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Effect of Foliar Application of Growth Regulators on Vegetative and Physiological Growth Parameters in Ajowan (*Trachyspermum ammi* L. Sprague)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors YRR, GR, PS and AVDD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GR, PS and AVDD managed the analyses of the study. Authors YRR and PS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during rabi season of 2018-2019, at college farm, College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District, Andhra Pradesh. The experiment was laidout in a Randomised Block Design with eleven treatments (viz., T1- NAA @ 50 ppm, T2-NAA @ 100 ppm, T3-GA3 @ 50 ppm, T4-GA3 @ 100 ppm, T5-Thiourea @ 250 ppm, T6-Thiourea @ 500 ppm, T7-28-Homobrassinolide @ 0.1 ppm, T8-28-Homobrassinolide @ 0.2 ppm, T9-Triacontinol @ 2.5 ppm, T10-Triacontinol @ 5 ppm, T11-(Control)

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Water spray) and three replications. The treatments were imposed at 30 and 45 DAT in the form of foliar spray. Foliar application of GA3@ 100 ppm (T4) had recorded the maximum plant height (108.20 cm), leaf area (9.53 cm2) and leaf area index (0.74). Foliar application of thiourea @ 250 ppm (T5) had recorded the maximum values with respect to number of primary branches (15.03 plant-1), number of secondary branches (83.40 plant-1), plant spread (1793 cm2 plant-1), fresh weight (376.29 g plant-1), dry weight (103.54 g plant-1) and number of leaves plant-1((298.8). The same treatment (T5) had recorded the highest values with respect to crop growth rate (1.44 gm-2d-1), chlorophyll-a (1.40 mg g-1), chlorophyll-b (0.076 mg g-1) and total chlorophyll contents (1.48 mg g-1) in the leaves.

Keywords: Growth regulators; ajowan, LAI; crop growth rate; chlorophyll content.

1. INTRODUCTION

Ajowan or Bishop's weed (*Trachyspermum ammi L*. Sprague) belongs to the family Umbelliferae. It is originated in the Central Asiatic and Abyssinian regions [1]. It is cultivated in the South West Asian countries such as Afghanistan, Iran, Iraq, India and in Pakistan. In India it is cultivated in an area of 36000 ha with a production of 25000 tonnes during the year 2017-18 [2] on a commercial scale in the states of Rajasthan, Andhra Pradesh, Uttar Pradesh, Haryana, Gujarat, Punjab and West Bengal.

Ajowan seeds are consumed as spice because of its characteristic aromatic smell and pungent in taste mainly used as a household remedy for indigestion and in small quantities for flavouring of food as an antioxidant and preservative in confectionary, beverages and in pan mixtures. Ajowan seeds are much valued for its carminative, antispasmodic, tonic and stimulant properties. Ajowan seeds are effective in control of diarrhea, flatulence, dyspepsia, sore throat, bronchitis and are often used as an ingredient of cough mixtures. The roots of Ajowan plant have carminative and diuretic properties and are used in stomach disorders and in febrile conditions. The paste of crushed fruits is applied externally for relieving colic pains [3].

The availability of scientific literature on crop improvement in ajowan through the application of plant growth regulators is very meager even though the crop had a high demand with lot of medicinal values. Hence, the present investigation was aimed to know the influence of various plant growth regulators on vegetative like plant height, plant spread, fresh weight, dry weight and physiological growth parameters like crop growth rate, chlorophyll-a, chlorophyll-b and total chlorophyll content in ajowan.

