International Journal of Plant & Soil Science

Volume 36, Issue 7, Page 988-996, 2024; Article no.IJPSS.119626
ISSN: 2320-7035

Effect of Plant Growth Regulators on Growth and Flower Yield of Lisianthus (*Eustoma grandiflorum*) Under Prayagraj Agro Climatic Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i74810

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119626

Original Research Article

Received: 06/05/2024
Accepted: 02/07/2024
Published: 05/07/2024

ABSTRACT

The experiment was carried out under naturally ventilated polyhouse conditions, Department of Horticulture, SHUAT S, Prayagraj, during November, 2023 to April, 2024. The experiment was laid out in Completely Randomized Design (CRD) with three replications. There were ten treatments comprising of CCC, GA3, NAA at different concentrations viz., GA3 (100, 200, 300) ppm and CCC (250, 500, 750) ppm and NAA (30, 45, 60) ppm along with control. The results revealed that foliar application of 300 ppm GA3 for Lisianthus, significantly enhanced the treatment T3 - GA3 at 300 ppm was found in superior among other treatments in terms of plant height (20.66cm), number of leaves (33.06), plant spread (11.3cm), stem diameter (3.23cm), leaf area (15.43cm^2), bud length

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Cite as: *Poorani, Siva, Vijay Bahadur, and Urfi Fatmi. 2024. "Effect of Plant Growth Regulators on Growth and Flower Yield of Lisianthus (Eustoma Grandiflorum) Under Prayagraj Agro Climatic Conditions". International Journal of Plant & Soil Science 36 (7):988-96. https://doi.org/10.9734/ijpss/2024/v36i74810.*

(2.62cm), number of buds per plant (6.43), stalk length (5.70cm), Number of flowers per plant (6.43), number of branches per plant (3.12),chlorophyll content (66.10), minimum number of days for bud initiation (122.50), Flower yield per plant (6.43), flower yield per 250m^2 (40187.50), benefit cost rat io (4.08) per 250 m^2 was also observed in T3 - GA3 at 300 ppm.

Keywords: Lisianthus; AA; GA3; CCC; polyhouse; PGR; yield.

1. INTRODUCTION

"Eustoma grandiflorum Shinn. Syn. *Lisianthus russelianus* Hook., (2n=36) belongs to family Gentianaceae. Lisianthus is also known as _Texas Blue Bell'and Prairie Gentian" Halevy and Kofranek, [1]. "Eustoma is named after the two Greek words Eu (beautiful, good, well), and stoma (mouth). Although delicate and soft-hued in style, Lisianthus flowers boast powerful symbolism. This floral species represents charisma, appreciation, and gratitude. It mainly used for beautification, bouquets, showy purposes and decorating walls, fences, gates, hedges. It is not only popular as a cut flower but also a bedding plant and a pot plant in the market" Grueber [2] and Harbaugh [3]. "Lisianthus *(Eustoma grandiflorum [Raf.] Shinn*) is an ornamental species that has acquired great importance due to the attractiveness of its flowers, bright colours and long vase life. As cut flower, its acceptance in the international markets has increased in recent years and currently it is among the 10 most sold flowers in the world. It is a plant native to the northern states of Mexico and southern United States of America" Domı´nguez-Ramı´rez [4,5,6]. "Lisianthus is an annual or biannual species; the period from sowing to flowering can be divided into two stages. The first one is from seed germination up to the liners are ready for transplant; in this stage, the plants form a rosette with four leaf pairs. The second stage begins with the elongation of the stems and ends with flowering. Lisianthus has been ranked one of the lucrative and expensive cut flowers in the world. It has a great cosmopolitan demand mainly for its large and attractive flowers, long and hard stem, wide range of colors specially have purple, blue, lavender and has a long vase life which are the common traits of an ideal and best quality cut flower. Lisianthus, herbaceous annual growing to 15 to 60 cm tall, with bluish green, slightly succulent leaves. These are having large funnel-shaped flowers growing 32cm long straight stems, sometimes erect single stems, other times growing on branching stems that can rise to be eighteen feet tall". "The flowers can grow up to two inches across and can be found in a variety of colors. Lisianthus are long-stemmed flowers in cymes, with often only a few openings at a time. Sepals on Lisianthus are only fused close to the base and are much smaller than petals" [7,8,9]. In Tamil Nadu, production of lisianthus is concentrated in limited area in the hill stations namely, Ooty and Kodaikanal. Lisianthus is a crop which has immense potential as cut flower and pot plant Katharai et al. [10]. Research work on the use of Gibberellic acid, CCC, NAA plays a vital role in improving the vegetative growth characters of the plants as they enhance the elongation and cell division by promoting the DNA synthesis in the cell. It reduced the juvenile phase due to increase in photosynthesis and respiration with enhanced CO2 fixation in the plant Thirumal et al. [11] Gibberellic acid (GA3) is endogenous plant hormone, belongs to gibberellins group and takes part in various metabolic processes Eason [12] GA3 is mostly known to enhance the production of hydrolyses (α-amylase) in the endosperm of cereals Kolumbina.et.al., [13].

