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Complementary Effect of Nano-Urea on the Performance of Geranium (*Pelargonium graveolens* L.) under Eastern Dry Zone of Karnataka

M.L. Chaithra, B.N. Dhananjaya[1*], B.N. Maruthi Prasad, T.H. Shankarappa[2], B.S. Harish, B.R. Premalatha[2] and J. Jayappa[3]

Department of Plantation, Spices, Medicinal and Aromatic Crops, [1]Department of Soil Science,
[2]Department of Natural Resource Management, [3]Department of Entomology,
College of Horticulture, UHS Campus, GKVK Post, Bengaluru-560 065, India
**E-mail: bndssac@gmail.com*

Abstract: The present investigation was under taken to enhance the nitrogen use efficiency of applied conventional nitrogen fertilizer and to reduce the cost of cultivation so as to harness the better foliage yields of geranium. The recommended dose of nitrogen, 210 kg/ha is applied in six equal split doses at an interval of two months while, phosphorus and potassium as a single basal dose for geranium. The hypothesis of reducing the nitrogen dosage of conventional fertilizer through the complimentary spraying of nano-urea was tested during the *Rabi* season of 2022-23. Soil application of 50 per cent RDN (105 kg N/ha) through neem coated urea in three equal split doses and three sprays of nano-urea (150 g N/ha) at two months interval alternatively along with soil application of recommended doses of FYM (10 t/ha), P (35 kg P_2O_5/ha) and K (35 kg K_2O/ha) had produced superior growth attributes (plant height, number of leaves, branches and plant spread) at different stages of geranium growth in main as well as ratoon crops. The yield attributes such as fresh herbage yields of 22.30 and 32.89 t/ha, dry herbage yields of 5.33 and 8.21 t/ha and essential oil yields of 92.23 and 129.82 kg/ha in main and ratoon crops, respectively were significantly high in this treatment and realized highest net returns of Rs.14, 59, 453 per ha with a cost benefit ratio of 2.25.

Keywords: Nano-urea, Nitrogen levels, Geranium, Oil yield, Net returns

Deterioration of soil health has been reported to be the major cause for stagnation of the crop productivity in India. In India, about 82 per cent of the total fertilizer consumed is through urea. Around 30-40 per cent of nitrogen supplied through urea is utilized by plants and the rest gets wasted as a result of leaching, volatilization, denitrification and run off, indicating its low nitrogen use efficiency. The high N loss coupled with its low use efficiency forced the farmers to increase the amounts of applied N fertilizers in order to achieve better crop production (Rathnayaka et al., 2018), which resulted in escalated costs of the farming practice as well as increased environmental implications (Marchiol 2019). Therefore, there is a need to improve the N availability for plants, while reducing its harmful effects on the environment. One such possibility is the use of nano-materials of less than 100 nm size as they offer higher absorption rate, utilization efficacy, and minimum losses (Kumar et al., 2020).

Nitrogen is a basic component of purines and pyrimidine in nucleic acids (DNA and RNA), playing a pivotal role in biological inheritance, genetic variation and protein synthesis. The amino groups of peptides, proteins and enzymes primarily consist of nitrogen, thereby conferring its indispensable function in maintaining organismal activities. Furthermore, as an integral part of chlorophyll molecules, nitrogen facilitates light energy absorption during photosynthesis. It also significantly promotes root development and optimizes photosynthetic efficiency (Cao et al., 2025). It is responsible for greenness, vigorous growth and overall crop development; therefore, it must be available for plants in adequate amounts. Nano-fertilizers have particle size smaller than the pore size of plant leaves, allowing for greater penetration into plant tissues from the applied surface thereby improve the absorption and nutrient use efficiency. Foliar application of nano-urea liquid along with minimum quantity of conventional urea at critical crop growth stages of a plant effectively fulfils its nitrogen requirement and leads to higher crop productivity and quality in comparison to only conventional urea application (Oinam et al., 2025).

