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Effect of nano urea on growth and yield of scented geranium (*Pelargonium graveolens* L. Herit)

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Abstract

Nanotechnology holds promise for optimizing nutrient delivery in agriculture. This study examines the impact of nano urea, a nanoscale urea formulation, on scented geranium (*Pelargonium graveolens*) growth and yield. A randomized controlled trial compared nano urea with traditional urea on various growth and yield parameters. Nano urea treatment, T_7- 15 kg N neem coated urea + 0.5 ml l^{-1} nano urea improved the growth and yield of scented geranium. Plants sprayed with nano urea had maximum growth (plant height, number of scented leaves per plant, number of branches per plant, plant spread), yield (fresh herbage yield (1.53 and 1.26 kg per plant, 28.76 and 25.56 kg per net plot and 14.27 and 12.68 t per hectare) and essential oil yield per hectare (14.70 and 13.11 kg) in both the main as well as ratoon crops respectively.

Keywords: Scented geranium, *Pelargonium graveolens*, nano urea, growth and yield

Introduction

Scented geranium (*Pelargonium graveolens* L. Herit) is a member of the Geraniaceae family, used to extract essential oil. There are about 250 plant species in the genus *Pelargonium*, which are found in places including Australia, Europe, South Africa and Asia. Through the spice trade and the harvesting of medicinal herbs by sailors, *Pelargonium* species were transported from the southern tip of Africa to Britain and Holland. The cultivar rose from Reunion, which is a cross between *Pelargonium capitatum* and *Pelargonium radens* and was exported as the "Burbon type", is a prolific producer of essential oils (Weiss, 1997). Plants differ in the quantity, length and degree of their branches (Swamy *et al*., 1960; Weiss, 1997; Demarne, 2002a; Miller, 2002). The leaves are opposite-on-the-stem, green, velvety, hairy, fragrant have 5 to 7 lobes that are roughly split. They are also highly denticulated. By distilling tender shoots and leaves, essential oil is produced. The ability of these plant parts to produce the essential oil necessitates maximum production of herbage and preservation of the subsequent ability of the shoot to develop (Demarne and Vande-Walt, 1989). According to Joy *et al*. (2001) and Boukhris *et al*. (2012), citronellol (19.28–40.23%), geraniol (6.45–18.40%), linalool (3.96–12.90%), iso-menthone (5.20–7.20%), citronellyl formate (1.9–7.55%) and Guaia-6, 9–diene (0.15–4.40%) are the major components of geranium essential oil.

Around 600 tonnes of scented geranium oil is consumed annually on a global scale and this has promoted the cultivation of the crop (Anon., 2009; Demarne, 2002). Egypt, an African nation, produces more than 55 tonnes of oil per year (Motsa *et al*., 2006). Since the crop was found to respond very well to nitrogen, considerable quantities (240 kg ha^{-1}) of nitrogen fertilizers may be required to get higher geranium yields (Prakasa Rao *et al*., 1988).

Since the beginning of the green revolution, intensive farming techniques have been introduced and developed, but they have been judged unsustainable because the utilization efficiency of applied chemicals, including mineral fertilizers, has stayed below 30 per cent. Among mineral nutrients, nitrogen is the first and foremost nutrient required for crop plants as it is the constituent of chlorophyll and many proteins and enzymes and thus plays a significant role during the vegetative growth of crops. Nitrate (NO^{-3}) and ammonium (NH^{+4}) are two forms of nitrogen, taken up by plants. Nitrogen is lost through the nitrate leaching, de-nitrification and ammonia volatilization processes (Kumar *et al*., 2021).

Nano urea can also be employed to increase resistance to abiotic stress. Crops produced under drought stress conditions sprayed with nano urea have better physiological features. Nano urea is a key technique in agriculture for increasing nutrient use efficiency, lowering fertilizer waste and enhancing crop productivity and yield (Baboo, 2021). Considering the significance of this crop and nano urea, the present investigation was taken up with the objective to study the effect of nano urea on

growth, fresh herbage and essential oil yield of scented geranium.