Fig. 1. Morphology Of *Eustoma Grandiflorum*

2. MATERIALS AND METHODS

The present investigation was carried out under naturally ventilated polyhouse department of horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, in November 2023- April 2024. The Lisianthus seedling F_1 Rosie variety was planted on polythene bags. The bags were filled with a mixture of soil, vermicompost, Farm yard manure and cocopeat in the ratio of 1:1:1:1. Before planting the seedling in the polythene bags, soil was treated with fungicide, i.e. Copper

oxychloride at 2%. During transplanting potting media was pressed firmly around the seedlings so that they do not get disturbed after irrigation. Also in this experiment, plant was sprayed with Gibberellic acid (GA_3) (at 100, 200, 300 ppm), cycocel (CCC) (at 250, 500, 750 ppm) and Naphthalene Acetic Acid (NAA) (at 30, 60, 90 ppm). Foliar spraying was repeated for several periods 30, 60, 90, 120, 150 days of intervals, three plants were selected randomly from each treatment per replication and their observation were recorded at 30 days intervals. Statistical analysis was conducted using Fisher's analysis of variance (ANOVA) technique, in accordance with the guidelines.

3. RESULT AND DISSCUSSION

Effect of plant growth regulators on different concentration of vegetative, flowering, yield and economic parameters are presented in Tables 2, 3, 4 and 5 respectively. The Data was taken from DEC-APR.

3.1 Vegetative Parameter

3.1.1 Plant height (cm)

Maximum Plant height (cm) was observed with T_3 - GA_3 at 300ppm (20.66 cm) which was at par with T7- CCC at 750 ppm (18.19 cm) whereas, minimum was reported in T_0 - Control (13.86 cm). These are similar finding reported by Kathari [10] in lisianthus. and Aparna [14] reported GA_3 induce m-RNA synthesis pertaining to hydrolytic enzymes, which promotes mitotic activity in apical meristem and increase cell division and cell elongation, leading to increased length of internodes, in turn increases the plant height. Providing conductive environment inside the naturally ventilated polyhouse at night time helped in better plant height also.

3.1.2 Number of leaves per plant

Maximum number of leaves per plant was observed with T_3 - GA_3at 300ppm (33.06) which was at par with T_9 - NAA at 60 ppm (29.40) whereas, minimum was reported in T_4- CCC at 250ppm (25.0). Similar trend was also observed previously in chrysanthemum Habiba et al. [15] and he reported GA3 influencing the increased vegetative growth by increasing cell division and cell elongation is the reason behind the production of a greater number of leaves per plant.

3.1.3 Plant Spread (cm^2)

Maximum Plant Spread (cm^2) was observed with T_3 - GA_3 at 300 ppm (11.3 cm^2) which was at par with T_5 - CCC at 500 ppm (9.54 cm^2) whereas, minimum was reported in T_0 - Control (7.96 cm^2). This might be attributed to the higher concentration of GA3, which is more efficient in cell multiplication and elongation of immature tissues, whereas lesser quantities were less favourable. Palei [16] and Doddagoudar [17] comparable results reported that the application of GA3 plant growth regulators enhances cell division with rapid internode elongation and is confined in the sub-apical meristem, which increases the plant spread.

