https://doi.org/10.17221/15/2024-HORTSCI

Integrated effect of inorganic and bio-organic nutrients on alstroemeria growth, flowering and soil dynamics

Shweta Sharma[1], Anshul Kumar[1], Sabhya Pathania[1]*, B.P. Sharma[1], Bharati Kashyap[1], Abeer Hashem[2], Graciela Dolores Avila-Quezada[3], Elsayed Fathi Abd_Allah[4]*

[1]*Department of Floriculture and Landscape Architecture, Dr. Y.S. Parmar University of Horticulture and Forestry Nauni, Himachal Pradesh, India*
[2]*Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia*
[3]*Faculty of Agrotechnological Sciences, Autonomous University of Chihuahua, Chihuahua, México*
[4]*Department of Plant Production, College of Food Science and Agriculture, King Saud University, Riyadh, Saudi Arabia*

**Corresponding authors: choudharyansh209@gmail.com; sabhyapathania2266553@gmail.com*

Citation: Sharma S., Kumar A., Pathania S., Sharma B.P., Kashyap B., Hashem A., Avila-Quezada G.D., Abd_Allah E.F. (2025): Integrated effect of inorganic and bio-organic nutrients on alstroemeria growth, flowering and soil dynamics. Hort. Sci. (Prague), 52: 144–154.

Abstract: Optimum nutrition is essential for quality cut flower production and for improving soil health. The study aims to evaluate the interaction between bio-organic and inorganic nutrient sources in enhancing alstroemeria (*Alstroemeria hybrida* L.) cut flower production and soil health for sustainable cultivation practice. Randomised block methodology involving 20 treatment combinations of inorganic fertilisers (NPK) and biostimulants (Panchgavya and Jeevamrit) applied at varying concentrations. Significant outcomes emerged from the combined influence of inorganic and organic sources of nutrients. The application of the 100% recommended dose of fertiliser (RDF) with 75 mL of Panchgavya resulted in substantial improvements in alstroemeria growth parameters, including plant height (7.8%), early flowering (13.08%), flower diameter (20.03%) and the number of flowering stems (25.3%) over the control (100% RDF). Plant spread (24.1%) and number of florets/stem (26.6%) were improved with the application of 100% RDF with 50 mL of Panchgavya when compared with the control. Soil nutrient content, i.e. available nitrogen (11.5%), phosphorus (28.7%), potassium (13.8%) and microbial populations, i.e. fungal (35.4%) and bacterial (28.2%) colonies also exhibited noteworthy enhancements with the application of 100% RDF with 75 mL of Panchgavya over the control. The study concludes that the application of 100% RDF with 75 mL of Panchgavya increased quality cut flower production in alstroemeria.

Keywords: alstroemeria; biostimulants; capri; growth and flowering; inorganic fertilisers; microbial count; Panchgavya

Supported by the Researchers Supporting Project (RSP2025R134) of the King Saud University, Riyadh, Saudi Arabia.

https://doi.org/10.17221/15/2024-HORTSCI

The floriculture sector is rapidly gaining prominence as a lucrative enterprise worldwide, driven by an increasing per capita consumption of flowers because of globalisation (Adebayo et al. 2020). With an annual growth potential of 25–30%, the floriculture industry has the capacity to generate 20–25 times higher foreign exchange than traditional agricultural crops. Cut flowers represent the leading segment in commercial ornamental plant production, with the global market valued at USD 36.4 billion in 2022 and projected to reach USD 45.5 billion by 2027, growing at a compound annual growth rate (CAGR) of 4.6% (Markets and Markets, 2023). The increasing demand has led to the emergence of new production centres in Latin America, Africa, and Asia, in contrast to traditionally dominant regions such as the USA, Japan, the Netherlands, and Colombia (Ranjan et al. 2013).

Alstroemeria is emerging as a significant crop in the cut flower market (Anand et al. 2020). The major cultivation of alstroemeria is predominantly done in the Netherlands (approximately 110 ha). In India, the Agriculture Ministry under the Indian government introduced alstroemeria in 2001 as part of the FAD (Floriculture Adoption and Development) programme (Kashyap et al. 2018). Within India, the majority of alstroemeria cultivation occurs in the hilly regions of Himachal Pradesh, Jammu, Kashmir and the Nilgiris.

Alstroemeria hybrida L., characterised by its bulbous nature, holds significant commercial value as a cut flower. This plant is rhizomatous and a member of the *Alstroemeriaceae* family (Dhiman, Kashyap 2021). The areas with the highest diversity of this genus are Central Chile (Mediterranean region) at altitudes ranging from sea level to around 1 000 m above sea level and Southeast Brazil (mountain region), 500 m to 2 500 m above sea level (Aros et al. 2019).

Alstroemeria is known to be a heavy feeder, and the widespread use of sole chemical fertilisers in plant production poses a significant threat to the ecology and environment. Issues such as nitrogen volatilisation, denitrification, leaching and the accumulation of non-available phosphorus in the soil are adverse outcomes of the exclusive heavy usage of inorganic fertilisers (Pahalvi et al. 2021). Given the current global context, there is a pressing need for eco-friendly farming practices. As a sustainable alternative, biofertilisers and biostimulants have gained traction and are recommended for integration with inorganic fertilisers, showing promise in enhancing crop quality and yield. The combined use of inorganic nutrient sources and organic liquid products, such as Panchgavya and Jeevamrit, has demonstrated positive effects, contributing to increased crop growth, yield and quality, along with the potential to enhance the physical characteristics, fertility and microbial diversity of the soil. These organic products serve as rich sources of macro and micro nutrients, growth-promoting regulators [auxin and GA (gibberellic acid)], amino acids and microbes (Palekar 2006).

Due to awareness regarding soil health and excessive use of chemical fertilisers in modern-day farming, there was a shift from conventional methods to integrated nutrient management systems. Most of the components used to prepare liquid organic fermented manures like Jeevamrit and Panchgavya are easily available in farms, viz. cow dung, cow urine, milk, curd, ghee, legume flour and jaggery (Shraddha et al. 2023) and are eco-friendly. The general dose of Jeevamrit and Panchgavya application is 5–10% (Kumar et al. 2021; Das et al. 2023).

Despite the increasing prominence of alstroemeria in the floriculture sector, limited knowledge about its comprehensive nutritional requirements remains. This study was undertaken to identify the optimal combined sources of nutrition and their appropriate doses, embracing the concept of integrated nutrient management (INM).

