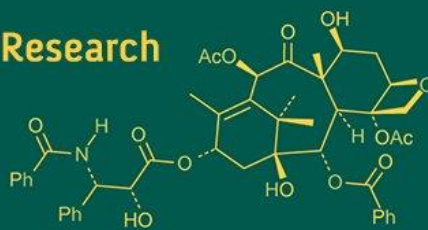


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Effect of sustainable nutrient management on growth and flowering of Lisianthus (*Eustoma grandiflorum* Shinn.) var. Rosita 3 bright blue under protected cultivation

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Abstract

The present investigation entitled “Studies on sustainable nutrient management for growth and flowering of lisianthus var. Rosita 3 Bright Blue under protected cultivation” was conducted during 2025-26 at the Department of Horticulture, College of Agriculture, Shivamogga. The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments, viz., T₁ (100% RDF), T₂ (70% N + 100% PK + *Azotobacter*), T₃ (70% P + 100% NK + PSB), T₄ (70% K + 100% NP + KSB), T₅ (80% N + 100% PK + *Azotobacter*), T₆ (80% P + 100% NK + PSB), T₇ (80% K + 100% NP + KSB), T₈ (70% RDF + *Azotobacter* + PSB + KSB) and T₉ (80% RDF + *Azotobacter* + PSB + KSB), each replicated thrice. The results revealed that application of 80 percent RDF + *Azotobacter* + PSB + KSB recorded maximum plant height (82.50 cm), plant spread (12.66 cm E-W and 12.92 cm N-S), internodal length (6.40 cm), stem girth (4.99 mm), number of leaves (40.13), leaf area (56.26 cm²), branches per plant at peak growth stage (3.30). The same treatment also resulted in early flower bud initiation (67.37 days), flower opening (77.80 days), 50 percent flowering (81.87 days), flower stalk harvesting (85.13 days) and the longest flowering duration (22.47 days). Hence, application of 80 percent RDF + *Azotobacter* + PSB + KSB effectively enhanced vegetative growth and flowering while reducing chemical fertilizer requirement by 20 percent, thereby promoting sustainable lisianthus production under protected cultivation.

Keywords: Lisianthus, sustainable nutrient management, biofertilizers, protected cultivation, flowering

Introduction

Floriculture is a specialized branch of horticulture concerned with the cultivation of flowering and ornamental plants for gardens, landscaping and cut flower production. It contributes significantly to beautification of surroundings and improvement of environmental conditions. In recent years, floriculture has gained importance as a commercially viable sector due to increasing demand for decorative flowers in both domestic and global markets. Lisianthus (*Eustoma grandiflorum*), commonly called ‘Prairie Gentian’ and ‘Texas Blue Bell’ is a member of the family Gentianaceae (2n = 36) (Halevy and Kofranek, 1984) [5]. The genus *Eustoma* is derived from the Greek words *eu*, meaning “beautiful,” “good,” or “well” and *stoma*, meaning “mouth,” referring to the attractive, well-shaped flowers of the plant. It native to warm regions of Northern-South America, Southern-United States, Mexico and the Caribbean islands.

It is an annual to short-lived perennial herb growing up to 80 cm in height. It possesses simple, opposite, sessile, bluish-green slightly succulent leaves and attractive bell-shaped flowers borne singly or in terminal panicles on long pedicels. The flowers occur in shades of purple, lavender, pink and white. The plant bears 5-6 stamens with yellow linear anthers, a slender style with a bilobed stigma and produces ellipsoid, two-valved capsules containing numerous minute, reticulate seeds. It grows best under a moderate climate with temperatures ranging from 16-24 °C and a light intensity of 4,000-6,000 foot-candles. It is commercially propagated through seeds and healthy seedlings with four to five pairs of true leaves are transplanted to the main field or protected cultivation structure for optimum establishment and growth.

Lisianthus is a heavy-feeding crop requiring relatively high levels of nitrogen and potassium for optimum vegetative growth and flower quality. Fertigation with nitrate-based nitrogen and adequate calcium supplementation is recommended to ensure balanced growth and to prevent physiological disorders such as tip burn, bud abortion and weak stems. Fertilizer application is generally reduced or discontinued after visible bud initiation to improve flower development and quality.