Rose scented geranium (*Pelargonium graveolens* L.) of genus *Pelargonium* L. Herit, belongs to the family Geraniaceae, is one of the economically important aromatic crops, from which highly prized geranium essential oil is extracted for flavour and fragrance. Monoterpenoids and acetate esters of monoterpenols are the main constituents of geranium essential oil with a rose fragrance. These include citronellol, geraniol, citronellyl acetate, geranyl acetate, isomenthone, menthone and linalool, *etc*. Geranium essential oil is basically used in perfumery, beauty and aroma therapy industries all around the world. It is one of the quality skin care oil as it is used for opening skin pores and cleansing complexions. In addition, geranium essential oil is used in treatment of infectious diseases, haemorrhoids, inflammation, serious menorrhea, internal organ ulcers, jaundice, liver issues, sterility, urinary stones and even cancer. Leaves are also utilized as herb drink to fight anxiety, relief strain, boost blood flow, and to treat inflammation (Cocos et al., 2023). Presently, it is being commercially cultivated mainly in the Nilgiris and Kodaikanal hills of Tamil Nadu and in and around Bengaluru in Karnataka in an area of about 2000 ha. The available nitrogen status of soils in Eastern dry zone of Karnataka is low because of higher temperature and semi-arid climate leading to more volatilization loss of applied conventional nitrogenous fertilizers. Application of nano-urea could reduce the volatilization loss of nitrogen and enhance the use efficiency of applied conventional nitrogenous fertilizers. The spraying of nano-urea to foliage may complement for the soil applied nitrogen in harnessing better yields (Acharjee et al., 2025). Therefore, the present investigation was under taken to study the effect of nitrogen levels and number of nano-urea sprays on performance of geranium as test crop at College of Horticulture, Bengaluru.

MATERIAL AND METHODS

The experiment was carried out during *Rabi* 2022-23 at College of Horticulture, Bengaluru, located at $12^{\circ}58^{1}$ N latitude and $77^{\circ}35^{1}$ E longitudes at an altitude of 930 m above MSL. Soil samples were collected from 0-15 cm depth randomly in a zig-zag manner to represent entire experimental site before initiation of the experiment and was analyzed for various physico-chemical properties by following standard procedures. The soil of the experimental site was sandy loam in texture, slightly acidic in reaction (pH: 6.26), low in soluble salts (EC: 0.09 dS/m), organic carbon (0.39%) and available N and K_2O (144.25 and 130.77 kg/ha, respectively) contents while medium in available P_2O_5 (30.00 kg/ha) status.

The geranium is an aromatic perennial crop and requires continuous supply of nitrogen throughout the crop growth period. The nitrogen is applied in six equal split doses at an interval of two months while, phosphorus and potassium as a single basal dose. The effect of reduction of nitrogen dosage through conventional urea by the complementary application of nano-urea sprays on the performance of geranium was observed using randomised complete block design with three replications consisting of eight treatments (Table 1).

The 1250 mL per hectare of IFFCO liquid nano-urea having 4% N was sprayed on to foliage @ 2 mL per litre of water which supplies only 50 grams of nitrogen per spray. Sixty days old rooted stem cuttings of geranium (*Pelargonium graveolens* L) cultivar 'Cim-Bio 171' were transplanted with a spacing of 60 cm x 60 cm in each plot in November 2022. The plots were kept completely free from weeds by regular hand weeding at 20 days interval till harvest of the crop. The plots were irrigated immediately after transplanting and later irrigation was done once in three to four days depending on soil moisture status and weather conditions besides, all the plant protection measures were taken.