MATERIAL AND METHODS

Experimental location. This study was carried out at Dr. Y.S. Parmar University of Horticulture and Forestry Nauni, Himachal Pradesh, India, and the trial was conducted over 2 years (2017–2018 and 2018–2019). The experiment was conducted at 30°52'0" North latitude and of 77°11'30" East longitude) with an elevation of 1 270 m above mean sea level. The climate in this area is generally subtemperate to sub-tropical, with warm summers and chilly winters. The climatic conditions during four different flushes, i.e. October 2017 to October 2019, are presented in Figure 1.

Before the start of the experiment, initial soil samples, 15 in number, were taken at 0–0.15 m depth from different locations in the experimental plot in a zig-zag pattern. A composite sample was prepared, further air dried, and was analysed in the Department of Soil Science and Water Management,

https://doi.org/10.17221/15/2024-HORTSCI

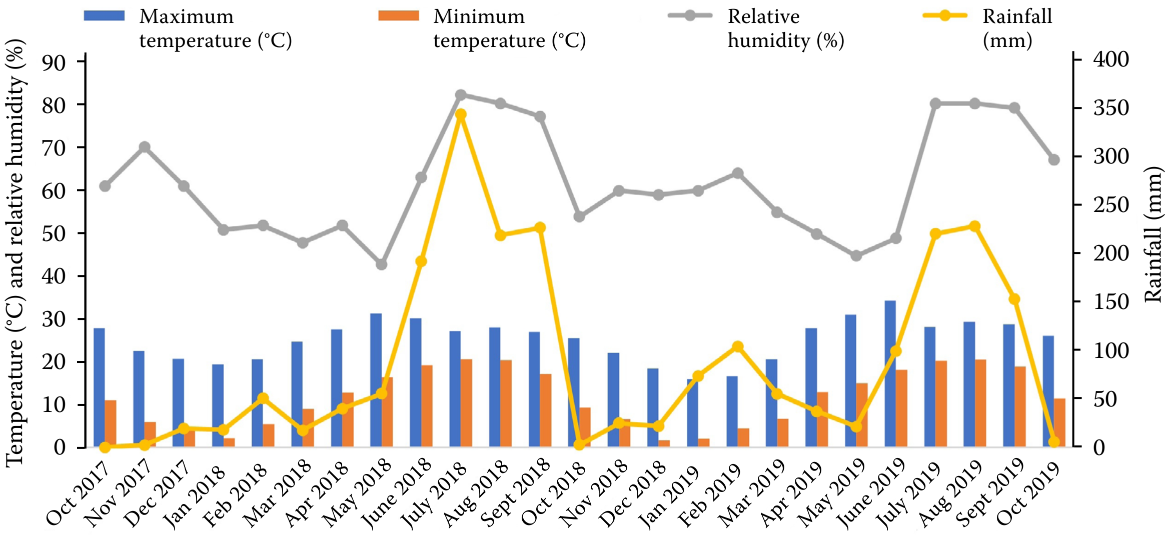

Figure 1. Agrometeorological data during the field experiment (2017–2019)

Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India, for various physicochemical attributes, viz. soil pH (potential of hydrogen), EC (electrical conductivity), OC (organic carbon), available nitrogen (N), available phosphorus (P) and available potassium (K) and results are shown in Table 1.

Planting material. Alstroemeria cv. 'Capri' (Figure 2) plants were procured from the Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India. Alstroemeria plants were meticulously selected, having 0.15–0.20 m length with 2–3 active growing points and 8–10 tuberous roots (Figure 3), and visually examined for any visible insect-pests and disease symptoms before being planted at a distance of 0.50 m × 0.50 m in beds that were 1 m × 1 m under a shade net (75% shade) area comprising 200 m^2, each experimental plot consist of 4 plants/m^2, accommodating total 240 plants in the experiment. The isolation distance between each experimental bed was maintained at 0.5 meter. The planting of rhizomes was done on 15th October, 2017.

Table 1. Initial soil characteristics of the experimental plot

Properties	Values	Reference
Soil pH	6.71	Jackson (1973)
EC	0.27 dS/m	Jackson (1973)
Soil OC content	2.51 g/kg	Walkley and Black (1934)
Available N	285.63 kg/ha	Subbiah and Asija (1956)
Available P	30.55 kg/ha	Olsen et al. (1954)
Available K	193.58 kg/ha	Merwin and Peech (1951)

pH – potential of hydrogen; EC – electrical conductivity; OC – organic carbon; N – nitrogen; P – phosphorus; K – potassium

Figure 2. Alstroemeria cultivar 'Capri'

Figure 3. Planting material of alstroemeria cv. 'Capri'

https://doi.org/10.17221/15/2024-HORTSCI

Treatment details. The experiment was set up using a randomised block design, including three replications and twenty treatments (Table 2).

RDF, i.e. 150 : 100 : 150 ppm NPK (Singh et al. 2017) was applied through 19 : 19 : 19 (526.32 mg/L) and the remaining 50 ppm of N and K were supplemented through urea (108.70 mg/L) and MOP (muriate of potash) (83.33 mg/L). Similarly, 75% RDF was applied through 19 : 19 : 19 (394.73 mg/L) and the remaining 37.5 ppm of N and K was supplemented through urea (81.52 mg/L) and MOP (62.5 mg/L).

Preparation of Jeevamrit was done by mixing cow urine (10 L), cow dung (10 kg), jaggery (2 kg), pulse flour (2 kg), soil below tree (0.5 kg) and water (200 L) in plastic drum covered with the wet jute bag and kept in the shade. Stirring of the mixture was done twice a day in a clockwise manner. On the fifth day, the solution was filtered, and the filtrate was used for the soil application as drenching after dilution (25 mL Jeevamrit means 2.5% Jeevamrit, i.e. 250 mL in 1 L of water and so on) at the 21-day interval, starting from 1 month of planting up to peak flowering.

Panchgavya was prepared by mixing cow urine (3 L), cow dung (5 kg), cow milk (2 L), cow ghee (1 kg), cow curd (2 kg), coconut water (3 L), banana (1 dozen) and jaggery (2 kg) in an earthen pot, covered with muslin cloth and kept in the shade. Stirring of the mixture was done twice a day in a clockwise manner. After 21 days, the mixture was filtered through a cotton cloth and used as per the treatments. Each treatment of Pachgavya was applied to the soil as a drenching at 21-day intervals, starting from 1 month of planting up to peak flowering. Filtrate was applied to the soil after dilution, similar to Jeevamrit. The nutrient and microbial status of the biostimulants used is given in Table 3.

