Plant Archives Vol. 25, Supplement 2, 2025 pp. 2212-2220 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.281

ENHANCING AJMER CORIANDER-1 PRODUCTION: EXPLORING THE IMPACT OF CUTTING AND GA_3 APPLICATION ON GROWTH, SEED YIELD AND QUALITY IN MID HILL REGIONS OF HIMACHAL PRADESH INDIA

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(Date of Receiving : 01-04-2025; Date of Acceptance : 11-06-2025)

ABSTRACT

Coriander (*Coriandrum sativum* L., 2n=22) is primarily cultivated for its seeds, greens and use in culinary traditions. It also has medicinal benefits. It faces problem such as poor germination impacting growth and yield. Cutting × GA_3 study on Ajmer Coriander -1 was performed to assess the effect on growth, seed yield and quality at Dr. Y S Parmar University of Horticulture and Forestry Nauni, Solan, HP during Rabi season 2021-22. The treatments comprised of cutting at 45 DAS (C) viz., C_1 (no cutting), C_2 (cutting) and five GA_3 application at 55 DAS (G) i.e., G_1 (25 ppm), G_2 (50 ppm), G_3 (75 ppm), G_4 (100 ppm) and G_5 (no GA_3). It was concluded that treatment combination C_2G_3 was highly significant for recording maximum number of umbels plant^{-1} (26.53), number of seeds umbel^{-1} (54.62), number of seeds plant^{-1} (1449.56), highest seed yield (12.57 g plant^{-1} and 1266.67 g plot^{-1}) and 1000 seed weight (12.51g). Treatment combination C_1G_4 (no cutting at 45 DAS + GA_3 application @100 ppm at 55 DAS) showed maximum values for growth traits viz., plant height at peak reproductive stage (116.85 cm), length of flowering stalk (4.97 cm), minimum days to 50 % flowering (78.83) and days to seed maturity (157.66). It could be deciphered that combination C_2G_3 indicated highly significant responses for yield contributing characters. Therefore, the treatment combination C_2G_3 (cutting at 45 DAS + GA_3 application @ 75 ppm at 55 DAS) can be recommended to coriander growers for commercial cultivation of quality seed after multi-location testing.

Keywords: Coriander, cutting, gibberellic acid, umbels, multi-location testing

Introduction

India being "Home of Spices" since the time immemorial (Awasthi and Pandey, 2016), has a unique place among global spice propect as the largest producer, consumer and exporter of seed spices (Prapakaran, 2019). Seed spices include coriander, fenugreek, cumin,-fennel etc. Seed spices are known to possess anticancer, antidiabetic, antimicrobial, hypolipidemic, have insecticidal properties, used in menstrual issues, helps in digestibility of food, hypertension, modulates detoxification enzymes and stimulates immune system (Rathore *et al*., 2013). The spice production in the country has increased from 6.76 (MT) in the year 2014-2015 to record level of about 10.7 (MT) with a 60 % increase in the year 2020-2021 (Malhotra *et al*., 2021).

Coriander (*Coriandrum sativum* L., 2n=22) being from Apiaceae family is an annual herbaceous plant, primarily cultivated for its seeds and tender green leaves. India stands as the world's largest producer, consumer, and exporter of coriander seeds, with an annual production averaging around 831.91 tonnes from an area of 661.77 hectares and a productivity rate of 12.57 quintals per hectare. Madhya Pradesh is the highest coriander-producing state in India, contributing 401.35 tonnes from 296.27 hectares in the 2020-2021 period. In Himachal Pradesh, coriander cultivation spans an area of 0.132 hectares, yielding an annual

production of 0.065 tonnes with an average yield of 492 kg per hectare (Malhotra *et al*., 2021).

Coriander plants are highly regenerative; they can be repeatedly harvested for their leaves and young shoots by clipping or cutting, a technique that has a substantial impact on the quantity and quality of the seeds produced (Datta *et al*., 2008). Plant growth regulators have a significant potential to increase agricultural productivity by promoting plant growth and altering the pool of primary and secondary metabolites. In coriander, gibberellic acid in particular has been demonstrated to enhance the yield attributing characters (Kumar *et al*., 2018; Kurmi *et al*., 2020). Obtaining the best crop yields depends critically on having access to high-quality seeds. Seed quality has a major effect on agricultural production; it accounts for 15–25% of total crop yields (Chauhan *et al*., 2016), hence good quality seeds are a must.

