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Effect of plant growth regulator on growth, yield and quality parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana under Telangana conditions

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Abstract
An investigation on "Effect of plant growth regulator on growth, yield and quality parameters of calendula (*Calendula officinalis* L.) var. Fiesta Gitana under Telangana conditions" was carried out in the research field of the Department of Floriculture and Landscaping, College of Horticulture Rajendranagar, SKLTSHU during the year 2024. The purpose of research was to observe the effect of different concentrations of Gibberellic acid (150, 200 ppm), Salicylic acid (100, 150 ppm), Cycocel (1000, 1500 ppm) and Alar (B-9) (500, 1000 ppm) in calendula plant growth attributes, yield attributes and quality attributes. The results revealed that maximum plant height (48.96 cm), flower diameter (6.40 cm), stalk length (7.61 cm) and Maximum flower longevity (12.86 days) were noted under GA_3@ 200 ppm and the maximum plant spread (45.90 cm), leaf area index (4.17), internodal length (6.40 cm), days taken to first bud initiation (52.58), days taken to 50% flowering (58.85), days taken from bud to full blooming (4.00), days taken to first harvest (65.56), Fresh flower weight (6.82 g), number of flowers per plant (27.75 days), number of pickings (4.66), flower yield per plant (189.27 g), flower yield per plot (3.79 kg), flower yield at end of experiment (11.37 kg), flower yield per hectare (189.60 quintals). In research, control was reported minimum for every trait from different concentrated PGRs taken in the investigation.

Keywords: Calendula, plant growth regulators; gibberellic acid, salicylic acid, cycocel, alar (B-9), growth, yield and quality parameters

Introduction
Calendula (*Calendula officinalis* L) belong to Asteraceae family is a short lived aromatic herbaceous perennial plant that often known as pot marigold. It is a free blooming annual with beautiful crowns, grown for garden decoration and cut flower purpose. The flower is found in diverse colors (Gold, orange, yellow, red and pink) and used in making bouquets, garland and vase arrangements. It is a spring summer and winter annual, which is grown extensively in beds, baskets and boxes. The petals are a popular choice for floral arrangements and potpourri. They can also be cooked and consumed. Calendula is also used for their medicinal properties; calendula has anti-inflammatory, anti-septic, anti-viral, anti-bacterial properties and help to boost the immune system. Calendula has been for long a popular domestic remedy for skin problems ranging for bites and stings to wounds and even various veins (Randhawa *et al*., 1986) [18]. Calendula plant material contains a variety of active substances, including essential oil, triterpene saponins (calendulosides), flavonoids, carotenoids, saponins, polyacetylenes, sterols, carbohydrates, vitamin C, mucilages and minerals such as manganese, making it an important source of pharmaceutical and medical preparations (Yadaw *et al*., 2023) [24].
Gibberellic acid (GA_3) is a well-recognized plant growth regulator for flower induction in many herbaceous flower crops. The flower formation of long day or long short day plant can be controlled by regulating the endogenous level of gibberellins-like substances though the use of such growth promoter. (Bhuneshwar *et al*., 2022) [3]. Salicylic Acid (SA), as a natural phenolic secondary metabolite, in various aspects of vital processes like ethylene biosynthesis, stomata conductance, respiration, senescence and the activation of defence systems against different

pathogens is well documented. Applying salicylic acid to various species has been shown considerable change in flowering components, increased number of flowering parts in the plants. (Bhuneshwar *et al*., 2022) [3]. Cycocel (CCC) is a versatile group of compounds known for their ability to inhibit stem elongation by impeding cell division in the sub-apical meristem, typically without exerting similar effects on the apical meristem (Khudus *et al*., 2017) [11]. These substances modify plant characteristics such as height, number of leaves, size of leaves and flowers, branching habits, internode length, fresh and dry weight and root growth. Growth regulators, such as daminozide (Alar B-9) is successfully applied to obtain higher quality yield to avoid lodging of plants and to control height, branching and flowering in chrysanthemum like in many other plant species (Larson, 1985; Hayashi *et al*., 2001; Karlovic *et al*., 2004) [14, 7, 8].