2. MATERIALS AND METHODS

The present investigation was carried out during *Rabi* season of 2018-2019 at research farm of College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District, Andhra Pradesh. The experiment was laidout in a Randomised Block Design with eleven treatments (*viz*., T_1- NAA @ 50 ppm, T_2-NAA @ 100 ppm, T_3-GA_3 @ 50 ppm, T_4-GA_3 @ 100 ppm, T_5-Thiourea @ 250 ppm, T_6-Thiourea @ 500 ppm, T_7-28-Homobrassinolide @ 0.1 ppm, T_8-28-Homobrassinolide @ 0.2 ppm, T_9-Triacontinol @ 2.5 ppm, T_{10}-Triacontinol @ 5 ppm, T_{11}-(Control) Water spray) and three replications. The treatments were imposed at 30 and 45 DAT in the form of foliar spray. The data on plant height (cm), number of primary and secondary branches plant^{-1}, plant spread (cm^2), number of leaves plant^{-1}, fresh and dryweight plant^{-1}(g) were recorded for five plants randomly selected in each plot and in each replication at 60,80,100 and 120 DAT, but the maximum values were shown in the tables. The physiological parameters viz leaf area plant^{-1}(cm^2) was recorded with the help of ∆T leaf area meter. The leaf area index and crop growth rate were calculated by using the following formulae as suggested by Watson DJ [4].

Leaf area index was calculated by using the following formula

LAI= Total leaf area (LA) / Total land area (P) and

Crop Growth Rate (CGR) was calculated by using the following formula and expressed as gm^{-2}d^{-1}.

$$CGR = \frac{(W2 - W1)}{(t2 - t1)} \times \frac{1}{A}$$

Where,

W_1 = Dry weight of plant at time t_1
W_2 = Dry weight of plant at time t_2
$t_2 - t_1$ = Time interval in days
A = Land area (m^2)

Weigh 1 g of finely cut leaf tissue was placed in a test tube and add 50 mL of dimethyl sulphoxide. The test tubes were incubated at 80°C for two hours. After two hours, the test tubes were takenout from the oven and cooled to room temperature. Three mL aliquot was analyzed with the help of spectrophotometer (Shimadzu) at 645 and 663 nm. The Chlorophyll-a, Chlorophyll-b and total Chlorophyll contents in leaves were determined as described by Hiscox and Israelstam [5]. Chlorophyll-a, Chlorophyll-b, Total Chlorophyll contents in the leaf extract were calculated by using the following equations and were expressed in mgg^{-1} leaf tissue.

$$\text{Chlorophyll a} = (12.7 \times A_{663nm}) - (2.69 \times A_{645nm}) \times \left(\left(\frac{V}{1000}\right) \times W\right)$$

$$\text{Chlorophyll b} = (22.9 \times A_{645nm}) - (4.68 \times A_{663nm}) \times \left(\left(\frac{V}{1000}\right) \times W\right)$$

$$\text{Total Chlorophyll} = (20.02 \times A_{645nm}) + (8.02 \times A_{663nm}) \times \left(\left(\frac{V}{1000}\right) \times W\right)$$

Where, A is absorbance at specific wavelength, V is the final volume of chlorophyll extract and W is fresh weight of tissue.

The data recorded on various growth parameters were tabulated and were statistically analyzed in a Randomised Block Design as per the outlines suggested by Panse and Sukhatme [6].

3. RESULTS AND DISCUSSION

3.1 Plant Height (Cm)

The data on plant height is presented in Table 3. Significant differences were found among the treatments for plant height. Foliar application of GA_3 @ 100 ppm (T_4) had recorded the maximum (108.20 cm) plant height, which was on par with T_{10} treatment (application of triacontanol @ 5 ppm as foliar spary).The plant height was minimum in T_{11} (Control) treatment.

The increase in plant height with the application of growth regulators might be due to increased plasticity of the cell wall followed by hydrolysis of starch into sugars which lowers the water potential of cell thereby resulting in entry of water into the cell by creating full turgor pressure, leads to more cell elongation. The osmotically driven responses were found to be more in plants treated with GA_3 @100 ppm as foliar spray thus resulting in increased cell elongation and rapid cell division in the growing portion which lead to an increase in length of internodes (Sargent) [7] than in plants sprayed with water (control). The results are in conformity with the findings of Pariari et al. [8] in coriander, Bairva et al. [1] in fenugreek, Rohamare et al. [9] in ajowan.

3.2 Plant Spread (Cm^2)

Non significant differences were found among the treatments for plant spread.