Therefore, keeping in view the above facts, present investigation was carried out to maximize the success of cutting and GA_3 application on growth, flowering, seed yield and quality attributes in coriander.

Materials and Methods

The research being carried out in the experimental field area and laboratory of Department of Seed Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) during Rabi season 2021-2022. The experiment was laid out in Randomized Complete Block Design (factorial) with ten treatments replicated three times.

Planting material

Healthy, bold and disease-free seeds of Coriander var. Ajmer Coriander- 1 (ACr-1) were procured from ICAR-National Research Centre on Seed Spices, Ajmer, and Rajasthan.

Treatment details

The study involved two factors. The first factor was cutting (C), with two levels: no cutting (C_1) and cutting (C_2). The cutting treatment was performed at 45 days after sowing (DAS), with the plants being cut 6 inches above ground level to encourage the development of side shoots. The second factor was the application of gibberellic acid (GA_3) (G), which included five levels: GA_3 at 25 ppm (G_1), GA_3 at 50 ppm (G_2), GA_3 at 75 ppm (G_3), GA_3 at 100 ppm (G_4), and no GA_3 application (G_5). Different plots were sprayed with varying GA_3 concentrations using a hand knapsack sprayer and administered at 55 days after sowing (DAS).

Sr. No.	Treatments	Treatment combinations	Treatment details
1.	T_1	C_1G_1	25 ppm GA_3 + no cutting
2.	T_2	C_1G_2	50 ppm GA_3 + no cutting
3.	T_3	C_1G_3	75 ppm GA_3 + no cutting
4.	T_4	C_1G_4	100 ppm GA_3 + no cutting
5.	T_5	C_1G_5 (Control)	No GA_3 + no cutting
6.	T_6	C_2G_1	25 ppm GA_3 + cutting
7.	T_7	C_2G_2	50 ppm GA_3 + cutting
8.	T_8	C_2G_3	75 ppm GA_3 + cutting
9.	T_9	C_2G_4	100 ppm GA_3 + cutting
10.	T_{10}	C_2G_5	No GA_3 + cutting

Results and Discussion

The variance analysis illustrated significant variations among cutting, GA_3 application and their interactions at 5 % level of significance for the entire field.

Growth and yield performance

Days to field emergence: The effect of cutting, GA_3 and their interaction had non-significant effects on days to field emergence as shown in table 1. The possible reason for this could be that the treatments of cutting and GA_3 application are applied after seedling emergence at 45 and 55 DAS, respectively. As a result, data observed for this trait was established insignificant.

Days to 50% flowering: Observations recorded on the effect of cutting and GA_3 application on days to 50 % flowering showed significant variations as shown in Table 1. Minimum (85.83) days were noted in C_1 (no cutting) whereas, maximum (86.83) days were observed in C_2 (cutting). Also, G_4 (100 ppm) took minimum (81.67) days and G_5 (no GA_3) took maximum (90.67) days to 50 % flowering. Treatment combination C_1G_4 (no cutting at 45 DAS + GA_3 application @ 100 ppm at 55 DAS) took minimum (78.83) days and C_1G_5 (no cutting at 45 DAS + no GA_3 application at 55 DAS) took maximum days (90.83 days). Plants without cutting treatments have a shorter time to blooming as they move from the vegetative to the reproductive phase more quickly. Furthermore, early blooming might be attributed to increased amounts of endogenous gibberellins assisting the rapid shift from vegetative to reproductive development. GA_3 is metabolised to florigen that stimulates blooming. The results are congruent with those of Haokip *et al*. (2016) and Andrabi *et al*. (2019) for coriander, Krishnaveni *et al*. (2016) for fenugreek, and Chatterjee R. and Choudhuri P. (2012) for cowpea.

Plant height at peak reproductive stage (cm): Table 1 shows the effects of cutting and GA_3 spraying on plant height (cm) at the peak reproductive stage.

Maximum (107.99 cm) plant height was recorded in C_1 (no cutting) and minimum (105.34 cm) was observed in C_2 (cutting). In case of GA_3 application, highest plant height (112.77 cm) was recorded in G_4 (100 ppm), while lowest (101.05 cm) was reported in G_5 (no GA_3). In case of interaction effect, maximum (116.85 cm) plant height was recorded in treatment combination C_1G_4 (no cutting at 45 DAS + GA_3 application @ 100 ppm at 55 DAS). Increased plant height in C_1G_4, may be due to the fact that the plants which had not been given a cutting treatment did not lose their growth habit as compare to plants which were given a cutting treatment, took more time to grow and the height remained less when compared to non-cutting treatment plants.

