**Original Research Article**

Influence of Nano urea and mineral nutrition on economic profitability of French marigold (*Tagetes patula* L.)

**Abstract**

*Tagetes patula* L. is one of the most popular and commercial loose flower crops of Jammu, India. Popularly known as the city of temples, the Jammu region witnesses a huge demand for marigold flowers for garland making, offerings in temples and other decorative purposes during various festive occasions. As a result, the production of flowers in Jammu alone cannot meet the ever-increasing demand, and flowers worth lakhs need to be procured from neighbouring states. This study was conducted with the aim of exploring and elucidating the potential impact of different concentrations of nano-urea on vegetative growth, flowering, fruiting, and yield. The study was conducted at the Experimental Farm, Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha during the years 2022-2023&2023-24. The experiment was laid out in Complete Randomized Block Design with three replication and fifteen treatments viz., T1 =100% RDF (Control i.e. 200 kg N, 100 kg P2O5 and 100 kg K2O/ha);T2 = 100% RDF + 1ml/l nano urea foliar application;T3 =100% RDF + 1.5 ml/l nano urea foliar application;T4 =100% RDF + 2 ml/l nano urea soil application;T5 = 100% RDF + 4 ml/l nano urea soil application;T6 = 75% RDF;T7=75% RDF + 1ml/l nano urea foliar application;T8 = 75% RDF + 1.5 ml/l nano urea foliar application;T9 = 75% RDF + 2 ml/l nano urea soil application;T10 = 75% RDF + 4 ml/l nano urea soil application;T11 = 50 % RDF;T12 = 50 % RDF + 1 ml/l nano urea foliar application;T13 = 50 % RDF + 1.5ml/l nano urea foliar application;T14 = 50 % RDF + 2 ml/l nano urea soil application;T15 = 50 % RDF + 4 ml/l nano urea soil application. The results revealed that the data revealed that maximum plant height (84.36 cm), plant spread (65.34 cm), number of laterals (20.40) and Chlorophyll content (48.38) with the application of 100% RDF + 1.5ml/L nano urea foliar application. The pooled data furthermore, revealed the maximum number of flowers per plant (148.06), flower diameter (5.93 cm), flowering duration (56.22 days), weight of flower (5.01 g), flower yield per plant (0.74 kg), the cost: benefit ratio during the year 2022-2023 and 2023-2024 (4.98 and 5.77, respectively) were recorded maximum in the treatment combination of 75% RDF + 1.5ml/L nano urea foliar application. Spray of nano urea produces significantly higher seed yield, which was significantly higher than the other nano urea treatments. This can be attributed to higher photosynthetic activities in the crop provided with a spray of nano urea than the other treatments, which stimulated growth in both roots and shoots.

Key words: French marigold; profitability; mineral nutrition; nano urea; application; foliar

