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# Comparative Study on the Efficacy of Various Nano Fertilizer Levels, NPK Foliar, and Soil Applications in Enhancing the Growth and Yield of Kharif Maize *(Zea mays* L.)

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**ABSTRACT**

Maize holds significant importance as a staple crop in the rainfed regions of the Northern plains of Punjab. To maximize the utilization of nitrogen-based fertilizers, the exploration of Nano Fertilizers becomes imperative. This research paper aims to compare the effectiveness of different levels of nano fertilizers, NPK foliar application, and soil application on the growth and yield of Kharif maize (*Zea mays* L.). The study's objective is to assess the potential of nano fertilizers as a viable alternative to conventional fertilizers for enhancing crop productivity. A randomized block design with eight treatments and three replications was employed for this investigation. The results indicated that Treatment 8 (50% soil application + 50% Nano NPK) exhibited superior performance in terms of influencing growth attributes and yield of Kharif maize. However, Treatments 50% NPK and Nano NPK, with soil application and foliar application respectively, showcased promising outcomes compared to other treatments. These findings suggest that this combination could be an appropriate management strategy to achieve sustainability. Moreover, the use of Nanoparticle fertilization proves to be a safe method for elevating plant nutrition levels without compromising the environment. This research paper provides detailed insights into the application of Nano urea, Nano NPK, and foliar NPK (19:19:19) in relevant treatments.

***Key words:*** *Nano fertilizers, NPK foliar application, Soil application, Growth, Yield, Maize*

## Introduction

Maize (*Zea mays*) is the third most important cereal crop after rice and wheat and ranked in first in productivity. Maize (*Zea mays* L.) is one of the most important staple crops worldwide, serving as a vital source of food, feed, and industrial raw materials . Achieving high yields and maintaining soil fertility

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are crucial for sustainable maize production. Maize is one of the oldest crop as its origin is about 4500 years or even older than that it has the highest productivity among the cereals and it is regarded as queen of cereals total world product. Achieving high yields and maintaining soil fertility are crucial for sustainable maize production of maize was 1206.96 million metric tonnes during 2022. Around 193.7 million- hectare land is under maize crop with 5.75 tonnes per hec$^{-1}$ productivity. The United States produces the most maize, followed by China. India ranks 7 in maize production with 30,000 (in 1000 metric tonnes). In India, maize is grown on 9.2 million hectare with 27.8 million metric tonnes. Major states cultivating maize are Punjab, Uttar Pradesh, Andhra Pradesh, Haryana, Gujarat and Rajasthan. Andhra Pradesh has the highest productivity of maize. In Punjab, maize was grown on 1.07 lakh hectare land with 3.9 lakh tonnes of production. Productivity of maize under Punjab conditions is 36.65 q ha$^{-1}$. Maize has been used for human as well as animal consumption. Maize was commonly grown for grain and fodder purposes. In India, it is continuously grown all round the year. Maize has a significant nutritional value since it comprises 72 percent starch, 10% protein, 8.5 percent fiber, 4.8 percent oil, 3.0 percent sugar, and 1.7 percent ash. Biofertilizers are also a good source of nutrients as they bind atmospheric nitrogen and ammonium ion, which are unavailable to plants, and release them into the soil which improves soil fertility (Ajithkumar *et al.*, 2021). Nano fertilizer are excellent source in agriculture for increasing crop growth, yield, and quality parameters by improving nutrient efficiency, reducing fertilizers waste, and reducing cultivation costs. Nano-fertilizers increase the photosynthetic and prophylaxis process and provides larger surface area for various metabolic activities in the plant. The usage of nitrogen (N) in Nano-fertilizer treatments has been better than in standard fertilizer treatments. Plants grown using Nano fertilizer accumulated more nitrogen, according to the study. Nanofertilizers are known to release nutrients slowly and steadily over a period of more than 30 days, which However, the excessive and improper use of conventional fertilizers can lead to environmental pollution and nutrient imbalances. In recent years, nanotechnology has emerged as a promising approach for improving nutrient uptake efficiency and crop productivity. Nano fertilizers, with their nanosized particles and enhanced nutrient release properties, offer potential benefits in nutrient management and plant growth promotion. Additionally, foliar application of nutrients, particularly NPK, has gained attention for its effectiveness in delivering essential elements directly to plant tissues. This study aims to compare the effects of different levels of nano fertilizers, NPK foliar application, and soil application of fertilizers on the growth and yield of Kharif maizemay help to improve nutrient use efficiency without causing any adverse side effects. The loss of nutrients is significantly decreased in terms of environmental safety because the Nano-fertilizers are designed to supply slowly over a long period of time. Although research on Nano-fertilizers is scarce around the world, the literature reviewed clearly revealed that these interactive fertilizer have the potential to help farmers maintain production. Nano fertilizer treatment improved tremendously in maize development, yield, quality, and nutrient uptake compared to regular urea, demonstrating that nano materials enhance plant growth and hence dry weight, leaf area, and growth rate. Nano fertilizer has a significant favorable impact on soil mineral nitrogen because it is available for plant uptake. In comparison to standard fertilizer effect Nano-fertilizer application in soil showed better pH, moisture, EC, and available nitrogen. Because of its ability to increase yield, improve soil fertility, reduce contamination, and maintain a better environment for microorganisms. Nano fertilizers play a vital role in crop physiological and biochemical processes by enhancing nutrient availability, which helps in improving metabolic processes and promoting meristematic activities, resulting in increased apical growth and photosynthetic area.