Growth and flowering parameters. Data was recorded over a two-year span (2017–2019); data encompasses four successive flower flushes: the 1st (March–June 2017), 2nd (August–October 2017), 3rd (March–June 2019), and 4th (August–October 2019). The data on plant height was measured from the ground level to the top of the inflorescence on the longest shoot. Plant spread was recorded as the average of the distances measured in centimetres from east to west and north to south directions using a scale, taken at peak flowering. Days to flowering were recorded as the number of days from

Table 2. Details of the experimental field's treatment

Treatment number	Treatment detail
T_1	100% RDF (control)
T_2	75% of RDF
T_3	25 mL Jeevamrit
T_4	50 mL Jeevamrit
T_5	75 mL Jeevamrit
T_6	25 mL Panchgavya
T_7	50 mL Panchgavya
T_8	75 mL Panchgavya
T_9	100% RDF + 25 mL Jeevamrit
T_{10}	100% RDF + 50 mL Jeevamrit
T_{11}	100% RDF + 75 mL Jeevamrit
T_{12}	100% RDF + 25 mL Panchgavya
T_{13}	100% RDF + 50 mL Panchgavya
T_{14}	100% RDF + 75 mL Panchgavya
T_{15}	75% of RDF + 25 mL Jeevamrit
T_{16}	75% of RDF + 50 mL Jeevamrit
T_{17}	75% of RDF + 75 mL Jeevamrit
T_{18}	75% of RDF + 25 mL Panchgavya
T_{19}	75% of RDF + 50 mL Panchgavya
T_{20}	75% of RDF + 75 mL Panchgavya

RDF – recommended dose of fertiliser

Table 3. Nutrient and microbial status of Jeevamrit and Panchgavya

Parameters	Jeevamrit	Panchgavya
Nutrient Status		
pH	7.9	6.78
EC (ds/m)	5.9	1.93
Total N (%)	5.1	0.4
Total P (mg/L)	170.4	184.7
Total K (mg/L)	238.6	191.2
Total Fe (mg/L)	16.41	33.32
Total Cu (mg/L)	0.62	0.88
Total Zn (mg/L)	2.73	1.43
Total Mn (mg/L)	3.85	2.16
Microbial status		
Bacteria (CFU)	11.3×10^6	19.3×10^6
Fungi (CFU)	6.4×10^4	8.3×10^4
Actinomycetes (CFU)	7.8×10^4	10.7×10^4
Dehydrogenase (μg/mL)	3.75	76.37
Phosphate (μg/mL)	7.61	38.16

pH – potential of hydrogen; EC – electrical conductivity; N – nitrogen; P – phosphorus; K – potassium; Fe – iron; Cu – copper; Zn – zinc; Mn – manganese; CFU – colony forming units

https://doi.org/10.17221/15/2024-HORTSCI

planting until the first flower reached the harvesting stage (when 40–60% of florets showed colour). The number of flowering stems per plant was counted at peak flowering. The number of florets per stem was determined by counting all florets on five randomly selected stems from each plant. Flower diameter was measured as the average distance between the apices of the distal florets from east to west and north to south directions, based on five randomly selected fully opened flowers from each plant. Data was collected from all 4 plants, and statistical analysis was performed using their mean values.

Soil nutrients and microbial parameters. Data was recorded for a total of 4 consecutive flower flushes. After each flower flush was harvested, 4 samples of the growing media from 0 to 0.15 m depth were taken from each treatment and a composite sample was prepared. Samples were pulverised using a pestle and mortar after being air-dried in the shade and sieved through a 2 mm sieve. The pH level was determined through potentiometric analysis utilising a 1 : 2 soil-to-water suspension, alongside measuring electrical conductivity using the Wheatstone bridge circuit method with the same 1 : 2 soil-to-water suspension (Jackson 1973). The available N was determined using the alkaline potassium permanganate technique, following the procedures outlined by Subbiah and Asija (1956). P content in the soil was quantified using Olsen's extractant (sodium bicarbonate) method and measured on a UV spectrophotometer (NUKES, Canada) at a wavelength of 660 nm (Olsen et al. 1954). Available K was assessed using the ammonium acetate method, and its content was measured using a flame photometer (Systronics India Ltd., Gujarat) (Merwin, Peech 1951). Bacterial colonies were counted using the serial dilution method; the media used was prepared in accordance with Atlas (1995), and the population was expressed as colony forming units (CFU) per gram of dried soil. The number of fungi spores was determined using the wet-sieving and decanting method (Gerdemann, Nicolson 1963).

Statistical analysis. The recorded data were analysed using SPSS version 21 statistical software (SPSS, Chicago, IL, USA) and MS Excel. According to Panse and Sukhatme (1995), variance analysis for a randomised block design (RBD) was performed. Duncan's multiple range test (DMRT) was applied to compare the differences among treatment means.

RESULTS

Synergistic effect of bio-organic and inorganic nutrients on alstroemeria growth and flowering attributes. Integrated use of bio-organic and inorganic nutrients improved the alstroemeria growth and flowering attributes significantly (Figure 4 and Table 4). Treatment T_{14} exhibited the tallest plant height, reaching 1.2 m, representing a 7.89% increase compared to the control/RDF (T_1). Additionally, it surpassed the sole application of Jeevamrit (T_5) by 11.82%, the sole application of Panchgavya (T_8) by 9.82%, and even outperformed the

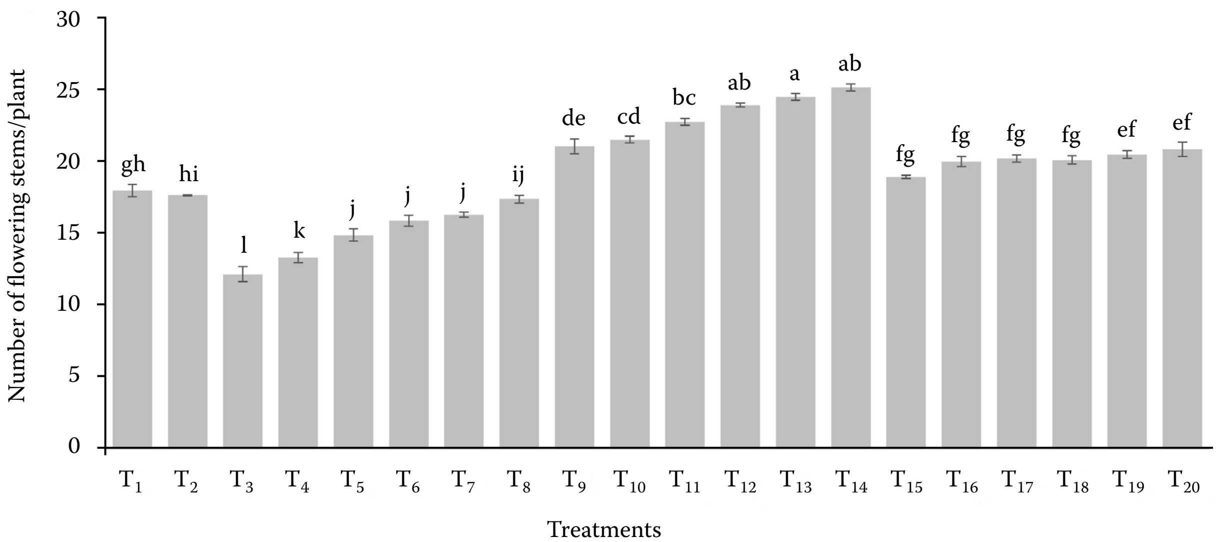

Figure 4. Effect of different treatments on the number of stems per plant in alstroemeria
For treatment detail (T_1–T_{20}) see Table 2

