Original ResearchArticle

Influence Of ElicitorsAnd Seed Rate On Enhancing GrowthAnd Yield Of Black Cumin (*Nigella sativa)*

Abstract

Theinfluenceofelicitors(differenttypes*viz.*,T_1=Control,T_2=Salicylicacid50ppm,T_3=Gibberellic acid 100ppm,T_4=Pinchingandseedrate(differentlevels*viz.*,R_1=8kgha^{-1},R_2=10kgha^{-1},R_3= 12 kg ha^{-1}) onenhancinggrowth and seed yield of black cumin was investigated at Horticulture Farm, Sher-e-Bangla AgriculturalUniversity,Dhaka, Bangladesh, during November 2020 to March 2021. Growth related data wasmaximumonT_4 (Pinching)treatmentbutincaseofseedyield,T_2(Salicylicacid50ppm)treatment showedthebestresult.Incase of growth characters, R_1(8 kg ha^{-1} seed rate) treatment revealed the best resultbutincaseofseedyield,R_3 (12 kg ha^{-1} seed rate) treatment showed the best result. Under this investigation,itwasrevealed that the highest seed yield per hector (3.88 t) was found from the of T_2R_3 (Salicylicacid50ppmand12kg/haseed rate) treatment combination which is statisticallysimilar (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/haseed rate) treatment combination. The highest grossreturn(Tk.1166520),netreturn(Tk. 832522)wereobtainedfromthetreatmentcombinationT_2R_3 (Salicylicacid50ppm and 12 kg/ha seed rate)wherethelowestgrossreturn(Tk.485010),netreturn(Tk.220500)wereobtainedfromT_1R_1 (controland8kg/haseedrate)treatmentcombination. ThehighestBCR (3.57) wasobtain from the treatmentcombinationT_4R_3(Pinchingand12kg/haseedrate) where the lowest BCR (1.83) was found fromT_1R_1 (controland8kg/haseedrate)treatmentcombination. Economic analysis revealed that the treatmentcombinationT_4R_3 (pinchingand12kg/haseedrate)waseconomicallyprofitablethanT_2R_3 (Salicylic acid 50ppm and 12 kg/ha seed rate) treatment combination for black cumin cultivation.

1. Introduction

Nigella(*Nigellasativa*L.)iswellknownasblackcuminorkalojira.Thenamenigelladerivesfromthe Latinnigellusorniger,meaningblackkalajiraisanannualherbaceous plantbelonging tothe Ranunculaceaefamily.*Nigella*isanimportantseedspicehas originated from Mediterranean region of Asia to North India. *Nigella* is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan,IndiaandTurkey[1].InBangladesh,itcovers14742hectares ofland,with atotal annual productionof16526tons[2],overthe Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kushtia, Bogra,RangpurandNatoredistricts[3],[4]. Theripeseedofblackcumincontains7%moisture,4.34% ash,23%protein,0.39%fat,4.99%starchand5.44%rawfiber[5].*N.sativa*seedscontain30-35%oil and0.5-1.5%essentialoilwhichhasseveralusesinthepharmaceuticalandfoodindustries[6].The majormedicinalcomponentsare*thymoquinone*and*nigellone*(adimerofthymoquinone). These were attributed to impartanti-tumor,anti-inflammatoryandanti-diabeticproperties[7],[8].Buttheproper growthanddevelopmentofblackcuminishindered by some factors *viz.,* climatic, varietal and nutritional management.Among these factors the nutritional management, more emphasized to elicitors and seed ratearethemostimportantthatcanimprovetheyieldperformanceofblackcumininprevailingclimatic condition ofBangladesh. Several biotechnologicalstrategieshavebeenappliedfortheproductivity

