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EFFECT OF NUTRIENT LEVELS AND SPACING ON VEGETATIVE GROWTH AND YIELD OF LISIANTHUS (*EUSTOMA GRANDIFLORA*) UNDER POLYHOUSE CONDITION

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ABSTRACT

Lisianthus is a significant cut flower crop widely used in floral arrangements and bouquets. Despite its high market demand, its cultivation is not yet popularized and there is no established set of agro-techniques for Zone 5. In light of this, an experiment was conducted at the Floriculture Unit of the Department of Horticulture, University of Agricultural Sciences, Bangalore, during the 2022-23 growing season. The study aimed to investigate the "Effect of Spacing and Nutrient Level on Growth and Yield of Lisianthus (*Eustoma grandiflorum*) Flowers under Polyhouse Conditions." The experiment was designed using a Factorial Completely Randomized Design (FCRD) with twelve treatments and three replications. The findings indicated that applying 125 percent of the recommended nutrient level combined with a spacing of 15 cm × 30 cm resulted in the maximum plant height (108.59 cm) and chlorophyll content (63.20). Additionally, the highest number of leaves per plant (54.67), the largest plant spread (56.33 cm²) and the most spikes per plant (5.67) were observed with 125 percent nutrient level and a spacing of 30 cm × 30 cm. The maximum yield per square meter (190.67 spikes) and per hectare (1,906,667 spikes) was achieved with 125 percent nutrient level and a spacing of 15 cm × 15 cm. These results suggest that optimizing nutrient levels and spacing is crucial for maximizing the growth, yield and quality of Lisianthus flowers under polyhouse conditions in Zone 5.

Key words : Lisianthus, Spacing, Fertlizer dose, Growth, Yield.

Introduction

Floriculture, a branch of ornamental horticulture, focuses on the production of flowering and foliage plants for both commercial and decorative purposes. This sector is a significant part of the horticulture industry, valued for its aesthetic, social, and economic contributions. Globally, around 140 countries engage in commercial floriculture.

Lisianthus is an annual, herbaceous, day-neutral plant. Long days particularly promote stem elongation in white-colored varieties (Halevy and Kofranek, 1984). The plant thrives under a light intensity of 3000 foot-candles. Initially, it forms rosettes of basal leaves, followed by a leafy stem that bears flowers with long pedicels at the axis of the upper leaves, ending with a flower. Lisianthus can grow to a height of 30-90 cm, with each stem bearing 16-24 flowers. Each flower is about 7-8 cm in diameter and 7-10 cm long, resembling roses. There are also dwarf varieties that grow up to 20 cm tall, featuring bluish-green, slightly succulent leaves and large, funnel-shaped flowers on long, straight stems, which can be either erect single stems or branching stems.

Lisianthus flowers can be single or double-flowered, with colors ranging from pink, purple, white, lavender, yellow, carmine-red, blue, to bicolor. The plant is commercially propagated by seeds, which are very small and sold as pelleted seeds, with each gram containing about 800-1300 seeds depending on the variety. It takes about two months for the seedlings to reach the transplanting stage (4-6 leaves) from the date of sowing. During the seedling stage, root growth is faster than shoot growth. The total crop cycle is about 5-6 months. Lisianthus grows best at day temperatures of about 21ºC and night temperatures of about 18ºC. Higher temperatures in the early growth stages can cause seedling rosetting.

Enhanced yield and quality of Lisianthus can be achieved through precise spacing, which plays a significant role in optimizing the microclimate around the root zone. Proper spacing improves the availability of nutrients, aeration, and light intensity (Langton *et al.*, 1999), leading to better growth, yield, and quality. Ideal spacing not only helps in producing high-quality cut flowers but also improves land usage, preserves soil moisture, controls weeds, and ensures the availability of nutrients necessary for subsequent crop production and quality (Sanjib *et al.*, 2002).

Sustainable flower production requires optimal fertilizer management and nutrients. Healthy plant growth depends on all essential fertilizer elements; a deficiency in any one element can cause various symptoms. Each element plays a crucial role in plant and flower development.

