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Studies on the Impact of Spacing, Pinching and Growth Retardants on Vegetative Growth and Flowering Behaviour of Salvia

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Authors' contributions

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

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ABSTRACT

The present investigation entitled "Studies on the impact of spacing, pinching and growth retardants on vegetative growth and flowering behaviour of Salvia*"* was conducted at College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during December 2021 to April 2022. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising of 12 treatment combinations which includes the first factor spacing with

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two levels i.e., S_1 (20 cm x 25 cm) and S_2 (25 cm x 25 cm), second factor pinching with two levels i.e., P_0 (no pinching) and P_1 (pinching) and the third factor application of growth retardants with three levels i.e., G_0 (control), G_1 (CCC @500ppm) and G_2 (MH @100ppm). The findings revealed that pinching and the application of growth retardants had a greater impact on critical flowering attributes than the spacing experimented with in this study. Treatment combination $S_2P_1G_1$ i.e., T_{11} was proved to be better and yielded significant improvements. Based on the results it was concluded that pinching and application of CCC resulted in better growth and development in salvia regarding vegetative and flowering characters. Thus, the treatment combination $S_2P_1G_1$ i.e., T_{11} was found to be superior for vegetative growth characters like plant height, the number of branches, the number of leaves and flowering characters like the number of flower spikes per plant, length of flower spike, and length of florets.

Keywords: Vegetative growth; red salvia flowers; flowering behaviour; growth retardants.

1. INTRODUCTION

"Ornamental flowering annuals are highly valued for their attractive look and appearance and enhance the beauty of gardens. Salvia is indigenous to Brazil but it is also found in India as a seasonal flowering plant. Red salvia flowers are grown as annual plants in temperate zones, but they are damaged by hard frosts and do not survive through cold winters. Salvia requires a sunny area with a loamy and well-drained soil rich in organic matter for proper growth" [1-3]. This genus is a member of the "Lamiaceae" family, which is well-known for producing several aromatic and therapeutic plants. Salvia is known to contain the chemicals "salviarin" and "splendidin," which are chemically comparable to "salvinorin," as well as a "neoclerodane diterpene" that is supposed to be sedative and calming. *Salvia splendens* L. is a popular bedding plant that is primarily used to bring a burst of vibrant color to landscapes. It can be cultivated by sowing seeds from August to the beginning of October, blooms from winter to spring, and can carry its spikes until the next summer.

Spacing influences the compactness of plants. Pinching is one of the most suitable tactics for the successful cultivation of cut flowers as well as potted ornamental plants. In flower crops viz., chrysanthemum, China aster, carnation, marigold, etc., flowering depends on the number of flowers bearing branches, which can be manipulated by arresting vertical growth and encouraging lateral branches through pinching. Pinching removes the source of apical dominance and assimilates are diverted into lateral buds that encourage branching to produce a bushy growth with a greater number of flowers. The application of plant growth retardants is generally done in horticultural and agricultural crops. These retardants are applied for obtaining vigorous lateral growth of plants which are of small stature and is achieved by reducing the process of stem elongation [4,5]. They stimulate the plant branching habit that results in compact plants with reduced internodal length [6,7]. Growth retardants also influence plant flowering behavior, resulting in early flowering or more flowers per plant [8,9], enhancing the hue intensity of leaves and bracts [10], and improving the plant's ability to withstand various stresses encountered during transport and handling [11].The current study was conducted to determine the influence of spacing, pinching, and growth retardants on Salvia growth and flowering behaviour in order to generate beautiful pot plants by manipulating growth and promoting flowering by cultural or chemical approaches.

2. MATERIALS AND METHODS

The experiment was carried out from December 2021 to April 2022 at the College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha.

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications.