## Materials and Methods

The experiment was conducted at Agriculture Research Farm LPU in Phagwara, Punjab, specifically in Chaheru village of Kapurthala district (31°14’48.86"N 75°42’12.73"E), which falls within the northern plain zone. The study area is located between the Sutlej and Beas rivers and belongs to the central plain region of Punjab. The soil in the village is predominantly alluvial soil, and the climate is characterized as sub-tropical monsoon-type with an average rainfall of 60 mm.

The experimental field had sandy clay loam soil texture. To prepare the soil for maize cultivation, it was plowed once using a tractor-drawn cultivator,

followed by two turnings with a rotavator to achieve the desired tilth. Maize hybrid DKC-9208 seeds were sown on June 17, 2022, using the ridge method with a seed rate of 20 kg/ha and a spacing of 60 cm × 20 cm. The plot size was 5 m × 4 m, and the crop was harvested in September 2022.

Fertilizers were applied based on the recommended dose of 120:60:40 kg/ha of $N:P_2O_5:K_2O$. Half of the nitrogen and the full doses of phosphorus and potassium were appliedas a basal dose, while the remaining half of nitrogen was applied at the knee-high stage as a top-dressing. All other agronomic management practices followed the recommended package of practices for the region.

The experiment was designed in a randomized block design with eight treatments and three replications. The treatments investigated in this study were as follows:

1. T1: Absolute control (no fertilizer application)
2. T2: Recommended dose of fertilizer (RDF)
3. T3: 100% Nano urea application
4. T4: 100% Nano NPK foliar spray at knee height, tasseling, and silking stages, at a concentration of 2%
5. T5: NPK 19:19:19 simple foliar spray at knee height, tasseling, and silking stages, at a concentration of 2%
6. T6: 75% soil application + 25% Nano urea foliar spray at knee height, tasseling, and silking stages, at a concentration of 2 ml/L
7. T7: 75% soil application + 25% Nano NPK foliar spray at knee height, tasseling, and silking stages, at a concentration of 3 ml/L
8. T8: 50% soil application + 50% Nano foliar spray at knee height, tasseling, and silking stages, at a concentration of 4 ml/L

The Nano-urea used in the trial was manufactured by Indian Farmers Fertilizer Cooperative Limited (IFFCO), while the Nano NPK was obtained from Geolife company. Data related to plant height (cm), number of leaves, stem girth, leaf area index, dry weight, and chlorophyll content were recorded at 30, 60, and 90 days after sowing. Yield and stover yield were measured at harvest.