Observations on growth parameters *viz.*, plant height (cm), number of leaves per plant (No.), number of branches per plant (No.) and the plant spread was measured in both N-S and E-W directions (cm^2). The first harvesting of foliage was done at 120 days after transplanting and subsequent harvests at 3 months interval. Fresh herb from each plot was harvested and weighed and expressed in kilogram to get the fresh herbage yield per plot. Fresh and dry herbage yield per plot was converted to per hectare on area basis and expressed in tonnes (t). The essential oil content was determined by hydro-distillation in a clevenger apparatus as described by Babu and Kaul (2005) and expressed in percentage. The essential oil yield was calculated based on the oil content and fresh herbage yield per plant, per plot and per hectare and is expressed in milliliters. The quality attributes of oil *viz*., acid value, saponification value, ester value, specific gravity and refractive index were calculated. The acid and saponification values of oil in terms of mg KOH per gram of oil were calculated as described by Pearson (1976). The ester value of oil was calculated by subtracting acid value from the saponification value while, specific gravity was calculated by dividing the weight of 1 mL of oil by

Table 1. Treatment details

Sl. No.	Treatment details
T_1	Control (Only recommended FYM @ 10 t/ha)
T_2	100% RDN (210 kg/ha) through NCU in six equal split doses at 2 months interval
T_3	83% RDN (175 kg/ha) through NCU in five equal split doses + 1 spray of nano-urea
T_4	67% RDN (140 kg/ha) through NCU in four equal split doses + 2 sprays of nano-urea
T_5	50% RDN (105 kg/ha) through NCU in three equal split doses + 3 sprays of nano-urea
T_6	33% RDN (70 kg/ha) through NCU in two equal split doses + 4 sprays of nano-urea
T_7	17% RDN (35 kg/ha) through NCU as basal dose + 5 sprays of nano-urea
T_8	Six sprays of nano-urea at 2 months interval

Note:
1. Recommended FYM 10 t/ha was applied to all treatments including control
2. Recommended P_2O_5 (35 kg/ha) and K_2O (35 kg/ha) were applied to all treatments except control
3. RDN: Recommended Dose of Nitrogen (210 kg/ha); NCU: Neem Coated Urea

the weight of 1 mL of water at room temperature and refractive index was measured using Abbe's refractometer at room temperature.

The cost incurred from land preparation to harvest of crop including cost of all the inputs, cost of all the operations carried out, supervision charge and pre farm to marketing charge were taken into consideration for working out the cost of cultivation and expressed as rupees per hectare. Gross returns per hectare was calculated by taking into consideration of economic yield obtained per hectare and the price of the essential oil prevailing in the market at the time of harvest as per price list of Fragrances and Flavours Association of India. The net returns per hectare was calculated by deducting cost of cultivation per hectare from the gross returns per hectare. The cost benefit ratio was worked out by dividing net returns (Rs./ha) by cost of cultivation (Rs./ha). The experimental data were analyzed using SPSS16 statistical software.

RESULTS AND DISCUSSION

Plant height: The plant height showed an increasing trend with the advancing stages of crop growth and was highest at harvest (Table 2). Significantly maximum plant height was at 30 and 60 DAT (19.40 and 30.87 cm, respectively) in main crop and at 30 DAFH (27.20 cm) in ratoon crop in the treatment which received alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_5). This might be attributed to improved nitrogen uptake by the plant due to synergetic effect of nano nitrogen through foliar penetration and conventional urea through roots uptake leading to improved photosynthesis, source and sink capacity (Benzon et al., 2015).

Number of leaves per plant: Significantly highest number of leaves per plant was observed in treatment which received alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_5) at 60 and 90 DAT (95.80 and 163.20, respectively) in main crop and at 90 DAFH (214.27) in ratoon crop (Table 2). Whereas, only six sprays of nano-urea at two months interval (300 g N/ha) along with soil application of recommended doses of FYM, P and K (T_8) had produced significantly a greater number of leaves per plant at 30 and 60 DAFH (79.27 and 150.13, respectively) in ratoon crop. However, both the treatments were *on par* with each other at all crop growth stages. This might be due to the fact that nitrogen delivered by foliar spray might have reached the cells more quickly through stomata or cuts and scrapes in the leaves, thereby helped to maintain continuity and speed of delivering the nutrients necessary for plant metabolic activities. Further, nitrogen increases the chlorophyll formation, rate of photosynthesis and overall growth of plant that might have resulted in formation of a greater number of leaves. These findings are in agreement with those findings of Rajasekar et al. (2017).

