

Original Research Article

INFLUENCE OF ELICITORS AND SEED RATE ON ENHANCING GROWTH AND YIELD OF BLACK CUMIN (*Nigella sativa*)

Abstract

The influence of elicitors (different types viz., T_1 =Control, T_2 =Salicylic acid 50ppm, T_3 =Gibberellic acid 100ppm, T_4 =Pinching and seed rate (different levels viz., R_1 =8kg/ha⁻¹, R_2 =10kg/ha⁻¹, R_3 =12 kg/ha⁻¹) on enhancing growth and seed yield of black cumin was investigated at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during November 2020 to March 2021. Growth related data was maximum on T_4 (Pinching) treatment but in case of seed yield, T_2 (Salicylic acid 50ppm) treatment showed the best result. In case of growth characters, R_1 (8 kg/ha⁻¹ seed rate) treatment revealed the best result but in case of seed yield, R_3 (12 kg/ha⁻¹ seed rate) treatment showed the best result. Under this investigation, it was revealed that the highest seed yield per hectare (3.88 t) was found from the T_2R_3 (Salicylic acid 50ppm and 12kg/ha seed rate) treatment combination which is statistically similar (3.6376 t) to T_4R_3 (Pinching and 12 kg/ha seed rate) treatment combination compared (1.61 t) to T_1R_1 (control and 8kg/ha seed rate) treatment combination. The highest gross return (Tk. 1166520), net return (Tk. 832522) were obtained from the treatment combination T_2R_3 (Salicylic acid 50ppm and 12 kg/ha seed rate) where the lowest gross return (Tk. 485010), net return (Tk. 220500) were obtained from T_1R_1 (control and 8kg/ha seed rate) treatment combination. The highest BCR (3.57) was obtained from the treatment combination T_4R_3 (Pinching and 12kg/ha seed rate) where the lowest BCR (1.83) was found from T_1R_1 (control and 8kg/ha seed rate) treatment combination. Economic analysis revealed that the treatment combination T_4R_3 (pinching and 12kg/ha seed rate) was economically profitable than T_2R_3 (Salicylic acid 50ppm and 12 kg/ha seed rate) treatment combination for black cumin cultivation.

1. Introduction

Nigella (*Nigella sativa* L.) is well known as black cumin or kalajira. The name *nigella* derives from the Latin *nigellus* or *niger*, meaning black. *kalajira* is an annual herbaceous plant belonging to the Ranunculaceae family. *Nigella* is an important seed spice that has originated from the Mediterranean region of Asia to North India. *Nigella* is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan, India and Turkey [1]. In Bangladesh, it covers 14742 hectares of land, with a total annual production of 16526 tons [2], over the Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kushtia, Bogra, Rangpur and Natore districts [3], [4]. The ripe seed of black cumin contains 7% moisture, 4.34% ash, 23% protein, 0.39% fat, 4.99% starch and 5.44% raw fiber [5]. *N. sativa* seeds contain 30-35% oil and 0.5-1.5% essential oil which has several uses in the pharmaceutical and food industries [6]. The major medicinal components are *thymoquinone* and *nigellone* (a dimer of thymoquinone). These were attributed to impart **anti-tumor, anti-inflammatory** and anti-diabetic properties [7], [8]. But the proper growth and development of black cumin is hindered by some factors viz., climatic, varietal and nutritional management. Among these factors the nutritional management, more emphasized to elicitors and seed rate are the most important that can improve the yield performance of black cumin in prevailing climatic **condition of Bangladesh. Several biotechnological strategies have been** applied for the productivity