enhancement, and elicitor application is recognized as the most practically feasible strategy for increasingtheproduction.Abiotic elicitors comprise of substance that are non-biological and are grouped inphysical,chemicalandhormonalfactors(e.g.salicylicacid,gibberellicacidandpinching).The use of GA_3involvedinpromotingflowersandseed yield of black cumin [9]. The growth regulator GA_3enhances theplantgrowth,flowerinduction,nutrientuptakeand photosynthesis [10].Salicylic acid (SA) is considered to be a hormone likesubstancethatisimportantintheregulationofplantgrowthand development, seed germination, fruit yield,glycolysis,floweringandheatproductioninthermogenic plants,ionuptake and transport, photosynthetic rate, stomatal conductance and transpiration [11]. Pinchingmakesblackcuminyieldscompact,bushyplantswithmorebloomsandalsohelps in breaking therosetteandalsoimprovetheplant'slooks.Theplantheight, stem diameter and number of inflorescencesincreasedasthenumberof pruning's [12]. Linear increase in yield was recorded as the pinchingseverityincreased.Seedrateisoneofthemainkeyfactorsforobtaining high yield and quality intheproductionofcrops.Seedrateisthe key factor determining affecting the yield and yield components.Severalstudiescarriedout in countries where systematically cultivated, have demonstrated thatsuitableseedratecanincreasethegrowthandyieldof*Nigellasativa*[13].InBangladesh,only limitedstudieshavebeendone regarding elicitors and seed rate for growth and yield of black cumin. The aimofthisstudywastoinvestigate 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. MATERIALSAND METHODS

2.1 Experimental Site and Experimental Framework

Theexperimentwas conducted during the period from November 2020 to March 2021 at the "Horticulture Farm"ofSher-e-BanglaAgriculturalUniversity,Dhaka-1207, Bangladesh. The experimental site was located at 23°74′ NlatitudeandE90°35′Elongitudesatanaltitudeof8.2 m. The experiment consisted of two factors as mentionedbelow: **Factor A**: Elicitors (Different types) *viz.*, T_1= Control, T_2= Salicylic acid 50ppm, T_3= Gibberellicacid100ppm,T_4=Pinching.**FactorB**:Seedrate(differentlevels)*viz.*,R_1=8kgha^{-1},R_2= 10 kgha^{-1},R_3=12 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with3replications.Thesizeofunitplotwas1m×1m.Thetotalnumberoftreatments was 12 and the number of plots were 36.

2.2 Planting Materials

Inthisexperimentblackcuminvariety,BARIKalozira-1wasused.BARIKalozira-1wasdevelopedby Spices Research Centre, BARI in 2009.

2.3Application of Manures and Fertilizers

Total10ton/hacow dung,125kgha^{-1} urea,95kgha^{-1} triplesuperphosphateand75kgha^{-1} muriateof potashwereappliedinthefield.The entire amount of cow dung, triple super phosphate and muriate of potashandhalfoftheureawereappliedatfinallandpreparationasabasal 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

Toenhancegermination,theseedsweresoakedinwaterfor48hoursbeforeseed sowing. Seeds were alsotreatedwithAutostin50WDG@2gperkgofseedsbeforesowing.Theseedsweresownon25 November,2020inrowscontinuouslybyhand.Theseedsweremixedwithloosesoilto maintain the uniformsowinginrows.The seeds were gently pressed by hands after sowing and covered with loose soil.

2.5Application of the treatments

Elicitorswereprayedat40and60daysaftersowing*viz.*, Salicylic acid - 50 ppm (in two equal doses of 25ppm),Gibberellic acid - 100ppm (in two equal doses of 50 ppm)as foliar spray and pinching was done at 40 days after sowing.