Nitrogen is vital for plant vegetative development as it contains nucleic acid and protein, promoting plant growth (Haque and Jakhro, 2001). It supports juvenile growth and stimulates the flower opening cycle during the flowering season (Fan *et al*., 2005). Phosphorus is key for stimulating strong bud and flower development. It is crucial in photosynthesis and respiration, enhancing bud development, seed formation and blooming. Root-stimulating fertilizers often contain higher phosphorus levels because it strengthens young roots and ensures a strong start. Potassium is essential for various aspects of plant growth and flower quality, including drought tolerance, disease resistance; stem strength, improved texture, color and photosynthesis (Ayemi *et al*., 2017).

Lisianthus is increasingly important as a cut flower in the international market, with strong potential for earning foreign exchange. For optimal growth of any crop, including Lisianthus, good climatic conditions, quality media and appropriate nutrients are essential. Standardizing spacing and nutrient management is crucial for producing export-quality flowers in our country.

Materials and Methods

The experiment was carried out at floriculture unit, Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bengaluru during 2022-23. The fertilizer dose and spacing were the two factors with 4 and 3 levels, respectively. The different levels of these factors were combined to obtain following treatments and 120:150:150 Kg NPK/ha (RDF of Gladiolus) was taken as the standard dose.

T_1 – N2S2 (100 % Nutrient level with spacing of 15 cm × 30 cm)

T_2 – N2S1 (100 % Nutrient level with spacing of 15 cm × 15cm)

T_3 – N2S3 (100 % Nutrient level with spacing of 15 cm × 45cm)

T_4 – N2S4 (100 % Nutrient level with spacing of 30 cm × 30 cm)

T_5 – N1S1 (75 % Nutrient level with spacing of 15 cm × 15cm)

T_6 – N1S2 (75 % Nutrient level with spacing of 15 cm × 30 cm)

T_7 – N1S3 (75 % Nutrient level with spacing of 15 cm × 45cm)

T_8 – N1S4 (75 % Nutrient level with spacing of 30 cm × 30 cm)

T_9 – N3S1 (125 % Nutrient level with spacing of 15 cm × 15 cm)

T_{10} – N3S2 (125 % Nutrient level with spacing of 15 cm × 30 cm)

T_{11} – N3S3 (125 % Nutrient level with spacing of 15 cm × 45 cm)

T_{12} – N3S4 (125 % Nutrient level with spacing of 30 cm × 30 cm)

The raised beds were irrigated to field capacity before transplanting. Two-month-old seedlings with well-developed root plugs were selected for transplanting. Transplanting was carried out during the cooler hours of the day, either early in the morning or late in the evening. Immediately after transplanting, a 0.2 percent humic acid solution was applied to the seedlings to promote root growth and help them overcome transplanting shock. Since, Lisianthus seedlings are highly susceptible to fertilizer injury, no chemical fertilizers were applied before or during transplanting. After the seedlings fully recovered from transplanting shock (21 days post-transplanting), the calculated amounts of nitrogen, phosphorus, and potassium were administered through chemical fertilizers according to the treatment recommendations. The plant growth parameters and yield parameters were recorded at regular intervals. The collected experimental data was analysed statistically by following the Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984).

Results and Discussion

Growth parameters

Plant height (cm) : Data recorded at 30, 60 and 90 days after transplanting (Table 1) showed that nutrient levels significantly affected plant height. N3 (125% nutrient level) produced the tallest plants (5.88 cm, 36.16 cm and 103.71 cm), while N1 (75% nutrient level) resulted in the shortest (5.31 cm, 29.94 cm and 96.75 cm). However, the impact of nutrient levels alone was statistically non-significant.

Spacing's impact on plant height was also statistically non-significant. S2 (15 cm × 30 cm spacing) had the tallest plants (5.89 cm, 35.01 cm and 103.12 cm), while S1 (15 cm × 15 cm spacing) had the shortest (5.31 cm, 31.30 cm and 98.02 cm).