## Results and Discussion

### Growth Parameters

#### Plant Height

The purpose of this study was to investigate the effects of different fertilizer doses on the growth characteristics of maize. Table 1 and Figure 1 present the data obtained during the study. The results demonstrated that as the maize plants matured, their height gradually increased until the end of the 60 and 90-day study period. Among the various fertilizer applications, the plot treated with T8 (50% RDF + 50% Nano NPK) fertilizer exhibited the maximum maize plant height, indicating that this treatment resulted in the tallest plants. Following T8, the next highest plant heights were observed in the plots treated with T7 (75% soil application + 25% Nano NPK) (foliar) and T6 (75% soil application + 25% Nano urea) (foliar). Conversely, the lowest plant height was recorded in the absolute control group (T1), where no fertilizer was applied.

**Table 1.** Impact of different levels of Nano fertilizers, NPK foliar with RDF fertilizers on the growth parameters of kharif maize.

| Treatments | Plant Height (cm) | | | No. of Leaves | | | Stem Girth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90DAS | 30 DAS | 60 DAS | 90 DAS | 30 DAS | 60 DAS | 90 DAS |
| Absolute Control | 38.100 | 56.900 | 84.367 | 8.41 | 9.29 | 8.433 | 2.50 | 2.40 | 2.43 |
| RDF (soil application) | 49.133 | 73.933 | 105.700 | 11.00 | 12.50 | 11.00 | 2.55 | 2.50 | 2.70 |
| Nano Urea (100%) | 90.033 | 123.633 | 158.200 | 12.08 | 13.16 | 12.08 | 3.10 | 3.50 | 3.43 |
| NanoNPK foliar (100%) | 77.300 | 108.900 | 141.767 | 11.50 | 13.08 | 11.50 | 2.83 | 3.03 | 3.16 |
| NPK 19:19:19(simple foliar) | 63.333 | 91.833 | 125.900 | 10.16 | 12.25 | 10.16 | 2.56 | 2.60 | 2.73 |
| 75% soil application + 25% Nano urea (foliar) | 105.800 | 141.100 | 173.467 | 11.91 | 13.91 | 11.91 | 3.10 | 4.16 | 4.46 |
| 75% soil application + 25% Nano NPK (foliar) | 118.133 | 160.900 | 186.900 | 12.16 | 13.83 | 12.16 | 3.14 | 5.03 | 5.40 |
| 50% soil application + 50% Nano NPK (foliar) | 144.567 | 177.367 | 200.000 | 13.58 | 14.25 | 13.58 | 3.23 | 5.60 | 6.46 |
| S. Em (±) | 3.527 | 5.141 | 3.561 | 0.560 | 0.633 | 0.572 | 0.095 | 0.142 | 0.174 |
| C.D.@ 5% | 10.802 | 15.744 | 11.196 | 1.714 | 1.938 | 1.753 | 0.291 | 0.434 | 0.532 |

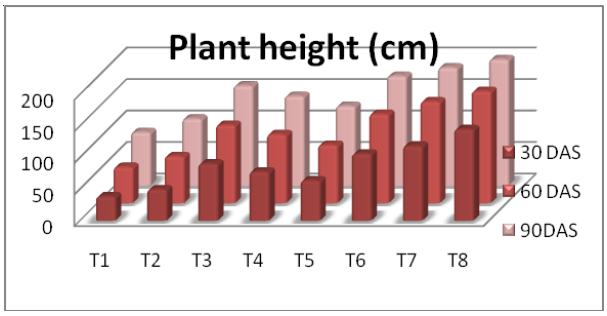


**Fig. 1.** Effect of Nano urea, Nano NPK (19:19:19) and foliar NPK(19:19:19) on plant height of maize

The interaction between Nano NPK foliar spray and soil application had a positive impact on maize growth. The application of Nano NPK through spraying showed superior results as it had a longer-lasting effect and influenced the physiological processes within the plant cells. These findings are consistent with the results reported by Sankar *et al.* (2020), Yomso and Menon (2021), and Massey and Gaur (2014).

