Journal of Scientific Research and Reports

Volume 30, Issue 10, Page 854-862, 2024; Article no.JSRR.124900
ISSN: 2320-0227

Influence of Plant Growth Regulators on Growth, Seed Yield and Economics of Coriander (*Coriandrum sativum* L.) cv. Jawahar Dhaniya-10

Reena Nair [a++*], Ankita Sharma [a#], Shreyansha Dubey [a†], Harshita Thakur [a†], Shubham Ahirwar [a‡] and Monika Koushale [a†]

[a] *Department of Horticulture, College of Agriculture, JNKVV, Jabalpur, (M.P.), 482 004, India.*

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/jsrr/2024/v30i102509

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/124900

Original Research Article

Received: 05/08/2024
Accepted: 07/10/2024
Published: 17/10/2024

ABSTRACT

An experiment was performed during the *Rabi* (October–March, 2021–22) at the Vegetable Research Center, Department of Horticulture, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh, India to study the effects of plant growth regulators (PGRs) on the growth, yield and

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[++] *Assistant Professor;*
[#] *Guest Faculty;*
[†] *MSc Research Scholar;*
[‡] *PhD, Research Scholar;*
**Corresponding author: E-mail: reena_nair2007@rediffmail.com;*

Cite as: *Nair, Reena, Ankita Sharma, Shreyansha Dubey, Harshita Thakur, Shubham Ahirwar, and Monika Koushale. 2024. "Influence of Plant Growth Regulators on Growth, Seed Yield and Economics of Coriander (Coriandrum Sativum L.) Cv. Jawahar Dhaniya-10". Journal of Scientific Research and Reports 30 (10):854-62. https://doi.org/10.9734/jsrr/2024/v30i102509.*

economics of coriander (*Coriandrum sativum* L.) cv. Jawahar Dhaniya-10. A Randomized Block Design with three replications was used, including nine PGR treatments: Salicylic acid (50 and 100 ppm), Jasmonic acid (50 and 100 ppm), Benzyl Adenine (10 and 20 ppm), and Brassinosteroid (0.5 and 1.0 ppm), with a water spray as the control. Spraying was conducted at 30 and 60 days after sowing (DAS). The results showed that the foliar application of Jasmonic acid at 50 ppm significantly increased growth parameters, achieving the highest plant height (111.97 cm) and the number of branches plant^{-1} (9.33). Earliness, indicated by 50% flowering, was observed at 55 days with Jasmonic acid at 50 ppm, followed by 59 days with Jasmonic acid at 100 ppm. For yield attributes, the highest values for the number of umbellets umbel^{-1} (7.62), seed yield (17.99 q ha^{-1}), and test weight (15.67 g) were recorded with 20 ppm Benzyl Adenine, followed by Brassinosteroid at 1.00 ppm (16.89 kg ha^{-1} yield). Additionally, the highest net return and benefit-cost ratio were also observed with 20 ppm Benzyl Adenine. Hence, it is concluded that the foliar application of Benzyl Adenine (BA) and Jasmonates can be effective in enhancing the growth and yield of coriander.

Keywords: Benzyl Adenine; brassinosteroid; coriander; jasmonic acid; salicylic acid.

1. INTRODUCTION

Coriander (*Coriandrum sativum* L.) is one of the oldest and most widely used seed spices, first cited in the Ebers papyrus in 1550 BC [1]. India is the leading producer, importer, and exporter of coriander. It grows to a height of 25 to 110 cm with compound leaves, becoming highly segmented and linear near the top. The inflorescence is a complex umbel with tiny umbellets. Fruits are globular, 3–4 mm in diameter, and turn yellow-brown when ripe. Coriander leaves are rich in vitamins, minerals, and iron. [2] reported that they are rich in vitamin A (12 mg 100 g^{-1}) and vitamin C (160 mg 100 g^{-1}). Leaves are low in saturated fat and cholesterol, and a good source of thiamine, zinc, and dietary fiber, with 84% water content. In addition to its nutritional benefits, coriander's growth and yield can be influenced by external factors such as plant growth regulators (PGRs).