https://doi.org/10.17221/15/2024-HORTSCI

Table 4. Synergistic effect of bio-organic and inorganic plant nutrients on alstroemeria cv. 'Capri' growth and flowering characteristics (pooled data of 2 years)

Treatments	Plant height (m)	Plant spread (m)	Number of days taken to flowering	Number of florets/stem	Flower diameter (mm)
T_1	$1.14^{c–h} \pm 0.02$	$0.58^{ij} \pm 0.02$	$118.42^{def} \pm 0.55$	$15.73^{gh} \pm 0.44$	$50.87^{def} \pm 1.05$
T_2	$1.14^{c–h} \pm 0.01$	$0.51^{l} \pm 0.02$	$118.92^{de} \pm 0.63$	$15.04^{hi} \pm 0.04$	$50.13^{ef} \pm 0.58$
T_3	$1.07^{i} \pm 0.01$	$0.50^{l} \pm 0.01$	$121.83^{a} \pm 0.11$	$10.14^{l} \pm 0.53$	$43.9^{g} \pm 0.85$
T_4	$1.08^{i} \pm 0.03$	$0.51^{l} \pm 0.01$	$121.17^{ab} \pm 0.19$	$11.28^{k} \pm 0.36$	$44.23^{g} \pm 0.99$
T_5	$1.10^{hi} \pm 0.03$	$0.53^{kl} \pm 0.02$	$120.33^{bc} \pm 0.58$	$13.84^{j} \pm 0.43$	$47.80^{fg} \pm 1.46$
T_6	$1.11^{e–i} \pm 0.03$	$0.55^{jk} \pm 0.02$	$120.50^{bc} \pm 0.35$	$13.96^{j} \pm 0.37$	$48.40^{fg} \pm 1.22$
T_7	$1.12^{d–i} \pm 0.01$	$0.55^{jk} \pm 0.02$	$119.50^{cd} \pm 0.25$	$14.03^{j} \pm 0.17$	$48.50^{fg} \pm 0.90$
T_8	$1.12^{d–i} \pm 0.02$	$0.64^{efg} \pm 0.01$	$118.92^{de} \pm 1.18$	$14.38^{ij} \pm 0.27$	$49.30^{ef} \pm 0.36$
T_9	$1.18^{a–d} \pm 0.01$	$0.67^{cde} \pm 0.01$	$116.00^{ijk} \pm 0.59$	$17.71^{de} \pm 0.53$	$57.20^{abc} \pm 1.44$
T_{10}	$1.20^{abc} \pm 0.02$	$0.68^{bcd} \pm 0.02$	$115.33^{jk} \pm 0.27$	$18.06^{cd} \pm 0.24$	$58.23^{abc} \pm 1.00$
T_{11}	$1.21^{ab} \pm 0.02$	$0.69^{abc} \pm 0.02$	$117.63^{e–h} \pm 0.37$	$18.79^{bc} \pm 0.24$	$58.40^{abc} \pm 0.91$
T_{12}	$1.21^{ab} \pm 0.02$	$0.71^{ab} \pm 0.01$	$116.56^{hij} \pm 0.38$	$19.17^{ab} \pm 0.15$	$59.30^{ab} \pm 0.60$
T_{13}	$1.22^{ab} \pm 0.02$	$0.72^{a} \pm 0.02$	$115.00^{k} \pm 0.03$	$19.92^{a} \pm 0.24$	$60.23^{a} \pm 0.77$
T_{14}	$1.23^{a} \pm 0.02$	$0.63^{fgh} \pm 0.02$	$113.08^{i} \pm 0.34$	$19.65^{ab} \pm 0.26$	$61.10^{a} \pm 0.51$
T_{15}	$1.16^{b–g} \pm 0.02$	$0.61^{ghi} \pm 0.01$	$118.00^{efg} \pm 0.12$	$16.04^{fg} \pm 0.12$	$51.80^{def} \pm 0.95$
T_{16}	$1.17^{a–f} \pm 0.01$	$0.63^{fgh} \pm 0.01$	$118.42^{def} \pm 0.55$	$15.73^{gh} \pm 0.44$	$53.83^{cde} \pm 2.50$
T_{17}	$1.17^{a–e} \pm 0.01$	$0.64^{efg} \pm 0.02$	$118.92^{de} \pm 0.63$	$15.04^{hi} \pm 0.04$	$54.00^{cde} \pm 3.06$
T_{18}	$1.18^{a–d} \pm 0.01$	$0.65^{def} \pm 0.02$	$121.83^{a} \pm 0.11$	$10.14^{l} \pm 0.53$	$54.87^{bcd} \pm 2.48$
T_{19}	$1.18^{a–d} \pm 0.01$	$0.65^{def} \pm 0.01$	$121.17^{ab} \pm 0.19$	$11.28^{k} \pm 0.36$	$55.07^{bcd} \pm 1.57$
T_{20}	$1.18^{a–d} \pm 0.01$	$0.60^{hi} \pm 0.01$	$120.33^{bc} \pm 0.58$	$13.84^{j} \pm 0.43$	$56.87^{abc} \pm 1.82$
Significance	*	*	*	*	*

For treatment detail (T_1–T_{20}) see Table 2

*significant

$^{a–l}$values in each column preceded by the same letter are not significantly different from one another ($P \leq 0.05$)

combined application of RDF and Jeevamrit (T_{11}) by 1.65%. Treatment T_{13} demonstrated the widest plant spread, measuring 0.7 m. It exceeded the control (T_1) by 22.41%, Jeevamrit (T_5) by 33.96%, Panchgavya (T_8) by 10.94%, and the combined application of RDF and Jeevamrit (T_{11}) by 2.90% in terms of plant spread. Early flowering is crucial for cut flower crops, with T_{14} exhibiting early flowering at 113.1 days, which was 4.51% earlier than the control (T_1), 6.02% earlier than Jeevamrit (T_5), 4.91% earlier than Panchgavya (T_8), and 3.86% earlier than the combined application of RDF and Jeevamrit (T_{11}). Moreover, T_{14} also boasted the highest number of flowering stems per plant at 25.3, surpassing the control (T_1) by 39.86%, Jeevamrit (T_5) by 68.87%, Panchgavya (T_8) by 44.58%, and RDF and Jeevamrit (T_{11}) by 10.51% (Figure 4).