**No. of leaves/ plant**

The number of leaves per plant was measured at 30, 60, and 90 days after sowing (DAS). Among the different fertilizer applications, the plot treated with T8 (50% RDF + 50% Nano NPK) fertilizers consistently exhibited the highest number of leaves. This was followed by T7 (75% soil application + 25% Nano NPK) (foliar) and T6 (75% soil application + 25% Nano urea) (foliar), indicating that the application of Nano NPK resulted in favorable outcomes. Conversely, the absolute control group (T1) consistently had the fewest leaves per plant.

The combination of 50% Nano NPK fertilizer and 50% soil fertilizer, when applied through spraying, showed increased efficiency in terms of nitrogen, phosphorus, and potassium. This enhanced nutrient availability positively influenced leaf growth. Additionally, the significant impact of additional Nano NPK on crop growth can be attributed to its ability to increase the leaf area per plant. The maximum number of leaves was reported when the 50% RDF + 50% NPK

**Nano fertilizers were applied**

Similar findings have been reported by Yomso and Menon (2021), Burhan *et al.* (2019), Massey and Gaur (2014), and Midde *et al.* (2021), further supporting the notion that Nano NPK fertilizers can promote leaf growth and increase the number of leaves per maize plant.

The results of this study indicate that the application of T8 (50% RDF + 50% Nano NPK) fertilizers or the use of Nano NPK in combination with soil fertilizers can effectively enhance leaf development in maize plants.

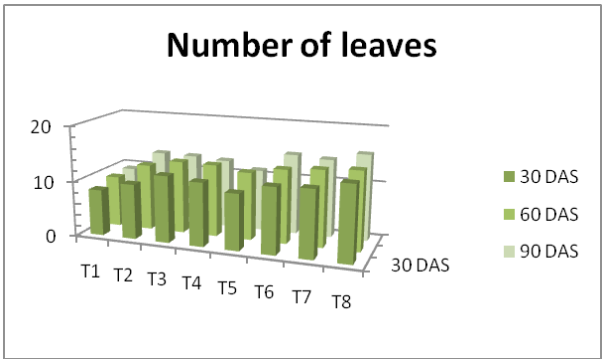


**Fig. 2.** Effect of Nano urea, Nano NPK (19:19:19) and foliar NPK(19:19:19) on number of leaves of maize

**Stem Girth**

A comparative study was conducted at various stages of sampling to examine the effects of different levels of Nano fertilizers, NPK foliar, and soil application of fertilizers on stem girth. At 30, 60, and 90 days after sowing (DAS), the highest stem girth was observed in the plots treated with T8 (50% RDF + 50% Nano-NPK) fertilizers, followed by T7 (75%soil application+ 25% Nano NPK) (foliar) and T6 (75% soil application + 25% Nano urea) (foliar). In contrast, the absolute control group exhibited the lowest stem girth (Table 1).

The increased stem girth can be attributed to the increase in the number of leaves, which subsequently led to an increase in biomass and photosynthetic rate. This effect can be attributed to the additional application of Nano NPK fertilizers. Similar findings were reported by S. A. M. Alzreejawi *et al.* (2020), Mehta and Bharat (2019), and Yomso and Menon (2021), emphasizing that the combination of Nano NPK and soil application resulted in the highest average values for stem girth. In summary, the results of this study demonstrate that the application of T8 (50% RDF + 50% Nano-NPK) fertilizers, along with the combination of Nano NPK and soil application, positively influenced stem girth in maize plants. The increase in stem girth can be attributed to the increased leaf count, resulting in enhanced biomass and photosynthetic rate.

