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

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF ELICITORS AND SEED RATE ON ENHANCING GROWTH AND SEED YIELD OF BLACK CUMIN (*Nigella sativa*)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **MOST. KHODAIZA BANU,** Registration No. **19-10214** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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DEDICATED TO

My Beloved Family and
Respected Research Supervisor

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ABSTRACT

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during November 2020 to March 2021 to study the influence of elicitors and seed rate on enhancing growth and yield of black cumin (*Nigella sativa*). The experiment consisted of two factors. Factor A: different types of elicitors as, T_1= Control, T_2= salicylic acid 50 ppm, T_3= gibberellic acid 100 ppm, T_4= pinching and Factor B: different levels of seed rate as, R_1= 8 kg/ha, R_2= 10 kg/ha, R_3= 12 kg/ha. The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed. Results revealed that in terms of elicitors, the highest seed yield per hector (3.29 t) was recorded from the T_2 (salicylic acid 50 ppm) treatment which is statistically similar with (3.19 t) T_4 (pinching) treatment compared (1.90 t) to T_1 (control) treatment. Again, in terms of different levels of seed rate treatments, the highest seed yield per hector (3.30 t) was found from the treatment R_3 (12 kg/ha seed rate) compared (2.33 t) to R_1 (8 kg/ha seed rate) treatment. In case of combined effect of elicitors and seed rate, the highest seed yield per hector (3.89 t) was found from the of T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination which is statistically similar (3.64 t) to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination and the lowest was obtained from T_1R_1 (control and 8 kg/ha seed rate) treatment combination. The highest BCR (3.57) was obtain from the treatment combination T_4R_3 (pinching and 12 kg/ha seed rate) where the lowest BCR (1.83) was found from T_1R_1 (control and 8 kg/ha seed rate) treatment combination. So, it can be concluded on the basis of economic point of view that the treatment combination T_4R_3 (pinching and 12 kg/ha seed rate) best and profitable than other treatment combination for black cumin cultivation.

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ABBREVIETION AND ACRONYMS

ABBREVIATION	FULL WORD
Abst.	Abstract
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of coefficient of variation
cm	Centimeter
DAS	Days after sowing
Df	Degrees of freedom
Ecol.	Ecology
et al	And others
Env.	Environment
FAO	Food and Agriculture Organization
g	Gram
LSD	Least of Significant Difference
MoP	Muriate of Potash
MS	Mean square
M.Sc.	Master of Science
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
UK.	United Kingdom
USA	United States of America
%	Per cent

CHAPTER I

INTRODUCTION

Black cumin (*Nigella sativa* L.) is an annual spicy herb and belongs to the *Ranunculaceae* family. Sometimes it is referred to as nigella or black seeds. It is native to the Mediterranean and Western Asia regions. It is cultivated in many parts of the world including the Middle East, North Africa and Asia where maximum diversity is found (Abu-Jadayil, 2002; Donmez and Mutlu, 2004; Tierra, 2005). As herb**,** black cumin has a rich nutritional value; it contains monosaccharides. The seed is rich in fatty acids, proteins and carbohydrates. It contains all essential amino acids and rich source of vitamins and minerals (Abu-Jadayil *et al*., 1999; Atta, 2003). Seeds are used both as a condiment in bread and cakes and in the preparation of traditional sweet dishes, pastry, pickles, and used as candies and liquors (Luetijohann, 1998; Thippeswamy and Naidu, 2005). In addition, black cumin oil has many medicinal usages (Ali and Blunden, 2003). Very limited information is available in the literature about cumin cultivation and production practices. Black cumin locally known as “Kalo jira” is a good source of nutritionally essential components. Black cumin seeds have been used as herbal medicine by various cultures and civilizations to treat and prevent a number of diseases. It is also famous for the saying of the Prophet Muhammad (SAW) "Hold on to use of the black cumin seed, for it has a remedy for every illness except death" (Bukhari, 1985). Scientific investigations have depicted its compositions i.e; moisture, oil, proteins, ash and total carbohydrates contents in the range of 3.8-7.0%, 22.0-40.35%, 20.85-31.2%, 3.7- 4.7% and 24.9-40.0%, respectively (Takruri and Dameh, 1998; Atta, 2003). Black cumin cultivation is increasing day by day in Bangladesh on account of its medicinal value. Bangladesh produces only 1068.06 metric tons of black cumin from 248.37 acres of land (Anonymous,2021). Now-a-days peoples are conscious about their health and as a result this type of medicinal spice has the great demand to the farmers. But the proper growth and development of black cumin is hindered by some factors *viz.*, climatic, varietal, nutritional management and seed rate. Among these factors the nutritional management, more emphasized to growth regulating hormone and seed rate are the most important that can improve the yield performance of black cumin in prevailing climatic condition of Bangladesh.

