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Optimizing plant density and spacing for morphological traits, floral characteristics, yield and economic returns in Lisianthus (*Eustoma grandiflorum*)

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Abstract

An experiment was conducted during 2024-25 at the Department of Horticulture, College of Agriculture, Navile, Shivamogga, to evaluate the influence of different planting densities on growth, flowering, flower quality, yield and economics of Lisianthus (*Eustoma grandiflorum* Shinn.). The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and four replications. The treatments comprised T_1-10 cm × 10 cm (100 plants/m²), T_2-10 cm × 15 cm (66 plants/m²), T_3-10 cm × 20 cm (50 plants/m²), T_4-15 cm × 15 cm (44 plants/m²), T_5-15 cm × 20 cm (33 plants/m²) and T_6-20 cm × 20 cm (25 plants/m²). The results revealed significant differences among the treatments. Closer spacing (T_1) produced the tallest plants (107.13 cm), maximum number of leaves (47.67), maximum branching (2.00) and longer internodes (12.03 cm), while wider spacing (T_6) promoted maximum leaf area (3217.99 cm²/plant) and plant spread (17.62 cm). Earliness in flowering was observed in T_1 with bud initiation, flower opening and stalk harvest at 64.30, 75.60 and 81.55 days, respectively, whereas T_6 recorded delayed flowering (67.75, 78.60 and 85.80 days). Flower quality traits were superior in T_1, which recorded higher stalk length (73.20 cm), stalk girth (1.15 mm), bud size, flower diameter (5.21 cm) and flower weight (4.76 g). Yield parameters were also highest in T_1 with 11.58 buds/plant, 1.64 spikes/plant and 161.42 spikes/m², compared to minimum values in T_6 (9.00 buds/plant, 1.01 spikes/plant, 30.19 spikes/m²). Economic analysis indicated maximum gross returns (₹ 98,65,200), net returns (₹ 85,50,200) and benefit-cost ratio (7.50) in T_1, whereas T_6 recorded the lowest values. Overall, the study concludes that closer spacing at 10 cm × 10 cm (100 plants/m²) is optimal for achieving higher growth, superior flower quality, enhanced yield and greater profitability in Lisianthus cultivation under naturally ventilated polyhouse conditions.

Keywords: Lisianthus, planting density, growth, flowering, yield, economics

Introduction

Lisianthus (*Eustoma grandiflorum* Shinn.), a member of the family Gentianaceae, is emerging as a premium cut flower of global significance, ranking among the top ten selling flowers in European and Asian markets and gaining recent popularity in India. Valued for its rose-like appearance, diverse colours, extended vase life and versatility as a cut flower, potted plant and ornamental bedding plant, it has attracted considerable attention from the floral industry. Cultivation of Lisianthus is influenced by temperature, light intensity, day length, planting density and cultural practices, which collectively determine growth, flowering and quality attributes. Although high planting densities increase yield per unit area, they may compromise stem strength and flower quality, highlighting the importance of optimizing spacing for commercial production. Despite its expanding popularity and remarkable breeding advancements that have diversified forms and colours, scientific studies focusing on the influence of planting density on yield and flower quality under Indian conditions remain limited. Therefore, the present investigation was undertaken to evaluate the effect of different planting densities on growth, yield and quality of Lisianthus with the aim of developing suitable agro-techniques for its successful commercial cultivation.

Materials and Methods

The experiment was conducted during the *Rabi* season of 2024 at the College of Agriculture, Shivamogga, under a naturally ventilated polyhouse using Lisianthus (*Eustoma grandiflorum* Shinn.) hybrid 'Rosita 3 Clear Pink'. The trial was laid out in a Randomized Complete Block Design (RCBD) with six plant spacings of T_1-10 × 10 cm (100 plants/m²), T_2-10 × 15 cm (66 plants/m²), T_3-10 × 20 cm (50 plants/m²), T_4-15 × 15 cm (44 plants/m²), T_5-15 × 20 cm (33 plants/m²)and T_6-20 × 20 cm (25 plants/m²) replicated four times in 1.0 m² plots. The beds (8.0 × 1.0 × 0.25 m) were prepared with a basal mixture of farmyard manure, vermicompost and cocopeat (2:1:1 kg/m²). Fertilizers were applied at 300:200:150 g $N:P_2O_5:K_2O$ per m², half of nitrogen and full phosphorus and potassium as basal, with the remaining nitrogen top-dressed at 30 days after transplanting (DAT). Ninety-day-old seedlings were transplanted on 9th November 2024. Standard aftercare practices including irrigation (overhead system), staking, weeding, gap filling, foliar nutrition and plant protection measures were adopted. The observations were recorded from five randomly tagged plants per plot at 30, 45, 60, 75and 90 DAT on morphological (plant height, leaf traits, plant spread, branching), flowering (bud initiation, flower opening, flowering duration), flower quality (bud and flower traits, stalk characters, spike weight), biochemical (chlorophyll content by DMSO method) and yield parameters (spikes/plant, per m²and per 1000 m²). Economics were assessed based on cost of cultivation, gross and net returns and benefit-cost ratio.