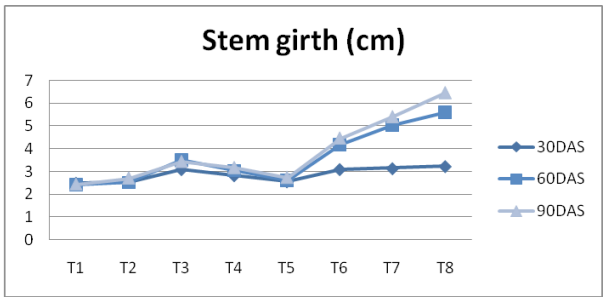


**Fig. 3.** Effect of Nano urea, Nano NPK (19:19:19) and foliar NPK (19:19:19) on stem girth of maize

### Chlorophyll content

Chlorophyll content was measured at different time points (30 DAS, 60 DAS, and 90 DAS) across various fertilizer treatments. The treatment T8, which consisted of a combination of 50% recommended dose of fertilizer (RDF) and 50% Nano NPK, exhibited the highest recorded chlorophyll content. Following closely were treatments T7 (75% soil application + 25% Nano NPK) and T6 (75% soil application + 25% Nano urea), which demonstrated relatively high chlorophyll levels. On the other hand, the lowest chlorophyll content was observed in T1 (absolute control), as indicated in Table 1. The application of foliar sprays containing Nano NPK and Nano urea at appropriate SPAD thresholds resulted in improved grain quality and fodder yield. Chlorophyll, being closely associated with nitrogen levels, plays a critical role in determining the final crop yield. The addition of Nano NPK to the recommended fertilizer dose increased nitrogen content, thereby boosting chlorophyll production and the overall photosynthetic rate of plants.

Studies conducted by Bayan Rokan Aziz and Dilzar Basit Zrar (2021), Vishvajeet D Jadhav *et al.*

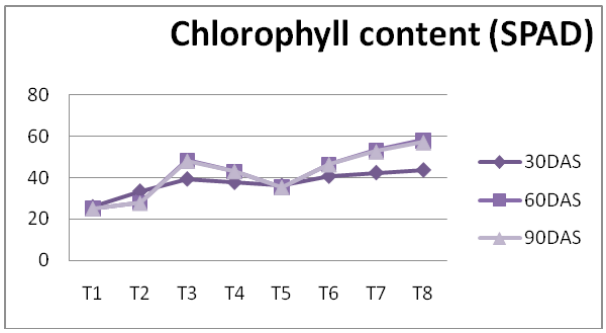


**Fig. 4.** Effect of Nano urea, Nano NPK (19:19:19) and foliar NPK(19:19:19) on Chlorophyll content of maize

(2022), and Mayasem Abed Naser Al-Jubouri *et al.* (2022) have revealed that the application of Nano-NPK via foliar spray, performed twice during the growth cycle, led to increased leaf count and enhanced chlorophyll content. These findings are depicted in the graph below.


**Fig. 5.** Effect of Nano urea, Nano NPK (19:19:19) and foliar NPK (19:19:19) on Dry weight of maize

### Dry weight

The study compared the dry weight of plants treated with different levels of Nano fertilizer in combination with recommended dose of fertilizer (RDF) at three different time points: 30 days after sowing (DAS), 60 DAS, and 90 DAS. Among all the treatments, the highest dry weight was recorded in treatment T8, which consisted of 50% RDF and 50% Nano-NPK. The second highest dry weight was observed in treatment T7, which involved 75% soil application of fertilizer and 25% Nano-NPK applied as foliar spray. Treatment T6, which included 75% soil application of fertilizer and 25% Nano urea applied as foliar spray, showed the third highest dry weight. The application of Nano fertilizers as foliar sprays increased nutrient uptake in the plants. Nano-fertilizers have the ability to increase the surface area available for various metabolic processes in the plant system, thereby enhancing photosynthesis and promoting the accumulation of dry matter in crops. These findings are consistent with similar results reported in studies conducted by Drocelle Nirere *et al.* (2019); Meena Dharam Singh *et al.* (2017), Akshay Glotra *et al.* (2022), and Sai Kumar Midde *et al.* (2022).