Elicitation is the induced or enhanced biosynthesis of metabolites due to addition of trace amounts of elicitors. 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). Gibberellic acid is a plant growth hormone actively involved in various physiological activities such as, growth, flowering and ion transport (Wareing and Philips, 1981; Khan, 2003). Use of growth regulators specially the gibberellic acid (GA_3) involved in promoting flowers and seed yield of black cumin (Shah and Samiullah, 2006). The growth regulator GA_3 enhances the plant growth, flower induction, nutrient uptake and photosynthesis (Hayat and Ahmad, 2007). Ouzounidou and Ilias (2005) reported that, the GA exerts a pleiotropic effect on plant developmental processes, such as seed germination, endosperm mobilization, stem elongation, leaf expansion, flower, fruit set and assimilate translocation. Pariari *et al*. (2012) pointed out that, GA_3 100 ppm increased plant height as compared to control and 50 ppm and 75 ppm of doses. The lower concentration (100 ppm) of GA_3 resulted in increased number of pods plant^{-1}, seeds plant^{-1}, 100-seed weight and seed yield plant^{-1} of soybean more efficiently than the higher concentration (200 ppm) and the control (Sarkar *et al.*, 2002). The spraying of GA_3 at 100 ppm produced many numbers of seeds per pod as compared to control in fenugreek (Vasudevan *et al*., 2008). Salicylic acid (SA) is a natural compound that plays a central role in certain physiological processes and defense responses in plants (Shi and Zhu, 2008). Salicylic acid 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 (Tamaoki *et al.*, 2013). The SA as natural plant hormone which can affect seed germination, cell growth, stomatal opening, expression of genes associated with senescence and fruit production (Klessing *et al.*, 2009). Foliar spray of SA increases pod plant^{-1}, number of seeds per pod^{-1}, seed weight plant$^{-1,}$ seed yield hectare^{-1} and protein content. Pinching is simply means removing the terminal growing portion of stem. It is practiced to induce branching and reduce the plant height, makes compact, bushy plants with more blooms and also helps in breaking the rosette and also improve the plant's looks. The plant height, stem diameter and number of inflorescences increased as the number of pinching increases (Brum *et al*., 2007). Linear increase in yield was recorded as the pinching severity increased.

Seed rate has important effect on yield and yield components such as the number of branches, number of umbels, number of seeds per capsule, plant and hectare, 1000 seed weight etc. As the higher plant densities affect negatively the yield and yield component, so optimal seed rate is very important for maximum seed yield. Seeding rate is the most important aspect in crop production. It is highly interrelated with plant density and/or plant spacing. In fact, it depends on various factors like soil fertility, farming system, variety etc.

In consideration with the mentioned idea, the present experiment was conducted to evaluate the influence of elicitors and seed rate on enhancing growth and seed yield of black cumin. In Bangladesh, only limited studies have been done regarding elicitors and seed rate for enhancing growth and yield of black cumin. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Keeping above facts in view, the present study was undertaken with the following objectives:

- ❖ to find out the suitable elicitor for better growth and seed yield of black cumin.
- ❖ to determine the optimum seed rate for better growth and yield attributes of black cumin.
- ❖ to find out the best combination of elicitor and seed rate for higher growth and seed yield of black cumin.
- ❖ to evaluate the cost and return in black cumin seed production.

CHAPTER II

REVIEW OF LITERATURE

Black cumin is an important oil seed crop in Bangladesh. For the improvement of growth and yield attributes of black cumin the influence of elicitors and seed rate is much important. The production of black cumin in Bangladesh is much lower than other developed countries. The research on black cumin with the application of different types elicitors and different levels of seed rate are not adequate in Bangladesh. Some of the important research findings regarding vegetative growth and yield of black cumin had been reviewed in this chapter.

2.1 Literature on elicitors

Jahan (2020) an experiment was carried out to evaluate the growth and yield of cabbage as influenced by different levels of boron and gibberellic acid (GA_3). The experiment comprised of two different factors such as, Factor A: four GA_3 levels *viz*. G_0 = Control (0ppm GA_3), G_1 = 70 ppm GA_3, G_2 = 100 ppm GA_3 and G_3 = 130 ppm GA_3 and Factor B: three levels of boron application *viz*. B_0 = Control (0 kg B ha^{-1}), B_1 = 4 kg B ha^{-1} and B_2 = 8 kg B ha^1. The treatment G_2 (100 ppm GA_3) produced the highest marketable cabbage yield (44.13 t/ha) and G_0 produced the lowest (39.43 t/ha). For boron (B) application, B_1 (4 kg B ha^{-1}) gave the highest marketable cabbage yield (45.38 t/ha) B_0 produced the lowest (36.57 t/ha). For combined effect, G_2B_1 gave the highest marketable cabbage yield (47.71 t ha^{-1}) and the lowest (34.49 t ha^{-1}) was from G_0B_0. Considering economic analysis, G_2B_1 showed the highest gross return (Tk 572520), net return (Tk 392400) and BCR (3.18) whereas G_0B_0 gave the lowest gross return (Tk. 413880), net return (Tk. 241841) and BCR (2.40). So, it can be concluded that 100 ppm GA_3 and 4 kg Boron is suitable for cabbage production compare to other treatment combinations.

Singh (2018) investigated the effect of Gibberellic acid and Nitrogen on yield and marketability of cabbage (*Brassica oleracea* var. *capitata* L.) cv. Pride of India". The experiment was set up with Randomized Complete Block Design(factorial) having sixteen treatments combining two factors (four each) like N_0G_0, N_0G_1, N_0G_2, N_0G_3, N_1G_0, N_1G_1, N_1G_2, N_1G_3, N_2G_0, N_2G_1, N_2G_2, N_2G_3, N_3G_0, N_3G_1, N_3G_2 and N_3G_3 which were replicated three times. The data were recorded for pre harvest parameters like Plant height, number of leaves per plant and plant canopy while postharvest observations like fresh weight of the whole plant, fresh weight of heads, diameter of head, thickness of head and yield of head and economic of production. The significantly superior results were observed with the treatment N_1G_3 (8Kg Nitrogen and 20 ppm GA_3 respectively) while minimum with control (N_0G_0).

Kirti and Kumar (2016) carried an experiment in order to increase the germination of tomato seeds under high temperature stress conditions seed priming by salicylic acid was investigated. The experiment was conducted to study the effect of salicylic acid on the tomato vegetative growth, yield and fruit quality. These factors included salicylic acid in three levels (0.25 mM, 0.5 mM and 0.75 mM) applied on tomato. Results indicated that germination and vegetative & reproductive growth of tomato severely reduced by high temperature. Seeds primed with 0.5mM salicylic acid not only improved germination percent but also reduced germination time under stress conditions. The TSS, TA, vitamin C and lycopene content of tomato fruit had significantly affected by application of salicylic acid. The exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in tomato fruit yield.