In the present investigation two levels of spacing viz., S_1 (20 cm x 25 cm), S_2 (25 cm x 25 cm), as main plot treatments and two levels of pinching viz., P_0 (No pinching), P_1 (Single pinching i.e., 15 days after transplanting) and application of growth retardants viz., G_0 (control), G_1 (CCC@500ppm) and G_2 (MH @100ppm) as sub plot treatments under each main plot treatment were included which were replicated thrice. Plant growth indicators were recorded, such as the height of the plant, the number of branches per plant, the number of leaves per plant, and the

List 1. Treatment combinations

S.NO	Treatments	Treatment Symbols	Details of treatment
1.	T_1	$S_1P_0G_0$	20cm x 25 cm + no pinching + control
2.	T_2	$S_1P_0G_1$	20cm x25cm+ no pinching + CCC@500ppm
3.	T_3	$S_1P_0G_2$	20cm x 25cm + no pinching +MH @100ppm
4.	T_4	$S_1P_1G_0$	20cm x 25cm + pinching + control
5.	T_5	$S_1P_1G_1$	20 cm x 25 cm + pinching +CCC@500ppm
6.	T_6	$S_1P_1G_2$	20cm x 25cm + pinching+ MH @100ppm
7.	T_7	$S_2P_1G_0$	25cm x 25 cm + no pinching + control
8.	T_8	$S_2P_1G_1$	25cm x 25 cm+ no pinching + CCC@500ppm
9.	T_9	$S_2P_1G_2$	25cm x 25 cm+ no pinching + MH @100ppm
10.	T_{10}	$S_2P_1G_0$	25cm x 25 cm+ pinching + control
11.	T_{11}	$S_2P_1G_1$	25cm x 25 cm+ pinching + CCC@500ppm
12.	T_{12}	$S_2P_1G_2$	25cm x 25 cm+ pinching+ MH @100ppm

number of flower spikes per plant, length of flower spikes, and the number of florets per spike. All of the data pertaining to different flowering aspects and growth factors was statistically analyzed. A variance analysis table was generated. At the 5% level of significance, the "F" test was used for assessing treatment effects. To compare treatment means, the critical difference at the 5% level was calculated.

3. RESULTS AND DISCUSSION

3.1 Vegetative Characters

Plant height: From the perusal of data presented in Table 1, it was found that no significant difference was recorded for factor levels of spacing. However, the treatments S_1 (18.61cm) and S_2 (18.68cm) were recorded similar plant height. The treatment pinching exhibited the significant difference. The lowest plant height was recorded for plants where pinching was done i.e., P_1 (17.93cm), whereas the highest plant height was observed in treatment where pinching was not done i.e., P_0 (19.36cm). The treatments of growth retardants exhibited significant difference and they are significantly different from each other. The highest plant height was obtained for control G_0 (21.35cm), followed by MH G_2 (18.16cm) and the lowest plant height was recorded for treatment CCC G_1 (16.43cm). The decreased plant height was due to the application of growth retardants, CCC and MH is because the growth retardants inhibit cell division [12] and act as an antagonist to gibberellin, due to which the vegetative attributes like apical growth and cell elongation are reduced and the reduction in plant height as a result of growth retardant application may be correlated with the formation of shorter internodal length as reported by Hashemabadi et al. (2012) in calendula, Sasikumar et al. [13] in marigold and Chikte et al. [14] in marigold.