Table 1. Treatment details

Sl.No.	Treatment	Notation
1	T_O	Control
2	T_1	GA3 at 100 ppm
3	T_2	GA3 at 200 ppm
4	T_3	GA3 at 300 ppm
5	T_4	Cycocel at 250ppm
6	T_5	Cycocel at 500ppm
7	T_6	Cycocel at 750ppm
8	T_7	NAA at 30 ppm
9	T_8	NAA at 45 ppm
10	T_9	NAA at 60 ppm

Table 2. Effect of different concentration of GA3, CCC and NAA on vegetative parameters of Lisianthus

Treatment Notation	Treatments	Plant spread (cm^2)	Plant height (cm)	Number of Leaves	Number of Shoots	Chlorophyll content (µmol m-2)	Stem Diameter (cm)	Leaf area (cm^2)
T_0	Control	7.96	13.86	26.29	2.18	61.43	1.85	13.34
T_1	GA3at 100 ppm	8.06	15.30	25.04	2.30	60.70	2.27	11.29
T_2	GA3at 200 ppm	8.09	16.28	26.26	2.35	60.86	2.14	13.35
T_3	GA3at 300 ppm	11.3	20.66	33.06	3.12	66.10	3.23	15.43
T_4	Cycocel at 250ppm	8.50	15.96	25.0	2.08	62.92	2.37	12.97
T_5	Cycocel at 500ppm	9.54	17.61	26.33	2.11	63.12	2.19	13.09
T_6	Cycocel at 750ppm	9.38	16.81	25.20	1.90	63.54	2.51	12.20
T_7	NAAat 30 ppm	9.5	18.19	27.53	1.94	64.61	2.47	13.38
T_8	NAAat 45 ppm	8.99	16.98	28.04	1.92	63.68	2.53	13.60
T_9	NAAat 60 ppm	9.1	16.21	29.40	1.87	63.65	2.42	13.93
	F-Test	**S**	**S**	**S**	**S**	**S**	**S**	**S**
	S.Ed (+)	0.14	0.90	0.30	0.16	0.53	0.25	0.92
	CD (5%)	0.30	0.89	0.64	0.33	1.11	0.54	1.93
	CV	1.95	6.57	1.38	8.97	1.03	13.21	8.52

Table 3. Effect of different concentration of GA3, CCC and NAA on floral parameters of Lisianthus

Treatment Notation	Treatments	Stalk length(cm)	Bud length(cm)	No. of buds per plants	No. of days for bud initiation	No. of flowers per plant
T_0	Control	3.92	2.13	4.49	4.49	4.49
T_1	GA3at 100 ppm	4.36	2.43	4.99	4.99	4.99
T_2	GA3at 200 ppm	3.77	2.45	5.31	5.31	5.31
T_3	GA3at 300 ppm	5.70	2.62	6.43	6.43	6.43
T_4	Cycocel at 250ppm	5.14	2.09	4.02	4.02	4.02
T_5	Cycocel at 500ppm	4.69	2.30	4.45	4.45	4.45
T_6	Cycocel at 750ppm	4.68	2.11	5.28	5.28	5.28
T_7	NAAat 30 ppm	4.75	2.08	5.13	5.13	5.13
T_8	NAAat 45 ppm	4.88	2.14	5.34	5.34	5.34
T_9	NAAat 60 ppm	4.93	2.11	5.19	5.19	5.19
	F-Test	S	S	S	S	S
	S.Ed (+)	0.12	0.09	0.25	0.25	0.25
	CD (5%)	0.25	0.18	0.54	0.54	0.54
	CV	3.22	4.87	6.25	6.25	6.25

Table 4. Effect of different concentration of GA3, CCC and NAA on yield parameters of Lisianthus

Treatment Notation	Treatments	Yield per plant	Yield per ($250\ m^2$)
T_0	Control	4.49	28062.50
T_1	GA3at 100 ppm	4.99	31187.50
T_2	GA3at 200 ppm	5.31	33187.50
T_3	GA3at 300 ppm	6.43	40187.50
T_4	Cycocel at 250ppm	4.02	25125.00
T_5	Cycocel at 500ppm	4.45	27812.50
T_6	Cycocel at 750ppm	5.28	33000.00
T_7	NAAat 30 ppm	5.13	32062.50
T_8	NAAat 45 ppm	5.34	33375.00
T_9	NAAat 60 ppm	5.19	32437.50
	F-Test	S	S
	S.Ed (+)	0.25	480.11
	CD (5%)	0.54	1017.78
	CV	6.25	13.05