Table 1: Data on the effect of cutting and GA_3 treatment on days to field emergence, days to 50% blooming, and plant height at peak reproductive stage (cm) of coriander.

Treatments	Days to field emergence			Days to 50 % flowering			Plant height (cm) at peak reproductive stage		
	C_1	C_2	Mean B	C_1	C_2	Mean B	C_1	C_2	Mean B
G_1	10.33	10.33	**10.33**	88.50	86.33	**87.42**	106.17	102.98	**104.57**
G_2	10.33	11.00	**10.66**	87.00	88.17	**87.58**	107.40	104.67	**106.04**
G_3	11.00	11.66	**11.33**	84.00	84.67	**84.33**	108.13	109.63	**108.88**
G_4	10.66	10.00	**10.33**	78.83	84.50	**81.67**	116.85	108.69	**112.77**
G_5	11.66	9.33	**10.50**	90.83	90.50	**90.67**	101.40	100.70	**101.05**
Mean A	**10.80**	**10.46**		**85.83**	**86.83**		**107.99**	**105.34**	
Factors	$CD_{0.05}$								
Cutting	N/S			0.74			1.26		
GA_3	N/S			1.17			1.99		
Cutting×GA_3	N/S			1.66			2.82		

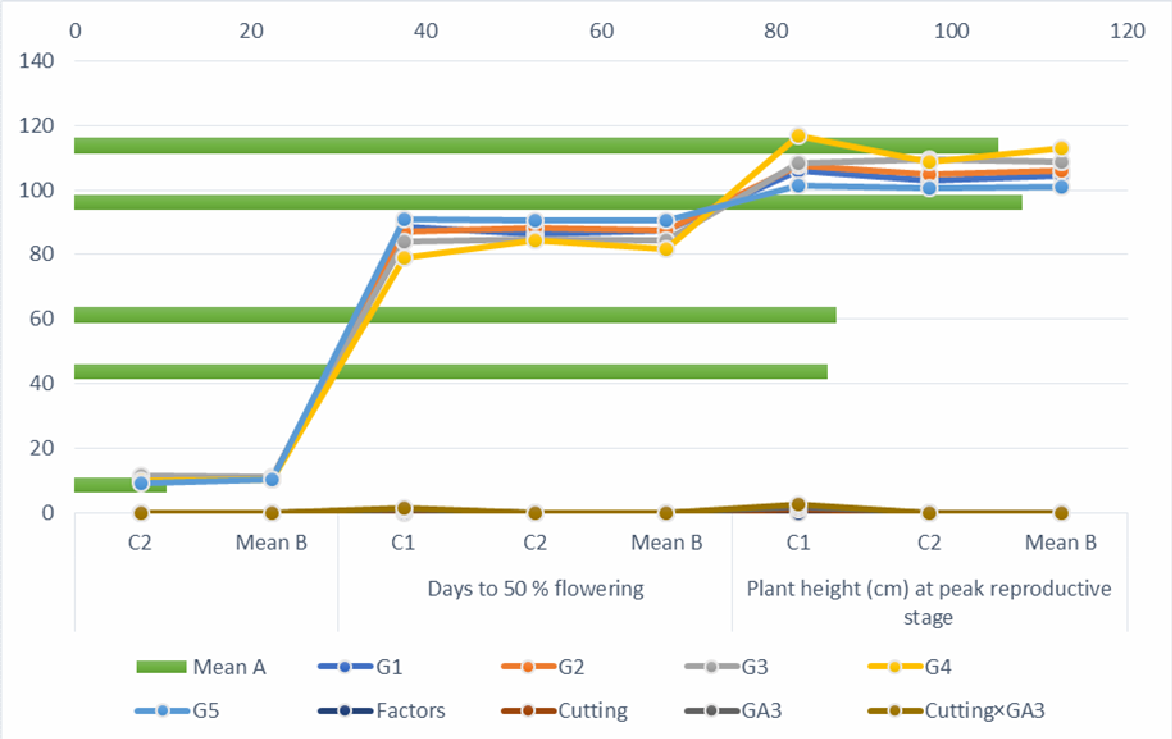

Fig. 1: Effect of cutting and GA_3 application on days to field emergence and days to 50% flowering and plant height at peak reproductive stage (cm) of coriander.