Plant growth regulators (PGRs) are organic compounds, other than nutrients, that affect physiological processes of plants when applied in small concentrations [3]. Plant Growth Regulators are applied to crops like coriander to enhance growth, yield and quality by affecting physiological processes such as nutrient uptake and water management [4]. At present, nine types of Plant Hormones (PHs) have been identified [5], including auxins, the first phytohormone discovered [6], salicylates (SA), ethylene (ET), cytokinins (CKs), gibberellins (GAs), brassinosteroids (BRs), jasmonates (JA), abscisic acid (ABA), and strigolactones (SL), the last PHs to be discovered [7] The acting mechanism behind various processes can vary with different hormones. Different hormones regulate a variety of plant processes, and sometimes a single process is regulated by multiple hormones [8]. The concentration, application technique, and duration of PGRs are among the variables that affect their efficacy. Application of exogenous PGR has been demonstrated to boost crop growth and yield [9]. Salicylic acid (SA) is a phenolic growth regulator that plays a significant role in controlling plant physiological processes. Foliar spray of SA plays a key role in the defense response of plant cells to environmental changes and reduces harmful effects of abnormal conditions. Jasmonic acid (JA) or jasmonates and its precursors, are the foundational phytohormones which regulate multifarious plant physiological processes including development, growth and defense responses to various abiotic and biotic stress factors. Brassinosteroids are new plant growth hormones with several plant growth-promoting activities and are a natural, safe, non-genotoxic, phytohormone that can be employed to increase the development, productivity and fruit quality [10]. Benzyl adenine (BA), also known as 6-benzylaminopurine (BAP), is a synthetic cytokinin that regulates plant growth and development. It's a first-generation plant growth regulator (PGR) that stimulates cell division, which in turn promotes plant growth, flower setting, and fruit quality. BA also acts as an inhibitor of respiratory kinase in plants, playing a significant role in regulating various plant growth processes [11], enhancing photosynthetic efficiency [12], and facilitating nutrient uptake, particularly potassium [13] reducing plants' sensitivity to ethylene [14], preventing leaf senescence [15,16], and lowering physiological stress.

Despite the known effects of PGRs on the other crops, research on their effects on coriander remains limited. This study addresses this gap by focusing on foliar sprays with Salicylic acid, Jasmonic acid, Benzyl Adenine and Brassinosteroid at varying concentrations. The goal is to identify the optimal concentrations that significantly improve vegetative and reproductive growth in coriander.

2. MATERIALS AND METHODS

2.1 Study Site

This study investigated the effects of various levels of plant growth regulator (PGR) foliar sprays on the growth, yield and economics of coriander. A field experiment was carried out during the *Rabi* season of 2021–22 at the Vegetable Research Centre, Maharajpur, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India. The experimental site is situated in the Kymore Plateau and Satpura Hill Agroclimatic Zone of Madhya Pradesh, at an elevation of 411 meters above mean sea level, located at 23˚10' N latitude and 79˚59' E longitude. The experimental plots were situated on medium-black Vertisols, characterized by uniform texture, medium NPK status, and high drainage capabilities.

2.2 Experimental Details

The experiment followed a randomized complete block design with three replications and nine treatments *viz*., Salicylic Acid (50 and 100 ppm), Jasmonic Acid concentrations (50 and 100 ppm), Benzyl Adenine (10 and 20 ppm), Brassinosteroid (0.5 and 1.0 ppm) and water spray as control. Foliar application was conducted twice i.e. 30 and 60 days after sowing.