Number of branches per plant: The number of branches per plant of geranium at different growth stages differed due to nitrogen levels and number of nano-urea sprays (Table 3).

Table 2. Plant height and number of leaves per plant of geranium as influenced by nitrogen levels and number of nano-urea sprays

Treatments	Plant height (cm)							Number of leaves per plant						
	Main crop				Ratoon crop			Main crop				Ratoon crop		
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAFH	60 DAFH	90 DAFH	30 DAT	60 DAT	90 DAT	120 DAT	30 DAFH	60 DAFH	90 DAFH
T_1	15.80	24.13	36.07	48.73	23.40	41.87	51.20	16.07	64.20	124.67	196.27	63.60	123.20	175.87
T_2	17.07	25.27	38.67	50.20	25.87	42.47	53.53	19.53	71.80	130.33	198.53	69.47	131.60	181.67
T_3	14.87	24.60	37.00	50.47	26.07	44.40	54.20	19.00	66.67	126.73	198.20	70.40	127.47	179.87
T_4	18.20	27.60	39.53	51.20	25.27	43.33	54.67	24.13	82.27	145.73	238.80	72.13	136.53	187.93
T_5	19.40	30.87	40.93	54.33	27.20	45.13	56.67	24.47	95.80	163.20	250.87	71.20	146.67	214.27
T_6	16.73	26.67	36.53	51.47	25.00	43.07	52.87	21.67	78.73	146.80	208.00	71.20	137.13	190.80
T_7	17.33	26.87	39.67	52.20	26.93	44.60	53.87	22.13	93.93	157.87	221.07	71.67	148.47	201.93
T_8	19.33	28.33	39.47	52.13	24.93	41.73	55.13	23.60	83.93	153.93	216.13	79.27	150.13	200.00
CD (p=0.05)	3.15	4.05	NS	NS	2.75	NS	NS	NS	21.40	28.18	NS	10.70	20.53	27.33

See Table 1 for treatment details
DAT: Days After Transplanting; DAFT: Days After First Harvest; NS: Non Significant

Maximum number of branches per plant were achieved with alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_5) at 60 and 90 DAT in main crop and at 60 and 90 DAFH in ratoon crop. This might be due to the fact that the plants received enough nitrogen through nano-urea as well as conventional urea at critical crop growth stages of geranium which would have maintained a constant supply of nitrogen thereby stimulated the cell elongation and meristematic activity in plants and ultimately resulted in a greater number of branches (Jassim et al., 2019).

Plant spread: Significantly maximum plant spread of 3177.67 cm^2 at 90 DAT in main crop was achieved with alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (Table 3). Significantly maximum plant spread of 2413.93 cm^2 at 30 DAFH in ratoon crop was noticed with soil application of 17% RDN (35 kg/ha) through neem coated urea as basal dose and five sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_7). However, both the treatments were *on par* with each other at 30 DAFH. The enhanced plant spread might be attributed to vigorous nature of plant growth at this level, as indicated by the greater number of branches and leaves. These findings are in agreement with findings of Sumathi et al. (2012) in *Pogostemon cablin*.

Fresh and dry herbage yields: The fresh and dry herbage yields data indicated that the treatment involving alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_5) had produced significantly maximum fresh herbage (22.30 and 32.89 t/ha) and dry herbage (5.33 and 8.21 t/ha) yields in both main and ratoon crops, respectively (Table 4). This might be attributed to the presence of greater number of leaves, branches, increased plant spread and optimum concentration of nitrogen which in turn might have enhanced the optimum uptake of P and K due to synergistic effect. The maximum fresh and dry herbage yields obtained due to combined soil application of conventional fertilizer in split doses and nano-urea which has been sprayed on plant surface that might have led to the storage of remaining nitrogen in plant cells which might have released slowly and prevented the plant biotic and abiotic stresses which in turn increased the vegetative growth (Khalil et al., 2019). Further, smaller particle size of nano-urea with greater specific surface area and number of particles per unit area of a fertilizer that might have provided greater opportunities for penetration and nutrient uptake, thus resulting in more vegetative growth and dry matter production (Fadhil et al., 2021). These findings are in line with findings of Mahmoodi et al. (2020) and Midde et al. (2022).