Materials and Methods

The experiment was carried out during early summer (January to April, 2024) at PG Research Block, Department of Floriculture and Landscaping, College of Horticulture, Rajendranagar, SKLTSHU, Hyderabad. Telangana which is situated at a Latitude of 17°.32' N and Longitude 78°.40' E and at an altitude of about 536 m above mean sea level (MSL). The soil in the field site is sandy loam soil. The field experiment was laid out in Randomized Block Design with nine treatments and replicated thrice with one variety Fiesta Gitana Orange *viz*., T_1 GA_3 @ 150 ppm, T_2 GA_3 @ 200 ppm, T_3 SA @ 100 ppm, T_4 SA @ 150 ppm, T_5 CCC @ 1000 ppm, T_6 CCC @1500 ppm, T_7 B-9 @ 500 ppm, T_8 B-9 @ 1000 ppm, T_9 Control (water spray). Data pertaining to growth parameters were recorded at regular intervals i.e., 30 DAT, 45 DAT, 60 DAT, yield and quality attributes were recorded at harvest and thereafter obsevations on different growth, yield and quality attributing characters were recorded from five randomly selected plants from each replication to find out the significant difference on growth, yield and quality contributing characters of calendula. Plant height, plant spread, stalk length and internodal length was measured with the help of meter scale. Stem diameter and flower diameter were measured by vernier callipers and leaf area index was measured by leaf area meter. Analysis of variance was worked out using standard statistical procedures as described by Panse and Sukhatme (1985) [16]. Standard Error of Mean (S.Em ±), Critical Difference (CD) at 5% probability and Co-efficient of Variance (CV %) was worked out for the interpretation of the results.