3.2.1 Number of primary branches plant^{-1}

The data on number of primary branches plant^{-1} is presented in Table 3. Significant differences were observed among the growth regulating chemical sprays with respect to number of primary branches plant^{-1}. Foliar sprays of thiourea @ 250 ppm (T_5) had resulted in more (15.03) number of primary branches plant^{-1}, which was on par with T_{10} (application of tricontanol @ 5 ppm as foliar spray) treatment (14.94). Minimum number of primary branches (10.92) plant^{-1} were noticed in T_{11} (water spray) treatment.

3.2.2 Number of secondary branches plant^{-1}

The data on number of secondary branches plant^{-1} is presented in Table 4. The differences among the growth regulator sprays with respect to number of secondary branches plant^{-1} were found significant. Foliar sprays of thiourea @ 250 ppm (T_5) had produced the highest (83.40) number of secondary branches plant^{-1}, which was on par with (75.80) T_{10} treatment (application of tricontanol @ 5 ppm as foliar spray) whereas the minimum number of secondary branches (56.10) plant^{-1} were recorded with control (T_{11}) treatment (water spray).

Application of thiourea @ 250 ppm as foliar spray might have increased the number of primary and secondary branches plant^{-1}. It could be attributed an increase in uptake of nutrients, water from the soil through expansion of root system and nitrate reductase activity as well as nitrogen metabolism in the leaves. It leads to an increased supply of water and nutrients and photoassimilates to the meristamatic tissue present in axillary buds was responsible for rapid cell division activity and production of more number of branches plant^{-1}. The results are in conformity with the findings of Balai [10], Balai and Keshwa [11], Meena et al. [12], Shanu et al. [13], Singh et al. [14] in coriander. Garg et al. [15] in cluster bean.

3.2.3 Number of leaves plant^{-1}

The data on number of leaves is presented in Table 5. Significant differences were observed among the growth regulating chemical sprays with respect to number of leaves plant^{-1}. Foliar sprays of thiourea @ 250 ppm (T_5) had registered the highest (298.8 leaves plant^{-1}) number of leaves plant^{-1}, which was on par with (283.10 leaves plant^{-1}) T_{10} (application of tricontanol @ 5 ppm as foliar spray), T_8 (application of 28 homobrassinolide @ 0.2 ppm as foliar spray), T_6 (application of thiourea @ 500 ppm as foliar spray) T_9 (application of tricontanol @ 2.5 ppm as foliar spray), T_7 (28 homobrassinolide @ 0.1 ppm as foliar spray),T_2 (application of NAA @100 ppm as foliar spray) T_1 (application of NAA @50 ppm as foliar spray) and T_3 (application of GA_3 @ 50 ppm as foliar spray) treatments but it was significantly superior (230.40 leaves plant^{-1}) to T_4 treatment (application of GA_3 @ 100 ppm as foliar spray). Minimum Number of leaves (218.40) plant^{-1} were observed in T_{11} (water spray) treatment.

Application of thiourea @ 250 ppm as foliar spray might have increased the number of leaves plant^{-1}. It could be evident from the data presented in Table 1. An increase in plant spread (1793 cm^2), primary (15.03) and secondary branches (83.40) plant^{-1}. An increase in number of primary and secondary branches plant^{-1} helps in production of more number of leaf primordial by supplying water and nutrients from the soil through expansion of root system and nitrate reductase activity as well as nitrogen metabolism in the leaves and also increased the supply of photoassimilates to the meristamatic tissue present in terminal and axillary buds was responsible for rapid cell division activity and production of more number of leaf primordia plant^{-1}.

Table 1. Effect of plant growth regulators on plant height, plant spread, number of branches and number of leaves plant^{-1}, fresh and dry weight plant^{-1} in ajowan at 120 DAT