In treatment T_{13}, the maximum number of florets per stem was recorded (19.9), marking a 26.61% increase over the control (T_1), 43.93% over Jeevamrit (T_5), 38.51% over Panchgavya (T_8) and 6.01% over the combined application of RDF and Jeevamrit (T_{11}). As for flower diameter, T_{14} exhibited the largest diameter at 61.1 mm, surpassing the control (T_1) by 20.09%, Jeevamrit (T_5) by 27.85%, Panchgavya (T_8) by 23.95%, and RDF and Jeevamrit (T_{11}) by 4.62%. On the other hand, the minimum values for plant height (1.1 m), plant spread (0.5 m), number of flowering stems per plant (12.3), number of florets per stem (10.1), flower diameter (43.9 mm) and delayed flowering (121.8 days) were observed in treatment T_3.

Synergistic effect of bio-organic and inorganic nutrients on soil attributes. INM has a significant effect on soil fertility and microbial population. The soil pH and electrical conductivity (EC) remained consistent across all treatments without any significant differences observed. Treat-

https://doi.org/10.17221/15/2024-HORTSCI

Table 5. Synergistic effect of bio-organic and inorganic plant nutrients on chemical and microbial properties of rhizosphere soil in alstroemeria cv. 'Capri' (pooled data of 2 years)

Treatments	Soil pH	EC (dS/m)	Available N content (kg/ha)	Available P content (kg/ha)	Available K content (kg/ha)	Bacterial count (× 10^{-5} CFU/g of soil)	Fungal count (× 10^{-5} CFU/g of soil)
T_1	6.96 ± 0.04	0.37 ± 0.01	320.19^{i} ± 0.92	42.28^{ghi} ± 0.54	228.55^{g} ± 1.00	15.02^{fg} ± 0.21	3.11^{ef} ± 0.23
T_2	6.96 ± 0.01	0.37 ± 0.01	315.02^{j} ± 0.78	41.41^{hij} ± 0.69	225.09^{h} ± 0.48	14.68^{g} ± 0.30	2.78^{f} ± 0.17
T_3	6.99 ± 0.13	0.39 ± 0.02	295.16^{n} ± 1.12	34.71^{n} ± 1.02	200.51^{m} ± 1.54	16.25^{d-g} ± 0.74	3.41^{a-f} ± 0.19
T_4	6.99 ± 0.03	0.39 ± 0.03	297.52^{mn} ± 1.34	36.21^{mn} ± 0.6	203.3^{lm} ± 0.96	16.52^{c-g} ± 0.36	3.45^{a-f} ± 0.12
T_5	6.99 ± 0.01	0.39 ± 0.01	300.32^{lm} ± 1.53	36.94^{lmn} ± 0.81	205.3^{l} ± 1.03	17.12^{b-f} ± 0.46	3.51^{a-f} ± 0.12
T_6	6.97 ± 0.12	0.39 ± 0.02	303.02^{l} ± 1.85	37.78^{klm} ± 1.18	210.14^{k} ± 0.98	15.32^{fg} ± 0.48	3.25^{def} ± 0.31
T_7	6.97 ± 0.06	0.42 ± 0.02	309.79^{k} ± 1.35	39.11^{jkl} ± 0.55	215.3^{j} ± 0.49	15.78^{efg} ± 0.73	3.28^{c-f} ± 0.40
T_8	6.97 ± 0.01	0.42 ± 0.03	313.02^{jk} ± 1.06	40.11^{ijk} ± 0.83	221.30^{i} ± 1.39	15.95^{efg} ± 0.54	3.35^{b-f} ± 0.24
T_9	6.97 ± 0.04	0.47 ± 0.01	341.75^{d} ± 1.22	47.23^{cde} ± 0.98	251.98^{c} ± 1.54	19.28^{ab} ± 0.69	4.253^{ab} ± 0.13
T_{10}	6.99 ± 0.10	0.47 ± 0.01	346.95^{c} ± 1.34	48.06^{bcd} ± 0.39	255.02^{bc} ± 1.57	19.32^{ab} ± 0.56	4.287^{ab} ± 0.52
T_{11}	7.02 ± 0.01	0.47 ± 0.04	348.59^{bc} ± 1.31	49.56^{bc} ± 1.22	256.90^{ab} ± 1.64	19.68^{a} ± 1.11	4.33^{a} ± 0.26
T_{12}	7.06 ± 0.09	0.47 ± 0.01	351.92^{b} ± 2.24	50.23^{b} ± 0.48	258.36^{ab} ± 0.92	19.22^{ab} ± 1.03	4.01^{a-e} ± 0.06
T_{13}	7.05 ± 0.01	0.45 ± 0.01	356.29^{a} ± 0.98	54.23^{a} ± 1.05	258.98^{a} ± 1.11	19.25^{ab} ± 1.47	4.077^{a-d} ± 0.26
T_{14}	7.05 ± 0.10	0.45 ± 0.02	357.12^{a} ± 1.53	54.54^{a} ± 0.68	260.02^{a} ± 0.71	19.26^{ab} ± 0.47	4.21^{abc} ± 0.28
T_{15}	7.01 ± 0.07	0.42 ± 0.03	323.22^{hi} ± 1.46	42.78^{gh} ± 1.58	230.26^{g} ± 1.29	18.02^{a-e} ± 0.67	3.68^{a-f} ± 0.37
T_{16}	7.00 ± 0.06	0.39 ± 0.02	325.22^{gh} ± 1.50	43.937^{fgh} ± 0.78	235.77^{f} ± 1.56	18.48^{a-d} ± 0.85	3.78^{a-e} ± 0.16
T_{17}	6.99 ± 0.14	0.36 ± 0.01	327.99^{fg} ± 1.18	44.64^{efg} ± 0.33	239.99^{e} ± 1.25	18.98^{ab} ± 0.53	3.91^{abcde} ± 0.20
T_{18}	6.99 ± 0.05	0.36 ± 0.01	331.79^{f} ± 1.39	46.26^{def} ± 0.33	244.69^{d} ± 1.34	17.65^{a-e} ± 0.86	3.501^{a-f} ± 0.37
T_{19}	7.00 ± 0.01	0.36 ± 0.01	336.85^{e} ± 0.37	47.03^{cde} ± 0.88	246.82^{d} ± 0.84	18.25^{a-d} ± 0.52	3.71^{a-f} ± 0.22
T_{20}	6.94 ± 0.08	0.36 ± 0.03	339.75^{de} ± 2.06	46.73^{de} ± 0.53	246.4^{d} ± 0.79	18.75^{abc} ± 0.90	3.78^{a-e} ± 0.32
Significance	ns	ns	*	*	*	*	*

