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**Sushma HA**
Ph.D Scholar, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

**Dr. Seenappa C**
Professor, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

**Dr. Lalitha BS**
Professor, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

**Dr. Jayadeva HM**
Professor, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

**Dr. Sathish A**
Professor, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

**Dr. Manjunatha R**
Professor, Department of Agricultural Entomology, College of Sericulture, Chintamani, Karnataka, India

**Corresponding Author:**
**Sushma HA**
Ph.D Scholar, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

# Impact of different methods and levels of nano urea and nano DAP application on soil chemical properties and fertility status in maize (*Zea mays*)

**Sushma HA, Seenappa C, Lalitha BS, Jayadeva HM, Sathish A and Manjunatha R**

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**Abstract**
The study evaluates the impact of different methods and levels of nano urea and nano DAP application on soil chemical properties and fertility status in maize (*Zea mays*). A field experiment was conducted at the Agronomy Field Unit, Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru, during the *kharif* season 2022. The experiment followed a split-split plot design with two application methods (soil and foliar), three levels of nano urea (2, 4, and 6 ml $L^{-1}$), and three levels of nano DAP (2, 4, and 6 ml $L^{-1}$), replicated thrice. The results showed that foliar application significantly improved maize grain yield (8239 kg $ha^{-1}$) compared to soil application (7784 kg $ha^{-1}$). Among the fertilizer levels, the highest grain yield was observed with nano urea @ 6 ml $L^{-1}$ (8177 kg $ha^{-1}$) and nano DAP @ 6 ml $L^{-1}$ (8162 kg $ha^{-1}$). However, the study found no significant impact of nano fertilizers on soil pH, electrical conductivity, organic carbon, and micronutrient availability, indicating that nano fertilizers, when applied in small quantities, do not alter soil chemical properties. This research underscores the potential of nano fertilizers to enhance maize productivity without negatively affecting soil fertility, thereby promoting sustainable agricultural practices.

**Keywords:** Maize, nano urea, nano DAP, soil fertility, foliar application, grain yield

## Introduction
Maize often referred to as the "Queen of cereals," is the world's third most significant cereal crop, highly adaptable and cultivated worldwide for both grain and fodder. Mainly cultivated as a *kharif* crop, maize is planted from late May to the end of June and harvested between September and October. Maize has a yield potential of 8 t $ha^{-1}$, which can be substantially enhanced to 12 t $ha^{-1}$ through improved field management practices.

The intensification of agricultural systems resulted in various negative impacts including increased soil erosion, declining soil fertility and reduced biodiversity at the local level; depletion and pollution of groundwater and eutrophication of surface water at the regional level and alterations in atmospheric composition and climate on a global scale. To sustain better soil quality in intensive agricultural systems, the focus should be on developing practical soil quality indicators and methods for assessing and monitoring soil quality, evaluating soil quality under various land use management systems such as cropping systems, tillage, and water and nutrient use practices and identifying the impact of management practices on improving, degrading, or maintaining the soil quality. Modern agriculture focuses on producing more with less land, water, and labour. Given these factors and the growing global population, there is increasing interest in developing management practices or tools that, either independently or in combination with crop management techniques ensure higher yields.

Foliar nutrition with specific nutrients at designated intervals plays a crucial role in preventing nutrient loss in crops. Foliar feeding of plants offers several benefits including a quick plant response, the use of small nutrient quantities, compensation for soil fixation issues, avoidance of root uptake challenges, and improved yield and fiber quality in cotton (Sohair *et al.*, 2018) [13]. Foliar fertilization serves as a supplement to soil fertilization.

Nanotechnology accurately detects and delivers the right amount of nutrients and pesticides, enhancing productivity, improving nutrient use efficiency and ensuring environmental safety.

Nanotechnology can be utilized throughout the entire agricultural production value chain (Tarafdar *et al*., 2012) [15]. Nanotechnology has enabled the use of nanoscale and nanostructured materials as fertilizer carriers or controlled-release vectors, facilitating the development of 'smart fertilizers' to improve nutrient use efficiency and lower environmental protection costs (Chinnamuthu and Boopathi, 2009) [3]. Therefore, an experiment was conducted to assess the impact of various methods of application of nano-fertilizers on soil chemical properties and fertility status in maize growing soils.