Treatments	Plant Height (cm)	Plant Spread (cm^2)	Number of Primary branches plant^{-1}	Number of Secondary Branches plant^{-1}	Number of Leaves plant^{-1}	Fresh weight plant^{-1}(g)	Dry weight plant^{-1}(g)
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	83.70	1707	12.94	60.20	258.8	223.80	70.89
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	85.80	1719	12.98	60.50	259.6	270.13	73.19
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	93.10	1697	12.36	59.80	247.2	207.76	67.48
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	108.20	1670	12.22	59.00	230.4	206.12	58.91
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	94.10	1793	15.03	83.40	298.8	376.29	103.54
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	89.70	1762	14.24	68.30	277.2	301.00	90.52
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	87.30	1735	13.83	64.30	276.6	290.35	77.81
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	92.80	1771	14.43	69.70	279.8	324.62	93.84
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	89.40	1749	13.86	65.80	276.6	292.35	89.43
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	94.60	1780	14.94	75.80	283.1	360.21	95.21
T_{11}: Control (Foliar spray of water at 30 and 45DAT	74.00	1602	10.92	56.10	218.4	162.43	47.83
Mean	90.25	1725.91	13.43	65.72	264.27	274.10	78.97
S Em	6.22	118.19	0.93	4.50	17.98	18.98	5.47
CD (0.05)	18.36	NS	2.76	13.28	53.06	56.01	16.15

NAA: Naphthelene Acetic Acid, GA3: Gibberellic acid, 28 HB: 28 Homobrassinolid, TRIA: Triacontanol

Table 2. Effect of plant growth regulators on leaf area, leaf area index, chlorophyll-a, chlorophyll-b at 60 DAT and total chlorophyll content in ajowan

Treatments	Leaf area $plant^{-1}$ (cm^2)	Leaf area Index	Chlorophyll -a ($mgg^{-1}FW$)	Chlorophyll -b ($mgg^{-1}FW$)	Total Chlorophyll content ($mgg^{-1}FW$)			
					60 DAT	80 DAT	100 DAT	120 DAT
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	10.08	0.93	2.77	0.11	2.88	1.69	1.00	0.74
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	10.57	1.02	3.21	0.12	3.33	1.75	1.15	0.81
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	15.08	1.05	2.36	0.06	2.42	1.41	0.96	0.69
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	16.61	1.47	1.88	0.03	1.91	1.26	0.95	0.68
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	15.29	1.31	4.00	0.43	4.43	2.51	2.00	1.48
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	11.20	1.2	3.75	0.23	3.99	2.22	1.59	1.32
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	11.08	1.1	3.74	0.15	3.76	2.13	1.54	1.19
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	14.44	1.22	3.83	0.25	4.07	2.30	1.77	1.36
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	11.14	1.1	3.33	0.21	3.53	1.86	1.41	1.30
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	15.82	1.46	3.87	0.28	4.15	2.33	1.85	1.40
T_{11}: Control (Foliar spray of water at 30 and 45DAT)	8.34	0.82	2.74	0.11	2.85	1.51	0.98	0.73
Mean	12.70	1.15	3.23	0.18	3.41	1.91	1.38	1.06
S Em	0.90	0.07	0.21	0.013	0.22	0.12	0.09	0.07
CD (0.05)	2.67	0.23	0.63	0.038	0.66	0.37	0.27	0.21

NAA: Naphthelene Acetic Acid, GA3: Gibberellic acid, 28 HB: 28 Homobrassinolid, TRIA: Triacontanol

3.2.4 Fresh weight of plant (g)

The data on fresh weight $plant^{-1}$, dry weight $plant^{-1}$ are presented in Table 4. Significant differences were found among the growth regulating chemical sprays with respect to fresh weight $plant^{-1}$. Foliar application of thiourea @ 250 ppm (T_5) had resulted in maximum fresh weight (376.29 g) $plant^{-1}$. T_5 treatment was on par with T_{10} (application of triacontanol @ 5 ppm as foliar spary) (360.21 $gplant^{-1}$) and T_8 treatments (application of 28 homobrassinolide @ 0.2 ppm as foliar spray) (324.62gplant⁻1), but it was significantly superior to T_6 treatment (application of thiourea @ 500 ppm as foliar spray) (301gplant⁻1). The minimum fresh weight $plant^{-1}$ was recorded with T_{11} (water spray/control) treatment (162.43 g $plant^{-1}$).