For treatment detail (T_1–T_{20}) see Table 2
pH – power of hydrogen; EC – electrical conductivity; N – nitrogen; P – phosphorus; K – potassium; ns – non-significant
*significant
$^{a-l}$values in each column preceded by the same letter are not significantly different from one another ($P \leq 0.05$)

https://doi.org/10.17221/15/2024-HORTSCI

ment T_{14} exhibited the highest available N content at 357.1 kg/ha, showcasing an 11.53% increase compared to the control (T_1). Additionally, it demonstrated an 18.87% increase over the sole application of Jeevamrit – 75 mL (T_5), a 14.09% increase compared to the sole application of Panchgavya – 75 mL (T_8) and even a 2.45% increase over the combined application of RDF and Jeevamrit – 75 mL (T_{11}). Treatment T_{14} yielded the highest P content recorded at 54.5 kg/ha, surpassing T_1 (control) by 28.88%, T_5 (Jeevamrit) by 47.68%, T_8 (Panchgavya) by 36.00% and T_{11} (RDF and Jeevamrit) by 10.05%. K content was found to be maximum (260.0 kg/ha) in T_{14}. It was found 13.75%, 26.66%, 17.49%, and 1.21% higher than T_1 (control), T_5 (Jeevamrit), T_8 (Panchgavya) and T_{11} (RDF and Jeevamrit), respectively for soil K. Treatment T_{11} exhibited the highest bacterial colonies recorded at 19.7×10^{-5} CFU/g of soil, marking a 31.08% increase over the control (T_1), a 14.94% increase compared to the sole application of Jeevamrit – 75 mL (T_5), a 23.28% increase compared to the sole application of Panchgavya – 75 mL (T_8) and a 2.18% increase compared to the combined application of RDF and Panchgavya – 75mL (T_{11}). Treatment T_{11} displayed the highest fungal colonies recorded at 4.3×10^{-5} CFU/g of soil, representing a 39.23% increase over the control (T_1), a 23.36% increase compared to the sole application of Jeevamrit – 75 mL (T_5), a 29.25% increase compared to the sole application of Panchgavya – 75 mL (T_8) and a 2.85% increase compared to the combined application of RDF and Panchgavya – 75mL (T_{11}). On the other hand, treatment T_3 exhibited the minimum available N, P, and K content, recorded at 295.2 kg/ha, 34.7 kg/ha, and 200.5 kg/ha, respectively. The lowest counts of bacterial and fungal colonies were found in treatment T_2, with 14.7×10^{-5} CFU/g of soil and 2.8×10^{-5} CFU/g of soil, respectively (Table 5).

DISCUSSION

Growth and flowering parameters. The application of RDF and Panchgavya increased the parameters that determine vegetative growth (plant height and plant spread). Maximum plant height was noted with the application of 100% RDF + 75 mL Panchgavya, and plant spread was noted to be maximum with the application of 100% RDF + 50 mL Panchgavya. The balanced nutrition was added for crop growth, and the quick and greater availability of plant nutrients improved the environment for root growth and proliferation, which in turn led to more vegetative mass being produced (Mujawar 2013). Tender coconut water, in Panchgavya, contains kinetin, which helps to increase the amount of chlorophyll in leaves that promotes growth and photosynthetic activity (Gore, Sreenivasa 2011). Rajiv et al. (2018) reported that application of vermicompost @ 5 t/ha + 75% RDF + Azophos 2 kg/ha + Panchagavya @ 3% + humic acid @ 1% increased plant height by 29.2% and plant spread by 59.86% over 100% RDF in *Jasminum auriculatum* L. Vimalendran and Wahab (2013) observed comparable increases in both plant height and spread when applying RDF along with four foliar sprays (administered at 15, 25, 35, and 45 days after sowing) of 3% Panchagavya in *Zea mays*.

The application of NPK at the recommended levels (100% RDF + 75 mL Panchgavya) resulted in early flowering. The improved absorption of nutrients by plants allowed them to complete the necessary vegetative phase faster. Furthermore, Panchgavya treatment may have accelerated the endogenous production of auxins, which could result in early growth and flowering (Sutar et al. 2019). Kumar et al. (2011) reported that applying a common basal dose + vermicompost 5t/ha + Panchagavya 3% resulted in early flowering by 4 days, i.e. 3.34% earliness over control plants in gladiolus. A similar result of early flowering by 37.34% over the control with the application of 50% RDF and 3% Panchgavya was also reported by Renukaradya et al. (2011) in carnation.

According to Healy et al. (1982), nutrition may play an important role in regulating flowering. Improved flowering attributes may be due to the balanced nutrient supply from fertilisers, which ensures the plant receives essential elements. At the same time, the organic inputs contribute to enhanced soil fertility, microbial activity and the presence of growth promoting substances that stimulate hormone production and influence physiological processes, ultimately leading to enhanced and robust flowering in alstroemeria. Application of 100% RDF + 75 mL Panchgavya resulted in a greater number of flowering stems per plant and flower diameter. Application of 100% RDF + 50 mL Panchgavya resulted in increased florets per stem. Similar results of a larger number of flowering stems (55.02%) were also recorded by Shrikant et al. (2015) in gerbera with the application of 100% RDF + 3% Panchgavya and 0.1% humic acid over the control. According to Waheeduzzama et al. (2013), the application of Panch-

https://doi.org/10.17221/15/2024-HORTSCI

gavya 3% and 50% RDF resulted in increased spathe breadth (7.69%) over the control in anthurium. A 46.94% increase was seen in the number of florets per stem in gladiolus when the combination of common basal dose + vermicompost 5 t/ha + Panchagavya 3% was applied (Kumar et al. 2011). Biostimulants' biochemical properties revealed that they possess nearly all of the major nutrients, such as N, P and K, along with micronutrients and growth hormones, like IAA (indole-3-acetic acid) and GA, which are essential for crop growth (Pathania et al. 2023). The combined application of RDF and Panchagavya enhanced alstroemeria's yield and flower quality parameters.