**INTRODUCTION**

*“Tagetes patula* L. is called French marigold, and it is an important annual flower crop used for ornamental and commercial purposes. The main components of French marigold are phenols, essential oil, vitamins (carotenoids), and flavonoids. French marigold was used to treat various diseases, for example, cough, colic, constipation, diarrhoea, rheumatism, and eye problems. Nowadays, marigolds are used as an antimicrobial, antiseptic, hepatoprotective, blood purifying, and diuretic agent” (El-Ziat et al., 2024). “It is one of the most popular and commercial loose flower crops of Jammu, India. In floriculture, marigold is one of India's most important commercially grown flower crops, which ranked third in number after roses and chrysanthemum. It belongs to the family Asleraceae. Marigold is broadly classified into African marigold (*Tagetes erecta* L.) and French marigold (*Tagetes patula* L.)” (Raj et al., 2022). “Popularly known as the city of temples, the Jammu region witnesses a huge demand for marigold flowers for garland making, offerings in temples and other decorative purposes during various festive occasions. As a result, the production of flowers in Jammu alone cannot meet the ever-increasing demand, and flowers worth lakhs need to be procured from neighbouring states. Keeping in view the importance of crop and the present demand of quality flowers, the investigations were carried out in an experiment with the combined application of fertilisers and nano urea for enhancing flower yield parameters in French marigold under Jammu subtropics. To fulfil the demand and rule out this limitation, it is necessary to increase its production through improved production technologies. Excessive use of chemical fertilisers following hit-and-trial methods by the farmers nowadays results in poor health of the soil, nutrient imbalances and ultimately poor fertiliser use efficiency. Also, small-hold farmers do not have access to chemical fertiliser because of the high price of fertilisers, poor distribution and other socio-economic factors involved. Therefore, modern nutrient management strategy aims towards the concept of sustainability.” (Rashid *et al*, 2022) “Nano urea is a liquid formulation manufactured by Nano Biotechnology Research Centre in association with Indian Farmers. Fertilisers Cooperative Limited. Nano urea, an innovative agricultural input based on nanotechnology, offers a particle size of 20 to 50 nm, providing a significantly larger surface area compared to conventional urea prills. The Indian Farmers Fertiliser Cooperative (IFFCO) nano urea (liquid) is officially recognised by the Government of India under the Fertiliser (Inorganic, Organic or Mixed) (Control) Order 1985. With a particle size of less than 100 nm, it contains 4% nitrogen (N) and has a shelf-life of approximately 2 years. The liquid nano urea, with a zeta potential greater than 30 for stability, is applied by spraying at a rate of 2-4 mL per litre of water, depending on crop nitrogen requirements, canopy development, and water needs” (Kumar et al., 2023). “It contains nano-scale nitrogen particles (55,000 nanoparticles) with a high surface area (10,000 times that of 1mm Urea prilled). On foliar application, these small particles are delivered directly to the plant cell, thereby releasing nitrogen inside the cells as per the requirement in a phased manner, which ensures low and targeted efficient release for providing the nutrients to the crop and thus increases nutrient use efficiency. Nano urea, when sprayed on crop leaves, triggers a pathway for the uptake and assimilation of nitrogen inside the plants.” (Attri *et al*, 2022). “Thus, foliar application of nano urea enhances the availability of nitrogen through stomata of leaves via gaseous uptake and may activate many enzymes involved in biochemical pathways for maintenance of biological membranes. Therefore, the present study is being undertaken in view of the importance of marigold (*Tagetes patula* L.) crop in the region, as well as the need for eco-friendly foliar and soil Nano-Urea under Jammu conditions as economically viable fertiliser-input options. In present farming practices, urea is used most extensively to supply nitrogen in plants due to its high N content (46% N) as well as its compatibility with other nutrients, but due to the high N loss and its low use efficiency, only 45-50% of nitrogen is used effectively in modern farming methods” (Iqbal *et al*., 2019), “and it forces the farmers to use more N fertilisers to improve crop output, which increases the costs of farming as well as having an adverse impact on the environment. In response to these challenges, the agricultural sector has witnessed a paradigm shift towards the development and utilisation of nanotechnology in agriculture. Nano-based agricultural products, such as nano fertiliser, offer innovative solutions to enhance crop performance while minimising environmental impacts” (Lal, 2008). “In light of this, Indian Farmers Fertiliser Cooperative Limited (IFFCO) has created a new nano fertiliser called IFFCO nano-urea (liquid) with the intention of replacing or minimising the negative impacts of the application of urea. This new fertiliser molecule has been evaluated on a variety of crops in various research institutes and state agricultural universities, as it has been discovered that the majority of crops are reacting well to nano-urea” (Kumar *et al*., 2021). “Therefore, this study was attempted with the aim of exploring and In present farming practices, urea is used most extensively to supply nitrogen in plants due to its high N content (46% N) as well as its compatibility with other nutrients, but due to the high N loss and its low use efficiency, only 45-50% of nitrogen is used effectively in modern farming methods” (Iqbal et al., 2019), “and it forces the farmers to use more N fertilisers in order to improve crop output, which increases the costs of farming as well as having an adverse impact on the environment. In response to these challenges, the agricultural sector has witnessed a paradigm shift towards the development and utilisation of nanotechnology in agriculture. 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**MATERIAL AND METHODS**

Site and location

The present investigation was conducted at Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, located at a latitude of 32 40ᴼ ', longitude of 74 58' and at an altitude of 332 meters ᴼ above mean sea-level in the Shiwalik foothills of North Western Himalayas, found below the critical level.