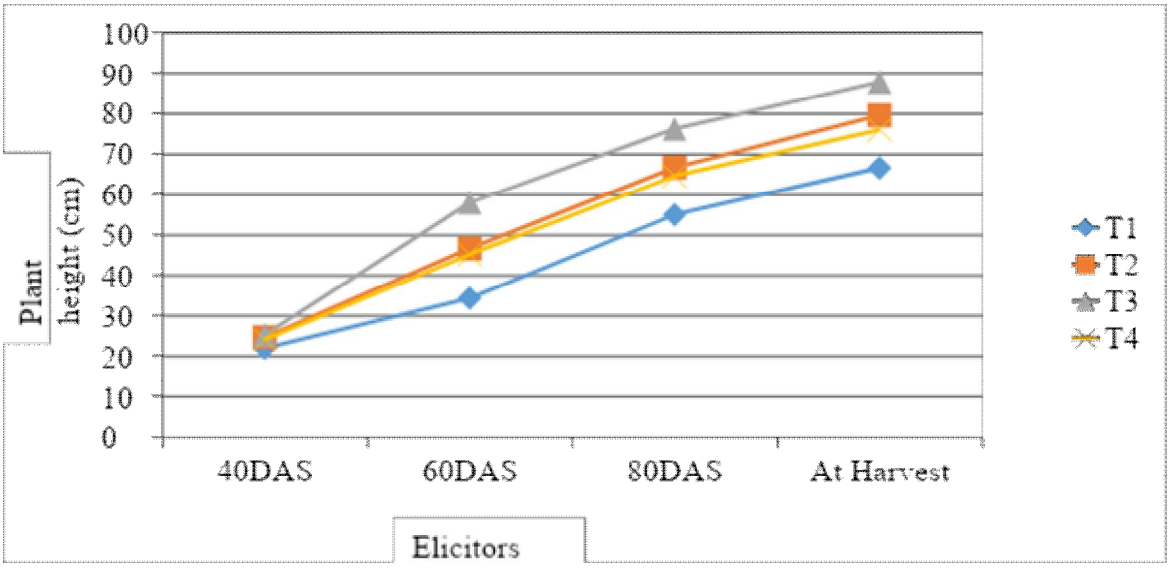
2.6StatisticalAnalysis Thecollecteddatawerecompiledandtabulated.Statisticalanalysiswasdone on various plant characters to find outthesignificanceofvarianceresultingfromtheexperimental treatments.Datawereanalyzedusinganalysis of variance (ANOVA) technique with the help of computer packageprogramStatistics10(software)andthemeandifferenceswere adjudged by least significant difference test (LSD) as laid out by [14].

3. RESULTSAND DISCUSSION

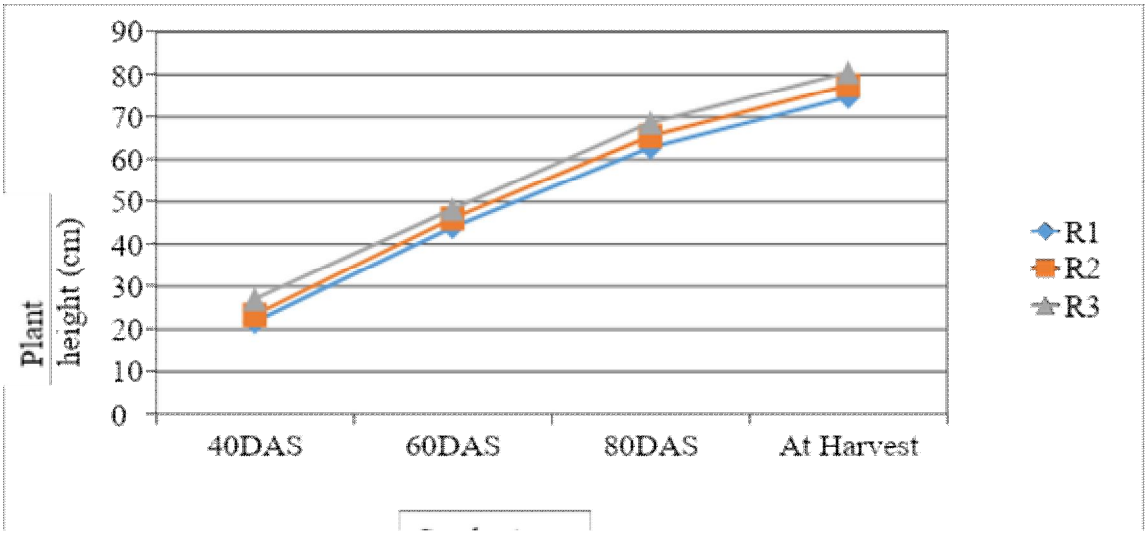
3.1 Plant height (cm)