The interaction between nutrient levels and spacing provided further insights. At 30 days, T_{12} (125% nutrient level with 30 cm × 30 cm spacing) produced the tallest plants at 6.37 cm, comparable to T_{10} (125% nutrient level with 15 cm × 30 cm spacing) at 6.25 cm. T_5 (75% nutrient

Table 1 : Effect of Nutrient levels and Spacing on plant height and plant spread of Lisianthus.

Treatments	Growth Parameter					
	Plant height (cm)			Number of leaves per plant		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Nutrient Level						
N1 – 75 % Nutrient level	5.31	29.94	96.75	9.08	20.55	42.82
N2 – 100 % Nutrient level	5.62	33.19	100.49	9.72	22.55	47.37
N3 – 125 % Nutrient level	5.88	36.16	103.71	9.95	24.77	51.08
F-test	NS	NS	NS	NS	NS	NS
S.Em ±	1.00	1.49	1.86	0.40	1.06	1.57
C.D. @ 5%	2.92	4.35	5.44	1.18	3.09	4.58
Spacing						
S1 – 15 cm × 15 cm	5.31	31.30	98.02	9.04	21.01	43.79
S2 – 15 cm × 30 cm	5.89	35.10	103.12	10.16	24.94	45.64
S3 – 15 cm × 45 cm	5.44	32.43	98.79	9.20	21.46	48.04
S4 – 30 cm × 30 cm	5.77	33.56	101.34	9.93	23.09	50.89
F-test	NS	NS	NS	NS	NS	NS
S.Em ±	1.16	1.72	2.15	0.47	1.22	1.81
C.D. @ 5%	3.37	5.02	6.28	1.36	3.57	5.29
Interactions						
T_1 – N2S2	5.81	33.45	102.44	10.27	24.27	45.67
T_2 – N2S1	5.73	32.62	98.79	9.53	21.27	44.17
T_3 – N2S3	5.41	32.68	99.13	9.40	21.90	48.33
T_4 – N2S4	5.53	34.01	101.60	9.67	22.77	51.33
T_5 – N1S1	4.71	28.33	95.38	8.73	19.53	39.87
T_6 – N1S2	5.62	31.49	98.29	8.80	22.30	41.27
T_7 – N1S3	5.50	29.57	96.29	9.00	19.87	43.47
T_8 – N1S4	5.41	30.36	97.03	9.80	20.50	46.67
T_9 – N3S1	5.49	33.13	99.89	8.87	22.23	47.33
T_{10} – N3S2	6.25	40.18	108.59	11.40	28.27	50.00
T_{11} – N3S3	5.40	35.05	100.95	9.20	22.60	52.33
T_{12} – N3S4	6.37	36.30	105.39	10.33	26.00	54.67
F-test	*	*	*	*	*	*
S.Em ±	2.00	2.98	3.73	0.81	2.12	3.14
C.D. @ 5%	5.84	8.70	10.88	2.36	6.18	9.16

*Significance at 5% level, NS – Non Significant, DAT – Days after transplanting
NOTE: 120:150:150 Kg NPK ha^{-1} (RDF of Gladiolus) was taken as the standard dose.

level with 15 cm × 15 cm spacing) produced the shortest plants at 4.71 cm, similar to T_{11} (75% nutrient level with 30 cm × 30 cm spacing) at 5.40 cm. At 60 and 90 days, T_{10} continued to produce the tallest plants (40.18 cm and 108.59 cm), comparable to T_{12} (36.30 cm and 105.39 cm). The shortest plants were produced by T_5 (28.33 cm and 95.38 cm), similar to T_7 (29.57 cm and 96.29 cm).

Optimal spacing likely enhanced rhizosphere area, improving water and nutrient absorption. Nitrogen supports protein synthesis and cell division, while potassium aids peptide bond synthesis, protein and glucose metabolism and cell division. Reduced plant height with closer spacing likely resulted from increased plant density and competition for resources. These findings align with Husna *et al*. (2022) on Lisianthus and Patil and Dhaduk (2010) on Gladiolus.