enhancement, and elicitor application is recognized as the most practically feasible strategy for increasing the production. Abiotic elicitors comprise of substance that are non-biological and are grouped in physical, chemical and hormonal factors (e.g. salicylic acid, gibberellic acid and pinching). The use of GA_3 involved in promoting flowers and seed yield of black cumin [9]. The growth regulator GA_3 enhances the plant growth, flower induction, nutrient uptake and photosynthesis [10]. Salicylic acid (SA) is considered to be a hormone like substance that is important in the regulation of plant growth and development, seed germination, fruit yield, glycolysis, flowering and heat production in thermogenic plants, ion uptake and transport, photosynthetic rate, stomatal conductance and transpiration [11]. Pinching makes black cumin yields compact, bushy plants with more blooms and also helps in breaking the rosette and also improves the plant's looks. The plant height, stem diameter and number of inflorescences increased as the number of prunings [12]. Linear increase in yield was recorded as the pinching severity increased. Seed rate is one of the main key factors for obtaining high yield and quality in the production of crops. Seed rate is the key factor determining affecting the yield and yield components. Several studies carried out in countries where systematically cultivated, have demonstrated that suitable seed rate can increase the growth and yield of *Nigella sativa* [13]. In Bangladesh, only limited studies have been done regarding elicitors and seed rate for growth and yield of black cumin. The aim of this study was to investigate the influence of elicitors, the influence of seed rate and suitable combination of elicitors and seed rate for better growth and seed yield of black cumin.

2. MATERIALS AND METHODS

2.1 Experimental Site and Experimental Framework

The experiment was conducted during the period from November 2020 to March 2021 at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The experimental site was located at 23°74' N latitude and 90°35' E longitude at an altitude of 8.2 m. The experiment consisted of two factors as mentioned below: **Factor A:** Elicitors (Different types) viz., T_1 = Control, T_2 = Salicylic acid 50ppm, T_3 = Gibberellic acid 100ppm, T_4 = Pinching. **Factor B:** Seed rate (different levels) viz., R_1 = 8 kg ha⁻¹, R_2 = 10 kg ha⁻¹, R_3 = 12 kg ha⁻¹. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The size of unit plot was 1 m × 1 m. The total number of treatments was 12 and the number of plots were 36.

2.2 Planting Materials

In this experiment black cumin variety, BARI Kalozira-1 was used. BARI Kalozira-1 was developed by Spices Research Centre, BARI in 2009.

2.3 Application of Manures and Fertilizers

Total 10 ton/hacow dung, 125 kg ha⁻¹ urea, 95 kg ha⁻¹ triple super phosphate and 75 kg ha⁻¹ muriate of potash were applied in the field. The entire amount of cow dung, triple super phosphate and muriate of potash and half of the urea were applied at final land preparation as a basal dose. Rest half of the Urea was applied in two equal splits at 25 and 50 days after seed sowing (DAS) followed by irrigation.

2.4 Sowing of seed

To enhance germination, these seeds were soaked in water for 48 hours before seed sowing. Seeds were also treated with Autostin 50WDG @ 2 g per kg of seeds before sowing. These seeds were sown on 25 November, 2020 in rows continuously by hand. These seeds were mixed with loose soil to maintain the uniform sowing in rows. The seeds were gently pressed by hands after sowing and covered with loose soil.

2.5 Application of the treatments

Elicitors were sprayed at 40 and 60 days after sowing viz., Salicylic acid - 50 ppm (in two equal doses of 25 ppm), Gibberellic acid - 100 ppm (in two equal doses of 50 ppm) as foliar spray and pinching was done at 40 days after sowing.