Cultivation practices:

Seedlings of French marigold (*Tagetes* *patula* L.)were transplanted at a spacing of 40 cm x 40 cm during the first fortnight of November thereby accommodating 20 seedlings per bed size of 2 m × 1.6 m. Transplanting was done during evening hours when the temperature was low to avoid the transplant shock. Light irrigation was given immediately after transplanting. The application of fertilisers, along with nano urea soil application, was done in accordance with the requirements of the treatments as per the technical programme of the experiment. Foliar spray of 1 ml and 1.5 ml of nano urea (according to the treatment combinations) was given twice during the experiment. The first foliar application of nano urea was given at 30 days after transplanting (DAT), and the second application at 60 days after transplanting. Intercultural operations and plant protection measures were adopted as per the recommended package of practices, whenever required from sowing to the crop harvest. The crop was irrigated as and when necessary to maintain the optimum moisture condition of the field. No insect-pest incidence was reported during the experimental trial period.

Experimental Treatment Details and Notations

The field experiment was conducted during the 2022–2023 growing season at the experimental farm of the Division of Floriculture and Landscaping. A Completely Randomized Block Design (CRBD) was employed, comprising three replications and fifteen treatment combinations to evaluate the impact of nano urea and varying levels of Recommended Dose of Fertilizers (RDF) on crop performance. The experimental treatments are T1 =100% RDF (Control i.e. 200 kg N, 100 kg P2O5 and 100 kg K2O/ha); T2 = 100% RDF + 1ml/l nano urea foliar application; T3 =100% RDF + 1.5 ml/l nano urea foliar application; T4 =100% RDF + 2 ml/l nano urea soil application; T5 = 100% RDF + 4 ml/l nano urea soil application; T6 = 75% RDF; T7=75% RDF + 1ml/l nano urea foliar application; T8= 75% RDF + 1.5 ml/l nano urea foliar application; T9 = 75% RDF + 2 ml/l nano urea soil application; T10 = 75% RDF + 4 ml/l nano urea soil application; T11 = 50 % RDF; T12 = 50 % RDF + 1 ml/l nano urea foliar application; T13 = 50 % RDF + 1.5ml/l nano urea foliar application; T14 = 50 % RDF + 2 ml/l nano urea soil application; T15 = 50 % RDF + 4 ml/l nano urea soil application.

Recording of data and economic calculations

Data on various growth, flowering and seed parameters were recorded and statistically analysed by applying the technique of analysis of variance using Completely Randomised Block Design (Gomez and Gomez 1985).The level of significance for the t-test was kept at 5% (P=0.05). The yield of loose flowers was calculated and expressed in kilograms. The economics of the individual treatment were calculated based on the total cost of cultivation and gross income. The expenditures incurred during the cropping period were computed taking into account the cost of land preparation, material inputs, irrigation, harvesting and assembling expenses, etc., with labour charges taken as ₹ 400 per man day. For calculating the gross income, the sale price of the loose flowers has been taken as ₹40/kg. Gross monetary returns (₹/ha) were worked out for different treatments as:

Gross Income = Marketable flower yield per Hectare x sale price of the flower in rupees

Net Income = Gross Returns – Total expenditure

Benefit Cost ratio (BCR) = Net returns/Total expenditure

**Results and Discussion**

The benefit-cost ratio (BCR) of the treatments is the most important factor which determines its usefulness and acceptance by the grower. It is the most important single factor which decides the adoption of any improved cultural practice by the grower. A treatment should not only be effective but also should be profitable in order to be accepted by a grower. In the present study, the different treatments showed a clear impact on the comparative economics of the production of flowers in French marigold.