2.3 Plant Growth Regulators and Their Preparations

The plants were sprayed twice with PGRs using a Knapsack battery sprayer until both sides of the leaves completely became wet. The Plant Growth Regulators were purchased from Sisco Research Laboratory (SRL), India. Stock solution of each PGR was prepared at 10^{-3} M. For a 10^{-3} M. solution:

$$1\ l = 0.001 \times \text{Molecular Weight of PGR (g)}.$$

The quantity of PGR required was Benzyl Adenine has a molecular weight of 225.249 g mol^{-1} and is used at concentrations of 10 ppm and 20 ppm, corresponding to quantities of 2.25 mg l^{-1} and 4.50 mg l^{-1}, respectively. Brassinosteroid, with a molecular weight of 480.70 g mol^{-1}, is applied at concentrations of 0.5 ppm and 1.0 ppm, equating to 0.24 mg l^{-1} and 0.48 mg l^{-1}. Jasmonic Acid has a molecular weight of 210.27 g mol^{-1} and is used at concentrations of 50 ppm and 100 ppm, which are equivalent to 10.513 mg l^{-1} and 21.027 mg l^{-1}. Salicylic Acid, with a molecular weight of 131.121 g mol^{-1}, is applied at concentrations of 50 ppm and 100 ppm, corresponding to 6.906 mg l^{-1} and 13.812 mg l^{-1}. Foliar applications were carried out using the final working concentrations of plant growth regulators. The required quantity of PGR was dissolve in 10 ml of ethanol. Mix thoroughly to ensure complete dissolution. Transfer the dissolved PGR solution to a 100 ml volumetric flask. Make up to final volume with distilled water of 100 ml. To prepare the Working Solution from the desired final concentration from the stock solution, dilution was done appropriately. For example for 0.5 ppm Brassinosteroid, 0.5 ml of the 10^{-3} M stock solution was added to 999.5 ml of distilled water to make a 1 liter solution.

2.4 Agronomical Practices

To prepare the land for coriander germination, ploughing and harrowing were carried out to achieve a fine tilth. Ploughing was performed twice in two directions using tractor-drawn implements, followed by harrowing to break up clods and level the soil surface. Before sowing, the coriander seeds of var. Jawahar Dhaniya-10 released from Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur were split into two pieces by rubbing and then treated with *Trichoderma viridae* @ 4 g kg^{-1} of seed. They were then manually seeded into the main field using the line sowing method, with a spacing of 30 cm between rows. Thinning was conducted at 25 days after sowing (DAS) to maintain a plant-to-plant distance of approximately 10 cm. The crop was fertilized with 1 t of FYM (Farmyard Manure) along with NPK @ 20:40:30 kg ha^{-1} as basal. The remaining $3/4^{th}$ dose (40 kg ha^{-1}) was top dressed at 30 and 60 days after sowing. Throughout the cultivation period, all standard practices for coriander were adhered to.

The data recorded were analyzed using MS-EXCEL with critical difference (CD) for comparing treatments means.

3. RESULTS AND DISCUSSION

3.1 Growth and Phenological Parameters

All plant growth regulators (PGRs) exhibited significant impacts on the growth and phenological parameters of coriander. Analysis of the results indicated that PGR treatments notably improved coriander's vegetative development. In terms of growth, Jasmonic acid 50 ppm significantly increased the plant height of (111.97 cm) and the number of branches plant^{-1} (9.33) at harvest. This represented a 27% increase in the plant height and a 19% increase in the number of branches compared to the control, as clearly delineated in Table 1. This was followed by 100 ppm SA (Salicylic Acid) with the plant height of 108.31 cm and 9.00 branches plant^{-1}. Treatment with BRs (Brassinosteroids) at 0.5 ppm exhibited the lowest rates in terms of the plant height (93.61 cm) and the number of branches plant^{-1} (8.20) at harvest among the plant growth regulators, while water spray recorded the lowest plant height (88.34 cm) and branches plant^{-1} (7.87) at harvest. Scrutiny of the data suggests that the 50 ppm JA treatment was the most effective in promoting vegetative growth, likely due to improved cell division and expansion. These findings are consistent with the previous research by [17], which emphasized the role of jasmonates in enhancing cell growth and development in similar crops. Correspondingly, [18] and [19] in Black Cumin reports that the highest plant height and maximum number of branches. Similarly, [20,21] in Cumin and [22] in Long pepper demonstrated that SA enhances plant height and branching by improving physiological processes such as photosynthesis and nutrient uptake. The current findings further substantiate the role of JA and SA in optimizing vegetative growth, providing specific concentrations that yield the best results for coriander.