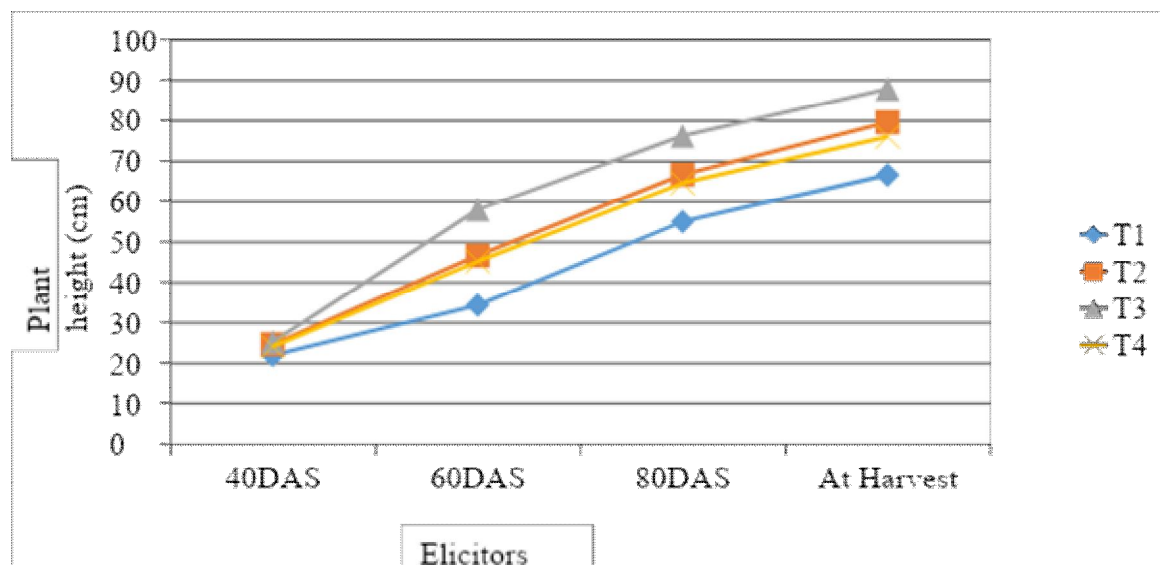
2.6 Statistical Analysis The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using an analysis of variance (ANOVA) technique with the help of computer package program Statistics 10 (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by [14].

3. RESULTS AND DISCUSSION

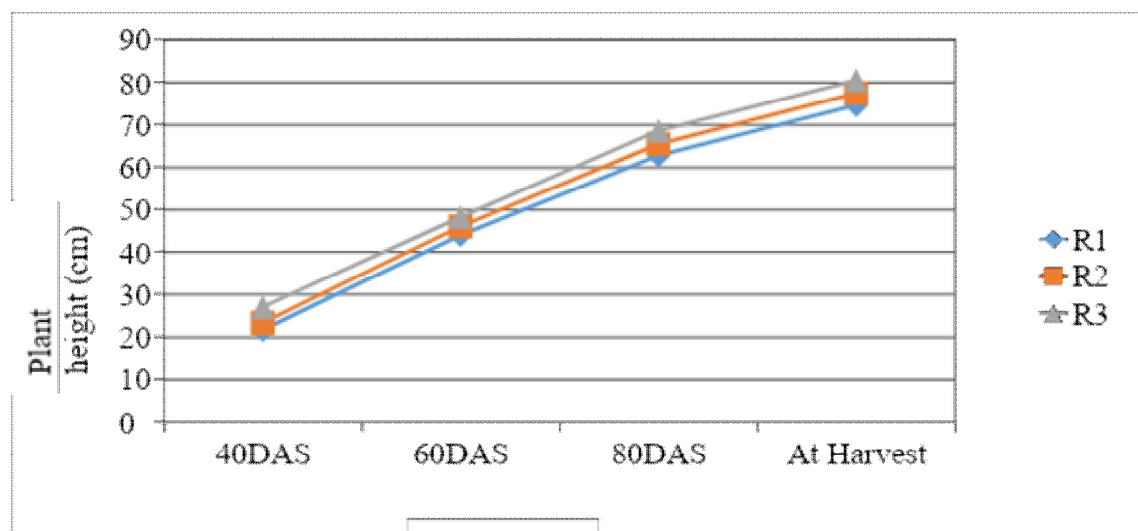
3.1 Plant height (cm)

Plant height of black cumin plant was significantly varied due to the elicitor's treatment (Fig 1). At harvest, the highest plant height (87.95cm) was found from the T_3 (100ppm GA₃) treatment and the shortest plant height (66.66cm) was produced from the control (T_1) treatment. [15] and [16] reported that, plant height increases with the application of GA₃ application. The application of optimum doses of GA₃ increased the internode elongation of stem. So, the height of plant was increased under present study with significantly varied with the application of GA₃.

Seed rate had a significant influence on plant height of black cumin plants at 40, 60, 80DAS and at harvest (Fig2). The highest plant height (80.54cm) was observed from R_3 (12kg/ha) seed rate and the lowest plant height (74.70cm) was obtained from R_1 (8 kg/ha) seed rate at harvest. These findings on plant height were in accordance with [17]; and [18], [13] found that an increasing seed rate in black cumin increased plant height. Similar results also reported by [19], who stated that increasing the plant density of black cumin (higher seed rate and closer inter-row spacing) within an area of land increased plant height, this may be due to higher competition among the plants.