 The pooled data revealed that maximum plant height (84.36 cm), plant spread (65.34 cm), number of laterals (20.40) and Chlorophyll content (48.38) with the application of 100% RDF + 1.5ml/L nano urea foliar application. while minimum plant height (73.39 cm), plant spread (54.44 cm chlorophyll content (41.64 spad value) were recorded with 50 % RDF (T11), whereas the minimum number of laterals (17.20) was recorded with 50 % RDF + 1.5ml/L nano urea foliar application (T13).

 “The greater plant height, plant spread, and number of laterals in French marigold might be due to a rapid increase in cell division and cell elongation activities by supplying an additional dose of nitrogen via foliar spray of nano urea at the peak vegetative growth stage of French marigold. The smaller size of nitrogen particles could potentially reduce the risk of toxicity and facilitate efficient nutrient uptake and soil fertility restoration” (Nongbet *et al*., 2022). A similar result was observed by Midde *et al*., (2021) and Velmurugan *et al*., (2021) in rice, who reported increased tiller number and root length, respectively, with the application of nano-urea.

 “Positive effect on the chlorophyll content in the leaves; this could be due to the higher availability of nitrogen molecules through the application of nano-urea, which may play a critical role in the formation of chlorophyll by being involved in enzyme activation and amino acid synthesis” (Chu *et al*., 2007). The present findings are in association with the findings of Uysal (2018) in apples and Silva Junior *et al*., (2013) in orchids, who reported that chlorophyll content in leaves was increasing with increasing nitrogen doses.

**Effect of nano-urea on flowering and yield parameters**

 The pooled data also revealed the maximum number of flowers per plant (148.06), flower diameter (5.93 cm), flowering duration (56.22 days), weight of flower (5.01 g), flower yield per plant (0.74 kg), the cost: benefit ratio during the year 2022-2023 and 2023-2024 (4.98 and 5.77, respectively) were recorded maximum in the treatment combination of 75% RDF + 1.5ml/L nano urea foliar application. whereas, the minimum number of flowers per plant (126.43), flower diameter (4.95 cm), and flowering duration (days) (53.39 days), was recorded with 50 % RDF (T11). while the minimum fresh weight of flower (3.81 g) and flower yield per plant (0.49 kg) was recorded with 50 % RDF + 2ml/L nano urea soil application (T14).

“The observed maximum duration of flowering, flower diameter and number of flowers might be due to the healthy and vigorous growth of French marigold plants enhanced by additional nitrogen fertilisation through nano-urea spray that stored sufficient amounts of photosynthates, which promoted early flowering in French marigold plants, which continued up to a later stage of crop growth. Other than this, it has also been observed that nitrogen can enhance localised cytokinin biosynthesis in plants” (Ding *et al*., 2014), “and an increased level of cytokinin can regulate the number of flowers in plants” (Barazesh and McStein, 2008). The research results are in conformity with the findings of Kaur and Kumar (2001) in the verbena plant and Dogra and Sirohi (2020) in the pansy plant; they reported that increasing the levels of nitrogen increased the duration of flowering and the number of flowers per plant. Enhancement in flowering attributes might also be evident from excellent physiological and biochemical activities due to the conjoint application of chemical fertilisers, nano urea soil and foliar application.

 “The behaviour of increasing the number of flowers, average flower weight and flower yield might be due to the application of an additional dose of nitrogen with RDF to the French marigold plants in combination with nano-urea because nitrogen is an important component of enzymes, vitamins, and chlorophyll molecules and is involved in nucleic and amino acid synthesis and protein production, which is important for cell growth and development. Nitrogen also affects the absorption and distribution of all other nutrients in the plant that are particularly important to the plant during flowering and development” (Carranca *et al*., 2018). The results obtained were in conformity with the findings of Reddy and Goyal (2020) in strawberry.

 The increment in fresh weight of French marigold plants might be due to significant improvements in all the growth parameters, such as plant height, plant spread, number of laterals, etc. The present findings are in association with the findings of Midde *et al*., (2022), who reported in rice that the application of nano-urea increased dry matter production. Rajonee *et al*., (2016) reported a higher dry weight of *Ipomoea aquatica* (Kalmi) plants treated with nano-nitrogen fertiliser.