## Material and Methods

A field experiment was conducted at the Agronomy Field Unit, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru during *kharif* 2022 to know the impact of different methods and levels of nano fertilizers application on soil chemical properties and nutrient status in maize growing soils. The experiment was laid out in split-split plot design involved eighteen treatment combinations consisting of two methods of nano fertilizer application (A) in main plot are $A_1$ (Soil application) and $A_2$ (Foliar application), sub plot consists of three levels of nano urea fertilizer (N) are $N_1$ (Nano urea @ 2 ml $L^{-1}$), $N_2$ (Nano urea @ 4 ml $L^{-1}$) and $N_3$ (Nano urea @ 6 ml $L^{-1}$) and sub-sub plot consists of three levels of nano DAP fertilizer (P) are $P_1$ (Nano DAP @ 2 ml $L^{-1}$), $P_2$ (Nano DAP @ 4 ml $L^{-1}$) and $P_3$ (Nano DAP @ 6 ml $L^{-1}$) and replicated thrice.

Maize crop was sown in a plot size of 5.4 m × 3.6 m with a distance between row to row (60 cm) and plant to plant (30 cm). Textural class of the soil includes red sandy loam texture. Before sowing of maize and after harvesting of the crop the soil chemical properties and nutrient status were analysed and presented statistically.

## Results and Discussion

The results of the field experiment conducted to know the impact of different methods and levels of nano fertilizers application on soil chemical properties and nutrient status in maize growing soils are presented in Table 1 to 5. The initial soil characteristics of experimental site is presented in Table 1, grain yield (kg $ha^{-1}$) presented in Table 2 and soil chemical properties and nutrient status as affected by different methods and levels of nano fertilizers application is presented in Table 3 to 5.

Initially experimental site soil (Table 1) contains coarse sand (53.8%), fine sand (14.7%), silt (16.3%) and clay (15.2%) with acidic pH (5.64) and normal electrical conductivity of 0.30 dS $m^{-1}$. But the soil was low in organic carbon (0.48%) content. The initial soil is medium in available nitrogen (398 kg $ha^{-1}$), high in available phosphorus (40.25 kg $ha^{-1}$) and medium in available potassium (266 kg $ha^{-1}$). Whereas, the initial nitrogen and potassium content was medium and phosphorus was high in availability because of previous crop in 2020 was sown with pigeonpea as a leguminous crop, that fixes atmospheric nitrogen and also helps in mineralization of potassium and also in 2021 the land was kept fallow and helped in restoration of soil fertility. The absence of crop extraction gives the soil time to regenerate essential nutrients for future plant growth. Whereas, the available micronutrient status, such as available iron (35.11 mg $kg^{-1}$), available manganese (10.97 mg $kg^{-1}$), available zinc (2.12 mg $kg^{-1}$) and available copper (2.34 mg $kg^{-1}$) was recorded higher content in the soil.

The grain yield of maize recorded significantly due to different methods and levels of application of nano fertilizers and their interactions (Table 2). Among the different methods of application, the foliar application obtained significantly higher grain yield (8239 kg $ha^{-1}$) over the soil application (7784 kg $ha^{-1}$). Among the levels of nano urea application, significantly higher grain yield (8177 kg $ha^{-1}$) was recorded with the application of nano urea @ 6 ml $L^{-1}$ followed by nano urea @ 4 ml $L^{-1}$ (8131 kg $ha^{-1}$). In contrast, lower yield (7726 kg $ha^{-1}$) was noticed with nano urea @ 2 ml $L^{-1}$. Among the different levels of nano DAP application, the application of nano DAP @ 6 ml $L^{-1}$ recorded significantly higher grain yield of 8162 kg $ha^{-1}$ which is at par with nano DAP @ 4 ml $L^{-1}$ (8099 kg $ha^{-1}$). However, lower grain yield (7773 kg $ha^{-1}$) was recorded with nano DAP @ 2 ml $L^{-1}$.

