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Effect of Nano Urea Application and Mineral Nutrition on Vegetative, Flowering and Yield of French Marigold (*Tagetes patula* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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

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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., T_1 =100% RDF (Control i.e. 200 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha);T_2 = 100% RDF + 1ml/l nano urea foliar application;T_3 =100% RDF + 1.5 ml/l nano urea foliar application;T_4 =100% RDF + 2 ml/l nano urea soil application;T_5 = 100% RDF + 4 ml/l nano urea soil application;T_6 = 75% RDF;T_7=75% RDF + 1ml/l nano urea foliar application;T_8 = 75% RDF + 1.5 ml/l nano urea foliar application;T_9 = 75% RDF + 2 ml/l nano urea soil application;T_{10} = 75% RDF + 4 ml/l nano urea soil application;T_{11} = 50 % RDF;T_{12} = 50 % RDF + 1 ml/l nano urea foliar application;T_{13} = 50 % RDF + 1.5ml/l nano urea foliar application;T_{14} = 50 % RDF + 2 ml/l nano urea soil application;T_{15} = 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.

Keywords: French marigold; profitability; mineral nutrition; nano urea; application; foliar.

1. INTRODUCTION

"Tagetes patula L. is called French marigold and is one of the most popular and commercial loose flower crops of Jammu, India. It belongs to the family Asteraceae. 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. 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 Fertilizer 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 (Kumar et al., 2023). 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 was being undertaken in view of the importance of marigold (*Tagetes patula* L.) crop in the region, 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.

2. MATERIALS AND METHODS

2.1 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 40°',

longitude of 74 58' and at an altitude of 332 meters ° above mean sea-level in the Shiwalik foothills of North Western Himalayas, found below the critical level.

2.2 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.

2.3 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 T_1 =100% RDF (Control i.e. 200 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha); T_2 = 100% RDF + 1ml/l nano urea foliar application; T_3 =100% RDF + 1.5 ml/l nano urea foliar application; T_4 =100% RDF + 2 ml/l nano urea soil application; T_5 = 100% RDF + 4 ml/l nano urea soil application; T_6 = 75% RDF; T_7=75% RDF + 1ml/l nano urea foliar application; T_8= 75% RDF + 1.5 ml/l nano urea foliar application; T_9 = 75% RDF + 2 ml/l nano urea soil application; T_{10} = 75% RDF + 4 ml/l nano urea soil application; T_{11} = 50 % RDF; T_{12} = 50 % RDF + 1 ml/l nano urea foliar application; T_{13} = 50 % RDF + 1.5ml/l nano urea foliar application; T_{14} = 50 % RDF + 2 ml/l nano urea soil application; T_{15} = 50 % RDF + 4 ml/l nano urea soil application.

2.4 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. 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

3. 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.

3.1 Vegetative Growth Parameters

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 (T_{11}), whereas the minimum number of laterals (17.20) was recorded with 50 % RDF + 1.5ml/L nano urea foliar application (T_{13}).

"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.

3.2 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 (T_{11}). 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 (T_{14}).

"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., (2021), 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.

Table 1. 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 2. 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
$C.D_{0.05}$	0.53	6.15	0.08	0.37	1.03

**Recommended dose of fertiliser (RDF): 200 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha)*

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

Treatments	Cost of cultivation	Flower yield/ ha		Gross income (Rs.)		Net income (Rs.)		B:C ratio	
Year	(Rs.)	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T_1	415451	46752.74	60330.89	1870110	2413235	1454659	1997784	3.50	4.81
T_2	416091	49883.75	61800.35	1995350	2472014	1579259	2055923	3.80	4.94
T_3	416411	49148.91	50825.81	1965956	2033032	1549545	1616621	3.72	3.88
T_4	416731	47086.81	56483.91	1883472	2259356	1466741	1842625	3.52	4.42
T_5	418011	50833.52	54166.09	2033341	2166644	1615330	1748633	3.86	4.18
T_6	412588	52724.39	52665.58	2108976	2106623	1696388	1694035	4.11	4.11
T_7	413228	59929.28	56991.66	2397171	2279667	1983943	1866439	4.80	4.52
T_8	413548	55494.63	55452.94	2219785	2218118	1806237	1804570	4.98	5.77
T_9	413868	53846.50	59432.42	2153860	2377297	1739992	1963429	4.20	4.74
T_{10}	415148	60386.35	68464.46	2415454	2738578	2000306	2323430	4.22	4.23
T_{11}	409725.5	32035.14	57480.36	1281406	2299215	871680	1889489	2.13	4.61
T_{12}	410365.5	43296.90	58021.95	1731876	2320878	1321510	1910513	3.22	4.66
T_{13}	410685.5	37513.32	53407.85	1500533	2136314	1089847	1725628	2.65	4.20
T_{14}	411005.5	35264.90	52212.85	1410596	2088514	999590.6	1677508	2.43	4.08
T_{15}	412285.5	46093.32	57780.99	1843733	2311240	1431447	1898954	3.47	4.61

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).

4. 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

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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