Regarding phenological traits, it was noted that jasmonates reduced the time to 50% flowering in coriander (Table 1). Specifically, JA at 50 ppm and 100 ppm resulted in the earliness by 55.00 days and 59.00 days, respectively. The control treatment took the longest time to reach 50% flowering (66.33 days). The timing of flowering in plants is crucial for optimizing reproductive success. To achieve this, plants have developed intricate signaling networks that allow them to coordinate flowering time in response to varying environmental conditions. Many phytohormones, such as auxin, gibberellin (GA), Abscisic acid (ABA), ethylene, and jasmonic acid (JA), have been reported to be involved in the regulation of flower opening with relation to both internal and external cues [23]. Hence, in addition to serving as a vital immune signal, the lipid-derived plant hormone jasmonate (JA) plays a significant role in regulating various developmental processes, including flowering time [24]. Involvement of JA in the regulation of flower opening was initially reported in the analysis of a JA-deficient mutant, defective in anther dehiscence1 (*dad1*), in Arabidopsis [25]. Jasmonic acid stimulates *SlMYB21* expression, which is required for coordinated flower opening and fertility in male and female organs in tomato were reported by [26]. Conversely, [27] in Strawberry and [19] in Black Cumin found the non-significant effect of methyl jasmonate for days to 50% flowering.

Table 1. Impact of PGRs on growth and phenological Traits in Coriander

Treatments	Plant height, cm	Branches per plant	Days to 50% flowering
T_1 Salicylic acid (50 ppm)	103.67	8.53	60.00
T_2 Salicylic acid (100 ppm)	108.31	9.00	61.33
T_3 Jasmonic acid (50 ppm)	111.97	9.33	55.00
T_4 Jasmonic acid (100 ppm)	106.80	8.40	59.00
T_5 Benzyl adenine (10 ppm)	103.27	8.67	62.67
T_6 Benzyl adenine (20 ppm)	106.05	8.87	63.00
T_7 Brassinosteroid (0.5 ppm)	93.67	8.20	63.33
T_8 Brassinosteroid (1.0 ppm)	99.91	8.73	64.67
T_9 Control (Water spray)	88.34	7.87	66.33
Mean	102.44	8.62	61.70
S.E.(m)±	2.313	0.259	1.482
C.D.($p=0.05$)	6.935	0.778	4.44
CV	3.912	5.217	4.16

3.2 Yield and its Attributes

The results indicated that the application of Plant Growth Regulators (PGRs) significantly increases the yield and yield-promoting attributes of coriander (Table 2). Regarding yield attributes, the foliar spray of 1.00 ppm Brassinosteroids (BRs) resulted the highest values for the number of umbels plant^{-1} (42.92), followed by 50 ppm Jasmonic Acid (JA) with 39.43 umbels plant^{-1} as portrayed in Table 2. For the number of Umbellets umbel^{-1} and the number of seeds umbel^{-1}, the highest results were observed with 20 ppm Benzyladenine (BA), which showed 7.62 umbellets umbel^{-1} and was comparable to 50 ppm JA with 7.23 umbellets umbel^{-1}. Additionally, 50 ppm JA produced the highest number of seeds umbel^{-1} (50.80), closely followed by 20 ppm BA with 48.13 seeds umbel^{-1}. Similarly, 20 ppm BA yielded the maximum seed yield (1799 kg ha^{-1}) and test weight (15.67 g), followed by 1.00 ppm BRs, which resulted in 16.89 kg ha^{-1} seed yield and a test weight of 14.71 g. Conversely, among the various PGRs tested, the minimum values recorded were 20.52 umbels plant^{-1}, 5.36 umbellets umbel^{-1}, 30.07 seeds umbel^{-1}, 1196 kg ha^{-1} seed yield, and a test weight of 10.41 g. These findings highlight the efficacy of specific PGRs in enhancing the productivity of coriander, with 20 ppm BA and 1.00 ppm BRs showing particularly notable results.