Sustainable nutrient management has emerged as an important approach in protected floriculture for enhancing crop productivity while reducing dependence on chemical fertilizers and maintaining soil health. Integration of inorganic fertilizers with beneficial biofertilizers improves nutrient availability, enhances nutrient use efficiency and promotes sustainable flower production. In Lisianthus, appropriate nutrient management plays a vital role in regulating vegetative growth and flowering under protected cultivation. Therefore, the present investigation entitled "Studies on Sustainable Nutrient Management for Growth, Flowering, Yield and Quality of Lisianthus (*Eustoma grandiflorum*) under Protected Cultivation" was undertaken with the following objectives:

1. To study the effect of sustainable nutrient management for growth of Lisianthus under protected cultivation.
2. To study the effect of sustainable nutrient management for flowering of Lisianthus under protected cultivation.

Materials and Methods

The present investigation was conducted during 2025-26 at the Department of Horticulture, College of Agriculture, Navile, Shivamogga, under a naturally ventilated polyhouse. The experimental site is situated at 13°55' N latitude and 75°34' E longitude, with an altitude of 650 m above mean sea level, representing the Southern Transition Zone (Zone VII) of Karnataka. The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising nine treatment combinations with three replications. The treatments consisted of T₁ (100% RDF), T₂ (70% N + 100% PK + *Azotobacter*), T₃ (70% P + 100% NK + PSB), T₄ (70% K + 100% NP + KSB), T₅ (80% N + 100% PK + *Azotobacter*), T₆ (80% P + 100% NK + PSB), T₇ (80% K + 100% NP + KSB), T₈ (70% RDF + *Azotobacter* + PSB + KSB) and T₉ (80% RDF + *Azotobacter* + PSB + KSB). Seedlings were transplanted at a spacing of 10 × 10 cm, accommodating 100 plants in each plot of 1.0 × 1.0 m².

The recommended fertilizer dose for lisianthus was 15 g N, 18 g P₂O₅ and 18 g K₂O m⁻², supplied through urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. The fertilizer quantities for the 70 and 80 percent RDF treatments were adjusted proportionately. During bed preparation, the entire dose of phosphorus and potassium along with half of the recommended nitrogen was applied as a basal application. The remaining half of the nitrogen was top-dressed at 30 days after transplanting (DAT). In addition to the basal fertilizer application, foliar nutrition was provided through water-soluble fertilizers, namely 19:19:19 (4 g L⁻¹), calcium nitrate (3 g L⁻¹) and micronutrients (0.5%), which were sprayed twice a week starting from 30 DAT. Biofertilizers, namely *Azotobacter chroococcum*, phosphate-solubilizing bacteria (PSB; *Bacillus megaterium*) and potassium-solubilizing bacteria (KSB; *Frateruria aurantia*), were applied at 2 g plant⁻¹ as per the treatments at the time of planting. In addition,

mycorrhiza and *Trichoderma* were applied uniformly at 2 kg ha⁻¹ in all treatments except control.

The observations were recorded from five randomly selected and tagged plants at appropriate stages of crop growth and were statistically analysed for growth and flowering parameters like plant height, spread of plant height, plant spread, internodal length, stem girth, leaf area, number of leaves, number of branches at peak growth stage, days taken for flower bud initiation, flower opening, 50 percent flowering, flower stalk harvesting and duration of flowering.

Results and Discussion

Growth parameters

The data presented in Table 1. shows that growth parameters were significantly affected by different nutrient combinations. The treatment receiving 80 percent RDF along with *Azotobacter*, PSB and KSB (T₉) recorded maximum plant height (82.50 cm), plant spread (12.66 cm and 12.92 cm in E-W and N-S direction, respectively), internodal length (6.40 cm), stem girth (4.99 mm), number of leaves (40.13 plant⁻¹), number of branches (3.30 plant⁻¹) and leaf area (56.26 cm²) which was followed by treatment T₈ (70 percent RDF along with *Azotobacter*, PSB and KSB) which recorded plant height (80.87 cm), plant spread of 11.95 cm (E-W) and 12.20 cm (N-S), internodal length (5.89 cm), stem girth (4.83 mm), number of leaves per plant (38.53), branches per plant (3.03) and leaf area (54.21 cm²). In contrast, the control treatment (T₁) recorded the minimum plant height (73.18 cm), plant spread of 10.74 cm (E-W) and 10.96 cm (N-S), internodal length (5.35 cm), stem girth (4.17 mm), number leaves per plant (34.80), branches per plant (2.50) and leaf area (47.80 cm²).