Number of branches: Analyzing the data in Table 2, it was found that there were no significant variations in the treatments spacing levels. However, the treatments S_1 (13.32) and S_2 (13.45) were recorded similar number of branches per plant. The treatment pinching exhibited significant difference where the maximum number of branches per plant were recorded for plants where pinching was done i.e., P_1 (15.58) whereas the minimum number of branches per plant were recorded in treatment where pinching was not done i.e., P_0 (11.19). The treatments of growth retardants exhibited significant difference and they were statistically significant where the maximum number of branches per plant were recorded for treatment CCC G_1 (14.50) followed by MH G_2 (12.90) over control G_0 (12.77). The interaction between spacing and pinching revealed statistically significant results. The minimum number of branches per plant were recorded for treatment S_1P_0 (10.86) and the maximum number of branches per plant were recorded for treatment S_1P_1 (15.78) which remained statistically at par with S_2P_1 (15.38). The S x G interaction revealed significant results where the minimum number of branches $plant^{-1}$ were recorded for S_1G_0 (12.46) and the maximum number of branches per plant were recorded for treatment S_2G_1 (14.81). The P x G interaction was found to be significant. The minimum number of branches per plant were recorded for treatment P_0G_0 (10.61), whereas the maximum number of branches per plant were recorded for treatment P_1G_1 (17.26). The interaction S x P x G also yielded significant results where the minimum number of branches per plant were recorded for treatment $S_1P_0G_0$ (10.13) and the maximum number of branches per plant were recorded for treatment $S_2P_1G_1$

(17.76). The maximum number of branches recorded under pinching might have resulted due to breaking apical dominance. As a result of which there was enhanced cell division, increased cell size as well as leaf area and thus greater photosynthetic activity and it was evident that pinching results in production of more branches from the research findings of Rathore et al. [15] in marigold and Singh et al. [16] in chrysanthemum.

Table 1. Impact of spacing, pinching and growth retardants and their interaction on plant height (cm) in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	CCC 500ppm (G_1)	MH 100ppm (G_2)		
20 cm x 25 cm (S_1)	No pinching (P_0)	21.90	17.16	18.32	**19.13**	
	Pinching (P_1)	20.75	16.02	19.06	**18.09**	
	Mean	**21.33**	**16.59**	**17.90**		**18.61**
25 cm x 25 cm (S_2)	No pinching (P_0)	21.39	19.06	18.34	**19.60**	
	Pinching (P_1)	21.34	13.48	18.48	**17.70**	
	Mean	**21.37**	**16.27**	**18.41**		**18.68**
Pinching(P)	No pinching (P_0)	21.65	18.11	18.33		**19.36**
	Pinching (P_1)	21.05	14.75	17.98		**17.93**
	Grand Mean	**21.35**	**16.43**	**18.16**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.154	NS	
Pinching (P)				0.154	0.452	
Growth retardants (G)				0.189	0.554	
Interactions						
Spacing x Pinching (S x P)				0.218	NS	
Spacing x Growth retardants (S x G)				0.267	NS	
Pinching x Growth retardants (P x G)				0.267	0.783	
Spacing x Pinching x Growth retardants (S x P x G)				0.378	1.108	

Table 2. Impact of spacing, pinching and growth retardants and their interaction on number of branches per plant in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	CCC 500ppm (G_1)	MH 100ppm (G_2)		
20 cm x 25 cm (S_1)	No pinching (P_0)	10.13	11.60	10.86	**10.86**	
	Pinching (P_1)	14.80	16.76	15.80	**15.78**	
	Mean	**12.46**	**14.18**	**13.33**		**13.32**
25 cm x 25 cm (S_2)	No pinching (P_0)	11.10	11.86	11.60	**11.52**	
	Pinching (P_1)	15.06	17.76	13.33	**15.38**	
	Mean	**13.08**	**14.81**	**12.46**		**13.45**
Pinching(P)	No pinching (P_0)	10.61	11.73	11.23		**11.19**
	Pinching (P_1)	14.93	17.26	14.56		**15.58**
	Grand Mean	**12.77**	**14.50**	**12.90**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.175	NS	
Pinching (P)				0.175	0.512	
Growth retardants (G)				0.214	0.628	
Interactions						
Spacing x Pinching (S x P)				0.247	0.725	
Spacing x Growth retardants (S x G)				0.303	0.888	
Pinching x Growth retardants (P x G)				0.303	0.888	
Spacing x Pinching x Growth retardants (S x P x G)				0.428	1.255	