Number of Leaves per plant : Findings of the experiment (Table 1) revealed that at 30, 60 and 90 days after transplanting, N3 (125% nutrient level) recorded the highest number of leaves per plant (9.95, 24.77 and 51.08, respectively), while N1 (75% nutrient level) had the lowest (9.08, 20.55 and 42.82, respectively). However, the impact of nutrient level alone was statistically non-significant.

The effect of spacing on plant height was statistically non-significant. S2 (15 cm × 30 cm spacing) recorded the highest number of leaves per plant at 30 and 60 days (10.16 and 24.94, respectively), while S4 (30 cm × 30 cm spacing) had the highest at 90 days (50.89). The lowest leaf counts were in S1 (15 cm × 15 cm spacing) at 30, 60 and 90 days (9.04, 21.01 and 43.79, respectively).

At 30 days, T_{10} (125% nutrient level with 15 cm × 30 cm spacing) had the highest leaf count (11.40), comparable to T_{12} (125% nutrient level with 30 cm × 30 cm spacing) at 10.33. At 60 days, T_{10} recorded the highest leaves (28.27), similar to T_{12} (26.00) and T_1 (100% nutrient level with 15 cm × 45 cm spacing) at 24.27. At 90 days, T_{12} had the most leaves (54.67), comparable to T_{11} (125% nutrient level with 15 cm × 45 cm spacing) at 52.33 and T_4 (100% nutrient level with 30 cm × 30 cm spacing) at 51.33.

The maximum number of leaves per plant was likely due to wider spacing and higher fertilizer application. Nitrogen increases leaf cell size and number, enhancing photosynthesis and vegetative growth. Phosphorus aids photosynthesis, respiration and energy storage, while potassium supports peptide bond production and protein and carbohydrate metabolism. Similar findings were reported by Bhande *et al*. (2015) in Gladiolus.

The minimum number of leaves at 30 days was observed in T_5 (75% nutrient level with 15 cm × 15 cm spacing) at 8.73, comparable to T_6 (75% nutrient level with 15 cm × 30 cm spacing) at 8.80. At 60 days, T_5 again had the lowest leaf count (19.53), similar to T_7 (75% nutrient level with 15 cm × 45 cm spacing) at 19.87. At 90 days, T_5 had the fewest leaves (39.87), comparable to T_6 (41.27). The decrease in leaf count was likely due to smaller spacing, increasing plant density and competition for macronutrients essential for growth. Similar findings were reported by Bhande *et al*. (2015) in Gladiolus.

Plant spread (cm²) : Data on plant spread (Table 2) revealed that at 30, 60 and 90 days after transplanting, N3 (125% nutrient level) recorded the maximum plant spread (25.34, 42.02 and 53.17 cm², respectively), while N1 (75% nutrient level) had the minimum plant spread (21.52, 34.15 and 45.66 cm²). However, the impact of nutrient levels alone was statistically non-significant.

The effect of spacing on plant spread was also statistically non-significant. At 30, 60 and 90 days after transplanting, S4 (30 cm × 30 cm spacing) recorded the maximum plant spread (25.46, 40.88 and 52.49 cm²), while S1 (15 cm × 15 cm spacing) had the least plant spread (22.12, 36.20 and 47.42 cm²).

Data on plant spread at 30, 60 and 90 days revealed that T_{12} (125% nutrient level with 30 cm × 30 cm spacing) had the maximum plant spread (28.03, 44.67 and 56.33 cm²), comparable to T_{11} (125% nutrient level with 15 cm × 45 cm spacing) at 26.13, 42.33 and 54.00 cm². The least plant spread was observed in T_5 (75% nutrient level with 15 cm × 15 cm spacing) at 20.00, 32.43 and 43.50 cm², similar to T_6 (75% nutrient level with 15 cm × 30 cm spacing) at 21.17, 33.27 and 44.73 cm².