Materials and methods

Field experiment was conducted in Research block of the Department of Plantation, Spices, Medicinal and Aromatic Crops, KRCCH, Arabhavi, Karnataka. A randomized block design with three replications and Kelkar type variety was used to conduct the experiment. The gross plot size was 5.4 m × 4.8 m with 60 cm × 60 cm spacing.

Soil analysis was done before planting and after planting to know the effect of nano urea on growth, yield and essential oil quality of scented geranium (*Pelargonium graveolens* L.). Before planting, the experimental area had the pH of 8.6, EC of 1.28 dSm^{-1}, organic matter of 0.94 per cent, available nitrogen of 356.92 kg ha^{-1}, available phosphorus of 36.00 kg ha^{-1} and available potassium of 131.09 kg ha^{-1}. The following treatments were imposed.

T_1- Control (Without any fertilizer), T_2- Check- RDF (10 t ha^{-1} FYM + 210: 35: 35 kg ha^{-1} $year^{-1}$ NPK), T_3- 15 kg N neem coated urea + 0.1 ml l^{-1} nano urea, T_4- 15 kg N neem coated urea + 0.2 ml l^{-1} nano urea, T_5- 15 kg N neem coated urea + 0.3 ml l^{-1} nano urea, T_6- 15 kg N neem coated urea + 0.4 ml l^{-1} nano urea, T_7- 15 kg N neem coated urea + 0.5 ml l^{-1} nano urea and T_8- 0.5 ml l^{-1} nano urea (only nano urea spray). RDF: 10 t/ha FYM + 210: 35: 35 kg ha^{-1} $year^{-1}$ NPK (commercial N fertilizer in six equal split doses at 2 months interval). RD FYM and RD PK were applied for all the treatment except T_1 and T_8. 15 kg N was supplied as basal dose for main crop and also for ratoon crop. Foliar spray of nano urea was taken up at 45 days interval (Main crop: 3 sprays and ratoon crop: 1 spray). Each spray solution was applied at 500 l ha^{-1}.

The average plant height was calculated by measuring individual plant height of five randomly labeled plants per plot using a meter scale and then dividing the sum of the plant height by the total number of randomly selected plants measured. By counting the leaves and branches from the base of the randomly labeled plants, the number of branches per plant was estimated. The east-west and north-south spread of the plant was recorded by measuring individual plant spread of five randomly labeled plants per plot using a meter scale and average was worked out and expressed in centimeters. The main crop was harvested 150 days after transplanting and ratoon crop was harvested 90 days after the main crop harvest.

The leaf to shoot ratio was calculated on dry weight basis by dividing the dry leaf weight by total shoot dry shoot weight of individually tagged plants and the mean was calculated and represented in grams per plant. At the time of harvest, the fresh yield per plot was noted. Based on the fresh yield per plot (kg), the fresh yield per hectare (t) was calculated. The essential oil was extracted using steam distillation process. After the distillation, the oil was collected and measured in kg ha^{-1}.

Results and discussion

Among the growth characters, plant height, number of leaves and number of branches

showed an increasing trend at various growth phases.

Similarly increasing plant spread was also noticed (Table 1 and Fig. 1). Effect of foliar spray of nano urea on growth parameters was observed at 60, 120 DAT, main crop harvest (150 DAT) and at ratoon crop harvest (90 DAH).

All the growth parameters in scented geranium was influenced by nano urea. Maximum plant height (84.53 cm) at main crop harvest was noticed in T_2- Check- RDF (10 t ha^{-1} FYM + 210: 35: 35 kg ha^{-1} $year^{-1}$ NPK) and during ratoon crop harvest in T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea (68.47 cm).

At 60 DAT, 120 DAT, main crop harvest (150 DAT) and ratoon crop harvest (90 DAH), the treatment T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea recorded maximum number of leaves per plant (82.40, 289.93, 355.27 and 330.60, respectively). The same treatment also showed significantly higher number of branches per plant (7.20, 14.20, 15.60 and 33.33, respectively) compared to other treatments.

The number of branches increased during ratoon crop which may be the reason for reduced plant height. In both the main crop and ratoon, T_2-Check- RDF (10 t ha^{-1} FYM + 210: 35: 35 kg ha^{-1}) recorded maximum E-W plant spread (76.93 and 67.07 cm, respectively).