3.2.5 Dry weight of the plant (g)

Significant differences were existed among the treatments for dry weight $plant^{-1}$. Foliar sprays of thiourea @ 250 ppm (T_5) had recorded the maximum dryweight $plant^{-1}$ (103.54 g $plant^{-1}$). T_5 treatment was on par with T_{10} (application of triacontanol @ 5 ppm as foliar spary) (95.21 g $plant^{-1}$),T_8 (application of 28 homobrassinolide @ 0.2 ppm as foliar spray) (93.84 g $plant^{-1}$), T_6 (application of thiourea @ 500 ppm as foliar spray) (90.52 g plant⁻1) and T_9 (application of triacontanol @ 2.5 ppm as foliar spary) treatments (89.43 g $plant^{-1}$). Minimum dry weight $plant^{-1}$ was (47.83 $gplant^{-1}$120 DAT) was recorded with T_{11} (water spray/control) treatment.

Fresh and dry weights $plant^{-1}$ were significantly influenced by the foliar application of different growth regulating chemicals in ajowan. Foliar application of thiourea @ 250 ppm was responsible for initiation of more number of primary (15.03)/seconday (83.40) branches as well as maximum plant spread (1793cm^2) and more number of leaves (298.8) $plant^{-1}$. Thiourea had increased the photosynthetic capacity of leaves by improving the leaf gaseous exchange characteristics; helps in accumulation of more dry matter in plant parts thereby increased the both fresh and dry weights of the plants. The results are in line with the findings of Shanu et al. [13] and singh et al. [14] in coriander.

3.2.6 Leaf area plant^{-1} (cm^2)

The data on leaf area is presented in Table 5. Significant differences were observed among growth regulating chemical sprays with respect to leaf area plant^{-1}. Leaf area plant^{-1}was maximum (16.61 cm^{2}plant$^-$1) in T_4 (application of GA_3 @ 100 ppm as foliar spray) T_4 was on par with T_{10} (application of triacontanol @ 5 ppm as foliar spary) (15.82 cm^{2}plant^{-1}) and T_5 treatments (application of thiourea @ 250 ppm as foliar spray) (15.29cm^{2}plant^{-1}) but it was significantly superior to T_3 (application of GA_3 @ 50 ppm as foliar spray) treatment (15.08 cm^{2}plant$^-$1). Minimum leaf area plant^{-1}(8.34, cm^2 plant$^-$1) was recorded in T_{11} (water spray/control) treatment.

Application of GA_3 @ 100 ppm as foliar spray had recorded the highest leaf area plant^{-1} could be attributed to the expansion of cells. The present results are in harmony with the findings of Talab et al. [16] and Tariq et al. [17] in fenugreek.

3.2.7 Leaf area index

The data on leaf area index is presented in Table 6. The differences among treatmental means were found significant for leaf area index. Foliar application of gibbarellicacid @ 100 ppm (T_4) had recorded the maximum leaf area index (1.47), which was on par with T_{10} (application of tricontanol @ 5 ppm as foliar spray) (1.46) and T_5 (application of thiourea @ 250 ppm as foliar spray) (1.31) treatments. Minimum leaf area index was (0.82) was recorded by T_{11} (water spray/control) treatment.

The number of leaves plant^{-1} were largely dependent upon the number of nodes and also on the number of branches on the main shoot of the plants. The number of branches plant^{-1} was likely to have more number of leaves plant^{-1} but the expansion of leaves on the branches may show different trend. In the present study application of thiourea had resulted in an

Table 3. Effect of plant growth regulators on plant height, plant spread and number of primary branches plant^{-1} in ajowan