Apart from that, the rise in plant height might be attributed to an increase in cell wall flexibility, followed by hydrolysis of starch to sugars, reducing cell's water potential, causing inter-nodal elongation. Exogenous GA_3 treatment may have promoted protein synthesis and resulted in enhanced plant height. Similar findings were reported by Haokip *et al.* (2016), Yugandhar *et al.* (2016), Andrabi *et al.* (2019), Deokar

et al. (2020) for coriander, Abbas (2017) for carrot, and Akter *et al*. (2007) for mustard.

Length of flowering stalk (cm): Observations recorded on the effect of cutting and GA_3 application on length of flowering stalk (cm) showed significant variations as shown in Table 2. Maximum (4.31cm) length of flowering stalk was recorded in C_1 (no cutting) whereas, minimum (3.84 cm) length of flowering stalk was recorded in C_2 (cutting). G_4 (100 ppm GA_3) recorded maximum (4.74 cm) length of the flowering stalk which was remarkably better than other treatments. The interconnected effect of cutting and GA_3 application was also found to be significant on this attribute. Length of flowering stalk (cm) was observed maximum (4.97 cm) in C_1G_4 and minimum (3.07 cm) C_2G_5. Uncut plants don't lose their growth habit as compared to cut plants. Also, the increased concentration of GA_3 helped in elongation of the flowering stalk. These findings are concord with the results of Haokip *et al*. (2016) and Andrabi *et al*. (2019) in coriander.

Number of umbels per plant: Data analysis revealed considerable changes in the effect of cutting and GA_3 treatment on the quantity of umbels per plant, as seen in Table 2. The highest number of umbels per plant (22.44) was reported in C_2, while the lowest number (19.35) was seen in C_1. G_3 (75 ppm) produced the most umbels per plant (24.48), outperforming all other treatments. The number of umbels per plant was highest (26.53) in C_2G_3, which was statistically equivalent to C_2G_4, whereas C_1G_5 had the fewest (17.46) umbels per plant. Increased branches due to cutting could have led to the increase in number of reproductive structures. The higher concentration of GA_3 boosted photosynthetic efficiency and assimilate availability, allowing photosynthates to separate from reproductive structures. These findings are consistent with those of Haokip *et al*. (2016), Parmar *et al*. (2018), Singh *et al*. (2012), Maheriya *et al*. (2015), Singh N. and Kaur A. (2022) for coriander, Kumar *et al*. (2017) for fenugreek, Pariari *et al*. (2012) for cumin, and Shetty A.A. and Rana M.K. (2012) for Ajwain.

Days to seed maturity: The data regarding the impact of cutting and GA_3 application on days to seed maturity revealed significant variations, as presented in Table 2. The shortest time to seed maturity (171.67 days) was observed in the no-cutting treatment (C_1), whereas the longest time (173.67 days) was recorded in C_2. In case of GA_3 application the shortest time (163.33 days) was noted with 100 ppm GA_3 application (G_4), while the longest time (181.33 days) was observed in the absence of GA_3 application (G_5). The shortest time to seed maturity (157.66 days) was recorded with the combination of no cutting at 45 DAS and GA_3 application at 100 ppm at 55 DAS (C_1G_4). In contrast, the longest time (181.67 days) was found with C_1G_5.

Table 2: Data pertaining to the effect of cutting and GA_3 application on length of flowering stalk (cm), number of umbels per plant and days to seed maturity of coriander.

Treatments	Length of flowering stalk (cm)			Number of umbels per plant			Days to seed maturity		
	C_1	C_2	Mean B	C_1	C_2	Mean B	C_1	C_2	Mean B
G_1	3.88	3.63	**3.76**	17.80	20.30	**19.05**	177.00	172.67	**174.83**
G_2	4.15	3.74	**3.94**	18.76	22.13	**20.45**	174.00	176.33	**175.17**
G_3	4.59	4.26	**4.43**	22.43	26.53	**24.48**	168.00	169.33	**168.67**
G_4	4.97	4.51	**4.74**	20.30	25.26	**22.78**	157.67	169.00	**163.33**
G_5	3.93	3.07	**3.50**	17.46	18.00	**17.73**	181.67	181.00	**181.33**
Mean A	**4.31**	**3.84**		**19.35**	**22.44**		**171.67**	**173.67**	
Factors	$CD_{0.05}$								
Cutting	0.11			0.86			1.48		
GA_3	0.17			1.37			2.34		
Cutting×GA_3	0.24			1.93			3.31		

The involvement of GA_3 in the transition from vegetative to floral apices contributed to the reduced days to seed maturity. These findings are consistent with the results reported by Yugandhar *et al*. (2014) in coriander, as well as by Krishnaveni *et al*. (2016) and Yousuf M. and Nayak H. (2018) in fenugreek.