The maximum plant spread was likely due to wider spacing and increased macro nutrient supply. Potassium accelerates carbohydrate synthesis and movement, nitrogen promotes rapid vegetative growth and amino acid synthesis, while phosphorus stimulates early growth and cell wall development, leading to greater plant spread. The least plant spread was likely due to higher plant density and competition for nutrients, particularly nitrogen. The research findings of current experiment are persistent with the observations of Sarakar *et al*. (2020) in China aster and Shivaprasad *et al*. (2016) in Rose.

Chlorophyll content (SPAD values) : The experimental results (Table 2) depicts that among the nutrient levels studied, N3 (125% nutrient level) recorded the highest chlorophyll content (61.67, 57.92 and 60.75 at 30, 60 and 90 days after transplanting, respectively). N1 (75% nutrient level) had the lowest chlorophyll content

Table 2 : Effect of Nutrient levels and Spacing on Number of leaves per plant and Chlorophyll content of Lisianthus.

Treatments	Growth Parameter					
	Plant Spread (cm^2)			Chlorophyll content (SPAD)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Nutrient Level						
N1 – 75 % Nutrient level	21.52	34.15	45.66	55.18	52.13	54.78
N2 – 100 % Nutrient level	24.55	39.15	50.33	57.12	55.42	56.81
N3 – 125 % Nutrient level	25.34	42.02	53.17	61.67	57.92	60.75
F-test	NS	NS	NS	NS	NS	NS
S.Em ±	0.71	1.03	1.54	1.16	0.35	0.10
C.D. @ 5%	2.06	3.00	4.50	3.38	1.04	0.31
Spacing						
S1 – 15 cm × 15 cm	22.12	36.20	47.42	56.85	53.33	56.14
S2 – 15 cm × 30 cm	23.30	37.81	48.72	59.80	57.18	59.28
S3 – 15 cm × 45 cm	24.33	38.87	50.24	57.00	54.23	56.57
S4 – 30 cm × 30 cm	25.46	40.88	52.49	58.31	55.89	57.80
F-test	NS	NS	NS	NS	NS	NS
S.Em ±	0.82	1.19	1.78	1.34	0.41	0.12
C.D. @ 5%	2.38	3.47	5.20	3.90	1.20	0.36
Interactions						
T_1 – N2S2	24.33	38.53	49.77	58.87	57.67	58.37
T_2 – N2S1	23.57	36.73	48.10	55.69	53.67	55.27
T_3 – N2S3	24.90	39.77	50.67	56.10	54.00	56.27
T_4 – N2S4	25.40	41.57	52.80	57.86	56.33	57.33
T_5 – N1S1	20.00	32.43	43.50	53.87	50.67	53.43
T_6 – N1S2	21.17	33.27	44.73	56.47	53.87	56.27
T_7 – N1S3	21.97	34.50	46.07	54.90	51.33	54.37
T_8 – N1S4	22.93	36.40	48.33	55.50	52.67	55.07
T_9 – N3S1	22.80	39.43	50.67	60.99	55.67	59.73
T_{10} – N3S2	24.40	41.63	51.67	64.12	60.00	63.20
T_{11} – N3S3	26.13	42.33	54.00	59.99	57.37	59.07
T_{12} – N3S4	28.03	44.67	56.33	61.57	58.67	61.00
F-test	*	*	*	*	*	*
S.Em ±	1.41	2.06	3.08	2.32	0.71	0.21
C.D. @ 5%	4.12	6.01	9.00	6.76	2.07	0.62

*Significance at 5% level, NS – Non Significant, DAT – Days after transplanting
NOTE: 120:150:150 Kg NPK ha^{-1} (RDF of Gladiolus) was taken as the standard dose.

(55.18, 52.13 and 54.78). However, the effect of nutrient levels alone was statistically non-significant.

The individual impact of spacing on chlorophyll concentration was statistically non-significant at all growth stages. However, S2 (15 cm × 30 cm spacing) recorded the highest chlorophyll content (59.80, 57.18 and 59.28 at 30, 60 and 90 days, respectively), while S1 (15 cm × 15 cm spacing) had the lowest (56.85, 53.33 and 56.14).