Treatments	Plant Height (cm)			Plant Spread (cm^2)			Number of primary branches plant^{-1}		
	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	70.90	80.20	83.00	1143	1423	1632	6.40	8.75	12.81
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	72.40	82.80	85.00	1151	1442	1643	6.50	8.90	12.86
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	78.20	85.50	92.20	1136	1418	1621	6.30	8.70	12.23
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	89.10	100.10	106.20	1115	1401	1603	6.30	8.30	12.02
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	78.90	89.60	94.00	1203	1506	1699	7.30	10.95	14.92
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	77.10	84.70	89.00	1181	1482	1671	6.80	10.35	13.96
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	73.60	83.30	87.00	1165	1458	1650	6.50	10.05	13.51
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	77.30	85.20	92.20	1190	1493	1683	6.90	10.75	14.03
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	75.20	83.80	89.00	1173	1470	1662	6.60	10.15	13.56
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	82.60	91.30	94.00	1226	1533	1721	7.20	10.80	14.52
T_{11}: Control (Foliar spray of water at 30 and 45DAT)	50.50	66.30	72.00	1073	1384	1576	5.40	7.90	10.72
Mean	75.07	84.80	89.42	1159.64	1455.45	1651.00	6.56	9.60	13.19
S Em	5.24	5.80	6.16	79.46	99.62	113.18	0.44	0.67	0.92
CD (0.05)	15.46	17.11	18.20	234.41	293.88	333.89	1.32	1.97	2.71

NAA: Naphthelene Acetic Acid, GA3: Gibberellic acid, 28 HB: 28 Homobrassinolid, TRIA: Triacontanol

Table 4. Effect of plant growth regulators on number of secondary branches plant^{-1}, fresh weight and dry weight of the plant in ajowan

Treatments	Number of secondary branches plant^{-1}			Fresh weight of the plant (g)			Dry weight of the plant (g)		
	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	25.40	48.80	56.90	87.25	155.00	211.67	41.67	61.83	68.50
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	26.50	49.40	57.60	98.34	173.33	243.33	47.13	63.67	70.67
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	25.40	42.40	56.00	83.14	135.00	196.67	35.11	43.33	65.33
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	24.00	42.30	55.70	81.20	123.33	189.50	32.22	39.50	57.00
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	39.60	65.80	79.20	156.98	301.67	363.33	69.14	94.83	98.17
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	30.03	53.80	64.10	137.56	253.33	288.33	57.23	75.67	87.50
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	28.50	50.00	59.30	104.00	178.33	278.33	49.52	66.50	75.00
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	31.10	54.80	65.40	142.72	270.00	320.00	59.20	76.50	88.67
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	28.50	51.30	62.80	114.25	191.67	285.00	53.65	68.83	86.33
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	33.00	59.10	72.30	145.60	276.67	343.33	62.41	79.67	91.83
T_{11}: Control (Foliar spray of water at 30 and 45DAT)	17.60	41.10	50.10	79.80	121.67	148.33	29.33	35.67	46.33
Mean	28.17	50.80	61.76	111.89	198.18	260.71	48.78	64.18	75.94
S Em	2.01	3.45	4.23	7.88	14.21	18.23	3.38	4.43	5.25
CD (0.05)	5.95	10.18	12.48	23.26	41.92	53.79	9.98	13.09	15.49

NAA: Naphthelene Acetic Acid, GA3: Gibberellic acid, 28 HB: 28 Homobrassinolid, TRIA: Triacontanol

increase in number of branches and number of leaves plant^{-1} but the application of GA_3@ 100 ppm had resulted in rapid increase in leaf area due to rapid cell division and cell elongation activities. This in turn could have increased the leaf area index. These results are corroborated with the findings of Talab et al. [16] and Tariq et al. [17] in fenugreek.

3.2.8 Crop growth rate (gm^{-2}d^{-1})

The data on crop growth rate was shown in Table 5. Significant differences were found among the treatments for crop growth rate. The crop growth rate was maximum (3.30 gm^{-2} d^{-1}) at 60-80 DAT and gradually decreased to 0.80 gm^{-2} d^{-1}at 100-120 DAT. Foliar sprays of thiourea @ 250 ppm (T_5) had recorded the maximum crop growth rate (6.12 gm^{-2}d^{-1}) at 80-100 DAT which was followed by T_{10} treatment (application of triacontanol @ 5 ppm as foliar spary) (4.87 gm^{-2} d^{-1} at 80-100 DAT). Minimum crop growth rate (2.97 gm^{-2} d^{-1} at 80-100 DAT) was recorded by T_{11} (water spray/control) treatment. Crop growth rate was gradually decreased from 60-80 DAT to 100-120 DAT, it could be attributed decrease in leaf area and leaf dry weight due to aging, senescence and translocation of drymatter from leaves into reproductive organs. Foliar sprays of thiourea had recorded the highest crop growth rate could be due to presence of more number of primary (15.03)/secondary (83.40) branches, leaves (298.8) and drymatter accumulation plant^{-1} (103.54 g plant $^{-1}$) and also maintenance of greenness of leaves for longer period of time by delaying ageing and senescence process in thiourea treated ajowan plants. The results are in association with the findings of Balai [10] and Kuri et al. [18] in coriander.