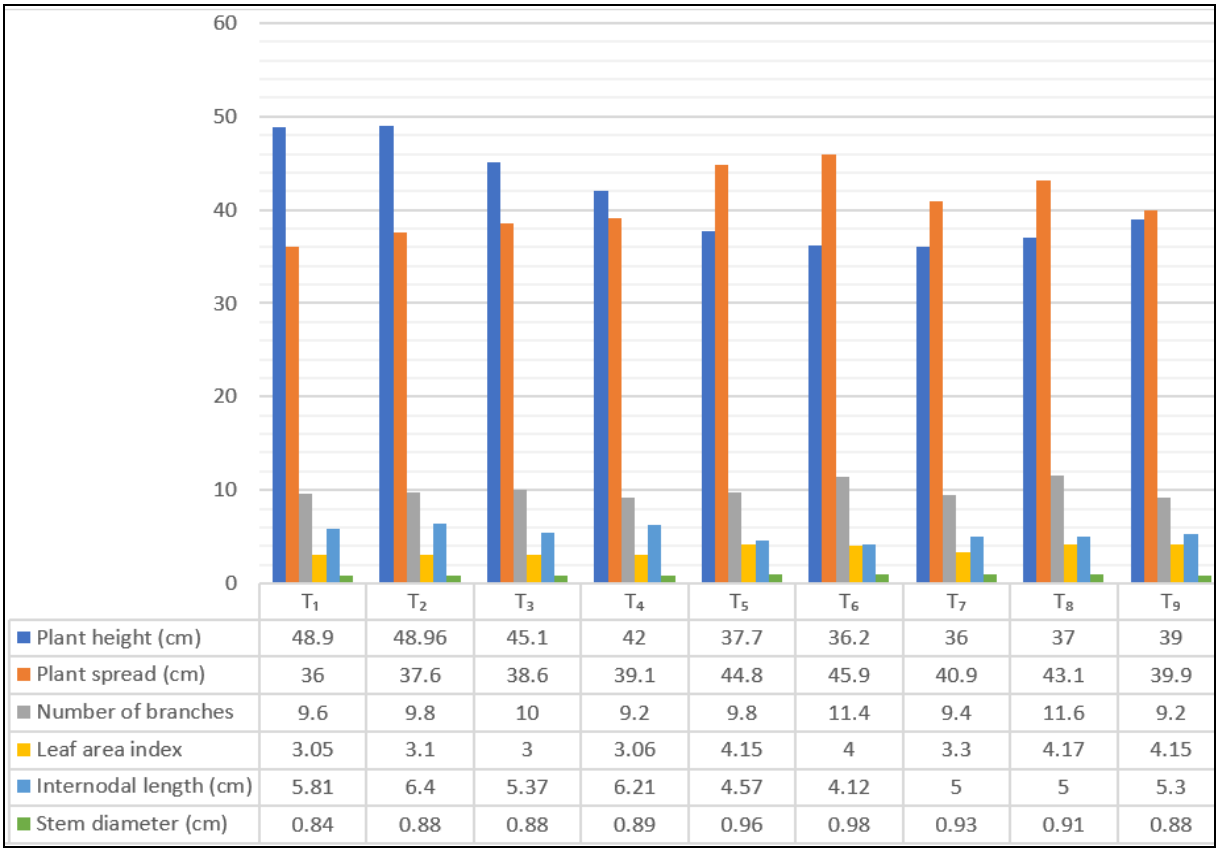
Results and Discussions

Growth

Data indicates that vegetative parameters were significantly influenced by different treatments (Table 1). The maximum plant height (48.96 cm) significantly was recorded in treatment T_2 (GA_3@200ppm), par with T_1 (GA_3@150ppm) (48.90 cm). The minimum plant height (36.00) was recorded with the treatment T_7 Alar (B-9) @500 ppm respectively. (Delvadia *et al*., 2009) [5]. Maximum spread of plant (45.90 cm) was recorded with treatment T_6 (CCC @1500 ppm) par with T_5 (CCC @1000 ppm) (44.80 cm). The minimum plant spread (36.00 cm) was recorded with treatment T_1 (GA_3 @150 ppm) respectively. (Kumar *et al*., 2019) [13]. The maximum number of branches per plant (11.60) was recorded under the treatment T_8 Alar (B-9) @ 1000 ppm which was at par with T_6 Cycocel (CCC) 11.40, the minimum number of branches of (9.20) was recorded under the treatment T_9 Control. (Aklade *et al*., 2009, Khan *et al*., 2012) [1, 9]. The maximum leaf area index per plant (4.17) was recorded under the treatment T_8 Alar (B-9) @ 1000 ppm which was at par with T_6 Cycocel (CCC) 4.15, while the minimum leaf area (3.05) was recorded under the treatment T_1 Gibberellic acid (GA_3) @ 150 ppm. (Ganesh *et al*., 2014) [6]. The maximum internodal length per plant (6.40 cm) was recorded under the treatment of T_2 Gibberellic acid (GA_3) which is at par with T_4 Salicylic acid 6.21 cm, while the minimum internodal length (4.12 cm) was recorded under the treatment of T_6 Cycocel (CCC) @ 1500 ppm. (Tannirwar *et al*., 2011) [23]. The stem diameter in the plants does not exhibit any significant variations at all three different intervals but the maximum stem diameter 0.98 cm was recorded under the treatment T_6 -Cycocel (CCC) @ 1500 ppm, while the minimum stem diameter 0.84 cm was recorded under the treatment of T_1 Gibberellic acid (GA_3) @ 150 ppm.

Table 1: Effect of plant growth regulators on vegetative parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange.

Treatments	Plant height (cm)	Plant spread (cm)	Number of branches	Leaf area index	Internodal length (cm)	Stem diameter (cm)
T_1 - Gibberellic acid (GA_3) @ 150 ppm	48.90^{ab}	36.00^{f}	9.60^{cd}	3.05^{c}	5.81^{b}	0.84
T_2 - Gibberellic acid (GA_3) @ 200 ppm	48.96^{a}	37.60^{ef}	9.80^{bc}	3.10^{bc}	6.40^{a}	0.88
T_3 - Salicylic acid (SA) @ 100 ppm	45.10^{b}	38.60^{de}	10.0^{b}	3.00^{c}	5.37^{c}	0.88
T_4 - Salicylic acid (SA) @ 150 ppm	42.00^{c}	39.10^{cde}	9.20^{e}	3.06^{c}	6.21^{ab}	0.89
T_5 - Cycocel (CCC) @ 1000 ppm	37.70^{de}	44.80^{ab}	9.80^{bc}	4.15^{a}	4.57^{e}	0.96
T_6- Cycocel (CCC) @ 1500 ppm	36.20^{e}	45.90^{a}	11.40^{a}	4.00^{ab}	4.12^{f}	0.98
T_7 - Alar (B-9) @ 500 ppm	36.00^{e}	40.90^{c}	9.40^{de}	3.30^{b}	5.00^{d}	0.93
T_8 - Alar (B-9) @ 1000 ppm	37.00^{de}	43.10^{b}	11.60^{a}	4.17^{a}	5.00^{d}	0.91
T_9 - Control (Water spray)	39.00^{d}	39.90^{cd}	9.20^{e}	4.15^{ab}	5.30^{cd}	0.88
Mean	41.21	40.66	10.00	3.55	5.31	0.91
SEm ±	0.67	0.68	0.10	0.06	0.10	0.16
LSD at 5%	2.07	2.11	0.31	0.18	0.32	NS