Plantheightof black cumin plant was significantly varied due to the elicitor's treatment (Fig 1). At harvest, thehighestplantheight(87.95cm)wasfoundfromtheT_3 (100ppmGA3)treatmentandtheshortest plantheight(66.66cm)was produced from the control (T_1) treatment. [15] and [16] reported that, plant height increases with the application of GA_3 application. The application of optimum doses ofGA_3 increasedtheinternodeelongationofstem.So,theheightofplantwasincreasedunderpresentstudy with significantly varied with the application of GA_3.

Seedratehadasignificantinfluencedonplantheightofblackcuminplantsat40,60, 80DAS and at harvest(Fig2).Thehighestplantheight(80.54cm)wasobservedfromR_3 (12kg/ha) seed rateand the lowestplantheight(74.70cm)wasobtained 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 increasedplantheight.Similarresultsalsoreportedby[19],whostatedthat 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.

Combinationsofelicitorsandseedratealsoshowedstatisticallysignificantvariationincaseofplant heightat40,60,80DASandatharvest(Table2).Atharvest,the highest plant height (92.93cm)was producedfromT_3R_3 (GA3100ppmand12kg/ha)treatmentcombinationandthelowestplantheight (63.80 cm) was found fromT_1R_1 (control and 8 kg/ha) treatment combination.

3.2 Number of leaves per plant

Fromthecurrent investigation, the number of leaves per plant of black cumin was recorded at different daysaftersowing*i.e.*40DAS,60DAS,and80DAS(Table1).Thenumberofleaves per plant of black cuminvariedsignificantly due to the application of different types of elicitors at different days after sowing (DAS).At80DAS,themaximumnumberofleavesperplant(78.04)wasrecordedfromT_4 (pinching) treatment,whilethelowestnumberofleavesperplant(58.65)was obtained from T_1(control) treatment. Increaseinnumberofleavesperplantasaresultofpinchinghasbeenobservedpreviouslyinchina aster, field bean and bottle gourd.

Numberofleavesperplantofblackcuminwassignificantlyvariedduetotheeffectofseedratewhich wasrecordedatdifferentdaysaftersowing*i.e.*40DAS,60DAS,80DAS(Table1).Fromthe observation of80DAS,thehighestnumberofleavesperplant(71.23)wasrecordedfromthe treatment R_1 (8 kg/ha) seedrateandthelowestnumberofleavesperplant(66.85)wasrecordedfromthetreatmentR_3(12 kg/ha) seed rate.

Combinedeffectof elicitors and seed rate in terms of number of leaves per plant of black cumin varied significantlyat40DAS,60DASand80DAS(Table2).At80DAS,thehighestnumber of leaves per plant (80.23)wasrecordedfrom T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination and the lowest numberofleavesperplant(56.37) was produced from T_1R_3 (control and 12 kg/ha seed rate) treatment combination.

Table1.Effectofelicitorsand 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
Different types of elicitors	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	42.76c	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,T_1=Control,T_2=Salicylicacid 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.

4.3 Branches per plant at harvest

Thevariation 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 T_4 (pinching)treatment and the minimum number of branches (25.74) was found inT_1 (control) treatment (Table 1).

Asignificantvariationwasfoundinthenumberofbranchesperplantwasobservedduetoeffectof differentlevelsofseedrateinblackcuminplant.Atharvest,thehighestnumberofbranchperplant