3.2.9 Chlorophyll a/chlorophyll b and total chlorophyll contents in leaves (mg g^{-1})

The data on chlorophyll-a, chlorophyll b is shown in Table 6 and total chlorophyll contents in leaves are shown in Table 2. The differences among the growth regulator sprays with respect to chlorophyll-a, chlorophyll b and total chlorophyll contents were found significant. Chlorophyll a, Chlorophyll b and total chlorophyll contents were gradually decreased from 4, 0.43 and 4.41 mgg^{-1} FW respectively at 60 DAT to 1.40, 0.076 and 1.87 mgg^{-1}FW respectively at 120 DAT. Foliar sprays of thiourea @ 250 ppm (T_5) had resulted in higher amounts of chlorophyll-a, chlorophyll–b and total chlorophyll contents in leaves (4, 0.430 and 4.41 mgg^{-1} FW respectively) at 60 DAT. The treatment was on par with T_{10} (application of triacontanol @ 5 ppm as foliar spray) (3.87 and 4.15 mgg^{-1}FW) T_8 (application of 28 homobrassinolide @ 0.2 ppm as foliar spray) (3.83 and 4.07 mgg^{-1}FW) and T_6 treatments (application of thiourea @ 500 ppm as foliar spray) (3.75 and 3.99 mgg^{-1} FW) for chlorophyll a and total chlorophyll contents in leaves respectively at 60 DAT. Minimum chlorophyll-a, chlorophyll b and total chlorophyll contents were (1.88, 0.030 and 2.41 mgg^{-1} FW respectively) recorded by T_4 (application of GA_3 @ 100 ppm as foliar spray) treatment at 60 DAT.

Foliar sprays of thiourea @ 250 ppm had recorded the highest total chlorophyll contents in leaves could be attributed to sulphur nutrient present in thiourea was responsible for the formation of chlorophyll molecules by activation of various enzymes that led to an increase in total chlorophyll content of leaves as earlier reported by Meena et al. [19] in corinander. Thiourea had maintained the greenness of the leaves for longer period of time by delaying leaf ageing and senescence as reported by Sahu and Singh [20]. Thiourea exhibits cytokinin like activity (Vassilev and Mashev [21]. The decrease in total chlorophyll content was observed by application of GA3 @100 ppm might be due to lanky growth of plant leading to wiry appearance in the architecture which further had led to masking effect from light and thus inhibiting the synthesis of chlorophyll molecule to the maximum possible extent by the plants. The results in corroborate with the findings of Shanu et al. [13], Kuri et al. [18] in coriander and Choudhary et al. [22] in ajowan.

Table 5. Effect of plant growth regulators on crop growth rate, number of leaves plant^{-1} and leaf area plant^{-1} in ajowan