Table 5. Effect of different concentration of GA3, CCC and NAA on Economic parameters of Lisianthus

Treatment Notation	Treatments combination	Total cost of cultivation	Gross Return	Net Retutn	Benefit cost ratio
T_0	Control	94875.00	280625.0	185750.00	2.95
T_1	GA3 at 100 ppm	96063.00	311875.0	215812.00	3.24
T_2	GA3 at 200 ppm	97263.00	331875.0	214612.00	3.20
T_3	GA3 at 300 ppm	98463.00	401875.0	303412.00	4.08

Treatment Notation	Treatments combination	Total cost of cultivation	Gross Return	Net Retutn	Benefit cost ratio
T_4	Cycocel at 250ppm	102863.00	251250.0	148387.00	2.44
T_5	Cycocel at 500ppm	107752.00	278125.0	170373.00	2.58
T_6	Cycocel at 750ppm	113461.00	330000.0	216539.00	2.90
T_7	NAA at 30 ppm	95231.00	320625.0	225394.00	3.36
T_8	NAA at 45 ppm	95355.00	333750.0	238395.00	3.50
T_9	NAA at 60 ppm	95434.00	324375.0	228941.00	3.39

3.1.4 Number of shoots per plant

Maximum number of shoots per plant was observed with T_3 - GA_3 at 300 ppm (3.12) which was at par with T_2 - GA_3 at 200 ppm (2.35) whereas, minimum was reported in T_9- NAA at 60ppm (1.87). The increase in number of branches per plant application of GA3 may be ascribed to increase cell division and cell enlargement, promotion of protein synthesis in the plant. Stimulation of branching may also be attributed to the breakage of apical dominance. [18].

3.1.5 Chlorophyll content

The maximum Chlorophyll content was observed with T_3 - GA_3 at 300 ppm (66.10 µmol m^{-2}) which was at par with T_7- NAA at 30 ppm (64.61 µmol m^{-2}) whereas, minimum was reported in T_1- GA_3 at 100ppm (60.70 µmol m^{-2}). Changes in chlorophyll content caused by growth regulators may be attributed to decrease chlorophyll breakdown and enhance the chlorophyll synthesis.

3.1.6 Stem diameter (cm)

The maximum Stem diameter (cm) was observed with T_3 - GA_3 at 300ppm (3.23 cm) which was at par with T_8- NAA at 45 ppm (2.53 cm) whereas, minimum was reported in T_0 - Control (1.85 cm). Increase in stem diameter is directly proportional to increase in plant height. The maximum plant height was obtained in T3 which may have been led to maximum diameter of stem T3. With the increase in the concentration of GA3 diameter increases due to a reflection of the stimulation of cambium and its immediate cell progeny. Similar Doddagoudar [17], reported comparable results in marigold.

3.1.7 Maximum Leaf area (cm^2)

The data on vegetative parameters are given in Table 2. It is clear from the table that is significant difference among the treatments for number of leaves per plant of lisianthus. Kumar [19] reported that GA3 promotes cell division and cell elongation, thereby increase the leaf length and leaf area and enhance sugar translocation.

3.2 Floral Parameters

3.2.1 Stalk length(cm)

The maximum Stalk length (cm) was observed with T_3 - GA_3 at 300ppm (5.70 cm^2) which was at par with T_4- Cycocel at 250ppm (5.14 cm^2) whereas, minimum was reported in T_0 - Control (3.92 cm^2). GA3 was the best for obtaining better growth of plants, maximum number of cut blooms with longer stalk as well as bigger flower size obtained. A similar trend was observed previously in China aster by Sailaja and Panchali [20].

3.2.2 Bud length (cm)

The maximum Bud length (cm) was observed with T_3 - GA_3 at 300ppm (2.62 cm) which was at par with T_2- GA3 at 200 ppm and T1 GA3 at 100 ppm (2.45 cm) whereas, minimum was reported in T_7 - NAA at 30 ppm (2.08 cm). Justo et al.in carnation reported that the increase in the length of the flower bud in GA3 treated plants is due to rapid cell elongation, increased cell divisions and cell enlargement. Foliar application of GA3 also significantly increased flower bud length.