Results of the present experiment, when compared with the results of the other researchers in alstroemeria cv 'Capri', it was observed that there was an 18.27% increase in plant height, 16.94% in yield and 18.64% in flower diameter (Kashyap et al. 2018). Early flowering was observed by 13.10% when compared with the results of Negi et al. (2022) in alstroemeria cv 'Capri'. The cut stems produced were of A-grade, i.e. length/height ≥ 0.75 m (Kumar et al. 2023) with the integrated application of RDF and Panchagavya.

Soil nutrients and microbial parameters. Integrated application of RDF and Panchagavya improved soil macronutrient content. The increased mineralisation and enhanced conversion of organically bound N into readily available forms caused by the INM approach increased N availability in the growing medium, with the simultaneous enhancement in nutritional dose (Kachroo, Razdan 2006). In order to boost the availability of P in soil, biostimulants produce a variety of organic acids that solubilise phosphate and other phosphate-bearing minerals (Calvo et al. 2014). The amount of K that accumulated in the soil was dramatically impacted by varied NPK dosages combined with various biostimulant doses. The direct supplementation of K to the growing media's pool of readily available K and the release of K as a result of the organic matter and clay interaction are two possible explanations for this rise in available K content (Mitra et al. 2010). An increase in available N, P and K content in soil by 19.5%, 16.22% and 15.34%, respectively, has also been observed by Gopakkali and Sharanappa (2014) with the application of RDF 100% and 4% Panchgavya in rice. Colonies of naturally occurring effective microorganisms were improved with the combined application of 100 % RDF and 75 mL Jeevamrit. This is due to the presence of naturally existing advantageous microorganisms that were detected in biostimulants, primarily bacteria, actinomycetes and certain fungi (Devakumar et al. 2014). Additionally, organic manures and biostimulants serve as superior food for the soil microbial population and raise the amount of available N and carbon, directly influencing the population of microorganisms and their activity (Vaish et al. 2020). In a similar study by Rathore et al. (2023), the application of 90% RDF + 5% Panchgavya and 5% Jeevamrit in brinjal resulted in a higher amount of bacterial (40.49%) and fungal (37.89%) count in soil.

CONCLUSION

In conclusion, this study has investigated the relationship between bio-organic and inorganic nutrients in alstroemeria cultivation. Findings suggest that the application of 100% RDF in combination with 75 mL of Panchgavya improved the number of cut flower stems with larger flower diameters and more florets per stem. Additionally, it enhances soil nutrient content, including available N, P and K, while also promoting microbial populations. The results underscore the importance of adopting an integrated approach to nutrient management in alstroemeria cultivation to improve yield, enhance soil fertility, and ensure long-term environmental sustainability compared to the sole use of inorganic fertilisers.

Acknowledgement: The authors are grateful to the Department of Floriculture and Landscape Architecture, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India, for providing research infrastructure for conducting the experiment. The authors would like to extend their sincere appreciation to the Researchers Supporting Project Number (RSP2025R134), King Saud University, Riyadh, Saudi Arabia.

REFERENCES

Adebayo I.A., Pam V.K., Arsad H., Samian M.R. (2020): The global floriculture industry: Status and future prospects. Chapter 1. In: Hakeem K.R. (ed.): The Global Floriculture Industry: Shifting Directions, New Trends and Future Prospects. 1st Ed. New York, Apple Academic Press: 1–14.

https://doi.org/10.17221/15/2024-HORTSCI

Anand M., Kamalkumaran P.R., Nanthakumar S. (2020): Open field cut flowers – Alstroemeria. Biotica Research Today, 2: 166–167.

Aros D., Suazo M., Rivas C., Zapata P., Úbeda C., Bridgen M. (2019): Molecular and morphological characterization of new interspecific hybrids of alstroemeria originated from *A.* c*aryophylleae* scented lines. Euphytica, 215: 93.

Atlas R.M. (1995): Handbook of Media for Environmental Microbiology. New York, CRC Press.

Calvo P., Nelson L., Kloepper J.W. (2014): Agricultural uses of plant biostimulants. Plant and Soil, 383: 3–41.

Das S.K., Mishra V.K., Laha R., Devi E.L., Bhutia T.L. (2023): Integrated organic nutrient management for soil and plant health management under organic and natural farming. Indian Farming, 73: 28–31.

Devakumar N., Shubha S., Gouder S.B., Rao G.G.E. (2014): Microbial analytical studies of traditional organic preparations beejamrit and jeevamrutha. In: Proceedings of the 4th ISOFAR Scientific Conference. Building Organic Bridges, Istanbul, October 13–15, 2014: 639–642.

Dhiman M.R., Kashyap B. (2021): *Alstroemeria*: Conservation, characterization, and evaluation. Chapter 5. In: Datta S.K., Gupta Y.C. (eds): Floriculture and Ornamental Plants. Handbooks of Crop Diversity: Conservation and Use of Plant Genetic Resources. Singapore, Springer: 117–151.

Gerdemann J.W., Nicolson T.H. (1963): Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting. Transactions of the British Mycological Society, 46: 235–244.

Gopakkali P., Sharanappa (2014): Effect of organic production techniques on the growth, yield, quality and economics of chilli (*Capsicum annuum*) and soil quality in dry zone of Karnataka. Indian Journal of Agronomy, 59: 151–156.

Gore N., Sreenivasa M. (2011): Influence of liquid organic manures on growth, nutrient content and yield of tomato (*Lycopersicon esculentum* Mill.) in the sterilized soil. Karnataka Journal of Agricultural Sciences, 24: 153–157.

Healy W.E., Wilkins H.F., Celusta M. (1982): Role of light quality, photoperiod and high-intensity supplemental lighting on flowering of *Alstroemeria* 'Regina'. Journal of the American Society for Horticultural Science, 107: 1046–1049.

Jackson M.L. (1973): Soil Chemical Analysis. New Delhi, Prentice Hall of India Private Limited.

Kachroo D., Razdan R. (2006): Growth, nutrient uptake and yield of wheat (*Triticum aestivum*) as influenced by biofertilizers and nitrogen. Indian Journal of Agronomy, 51: 37–39.

Kashyap B., Dhiman S.R., Sharma P., Gupta Y.C., Sharma M. (2018): Evaluation of different genotypes of Peruvian lily (*Alstroemeria hybrida* L.) under Nauni, Solan, Himachal Pradesh conditions. International Journal of Farm Sciences, 8: 17–21.