Here, T_1 = Control, T_2 = Salicylic acid 50ppm, T_3 = Gibberellic acid 100ppm, T_4 = Pinching.
 Fig.1. Effect of elicitors on plant height of black cumin.



Here, R_1 = 8 kg/ha seed rate, R_2 = 10 kg/ha seed rate, R_3 = 12 kg/ha seed rate.
 Fig.2. Effect of seed rate on plant height of black cumin.

Combinations of elicitors and seed rate also showed statistically significant variation in case of plant height at 40, 60, 80 DAS and at harvest (Table 2). At harvest, the highest plant height (92.93 cm) was produced from T₃R₃ (GA3 100 ppm and 12 kg/ha) treatment combination and the lowest plant height (63.80 cm) was found from T₁R₁ (control and 8 kg/ha) treatment combination.

3.2 Number of leaves per plant

From the current investigation, the number of leaves per plant of black cumin was recorded at different days after sowing i.e. 40 DAS, 60 DAS, and 80 DAS (Table 1). The number of leaves per plant of black cumin varied significantly due to the application of different types of elicitors at different days after sowing (DAS). At 80 DAS, the maximum number of leaves per plant (78.04) was recorded from T₄ (pinching) treatment, while the lowest number of leaves per plant (58.65) was obtained from T₁ (control) treatment. Increase in number of leaves per plant as a result of pinching has been observed previously in china aster, field bean and bottle gourd.

Number of leaves per plant of black cumin was significantly varied due to the effect of seed rate which was recorded at different days after sowing i.e. 40 DAS, 60 DAS, 80 DAS (Table 1). From the observation of 80 DAS, the highest number of leaves per plant (71.23) was recorded from the treatment R₁ (8 kg/ha) seed rate and the lowest number of leaves per plant (66.85) was recorded from the treatment R₃ (12 kg/ha) seed rate.

Combined effect of elicitors and seed rate in terms of number of leaves per plant of black cumin varied significantly at 40 DAS, 60 DAS and 80 DAS (Table 2). At 80 DAS, the highest number of leaves per plant (80.23) was recorded from T₄R₁ (pinching and 8 kg/ha seed rate) treatment combination and the lowest number of leaves per plant (56.37) was produced from T₁R₃ (control and 12 kg/ha seed rate) treatment combination.

Table 1. Effect of elicitors and seed rate on number of leaves and number of branches per plant of black cumin.

Treatment	Number of leaves at different days after sowing			Number of branches per plant at harvest
	40DAS	60DAS	80DAS	
T ₁	8.05 c	33.15 d	58.65 d	25.74 d
T ₂	8.14 c	51.89 b	72.65 b	44.90 b
T ₃	8.61 b	42.98 c	66.27 c	34.22 c
T ₄	11.78 a	54.72 a	78.04 a	49.29 a
Lsd _{0.05}	0.2837	0.9390	0.8357	0.3982
CV%	7.45	5.21	4.89	6.45
Different level of seed rate				
R ₁	10.05 a	48.59 a	71.23 a	41.42 a
R ₂	9.18 b	45.71 b	68.62 b	38.22 b
R ₃	8.20 c	42.76 c	66.85 c	35.98 c
Lsd _{0.05}	0.2457	0.8132	0.7237	0.3448
CV%	7.45	5.21	4.89	6.45

In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, T₁=Control, T₂=Salicylic acid 50 ppm, T₃= Gibberellic acid 100 ppm, T₄= Pinching. R₁= 8 kg/ha seed rate, R₂= 10 kg/ha seed rate, R₃= 12 kg/ha seed rate.

4.3 Branches per plant at harvest

The variation in number of branch per plant at different types of elicitors was also significant at harvest. At harvest, the maximum number of branches per plant (49.29) was observed from T₄ (pinching) treatment and the minimum number of branches (25.74) was found in T₁ (control) treatment (Table 1).