Meena *et al.* (2015) carried out a study to the effect of plant growth regulators and sulfur on productivity of coriander. Results showed that application of thiourea @ 500 ppm as foliar spray being at par with triacontanol @ 1000 ppm and brassinolide @1.0 ppm significantly increased chlorophyll content in leaves over water spray. Whereas, dry matter accumulation per plant, seed, straw, biological yields, N and S content in both seed and straw increased significantly with 500 ppm thiourea spray as compared to water spray and brassinolide but remained at par with 1000 ppm triacontanol. Application of sulfur in increasing levels up to 40 kg ha^{-1} significantly increased the dry matter accumulation per plant, chlorophyll content in leaves seed, straw, biological yield, N and S concentration of coriander over control and 20 kg S ha^{-1}.

Mura *et al*. (2015) conducted a field experiment during the *pre-kharif* season of 2008 on a clay to investigate the effect of pre-sowing treatment of growth regulators and agrochemicals on germination, dry matter accumulation, chlorophyll content and yield of sesame (*Sesamum indicum* L.) cv. Rama. Before sowing, the seeds of sesame were soaked overnight with different concentrations of growth regulators and agrochemicals like GA_3, KH_2PO_4 and Na_2HPO_4. Dry seeds were sown in the control plot. The growth regulators and agrochemicals were used in different concentrations (100 ppm GA_3, 200 ppm GA_3, 200 ppm KH_2PO_4, 500 ppm KH_2PO_4, 200 ppm Na_2HPO_4, 500 ppm Na_2HPO_4) for pre-sowing soaking of seeds. It was found that pre-sowing treatments of growth regulators and agrochemicals had a significant effect on the germination, dry matter accumulation, seed yield, oil yield and test weight. The highest yield in terms of both seed (749.4 kg ha^{-1}) and oil yield were recorded from the seed treatment with 200 ppm GA_3 treatment whereas the lowest data was recorded from the dry seed. 200 ppm GA_3 treatment also recorded the highest germination percentage (90.0), vigour index, dry matter accumulation, test weight and oil yield. The chlorophyll content of leaves in terms chlorophyll a, chlorophyll b and total chlorophyll was also found to be higher in plants grown from GA_3 treated seeds.

Siddik *et al*. (2015) undertook an experiment to examine the response of different levels of foliar application of 1-napthaleneaciticacid (NAA) on morpho-physiology, yield contributing attributes and seed yield of sesame. The treatments of this experiment consisted of four different levels of NAA *viz*., A_0 = 0 ppm, A_1 = 25 ppm, A_2 = 50 ppm and A_3 = 75 ppm. The research was laid out in single factors Randomized Complete Block Design (RCBD) with four replications. In this study, NAA significantly increased morphological characters- plant height, leaf number $plant^{-1}$, branch number $plant^{-1}$, fresh and dry weight of shoot and root other than leaf and branch number $plant^{-1}$ of at 30 and 40 DAS. As morphological parameters NAA also significantly improves yield contributing characters of sesame-the number of pod $plant^{-1}$, diameter and length of pod, seed weight $plant^{-1}$ and $plot^{-1}$, thousand seed weight compared to without NAA. The foliar application of 50 ppm NAA increased seed yield of sesame (1.22 t ha^{-1}) which is consistent with the results of morph-physiological and yield contributing characters of this study.

Alam (2015) carried an experiment to evaluate effort of varieties and salicylic acid on morph-physiology and yield of mustard. Factor A: Mustard varieties (5 varieties)–V_1: Tori 7, V_2: BARI Sarisha 13, V_3: BARI Sarisha 14 and V_4: BARI Sarisha 15, V_5: BARI Sarisha 16. Factors B: Levels of salicylic acid (3 levels) – S_0: 0 mM SA (control), S_1: 0.2 mM SA, S_2: 0.4 mM SA; it replicated three times. The highest plant height, leaf number and number of branches per plant were found in V_5 (BARI Sarisha 16). The lowest transpirational water loss (%) was recorded in

V_5. Due to different mustard varieties, the highest number of siliqua per plant (185.23) was observed from V_5, whereas the lowest number (85.00) was found from V_2. The salicylic acid showed significant reduction of days required to flowering and harvesting. The highest number of siliqua per plant (113.88) the highest seed yield (1.74 t/ha) was found from S_2, while the lowest number (107.78), the lowest seed yield (1.47 t/ha) was observed from S_0. For the interaction effect of mustard varieties and levels of salicylic acid, the highest number of siliqua per plant (192.23), the highest seed yield (2.30 t/ha) was observed from S_2V_5 and the lowest number of siliqua per plant (73.33), the lowest seed yield (1.01 t/ha) was from S_0V_4 treatment combination. Separately, the higher dose of NAA, 75 ppm failed to produce better results of this experiment including seed yield. These results suggest that NAA shows a positive consequence to increase the seed yield of sesame by changing the plant architecture and biomass production. Based on the present results, it can be suggested that the 50 ppm NAA is appropriate for higher yield of sesame.