The superior growth performance observed under T₉ (80% RDF + *Azotobacter* + PSB + KSB) may be attributed to the synergistic effect of balanced inorganic fertilization and beneficial biofertilizers, which collectively enhanced nutrient availability, nutrient uptake and physiological efficiency of the plants. *Azotobacter* fixes atmospheric nitrogen and produces plant growth-promoting substances such as indole-3-acetic acid (IAA), gibberellins and cytokinins that stimulate root proliferation, meristematic activity, cell division and vegetative growth (Vessey, 2003; Richardson *et al.*, 2009) [18, 12]. This enhanced nitrogen availability promotes chlorophyll synthesis, protein formation and nucleic acid metabolism, resulting in increased plant height and vigorous vegetative growth, as also reported by Kumar *et al.* (2019) [10] in chrysanthemum, Verma *et al.* (2023) [17] in China aster and Kumari *et al.* (2024) [11] in lisianthus.

Phosphate-solubilizing bacteria (PSB) convert insoluble phosphorus into plant-available forms through the secretion of organic acids and phosphatase enzymes, thereby improving phosphorus uptake required for ATP synthesis, energy transfer, root development and rapid cell division (Richardson *et al.*, 2009) [12]. Adequate phosphorus availability promotes continuous leaf initiation, cell expansion and canopy development, resulting in increased plant spread, internodal length and leaf area. Similar findings were reported by Singh *et al.* (2019) [16] in marigold and Kumari *et al.* (2024) [11] in lisianthus.

Potassium-solubilizing bacteria (KSB) increase potassium availability by solubilizing mineral-bound potassium through the production of organic acids (Sheng and He,

2006) [15]. Potassium plays a crucial role in enzyme activation, stomatal regulation, carbohydrate translocation, osmotic adjustment and maintenance of cellular turgor, thereby enhancing stem girth, mechanical strength and overall plant vigour. Improved potassium nutrition also facilitates efficient translocation of photosynthates from source to sink, resulting in greater biomass accumulation and stronger flower-bearing stems, as reported by Sharma *et al.* (2025) [13].

The combined action of *Azotobacter*, PSB and KSB improved root growth, nutrient acquisition and nutrient use efficiency, leading to enhanced chlorophyll synthesis and photosynthetic activity (Vessey, 2003) [18]. Increased leaf area improved light interception and carbon assimilation, resulting in greater dry matter production and overall plant growth. Furthermore, cytokinins produced by *Azotobacter* promoted axillary bud development and reduced apical dominance, leading to a significantly higher number of branches (Richardson *et al.*, 2009) [18]. Similar improvements in vegetative growth under integrated nutrient management have also been documented by Kumar *et al.* (2019) [10] in chrysanthemum, Verma *et al.* (2023) [17] in China aster, Sharma *et al.* (2021) [14] in alstroemeria and

Kumari *et al.* (2024) [11] in lisianthus. Thus, the integration of 80 percent RDF with *Azotobacter*, PSB and KSB produced a complementary effect that enhanced vegetative growth while reducing chemical fertilizer application by 20 percent without compromising plant performance.

Flowering parameters

Among the treatments, T₉ (80% RDF + *Azotobacter* + PSB + KSB) recorded the minimum number of days to flower bud initiation (67.37 days), flower opening (77.80 days), 50 percent flowering (81.87 days) and flower stalk harvesting (85.13 days) along with the longest flowering duration (22.47 days). This was followed by the treatment T₈ (70% RDF + *Azotobacter* + PSB + KSB) which recorded 69.13 days flower bud initiation, 79.33 days flower opening, 83.67 days for 50 percent flowering, 87.20 days for flower stalk harvesting and 21.04 days of flowering duration. Conversely, the control treatment (T₁) resulted in maximum number of days for flower bud initiation (73.20 days), flower opening (84.53 days), 50 percent flowering (90.33 days) and flower stalk harvesting (93.33 days), while recording the minimum flowering duration (16.65 days) presented in Table 2.