A significant variation was found in the number of branches per plant was observed due to effect of different level of seed rate in black cumin plant. At harvest, the highest number of branch per plant

(41.42) was produced in R₁ (8 kg/ha seed rate) treatment while the lowest number of branches per plant (35.98) was found in R₃ (12 kg/ha seed rate) treatment. There were statistically significant differences among the treatment combinations of elicitors and seed rate in respect of number of branches per plant at harvest. The highest number of branches per plant (51.63) was obtained from T₄R₁ (pinching and 8 kg/ha seed rate) treatment combination while the lowest number of branches per plant (24.23) was observed from T₁R₃ (control and highest seed rate) treatment combination at harvest. (Table 2).

Table 2. Combined effect of elicitors and seed rate on plant height, number of leaves and number of branches per plant of black cumin.

Treatment combination	Plant height (cm) at different days after sowing				Number of leaves at different days after sowing			Number of branches per plant at harvest
	40DAS	60DAS	80DAS	At Harvest	40DAS	60DAS	80DAS	
T ₀ R ₁	19.65 h	33.03 i	52.33 j	63.80 i	8.53 fg	36.90 g	61.17h	27.13 i
T ₀ R ₂	21.07 gh	33.60 i	54.93 i	67.64 h	8.03 hi	33.83 h	58.40 i	25.87 j
T ₀ R ₃	25.50 cd	36.53 h	57.90 h	68.53 h	7.60 ij	28.73 i	56.37j	24.23 k
T ₁ R ₁	22.76 fg	45.09 f	65.50ef	77.57 ef	9.15de	55.17 b	74.30 c	49.57 b
T ₁ R ₂	23.90 def	46.83 e	66.53 e	79.77de	8.13gh	51.90 c	72.53d	43.53 d
T ₁ R ₃	27.57 ab	48.16 d	68.16 d	81.56 cd	7.15 j	48.60 d	71.13d	41.60 e
T ₂ R ₁	22.30 fg	54.90 c	71.20 c	83.87 bc	9.27 d	44.43 e	69.23e	37.35 f
T ₂ R ₂	24.80cde	58.36 b	75.50 b	87.06 b	8.73 ef	43.00ef	65.87 f	33.53 g
T ₂ R ₃	28.70 a	60.86 a	82.16 a	92.93 a	7.82 hi	41.53 f	63.70g	31.77 h
T ₃ R ₁	22.30 fg	42.93 g	62.13 g	73.57 g	13.27a	57.90 a	80.23a	51.63 a
T ₃ R ₂	23.70 ef	45.43 f	65.13 f	75.60 fg	11.83b	54.10 b	77.67b	49.93 b
T ₃ R ₃	26.50 bc	47.33de	66.63 e	79.15de	10.23 c	52.17 c	76.23b	46.33 c
Lsd _{0.05}	1.7017	1.2874	1.1956	3.4315	0.4913	1.6263	1.4475	0.6897
CV%	3.87	4.60	7.25	6.32	7.45	5.21	4.89	6.45

In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, T₁=Control, T₂=Salicylic acid 50ppm, T₃= Gibberellic acid 100ppm, T₄= Pinching. R₁= 8 kg/ha seed rate, R₂= 10 kg/ha seed rate, R₃= 12 kg/ha seed rate.

4.4 Days to first flowering

In case of days to first flowering of black cumin against the effect of the treatment of elicitors was found significant (Table 3).

Results revealed that, the longest days (60.67) were needed to reach the 1st flowering stage by the plant treated with T₄ (pinching) treatment and the shortest days (46.11) were needed by the plant treated with T₃ (GA3 100ppm) treatment. The application of GA₃ may improve the earlier development of flowering. So, application of GA₃ the earlier 1st flowering was observed under present study by inducing the more florigen hormone.

A significant variation was found in case of days to first flowering was observed due to effect different level of seed rate in black cumin plant. The longest days (55.67) were needed to reach the 1st flowering stage by the plant treated with R₃ (12 kg/ha seed rate) treatment and the shortest days (50.50) were needed by the plant treated with R₁ (8 kg/ha seed rate) treatment.

