t/ha and lowest was observed as 2.37 t/ha and 4.18 t/ha in T_0 (control) respectively. Treatments T_6 was found statistically at par with treatments T_5 and T_4.The above results are in accordance with Srivastava *et al*. (2023) on maize plants.

Table 2: Effect of different treatments of Nano urea based N application on yield parameters of maize crop

Treatments	Number of cobs/plant	Number of grains/cob	Seed Index (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
	At harvest					
T_0	1.15	196.78	26.90	2.37	4.18	22.72
T_1	1.31	224.42	27.10	3.16	5.06	23.85
T_2	1.46	259.08	27.80	3.65	5.39	24.80
T_3	1.54	278.18	28.77	4.14	5.82	24.59
T_4	1.62	322.56	30.10	4.38	6.13	24.83
T_5	1.69	334.65	34.71	4.82	6.73	25.27
T_6	1.75	358.61	38.20	5.14	7.26	25.48
T_7	1.44	248.08	28.76	3.47	5.24	23.48
T_8	1.50	251.94	29.38	4.10	5.66	24.16
CD	0.05	1.48	0.35	0.05	0.03	0.29
CV	2.50	0.38	0.84	1.00	0.42	0.96
SE(m±)	0.01	0.50	0.12	0.01	0.01	0.09
SE(d±)	0.02	0.71	0.17	0.02	0.01	0.14

4. Conclusion

The overuse of synthetic fertilizers, insecticides, and other chemical inputs has prompted concerns about the long-term effects on soil physiochemical characteristics, microbial diversity, and agricultural yield. As a result, there is an urgent need for alternative solutions that promote sustainable agriculture methods while maintaining optimal yields and soil quality. Nanotechnology is developing technology and has promising applications in the fuel of agriculture. It involves science and researchers across the globe to produce new innovative-based things in agriculture. Nanotechnology helped to show antibacterial, antimicrobial, antifungal activities to the crop, it also improved the yield, reduced soil pollution, and hence, increase nutrient use efficiency. The nano-based fertilizers as good advantages as it provides good yield, values, index to as compared to normal fertilizers. The fertilizers can directly involve plant cells through the cell wall structure. The nano fertilizers enhanced the growth and yield attributes of the field maize crop. The yield parameters including number of cobs/plant (1.75±0.03), number of grains/cob (358.61±0.14), seed index (38.20±0.07 g), seed yield (5.14±0.02 t/ha), Stover yield (7.26±0.02 t/ha) and Harvest index (25.48±0.04%) was recorded more in treatment T_6 and lowest was observed in T_0 (control) at harvest. It is understandable from the field study the application of nano urea doses increases the growth, yield, quality and economics attributes with increase the RDN levels. The treatment T_6 (50% RDN basal + Two FSNU@4ml/Lt. at 35 DAS & 65DAS) had maximum effect on growth and development of maize crop.

5. Acknowledgements

This statement accepts that each author has made a significant contribution to the manuscript and is prepared to accept public accountability for its contents. The author(s) are also highly thankful to Lovely professional university, Punjab, India.

6. Competing interests

The authors declare no competing interests.

7. Authors' Contributions

'Suhail Fayaz' designed the study, 'Shoaib Khan' performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. 'Navjot Rana 'managed the analyses of the study.'Shoaib Khan' managed the literature searche. All authors read and approved the final manuscript."

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