Experimental Results

Morphological Parameters

At 90 DAT, plant height was maximum in T_1 (10 cm × 10 cm) with 107.13 cm, followed by T_2 (10 cm × 15 cm) with 99.82 cm, while the minimum of 98.67 cm was observed in T_6 (20 cm × 20 cm). The number of leaves was highest in T_1 with 44.37, followed by T_2 with 45.67, whereas T_6 recorded the lowest (39.50 leaves/plant). Maximum leaf length (12.20 cm) and leaf width (6.75 cm) were recorded in T_6, while the minimum values (11.57 cm and 6.08 cm, respectively) were observed in T_1. Leaf area was highest in T_6 with 3217.99 cm²/plant, followed by T_5 (2461.92 cm²/plant), whereas T_1 recorded the minimum (1660.58 cm²/plant). Conversely, the leaf area index (LAI) was maximum in T_1 (16.61), followed by T_2 (12.83) and minimum in T_6 (8.04). Plant spread was maximum in T_6 both East-West (16.58 cm) and North-South (17.62 cm), while minimum spread was observed in T_1 (10.21 cm and 10.51 cm, respectively). The number of branches was highest in T_1 (2.00) and lowest in T_6 (1.15). Internodal length was maximum in T_1 (12.03 cm) and minimum in T_6 (10.47 cm).

Flowering Parameters

Closer spacing significantly reduced the days required for flowering. T_1 recorded the minimum days for bud initiation (64.30 days), flower opening (75.60 days) and stalk harvest (81.55 days), while maximum days were taken by T_6 (67.75, 78.60and 85.80 days, respectively). Duration of flowering was longest in T_1 (20.93 days), followed by T_2 (19.40 days) and minimum in T_6 (17.65 days) is represented in Table 1.

Table 1: Effect of planting densities on flowering parameters at peak growth stage

Treatment No.	Treatment details	Days taken for flower bud initiation	Days taken for flower opening	Days taken for flower stalk harvesting	Duration of flowering (days)
T_1	10 cm × 10 cm	64.30	75.60	81.55	20.93
T_2	10 cm × 15 cm	66.45	77.65	84.40	19.40
T_3	10 cm × 20 cm	66.58	77.73	84.90	18.30
T_4	15 cm × 15 cm	67.40	78.10	85.10	18.20
T_5	15 cm × 20 cm	67.45	78.35	85.45	17.93
T_6	20 cm × 20 cm	67.75	78.60	85.80	17.65
S. Em±		0.25	0.18	0.32	0.36
CD @ 5%		0.91	0.66	1.18	0.92

Flower Quality Parameters

Table 2: Effect of planting densities on flower quality parameters of Lisianthus cut flower

Tr. No.	Treatment details	No. of buds/plant	Stalk length (cm)	Stalk girth (mm)	Flower stalk weight (g)	Flower Bud length (cm)	Flower bud diameter (cm)	Flower length (cm)	Flower diameter (cm)	Individual weight of flower (g)
T_1	10 cm × 10 cm	11.58	73.20	1.15	20.63	2.69	1.67	5.79	5.21	4.76
T_2	10 cm × 15 cm	10.25	71.47	1.13	20.11	2.54	1.55	5.49	4.84	4.53
T_3	10 cm × 20 cm	10.00	66.75	1.12	19.73	2.52	1.52	5.31	4.81	4.42
T_4	15 cm × 15 cm	9.67	66.53	1.12	19.29	2.48	1.51	5.31	4.42	4.28
T_5	15 cm × 20 cm	9.42	66.20	1.11	18.82	2.42	1.50	5.29	4.41	4.08
T_6	20 cm × 20 cm	9.00	65.62	1.09	18.63	2.31	1.40	5.19	4.34	3.86
S. Em±		0.20	0.93	0.03	0.13	0.08	0.04	0.13	0.12	0.15
CD @ 5%		0.60	2.79	0.10	0.39	0.13	0.12	0.38	0.37	0.45

Flower quality attributes were significantly influenced by plant spacing. T_1 recorded maximum stalk length (73.20 cm), stalk girth (1.15 mm), stalk weight (20.63 g), flower bud length (2.69 cm), bud diameter (1.67 cm), flower length (5.79 cm), flower diameter (5.21 cm) and individual flower weight (4.76 g). In contrast, T_6 consistently recorded the lowest values for these parameters (stalk length 65.62 cm, girth 1.09 mm, stalk weight 18.63 g, bud length 2.31 cm, bud diameter 1.40 cm, flower length 5.19 cm, flower diameter 4.34cm and flower weight 3.86 g) is represented in Table 2.