Number of leaves: Examining the data in Table 3, it was found that there was no statistically significant difference in the treatment spacing levels. However, the treatments S_1 (53.63) recorded maximum number of leaves per plant and S_2 (52.95) recorded minimum number of leaves per plant. The treatment pinching exhibited significant difference where the maximum number of leaves per plant were recorded for plants where pinching was done i.e., P_1 (59.47), whereas the minimum number of leaves per plant were recorded in treatment where pinching was not done i.e., P_0 (47.10). The treatments of growth retardants also exhibited significant difference and they were statistically significant where the maximum number of leaves per plant were recorded for treatment CCC G_1 (55.87) over control G_0 (52.05). The interaction between spacing and pinching showed non-significant. However, the minimum number of leaves per plant were recorded for treatment S_1P_0 (46.92) and the maximum number of leaves per plant were recorded for treatment S_1P_1 (60.33). The S x G interaction revealed significant results where the minimum number of leaves per plant were recorded for S_2G_1 (49.33) and the maximum number of leaves per plant were recorded for treatment S_1G_1 (56.02). The P x G interaction was also found to be significant where the minimum number of leaves per plant were recorded for treatment P_0G_2 (45.75), whereas the maximum number of leaves per plant were recorded for treatment P_1G_1 (63.03). The interaction S x P x G was also found to be significant where the minimum number of leaves per plant were recorded for treatment $S_1P_0G_2$ (45.20) and the maximum number of leaves per plant were recorded for treatment $S_2P_1G_1$ (63.16). The increase in metabolic activity, photosynthetic activity, and cell division might be the cause for the higher number of leaves per plant at various pinching intervals. These results corroborated with the research findings Habiba et al. [17] in chrysanthemum and Jamal et al. [18] in Lisianthus.

3.2 Flowering Characters

Number of flower spikes per plant: A considerable difference was seen between the various spacing levels following a review of the data in Table 4. The average number of flower spikes per plant was significantly greater in treatment S_2 (8.45) than in treatment S_1 (7.33), although they were not statistically similar. Additionally, significant results were obtained from pinching plants in P_1 (8.66), which produced more flower spikes per plant than P_0 (7.12), which were not pinched. Significant results were obtained as well with the growth retardant treatments, regarding the treatment CCC G_1 (8.72) producing more flower spikes than the control G_0 (7.25). "However, the interactions between S x P and S x P x G was found to be non-significant. But the interactions between S x G and P x G were statistically significant where more number of flower spikes were produced in treatment S_2G_1 (9.80), P_1G_1 (10.05) respectively and least number of flower spikes per plant were produced in treatment S_1G_0 (6.06), P_0G_0 (6.70) respectively" [19]. According to studies by Subhendu et al. [20] in chrysanthemum and Singh et al. [16] in marigold, this increase in flower spikes as a result of pinching could have been due to restriction of terminal growth, which produced more lateral branches and could have led to lateral bud initiation from where flowers originate.

Length of flower spikes: After reviewing the data provided in Table 5, it was observed that there were no notable variations across the various spacing levels. A considerable variation was noted between the pinching levels, with P_1 (18.36 cm) recording a maximum spike length greater than P_0(17.05 cm). However, there are also notable differences between the growth retardant treatments, with the treatment CCC G_1 (19.79cm) exhibiting a maximum spike length greater than MH G_2 (16.01cm) and the control G_0 (17.30cm). It was discovered that there was no considerable interaction between S x P, S x G and P x G, and S x P x G. Better availability of carbohydrates and other nutrients for floral development may be the reason for this spike length improvement. As reported by Singh et al. [16] in marigold and Ashvini et al. [21] in china aster, "this might be the consequence of delayed flower bud initiation and can be associated with the previous vegetative characteristics, such as number of branches and leaves, which may have made the treated plants more sturdy and fresh for a longer period of time. This could have sustained the supply of flowering inducing hormones for a longer period of time and might have prolonged the duration of flowering".