Mohsen Kazemi (2014). This experiment was conducted to study the effect of salicylic acid and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. These factors included salicylic acid in 2 levels (0.5 and 0.75 $mmolL^{-1}$) and methyl jasmonate in 3levels (0.25, 0.5 and 0.75 $mmolL^{-1}$) applied on tomato. Results indicated that salicylic acid (0.5 $mmolL^{-1}$) and methyl jasmonate (0.25 $mmolL^{-1}$) either alone or in combination (0.5 $mmolL^{-1}$+ 0.25$mmolL^{-1}$) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom end rot, but methyl jasmonate application alone or in combination had not significant effect on blossom end rot and leaves -NK content. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid and methyl jasmonate either alone or in combination (0.5 $mmolL^{-1}$SA+ 0.25$mmolL^{-1}$MJ). Application of salicylic acid with methyl jasmonate improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Mohsen Ali (2014). This study aimed at studying the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits. The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, while reduced blossom end rot. On the contrary, MJ (1 mM) application significantly decreased vegetative growth while increasing reproductive growth. The application of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content. In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato.

Meena *et al*. (2014) conducted a study aims to examine the effect of Plant growth regulators and sulphur on productivity of coriander. The experiment consisting of four PGRs (1000 ppm Triacontanol, 1.0 ppm Brassinolide, 500 ppm Thiourea and water spray) and four levels of sulphur (0, 20, 40 and 60 kg/ha) making 16treatment combinations under randomized block design (RBD) with three replications. Results showed that significantly higher plant height, dry matter accumulation per plant, chlorophyll content, number of branches per plant, number of umbels per plant, umbellets per umbel, seeds per umbellet, seed, straw and biological yields were obtained with 500 ppm thiourea spray as compared to water spray and brassinolide but remained at par with 1000 ppm triacontanol. Application of sulphur up to 40 kg/ha significantly increased all mentioned above growth, yield attributes and yield of coriander over control and 20 kg S ha^{-1}. In terms of net returns and B: C ratio, the treatment 500 ppm thiourea and 40 kg S ha^{-1} fetched significantly higher net returns and B: C ratio over rest of the treatment. It was concluded that independent application of 500 ppm thiourea as foliar spray twice at 45 and 80 days after sowing and soil applied sulphur at 40 kg ha^{-1} is recommended as these treatments fetched significantly higher economic net returns from coriander.

Yugandhar (2014) conducted a field experiment to know the effect of growth regulators on growth, seed yield and quality of Coriander *(Coriandrum sativum* L.) cv. "Sudha" during *rabi* 2013-2014. The experiment consists of 6 levels of plant growth regulators *viz*., GA_3 (50 and 75 ppm), NAA (10 and 25 ppm) and Cycocel (100 and 250 ppm) as presoaking, foliar spray at 30 and 60 DAS. An absolute control was also maintained. The experiment consists of 7 treatments replicated thrice in a randomized block design. The results indicated that application of 75 ppm GA_3 resulted in maximum plant height (78.09 cm). However, maximum number of primary branches per plant (7.13), number of secondary branches per plant (16.13), number of umbels per plant (28), number of umbellets per umbel (6.33), number of seeds per umbel (34.73), seed yield per plant (9.02 g) and seed yield per hectare (18.46 q) was maximum with 250 ppm Cycocel. However, 75 ppm GA_3

followed by 50 ppm GA_3 recorded minimum number days to 50 per cent flowering (40.33) and maturity (85.00). Among the quality parameters, maximum carbohydrate content (23.09 %), protein content (16.12 %) was noticed with 75 ppm GA_3. Similarly, lowest moisture content (9.19 %) in seeds was also observed with 75 ppm GA_3. While, the essential oil content (0.43 %) in seeds was maximum with 50 ppm GA_3. Economics study showed that maximum net returns and B: C ratio (Rs.1, 38,947 ha^{-1} and 3.91: 1) was recorded with Cycocel 250 ppm followed by 75 ppm GA_3 and Cycocel 100 ppm.

Karim (2013) conducted a study in order to examine the effect of salicylic acid on growth, yield and yield components of strawberry plants with this factor included of salicylic acid in 3 levels (0.25,0.5 and 75 mM) spray on strawberry. Results showed that salicylic acid 0.25 mM significantly affected on growth, yield and yield components of strawberry plants.

Ghasemi-Fasaei, (2013) revealed that foliar application of SA decreased mean dry weight of cucumber by 31%, while its effect on mean dry weight of chickpea was negligible. Foliar application of SA reduced mean uptake of Cu and Fe in chickpea shoot by 31 and 18%, respectively. The effect of SA on mean Zn uptake in chickpea shoot was negligible. Foliar application of SA caused an increase in mean Mn uptake of chickpea shoot by about 7%. The influence of SA levels on mean dry matter weight in chickpea was uncertain. The effects of SA levels on the uptakes of manganese was insignificant. Application of SA (4 mg/kg) increased mean uptakes of Fe, Cu and Zn by 7.1, 8.5 and 9.6%, respectively. Application of SA (4 mg/kg) increased mean uptakes of metal micronutrients compared to the control although the increase for Fe uptake was negligible. Application of SA (4 mg/kg) increased mean uptakes of Mn, Cu and Zn by 18.7, 100, and 18.6%, respectively. In chickpea shoot, the uptakes of all metal micronutrients other than Fe were significantly correlated with each other. According to the results of present study it appears that SA was efficient to be recommendable for correcting metal micronutrients deficiency under micronutrients deficient conditions.

Salwa *et al.* (2013) investigated that the effect of SA on growth criteria (shoot height and shoot dry weight), soluble sugars and protein, antioxidant enzymes (SOD, APX and GR) activities and specific activities, lipid peroxidation, electrolyte leakage and yield criteria (Pod weight, seed weight, seed number and 100 gm seed weight). The obtained results showed that salt treatments provoked oxidative stress in faba bean plants as shown by the increase in lipid per oxidation and electrolyte leakage and consequently negatively affected growth and yield criteria. Foliar spray with SA at the concentration of 2 mM followed by 1 mM mitigated the harmful effects of salt stress through the enhancement of the protective parameters, such as antioxidant enzymes, soluble sugars and proteins and consequently improved growth and yield criteria.