The increase in the number of umbels plant^{-1} observed with the application of 1.00 ppm Brassinosteroids (BRs) can be attributed to its role in promoting cell elongation, expansion, division, seed germination, xylem differentiation, reproductive development, and growth [28,29]. BRs facilitate various mechanical and biochemical changes that enhance plant structure and function, thereby contributing to a greater number of umbels plant^{-1} [30] which coincides with [31] in Tomato and [32] in Dry bean, Soybean & Groundnut. Similarly, the positive outcomes from the foliar spray of 20 ppm Benzyl adenine (BA) can be explained by the cytokinin's ability to stimulate cell division and regulate metabolic processes. Cytokinins like BA influence vegetative development traits and plant constituents, which collectively enhance fruit and yield [33]. For instance, earlier studies by [34] indicated that BRs and cytokinins could improve plant growth and yield, but the extent observed in the current study, particularly with 1.00 ppm BRs and 20 ppm BA, is significantly higher. Furthermore, Brassinosteroids have been extensively reported to improve plant health, plant nutrient assimilation, vitamins, antioxidants, and carbohydrates [35]. Additionally, the study by Ahmad [36,18] in Chilli and [19] in Black Cumin also reported that JA positively influenced the yield attributes of coriander, which aligns with the present results showing JA's substantial impact at 50 ppm. Therefore, the current study not only confirms the beneficial effects of these PGRs but also provides more precise concentrations that optimize coriander yield and yield-promoting attributes.

Table 2. Effect of PGRs on yield and its attributing traits in coriander

Treatments	Umbels plant^{-1}	Umbellets Umbel^{-1}	Seeds umbel^{-1}	Seed Yield (kg ha^{-1})	Test weight (g)
T_1 Salicylic acid (50 ppm)	27.83	6.14	33.80	1425	12.41
T_2 Salicylic acid (100 ppm)	24.88	5.76	35.07	1475	12.85
T_3 Jasmonic acid (50 ppm)	39.43	7.23	50.80	1685	14.68
T_4 Jasmonic acid (100 ppm)	28.80	6.98	43.87	1519	13.23
T_5 Benzyl adenine (10 ppm)	32.82	6.54	35.67	1585	13.80
T_6 Benzyl adenine (20 ppm)	34.83	7.62	48.13	1799	15.67
T_7 Brassinosteroid (0.5 ppm)	27.98	6.68	45.20	1603	13.96
T_8 Brassinosteroid (1.0 ppm)	42.92	7.12	45.93	1689	14.71
T_9 Control (Water spray)	20.52	5.36	30.07	1196	10.41
Mean	31.11	6.60	40.95	1553	13.53
S.E.(m)±	0.947	0.173	1.457	0.367	0.319
C.D.($p=0.05$)	2.839	0.518	4.370	1.100	0.958
CV	5.272	4.538	6.166	4.094	4.094

Table 3. Effect of PGRs on economics of coriander

Treatments	Net returns, Rs	B:C Ratio
T_1 Salicylic acid (50 ppm)	147087.37	2.21
T_2 Salicylic acid (100 ppm)	154530.43	2.32
T_3 Jasmonic acid (50 ppm)	186099.96	2.79
T_4 Jasmonic acid (100 ppm)	161206.39	2.42
T_5 Benzyl adenine (10 ppm)	170958.29	2.56
T_6 Benzyl adenine (20 ppm)	203026.08	3.04
T_7 Brassinosteroid (0.5 ppm)	147950.99	1.60
T_8 Brassinosteroid (1.0 ppm)	134912.39	1.14
T_9 Control (Water spray)	112699.88	1.69
Mean	157607.98	2.21
S.E.(m) ±	5505.92	
C.D.(*p=0.05*)	16506.7	
CV	6.051	
1 US$= 82.113 INR (average of harvesting month)		