	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Plant height (cm)	48.9	48.96	45.1	42	37.7	36.2	36	37	39
Plant spread (cm)	36	37.6	38.6	39.1	44.8	45.9	40.9	43.1	39.9
Number of branches	9.6	9.8	10	9.2	9.8	11.4	9.4	11.6	9.2
Leaf area index	3.05	3.1	3	3.06	4.15	4	3.3	4.17	4.15
Internodal length (cm)	5.81	6.4	5.37	6.21	4.57	4.12	5	5	5.3
Stem diameter (cm)	0.84	0.88	0.88	0.89	0.96	0.98	0.93	0.91	0.88

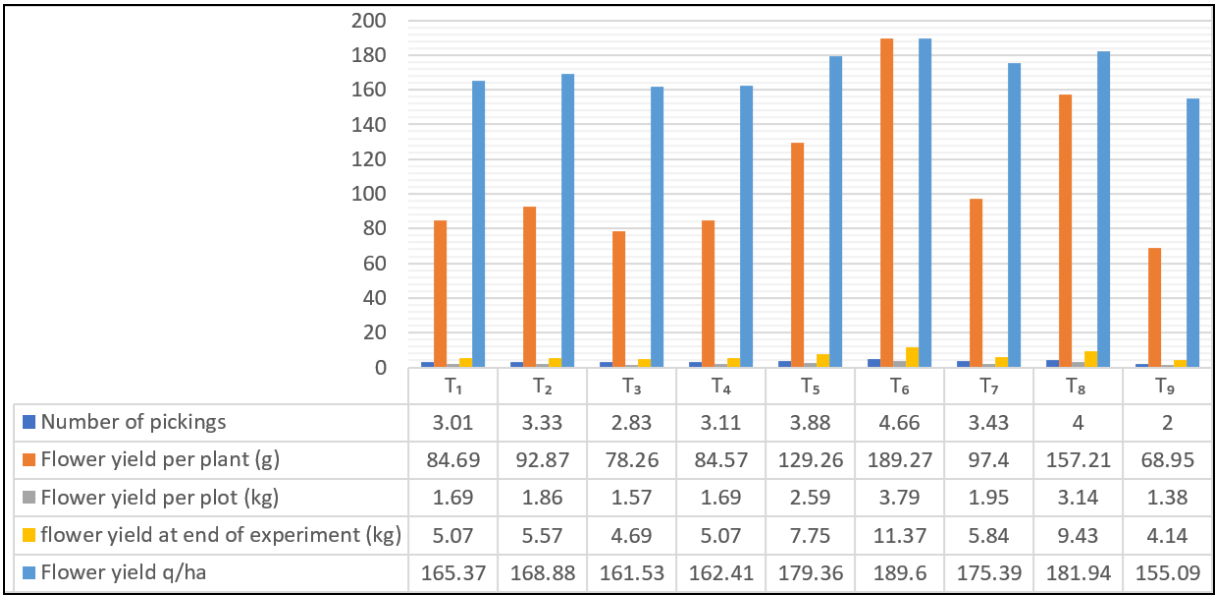
Fig 1: Effect of plant growth regulators on vegetative parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange

Yield parameter

The data pertaining to yield parameters under different treatments are presented in Table 2. Significantly maximum number of pickings (4.66) was noticed under the treatment T_6 - Cycocel (CCC) @ 1500 ppm which was followed by T_8 - Alar (B-9) @ 1000 ppm 4.00, while the minimum number of pickings (2.00) was recorded under the treatment T_9 - Control (water spray). (Sasikumar *et al*., 2015, Sharma *et al*., (2016) and Khandelwal *et al*., 2003) [19, 20, 10]. The maximum flower yield per plant (189.27g) was noticed under the treatment T_6 Cycocel (CCC) @ 1500 ppm which is followed by (157.21g) under the treatment of T_8 Alar (B-9) @ 1000 ppm, while the minimum flower yield per plant (68.95 g) was observed in T_9 Control (water spray). (Dali *et al*., 2019) [4]. Significantly maximum flower yield per plot (3.79 kg) was noticed under the treatment T_6 - Cycocel (CCC) @ 1500 ppm which was followed by T_8 - Alar (B-9) @ 150 ppm (3.14 kg), while the minimum number of flower yield per plot was recorded under the treatment T_9 - Control (water spray). Significantly maximum total flower yield at end of experiment (11.37 kg) was noticed under the treatment the treatment T_6 - Cycocel (CCC) @ 1500 ppm which was followed by T_8 - Alar (B-9) @ 1000 ppm (9.43 kg), while the minimum total flower yield at end of experiment (4.14 kg) was recorded under the treatment T_9 - Control (water spray). (Sudhagar and Kamalakannan 2017) [22]. Significantly maximum flower yield per hectare (189.60 quintals) was noticed under the treatment the treatment T_6 - Cycocel (CCC) @ 1500 ppm which was on par with T_8 - Alar (B-9) @ 1000 ppm (181.94) quintals, while the minimum flower yield (155.09 quintals) per hectare was recorded under the treatment T_9 - Control (water spray).

Table 2: Effect of plant growth regulators on yield parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange

Treatments	Number of pickings	Flower yield per plant (g)	Flower yield per plot (kg)	Flower yield at end of experiment (kg)	Flower yield q/ha
T_1 - Gibberellic acid (GA_3) @ 150 ppm	3.01^{d}	84.69^{e}	1.69^{e}	5.07^{de}	165.37^{d}
T_2 - Gibberellic acid (GA_3) @ 200 ppm	3.33^{c}	92.87^{d}	1.86^{d}	5.57^{d}	168.88^{cd}
T_3 - Salicylic acid (SA) @ 100 ppm	2.83^{e}	78.26^{f}	1.57^{e}	4.69^{de}	161.53^{de}
T_4 - Salicylic acid (SA) @ 150 ppm	3.11^{d}	84.57^{e}	1.69^{e}	5.07^{de}	162.41^{de}
T_5 - Cycocel (CCC) @ 1000 ppm	3.88^{b}	129.26^{c}	2.59^{c}	7.75^{c}	179.36^{b}
T_6- Cycocel (CCC) @ 1500 ppm	4.66^{a}	189.27^{a}	3.79^{a}	11.37^{a}	189.60^{a}
T_7 - Alar (B-9) @ 500 ppm	3.43^{c}	97.40^{d}	1.95^{d}	5.84^{d}	175.39^{bc}
T_8 - Alar (B-9) @ 1000 ppm	4.00^{b}	157.21^{b}	3.14^{b}	9.43^{b}	181.94^{ab}
T_9 - Control (water spray)	2.00^{f}	68.95^{g}	1.38^{f}	4.14^{e}	155.09^{e}
Mean	3.36	109.16	2.18	6.55	171.06
SEm ±	0.05	1.73	0.04	0.40	2.68
LSD at 5%	0.17	5.34	0.15	1.24	8.28



	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Number of pickings	3.01	3.33	2.83	3.11	3.88	4.66	3.43	4	2
Flower yield per plant (g)	84.69	92.87	78.26	84.57	129.26	189.27	97.4	157.21	68.95
Flower yield per plot (kg)	1.69	1.86	1.57	1.69	2.59	3.79	1.95	3.14	1.38
flower yield at end of experiment (kg)	5.07	5.57	4.69	5.07	7.75	11.37	5.84	9.43	4.14
Flower yield q/ha	165.37	168.88	161.53	162.41	179.36	189.6	175.39	181.94	155.09