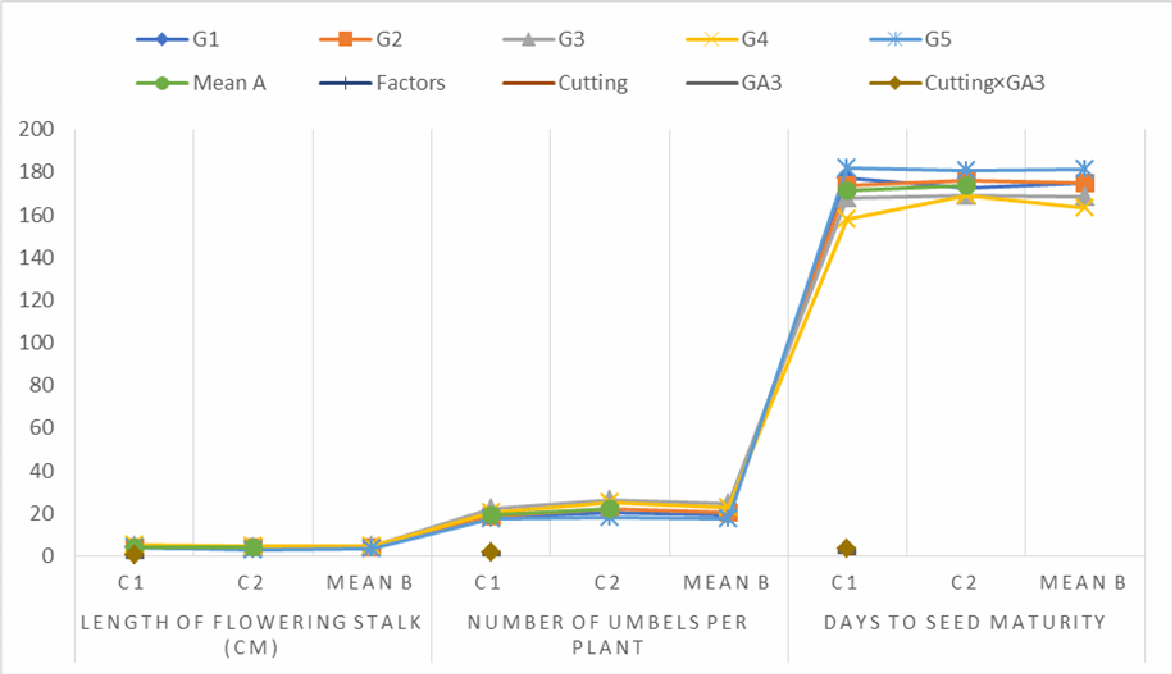

Fig. 2: Effect of cutting and GA_3 application on length of flowering stalk, number of umbels per plant and days to seed maturity in coriander.

Number of seeds per umbel: Table 3 displays large variability in data about the impact of cutting and GA_3 application on the quantity of seeds per umbel. The highest number of seeds per umbel (47.72) was found in C_2, while the lowest (45.21) was found in C_1 (no cutting). The largest (53.14) number of seeds per umbel was recorded in G_3, while the least (36.62) was found in G_5. Number of seeds per umbel was recorded maximum (54.62) in C_2G_3 which was statistically at par with C_2G_4, whereas, minimum (36.14) number was observed in C_1G_5. This might be due to increase in physiological activities, increase in number of branches and availability of assimilates for partitioning and maintenance of positive source sink gradient of photosynthates. These findings are concord with the results reported by Maheriya *et al*. (2015), Haokip *et al*. (2016), Kurmi *et al*. (2020), Singh and Kaur (2022) in coriander, Reddy P.P. and Hore J.K. (2020) in fenugreek and Ahmad *et al*. (2020) in alfalfa.