Treatments	Crop growth rate ($g\ m^{-2}d^{-1}$)			Number of leaves plant^{-1}			leaf area plant^{-1} (cm^2)		
	60 DAT	80 DAT	100 DAT	60 DAT	80 DAT	100 DAT	80 DAT	100 DAT	120 DAT
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	2.32	2.36	0.66	51.2	154.93	207.66	7.62	6.22	6.13
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	2.35	2.97	0.70	52	155.58	215.00	8.57	6.89	6.76
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	1.95	2.10	0.60	50.4	151.87	194.66	9.60	7.24	7.18
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	1.85	1.87	0.53	49	146.50	193.35	11.68	9.62	9.53
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	4.71	6.12	1.44	58.4	203.89	249.18	10.66	8.9	8.8
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	2.98	3.38	0.86	54.4	191.73	221.24	9.3	7.13	7.04
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	2.63	3.29	0.78	52	160.19	216.30	9.02	6.98	6.87
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	4.25	4.87	0.92	55.2	198.42	235.92	9.40	7.18	7.12
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	2.67	3.38	0.84	52.8	174.77	220.65	9.10	7.07	6.97
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	4.27	4.87	0.94	57.6	199.12	238.00	11.04	9.22	9.2
T_{11}: Control (Foliar spray of water at 30 and 45DAT)	0.54	2.97	0.42	43.2	130.65	157.15	7.04	6.12	6.04
Mean	2.80	3.30	0.80	52.38	169.79	213.56	9.36	7.50	7.42
S Em	0.19	0.28	0.05	3.57	11.51	14.51	0.64	0.51	0.50
CD (0.05)	0.58	0.84	0.17	10.53	33.95	42.81	1.89	1.50	1.49

NAA: Naphthelene Acetic Acid, GA3: Gibberellic acid, 28 HB: 28 Homobrassinolid, TRIA: Triacontanol

Table 6. Effect of plant growth regulators on leaf area index, chlorophyll – a and chlorophyll - b in ajowan

Treatments	leaf area index			Chlorophyll - a (mg/g)			Chlorophyll - b (mg/g)		
	80 DAT	100 DAT	120 DAT	80 DAT	100 DAT	120 DAT	80 DAT	100 DAT	120 DAT
T_1: Application of NAA @ 50 ppm as foliar spray at 30 and 45 DAT	0.83	0.79	0.45	1.66	0.98	0.740	0.024	0.021	0.004
T_2: Application of NAA @ 100 ppm as foliar spray at 30 and 45 DAT	0.92	0.9	0.48	1.72	1.12	0.810	0.030	0.027	0.004
T_3: Application of GA_3 @ 50 ppm as foliar spray at 30 and 45 DAT	1.03	0.7	0.58	1.40	0.95	0.690	0.011	0.008	0.002
T_4: Application of GA3 @ 100 ppm as foliar spray at 30 and 45 DAT	1.44	1.31	0.74	1.25	0.95	0.680	0.010	0.003	0.001
T_5: Application of Thiourea @ 250 ppm as foliar spray at 30 and 45 DAT	1.25	1.16	0.73	2.30	1.80	1.400	0.207	0.200	0.076
T_6: Application of Thiourea @ 500 ppm as foliar spray at 30 and 45 DAT	1.11	0.94	0.52	2.16	1.55	1.297	0.059	0.037	0.019
T_7: Application of 28 HB @ 0.1 ppm as foliar spray at 30 and 45 DAT	0.99	0.92	0.49	2.16	1.52	1.180	0.030	0.028	0.005
T_8: Application of HB @ 0.2 ppm as foliar spray at 30 and 45 DAT	1.12	1.01	0.6	2.21	1.72	1.330	0.087	0.051	0.026
T_9: Application of TRIA @ 2.5 ppm as foliar spray at 30 and 45 DAT	1.08	0.94	0.5	1.82	1.38	1.290	0.040	0.030	0.008
T_{10}: Application of TRIA @ 5 ppm as foliar spray at 30 and 45 DAT	1.43	1.28	0.74	2.24	1.77	1.370	0.092	0.080	0.028
T_{11}: Control (Foliar spray of water at 30 and 45DAT)	0.66	0.61	0.34	1.49	0.96	0.730	0.020	0.016	0.003
Mean	1.08	0.96	0.58	1.86	1.34	1.047	0.05	0.04	0.01
S Em	0.07	0.06	0.04	0.12	0.09	0.07	0.005	0.004	0.002
CD (0.05)	0.21	0.19	0.12	0.36	0.26	0.21	0.015	0.013	0.005

4. CONCLUSION

Ajowan growth was stimulated with increasing concentrations of exogenous applied plant growth regulators. On the basis of present experiment foliar spray of thiourea 250 ppm at 30 and 45 days after transplanting was found effective for increasing vegetative and physiological parameters in ajowan.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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