The increase in yield might be directly associated with a concomitant increase in growth and yield attributes of French marigold, because of improved nutritional environment in the plant metabolic system, leading to higher plant metabolism and photosynthetic activity due to nano urea. Spray of nano urea produces significantly higher seed yield, which was significantly higher than the other nano urea treatments. This can be attributed to higher photosynthetic activities in the crop provided with a spray of nano urea than the other treatments, which stimulated growth in both roots and shoots, which consequently induced higher biomass production that finally resulted in the production of significantly higher yield. Similar results were also observed by Kumar *et al*. (2020) and Kumar *et al*. (2022)

Table 1. Effect of nano urea and mineral nutrition on flowering attributes of French marigold (*Tagetes patula* L.)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment Details | Flower fresh weight (g) | Number of flowers planted -1 | Flower yield plant-1 (Kg)  | Flower diameter (cm) | Flowering duration (days) |
| T1 = 100% RDF (Control)\* | 4.45 | 134.89 | 0.60 | 5.12 | 54.62 |
| T2 = 100% RDF + 1ml/l nano urea foliar application | 4.53 | 138.77 | 0.63 | 4.84 | 54.83 |
| T3 = 100% RDF + 1.5 ml/l nano urea foliar application | 4.11 | 136.83 | 0.56 | 5.51 | 54.86 |
| T4 = 100% RDF + 2 ml/l nano urea Soil application | 4.28 | 135.90 | 0.58 | 5.42 | 54.78 |
| T5 = 100% RDF + 4 ml/l nano urea Soil application | 4.24 | 139.27 | 0.59 | 5.36 | 54.95 |
| T6 = 75% RDF | 4.23 | 140.16 | 0.59 | 5.39 | 54.69 |
| T7 = 75% RDF + 1ml/l nano urea foliar application | 4.45 | 147.79 | 0.66 | 5.80 | 55.91 |
| T8 = 75% RDF + 1.5 ml/l nano urea foliar application | 5.01 | 148.06 | 0.74 | 5.93 | 56.22 |
| T9 = 75% RDF + 2 ml/l nano urea Soil application | 4.43 | 143.74 | 0.64 | 5.54 | 54.78 |
| T10 = 75% RDF + 4 ml/l nano urea soil application | 4.22 | 144.80 | 0.61 | 5.36 | 55.34 |
| T11 = 50 % RDF  | 3.92 | 126.43 | 0.50 | 4.53 | 53.39 |
| T12 = 50 % RDF + 1 ml/l nano urea foliar application | 4.27 | 133.17 | 0.57 | 4.85 | 54.00 |
| T13 = 50 % RDF + 1.5ml/l nano urea foliar application | 4.02 | 130.01 | 0.52 | 4.86 | 54.21 |
| T14 = 50 % RDF + 2 ml/l nano urea soil application | 3.81 | 128.01 | 0.49 | 4.58 | 53.69 |
| T15 = 50 % RDF + 4 ml/l nano urea soil application | 4.25 | 137.08 | 0.58 | 5.08 | 54.17 |
| C.D0.05 | 0.53 | 6.15 | 0.08 | 0.37 | 1.03 |

\*Recommended dose of fertiliser (RDF): 200 kg N, 100 kg P2O5 and 100 kg K2O/ha)

