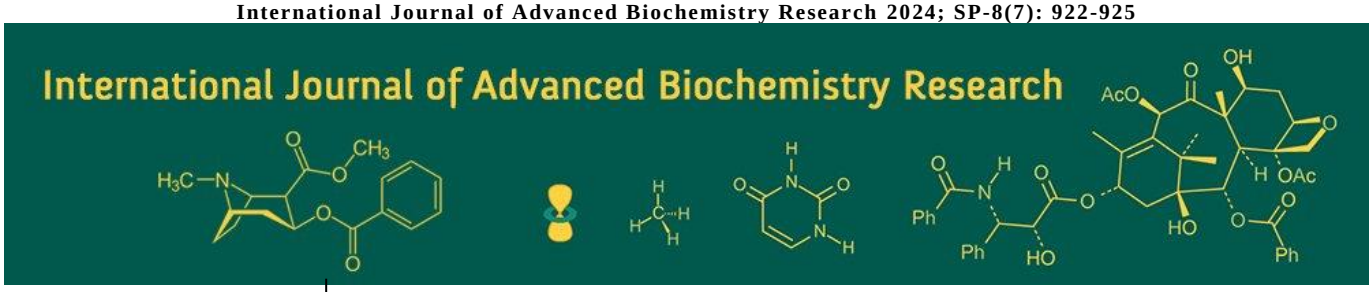

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Effect of plant growth retardant and pinching on growth, flowering and yield of annual chrysanthemum *(Chrysanthemum coronarium* L.) cv. local yellow

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Abstract
The present investigation was conducted at Instructional Farm, Jambuvadi, Department of Floriculture & Landscape Architecture, College of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat) from October to March 2023-24. In the case of plant growth retardant, the result revealed that cycocel (1500 ppm) (R_2) recorded better result for the growth, flowering and yield parameters as compared to other treatments. In case of pinching, no pinching (P_0) showed better result for minimum days to first flower bud appearance (29.51 days) and days to first flowering (36.43 days), maximum flower diameter (6.92 cm), fresh weight of flower (6.49 g) and fresh weight of hundred flowers (530.43 g). While, single pinching (P_1) noted better result for leaf area (64.25 cm^2) and stem diameter (2.71 cm). Whereas, minimum plant height (87.48 cm), maximum number of branches per plant (32.10), plant spread (E-W) (71.14 cm) & (N-S) (70.44 cm), number of flowers per plant (128.24), flowering span (56.62 days), number of pickings of flowers (11.63), flower yield per plant (391.44 g), flower yield per plot(9.78 kg), flower yield per hectare (28.99 t). In case of interaction, the treatment combination of plant growth retardant cycocel (1500 ppm) with double pinching well performed in plant spread (E-W) (81.94 cm) & (N-S) (85.71 cm), number of flowers per plant (144.00), flower yield per plant (404.91 g), flower yield per plot (10.12 kg), flower yield per hectare (29.99 t). From the present study, it can be inferred that an application of cycocel (1500 ppm) with double pinching (R_2P_2) increased flower yield in annual chrysanthemum.

Keywords: Plant growth retardant, pinching, growth, yield

Introduction
Chrysanthemum belongs to the family Asteraceae. There are over 160 varieties of chrysanthemum, with the modern fall-flowering perennial (*Chrysanthemum morifolium*) being the most popular, typically propagated through suckers. In contrast, annual chrysanthemums are propagated through seeds and include three species: *Chrysanthemum segetum* (Corn marigold), *Chrysanthemum carinatum* (tricolored chrysanthemum), and *Chrysanthemum coronarium* (Crown daisy or Garland chrysanthemum). The annual chrysanthemum (*Chrysanthemum coronarium* L.), also known as crown daisy, is native to Southern Europe. It is a branching annual with finely cut foliage, reaching a height of up to one meter. The flowers range in size from 2.5 to 4 cm and typically exhibit shades of yellow and white with a cream zone at the centre. Unlike florist chrysanthemums, annual chrysanthemums have an indeterminate growth habit and are short-duration species. They are fast-growing, winter-blooming annuals.
Chlormequat (Cycocel) is an organic compound with the formula $ClCH_2CH_2N(CH_3)^{+3}$ and paclobutrazol that is used as a plant growth retardant. The reason for the use of growth retardants is obvious, as they play an important role in reducing the inter nodal length by blocking the synthesis of gibberellins. The plant remains small, compact with deeper green foliage, and yields bigger size flowers. Chemicals can effectively control plant height, flowering time, and flower size when applied at the right time and concentration. Annual chrysanthemum flowers are short-duration and generally tall-growing. Cycocel, an organic compound, is used as a plant growth retardant to manage plant height, flowering time, and flower size. Paclobutrazol is utilized to curb vegetative growth and maximize flower production and yield.