Number of florets per spike: Significant differences were found between the various levels of spacing after looking through the data in Table 6. The number of florets per spike was higher in treatment S_2 (66.48) than in treatment S_1 (60.33). Another interesting finding from pinching was that, compared to plants that were not pinched P_0 (58.33), pinched plants P1 (68.48) produced more florets per spike. In addition, there are significant variations between the growth retardant treatments i.e., CCC G_1 (68.33) generated more flower spikes than control G_0 (58.80). It was discovered that the interaction between S and P was not significant. However, the interaction between S x G, P x G and S x P x G were found to be significant and the treatment S_2G_1 (74.53), P_1G_1 (77.93), $S_2P_1G_1$ (82.40) recorded maximum number of florets per spike respectively and the minimum number of florets per spike were recorded in S_1G_0 (55.06), P_0G_0 (52.26), $S_1P_0G_0$ (45.60) respectively. This increase in number of florets per spike might be correlated with increase in number of flowers and spike length as reported by Vinayak et al. [22] in salvia.

Fig. 1. Pinched plants at 45 DAT

Fig. 2. Non pinched plants at 45 DAT

Table 3. Impact of spacing, pinching and growth retardants and their interaction on number of leaves per plant in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	CCC 500ppm (G_1)	MH 100ppm (G_2)		
20 cm x 25 cm (S_1)	No pinching (P_0)	45.33	49.14	46.30	**46.92**	
	Pinching (P_1)	55.23	62.90	62.86	**60.33**	
	Mean	**50.28**	**56.02**	**54.58**		**53.63**
25 cm x 25 cm (S_2)	No pinching (P_0)	48.40	48.26	45.20	**47.28**	
	Pinching (P_1)	59.23	63.16	53.46	**58.62**	
	Mean	**53.81**	**55.71**	**49.33**		**52.95**
Pinching(P)	No pinching (P_0)	46.86	48.70	45.75		**47.10**
	Pinching (P_1)	57.23	63.03	58.16		**59.47**
	Grand Mean	**52.05**	**55.87**	**51.95**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.407	NS	
Pinching (P)				0.407	1.194	
Growth retardants (G)				0.499	1.463	
Interactions						
Spacing x Pinching (S x P)				0.576	NS	
Spacing x Growth retardants (S x G)				0.705	2.069	
Pinching x Growth retardants (P x G)				0.705	2.069	
Spacing x Pinching x Growth retardants (S x P x G)				0.997	2.926	

Table 4. Impact of spacing, pinching and growth retardants and their interaction on number of flower spikes per plant in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	CCC 500ppm (G_1)	MH 100ppm (G_2)		
20 cm x 25 cm (S_1)	No pinching (P_0)	6.06	6.33	7.13	**6.51**	
	Pinching (P_1)	7.53	8.96	8.00	**8.16**	
	Mean	**6.80**	**7.65**	**7.56**		**7.33**
25 cm x 25 cm (S_2)	No pinching (P_0)	7.33	8.46	7.40	**7.73**	
	Pinching (P_1)	8.06	11.13	8.30	**9.16**	
	Mean	**7.70**	**9.80**	**7.85**		**8.45**
Pinching(P)	No pinching (P_0)	6.70	7.40	7.26		**7.12**
	Pinching (P_1)	7.80	10.05	8.15		**8.66**
	Grand Mean	**7.25**	**8.72**	**7.70**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.102	0.300	
Pinching (P)				0.102	0.300	
Growth retardants (G)				0.125	0.367	
Interactions						
Spacing x Pinching (S x P)				0.145	NS	
Spacing x Growth retardants (S x G)				0.177	0.519	
Pinching x Growth retardants (P x G)				0.177	0.519	
Spacing x Pinching x Growth retardants (S x P x G)				0.250	NS	