Comparison to different level of Nano fertilizer with RDF, The Dry weight recorded at 30 DAS,60 DAS and 90 DAS, The highest treatment T8 (50% RDF +50% Nano-NPK) showed highest among all followed by T7 (75% soil application + 25% Nano NPK) (foliar) and T6(75% soil application + 25% Nano urea) (foliar) showed second and third highest treatment respectively. The Nano fertilizers foliar

spray increased nutrient uptake. The surface area that is available for different metabolic processes in the plant system is increased by Nano-fertilizers, which speeds up photosynthesis and increases crop dry matter. The similar results were found in Drocelle Nirere *et al*., (2019), Meena Dharam Singh *et al.* (2017), Akshay Glotra *et al.,* (2022), Sai Kumar Midde *et al*., (2022).

**Yield attributes**

In terms of yield attributes, the highest mean values for both overall yield and stover yield were observed in treatment T8, which consisted of 50% recommended dose of fertilizer (RDF) combined with 50% Nano-NPK. Following closely were T7, which involved 75% soil application of fertilizer and 25% Nano-NPK applied as a foliar spray, and T6, which included 75% soil application of fertilizer and 25% Nano-urea as a foliar spray. The lowest mean value for yield and stover yield was recorded in the absolute control treatment (T1).

The application of Nano-NPK fertilizer has been reported to have positive effects on crop production, increasing both yield and nutrient content in plant cells, particularly in grains. The use of 50% soil application of fertilizer also resulted in increased yield and stover production in maize, with the foliar application of Nano-NPK contributing to the enhanced maize yield. This increase in yield can be attributed to the longer-lasting presence of Nano materials in plant cells, which leads to higher yields over an extended period.

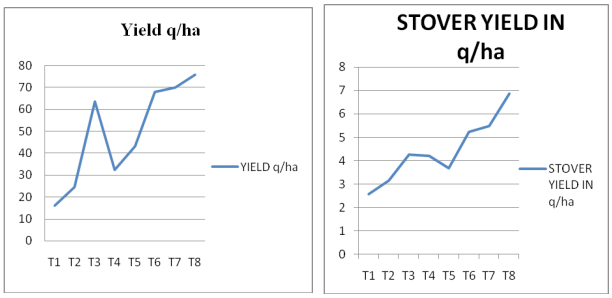


**Fig. 6.** Effect of Nano urea, Nano Npk(19:19:19) and foliar NPK(19:19:19) on Yield and stover yield of maize

**Table 2.** Impact of different levels of Nano fertilizers, NPK foliar with RDF fertilizers on Chlorophyll content and dry weight.

| Treatments | Chlorophyll content (SPAD) | | | Dry weight (cm) | | |
|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 30 DAS | 60 DAS | 90 DAS |
| Absolute Control | 25.900 | 25.03 | 25.03 | 1.86 | 13.40 | 120.9 |
| RDF (soil application) | 33.467 | 27.73 | 27.73 | 2.00 | 14.30 | 126.1 |
| Nano Urea (100%) | 39.333 | 48.13 | 48.13 | 3.23 | 20.40 | 152.1 |
| Nano NPK foliar (100%) | 37.733 | 43.13 | 43.13 | 2.76 | 17.90 | 147.3 |
| NPK 19:19:19(simple foliar) | 36.167 | 35.40 | 35.40 | 2.26 | 16.30 | 143.0 |
| 75% soil application + 25% Nano urea (foliar) | 40.700 | 46.50 | 46.50 | 3.86 | 22.33 | 156.0 |
| 75% soil application + 25% Nano NPK (foliar) | 42.400 | 53.13 | 52.66 | 4.33 | 27.00 | 164.8 |
| 50% soil application + 50% Nano NPK (foliar) | 43.667 | 58.10 | 57.16 | 5.00 | 30.80 | 172.5 |
| S. Em (±) | 1.550 | 1.766 | 1.673 | 0.119 | 0.914 | 6.951 |
| C.D.@ 5% | 4.748 | 5.408 | 5.123 | 0.364 | 2.798 | 6.288 |