Yield Parameters

Yield attributes were highest under closer spacing. T_1 recorded the maximum number of buds (11.58/plant), spikes per plant (1.64) and spikes per m² (161.42). In contrast, the minimum was observed in T_6, with 9.00 buds/plant, 1.01 spikes/plantand 30.19 spikes/m² presented in Table 3.

Table 3: Effect of planting densities on yield parameters of Lisianthus cut flower

Treatment No.	Treatment details	Number of spikes per plant	Number of spikes per m^2	Number of spikes per 1000 m^2
T_1	10 cm × 10 cm	1.64	164.42	1,64,420
T_2	10 cm × 15 cm	1.48	98.33	98,330
T_3	10 cm × 20 cm	1.41	70.85	70,850
T_4	15 cm × 15 cm	1.33	58.66	58,600
T_5	15 cm × 20 cm	1.24	40.92	40,920
T_6	20 cm × 20 cm	1.01	30.19	30,190
S. Em±		0.08	19.99	16907.34
CD @ 5%		0.12	51.42	43,503.55

Economics

Economic analysis revealed that T_1 was the most profitable treatment, with a gross return of ₹ 98,65,200, net return of ₹ 85,50,200and a B:C ratio of 7.50, while T_6 recorded the least profitability (gross return ₹ 18,11,400, net return ₹ 13,33,400, B:C ratio 3.79).

Discussion

Growth parameters

The study revealed that plant height ranged from 98.67 cm (T_6 at 20 cm × 20 cm) to 107.13 cm (T_1 at 10 cm × 10 cm) at 90 DAT. Similarly, the number of leaves was maximum in T_1 (47.67) and minimum in T_6 (39.50). Wider spacing promoted larger leaf size, with maximum leaf length (12.20 cm) and width (6.75 cm) recorded in T_6, while the lowest values were observed in T_1 (11.57 cm and 6.08 cm). Leaf area followed a similar trend, being highest in T_6 (3217.99 cm²/plant) and lowest in T_1 (1660.58 cm²/plant), whereas the leaf area index (LAI) was maximum in T_1 (16.61) and minimum in T_6 (8.04). Plant spread was greater under wider spacing (17.62 cm N-S and 16.58 cm E-W in T_6) compared to 10.51 cm and 10.21 cm in T_1. The number of branches was maximum in T_1 (2.00), while internodal length was also longer (12.03 cm) under closer spacing compared to 10.47 cm in T_6. These findings confirm the role of higher density in promoting vertical growth and branching, while wider spacing favours leaf expansion and spread. Similar results were reported by Husna *et al*. (2022) [7] in Lisianthus.

Flowering parameters

Closer spacing significantly hastened flowering, with T_1 recording minimum days for bud initiation (64.30 days), flower opening (75.60 days) and stalk harvest (81.55 days), while maximum values were recorded in T_6 (67.75, 78.60and 85.80 days, respectively). Flowering duration was longest in T_1 (19.93 days) and shortest in T_6 (17.65 days). The earlier flowering under denser spacing may be due to reduced vegetative growth and efficient assimilate allocation to reproductive organs. These findings are consistent with Tyagi *et al*. (2008) [19], who observed earlier flowering under closer spacing in tuberose.

Flower quality parameters

Flower quality traits were superior under closer spacing. T_1 recorded the highest stalk length (73.20 cm), stalk girth (1.15 mm), stalk weight (20.63 g), bud length (2.69 cm), bud diameter (1.67 cm), flower length (5.79 cm), flower diameter (5.21 cm) and individual flower weight (4.76 g). Conversely, T_6 recorded the lowest values: stalk length (65.62 cm), girth (1.09 mm), stalk weight (18.63 g), bud length (2.31 cm), bud diameter (1.40 cm), flower length (5.19 cm), flower diameter (4.34 cm) and flower weight (3.86 g). The improvement in floral traits at closer spacing may be attributed to optimal nutrient uptake and carbohydrate accumulation in reproductive structures. Similar observations were made by Yashaswini (2022) [20] in Hydrangea.

Yield parameters

Yield attributes showed significant variation with spacing. The number of buds per plant was maximum in T_1 (11.58) and minimum in T_6 (9.00). Spikes per plant were higher in T_1 (1.64) compared to 1.01 in T_6 and spikes per m² followed a similar trend, being highest in T_1 (161.42) and lowest in T_6 (30.19). Despite slightly lower individual plant performance at higher density, the greater number of plants per unit area enhanced overall yield. These findings are in accordance with Dali *et al*. (2023) [4], who reported that closer spacing in Chrysanthemum enhanced flower yield per square meter.