Rastogi *et al.* (2013) reported that, the commercial importance of linseed (*Linum usitatissimum* L.) has attracted breeders to increase its seed yield using various breeding approaches. Plant growth regulators (PGRs) have a significant role in enhancing yield and its related traits in linseed. In the present study, two plant growth hormones, auxin and gibberellic acid, were applied individually, as well as in combinations, in order to study their effect on yield and its components in "Neelam", which is a high yielding variety of linseed. A comparative study was done under pot and field condition. A combined dose of auxin (1.0 mg L^{-1}) and gibberellin (200 mg L^{-1}) is recommended for the enhancement of seed yield, whereas a 0.5 mg L^{-1} dose of auxin is recommended for the enhancement of vegetative growth. It was concluded that the plant growth regulators can be successfully employed to enhance the yield in this economically important oil seed crop.

Pariari *et al*. (2012) conducted a field study to determine the effect of GA_3 and NAA on the growth and yield of black cumin. The treatments comprised 25 (T_1), 50 (T_2), 75 (T_3), 100 ppm GA_3 (T_4), 25 (T_5), 50 (T_6), 75 (T_7), 100 ppm NAA (T_8) and control (T_9). Data were recorded on the plant height, branches per plant, pods per plant, fruit length, fruit diameter, 1000 seed weight, seed yield and volatile oil content of black cumin. Results showed that GA_3 had a significant function on cell division in the apical meristem, whereas, NAA at higher concentrations induced the reproductive phase. Hence, the vegetative parameters showed better results with increased concentration of GA_3, however, seed yield and other yield attributes showed significant increase with the application of NAA at higher concentrations. NAA at 100 ppm was the best treatment and recorded the maximum seed yield of black cumin.

El-Yazied (2011) conducted a field experiment to study the effect of foliar application with 50 and 100 ppm of SA and 50 and 100 ppm chelated Zn and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, fruiting and fruit quality of sweet pepper (cv. California Wonder) during autumn 2009 and 2010 seasons. Results indicated that different applied treatments significantly increased all studied growth parameters, namely, number of branches and leaves per plant, leaf area per plant and leaf dry weight. Furthermore, the highest early, marketable and total yields as well as physical characters of sweet pepper fruits were obtained with 100 ppm SA plus chelated 50 ppm zinc followed by 50 ppm SA plus 100 ppm Zn.

An experiment was conducted by Roy and Nasiruddin (2011) to study the effect of GA_3 on growth and yield of cabbage. The experiment was consisted of four concentrations of GA_3, *viz*., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3. The highest diameter (23.81 cm) of cabbage head was found in 50 ppm GA_3 while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm GA_3). The application of different concentrations of GA_3 was influenced independently on the growth and yield of cabbage. Significantly the highest yield (104.66 t ha^{-1}) was recorded from 50 ppm GA_3.

Shah (2011) conducted an experiment on black cumin with PGRs. The leaves of 40-day old plants of black cumin were sprayed with 10^{-7}, 10^{-6}, 10^{-5} M 4Cl-IAA, and 10^{-6}, 10^{-5} and 10^{-4} M kinetin. Both the hormones improved vegetative growth, photosynthetic efficiency and seed yield of the test plants as compared to deionized water (control). However, 10^{-6} M 4-Cl-IAA was most prominent in its effect, generating 42, 30, 40, 41 and 51% higher values for carbonic anhydrase, nitrate reductase, net photosynthetic rate, leaf protein content and dry mass respectively, over control in 70-day old plants. Similarly, capsule number and seed yield per plant were elevated by 41 and 43% over the untreated control at harvest (130 days after sowing) following the same treatment. Overall, the auxin showed a higher efficiency than kinetin in all treatment concentrations.

Influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage were studied by Lendve *et al.* (2010) found that application of GA @ 50 ppm was significantly superior over most of the treatments in terms of number of the leaves, plant spread, circumference of stem, left area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root. The treatment GA @ 75 ppm which exhibited better results for days required for head initiation and head maturity.

Yu *et al.* (2010) conducted an experiment with '8398' *(Brassica oleracea* var. *capitata* L.) cabbage plants with 7 true leaves and 'Jingfeng No. 1' cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and 'Jingfeng No. 1' cabbage plants vernalized for 21 days were treated by high temperature of 37^0 C for 12 hours to explore the changes of endogenous hormone during devernalization in cabbage. The results showed that: GA_3 content had less changes, IAA content rose and ABA content decreased during devernalization. Compared with CK (vernalization period), GA_3 and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower GA_3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

A study was conducted by Roy *et al.* (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and GA_3 on growth and yield of cabbage. The two-factor experiment consisted of four levels of starter solution, viz., 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of GA_3, viz., 0, 25, 50 and 75ppm. The application of starter solution and different concentrations of GA_3 influenced independently and also in combination on the growth and yield of cabbage. The highest yield (104.93 t ha^{-1}) was obtained from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t ha^{-1}) was recorded from the control. Significantly the highest yield (104.66 t ha^{-1}) was found from the treatment of 50 ppm GA_3, while the lowest yield (66.56 t ha^{-1}) was recorded from control. In case of combined effect, the highest yield of cabbage (121.33 t ha^{-1}) was obtained from the treatment combination of 1.5% starter solution + 50 ppm GA_3 followed by 1.5% starter solution + 75 ppm GA_3 (115.22 t ha^{-1}), while the lowest yield (57.11 t ha^{-1}) was produced by the control treatment. Economic analysis revealed that 1.5% starter solution + 50 ppm GA_3 treatment was the best treatment combination in respect of net return (Tk. 173775 ha^{-1}) with a benefit cost ratio of 3.52.