Kumar A., Avasthe R.K., Babu S., Singh R., Verma G., Dhaka A.K., Kumar S., Saha S., Devi E., Bhupenchandra I., Gudade B.A., Hasanain M. (2021): Jeevamrut: A low cost organic liquid manure in organic farming for sustainable crop production. Kerala Karshakan e-journal, 9: 32–34.

Kumar A., Kashyap B., Dhiman S.R., Pathania S. (2023): Advances in production technology of Alstroemeria. Chapter 1. In: Kumar A., Prakash S., Shreekant, Singh S., Veeresh (eds). Advances in Production Technology of Commercial Flowers. 1st Ed. Delhi, Integrated Publication: 3–16.

Kumar R., Kumar R., Kumar P. (2011): Effect of integrated use of chemical fertilizers, biofertilizers and biostimulants in gladiolus (*Gladiolus grandiflorus* L.) cv. Sancerre. Progressive Horticulture, 43: 149–152.

Markets and Markets (2023): Cut flowers market by type (rose, chrysanthemum, carnation, gerbera, lilium), application (home & commercial), distribution channel (supermarkets & hypermarkets, specialty stores/florists, online retail) and region – Global forecast to 2027. Available at https://www.marketsandmarkets.com/Market-Reports/cut-flowers-market-18187231.html (accessed May 8, 2024).

Merwin H.D., Peech M. (1951): Exchangeability of soil potassium in the sand, silt and clay fractions as influenced by the nature and complementary exchangeable cation. Soil Science Society of America Journal, 15: 125–128.

Mitra S., Roy A., Saha A.R., Maitra D.N., Sinha M.K., Mahapatra B.S., Saha S. (2010): Effect of integrated nutrient management on fibre yield, nutrient uptake and soil fertility in jute (*Corchorus olitorius*). Indian Journal of Agricultural Sciences, 80: 801–804.

Mujawar J.U. (2013): Effect of organic and inorganic sources of nutrients on soil fertility and yield of brinjal (*Solanum melongena* L.). [MSc. Thesis.] Dharwad, College of Agriculture in Dharwad: 1–91.

Negi R., Kashyap B., Dhiman S.R., Sharma P., Gupta R.K. (2023): Standardization of growing medium for growth and flowering of alstroemeria cv. 'Capri' under Solan-Nauni conditions. International Journal of Bio-resource and Stress Management, 13: 1296–1301.

Olsen S.R., Cole C.V., Watanable F.S., Dean L.A. (1954): Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. United States Department of Agriculture Circular No. 939. Washington, D.C., US Government Printing Office.

Pahalvi H.N., Rafiya L., Rashid S., Nisar B., Kamili A.N. (2021). Chemical fertilizers and their impact on soil health. Chapter 1. In: Dar G.H., Bhat R.A., Mehmood M.A., Hakeem K.R. (eds): Microbiota and Biofertilizers. Volume 2. Switzerland, Springer Cham: 1–20.

Palekar S. (2006): Text Book on Shoonya Bandovalada Naisargika Krushi. Bangalore, Swamy Anand, Agri Prakashana.

Panse V.G., Sukhatme P.V. (1995): Statistical Methods of Agricultural Workers. New Delhi, Indian Council of Agricultural Research.

Pathania S., Dilta B.S., Kumar A. (2023): Response of biostimulants on growth, flowering, seed yield and quality of China aster [*Callistephus chinensis* (L.) Nees]. International Journal of Bio-resource and Stress Management, 14: 1108–1115.

Rajiv G., Sha K., Madhavan S., Thirupathi M. (2018): Effect of integrated nutrient management on growth and flower yield of mullai (*Jasminum auriculatum* L.). Agricultural Research Journal, 55: 380–382.

Ranjan P., Ranjan J.K., Das B., Ahmed N. (2013): High value flower cultivation under low cost greenhouse in NW Himalayas. International Journal of ChemTech Research, 5: 789–794.

Rathore G., Kaushal R., Sharma V., Sharma G., Chaudhary S., Dhaliwal S.S., Alsuhaibani A.M., Gaber A., Hossain A. (2023): Evaluation of the usefulness of fermented liquid organic formulations and manures for improving the soil fertility and productivity of brinjal (*Solanum melongena* L.). Agriculture, 13: 417.

Renukaradya S., Pradeepkumar C.M., Santhosha H.M., Dronachari M., Shashikumar R.S. (2011): Effect of integrated system of plant nutrition management on growth, yield and flower quality of carnation (*Dianthus caryophyllus* L.) under green house. The Asian Journal of Horticulture, 6: 106–112.

Shrikant S., Jawaharlal M.M., Ganga M. (2015): Optimization of fertigation level and biostimulants on gerbera (*Gerbera jamesonii* Bolus ex Hooker f.) var Debora under polyhouse conditions. Environment and Ecology, 33: 321–325.

Shraddha, Shukla Y.R., Thakur K., Vashishat R.K., Sharma S., Chandel R.S., Dhingra S., Alam T., Khargotra R., Jyoti K. (2023): Impact of fermented organic formulations combined with inorganic fertilizers on broccoli (*Brassica oleracea* L. var. *italica* Plenck) cv. Palam Samridhi. Heliyon, 9: e20321.

Singh J., Dilta B.S., Baweja H.S., Kumar V. (2017): Impact of growing media and NPK on growth and flowering of Alstroemeria cv. Capri. Bulletin of Environment, Pharmacology and Life Sciences, 6: 16–21.

Subbiah B.V., Asija G.L. (1956): A rapid procedure for estimation of available nitrogen in soils. Current Science, 25: 259–260.

Sutar R., Sujith G.M., Devakumar N. (2019): Growth and yield of Cowpea [*Vigna unguiculata* (L.) Walp] as influenced by jeevamrutha and panchagavya application. Legume Research, 42: 824–828.

Vaish S., Garg N., Ahmad I.Z. (2020): Microbial basis of organic farming systems with special reference to biodynamic preparations. Indian Journal of Agricultural Sciences, 90: 1219–1225.

Vimalendran L., Wahab K. (2013): Effect of foliar spray of Panchagavya on yield attributes, yield and economics of babycorn. Journal of Agronomy, 12: 109–112.

Waheeduzzama M., Jawaharlal M., Arulmozhiyan R., Raja N.A. (2013): Standardization of integrated nutrient management practices to improve flower yield and quality in *Anthurium andreanum* cv. Meringue. Madras Agricultural Journal, 100: 469–472.

Walkley A., Black I.A. (1934): An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29–38.

Received: January 23, 2024
Accepted: November 6, 2024
Published online: May 23, 2025