3.3 Economics

Economic analysis is also an important aspect in PGRs impact assessment studies. The cost-benefit analyses were performed to evaluate the cost-effectiveness of using PGRs in coriander cultivation, considering yield increases, quality improvements, and market prices. It is also important to study market acceptance and consumer preferences for coriander grown with PGRs to assess potential economic benefits and marketability. The application of 20 ppm BA (Table 3) resulted in the highest net return (Rs. 203026.08) and B:C ratio of 3.04. This was followed by 50 ppm JA, with B:C ratio of 2.79. The superior performance of 20 ppm BA is attributed to its effectiveness in increasing the number of umbellets umbel^{-1} and seeds umbel^{-1}, leading to higher seed yield (kg ha^{-1}) and greater test weight (g) compared to other treatments. Benzyl Adenine (BA) is a synthetic plant growth regulator classified as a cytokinin phytohormone, known for increasing cytokinin levels in plants [37]. Cytokinins are essential for shoot initiation, growth, bud development, differentiation, and promoting cell division [38]. In summary, BA enhances vegetative growth indices by improving photoassimilate partitioning, increasing nutrient uptake, and particularly boosting cell division [39].

4. CONCLUSION

The study demonstrated that the application of Plant Growth Regulators (PGRs) significantly enhanced the vegetative growth, yield, and economic returns of coriander. Jasmonic Acid (50 ppm) enhanced vegetative growth, resulting in the tallest plants and earlier flowering. Brassinosteroids (1.0 ppm) maximized the number of umbels per plant, while Benzyladenine (20 ppm) increased the number of umbellets per umbel, seed yield, and test weight. Economically, Benzyladenine (20 ppm) provided the highest net returns and benefit-cost ratio, followed by Jasmonic Acid. This corroborated earlier research, which indicated the benefits of these PGRs in enhancing plant growth and yield.

5. LIMITATIONS OF THE STUDY

The experiment was conducted in a specific location, Kymore Plateau and Satpura Hills Agroclimatic zone of Madhya Pradesh during a single growing season. Furthermore, the study focused exclusively on the one coriander variety and the effectiveness of plant growth regulators (PGRs) may differ when applied to other coriander varieties.

6. FUTURE ASPECTS

To enhance the reliability of results, future research should include multi-location trials across various agro-climatic zones and examine varietal comparisons, as different coriander varieties and spice crops may respond differently to PGRs. Long-term studies should focus on assessing the impact of PGRs on yield, soil health, pest resistance, and crop sustainability, while also monitoring residual effects to ensure environmental safety. Expanding research to include a broader range of PGRs or combinations can provide insights into optimizing growth under stress conditions like drought. Future work should also determine the optimal dosage and application method to maximize performance. Additionally, evaluating the long-term economic feasibility of PGR use will be critical for widespread adoption in coriander cultivation.