Table 2. Effect of nano urea and mineral nutrition on vegetative parameters of French marigold (*Tagetes patula* L.)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment Details | Plant height (cm) | Plant spread (cm) | Number of laterals | Chlorophyll content(SPAD value) |
| T1 = 100% RDF (Control) | 62.16 | 62.16 | 17.56 | 46.60 |
| T2 = 100% RDF + 1ml/l nano urea foliar application | 64.60 | 64.60 | 19.60 | 46.28 |
| T3 = 100% RDF + 1.5 ml/l nano urea foliar application | 65.34 | 65.34 | 20.40 | 48.38 |
| T4 = 100% RDF + 2 ml/l nano urea Soil application | 64.14 | 64.14 | 18.86 | 46.87 |
| T5 = 100% RDF + 4 ml/l nano urea Soil application | 64.57 | 64.57 | 18.91 | 45.96 |
| T6 = 75% RDF | 63.93 | 63.93 | 19.12 | 48.21 |
| T7 = 75% RDF + 1ml/l nano urea foliar application | 62.53 | 62.53 | 18.46 | 48.17 |
| T8 = 75% RDF + 1.5 ml/l nano urea foliar application | 63.01 | 63.01 | 18.37 | 47.99 |
| T9 = 75% RDF + 2 ml/l nano urea Soil application | 62.57 | 62.57 | 18.83 | 47.31 |
| T10 = 75% RDF + 4 ml/l nano urea soil application | 64.02 | 64.02 | 18.81 | 47.10 |
| T11 = 50 % RDF  | 54.44 | 54.44 | 17.30 | 41.64 |
| T12 = 50 % RDF + 1 ml/l nano urea foliar application | 60.01 | 60.01 | 17.40 | 46.08 |
| T13 = 50 % RDF + 1.5ml/l nano urea foliar application | 59.10 | 59.10 | 17.18 | 45.94 |
| T14 = 50 % RDF + 2 ml/l nano urea soil application | 56.73 | 56.73 | 17.71 | 44.91 |
| T15 = 50 % RDF + 4 ml/l nano urea soil application | 60.79 | 60.79 | 17.72 | 46.54 |

Table 3. Effect of Nano urea and fertilizer application on economics of French marigold (*Tagetes patula)* L.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatments** | **Cost of cultivation****(Rs.)** | **Flower yield/ ha** | **Gross income (Rs.)** | **Net income (Rs.)** | **B:C ratio** |
| **Year** | **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **T1** | 415451 | 46752.74 | 60330.89 | 1870110 | 2413235 | 1454659 | 1997784 | 3.50 | 4.81 |
| **T2** | 416091 | 49883.75 | 61800.35 | 1995350 | 2472014 | 1579259 | 2055923 | 3.80 | 4.94 |
| **T3** | 416411 | 49148.91 | 50825.81 | 1965956 | 2033032 | 1549545 | 1616621 | 3.72 | 3.88 |
| **T4** | 416731 | 47086.81 | 56483.91 | 1883472 | 2259356 | 1466741 | 1842625 | 3.52 | 4.42 |
| **T5** | 418011 | 50833.52 | 54166.09 | 2033341 | 2166644 | 1615330 | 1748633 | 3.86 | 4.18 |
| **T6** | 412588 | 52724.39 | 52665.58 | 2108976 | 2106623 | 1696388 | 1694035 | 4.11 | 4.11 |
| **T7** | 413228 | 59929.28 | 56991.66 | 2397171 | 2279667 | 1983943 | 1866439 | 4.80 | 4.52 |
| **T8** | 413548 | 55494.63 | 55452.94 | 2219785 | 2218118 | 1806237 | 1804570 | 4.98 | 5.77 |
| **T9** | 413868 | 53846.50 | 59432.42 | 2153860 | 2377297 | 1739992 | 1963429 | 4.20 | 4.74 |
| **T10** | 415148 | 60386.35 | 68464.46 | 2415454 | 2738578 | 2000306 | 2323430 | 4.22 | 4.23 |
| **T11** | 409725.5 | 32035.14 | 57480.36 | 1281406 | 2299215 | 871680 | 1889489 | 2.13 | 4.61 |
| **T12** | 410365.5 | 43296.90 | 58021.95 | 1731876 | 2320878 | 1321510 | 1910513 | 3.22 | 4.66 |
| **T13** | 410685.5 | 37513.32 | 53407.85 | 1500533 | 2136314 | 1089847 | 1725628 | 2.65 | 4.20 |
| **T14** | 411005.5 | 35264.90 | 52212.85 | 1410596 | 2088514 | 999590.6 | 1677508 | 2.43 | 4.08 |
| **T15** | 412285.5 | 46093.32 | 57780.99 | 1843733 | 2311240 | 1431447 | 1898954 | 3.47 | 4.61 |

**CONCLUSION**

In conclusion, the greater plant height, plant spread, and number of laterals in French marigold might be due to a rapid increase in cell division and cell elongation activities by supplying an additional dose of nitrogen via foliar spray of nano urea at the peak vegetative growth stage of French marigold. Additionally, Spray of nano urea produces significantly higher seed yield, which is significantly higher than the other nano urea treatments. This can be attributed to higher photosynthetic activities in the crop provided with a spray of nano urea than the other treatments, which stimulated growth in both roots and shoots.