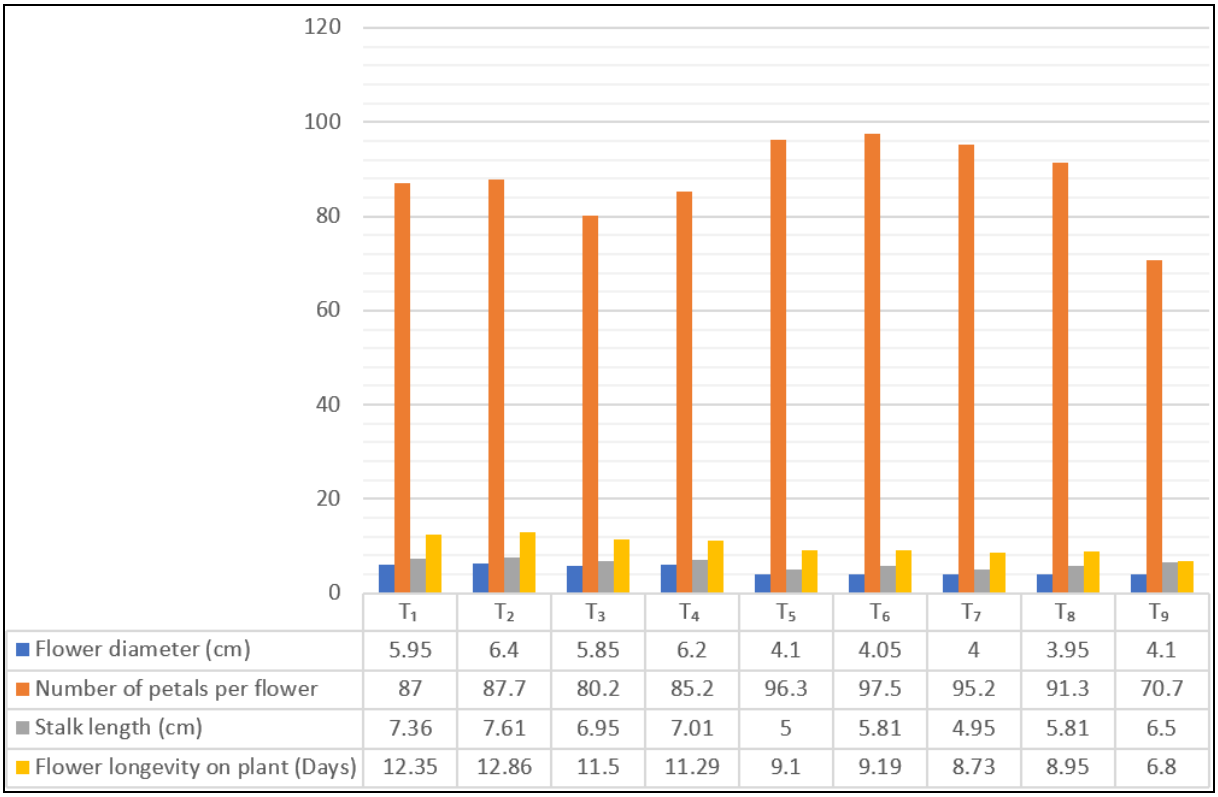
Fig 2: Effect of plant growth regulators on yield parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange

Quality parameters

The data pertaining to quality parameters under different treatments are presented in Table 3. Significantly maximum flower diameter 6.40 cm was recorded under the treatment T_2 - Gibberellic acid (GA_3) @ 200ppm, which is at par with T_4- Salicylic acid @ 150 ppm 6.20 cm, followed by T_1 - Gibberellic acid (GA_3) @ 150 ppm 5.95 cm and T_3 - Salicylic acid (SA) @ 100 ppm 5.85, while the minimum flower diameter 4.00 was recorded under the treatment T_7 - Alar (B-9). (Baghele *et al.*, 2012, Pooja *et al.*, 2015) [2, 17]. Among all the treatments maximum number of petals per flower 97.50 was recorded under the treatment T_6 - Cycocel @ 1500 ppm, which was at par with T_5 - Cycocel 96.30, while the minimum number of petals per flower 70.70 was recorded under the treatment T_9 - Control (water spray). Significantly maximum Stalk length 7.61 cm was recorded under the treatment T_2 - GA_3 @ 200 ppm on par with T_1 - Gibberellic acid (GA_3) @ 150 ppm 7.36 cm and followed by T_3 - Salicylic acid (SA) @ 100 ppm 6.95 cm and T_4 -Salicylic acid (SA) @ 150 ppm 7.01 cm, While the minimum stalk length 4.95 was recorded under the treatment T_7 - Alar (B-9) which was at par with T_5 - Cycocel (CCC) @ 1000 ppm 5.00 cm. (Palei *et al.* 2016). Significantly maximum flower longevity 12.86 Days was recorded under the treatment T_2 - Gibberellic acid (GA_3) @ 200 ppm on par with T_1 - Gibberellic acid (GA_3) @ 150 ppm 12.35 Days and followed by T_3 - Salicylic acid (SA) @ 100 ppm 11.50 Days and T_4 Salicylic acid (SA) @ 150 ppm 11.29 Days, While the minimum flower longevity 6.80 Days was recorded under the treatment T_9 - Control (water spray). (Koriesh *et al.*, 1989) [12].