Significant difference was found during the combined application of elicitors and seed rate on days to first flowering of black cumin plant (table 4). The highest days (62.33) to needed first flowering obtained from T₃R₃ (pinching and 12 kg/ha seed rate) treatment combination and lowest (45.33) days were observed from the T₃R₁ (GA₃ and lowest seed rate) treatment combination.

4.7 Number of capsule per plant

The number of capsules per plant was significantly affected by different types of elicitors (Table 3).

Number of capsules per plant increased with the different treatment of elicitors. The highest number of capsules per plant (40.42) was recorded from T₄ (pinching) treatment. The lowest number of capsules per

plant(19.98) was obtained from T₁ (control) treatment. In this study, more numbers of pods were observed in pinched plants as compared to un-pinched plants. Plants having a greater number of lateral branches have vigorous vegetative growth, which in turn have good photosynthetic efficiency and have greater translocation of photosynthates from source to sink which in turn have beneficial effects on reproductive growth.

Significant variations were clearly evident in case of number of capsules per plant with different levels of seed rate (Table 3). The highest number of capsules per plant (36.10) was resulted from R₁ (8 kg/ha seed rate) treatment and the lowest number of capsules per plant (28.74) was obtained from (12 kg/ha seed rate) R₃ treatment. [20] reported that with the increase in seed rate, number of filled pods/ plant decreased. [21] reported that seed rate had negative correlation with the number of filled pods/ plants. The combination of elicitors and seed rate gave the highest number of capsules per plant (44.23) was recorded from T₄R₁ (pinching and 8 kg/ha seed rate) (Table 4). The lowest number of capsules per plant (17.62) was obtained from the T₁R₃ (control and 12 kg/ha seed rate) treatment combination in black cumin.

Table 3. Effect of elicitors and seed rate on days to first flowering, number of capsules per plant, weight of seeds per plant (g), 1000 seeds weight (g) and seed yield (t/ha) of black cumin.

Treatment	Days to first flowering	Number of capsules per plant	Weight of seeds per plant (g)	1000 seeds weight (g)	Seed Yield (t/ha)
Different types of elicitors					
T ₁	58.78 b	19.98 d	4.6833 d	2.30 d	190.47 c
T ₂	52.78 c	39.21 b	8.0678 a	3.04 b	328.99 a
T ₃	46.11 d	30.15 c	6.9344 c	2.63 c	306.13 b
T ₄	60.67 a	40.42 a	7.65 b	3.24 a	319 ab
Lsd _{0.05}	0.5378	0.0723	0.3055	0.0747	17.486
CV%	8.75	5.26	7.25	4.20	7.25
Different level of seed rate					
R ₁	53.50 c	36.10 a	6.26 c	3.01 a	233.37 c
R ₂	54.58 b	32.49 b	6.8733 b	2.79 b	295.07 b
R ₃	55.67 a	28.74 c	7.3683 a	2.62 c	330.01 a
Lsd _{0.05}	0.4658	0.0626	0.2646	0.0647	15.144
CV%	8.75	5.26	7.25	4.20	7.25

In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at 0.05 level of probability. Here, T₁=Control, T₂=Salicylic acid 50ppm, T₃=Gibberellic acid 100ppm, T₄= Pinching. R₁= 8 kg/ha seed rate, R₂= 10 kg/ha seed rate, R₃= 12 kg/ha seed rate.

4.13 Weight of seed per plant (g)

Weight of seeds per plant of black cumin due to different types of elicitors was found remarkably significant (Table 3). Weight of seeds per plant was increased with the application of different elicitors. Results revealed that, the highest weight of seeds per plant (8.0678 g) was obtained from the plants treated with T₂ (salicylic acid 50ppm) treatment and the lowest weight of seeds per plant (4.6833 g) was observed from the plants treated with T₁ (control) treatment.

Significant variation in weight of seeds per plant (1 m²) was observed among the application of different levels of seed rate represented (Table 3). Application of R₃ treatment (seed rate 12 kg/ha) gave the highest weight of seeds per plant (7.3683 g). The lowest weight of seeds per plant (6.26 g) was obtained from R₁ (8 kg/ha seed rate) treatment.