A field experiment was conducted by Chauhan and Tandel (2009) during the rabi season. Results showed that spray of GA_3 and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant growth regulator treatments for growth, yield and quality characters of cabbage was GA_3@100 mgL^{-1} foliar spray at 30 and 45 days after transplanting (DAT) followed by NAA @100 mgl^{-1} foliar spray at 30 and 45 DAT.

The effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was investigated by Dhengle and Bhosale (2008) in the field. The highest yield was obtained with GA_3 at 50 ppm followed by NAA at 50 ppm (332.01 and 331.06 q ha^{-1}, respectively) Combinations and higher concentrations of plant growth regulators proved less effective.

Hayat *et al.* (2008) reported that *Lycopersicon esculentum* L.cv. K-25 plants under water stress condition and water holding for 10 days at 20 (WS I) and 30 (WS II) days after sowing (DAS). Seedlings were sprayed with 10^5 M salicylic acid (SA) at 45 DAS. The water stress at earlier stage of growth (20 days stage) was more inhibitory as compared to the later stage (30 days stage). A follow-up treatment with SA protected against the stress generated by water and significantly influenced several parameters. However, proline content and antioxidant enzymes increased under drought as well as under SA treatments.

Kumar *et al.* (2008) conducted an experiment to study the effect of different concentration of ethrel in comparison with the commercial form of growth promoter ace in promoting growth and yield of black cumin during 2006 and 2007. In this experiment growth regulators were ethrel (50 ppm, 75 ppm, 100 ppm and 125 ppm) along with ace (a commercial bioregulator @ 0.5 ml/L). Further to get a comparison one untreated control treatment was included to have a clear picture of controlled plants as compared to growth regulator treatment. The results clearly indicated that there was increase in seed yield with all the treatments except the control (untreated) plot. Among all the treatments, ethrel @ 75 ppm proved to be most effective in promoting growth and gave highest seed yield (6.03 q ha^{-1}), followed by ethrel @ 100 ppm (5.59 q ha^{-1}) which was statistically at par.

Verma and Sen (2008) suggested that, GA_3 at 50 ppm applied through pre-plant soaking + spraying 20 DAS significantly improve the vegetative growth of coriander herb.

Akter *et al*. (2007) conducted an experiment in pot house to evaluate the effects of GA_3 on growth, and yield of mustard var. Binasarisha-3. Four concentrations viz., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. The results showed that different levels of GA_3 significantly influenced the plant height, number of fertile siliqua plant^{-1}, number of seeds siliqua^{-1}, number of flowers plant^{-1}, setting of siliqua plant^{-1} (%), and harvest index. Results revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua plant^{-1}, number of flowers plant^{-1}, siliqua plant^{-1} (%), dry matter yield, number of seeds siliqaua^{-1}, and harvest index, while the number of flowers plant^{-1} was significantly increased with the application of 75 ppm GA_3. The highest seed yield plant^{-1} was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield plan^{-1} was positively correlated with plant height, number of seeds siliqua^{-1}, number of fertile siliqua plant^{-1} and % of setting siliqua plant^{-1}.

Shah and Ahmad (2007) conducted an experiment to study the combined effects of foliar sprays of water or 1, 10 and 100 µM aqueous solutions of GA_3 or kinetin (KIN) to 40 days old plants of *Nigella sativa* (L.) on net photosynthetic rate, nitrogen metabolism, and the seed yield. The 10 µM solutions of both the hormones, especially GA_3, appreciably increased the activities of nitrate reductase and carbonic anhydrase, chlorophyll and total protein contents and net photosynthetic rate in the leaves, along with capsule number and seed yield plant^{-1}, at harvest.

Shah and Ahmad (2006) conducted a field trial on black cumin (*Nigella sativa* L.), sprayed with either deionized water (control) or 10^{-5} M GA_3 at 40 (vegetative stage) or 60 (flowering stage) days after sowing (DAS) to characterize the effects of hormone treatment on the mentioned parameters and select the suitable growth stage for spray in order to achieve desired results. Capsule number plant^{-1}, seeds /capsule, 1000 seed weight, seed yield q ha^{-1}, harvest index and seed yield merit (SYM) were analyzed at harvest (130 DAS). It was noted that growth, NPK accumulation and seed yield were maximal when spraying of GA_3 was carried out at 40 DAS. However, spraying at 60 DAS was not much effective in terms of the parameters studied. Moreover, there was a significant difference in spray treatments at various growth stages only when GA_3 was sprayed and not when water was sprayed.

Shah (2006) conducted a pot trial to study the effect of foliar spray of 0 (deionized water), 10^{-6}, 10^{-5} and 10^{-4} M each of GA_3 or kinetin (KIN) at 40 days after sowing (vegetative stage) on growth and yield of black cumin (*Nigella sativa* L.). Application of 10^{-5} M GA_3 was found to be more effective than KIN in promoting shoot length, plant dry weight, leaf number, leaf area and branch number observed 70 days after sowing (DAS). Application of 10^{-5} M GA_3 resulted in more capsule number, seed yield and seed yield merit, which was found increased by 43.33, 43.85 and 53.62% respectively.