Number of seeds per plant: Analysis of data showed significant variations for the effect of cutting and GA_3 application on number of seeds per plant as shown in Table 3. Maximum (1091.24) number of seeds per plant was recorded in C_2 and minimum (887.13) in C_1. The effect of GA_3 application was found to be significant as G_3 recorded maximum (1304.59) and G_5 minimum (649.88) number of seeds per plant. Similarly, maximum (1449.66) number of seeds per plant was recorded in C_2G_3 which was statistically at par with C_2G_4, whereas, C_1G_5 resulted in minimum (630.76) number of seeds per plant. A higher number of seeds per plant may have resulted from enhanced assimilate availability for partitioning and maintaining a positive source-sink gradient of photosynthates. The results presented by Kumar *et al*. (2017), Rafat *et al*. (2017) in fenugreek, Pariari *et al*. (2012) in cumin, Khan *et al*. (1994) in spinach, and Ahmad *et al*. (2020) in lucerne are consistent with these findings.

Seed yield per plant (g): Observations recorded on the effect of cutting and GA_3 application on seed yield per plant (g) showed significant variations as shown in Table 4. Maximum (11.33 g) seed yield per plant was observed in C_2 whereas, minimum (9.05 g) was recorded in C_1. Also G_3 (75 ppm GA_3) showed maximum (11.16 g) seed yield per plant which was statistically at par with G_4 (100 ppm) and G_2 (50 ppm). Maximum (12.57 g) seed yield per plant was recorded in C_2G_3 interaction which was statistically at par with C_2G_4 and C_2G_2, whereas, C_1G_5 resulted in minimum (8.60 g) seed yield per plant. The reason might be due to yield contributing characters especially number of umbels per plant, number of seeds per umbels, number of seeds per plant in C_2G_3 which ultimately increased the seed yield per plant.

Table 3: Data pertaining to the effect of cutting and GA_3 application on number of seeds per umbel, number of seeds per plant and seed yield per plant (g) of coriander.

Treatments	Number of seeds per umbel			Number of seeds per plant			Seed yield per plant (g)		
	C_1	C_2	Mean B	C_1	C_2	Mean B	C_1	C_2	Mean B
G_1	42.68	45.74	**44.21**	759.69	928.08	**843.89**	8.91	10.40	**9.65**
G_2	48.18	47.44	**47.81**	903.96	1050.97	**977.46**	8.97	11.75	**10.36**
G_3	51.66	54.62	**53.14**	1159.52	1449.66	**1304.59**	9.74	12.57	**11.16**
G_4	48.44	53.72	**51.08**	981.71	1358.49	**1170.10**	9.02	12.52	**10.77**
G_5	36.14	37.10	**36.62**	630.76	669.00	**649.88**	8.60	9.39	**9.00**
Mean A	**45.21**	**47.72**		**887.13**	**1091.24**		**9.05**	**11.33**	
Factors	$CD_{0.05}$								
Cutting	1.20			55.58			0.56		
GA_3	1.91			87.88			0.88		
Cutting×GA_3	2.70			124.28			1.24		