The data on pH, EC and organic carbon content of soil as influenced by foliar and soil application of nano fertilizers at various levels were presented in Table 3. The soil parameters like pH, EC and organic carbon of soil did not show any significant difference between different methods and levels of application of nano urea and nano DAP and their interactions. Elumalai and Velmurugan (2015) [5] recorded similar observations in red soils of Tamil Nadu, they also reported that higher buffering capacity of soils will resist the minute change in pH, EC and organic carbon content of soil.

The soil available nutrients after harvest of maize as influenced by different methods and levels of application of nano urea and nano DAP are presented in Table 4-5.

The available nitrogen in the soil varied significantly with different methods of application, levels of nano urea and nano DAP (Table 4). Significantly higher available N (272 kg $ha^{-1}$) was recorded in the soil application as compared to foliar application (250 kg $ha^{-1}$). Nano urea application @ 2 ml $L^{-1}$ recorded significantly higher available nitrogen of 279 kg $ha^{-1}$ over nano urea @ 6 ml $L^{-1}$ (251 kg $ha^{-1}$) and nano urea @ 4 ml $L^{-1}$ (254 kg $ha^{-1}$). Among the different levels of nano DAP, application of nano DAP @ 2 ml $L^{-1}$ recorded significantly higher available N (275 kg $ha^{-1}$) as compared to nano DAP @ 6 ml $L^{-1}$ (252 kg $ha^{-1}$) and nano DAP @ 4 ml $L^{-1}$ (256 kg $ha^{-1}$).

Available phosphorus in the soil varied significantly with different methods and levels of nano urea and nano DAP application (Table 4). Significantly higher available soil $P_2O_5$ content (32.51 kg $ha^{-1}$) was recorded with soil application as compared to foliar application (28.09 kg $ha^{-1}$). Significantly higher available phosphorus of 33.39 kg $ha^{-1}$ was recorded with nano urea application @ 2 ml $L^{-1}$ over nano urea @ 4 ml $L^{-1}$ (29.15 kg $ha^{-1}$) and nano urea @ 6 ml $L^{-1}$ (28.36 kg $ha^{-1}$). Among the different levels of nano DAP, application of nano DAP @ 2 ml $L^{-1}$ recorded significantly higher available $P_2O_5$ (33.08 kg $ha^{-1}$) as compared to nano DAP @ 4 ml $L^{-1}$ (29.32 kg $ha^{-1}$) and nano DAP @ 6 ml $L^{-1}$ (28.50 kg $ha^{-1}$).

**Table 1:** Physico-chemical properties of the soil at the experimental site in ZARS, GKVK, UAS, Bangalore

| Sl. No. | Particulars | Values obtained | Methods employed |
|---|---|---|---|
| **I Physical composition (%)** | | | |
| 1 | Coarse sand | 53.8 | International pipette method (Piper, 1966) [10] |
| 2 | Fine sand | 14.7 | |
| 3 | Silt | 16.3 | |
| 4 | Clay | 15.2 | |
| 5 | Textural class | Red sandy loam | |
| **II Soil chemical properties** | | | |
| 1 | Soil pH (1:2.5 soil water suspension) | 5.64 | Potentiometric method (Piper, 1966) [10] |
| 2 | Electrical conductivity (dS $m^{-1}$) | 0.30 | Conductivity bridge (Jackson, 1973) [6] |
| 3 | Organic carbon (%) | 0.48 | Walkey and Black wet oxidation method (Jackson, 1973) [6] |
| 4 | Available nitrogen (kg $ha^{-1}$) | 398 | Alkaline potassium permanganate method (Subbaiah and Asija, 1956) [14] |
| 5 | Available phosphorus ($P_2O_5$ kg $ha^{-1}$) | 40.25 | Bray's method (Bray and Kurtz, 1945) |
| 6 | Available potassium ($K_2O$ kg $ha^{-1}$) | 266 | Flame photometer method (Jackson, 1973) [6] |
| 7 | DTPA extractable Fe (mg $kg^{-1}$) | 35.11 | Atomic absorption spectrophotometry (Lindsay and Norvell, 1978) [8] |
| 8 | DTPA extractable Mn (mg $kg^{-1}$) | 10.97 | |
| 9 | DTPA extractable Zn (mg $kg^{-1}$) | 2.12 | |
| 10 | DTPA extractable Cu (mg $kg^{-1}$) | 2.34 | |