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Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Attri, M., Sharma, M. and Sharma, B.C. 2022. Effect of Foliar Application of Nano Urea on Productivity and Profitability of Fine Rice under Irrigated Subtropics of Jammu Region*. Indian Journal of Ecology*. **49**(5): 1935-1938.
2. Barazesh, S. and Mc Steen P. 2008. Hormonal control of grass inflorescence development. *Trends in Plant Science*, 13(12): 656-662. <https://doi.org/10.1016/j.tplants.2008.09.007>
3. Carranca, C., Brunetto G. and Tagliavini M. 2018. Nitrogen nutrition of fruit trees to reconcile productivity and environmental concerns. *Plants*, **7**(1): 4. https://doi.org/ 10.3390/plants7010004.
4. Chu, H., Hosen Y. and Yagi K. 2007. NO, N2O, CH4 and CO2 fluxes in winter barley field of Japanese Andisol as affected by N fertilizer management. *Soil Biology and Biochemistry*, **39**(1), 330-339. https://doi.org/10.1016/ j. soilbio. 2006.08.003.
5. Ding, C., You J., Chen L., Wang S. and Ding Y. 2014. Nitrogen fertilizer increases spikelet number per panicle by enhancing cytokinin synthesis in rice. Plant Cell Reports 33, 363-371. https://doi.org/10.1007/s00299-013- 1536-9.
6. Dogra, S. and Sirohi H.S.2020. Influence of nitrogen levels and plant geometry on growth, flowering and seed production in pansy (Viola tricolour Hortensis) variety snow white. *The Pharma Innovation Journal*, **9**(7): 596- 599.
7. Iqbal, M., Umar S. and Mahmood zafar. 2019. Nano fertilization to enhance nutrient use efficiency and productivity of crop plants. Nanomaterials and plant potential, 473-505. https://doi.org/10.1007/978-3-030- 05569-1\_19.
8. Kaur, K. and Kumar R. 2001. Effect of nitrogen and phosphorus on verbena*. Journal of Ornamental Horticulture*, **4**(1) : 59-60.
9. Kumar, A., Singh, K., Sharma, S., Mishra, J.P., Sharmila, J.S and Kumar, Y. 2023.Effect of Organic manure, Bio-fertilizer and Nano-fertilizer on Yield and Economics of different Vegetable crops and soil nutrient status.Researchsquare.com. **1**(13):201-213.
10. Kumar, Y., Singh T., Raliya R. and Tiwari K.N. 2021. Nano Fertilizers for Sustainable Crop Production, Higher Nutrient Use Efficiency and Enhanced Profitability. *Indian Journal of Fertilisers*, **17**(11): 1206-1214.
11. Kumar A, Singh K, Verma P, Singh O, Panwar, A .and Singh T.E. 2022. Effect of nitrogen and zinc nano fertilizer with the organic farming practices on cereal and oil seed crops. *Scientific reports*. Apr 28, **12**(1): 1-7.
12. Kumar Y, Tiwari KN, Nayak RK, Abhimanyu RA, Singh SP. and Singh A.N. Nano fertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season crops of Uttar Pradesh. 2020. *Indian Journal of Fertilisers*, **16**(8): 772-786.
13. Lal, R. 2008. Promise and limitations of soils to minimize climate change. *Journal of soil and water conservation*, **63**(4): 113A-118A. [https://doi.org/10.2489/ 63.4.113A](https://doi.org/10.2489/63.4.113A).
14. Midde, S.K., Perumal M.S., Murugan G., Sudhagar R., Mattepally V.S. and Bada M.R. 2021. Evaluation of Nano urea on Growth and Yield Attributes of Rice (Oryza Sativa L.). Chemical Science Review and Letters, 11(42): 211- 214.