Combined application of elicitors and seed rate significantly influenced the weight of seeds per plant of black cumin. The treatment combination T₂R₃ (salicylic acid 50ppm and 12 kg/ha seed rate) gave the maximum weight of seeds per plant (8.5933 g) which was statistically similar (8.15 g) to T₄R₃ (pinching and 12 kg/ha seed rate) (Table 4). But the treatment combination T₁R₁ (control and 8 kg/ha seed rate) gave the lowest weight of seeds per plant (4.04 g).

4.14 1000 seeds weight (g)

Due to the effect of elicitors, 1000-seed weight (g) varied significantly. Higher 1000-seeds weight (3.24g) was given by T₄ (pinching) treatment while lower value (2.30g) was recorded from T₁ (control) treatment (Table 3). 1000-seeds weight (g) varied significantly due to the effect of seed rate. The highest 1000-seeds weight (3.01g) was given by R₁ (8kg ha⁻¹ seed rate) treatment. The lowest 1000-seed weight (2.62 g) was given by R₃ (12 kg/ha seed rate) treatment (Table 3).

Due to the combined effect of elicitors and seed rate, 1000-seeds weight (g) varied significantly. The maximum 1000-seeds weight (3.40g) was recorded in T₄R₁ (pinching and 8kg/haseedrate) treatment combination and it was statistically similar to T₄R₂ (pinching and 8 kg/ha seed rate) treatment combination. The treatment combination T₁R₃ (control and 12 kg/ha seed rate) which produced the lowest 1000-seeds weight (2.15 g) (Table 4).

Table 4. Combined effect of elicitors and seed rate on days to first flowering, number of capsules per plant, weight of seeds per plant (g), 1000 seeds weight (g) and Seed Yield (t/ha) of black cumin.

Treatment combination	Days to first flowering	Number of capsules per plant	Weight of seeds per plant (g)	1000 seeds weight (g)	Seed Yield (t/ha)
T ₀ R ₁	57.67 d	22.61 i	4.04 h	2.42 ef	161.67 i
T ₀ R ₂	58.33 cd	19.73 j	4.78 g	2.33 f	193.00 h
T ₀ R ₃	60.33 b	17.62 k	5.23 g	2.15 g	216.74 gh
T ₁ R ₁	52.33 f	42.63 b	7.60 cd	3.25 b	265.01 f
T ₁ R ₂	52.67 ef	39.17 d	8.01 bc	3.00 c	333.13 cd
T ₁ R ₃	53.33 e	35.83 e	8.5933a	2.87 d	388.84a
T ₂ R ₁	45.33 h	34.94 f	6.30 f	2.95 cd	225.03 g
T ₂ R ₂	46.33 g	29.80 g	7.00 e	2.54 e	342.67 bc
T ₂ R ₃	46.67 g	25.71 h	7.50 cde	2.41 f	350.71 bc
T ₃ R ₁	58.67 c	44.23 a	7.10 de	3.40 a	281.78 ef
T ₃ R ₂	61.00 b	41.25 c	7.70 bc	3.28 ab	311.47 de
T ₃ R ₃	62.33 a	35.79 e	8.15 ab	3.04 c	363.76 ab
Lsd _{0.05}	0.9315	0.1252	0.5292	0.1294	30.287
CV%	8.75	5.26	7.25	4.20	7.25

In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, T₁=Control, T₂=Salicylic acid 50ppm, T₃=Gibberellic acid 100ppm, T₄= Pinching. R₁= 8 kg/ha seed rate, R₂= 10 kg/ha seed rate, R₃= 12 kg/ha seed rate.

4.16 Seed yield (t/ha)

There was a statistically significant variation due to the effect of elicitors in case of seed yield (t/ha). Statistically higher seed yield (3.2899t/ha) was recorded in T₂ (salicylic acid 50ppm) treatment which was statistically similar (3.19t/ha) to T₄ (pinching) treatment while the T₁ (control) treatment gave lower value (1.9047 t/ha) (Table 3).