**Table 2:** Effect of different methods and levels of nano urea and nano DAP application on grain yield of maize

| Treatments | Grain yield (kg $ha^{-1}$) | | |
|---|---|---|---|
| Methods of application (A) | | | |
| $A_1$: Soil application | 7784 | | |
| $A_2$: Foliar application | 8239 | | |
| F-test | * | | |
| SEm± | 64 | | |
| CD at 5% | 392 | | |
| Levels of nano urea (N) | | | |
| $N_1$: Nano urea @ 2 ml $L^{-1}$ | 7726 | | |
| $N_2$: Nano urea @ 4 ml $L^{-1}$ | 8131 | | |
| $N_3$: Nano urea @ 6 ml $L^{-1}$ | 8177 | | |
| F-test | * | | |
| SEm± | 53 | | |
| CD at 5% | 172 | | |
| Levels of nano DAP (P) | | | |
| $P_1$: Nano DAP @ 2 ml $L^{-1}$ | 7773 | | |
| $P_2$: Nano DAP @ 4 ml $L^{-1}$ | 8099 | | |
| $P_3$: Nano DAP @ 6 ml $L^{-1}$ | 8162 | | |
| F-test | * | | |
| SEm± | 113 | | |
| CD at 5% | 331 | | |
| Interaction | F-test | SEm± | CD at 5% |
| A × N | NS | 75 | - |
| A × P | NS | 160 | - |
| N × P | NS | 196 | - |
| A × N × P | NS | 277 | - |

**Note:** CD = Critical difference NS = Non-Significant SEm± = Standard error of mean

**Table 3:** Effect of different methods and levels of nano urea and nano DAP application on soil pH, electrical conductivity (EC) and organic carbon (OC) of maize

| Treatments | pH | | | EC (dS $m^{-1}$) | | | OC (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of application (A)** | | | | | | | | | |
| $A_1$: Soil application | 5.59 | | | 0.298 | | | 0.457 | | |
| $A_2$: Foliar application | 5.60 | | | 0.299 | | | 0.461 | | |
| F-test | NS | | | NS | | | NS | | |
| SEm± | 1.64 | | | 0.066 | | | 0.004 | | |
| CD at 5% | - | | | - | | | - | | |
| **Levels of nano urea (N)** | | | | | | | | | |
| $N_1$: Nano urea @ 2 ml $L^{-1}$ | 5.62 | | | 0.299 | | | 0.456 | | |
| $N_2$: Nano urea @ 4 ml $L^{-1}$ | 5.60 | | | 0.299 | | | 0.461 | | |
| $N_3$: Nano urea @ 6 ml $L^{-1}$ | 5.59 | | | 0.299 | | | 0.461 | | |
| F-test | NS | | | NS | | | NS | | |
| SEm± | 0.01 | | | 0.003 | | | 0.002 | | |
| CD at 5% | - | | | - | | | - | | |
| **Levels of nano DAP (P)** | | | | | | | | | |
| $P_1$: Nano DAP @ 2 ml $L^{-1}$ | 5.61 | | | 0.298 | | | 0.456 | | |
| $P_2$: Nano DAP @ 4 ml $L^{-1}$ | 5.60 | | | 0.298 | | | 0.460 | | |
| $P_3$: Nano DAP @ 6 ml $L^{-1}$ | 5.60 | | | 0.298 | | | 0.461 | | |
| F-test | NS | | | NS | | | NS | | |
| SEm± | 0.09 | | | 0.003 | | | 0.01 | | |
| CD at 5% | - | | | - | | | - | | |
| Interaction | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% |
| A × N | NS | 0.01 | - | NS | 0.001 | - | NS | 0.003 | - |
| A × P | NS | 0.12 | - | NS | 0.003 | - | NS | 0.009 | - |
| N × P | NS | 0.15 | - | NS | 0.006 | - | NS | 0.010 | - |
| A × N × P | NS | 0.21 | - | NS | 0.008 | - | NS | 0.015 | - |