At 30, 60 and 90 days, T_{10} (125% nutrient level with 15 cm × 30 cm spacing) recorded the highest chlorophyll content (64.12, 60.00 and 63.20), on par with T_{12} (125% nutrient level with 30 cm × 30 cm spacing) at 61.57, 58.67 and 61.00. The lowest chlorophyll content was observed in T_5 (75% nutrient level with 15 cm × 15 cm spacing) at 53.87, 50.67 and 53.43, on par with T_7 (75% nutrient level with 15 cm × 45 cm spacing) at 54.90, 51.33 and 54.37.

The higher chlorophyll content with optimal spacing and higher nutrient levels may result from improved photosynthetic performance due to better photochemical

Table 3 : Effect of nutrient level and spacing on spike yield of Lisianthus.

Treatments	Yield parameters		
	Number of spikes per plant	Number of spikes m^{-2}	Number of spikes ha^{-1}
Nutrient level			
N1–75% Nutrient level	3.75	78.17	7,81,666.70
N2–100% Nutrient level	4.42	94.25	9,42,500.00
N3–125% Nutrient level	5.08	109.42	10,94,167.00
F–test	**NS**	**NS**	**NS**
S.Em±	0.16	3.75	37,49.85
C.D@ 5%	0.47	10.99	1,09,988.76
Spacing			
S1-15cm × 15cm	3.67	161.33	16,13,333.00
S2-15cm × 30cm	4.22	92.89	9,28,888.90
S3-15cm × 45cm	4.67	65.33	6,53,333.30
S4-30cm × 30cm	5.11	56.22	5,62,222.30
F–test	**NS**	**NS**	**NS**
S.Em±	0.18	4.32	43,254.91
C.D@ 5%	0.54	12.70	1,27,004.08
Interactions			
T_1(N2S2)	3.67	95.33	9,53,333.30
T_2(N2S1)	4.33	161.33	16,13,333.00
T_3(N2S3)	4.67	65.33	6,53,333.30
T_4(N2S4)	5.00	55.00	5,50,000.00
T_5(N1S1)	3.00	132.00	13,20,000.00
T_6(N1S2)	3.33	73.33	7,33,333.30
T_7(N1S3)	4.00	56.00	5,60,000.00
T_8(N1S4)	4.67	51.33	5,13,333.30
T_9(N3S1)	4.33	190.67	19,06,667.00
T_{10}(N3S2)	5.00	110.00	11,00,000.00
T_{11}(N3S3)	5.33	74.67	7,46,666.70
T_{12}(N3S4)	5.67	62.33	6,23,333.30
F–test	*	*	*
S.Em ±	0.32	7.49	74,919.71
C.D@ 5%	0.93	21.87	2,18,675.15

*Significance at 5% level, NS–Non Significant
NOTE: 120:150:150Kg NPK ha^{-1} (RDF of Gladiolus) was taken as the standard dose.

efficiency and fluorescence quenching. Lower nutrient levels and closer spacing likely reduce chlorophyll content. These findings align with Prathibha *et al.* (2018).

Yield parameters

The experimental data recorded on yield parameters were statistically analysed and presented in Table 3.

Number of spikes per plant : Among the various nutrient levels studied, the N3 (125% nutrient level) had the maximum number of spikes per plant (5.08), while the N1 (75% nutrient level) had the least (3.75), with the individual effect of nutrient level being statistically non-significant. Similarly, the effect of spacing on the number of spikes per plant was non-significant, with the S4 (30 cm × 30 cm) spacing yielding the highest number of spikes per plant (5.11) and S1 (15 cm × 15 cm) the lowest (3.67). The interaction between spacing and nutrient levels showed that T_{12} (125% nutrient level with 30 cm × 30 cm spacing) recorded the highest number of spikes per plant (5.67), on par with T_{11} (125% nutrient level with 15 cm × 45 cm spacing) at 5.33 spikes, likely due to increased potassium availability and wider spacing. Conversely, T_5 (75% nutrient level with 15 cm × 15 cm spacing) had the fewest spikes (3.00), on par with T_6 (75% nutrient level with 15 cm × 30 cm spacing) at 3.33 spikes, likely due to closer spacing enhancing competition for nutrients. These findings align with the studies by Mahadik *et al*. (2015) in Gladiolus, Shashank *et al.* (2013) in cut Chrysanthemum and Mane *et al.* (2007) in Tuberose.