Pinching is the process of removing of terminal growing portion of the stem to encourage branching and boost bloom production. A plant grows straight up due to apical dominance, but branching occurs if the growth tips are pinched off because assimilates are redirected into lateral buds. It is directly related to controlling flowering and producing high-quality blooms. To produce marketable attractive good keeping quality flowers to get a dwarf bushy plant and for getting quality flowers, cultural practices like pinching are necessary.

Materials and Methods

This experiment was conducted during 2023-24 located at Instructional Farm, Jambuvadi, Department of Floriculture & Landscape Architecture, College of Horticulture, Junagadh Agricultural University, Junagadh (21.5^0 N, 70.5^0 E; 60 m). The trial used a factorial Randomized Block Design, in which Factor A had five plant growth retardant treatments *i.e.* Control (R_0), Cycocel (1000 ppm) (R_1), Cycocel (1500 ppm) (R_2), Paclobutrazol (100 ppm) (R_3), Paclobutrazol (150 ppm) (R_4) and Factor B had three pinching treatments *i.e*. no pinching (P_0), single pinching (P_1), double pinching (P_2) with three replications. The spacing was 45 cm × 30 cm.

In all cases, half of the nitrogen was administered as a basal dose one day before transplanting, with the remaining half applied one month post-transplanting. The entire doses of phosphorus, potassium, and vermicompost, as specified by the treatments, were also applied as a basal dose one day before transplanting. Plant growth retardants were administered according to the treatments 30 days after transplanting (DAT). Single pinching was performed 20 DAT, involving the removal of the apical portion of the plant along with 2-3 leaves. For double pinching, a single pinch was followed by an additional pinching of all shoots 15 days later.

Result and Discussion

The effect of different plant growth retardant treatments and pinching with their interaction affect growth and yield are depicted in Tables 1, 2 and 3.

Growth Parameters

Effect of plant growth retardant

The effect of plant growth retardant significantly improved the growth parameters such as plant height, number of branches per plant, plant spread (E-W and N-S), leaf area and stem diameter. The minimum plant height (75.96 cm), leaf area (53.45 cm^2), maximum number of branches per plant (29.38), plant spread (E-W and N-S) (65.17 cm and 67.35 cm), were observed in cycocel (1500 ppm) at 90 DAT as compare to other treatments. This might be due to the diversion of carbohydrates or food material towards the auxiliary bud below the pinched portion and neutralized the effect of apical dominance which caused a reduction in plant height, an increase in the number of primary branches as well as plant spread. Similar findings were also reported by Mohanty *et al*. (2015) [8] in marigold and Ashvini *et al.* (2020) [2] in China aster. Stem diameter was found maximum with the application of cycocel (1000 ppm) (2.71 cm). This might be due to cycocel act as a growth retardant and arresting vertical growth and increasing the number of branches. A similar result was found by Khandelwal *et al.* (2003) [4] in African marigold.

Table 1: Effect of plant growth retardant and pinching on growth parameters of annual chrysanthemum

Treatments	Plant height (cm)	Number of branches per plant	Plant spread (cm)		Leaf area (cm^2)	Stem diameter (cm)
			E-W	N-S		
Factor A – plant growth retardant						
R_0	105.37	25.67	56.03	57.14	59.91	2.20
R_1	85.10	28.58	63.69	62.51	55.06	2.71
R_2	75.96	29.38	65.17	67.35	53.45	2.57
R_3	97.88	26.63	58.59	58.56	59.14	2.53
R_4	92.62	27.62	59.88	60.24	57.38	2.47
S.Em.±	2.443	0.765	1.763	1.806	1.609	0.076
C.D. at 5%	7.08	2.22	5.11	5.23	4.66	0.22
Factor B - Pinching						
P_0	94.21	23.19	53.60	54.81	49.05	2.32
P_1	92.47	27.44	57.28	58.23	64.25	2.71
P_2	87.48	32.10	71.14	70.44	57.66	2.46
S.Em.±	1.893	0.593	1.366	1.399	1.246	0.059
C.D. at 5%	5.48	1.72	3.96	4.05	3.61	0.17
Interaction: R × P						
S.Em.±	4.232	1.325	3.054	3.128	2.786	0.131
C.D. at 5%	NS	NS	8.85	9.06	NS	NS
C.V.%	8.02	8.32	8.72	8.86	8.47	9.08

Effect of pinching

The effect of pinching significantly improved the growth parameters such as plant height, number of branches per plant, plant spread (E-W & N-S), leaf area and stem diameter.