Seed yield (t/ha) showed statistically significant variation among the different levels of seed rate treatments. The maximum seed yield (3.300t/ha) was recorded in R₃ (12kg/haseedrate) treatment in black cumin. The lowest seed yield (2.3337 t/ha) was obtained from R₁ (8 kg/ha seed rate) treatment.

Seed yield (t/ha) showed statistically significant variation due to the combined effect of elicitors and seed rate. Statistically the maximum seed yield (3.8884 t/ha) was recorded in T₂R₃ (salicylic acid 50ppm and 12 kgK/haseedrate) treatment combination and it was statistically similar (3.6376t/ha) to T₄R₃ (pinching and 12kgK/ha seed rate) treatment combination. The lowest seed yield (1.6167 t/ha) was produced from T₁R₁ (control and 8 kg/ha seed rate) treatment combination (Table 4).

4.19 Economic analysis

Economic analysis is the major criterion to evaluate the best treatments which were economically sound and that can be accepted by farming community. The cost of cultivation, gross and net returns in addition to benefit cost ratio of different treatment combinations studied in the present investigation is presented in (Table 5). The total cost of cultivation was observed to range from Tk. 264518 T_1R_1 (Control and 8kg/ha seed rate) treatment combination to Tk. 369648 T_3R_3 (GA₃ and 12kg/ha seed rate) treatment combination. The highest gross return (Tk. 1166520) was obtained from T_2R_3 (Salicylic acid 50ppm and 8kg/ha seed rate) treatment combination and the lowest gross return (Tk. 485010) was recorded from T_1R_1 (control and 8kg/ha seed rate) treatment combination. The lowest net return (Tk. 220500) was recorded from T_1R_1 (control and 8kg/ha seed rate) treatment combination and the highest net return (Tk. 832522) was obtained from T_2R_3 (Salicylic acid 50ppm and 12kg/ha seed rate) treatment combination. The highest benefit cost ratio (3.57) estimated from T_4R_3 (Pinching and 12 kg/ha seed rate) treatment combination and the lowest benefit cost ratio (1.83) was obtained from T_1R_1 (Control and 8kg/ha seed rate) treatment combination.

Table 5. Economic analysis of black cumin influenced by elicitors and seed rate.

Treatments combination	Total cost of production (A+B)	Gross return (Tk./ha)	Net return (Tk./ha)	BCR
T_1R_1	264518	485010	220500	1.83
T_1R_2	266798	579000	312202	2.17
T_1R_3	294998	650220	355222	2.20
T_2R_1	303518	795030	461512	2.52
T_2R_2	318758	999390	680632	3.14
T_2R_3	333998	1166520	832522	3.49
T_3R_1	339168	675090	335922	1.99
T_3R_2	354408	1028010	673602	2.90
T_3R_3	369648	1052130	682482	2.84
T_4R_1	275318	845340	570022	3.07
T_4R_2	290558	934410	643852	3.22
T_4R_3	305798	1200408	894610	3.93

Here, T_1 =Control, T_2 =Salicylic acid 50ppm, T_3 =Gibberellic acid 100ppm, T_4 = Pinching. R_1 = 8 kg/ha seed rate, R_2 = 10 kg/ha seed rate, R_3 = 12 kg/ha seed rate.

Conclusion

This study revealed that elicitors and seed rate have a positive effect on growth and seed yield of black cumin. In case of seed yield of black cumin, the combination of elicitor T_2 (salicylic acid 50ppm) treatment which is statistically similar T_4 (pinching) treatment along with seed rate R_3 (12kg/ha) were given the better performance of all the yield contributing parameters and seed yield of black cumin. The treatment combination of T_2R_3 (Salicylic acid 50ppm and 12kg/ha seed rate) showed the best potentiality of seed yield of black cumin. But economic analysis revealed that the treatment combination T_4R_3 (pinching and 12kg/ha seed rate) was economically profitable than T_2R_3 (Salicylic acid 50ppm and 12 kg/ha seed rate) treatment combination for black cumin cultivation. So, T_4R_3 (pinching and 12kg/ha seed rate) treatment combination can be repeated in different agro ecological zones of Bangladesh.

The authors have declared that no **competing interests** exist

AUTHORS' CONTRIBUTIONS

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

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