Table 3: Effect of plant growth regulators on quality parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange

Treatments	Flower diameter (cm)	Number of petals per flower	Stalk length (cm)	Flower longevity on plant (Days)
T_1 - Gibberellic acid (GA_3) @ 150 ppm	5.95^{b}	87.00^{cd}	7.36^{a}	12.35^{ab}
T_2 - Gibberellic acid (GA_3) @ 200 ppm	6.40^{a}	87.70^{cd}	7.61^{a}	12.86^{a}
T_3 - Salicylic acid (SA) @ 100 ppm	5.85^{b}	80.20^{e}	6.95^{b}	11.50^{b}
T_4 - Salicylic acid (SA) @ 150 ppm	6.20^{ab}	85.20^{d}	7.01^{b}	11.29^{b}
T_5 - Cycocel (CCC) @ 1000 ppm	4.10^{c}	96.30^{ab}	5.00^{e}	9.10^{c}
T_6- Cycocel (CCC) @ 1500 ppm	4.05^{c}	97.50^{a}	5.81^{d}	9.19^{c}
T_7 - Alar (B-9) @ 500 ppm	4.00^{c}	95.20^{b}	4.95^{e}	8.73^{c}
T_8 - Alar (B-9) @ 1000 ppm	3.95^{c}	91.30^{bc}	5.81^{d}	8.95^{c}
T_9 - Control (water spray)	4.10^{c}	70.70^{f}	6.50^{c}	6.80^{d}
Mean	4.96	88.06	6.33	10.09
SEm ±	0.10	1.55	0.09	0.19
LSD at 5%	0.34	4.79	0.28	0.59



	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Flower diameter (cm)	5.95	6.4	5.85	6.2	4.1	4.05	4	3.95	4.1
Number of petals per flower	87	87.7	80.2	85.2	96.3	97.5	95.2	91.3	70.7
Stalk length (cm)	7.36	7.61	6.95	7.01	5	5.81	4.95	5.81	6.5
Flower longevity on plant (Days)	12.35	12.86	11.5	11.29	9.1	9.19	8.73	8.95	6.8

Fig 3: Effect of plant growth regulators on quality parameters of Calendula (*Calendula officinalis* L.) var. Fiesta Gitana Orange

Conclusion

The following conclusions may be made on the basis of the investigation on Calendula flower: The study suggested that treatment T_6 (Cycocel) at 1500 ppm was most effective plant growth regulator (PGR) for improving growth, yield and quality parameters of *Calendula officinalis* L. var. Fiesta Gitana under Telangana conditions. Therefore, Cycocel (CCC) at 1500 ppm is beneficial plant growth regulator for commercial cultivation of calendula var. Fiesta Gitana under Telangana conditions. The study found that Gibberellic Acid (GA_3) at 150 ppm was the most effective plant growth regulator (PGR) for enhancing the flower size and stalk length for cut flowers of Calendula var. Fiesta Gitana under the specific conditions of Telangana.

Future Line of Work

Further studies should investigate the optimal concentration and timing of different growth regulators application, in comparison to cycocel and gibberellic acid to maximize its efficacy to increase flower yield for potted plants and for cut flower production in calendula varieties in Agro-climatic conditions.

Conduct comparative studies to evaluate the performance of cycocel (CCC) and gibberellic acid (GA_3) against other emerging plant growth regulators, particularly in enhancing specific floral quality parameters such as color intensity and fragrance.

Analyze the cost-effectiveness of growth regulators application in large-scale commercial operations, considering factors such as input costs, market demand and potential for scalability in various regions.

The effect of various PGRs can also be studied on potted Calendula plants.

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