Influence of plant growth regulators on growth, seed yield, quality and economics of Coriander (*Coriandrum sativum* L.) cv. Jawahar Dhaniya-10

ABSTRACT

An experiment was conducted 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, quality, and economics of coriander (*Coriandrum sativum* L.) cv. Jawahar Dhaniya-10. The experiment was designed using a Randomized Block Design with three replications and included 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 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 q 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 spray application of Benzyl Adenine (BA) and jasmonates can be effective in enhancing the growth and yield of coriander.

Keywords: Coriander, salicylic acid, jasmonic acid, benzyl adenine, brassinosteroid

1. INTRODUCTION

Coriander (*Coriandrum sativum* L.) was first cited in the Ebers papyrus in 1550 BC [1] is one of the oldest and most widely used seed spices globally. 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.

Plant growth regulators (PGRs) are organic compounds, other than nutrients, that affect physiological processes of plants when applied in small concentrations. More specific responses include alteration of C partitioning, greater root: shoot ratios, enhanced photosynthesis, altered nutrient uptake, improved water status, and altered crop canopy [3]. At present, nine types of Plant Hormones (PHs) have been identified [4], including auxins, the first phytohormone discovered [5], salicylates (SA), ethylene (ET), cytokinins (CKs), gibberellins (GAs), brassinosteroids (BRs), jasmonates (JA), abscisic acid (ABA), and strigolactones (SL), the last PHs to be discovered [6] The acting mechanism behind various processes can vary with different hormones. Thus, a single hormone is sometimes observed to regulate a wide range of processes, both cellular and developmental, whereas, simultaneously, a single process might get regulated by multiple hormones [7]. 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 [8]. 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 [9]. 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 [10], enhancing photosynthetic efficiency [11], and facilitating nutrient uptake, particularly potassium [12] reducing plants' sensitivity to ethylene [13], preventing leaf senescence [14,15], and lowering physiological stress.

Research on the effects of exogenous applications of PGRs on coriander is limited. Thus, the study aimed to address this gap by investigating the impact of foliar sprays with varying concentrations of Salicylic acid, Jasmonic acid, Benzyl Adenine and Brassinosteroid. 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 conducted 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' North latitude and 79˚59' East 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 done 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×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^{-1}. 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 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 JNKW, 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. cm. The crop was fertilized with 1 t of FYM along with NPK @ 20:40:30 kg ha^{-1} as basal. The remaining 3/4^{th} dose (40 kg) 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 tabulated and statistically analysed to differentiate the superiority of treatment means using critical difference (CD) by MS-EXCEL software.

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. Among the various PGRs administered, 50 ppm of Jasmonic Acid (JA) resulted in the highest plant height (111.97 cm) and the greatest number of branches plant^{-1} (9.33) at harvest. This represented a 27% increase in 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 a 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 plant height (93.61 cm) and 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. This aligns with previous research by [16], which highlighted the role of jasmonates in promoting cell growth and development. Correspondingly, [17] and [18] in Black Cumin reports that the highest plant height and maximum number of branches. Similarly, [19], [20] in Cumin and [21] 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 earliness by 55.00 days and 59.00 days, respectively. The control treatment also took the maximum 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 [22]. 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 [23]. 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 [24]. Jasmonic acid stimulates *SlMYB21* expression, which is required for coordinated flower opening and fertility in male and female organs in tomato were reported by [25]. Conversely, [26] in Strawberry and [18] in Black Cumin found the non-significant effect of methyl jasmonate for days to 50% flowering.

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). Specifically, the use of 1.00 ppm Brassinosteroids (BRs) resulted in the highest 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 [27,28]. BRs facilitate various mechanical and biochemical changes that enhance plant structure and function, thereby contributing to a greater number of umbels plant^{-1} [29] which coincides with [30] in Tomato and [31] 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 [32]. For instance, earlier studies by [33] 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 [34]. Additionally, the study by [35], [17] in Chilli and [18] 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.

3.3. Economics

Economic analysis is also an important aspect in PGRs impact assessment studies. The cost-benefit analyses was 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 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 [36]. Cytokinins are essential for shoot initiation, growth, bud development, differentiation, and promoting cell division [37]. In summary, BA enhances vegetative growth indices by improving photoassimilate partitioning, increasing nutrient uptake, and particularly boosting cell division [38].

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 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.

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

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	B:C Ratio
T_1 Salicylic acid (50 ppm)	2.21
T_2 Salicylic acid (100 ppm)	2.32
T_3 Jasmonic acid (50 ppm)	2.79
T_4 Jasmonic acid (100 ppm)	2.42
T_5 Benzyl adenine (10 ppm)	2.56
T_6 Benzyl adenine (20 ppm)	3.04
T_7 Brassinosteroid (0.5 ppm)	1.60
T_8 Brassinosteroid (1.0 ppm)	1.14
T_9 Control (Water spray)	1.69
Mean	2.21

1 US$= 82.113 INR (average of harvesting month)

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