3.2.3 Number of buds per plant

The data on floral parameters are given in Table 3. It is clear from the table that significant difference among the treatments for number of buds per plant of lisianthus. The maximum number of buds per plant was observed with T_3- GA_3 at 300 ppm (6.43) which was at par with T_8 - NAAat 45 ppm (5.34) whereas, minimum was reported in T_4- CCC at 250ppm (4.02). The effect of different growth regulators showed significant influence on the number of buds per

plant. Similar results were recorded by Kumar et al. [21] in marigold.

3.2.4 Number of days for bud initiation

The minimum Number of days for bud initiation was observed with T_3 - GA_3 at 300 ppm (122.50) which was at par with T_5 - CCC at 500 ppm (128.7) whereas, maximum was reported in T_7- NAAat 30ppm (131.06). Holkar [22] reported that GA3 application enhances food translocation for the development of floral primordia, which leads to early flowering. This is due to increase in photosynthesis and respiration along with enhanced fixation by GA3 that led to flower bud initiation.

3.2.5 Number of flowers per plant

The maximum number of flowers per plant was observed with T_3 - GA_3 at 300 ppm (6.43) which was at par with T_8 - NAAat 45 ppm (5.34) whereas, minimum was reported in T_4- CCC at 250ppm (4.02). Increased number of flower is attributed to the production of large number of flower buds along with the fact that termination of vertical growth by pinching lead to more laterals/secondary branches at early stage of growth, which then had sufficient time to accumulate carbohydrates for proper flower bud differentiation producing a greater number of flowers per plant. GA3 helps in breaking bud dormancy and acts as florigen initiating flowering. Similar results were also reported by Mithilesh Kumar [23] in Marigold.

3.3 Yield Parameters

3.3.1 Flower yield per plant

The maximum flower yield per plant was observed with T_3 - GA_3 at 300 ppm (6.43) which was at par with T_8 – NAA at 45 ppm (5.34) whereas, minimum was reported in T_4– CCCat 250ppm (4.02). Increase in flower yield per plant due to the fact that plant growth regulators stimulate vegetative growth and induced changes in vegetative morphology, and thereby accelerate growth parameters. These findings are also in accordance with those of Rakesh [24] in carnation.

3.3.2 Flower yield per 250 m^2

The maximum flower yield per 250 m^2 was observed with T_3 - GA_3 at 300 ppm (40187.50) which was at par with T_8 - NAA at 45 ppm (33375.00) whereas, minimum was reported in T_4 – CCC at 250 ppm (25125.00). GA3 treatment enhance induction of flower bud break i.e., differentiation of floral primordia in the apical region which leads to increase production of flowers per plants and hence increase the flower yield. These results are also in close conformity with the findings of Ryagi [25] in Carnation.

3.4 Economic Parameter

The maximum gross return was observed with T_3 - GA_3 at 300 ppm (401875.0) which was at par with T_8 - NAA at 45 ppm (3.50) whereas, minimum was reported in T_4- CCC at 250 ppm (251250.0). The maximum net return was observed with T_3 - GA_3 at 300 ppm (303412.00) which was at par with T_8 - NAA at 45 ppm (3.50) whereas, minimum was reported in T_4- CCC at 250 ppm (148387.00). The maximum Benefit cost ratio was observed with T_3 - GA_3 at 300 ppm (4.08) which was at par with T_8 - NAA at 45 ppm (3.50) whereas, minimum was reported in T_4- CCC at 250 ppm (2.44).

4. CONCLUSION

From the present investigation, it is concluded that among the different treatments, the treatment T_3 - GA_3 at 300 ppm was found in superior among other treatments in terms of Plant height, number of leaves , plant spread , stem diameter, leaf area, bud length, number of buds per plant, stalk length , Number of flowers per plant, number of branches per plant, chlorophyll content, minimum number of days for bud initiation, Flower yield per plant, flower yield per 250m^2, benefit cost ratio per 250m^2 was also observed in T_3 - GA_3 at 300 ppm.GA3 at 300 ppm could be recommended for improved plant growth and flowering of Lisianthus (*Eustoma grandiflorum*).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors would like to express gratitude to the staffs of department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences for their support in this study. They also would like to give thanks all helping hands for their support on regular data collection and monitoring of research area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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The peer review history for this paper can be accessed here:
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