Table 5. Impact of spacing, pinching and growth retardants and their interaction on length of the flower spikes in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	CCC 500ppm (G_1)	MH 100ppm (G_2)		
20 cm x 25 cm (S_1)	No pinching (P_0)	14.90	19.13	15.07	**16.36**	
	Pinching (P_1)	17.63	19.11	17.04	**17.93**	
	Mean	**16.26**	**19.12**	**16.05**		**17.14**
25 cm x 25 cm (S_2)	No pinching (P_0)	17.86	19.46	15.86	**17.73**	
	Pinching (P_1)	18.83	21.48	16.06	**18.79**	
	Mean	**18.35**	**20.47**	**15.96**		**18.26**
Pinching(P)	No pinching (P_0)	16.38	19.30	15.46		**17.05**
	Pinching (P_1)	18.23	20.29	16.55		**18.36**
	Grand Mean	**17.30**	**19.79**	**16.01**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.400	NS	
Pinching (P)				0.400	1.173	
Growth retardants (G)				0.490	1.436	
Interactions						
Spacing x Pinching (S x P)				0.565	NS	
Spacing x Growth retardants (S x G)				0.692	NS	
Pinching x Growth retardants (P x G)				0.692	NS	
Spacing x Pinching x Growth retardants (S x P x G)				0.979	NS	

Table 6. Impact of spacing, pinching and growth retardants and their interaction on number of florets per spike in *Salvia*

Spacing (S)	Pinching (P)	Growth retardants (G)			Mean	Grand mean
		Control (G_0)	**CCC 500ppm (G_1)**	**MH 100ppm (G_2)**		
20 cm x 25 cm (S_1)	No pinching (P_0)	45.60	50.80	68.40	**54.93**	
	Pinching (P_1)	64.53	73.46	59.20	**65.73**	
	Mean	**55.06**	**62.13**	**63.80**		**60.33**
25 cm x 25 cm (S_2)	No pinching (P_0)	58.93	66.66	59.60	**61.73**	
	Pinching (P_1)	66.13	82.40	65.20	**71.24**	
	Mean	**62.53**	**74.53**	**62.40**		**66.48**
Pinching(P)	No pinching (P_0)	52.26	58.73	64.00		**58.33**
	Pinching (P_1)	65.33	77.93	62.20		**68.48**
	Grand Mean	**58.80**	**68.33**	**63.10**		
Effects				**SE(m)±**	**CD at 5%**	
Spacing (S)				0.499	1.464	
Pinching (P)				0.499	1.464	
Growth retardants (G)				0.611	1.793	
Interactions						
Spacing x Pinching (S x P)				0.706	NS	
Spacing x Growth retardants (S x G)				0.864	2.535	
Pinching x Growth retardants (P x G)				0.864	2.535	
Spacing x Pinching x Growth retardants (S x P x G)				1.222	3.585	

4. CONCLUSION

In accordance to the results, spacing had no noticeable effect on the majority of the characteristics. However, the behavior of salvia plants during flowering was significantly affected by pinching and the application of growth retardants, specifically cycocel. Pinching contributed to an upsurge in flowering efficiency. Similarly, application of growth retardants resulted in delayed flower bud initiation due to suppression activity of growth retardants. Hence, from the present experiment it can be concluded that the treatment combination $S_2P_1G_1$ i.e., T_{11} of spacing 25 cm × 25 cm + pinching + CCC@500 ppm was found to be best for most of the vegetative growth and flowering parameters including plant height (13.48cm), number of branches (17.76), number of leaves (63.16), number of flower spikes per plant (11.13), length of the spike (21.48cm) and number of florets per spike (82.40) in salvia.

5. FUTURE SCOPE

Impact of different levels of pinching in salvia should be further standardized. Effect of different levels of various growth retardants can also be studied. By conducting further research, you can gain a deeper understanding of the $S_2P_1G_1$ combination's effects and determine its suitability for widespread recommendation to farmers.

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Authors have declared that no competing interests exist.

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