Table 1: Effect of sustainable nutrient management on growth parameters of Lisianthus under protected cultivation

Treatments	Plant height (cm)	Number of leaves	Leaf area (cm ²)	Plant spread (cm)		Number of branches per plant	Internodal length (cm)	Stem girth (mm)
				E-W	N-S			
RDF-15:18:18 g of NPK per m ² (Control) (T ₁)	73.18	34.80	47.80	10.74	10.96	2.50	5.35	4.17
70% N + 100% PK + <i>Azotobacter</i> (T ₂)	73.97	35.07	49.45	11.21	11.32	2.57	5.56	4.27
70% P + 100% NK + PSB (T ₃)	74.38	35.07	49.88	11.24	11.45	2.60	5.60	4.32
70% K + 100% NP + KSB (T ₄)	75.33	35.87	50.11	11.45	11.61	2.77	5.76	4.46
80% N + 100% PK + <i>Azotobacter</i> (T ₅)	74.47	35.20	49.65	11.36	11.57	2.70	5.67	4.44
80% P + 100% NK + PSB (T ₆)	75.41	36.07	51.43	11.51	11.79	2.83	5.80	4.53
80% K + 100% NP + KSB (T ₇)	78.99	37.73	52.26	11.61	11.97	2.93	5.81	4.55
70% RDF + <i>Azotobacter</i> + PSB + KSB (T ₈)	80.87	38.53	54.21	11.95	12.20	3.03	5.89	4.83
80% RDF + <i>Azotobacter</i> + PSB + KSB (T ₉)	82.50	40.13	56.26	12.66	12.92	3.30	6.40	4.99
S.Em±	2.22	1.29	1.50	0.34	0.34	0.09	0.07	0.14
C.D at 5%	6.64	3.87	4.50	1.03	1.03	0.26	0.21	0.43

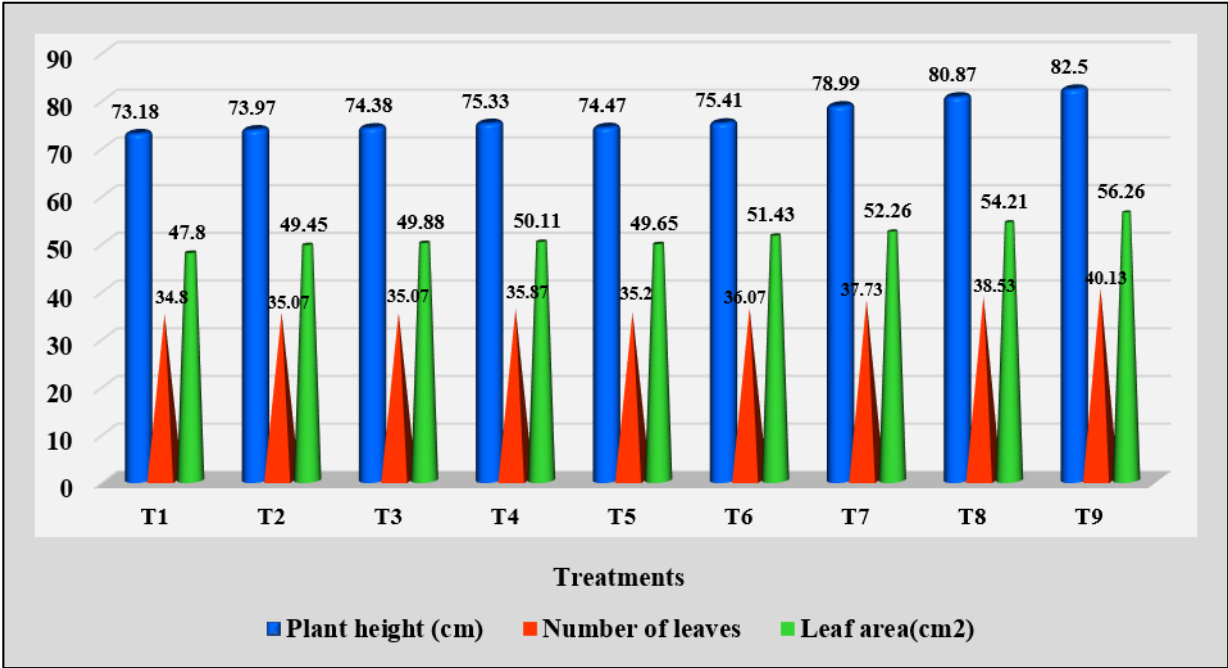


Fig 1: Effect of sustainable nutrient management on plant height, number of leaves and leaf area of Lisianthus under protected cultivation