Significantly minimum plant height (94.21 cm), maximum number of branches per plant (32.10) and plant spread (E-W & N-S) (71.14 cm and 70.44 cm) were observed in double pinching (P_2) at 90 DAT. This might be due to the diversion of carbohydrates or food material toward the auxiliary bud below the pinched portion and neutralized the effect of apical dominance which caused a reduction in plant height, an increase in the number of primary branches as well as plant spread. This conformed with the findings of Rathi *et al.* (2005) [12] and Suthar (2005) [16] in marigold and Panchal (2009) [10] in chrysanthemums. Significantly highest leaf area (64.25 cm^2) and stem diameter (2.71 cm) were observed in single pinching (P_1). This might be due to a reduction in vertical growth by removal of apical dominance which causes cell division and cell elongation and accumulated carbohydrates in branches resulting in thicker stems. Similar results were reported by Pawar (2001) [11] in chrysanthemum and Shivankar (2010) [15] in annual chrysanthemum.

Interaction effect of plant growth retardant and pinching

The interaction effect of plant growth retardant and pinching was observed as significant for plant spread (E-W & N-S). Maximum plant spread (E-W) & (N-S) was found in treatment combination cycocel (1500 ppm) with double pinching (81.94 cm & 85.71 cm). Similar findings were observed by Sasikumar *et al.* (2015) [13] in marigold and Sharma *et al.* (2016) [14] in chrysanthemum.

Flowering & Yield Parameters

Effect of plant growth retardant

The data from the investigation revealed that the application of plant growth retardant treatments exerted a significant influence on flowering and yield parameters *viz*., days to first flower bud appearance, days to first flowering, flower diameter, fresh weight of flower, fresh weight of hundred flowers, number of flowers per plant, flowering span, number of pickings, flower yield per plant, flower yield per plot and flower yield per hectare.

Table 2: Effect of plant growth retardant and pinching on flowering parameters of annual chrysanthemum

Treatments	Days to first Flower bud appearance	Days to first flowering	Flower diameter (cm)	Fresh weight of flower (g)	Fresh weight of a hundred flowers (g)	Flowering span (days)	Number of pickings of flowers
Factor A – Plant growth retardant							
R_0	37.19	45.15	5.42	4.86	388.42	45.35	8.20
R_1	34.69	41.24	6.13	5.44	459.92	50.11	9.49
R_2	32.57	40.12	6.32	5.78	468.64	51.02	9.80
R_3	36.09	43.90	5.61	5.00	401.24	46.75	8.69
R_4	35.33	42.54	5.95	5.22	432.10	48.75	9.16
S.Em.±	1.019	1.203	0.153	0.146	11.841	1.391	0.243
C.D. at 5%	2.95	3.49	0.44	0.42	34.30	4.03	0.70
Factor B - Pinching							
P_0	29.51	36.43	6.92	6.49	530.43	41.73	6.63
P_1	34.68	41.70	5.79	5.37	441.31	46.84	8.95
P_2	41.33	49.65	4.95	3.92	318.45	56.62	11.63
S.Em.±	0.789	0.932	0.118	0.113	9.172	1.077	0.188
C.D. at 5%	2.29	2.70	0.34	0.33	26.57	3.12	0.55
Interaction: R× P							
S.Em.±	1.765	2.084	0.265	0.253	20.509	2.409	0.421
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.V. %	8.69	8.48	7.79	8.32	8.26	8.62	8.04

Significantly minimum number of days to first flower bud appearance (32.57 days), days to first flowering (40.12 days), maximum flower diameter (6.32 cm), fresh weight of flower (5.78 g), fresh weight of hundred flowers (468.64 g), number of flowers per plant (94.49), flowering span (51.02 days), number of pickings of flowers (9.80), flower yield per plant (353.74 g), flower yield per plot (8.84 kg) and flower yield per hectare (26.20 t) were observed in cycocel (1500 ppm) as compared to other treatments. This effect could be attributed to Cycocel's ability to delay flowering. As a growth retardant, Cycocel inhibits the endogenous synthesis of gibberellins, which are responsible for flower bud initiation, thereby delaying flowering. Cycocel is also effective in increasing flower weight, likely due to the increase in flower diameter, disc diameter, and the accumulation of metabolites in the flower. Similar findings were reported by Sasikumar *et al.* (2015) [13] in marigold, Sharma *et al.* (2016) [14] in chrysanthemum, and Khandelwal *et al.* (2003) [4] in African marigold.