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 this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sahib NG, Anwar F, Gilani AH, Hamid AA, Saari N, Alkharfy KM. Coriander (*Coriandrum sativum* L.): A potential source of high-value components for functional foods and nutraceuticals—A Review. Phytotherapy Research. 2013; 27:1439–1456.
2. Girenko MM. Initial material and basic trends in breeding of some uncommon species of vegetables. Journal of Bullock VIR im. Vavilova. 1982;120:33–37.
3. Basit A, Akram M, Khan K, Kainat M, Rehim A, Bashir M. Biostimulants impact on agronomic traits of fortnight harvested *Zea mays.* Journal of agriculture and livestock farming. 2024;1(2).
4. Meshram JH, Singh SB, Raghavendra KP, Waghmare VN. Chapter 6 - Drought stress tolerance in cotton: progress and perspectives, Editor(s): Shanker, A.K., Shanker, C., Anand, A., Maheswari, M. Climate Change and Crop Stress, Academic Press. 2022;135–169.
5. Su YI, Xia S, Wang R, Xiao L. Phytohormonal quantification based on biological principles. Hormone Metabolism and Signaling in Plants. 2017;17: 431–470.
6. Darwin C, Darwin F. The Power of Movement in Plants. London: John Murray; 1880.
7. Gomez Roldan MV, Fermas S, Brewer P B, Puech-Pagès V, Dun EA, Pillot JP, Letisse F, Matusova R, Danoun S, Portais JC, Bouwmeester H, Becard G, Beveridge CA, Rameau C, Rochange SF. Strigolactone inhibition of shoot branching. Nature. 2008;455(7210):189–194.
8. Ciura J, Kruk J. Phytohormones as targets for improving plant productivity and stress tolerance. Journal of Plant Physiology. 2018;229:32–40.
9. Bharud RW, Deore BP, Patil VA. Effects of growth substances on the growth and yield of Methi. Journal Maharashtra Agriculture University. 1988;13:340–341.
10. Ghosh T, Panja P, Sau S, Datta P. Role of brassinolide in fruit growth, development, quality and cracking of litchi cv. Bombai grown in new alluvial zone of West Bengal. International Journal of Bio-resource and Stress Management. 2022;13(5):507–512.
11. Ibrahim SMM, Taha LS, Farahat MM. Vegetative growth and chemical constituents of Croton plants as affected by foliar application pf benzyl adenine and gibberellic acid. Journal of American Science. 2010;6:126–130.
12. Oosterhuis DM, Zhao D. Growth yield and physiological responses of field grown cotton to plant growth regulators. In: D. M. Oosterhuis (ed.), Proc. Cotton Research Meeting and Summaries of Research in Progress Univ. of Arkansas. Agricultural Experiment Station Special Report. 1998; 188:140–144.
13. Guo C, Oosterhuis DM, Zhao D. Enhancing mineral uptake of cotton plants with plant growth regulators. Arkanas Agriculture Experimental Scientific and Technical University of Arkanas Research Centre. 1994;436:83–87.
14. Serek M, Jones RB, Reid MS. Role of ethylene in opening and senescence of Gladiolus spices flowers. Journal of American Society of Horticulture Science. 1994;11:1014–1019.
15. Burke JJ. Cytokinin enhancement of cotton. U.S. Patent. 2009;7:634–870.
16. Burke JJ. 6-benzyladenine enhancement of cotton. Journal of Cotton Science. 2011;15:206–214.
17. Creelman RA, Mullet JE. Biosynthesis and action of Jasmonates in plants. Annual Review of Plant Physiology and Plant Molecular Biology. 1997;48:355–381.
18. Awang NA, Ismail MR, Omar D, Islam MR. Comparative Study of the application of Jasmonic acid and pesticide in chilli: Effects of physiological activities, yield and viruses control. Bioscience Journal of Uberlandia. 2015;31(3):672-681.