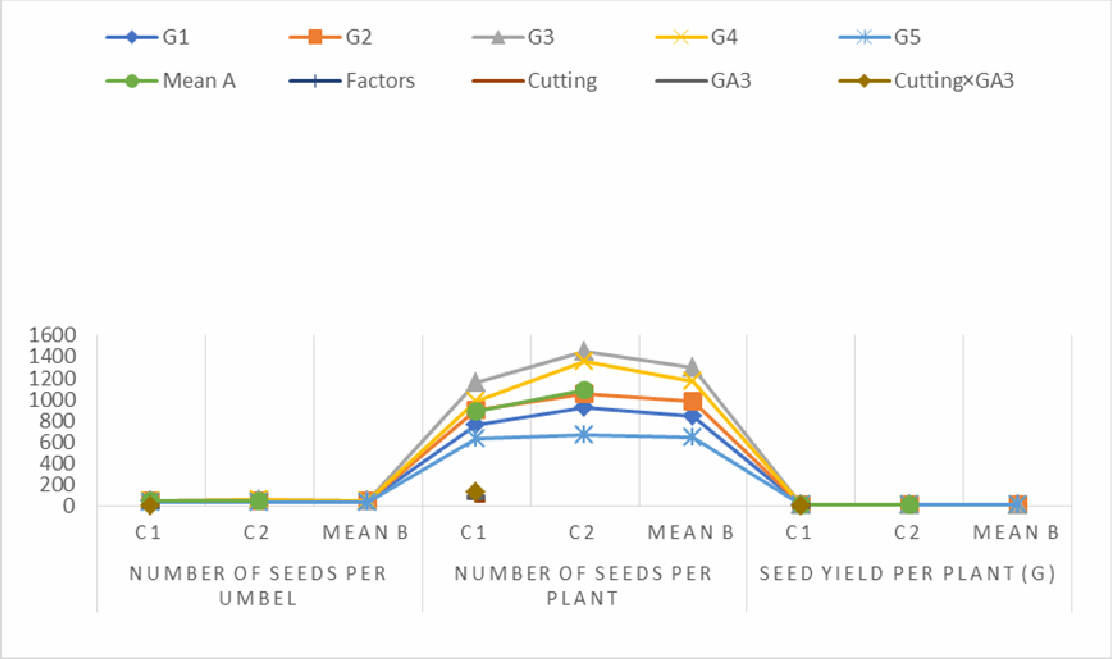

Fig. 3: Effect of cutting and GA_3 application on number of seeds per umbel, number of seeds per plant seed yield per plant of coriander.

Besides this, cutting and increased concentration of GA_3 helped in maximizing vegetative growth coupled with increased photosynthesis and greater mobilization of photosynthates towards reproductive sites might have increased seed yield per plant. Similar results were reported by Andrabi *et al.* (2019) in coriander, Kasture *et al.* (2002) in spinach, Maheriya *et al.* (2015) and Mane *et al.* (2008) in palak.

Seed yield (g/plot; q/ha): Data recorded on the effect of cutting and GA_3 application on seed yield per plot (g) showed significant variations as shown in Table 4. Maximum (1018.27 g/plot) seed yield was recorded in C_2 whereas, minimum (896.13 g/plot) was observed in C_1. In case of GA_3 application, maximum (1145.00 g/plot) seed yield was recorded in G_3 (75 ppm) which was statistically at par with G_4 (100 ppm) and minimum (780.67 g/plot) seed yield was observed in G_5 (no GA_3). In the interaction effect, maximum (1266.67 g/plot) seed yield was recorded in C_2G_3 which was statistically at par with C_2G_4, whereas, C_1G_5 resulted in minimum (770.66 g/plot) seed yield. Higher seed yield per plot and per hectare in C_2G_3, is resultant of yield contributing characters especially number of umbels per plant, number of seeds per umbels, number of seeds per plant and seed yield per plant. The increase availability of assimilates for partitioning and maintenance of positive source sink gradient of photosynthates might have led to increase the seed yield per plot and per hectare. Similar results were reported by Singh *et al.* (2012), Singh N. and Kaur A. (2022) in coriander, Ali *et al.* (2015) in onion, Singh H. and Gill S.S. (1983), Singh *et al.* (2000), Kasture *et al.* (2002) and Yugandhar *et al.* (2016) in spinach,

Mane *et al*. (2008), Naik *et al*. (2009) and Narayan *et al*. (2018) in palak.

1000 seed weight (g): Data pertaining to the effect of cutting and GA_3 application on 1000 seed weight (g) showed significant variations as shown in Table 4. Maximum 1000 seed weight was observed in C_2 (12.02 g) whereas, minimum was recorded in C_1 (10.63 g) .Analysis of data revealed highly significant results for the effect of GA_3 application on this trait. Maximum (12.17 g) 1000 seed weight was obtained in treatment G_3 (75 ppm) which was statistically at par with G_2 (50 ppm) and G_4 (100 ppm), whereas, minimum (9.94 g) was recorded in G_5 (no GA_3). Maximum (12.51 g) 1000 seed weight was recorded in C_2G_3 which was statistically at par with C_1G_3, C_2G_1, C_2G_2 and C_2G_4. However, C_1G_5 resulted in minimum (8.34 g) 1000 seed weight.

Maximum 1000 seed weight in C_2G_3, might be due to increased plant spread and accumulation of metabolites resulted in bolder seeds which ultimately increased the 1000 seed weight of coriander seeds. These results are coinciding with the findings of Singh *et al*. (2012), Kurmi *et al*. (2020) in coriander, Korla B.N. and Saini A. (2003), Thapa U. and Maity T.K. (2003) and Tania *et al*. (2015) in fenugreek.

Table 4: Data pertaining to the effect of cutting and GA_3 application on seed yield per plot and 1000 seed weight (g) of coriander.