(41.42)wasproducedinR_1(8kg/haseedrate)treatmentwhilethelowestnumberofbranchperplant (35.98) was found in R_3(12 kg/ha seed rate) treatment.
Therewerestatisticallysignificantdifferencesamongthetreatmentcombinationsofelicitorsandseed rateinrespectofnumberofbranchesperplantatharvest.Thehighest number of branches per plant (51.63)wasobtainedfromT_4R_1(pinchingand8kg/haseedrate)treatmentcombination while the lowest numberofbranchesperplant(24.23)wasobservedfromT_1R_3(controlandhighestseedrate) treatment combinationat 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_0R_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_0R_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_0R_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_1R_1	22.76 fg	45.09 f	65.50ef	77.57 ef	9.15de	55.17 b	74.30 c	49.57 b
T_1R_2	23.90 def	46.83 e	66.53 e	79.77de	8.13gh	51.90 c	72.53d	43.53 d
T_1R_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_2R_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_2R_2	24.80cde	58.36 b	75.50 b	87.06 b	8.73 ef	43.00ef	65.87 f	33.53 g
T_2R_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_3R_1	22.30 fg	42.93 g	62.13 g	73.57 g	13.27a	57.90 a	80.23a	51.63 a
T_3R_2	23.70 ef	45.43 f	65.13 f	75.60 fg	11.83b	54.10 b	77.67b	49.93 b
T_3R_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,T_1=Control,T_2=Salicylicacid 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.

4.4 Days to first flowering

Incaseofdaystofirstfloweringofblackcuminagainsttheeffectofthe treatment of elicitors was found significant (Table 3). Resultsrevealedthat,thelongestdays(60.67)wereneededtoreachthe1st floweringstagebytheplanttreatedwithT_4 (pinching)treatmentandtheshortestdays(46.11)were neededbytheplanttreatedwithT_3 (GA3100ppm)treatment.TheapplicationofGA_3mayimprovethe earlierdevelopmentofflowering.So,applicationofGA_3theearlier1st floweringwasobservedunder present study by inducing the more florigen hormone.
Asignificantvariationwasfoundincaseofdays to first flowering was observed due to effect different levelsofseedrateinblack cumin plant. The longest days (55.67) were needed to reach the 1stflowering stagebytheplanttreatedwithR_3 (12kg/haseedrate)treatmentandthe shortest days (50.50) were needed by the plant treated with R_1(8 kg/ha seed rate) treatment.
Significant difference was found during the combined application of elicitors and seed rate on days to first floweringofblackcuminplant(table4). The highest days (62.33) to needed first flowering obtained from T_3R_3(pinchingand12kg/haseed rate) treatment combination and lowest (45.33) days were observed from theT_3R_1 ($GA_3$and lowest seed rate) treatment combination.

4.7 Number of capsule per plant

The number ofcapsulesperplantwassignificantlyaffectedbydifferenttypesofelicitors(Table3). Numberofcapsulesperplantincreased with the different treatment of elicitors. The highest number of capsulesper plant (40.42) was recorded from T_4 (pinching) treatment. The lowest number of capsules per

plant(19.98) was obtained fromT_1 (control) treatment. In this study, more numbers of pods were observedinpinchedplantsascomparedtoun-pinchedplants.Plantshavinga greaternumberoflateralbrancheshavevigorousvegetative growth, which in turn have goodphotosynthetic efficiency and have greater translocation of photosynthates from source to sink which in turn have beneficial effects on reproductive growth.

Significantvariationswereclearlyevidentincaseofnumberofcapsulesper plant with different levels of seedrate(Table3). The highest number of capsules per plant (36.10) was resulted from R_1(8 kg/ha seed rate)treatmentandthelowest number of capsules per plant (28.74) was obtained from (12 kg/ha seed rate) R_3 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.

Thecombinationofelicitorsandseedrategavethehighest number of capsules per plant (44.23) was recordedfromT_4R_1 (pinchingand8kg/haseedrate)(Table4).Thelowest number of capsules per plant (17.62)wasobtainedfromtheT_1R_3 (controland12kg/haseedrate)treatmentcombinationinblack cumin.

Table3.Effectofelicitorsandseedrateondaystofirstflowering,numberofcapsulesperplant, weight of seeds per plant (g), 1000 seeds weight (g) andseed yield (t/ha) of black cumin.