Fatma Abd and El-Lateef Gharib (2006). The response of sweet basil (*Ocimum basilicum* L.) and marjoram (*Majorana hortensis*) plants to foliar application of salicylic acid (SA) at 10^{-5}, 10^{-4} and 10^{-3} M was determined in pot experiments. SA increased plant height, number of branches, nodes and leaves per plant, leaf area, fresh and dry weight of herbs, total carbohydrates, crude protein, total amino acids, free proline, photosynthetic pigments as well as microelement content and uptake up to 10^{-4} M relative to untreated controls and decreased thereafter in both basil and marjoram. All SA treatments enhanced putrescine, spermidine as well as total polyamines contents, while reduced the level of spermine in both plants. Oil percentage and yield per plant for three cuttings also increased about two folds on a fresh weight basis with SA application at 10^{-4} M in case of basil land 10^{-3} M in marjoram relative to untreated controls. GC/MS revealed that common components o (*Ocimum basilicum*) essential oil under all treatments were linalool (46.63 - 43.32%), methyl eugenol (13.83 - 5.68%), 1, 8 - cineol (13.20 -4.43%), eugenol (12.64-7.16%) and α-cadinol (9.59 - 4.46%). SA at 10^{-4} M increased the production of top quantity and quality of basil oil to the fragrance and food industries by increasing the percentage of eugenol and antioxidant activity in the herb. On the other hand, the marjoram essential oil contains cis-sabinene hydrate (37.50 - 14.27%), terpinen- 4-ol (24.33 -13.99%), p-cymene (18.21 - 2.29%), sabinene (17.69 - 4.11%), γ-terpinene (10.64 -4.77) in addition to α-terpineol (5.52 -3.96%), trans-sabinene hydrate (5.45 8.19%), α-terpinene (2.41 - 0.00%) and β-caryophyllene (3.82 - 1.76%). Moreover, SA at 10^{-5} M and 10^{-3} M improved oil quality by increasing the level of sabinene accompanied by a decrease in the proportion of cis-sabinene hydrate relative to controls. The data suggest that in both species, SA treatment especially at 10^{-4} M may have higher adaptive capacity to stress, originating from promoting polyamines synthesis and better osmotic adjustment.

Rakesh *et al*. (2005) carried out a field experiment to study the effects of GA_3 (0, 50, 100, 150 and 200 ppm) and pinching (no pinching and pinching after 35 and 45 days of transplanting) on flowering and yield of chrysanthemum cultivars (Flirt and Gauri) and reported that the number of flowers per plant increased with the increase in GA_3 concentration from 50 to 200 ppm and the maximum yield was recorded at 200 ppm GA_3 for both cultivars. Pinching of plants at 35 or 45 days after transplanting caused significant increase in yield of flowers per plant compared to the control. Flirt recorded a significant increase in yield of flowers per plant compared to Gauri with different treatment combinations of GA_3 and pinching. The highest yield was recorded in Flirt with 200 ppm GA_3.

Ranjit *et al*. (2005) carried out an experiment on the effects of pinching (single pinching, P_1; pinch in half, P_2; and double pinching, P_3) and its combination with N treatments on the growth and flower production of carnation cv. Tasman and found that the tallest plants (69.1 cm) were obtained under P_1N_2, followed by 61.7 cm under P_1N_1. P_3N_2 showed the shortest plants (52.6 cm). P_3N_2 produced the maximum branch number (9.5), maximum plant spread (31.2 cm). P_1N_2 showed the earliest flowering (170.9 days). P_3N_1 took the longest time to flower (196.9 days). Flowering was delayed with increasing pinching intensity. N at 200 resulted in early flowering, while 500 ppm resulted in delayed flowering. Flower size was highest among pinching treatments under P_1 (5.7 cm), and lowest under P_3 (5.2 cm). The maximum flower size of 5.8 cm was obtained under P_1N_2 or P_1N_1. Pinching and N treatments did not affect vase life.

El-Greedly *et al*. (2005) carried out a pot experiment to investigate the influence of different concentrations of stigma sterol (0, 100, 150 and 200 ppm) on growth, yield and endogenous hormones of two sesame cultivars. In general, increasing stigma sterol concentration up to 200 ppm significantly increased the growth, seed yield and number of capsules plant^{-1} as well as 1000-seeds weight was also increased due to increasing stigma sterol concentrations. Plants treated by 100 or 150 ppm showed approximately the same values of seeds plant^{-1}, while when it sprayed by high concentration (200 ppm), seed yield was increased.

An open field experiment was conducted in Nadia, West Bengal, India, by Pal and Biswas (2004) to investigate the effect of pinching and fertilizer application on the growth and flowering of carnation cultivars Desio (standard) and Supermix (spray). The greatest plant height (49.9 cm) was recorded under single pinching. Double pinching delayed flower production significantly over other methods. The longest flower stem (39.3 cm) was noted in single pinched plant. The largest flower size was recorded with the pinch and a half treatment, closely followed by the other pinching treatments. The longest duration of flowering (48.9 days) was recorded with the pinch and a half method and was at par with the double pinch method (48.5 days).

Sehrawat *et al*. (2003) carried out experiment on the effects of N rates and pinching (at 30, 40 or 50 days after transplanting or DAT) on the performance of *T. erecta* cv. African Giant Double Orange and found that pinching significantly reduced plant height, especially when conducted at 30 DATs. The highest number of flowers per plant (30.2) and flower yield (322.6 g per plant) were obtained with pinching at 30 DAT (30.2).

Sarkar *et al*. (2002) investigated a study to know the effect of plant growth regulators on yield of soybean. Plants of soybean cv. BS-3 were sprayed at three different times with two concentrations (100 and 200 ppm) of gibberellic acid (GA_3) and indole acetic acid (IAA). GA_3 at 100 ppm had regulatory effect to enhance the plant height, number of branches, number of leaves, leaf area per plant, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant, 100-seeds weight and seed yield (t/ha). On the other hand, 100 ppm IAA produced the highest plant height, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant and seed yield (t/ha), as compared to other plant growth regulators and control. IAA at 200 ppm increased number of branches, number of leaves, leaf area per plant, 100-seeds weight and net assimilation rate.