Essential oil yield: The essential oil yield in fresh herb of geranium differed significantly due to nitrogen levels and number of nano-urea sprays (Table 4). The highest essential oil yield in both main and ratoon crop of geranium (92.23 and 129.82 kg/ha, respectively) was obtained in treatment which received alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and

Table 3. Number of branches and plant spread of geranium as influenced by nitrogen levels and number of nano-urea sprays

Treatments	Number of branches per plant							Plant spread (cm^2)						
	Main crop				Ratoon crop			Main crop				Ratoon crop		
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAFH	60 DAFH	90 DAFH	30 DAT	60 DAT	90 DAT	120 DAT	30 DAFH	60 DAFH	90 DAFH
T_1	1.67	6.00	12.00	22.73	10.80	15.27	22.73	308.28	1567.92	2113.04	4135.63	1940.48	3676.35	5936.45
T_2	2.27	5.60	12.20	23.80	11.67	15.67	24.07	372.85	1507.05	2139.67	5485.00	2154.75	3948.28	6234.87
T_3	2.20	6.53	12.93	22.87	12.20	16.93	24.80	336.09	1997.72	2655.63	4729.64	2181.19	4546.57	7152.03
T_4	3.33	6.67	12.93	23.13	12.47	17.00	25.33	441.04	1857.97	2512.65	5252.96	2235.77	4235.12	6875.60
T_5	3.07	7.60	14.47	25.47	12.13	18.40	27.53	483.41	2340.27	3177.67	5655.41	2314.43	4701.07	7296.48
T_6	2.40	7.20	13.87	25.13	11.93	16.53	25.60	389.29	2535.23	2948.73	5126.08	1795.83	3881.49	6524.63
T_7	2.67	6.87	13.73	24.80	13.20	17.67	26.60	375.84	2424.33	2746.45	4834.51	2413.93	3850.03	6415.41
T_8	2.93	6.80	13.53	24.60	12.67	18.00	26.20	484.88	2322.17	3016.21	5020.64	2265.88	4338.56	7276.13
CD (p=0.05)	NS	1.44	1.99	NS	1.63	2.02	2.76	NS	NS	831.08	NS	480.95	NS	NS

See Table 1 for treatment details
DAT: Days After Transplanting; DAFT: Days After First Harvest; NS: Non Significant

three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (T_5). This was probably due to higher herbage yield and higher oil content. Rose-scented geranium had exhibited similar response to nitrogen levels (Bhaskar et al., 2001). The enhanced accumulation of essential oil in plants under the conditions of well supplied nitrogen might have resulted from the increased production of biomass and its direct impact on the biosynthesis of oil.

Quality parameters: The essential oil content in fresh herb of geranium differed significantly due to nitrogen levels and number of nano-urea sprays (Table 5). The essential oil content in both main and ratoon crops of geranium (0.43 and 0.42%, respectively) were significantly superior in plants treated with the six sprays of nano-urea at two months interval (300 g N/ha) along with soil application of recommended doses of FYM, P and K (T_8). In general, the essential oil content was more in main crop compared to ratoon crop. The response of volatile oil content to nano nitrogen fertilization might be attributed to *de novo* meristematic cell metabolism in building dry matter with essential oil production. Nitrogen being a part of three important coenzymes *viz*., ATP, NADPH and Co-A plays an important role in terpenoid biosynthesis (Sarab et al., 2008). However, other quality parameters *viz*., acid value, saponification value, ester value, specific gravity and refractive index of geranium essential oil in both main and ratoon crops were not influenced by nitrogen levels and number of nano-urea sprays (Table 5).