Number of Spikes per Square meter : Observations on the number of spikes per square meter, as shown in Table 3, indicated a substantial relationship between spacing, nutrient levels and the yield of Lisianthus. The highest number of spikes per square meter was recorded at the N3 (125% nutrient level) with 109.42 spikes, while the N1 (75% nutrient level) had the lowest with 78.17 spikes, although the nutrient level had a statistically non-significant impact on this measure. The effect of individual spacing on the number of spikes per square meter was also statistically non-significant. However, the S1 spacing (15 cm × 15 cm) yielded the most spikes per square meter (161.33) and S4 spacing (30 cm × 30 cm) the least (56.22). Interaction effects revealed that the T_9 combination (125% nutrient level with 15 cm × 15 cm spacing) had the highest number of spikes per square meter (190.67), followed by T_2 (100% nutrient level with 15 cm × 15 cm spacing) with 161.33 spikes. The lowest was T_8 (75% nutrient level with 30 cm × 30 cm spacing) at 51.33 spikes, similar to T_4 (100% nutrient level with 30 cm × 30 cm spacing) at 55.00 spikes. These results suggest that increased potassium levels and reduced spacing enhance plant density, leading to a higher yield of spikes per square meter. Conversely, reduced potassium availability and wider spacing lower plant density, reducing the overall

Plate 1 : Land prepared for transplanting of Lisianthus sapling.

Plate 2 : Transplanting stage of Lisianthus saplings.

Plate 3 : View of experimental plot after transplanting.

number of spikes per square meter. Similar findings were reported by Mahadik *et al.* (2015) and Rohidas *et al.* (2010) in Gladiolus.

Number of spikes per hectare : Observations on the yield per hectare showed that the maximum number of spikes was reported at the N3 nutrient level (125%), with 10,94,167.00 spikes per hectare, while the N1 nutrient level (75%) had the least with 7,81,666.70 spikes per hectare. However, the influence of nutrient level on yield was statistically non-significant. Similarly, the effect of spacing on the number of spikes per hectare was statistically non-significant, but the S1 spacing (15 cm × 15 cm) recorded the highest yield with 16,13,333.00 spikes per hectare and the S4 spacing (30 cm × 30 cm) had the lowest with 5,62,222.30 spikes per hectare. Interaction data showed that the T_9 combination (125% nutrient level with 15 cm × 15 cm spacing) significantly yielded the maximum number of spikes per hectare (19,06,667.00 spikes), followed by T_2 (100% nutrient level with 15 cm × 15 cm spacing) with 16,13,333.00 spikes per hectare. This increase is attributed to the combined effect of higher potassium levels and closer spacing, which increased plant density and overall yield.

Conclusion

The study concluded that applying 125 percent of the recommended nutrient level significantly enhances the growth of Lisianthus plants under polyhouse conditions in Zone 5. Specifically, a spacing of 15 cm × 30 cm yielded the tallest plants and highest chlorophyll content, while a spacing of 30 cm × 30 cm produced the highest number of leaves and the greatest plant spread. Maximum yield per square meter and yield per hectare were obtained in 125 per cent nutrient level with spacing of 15 cm × 15 cm. Therefore, optimizing both nutrient levels and plant spacing is essential for maximizing early vegetative growth and economic yield in these conditions. The outcomes of this study may be considered as baseline for designing plant nutrition studies in Lisianthus in future.

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Competing interests

Authors have declared that no competing interests exist.

Authors' contributions

Dr. R. Vasantha Kumari, designed the study, facilitated the resources required and provided technical guidance.

D.R. Karthik, Maintained crop in the field, statistical analysis and wrote the first draft of the manuscript.

Dr. M. Shalini, manuscript preparation.

All authors read and approved the final manuscript.

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