At main crop harvest, T_6-15 kg N neem coated urea + 0.4 ml l^{-1} nano urea and T_5-15 kg N neem coated urea + 0.3 ml l^{-1} nano urea recorded maximum N-S plant spread (67.00 and 67.00 cm, respectively). At ratoon crop harvest T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea recorded significantly higher N-S plant spread (67.47 cm).

The vegetative growth reflects the photosynthetic rate and good nutrient uptake of the plant. Furthermore, taller plants always had more leaves, branches and plant spread. The nano nitrogen in nano urea contributes to a rise in photosynthesis. Thus, greater photosynthesis enhanced the source-sink relationship, allowing plants to grow over time. The ability of nano urea to create new cells should have also assisted plants in growing taller, with more leaves, branches and overall plant spread. Nano urea is easily absorbed by plant cells when sprayed on leaves since it passes through stomata and other apertures with ease. It is easily dispersed from the source to the vacuole inside the plant according to its needs by the phloem. The plant's vacuole stores unused nitrogen, which is progressively released to support healthy plant growth.

Table 1. Effect of nano urea on plant height, number of leaves and number of branches in scented geranium

Treatments	Number of leaves per plant				Number of branches per plant			
	60 DAT	120 DAT	Main crop harvest	Ratoon crop harvest	60 DAT	120 DAT	Main crop harvest	Ratoon crop harvest
T_1- Control (without any fertilizer)	50.07	258.80	292.20	262.40	5.40	8.27	11.67	19.13
T_2- Check- RDF (10 t ha^{-1} FYM + 210: 35: 35 kg ha^{-1} $year^{-1}$ NPK)	72.93	281.53	348.07	313.73	6.60	12.40	14.00	29.53
T_3- 15 kg N neem coated urea + 0.1 ml l^{-1} nano urea	60.33	265.67	315.93	269.20	5.40	10.40	12.20	21.07
T_4- 15 kg N neem coated urea + 0.2 ml l^{-1} nano urea	64.60	270.60	328.53	273.73	5.80	11.40	13.13	23.40
T_5- 15 kg N neem coated urea + 0.3 ml l^{-1} nano urea	73.00	274.80	340.33	281.13	5.80	12.20	14.20	26.20
T_6- 15 kg N neem coated urea + 0.4 ml l^{-1} nano urea	77.73	281.00	349.13	289.07	5.87	12.73	14.60	33.27
T_7- 15 kg N neem coated urea + 0.5 ml l^{-1} nano urea	82.40	289.93	355.27	330.60	7.20	14.20	15.60	33.33
T_8- 0.5 ml l^{-1} nano urea (only nano urea spray)	65.27	274.13	345.00	277.80	6.20	9.40	13.87	22.20
Mean	68.29	274.56	334.31	287.21	6.03	11.38	13.66	26.02
S. Em±	1.56	5.07	1.02	1.18	0.09	0.11	0.14	0.44
C.D. @ 5%	4.72	15.39	3.09	3.59	0.28	0.32	0.42	1.33
CV (%)	14.54	4.21	5.95	7.65	9.79	15.92	8.90	19.92

DAT- Days after transplanting

Similar results of increased plant height, number of leaves, branches and plant spread caused by nano urea sprayed on the leaves were reported by Alhasan (2020) in basil, Mehmood *et al*. (2021) in tulsi, Parrey *et al*. (2023) in peppermint, Hendawy *et al*. (2012) in black cumin species and Khalid (2012) in medicinal Apiaceae plants.

Effect of nano urea on yield parameters

Yield characters *i.e.*, leaf to shoot ratio, fresh herbage yield per plant, fresh herbage yield per net plot, fresh herbage yield per hectare, essential oil content and essential oil yield per hectare showed an increasing trend at harvesting phase (Table 2).