Economics: The highest gross returns (₹ 21,09,475 / ha), net returns (₹ 14,59,453 / ha) and cost benefit ratio (2.25) were realized with the alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K (Table 6). This was due to reduced urea application and effect of nano-urea sprays at critical crop growth stages of geranium which resulted in higher

Table 4. Yield of geranium as influenced by nitrogen levels and number of nano-urea sprays

Treatments	Fresh herbage yield (t/ha)		Dry herbage yield (t/ha)		Essential oil yield (kg/ha)	
	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
T_1	14.04	22.11	3.41	4.68	39.49	60.13
T_2	16.52	30.18	4.00	6.80	57.86	106.50
T_3	16.22	28.61	3.93	6.41	57.26	107.72
T_4	16.04	29.89	4.00	6.79	49.78	104.60
T_5	22.30	32.89	5.33	8.21	92.23	129.82
T_6	16.81	30.71	4.19	7.11	68.30	98.37
T_7	15.26	24.64	3.70	6.04	56.18	82.93
T_8	19.30	26.68	4.74	6.52	83.79	110.82
CD (p=0.05)	2.68	4.64	0.67	2.34	24.84	31.11

See Table 1 for treatment details

Table 5. Quality attributes of geranium oil as influenced by nitrogen levels and number of nano-urea sprays

Treatments	Oil content (% v/w)		Acid value		Saponification value		Ester value		Specific gravity		Refractive index	
	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	0.29	0.27	5.98	5.98	35.53	37.40	29.55	31.42	0.91	0.92	1.46	1.47
T_2	0.35	0.35	6.36	5.24	37.40	37.40	31.04	31.79	0.92	0.92	1.47	1.47
T_3	0.35	0.37	5.98	5.24	39.27	41.14	33.29	35.90	0.91	0.90	1.47	1.47
T_4	0.31	0.35	5.98	5.98	39.27	35.53	33.29	29.55	0.91	0.92	1.48	1.48
T_5	0.41	0.39	5.98	5.61	37.40	41.14	31.42	35.53	0.91	0.92	1.47	1.47
T_6	0.41	0.32	6.36	4.86	41.14	39.27	34.78	34.41	0.91	0.91	1.48	1.48
T_7	0.37	0.33	5.61	5.98	41.14	37.40	35.53	31.42	0.92	0.91	1.47	1.47
T_8	0.43	0.42	5.24	4.86	41.14	43.01	35.90	38.15	0.92	0.92	1.48	1.48
CD (p=0.05)	0.11	0.08	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

See Table 1 for treatment details

Table 6. Economics of geranium oil production as influenced by nitrogen levels and number of nano urea sprays

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B : C ratio
T_1	585709	946390	360681	0.62
T_2	625326	1561420	936094	1.50
T_3	619330	1567310	947980	1.53
T_4	622244	1466610	844366	1.36
T_5	650022	2109475	1459453	2.25
T_6	626241	1583365	957124	1.53
T_7	602995	1321545	718550	1.19
T_8	620845	1848795	1227950	1.98

See Table 1 for treatment details

herbage and oil yields and as a result, higher net returns (Kumar et al., 2020).

CONCLUSION

The combined soil application of commercial nitrogen fertilizer and nano-urea spray had significant impact on growth, yield and quality of geranium. The treatment involving alternate soil application of 50% RDN (105 kg/ha) through neem coated urea in three equal split doses and three sprays of nano-urea at two months interval (150 g N/ha) along with soil application of recommended doses of FYM, P and K was most effective. This treatment not only provided optimal growth and yield but also had the highest cost benefit ratio, indicating favourable economic returns on investment.

AUTHOR'S CONTRIBUTION

It is the collaborative work of all the authors. ML Chaithra carried out the experiment and prepared the initial draft of the manuscript, author BN Dhananjaya gave technical guidance and supervised the experiment, BN Maruthi Prasad supplied the inputs and other resources, BS Harish conceptualized and formulated the hypothesis, TH Shankarappa prepared the manuscript, BR Premalatha recorded all the agronomic observations and J Jayappa analysed the data. All the authors have read and approved the final manuscript.

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