**Note:** CD = Critical difference NS = Non-Significant SEm± = Standard error of mean

Available potassium in the soil varied significantly due to the influence of different methods and levels of nano urea and nano DAP (Table 4). Significantly higher available $K_2O$ (259 kg $ha^{-1}$) was recorded with the soil application as compared to foliar application (236 kg $ha^{-1}$). Application of nano urea @ 2 ml $L^{-1}$ recorded significantly maximum amount of available potassium (264 kg $ha^{-1}$) over nano urea @ 4 ml $L^{-1}$ (242 kg $ha^{-1}$) and nano urea @ 6 ml $L^{-1}$ (238 kg $ha^{-1}$). Among the different levels of nano DAP, application of nano DAP @ 2 ml $L^{-1}$ recorded significantly higher available $K_2O$ (260 kg $ha^{-1}$) as compared to nano DAP @ 4 ml $L^{-1}$ (244 kg $ha^{-1}$) and nano DAP @ 6 ml $L^{-1}$ (239 kg $ha^{-1}$). Interaction effects of methods of application, levels of nano urea and nano DAP were non-significant on the available soil N, $P_2O_5$ and $K_2O$ content of maize at harvest. Higher crop uptake and higher yield in foliar applied treatments of nano fertilizers led to lower available nutrients in the soil. The increased and balanced level of fertility (N, $P_2O_5$ and $K_2O$) also assured the availability of these nutrients to the crop plants in adequate amount and remained in the soil in substantial quantity after fulfilling the crop requirement that ultimately improved the soil fertility. These results are in agreement with the findings of Jat *et al*. (2014) [7] and Daikho (2013) [4].

The soil available iron, copper, manganese and zinc after harvest of the crop did not show any significant difference due to different methods and levels of nano urea and nano DAP and their interactions (Table 5). Singh (2008) [12] reported that foliar application of nano nutrients had minimal impact on soil chemical properties. The application of a small quantity of nano particles did not alter the soil's chemical properties or its inherent nutrient status was reported by Chatterjee *et al*. (1985) [2], Prasad *et al*. (2012) [11] and Patil *et al*. (2006) [9].

**Table 4:** Effect of different methods and levels of nano urea and nano DAP application on available soil N, $P_2O_5$ and $K_2O$ status at harvest of maize

| Treatments | Available N (kg ha$^{-1}$) | | | Available $P_2O_5$ (kg ha$^{-1}$) | | | Available $K_2O$ (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Methods of application (A)** | | | | | | | | | |
| $A_1$: Soil application | 272 | | | 32.51 | | | 259 | | |
| $A_2$: Foliar application | 250 | | | 28.09 | | | 236 | | |
| F-test | * | | | * | | | * | | |
| SEm± | 1.10 | | | 0.27 | | | 1.40 | | |
| CD at 5% | 6.69 | | | 1.66 | | | 8.51 | | |
| **Levels of nano urea (N)** | | | | | | | | | |
| $N_1$: Nano urea @ 2 ml L$^{-1}$ | 279 | | | 33.39 | | | 264 | | |
| $N_2$: Nano urea @ 4 ml L$^{-1}$ | 254 | | | 29.15 | | | 242 | | |
| $N_3$: Nano urea @ 6 ml L$^{-1}$ | 251 | | | 28.36 | | | 238 | | |
| F-test | * | | | * | | | * | | |
| SEm± | 0.94 | | | 0.19 | | | 0.94 | | |
| CD at 5% | 3.06 | | | 0.61 | | | 3.05 | | |
| **Levels of nano DAP (P)** | | | | | | | | | |
| $P_1$: Nano DAP @ 2 ml L$^{-1}$ | 275 | | | 33.08 | | | 260 | | |
| $P_2$: Nano DAP @ 4 ml L$^{-1}$ | 256 | | | 29.32 | | | 244 | | |
| $P_3$: Nano DAP @ 6 ml L$^{-1}$ | 252 | | | 28.50 | | | 239 | | |
| F-test | * | | | * | | | * | | |
| SEm± | 3.84 | | | 0.48 | | | 3.50 | | |
| CD at 5% | 11.20 | | | 1.40 | | | 10.21 | | |
| Interaction | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% |
| A × N | NS | 1.33 | - | NS | 0.27 | - | NS | 1.32 | - |
| A × P | NS | 5.43 | - | NS | 0.68 | - | NS | 4.95 | - |
| N × P | NS | 6.65 | - | NS | 0.83 | - | NS | 6.06 | - |
| A × N × P | NS | 9.40 | - | NS | 1.18 | - | NS | 8.57 | - |