15. Nongbet, A., Mishra A.K., Mohanta Y.K., Mahanta S., Ray M. K., Khan M. and Chakrabartty I. 2022. Nano fertilizers: a smart and sustainable attribute to modern agriculture. *Plants*, **11**(19): 2587. https://doi.org/10.3390/plants111 92587.
16. Priyanka, T. K., Kamble.B. S, Subiya. R. K, Anuradha. R. W. and Gasti. V. D.2018 Interactive study of spacing and different levels of nutrients on flowering and yield attributes of crossandra (*Crossandra undulaefolia* Salisb.). *Journal of Pharmacognosy and Phytochemistry*, **7**(1):487-490.
17. Rashid, A., Laishram, N., Singh, A., Pandey, R.K. and Dogra, S. Conjoint Application of INM Modules on Vegetative, Flowering, and Seed Yield in French marigold. *International Journal of Plant & Soil Science*. **34**(4) : 26-34, 2022.
18. Rajonee, A.A., Nigar F., Ahmed S. and Huq S.I. 2016. Synthesis of nitrogen nano fertilizer and its efficacy. *Canadian Journal of Pure and Applied Sciences*, **10**, 3913-3919.
19. Silva Júnior, J.M.D., Rodrigues M., Castro E.M.D., Bertolucci S.K.V. and Pasqual M. 2013. Changes in anatomy and chlorophyll synthesis in orchids propagated in vitro in the presence of urea. *Acta Scientiarum Agronomy*, 35: 65-72. <https://doi.org/10.4025/actasciagron.v35i1.15356>
20. Tiwari, K.N., Kumar. Y, Nayak. Y, Rai. A, Singh. J and Srivastava. S.S.A. 2021. Nano Urea for enhancing yield and farmers profit with potato in Uttar Pradesh. *Annals of Plant and Soil Research*, 23: 495-500.
21. Uysal, E. (2018). Effects of nitrogen fertilization on the chlorophyll content of apple. *Meyve Bilimi*, **5**(1): 12-17.
22. Velmurugan, A., Subramanil T., Bommayasamy N., Ramakrishna, Kumar M. and Swarnam T.P. 2021. The effect of foliar application of Nano-Urea (liquid) on rice (*Oryza sativa* L.). *Journal of the Andaman Sciences Association*, **26**(2):
76-81.
23. Venkatesh, M., Babu. K.K, Prasanth. P, Lakshminarayana. D. and Kumar. S.P. 2022. Study on effect of different levels of nitrogen in combination with nano urea on growth and yield of marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. *The Pharma Innovation Journal*, **11**(11):1313- 1317.
24. Kumar, A., Ram, H., Kumar, S., Kumar, R., Yadav, A., Gairola , A., Kumar, V., & Sharma, T. (2023). A Comprehensive Review of Nano-Urea vs. Conventional Urea. *International Journal of Plant & Soil Science*, *35*(23), 32–40.
25. El-Ziat, R. A. M., Saudy, H. S., & Hewidy, M. (2024). The alteration in physiological status, growth and essential oil profile of French marigold (*Tagetes patula* L.) owing to seaweed extract and salicylic acid application. Journal of Soil Science and Plant Nutrition, 24(2), 3909-3922.
26. Raj, J., Sinha, J., Kumar, N., & Jangre, N. (2022). Economic Analysis of Marigold Flower in Research Farm of IGKV Raipur, Chhattisgarh, India. *International Journal of Environment and Climate Change*, *12*(10), 165–170.
27. Manish Kumar Sonkar, Goutam Mandal, Navdeep Kumar, Kotapati Priyanka, Madhu Kumar Prateek and Dhan Singh (2024).EFFECT OF NANO-UREA ON VEGETATIVE GROWTH, FLOWERING, FRUITING AND YIELD OF STRAWBERRY FRUITCV.WINTER DAWN.Plant Archives Vol. 24, No. 2, 2024 pp.2316-2320