Economics

Economic analysis confirmed that closer spacing was most profitable. T_1 (10 cm × 10 cm) recorded the highest gross returns (₹ 98,65,200), net returns (₹ 85,50,200) and benefit-cost ratio (7.50), while T_6 (20 cm × 20 cm) recorded the lowest gross returns (₹ 18,11,400), net returns (₹ 13,33,400) and B:C ratio (3.79). The superior economic efficiency under closer spacing is directly linked to the higher spike yield per unit area. Similar findings were reported by Dalvi *et al*. (2022) [5] in tuberose.

Best performing treatment 10 cm × 10 cm

Least performing treatment 20 cm × 20 cm

Plate 1: Overview of best and least performing treatment

Summary

The experiment on spacing in Lisianthus clearly demonstrated that plant density has a profound influence on growth, flowering, quality, yield and profitability. Among the treatments, closer spacing at 10 cm × 10 cm (T_1) consistently outperformed wider spacing at 20 cm × 20 cm (T_6) in most parameters. Higher density promoted taller plants (107.13 cm), more leaves (47.67/plant), greater branching (2.00) and longer internodes (12.03 cm), which together enhanced canopy development and resource use efficiency. In contrast, wider spacing provided each plant with greater access to light and nutrients, which translated into larger leaves (12.20 × 6.75 cm), higher leaf area (3217.99 cm²/plant) and broader spread (17.62 cm), though at the cost of reduced overall yield per unit area.

Flowering behaviour was also influenced by spacing. Closer spacing (T_1) significantly reduced the time taken for bud initiation (64.30 days), flower opening (75.60 days) and stalk harvest (81.55 days) and extended the flowering duration to 19.93 days, whereas wider spacing delayed flowering (up to 85.80 days for harvest) and shortened the blooming period (17.65 days). This earliness under denser planting may be attributed to a shift in assimilate partitioning towards reproductive growth rather than vegetative spread.

Flower quality attributes, including stalk length (73.20 cm), stalk girth (1.15 mm), stalk weight (20.63 g), bud size (2.69 × 1.67 cm), flower length (5.79 cm), flower diameter (5.21 cm) and individual flower weight (4.76 g), were markedly superior in T_1. Wider spacing (T_6) consistently showed lower quality values, with stalks only 65.62 cm long, smaller buds and lighter flowers (3.86 g), indicating weaker growth and lower sink strength.

In terms of yield, closer spacing proved most advantageous, producing 11.58 buds/plant, 1.64 spikes/plant and 161.42 spikes/m², compared to only 9.00 buds/plant, 1.01 spikes/plant and 30.19 spikes/m² in T_6. Although individual plants under wider spacing exhibited slightly larger vegetative structures, the overall yield per unit area was drastically reduced due to the lower plant population.

Economic analysis further highlighted the superiority of closer spacing. T_1 achieved the highest gross returns (₹ 98,65,200), net returns (₹ 85,50,200) and a benefit-cost ratio (7.50), which were more than double the values recorded in T_6 (gross return ₹ 18,11,400, net return ₹ 13,33,400, B:C ratio 3.79). This economic advantage directly corresponded with the higher marketable yield achieved under dense planting.

Overall, the study concludes that closer spacing (10 cm × 10 cm) is optimal for Lisianthus cultivation, as it enhances growth parameters like plant height and branching, promotes earlier and extended flowering, improves flower quality attributes, maximizes spike yield per unit area and ensures the highest profitability. Wider spacing, while beneficial for vegetative spread and leaf expansion, was found to be less effective in terms of yield and economics. Thus, adopting closer spacing can be recommended for commercial Lisianthus production to achieve both quantitative and qualitative gains.

Conclusion

The study clearly demonstrated that plant spacing plays a decisive role in regulating growth, flowering, quality, yield and profitability of Lisianthus. Closer spacing at 10 cm × 10 cm (T_1) proved most effective, producing taller plants (107.13 cm), more leaves (47.67/plant), earlier flowering (64.30 days for bud initiation, 75.60 days for flower opening), superior flower quality (stalk length 73.20 cm, flower diameter 5.21 cm, flower weight 4.76 g), higher yield (161.42 spikes/m²) and maximum returns (B:C ratio 7.50). In contrast, wider spacing at 20 cm × 20 cm (T_6) encouraged greater leaf expansion (3217.99 cm²/plant) and plant spread (17.62 cm), but resulted in delayed flowering, poor flower quality, reduced yield (30.19 spikes/m²)and the lowest profitability (B:C ratio 3.79). Hence, closer spacing of 10 cm × 10 cm is recommended for achieving optimum growth, yield and economic returns in Lisianthus cultivation under field conditions.

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