Treatment Different types of elicitors	Days to first flowering	Number of capsules per plant	Weight of seeds per plant (g)	1000 seeds weight (g)	SeedYield (t/ha)
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	8.0678a	3.04 b	328.99a
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	319ab
$LSD_{0.05}$	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	6.26c	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	7.3683a	2.62 c	330.01a
$LSD_{0.05}$	**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,T_1=Control,T_2=Salicylicacid50ppm,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.

4.13 Weight of seed per plant (g)

Weight of seeds per plant of black cumin due todifferenttypesofelicitorswasfoundremarkably significant(Table3).Weightofseedsperplantwasincreasedwith the application of different elicitors. Resultsrevealedthat,the highest weight of seeds per plant (8.0678 g) was obtained from the plants treatedwithT_2(salicylicacid50ppm)treatmentandthelowestweightofseedsperplant(4.6833 g) was observed from the plants treated withT_1(control) treatment.

Significantvariationinweightofseedsperplant(1m^2)wasobservedamongtheapplicationofdifferent levelsofseedraterepresented(Table3).ApplicationofR$_3$ treatment(seedrate12kg/ha)gavethe highestweightofseedsperplant(7.3683g).Thelowest weight of seeds per plant (6.26 g) was obtained from R_1(8 kg/ha seed rate) treatment.

Combinedapplicationofelicitorsand seed rate significantly influenced the weight of seeds per plant of blackcumin.ThetreatmentcombinationT_2R_3 (salicylicacid50ppmand12 kg/ha seed rate) gave the maximumweightofseedsperplant(8.5933g)whichwasstatisticallysimilar(8.15g)toT_4R_3 (pinching and12kg/haseedrate)(Table4).ButthetreatmentcombinationT_1R_1 (controland8kg/haseedrate) gave the lowest weight of seeds per plant (4.04g).

4.14 1000 seeds weight (g)

Duetotheeffectofelicitors,1000-seedweight(g)variedsignificantly. Higher 1000-seeds weight (3.24g) wasgivenbyT_4 (pinching)treatmentwhilelowervalue(2.30g)wasrecordedfromT_1 (control) treatment (Table 3). 1000-seedsweight(g)variedsignificantlyduetotheeffectofseedrate.Thehighest 1000-seeds weight (3.01g)wasgivenbyR_1 (8kg ha^{-1}seed rate) treatment. The lowest 1000-seed weight (2.62 g) was given by R_3 (12 kg/ha seed rate) treatment (Table 3).

Duetothecombinedeffect of elicitors and seed rate, 1000-seeds weight (g) varied significantly. The maximum1000-seedsweight(3.40g)wasrecordedinT_4R_1 (pinchingand8kg/haseedrate)treatment combination and it was statistically similar to T_4R_2 (pinching and 8 kg/ha seed rate) treatment combination.Thetreatmentcombination T_1R_3 (control and 12 kg/ha seed rate) which produced the lowest 1000-seeds weight (2.15 g) (Table 4).

Table4.Combinedeffectofelicitorsandseedrateondaystofirstflowering,numberofcapsules per plant,weight of seeds per plant (g),1000 seeds weight (g) andSeed 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)	SeedYield (t/ha)
T_0R_1	57.67 d	22.61 i	4.04 h	2.42 ef	161.67 i
T_0R_2	58.33 cd	19.73 j	4.78 g	2.33 f	193.00 h
T_0R_3	60.33 b	17.62 k	5.23 g	2.15 g	216.74 gh
T_1R_1	52.33 f	42.63 b	7.60 cd	3.25 b	265.01 f
T_1R_2	52.67 ef	39.17 d	8.01 bc	3.00 c	333.13 cd
T_1R_3	53.33 e	35.83 e	8.5933a	2.87 d	388.84a
T_2R_1	45.33 h	34.94 f	6.30 f	2.95 cd	225.03 g
T_2R_2	46.33 g	29.80 g	7.00 e	2.54 e	342.67 bc
T_2R_3	46.67 g	25.71 h	7.50 cde	2.41 f	350.71 bc
T_3R_1	58.67 c	44.23 a	7.10 de	3.40 a	281.78 ef
T_3R_2	61.00 b	41.25 c	7.70 bc	3.28 ab	311.47 de
T_3R_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,T_1=Control,T_2=Salicylicacid50ppm,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.