**Table 3.** Impact of different levels of Nano fertilizers, NPK foliarwith RDF fertilizers on the Yield and Stover yield of kharif maize.

| Treatments | Yield q/ha | Stover Yield q/ha |
|---|---|---|
| Absolute Control | 16.133 | 2.567 |
| RDF (soil application) | 24.633 | 3.140 |
| Nano Urea (100%) | 63.5 | 4.273 |
| Nano NPK foliar (100%) | 32.533 | 4.200 |
| NPK 19:19:19 (simple foliar) | 43.067 | 3.767 |
| 75% soil application + 25% Nano urea (foliar) | 67.9 | 5.327 |
| 75% soil application + 25% Nano NPK (foliar) | 70.033 | 6.477 |
| 50% soil application + 50% Nano NPK (foliar) | 75.733 | 7.880 |
| S. Em (±) | 2.200 | 0.192 |
| C.D.@ 5% | 6.737 | 0.587 |

Furthermore, the combination of foliar application with RDF resulted in a significant increase in grain and straw yield, as well as improvements in quality parameters. Similar findings have been reported in studies conducted by Yomso and Menon (2021), Mundhe *et al.* (2022), Ahmed *et al.* (2019), Sannathimmappa *et al.* (2023), Iqbal (2019), and Midde *et al.* (2022).

## Conclusion

In conclusion, this research study demonstrates that the application of Nano fertilizers, particularly Nano-NPK, in combination with a recommended dose of fertilizer (RDF), has a significant positive impact on various yield attributes in maize crops. The treatment involving 50% RDF and 50% Nano-NPK (T8) showed the highest mean values for overall yield and stover yield, indicating that the incorporation of Nano-NPK in fertilizer regimes can lead to substantial increases in crop production. Other treatments, such as T7 (75% soil application + 25% Nano-NPK) and T6 (75% soil application + 25% Nano-urea), also showed improved yield attributes compared to the control treatment.

The application of Nano-NPK fertilizer, whether through foliar spray or soil application, has been found to enhance nutrient content in plant cells, resulting in improved grain quality and increased yields. The long-lasting presence of Nano materials in plant cells contributes to sustained crop productivity over an extended period, further boosting overall yields. These findings are consistent with previous studies, providing further support for the positive effects of Nano fertilizers on crop production and yield attributes.

In summary, incorporating Nano fertilizers, particularly Nano-NPK, in agricultural practices can effectively enhance crop yields, improve nutrient content in plant cells, and contribute to sustainable agriculture and food security. Further research and field trials are needed to fully explore the potential of Nano fertilizers and their optimal application methods in different crop systems. The current study highlights the positive effects of foliar sprays and soil applications of Nano fertilizers on maize growth and production, particularly the treatment involving 50% RDF and 50% Nano-NPK. These findings suggest that Nano fertilizers may be involving 50% RDF and 50% Nano-NPK. These findings suggest that Nano fertilizers may be a viable alternative to chemical NPK fertilizers in sustainable agriculture. The use of Nano fertilizers, especially in foliar applications, offers new opportunities for agricultural practices while ensuring plant nutrition levels without causing environmental harm. Overall, the combination of soil treatment and foliar application of Nano urea, Nano-NPK, and simple NPK can result in higher growth, yield, quality, and nutrient uptake in maize plants.

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