The enhanced flowering behaviour observed under T₉ can be attributed to the synergistic effect of inorganic fertilizers and biofertilizers, which ensured a balanced and continuous supply of essential nutrients throughout the crop growth period. PSB increased the availability of phosphorus, a nutrient that plays a key role in energy transfer, ATP synthesis, cell division and floral differentiation, thereby accelerating the transition from vegetative to reproductive growth and promoting earlier flowering. Similarly, KSB improved potassium availability, which enhanced carbohydrate synthesis and translocation, supported floral bud development and flower maturation. *Azotobacter* further improved nitrogen availability and produced growth-promoting substances such as auxins and gibberellins, which stimulated protein synthesis, cell division, root development

and nutrient uptake efficiency. The combined action of these beneficial microorganisms along with 80 percent RDF accelerated floral induction, promoted rapid bud development and ensured synchronized reproductive growth, leading to earlier flower bud initiation, flower opening, 50 percent flowering and harvestable maturity. Similar beneficial effects of integrated nutrient management on flowering behaviour have been reported by Basoli *et al.* (2015) ^[3] in gladiolus, Akshatha *et al.* (2019) ^[1] in gerbera, Ayoub and Masoodi (2023) ^[2] in hyacinth, Indhumathi *et al.* (2023) ^[7] in gaillardia, Hadapad *et al.* (2024) ^[4] in alstroemeria, Harshavardhan *et al.* (2016) in carnation, Krushnaiah *et al.* (2018) ^[9] in Italian aster, Sharma *et al.* (2021) ^[14] in alstroemeria and Kaur and Singh (2024) ^[8] in chrysanthemum.

Table 2: Effect of sustainable nutrient management on flowering parameters of *Lisianthus* var. Rosita 3 Bright Blue under protected cultivation

Treatments	Days taken for flower bud initiation	Days taken for flower opening	Days taken for 50 percent flowering	Days taken for flower stalk harvesting	Duration of flowering (days)
RDF-15:18:18 g of NPK per m ² (Control) (T ₁)	73.20	84.53	90.33	93.33	16.65
70% N + 100% PK + <i>Azotobacter</i> (T ₂)	72.47	84.00	88.80	92.40	17.13
70% P + 100% NK + PSB (T ₃)	71.90	82.87	87.73	91.33	18.07
70% K + 100% NP + KSB (T ₄)	72.13	83.47	88.67	92.20	17.67
80% N + 100% PK + <i>Azotobacter</i> (T ₅)	71.60	82.00	86.93	90.53	18.87
80% P + 100% NK + PSB (T ₆)	70.03	80.60	85.00	88.53	20.13
80% K + 100% NP + KSB (T ₇)	71.33	81.47	85.60	89.27	19.60
70% RDF + <i>Azotobacter</i> + PSB + KSB (T ₈)	69.13	79.33	83.67	87.20	21.04
80% RDF + <i>Azotobacter</i> + PSB + KSB (T ₉)	67.37	77.80	81.87	85.13	22.47
S.Em±	1.10	1.16	1.02	1.00	0.82
C.D at 5%	3.30	3.47	3.07	2.99	2.47



Fig 2: Different development stages a) Bud initiation and colour development, b) Flower development and c) Fully developed flower of *Lisianthus* var. Rosita 3 Bright Blue



Fig 3: General view of the field at a) 75 days after transplanting and b) at peak flowering stages of *Lisianthus* under protected cultivation

Conclusion

From the present study, it can be concluded that application of 80 percent RDF along with *Azotobacter*, PSB and KSB (T₉) significantly improved the growth and flowering of lisianthus under protected cultivation. The integrated use of inorganic fertilizers and biofertilizers enhanced nutrient availability and promoted early flowering with superior vegetative growth. Thus, the application of 80 percent RDF along with *Azotobacter*, PSB and KSB reduced the requirement for inorganic fertilizer by 20 percent while maintaining superior crop performance, making it a sustainable and efficient nutrient management practice for commercial lisianthus cultivation.

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