Table 3: Effect of plant growth retardant and pinching on yield parameters of annual chrysanthemum

Treatments	Number of flowers per plant	Flower yield per plant (g)	Flower yield per plot (kg)	Flower yield per hectare (t)
	Factor A – Plant growth retardant			
R_0	77.31	310.71	7.76	23.01
R_1	93.02	348.71	8.71	25.82
R_2	94.49	353.74	8.84	26.20
R_3	81.00	316.05	7.90	23.41
R_4	87.07	323.28	8.08	23.94
S.Em.±	2.567	9.331	0.233	0.691
C.D. at 5%	7.44	27.03	0.68	2.00
	Factor B - Pinching			
P_0	55.12	275.47	6.88	20.40
P_1	76.37	324.59	8.11	24.04
P_2	128.24	391.44	9.78	28.99
S.Em.±	1.988	7.228	0.181	0.535
C.D. at 5%	5.76	20.94	0.52	1.55
	Interaction: R × P			
S.Em.±	4.446	16.162	0.404	1.197
C.D. at 5%	12.88	46.82	1.17	3.47
C.V. %	8.89	8.47	8.47	8.47

Effect of pinching

The variation due to different treatments of pinching was found significant in flowering and yield parameters such as days to first flower bud appearance, days to first flowering, flower diameter, fresh weight of flower, fresh weight of hundred flowers, number of flowers per plant, flowering span, number of pickings of flowers, flower yield per plant, flower yield per plot and flower yield per hectare.

Significantly minimum days to first flower bud appearance (29.51), days to first flowering (36.43), maximum flower diameter (6.92 cm), fresh weight of flower (6.49 g) and fresh weight of hundred flowers (530.43 g) were observed in no pinching (P_1). The decrease in flower diameter in pinched plants might be attributed to the fact that in pinched plants energy was shared by the developing side branches, while in the case of unpinched plants, the energy sharing was limited to the flower developing in the main branch only. That is why un-pinched plants have a fresh weight of flowers. Similar findings have been reported by Khobragade *et al.* (2012) [5] in China aster and Nain *et al.* (2017) [9] in marigold. However, a significant maximum number of flowers per plant (128.24), flowering span (56.62 days), number of pickings of flowers (11.63), flower yield per plant (391.44 g), flower yield per plot (9.78 kg) and flower yield per hectare (28.99 t) were observed in double pinching (P_3). The increase in the number of flowers due to the pinching treatment may be correlated with vegetative growth characteristics like characteristics of several branches. Due to the pinching treatment, more side branches were formed below the pinched portion of the main stem of the plant. This more vegetative growth obtained in pinched plants resulted in the production of a maximum number of flowers per plant. A similar result was also recorded by Maharnor *et al.* (2011) [7] in African marigold, Akshay *et al.* (2020) [1] in annual chrysanthemum.

Interaction effect of plant growth retardant and pinching: The result revealed that the interaction effect of plant growth retardant and pinching was reported significant in the number of flowers per plant, flower yield per plant, flower yield per plot and flower yield per hectare. However, it was noted as non-significant for days to first flower bud appearance, days to first flowering, flower diameter, fresh weight of flower, fresh weight of hundred flowers, flowering span and number of pickings of flowers.

The highest number of flowers per plant (144.00), flower yield per plant (404.91 g), flower yield per plot (10.12 kg) and flower yield per hectare (29.99 t) were observed in treatment combination of cycocel (1500 ppm) with double pinching. Similar results were also recorded by Dinesh Kumar (2007) [3] in African marigold.

Conclusion

Based on experimental data, it can be concluded that among plant growth retardant treatments, cycocel (1500 ppm) was found the most effective for growth and yield of annual chrysanthemum. While the maximum value of flowering parameters is noted in no pinching and all the yield parameters were influenced by double pinching. Thus it can be concluded that application of cycocel (1500 ppm) with double pinching is a successful strategy for enhancing the yield of flowers.

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