**Note:** CD = Critical difference NS = Non-Significant SEm± = Standard error of mean

**Table 5:** Effect of different methods and levels of nano urea and nano DAP application on available soil micronutrients status at harvest of maize

| Treatments | Available Fe (mg kg$^{-1}$) | | | Available Cu (mg kg$^{-1}$) | | | Available Mn (mg kg$^{-1}$) | | | Available Zn (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Methods of application (A)** | | | | | | | | | | | | |
| $A_1$: Soil application | 32.85 | | | 2.25 | | | 10.76 | | | 1.83 | | |
| $A_2$: Foliar application | 34.62 | | | 2.22 | | | 10.69 | | | 1.77 | | |
| F-test | NS | | | NS | | | NS | | | NS | | |
| SEm± | 4.50 | | | 0.01 | | | 0.02 | | | 0.37 | | |
| CD at 5% | - | | | - | | | - | | | - | | |
| **Levels of nano urea (N)** | | | | | | | | | | | | |
| $N_1$: Nano urea @ 2 ml L$^{-1}$ | 34.26 | | | 2.25 | | | 10.77 | | | 1.83 | | |
| $N_2$: Nano urea @ 4 ml L$^{-1}$ | 33.47 | | | 2.23 | | | 10.71 | | | 1.79 | | |
| $N_3$: Nano urea @ 6 ml L$^{-1}$ | 33.47 | | | 2.23 | | | 10.70 | | | 1.78 | | |
| F-test | NS | | | NS | | | NS | | | NS | | |
| SEm± | 0.22 | | | 0.01 | | | 0.02 | | | 0.01 | | |
| CD at 5% | - | | | - | | | - | | | - | | |
| **Levels of nano DAP (P)** | | | | | | | | | | | | |
| $P_1$: Nano DAP @ 2 ml L$^{-1}$ | 34.27 | | | 2.26 | | | 10.76 | | | 1.83 | | |
| $P_2$: Nano DAP @ 4 ml L$^{-1}$ | 33.66 | | | 2.23 | | | 10.71 | | | 1.79 | | |
| $P_3$: Nano DAP @ 6 ml L$^{-1}$ | 33.27 | | | 2.23 | | | 10.70 | | | 1.78 | | |
| F-test | NS | | | NS | | | NS | | | NS | | |
| SEm± | 0.45 | | | 0.03 | | | 0.14 | | | 0.02 | | |
| CD at 5% | - | | | - | | | - | | | - | | |
| Interaction | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% | F-test | SEm± | CD at 5% |
| A × N | NS | 0.31 | - | NS | 0.01 | - | NS | 0.02 | - | NS | 0.02 | - |
| A × P | NS | 0.64 | - | NS | 0.04 | - | NS | 0.20 | - | NS | 0.03 | - |
| N × P | NS | 0.78 | - | NS | 0.05 | - | NS | 0.24 | - | NS | 0.04 | - |
| A × N × P | NS | 1.10 | - | NS | 0.07 | - | NS | 0.35 | - | NS | 0.06 | - |

**Note:** CD = Critical difference NS = Non-Significant SEm± = Standard error of mean

## Conclusion

Different methods and levels of nano urea and nano DAP application enhances the grain yield of maize crop. However, these nano fertilizers did not affect the soil's chemical properties or nutrient status. The buffering capacity of soil resists minor changes in chemical properties and the application of nano fertilizers in smaller quantities did not result in any significant difference in soil chemical properties or nutrient status due to different methods and levels of various nano fertilizers, as well as their interactions. The application of nano fertilizers in small quantities enhances crop growth and minimizes environmental pollution.

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