19. Arpitha HS, Umesha K, Anilkumar GS. Influence of Elicitors on Growth and Yield of Black Cumin (*Nigella sativa* L.) Varieties. Asian Journal of Soil Science and Plant Nutrition. 2024; 10(2):182-189
20. Anjum SA, Xie XY, Wang LC, Saleem MF, Man C, Lei W. Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research. 2011a;6:2026–2032.
21. Rahimi AR, Rokhzadi A, Amini S, Karami E. Effect of salicylic acid and methyl jasmonate on growth and secondary metabolites in *Cuminum cyminum* L. Journal of Biodiversity and Environmental Sciences. 2013;3(12):140-149.
22. Harish. Salicylic acid mediated metabolite elicitation and growth response in long pepper (*Piper longum* L.). Kerala Agriculture University, Vellayani, Thiruvananthapuram. 2019.
23. Van Doorn WG, Kamdee, C. Flower opening and closure: an update. Journal of Experimental Botany. 2014;65:5749–5757.
24. Zhai Q, Zhang X, Wu F, Feng H, Deng L, Xu L, Zhang M, Wang Q, Li C. Transcriptional mechanism of Jasmonate Receptor COI1-Mediated delay of flowering time in Arabidopsis. The Plant Cell. 2015;27(10):2814–2828.
25. Ishiguro S, Kawai-Oda A, Ueda J, Nishida I, Okada K. The DEFECTIVE IN ANTHER DEHISCIENCE1 gene encodes a novel phospholipase A1 catalyzing the initial step of jasmonic acid biosynthesis, which synchronizes pollen maturation, anther dehiscence, and flower opening in Arabidopsis. Plant Cell. 2001;13(10):2191–2209.
26. Niwa T, Suzuki T, Takebayashi Y, Ishiguro R, Higashiyama T, Sakakibara H, Ishiguro S. Jasmonic acid facilitates flower opening and floral organ development through the upregulated expression of SlMYB21 transcription factor in tomato. Bioscience, Biotechnology, and Biochemistry. 2018; 82(2):292-303.
27. Nahakpam S, Bahera SK, Sahay S. Effect of methyl jasmonate on growth and flowering behavior of strawberry cv. Nabila. International Journal of Current Microbiology and Applied Sciences. 2020; 9(9):2690-2695.
28. Chaudhuri A, Halder K, Abdin M Z, Majee M, Datta A. Abiotic stress tolerance in plants: brassinosteroids navigate competently. International Journal of Molecular Sciences. 2022; 23(23):145-177.
29. Sharma N, Kour S, Kumar D, Kaur R, Khajuria A, Ohri P. Role of Brassinosteroids (BRs) in Modulating Antioxidative Defense Mechanism in Plants Growing under Abiotic and Biotic Stress Conditions. – In: Aftab, T., Hakeem, K. R. (eds.) Antioxidant Defense in Plants: Molecular Basis of Regulation. Springer Nature, Singapore. 2022.
30. Clouse SD, Sasse JM. Brassinosteroids: essential regulators of plant growth and development. Annual Review of Plant Physiology and Plant Molecular Biology. 1998;49:427–451.
31. Sridhara S, Ramesh N, Gopakkali P, Paramesh V, Tamam N, Abdelbacki AMM, Elansary HO, El-Sabrout AM, Abdelmohsen SAM. Application of Homobrassinolide enhances growth, yield and quality of tomato. Saudi Journal of Biological Sciences. 2021;28: 4800-4806.
32. Mota MM, van der Watt E, Khetsha ZP. Foliar Application of Brassinosteroids Improves the Yield and Morpho-Physiological Characteristics of *Arachis hypogeae* L., *Glycine max* L., and *Phaseolus vulgaris* L. Applied Ecology & Environmental Research. 2024;22(1).
33. Mok DWS, Mok MC. Cytokinin metabolism and action. Annual Review of Plant Physiology and Plant Molecular Biology. 2001;52:89–118.
34. Shah SS, Mir NA. Effect of brassinosteroids and cytokinins on growth and yield of coriander (*Coriandrum sativum* L.). Plant Growth Regulation. 2004;43(2):129–136.
35. Han C, Wang L, Lyu J, Shi W, Yao L, Fan M, Bai MY. Brassinosteroid signaling and molecular crosstalk with nutrients in plants. – Journal of Genetics and Genomics: S. 2023;1673-8527.
36. Ahmad R, Rehman HU, Iqbal Z, Ahmed S. Influence of Jasmonic acid on growth, yield and biochemical characteristics of coriander (*Coriandrum sativum* L.). Journal of Medicinal Plants Research. 2013; 7(7):310–314.
37. Ren B, Zhu Y, Zhang J, Dong S, Liu P, Zhao B. Effects of spraying exogenous hormone 6-benzyl adenine (6-BA) after waterlogging on grain yield and growth of summer maize. Field Crops Research. 2016;188:96–104.

38. Thomas R, Rainer E. Regulation of source/sink relations by cytokinins. Plant Growth Regulation. 2000;32(2–3):359–367.
39. Hazrati-Yadekori S, Tahmasebi-Sarvestani Z. Effects of different nitrogen fertilizer levels and hormone benzyl adenine (BA) on growth and ramet production of *Aloe vera* L. Iranian Journal of Medicinal and Aromatic Plants Research. 2012;28(2): 210–223.

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