Treatments	Seed yield per plot (g/plot)			1000 seed weight (g)		
	C_1	C_2	Mean B	C_1	C_2	Mean B
G_1	750.00	890.67	820.33	10.96	11.64	11.30
G_2	916.57	950.00	933.33	11.01	12.04	11.52
G_3	1023.33	1266.67	1145.00	11.82	12.51	12.17
G_4	1020.00	1193.33	1106.67	11.03	12.39	11.71
G_5	770.66	790.67	780.67	8.34	11.54	9.94
Mean A	896.13	1018.27		10.63	12.02	
Factors	$CD_{0.05}$					
Cutting	40.98			0.52		
GA_3	64.80			0.82		
Cutting×GA_3	91.64			1.17		

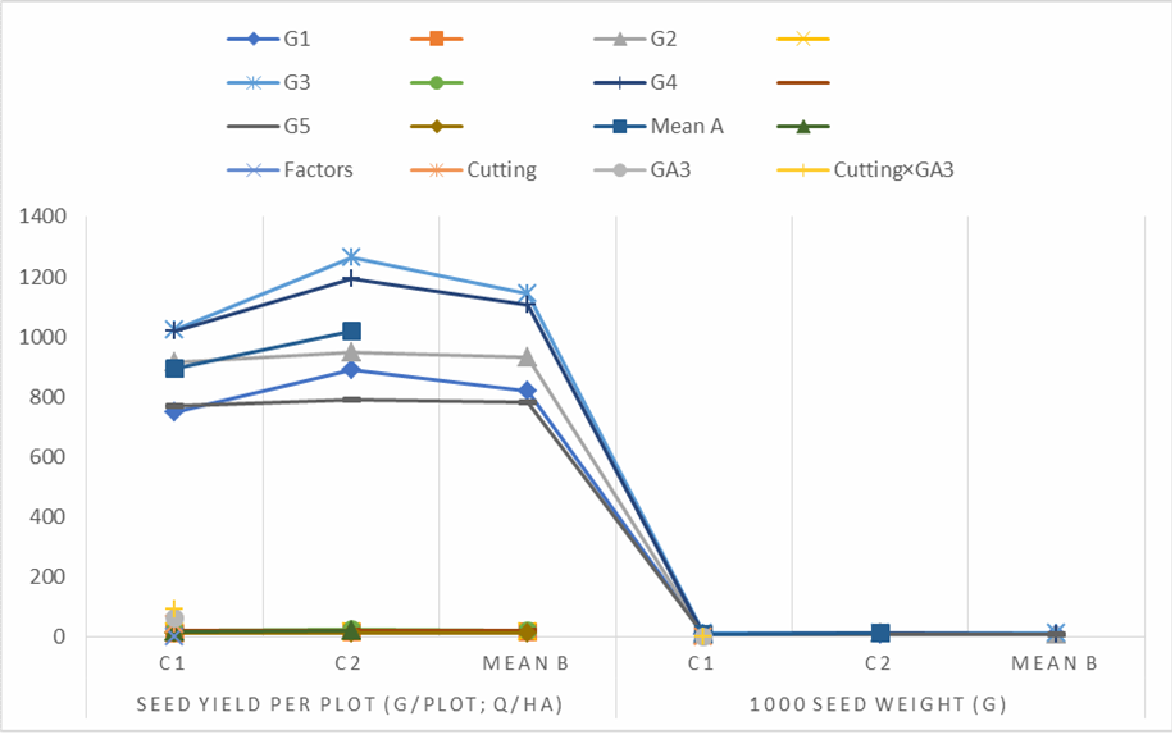

Fig. 4: Effect of cutting and GA_3 application on seed yield per plot and 1000 seed weight (g)

Conclusion

On the basis of experimental results obtained from the present investigation, it is concluded that the treatment combination C_2G_3 (cutting at 45 DAS + GA_3 application @ 75 ppm at 55 DAS) was found significantly superior over all other treatments for number of umbels/plant and number of seeds/umbel, number of seeds/plant, seed yield/plant, seed yield (g/plot; q/ha), and seed quality attributes like 1000 seed weight (g). It can be hence concluded that that some modification in the intercultural operations like cutting operations and application of growth promoting hormones like gibberellic acid (GA_3) can improve the growth and yield parameters of coriander and enhance its productivity.

Acknowledgements

The authors are grateful to the Professor and Head, Department of Seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) for providing all facilities for the research.

Author contribution statement

The authors have equally contributed in preparation of the manuscript and the research done.

Conflict of Interest

The authors associated with this research have no conflict of interest in any form with respect to this paper submitted. The authors have no competing interests to declare that are relevant to the content of this article.

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