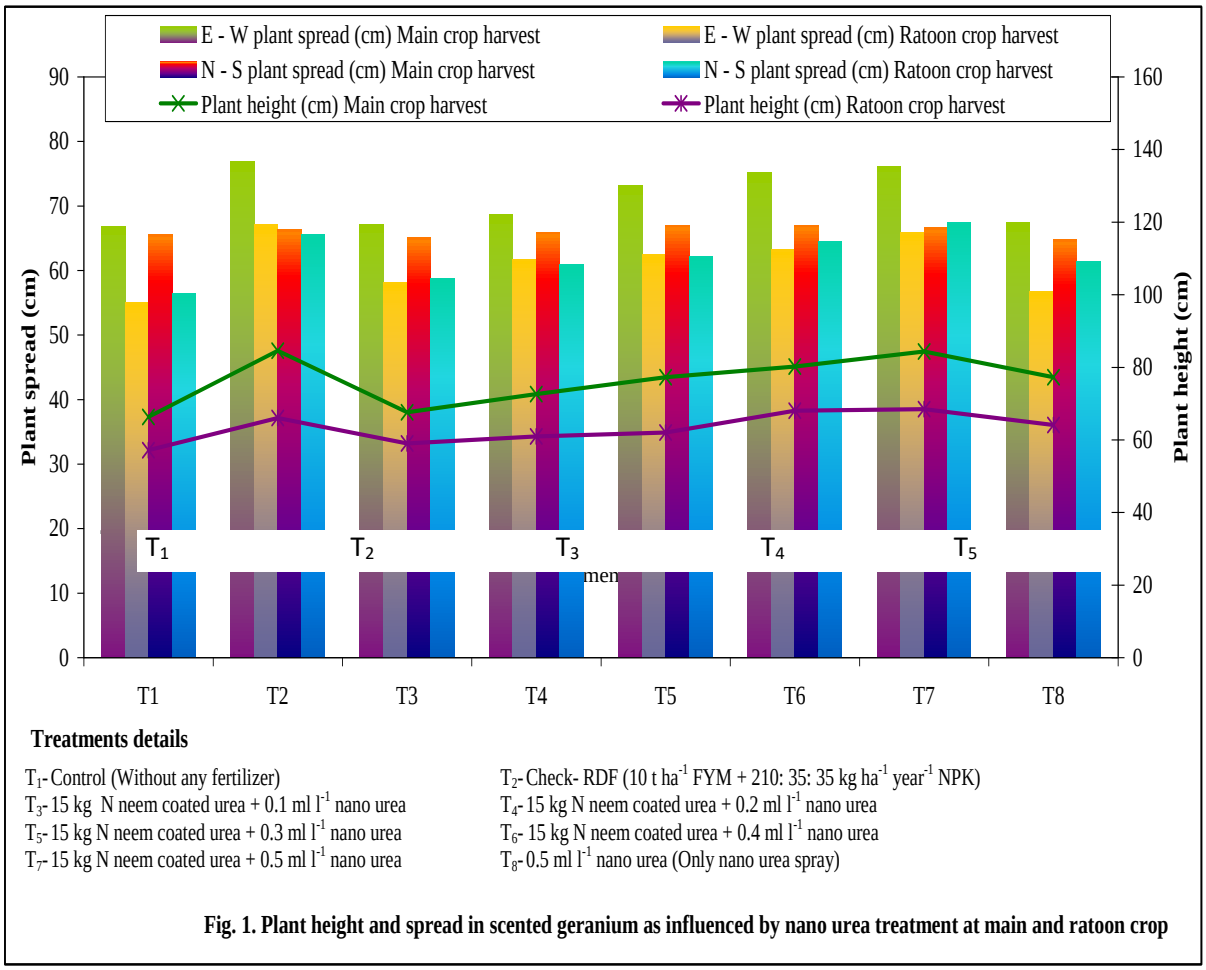

Fig. 1. Plant height and spread in scented geranium as influenced by nano urea in main and ratoon crop.

Among the foliar spray of different doses of nano urea, T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea and T_6-15 kg N neem coated urea + 0.4 ml l^{-1} nano urea recorded maximum leaf to shoot ratio at main crop harvest (1.11) but in ratoon crop the leaf to shoot ratio were on par among the treatments.