4.16 Seed yield (t/ha)

Therewasastatisticallysignificantvariation due to the effect of elicitors in case of seed yield (t/ha). Statisticallyhigherseedyield(3.2899t/ha)wasrecordedinT_2 (salicylicacid50ppm)treatmentwhich wasstatisticallysimilar(3.19t/ha)toT_4 (pinching)treatmentwhilethehT_1 (control)treatmentgavelower value (1.9047 t/ha) (Table 3) in black cumin.

Seedyield(t/ha)showedstatisticallysignificantvariationamongthedifferent levels of seed rate treatments.Themaximumseedyield(3.300t/ha)wasrecordedinR_3 (12kg/haseedrate)treatmentin black cumin.The lowest seed yield (2.3337 t/ha) was obtained from R_1(8 kg/ha seed rate) treatment.

Seedyield(t/ha)showedstatisticallysignificantvariationduetothe combined effect of elicitors and seed rate. Statistically the maximum seed yield (3.8884 t/ha) was recorded in T_2R_3(salicylic acid 50ppm and 12 kgK/haseedrate)treatmentcombinationanditwasstatisticallysimilar(3.6376t/ha)toT_4R_3 (pinching and12kgK/ha seed rate) treatment combination. The lowest seed yield (1.6167 t/ha) was produced from T_1R_1(control and 8 kg/ha seed rate) treatment combination (Table 4).

4.19 Economic analysis

Economicanalysisisthemajorcriteriatoevaluatethebesttreatments whichwereeconomicallysound andthatcanbeacceptedbyfarmingcommunity. The cost of cultivation, gross and net returns in addition tobenefitcostratio of different treatment combinations studied in the present investigation is presented in (Table5).Thetotalcostofcultivationwasobservedtorangefrom Tk.264518 T_1R_1 (Controland 8kg/ha seed rate) treatment combination to Tk. 369648 T_3R_3 ($GA_3$and 12kg/ha seed rate) treatment combination. Thehighestgrossreturn(Tk.1166520)wasobtainedfrom T_2R_3 (Salicylicacid50ppmand8kg/haseed rate)treatmentcombinationandthelowestgrossreturn(Tk.485010)wasrecordedfrom T_1R_1 (control and8kg/haseed rate) treatment combination. The lowest net return (Tk. 220500) was recorded from T_1R_1 (control and 8kg/ha seed rate) treatment combinationandthehighestnetreturn(Tk.832522)was obtainedfrom T_2R_3 (Salicylicacid50ppmand12kg/haseedrate)treatmentcombination. The highest benefitcost ratio (3.57) estimated from T_4R_3 (Pinching and 12 kg/ha seed rate) treatment combination and thelowestbenefitcostratio(1.83**)**wasobtained from T_1R_1(Control and8kg/ha seedrate) treatment combination.

Table 5. **Economic analysis of black cumin influencedby elicitors and seed rate**.

Treatments combination	Total cost of product ion (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=Salicylicacid50ppm,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

Thisstudyrevealedthatelicitorsandseedratehaveapositiveeffectongrowthandseedyieldof black cumin.Incase of seed yield of black cumin, the combination of elicitor T_2(salicylic acid 50ppm) treatment whichisstatisticallysimilar T_4 (pinching)treatmentalongwithseedrate R_3 (12kgK/ha)weregiventhe betterperformanceofalltheyieldcontributingparametersandseedyieldof black cumin.The treatment combinationof T_2R_3 (Salicylicacid50ppmand12kg/haseedrate)showed the best potentialityof seed yieldofblackcumin.Buteconomicanalysisrevealedthatthetreatmentcombination T_4R_3 (pinching and 12kg/haseedrate)waseconomicallyprofitablethan T_2R_3(Salicylic acid 50ppm and 12 kg/ha seed rate) treatmentcombinationforblackcumincultivation.So,T_4R_3 (pinchingand12kg/haseedrate) 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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