Increased leaf parameters like leaf number and leaf weight positively influence the leaf to shoot ratio. Increased leaf parameters were also recorded by Khalid (2012) in medicinal Apiaceae plants and Mehmood *et al*. (2021) in tulsi.

Among the foliar spray of different dose of nano urea, significantly highest fresh herbage yield per plant was recorded in T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea at main crop and ratoon crop harvest (1.53 and 1.26 kg, respectively), maximum fresh herbage yield per net plot (28.76 and 25.56 kg, respectively and maximum fresh herbage yield per hectare (14.27 and 12.68 t, respectively).

Table 2. Effect of different doses of nano urea on yield parameters at harvest of scented geranium

Treatment	Leaf to shoot ratio		Fresh herbage						Essential oil content (%)		Essential oil yield (kg ha^{-1})	
			Yield per plant (kg)		Net plot yield (kg)		Yield per hectare (t)					
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
T_1	0.92	0.73	0.80	0.74	17.23	11.16	8.55	5.54	0.0920	0.0990	7.87	5.48
T_2	1.00	0.86	1.45	1.24	26.59	21.45	13.19	10.64	0.0953	0.1030	12.57	10.72
T_3	0.98	0.78	1.05	0.76	20.13	14.77	9.99	7.32	0.0943	0.1020	9.42	7.47
T_4	0.97	0.80	1.08	0.93	21.95	16.12	10.89	8.00	0.0950	0.1023	10.35	8.18
T_5	1.06	0.85	1.22	0.98	24.67	19.07	12.24	9.46	0.0967	0.1030	11.84	9.74
T_6	1.11	0.89	1.36	1.08	26.98	21.15	13.38	10.49	0.1000	0.1033	13.38	10.84
T_7	1.11	0.91	1.53	1.26	28.76	25.56	14.27	12.68	0.1030	0.1034	14.70	13.11
T_8	1.00	0.80	1.04	0.92	21.57	16.44	10.70	8.15	0.0930	0.1027	9.95	8.37
Mean	1.02	0.83	1.19	0.99	23.49	18.21	11.65	9.04	0.0962	0.1023	11.26	9.24
S. Em±	0.02	0.06	0.02	0.02	0.83	0.43	0.41	0.21	0.0037	0.0009	0.40	0.26
C.D. @ 5%	0.06	NS	0.05	0.05	2.52	1.30	1.25	0.64	NS	NS	1.20	0.78
CV (%)	6.66	11.89	19.29	18.66	16.30	23.47	16.30	23.47	6.45	1.82	19.40	24.23

NS- Non-significant

A sufficient nitrogen supply from nano urea can encourage plant growth, increasing the fresh weight of the plants. A higher yield per hectare may result from increasing the fresh weight of individual plants, particularly from their above ground biomass *i.e*. economic part of scented geranium is above ground portion. Reports from Rao *et al*. (1990) in geranium, Hegab *et al*. (2018) in sage and Parrey *et al*. (2023) in peppermint supported these findings.

Scented geranium essential oil recovery was not found to be significant among the treatments at main crop harvest and ratoon crop harvest. Among the foliar spray of different dose of nano urea, during main crop and ratoon crop harvest T_7-15 kg N neem coated urea + 0.5 ml l^{-1} nano urea recorded significantly higher essential oil yield per hectare (14.70 and 13.11 kg, respectively). A sufficient nitrogen supply can encourage plant growth overall, increasing the amount of essential oils produced in scented geranium. Gulati and Duhan (1982), Bhaskar *et al*. (2001) and Mahmoodi *et al*. (2017) in scented geranium, *Borago officinalis* and scented geranium, respectively corroborated the present findings. During the ratoon crop, the yield of herbage was reduced which lead to the decrease in the essential oil yield. This reduced yield was due to the increased vegetative growth resulting in over-crowding and there was no sufficient space for plant growth as reported by Mahmoodi *et al*., (2017).

Conclusion

Foliar spray of nano urea has been demonstrated to enhance the growth parameters and yield of scented geranium. Thus, 15 kg N neem coated urea + 0.5 ml l^{-1} nano urea spray can be recommended to increase the yield and income of geranium farmers.

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