Nagel *et al*. (2001) carried out an experiment on exogenous application of cytokinin to raceme tissues of soybean (*Glycine max* L.). Which has been shown to stimulate flower production and to prevent flower abortion? Soybeans were grown hydroponically or in pots in the greenhouse, and 6benzylaminopurine (BA) was introduced into the xylem stream through a cotton wick for 2 weeks during anthesis. After the plants had matured, the number of pods, seeds per pod, and the total seed weight per plant were measured. In the greenhouse, application of 3.4×10^{-7} moles of BA resulted in a 79% increase in seed yield compared with controls. Data suggest that cytokinin levels play a significant role in determining total yield in soybeans, and that increasing cytokinin concentrations in certain environments may result in increased total seed production.

An experiment was conducted by Yadav *et al*. (2000) to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 250, 500 and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height (28.4 cm) and plant spread (0.18 m) was resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q ha^{-1}) was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm. Leaf area was the highest in 2 sprays of 500 ppm succinic acid.

Baydar (2000) studied an experiment to determine the effects of gibberellic acid (GA_3) on male and female sterility, seed yield, oil and fatty acid syntheses, growth and development properties in safflower (*Carthamus tinctorius* var. Yenice). GA_3 was applied in five different doses at three different stages, and induced male sterility at a rate of up to 93.0%. This finding has important implications for the practical use of GA_3 in hybrid seed production. GA_3 applications significantly decreased the seed yield per plant both in isolation and non–isolation. Although fatty acid syntheses did not change with any application, oil synthesis increased significantly from 33.8% to 38.8% with the application of 300 ppm GA_3 at the budding stage.

2.2 Literature on seed rate

Khan (2021) an experiment was carried out at the “Horticulture Farm” of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from November 2019 to March 2020 to study the influence of phosphorus fertilization and seed rates on yield components and yield of black cumin. The experiment consisted of two factors. Factor A: Four levels of phosphorus viz., P_0= control, P_1= 35 P kg/ha, P_2= 40 P kg/ha and P_3= 45 P kg/ha and Factor B: Three seed rates viz., R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}. Growth related data was maximum on P_3 (45 P kg/ha) treatment but in case of seed yield, P_2 (40 P kg/ha) treatment showed the best result. In case of growth characters, R_1 (8 kg seeds ha^{-1}) treatment revealed the best result but in case of seed yield, R_2 (10 kg seeds ha^{-1}) treatment showed the best result. The highest seed yield (1.27 t ha^{-1}) was obtained from P_2R_2 (40 P $kgha^{-1}$ + 10 kg seeds ha^{-1}) treatment combination. On the other hand, the lowest seed yield (0.94 t/ha) was obtained from of P_0R_3 (control + 12 kg seeds ha^{-}) treatment combination. So, it was revealed that the P_2R_2 treatment combination appeared to be best for achieving the higher growth and seed yield of black cumin.

Mengistu *et al.* (2021) a field experiment was conducted to investigate the effects of seeding rate and variety on growth, yield and some quality parameters of black cumin (Nigella sativa L.). Five seeding rate (10, 15, 20, 25 and 30 kg/ha) and three varieties namely Eden, Dirshaye and Local check were used. The highest plant for consecutive 30, 60 and 60DAS (18.54cm, local; 38.12cm, local and 46.77, Eden) was recorded as those varieties sawn at seeding rate of 30 kg/ha. The maximum mean number of primary branch measured at maturity time as (5.3) where recorded when Eden was sawn at 10 kg/ha. The mean earliest days to flower initiation (72.4 days) was recorded for Eden Variety while prolonged days to flower initiation (83.2) was recorded for local variety. Following similar patter, mean earliest days to maturity (142.8days) for Eden and prolonged days to maturity (146.3days) was recoded for local variety. Yield contributing characters like number of capsules per plant, number of seeds per capsule, 1000 seed weight, seed yield per plant and seed yield per hectare were maximum when cumin seed variety Eden sawn at seed rate of 10 kg/ha. These attributes were found to be minimum for all the three tested varieties sown at seed rate of 30 kg/ha. Among various levels of seed rate and three varieties tested, 10 kg/ha by Variety Eden could result in highest seed yield (685 kg/ha), though it is below national standard which ranged from 900-1600 kg/ha. Variety Eden resulted in maximum number of capsule (62.1) and greater seed yield per plant (4.27g) when sawn at 10kg/ha. Local variety achieved promising result for 1000seed weight (1.94g) which is 47.3% higher than that produced at 30 kg/ha seeding rate (0.46 g) for variety Dirshaye. Local varieties produced greater amount of essential oil. Based on the results of the experiment, Eden with 10 kg/ha could be used for popularization and need to be subjected to scaling up in the study area.

Behzad *et al.* (2021) conducted an experiment to determine the effect of seed rate on the growth and yield attributes of the wheat crop (Triticum aestivum L.) variety Mazar-99. The experiment was implemented on an experiment design with 4 replications and 5 seeding rates viz. 80, 100, 120, 140 and 160 kg/ha made up treatments. The result obtained from the current study reveal that all growth and yield characters were remarkably affected by seeding rate and seed rate of 100 kg per hectare of wheat variety Mazar-99 performed better with respect to different growth and yield parameters such as spike length, number of tillers, number of spike at each plant, leaf area, a total of spikelets per spike and stem girth, grain number/spike, the weight of spike, the weight of grain per spike, grain crop yield, straw crop weight, 1000-grain weight, and biological yield. Whereas 80 and 120 kg/ha were the second-best seeding rates after the 100 kg/ha. However, 160 kg/ha seed rate showed only superiority in plant height, but 140 kg/ha did not show any special superiority in any growth and yield characteristic evaluated in Takhar agro-climatic condition. Thus, a seeding rate of 100 kg per hectare could be recommended to the farmers for better wheat production.

Gezahegn *et al.* (2021) a field experiment was carried out for two successive cropping seasons to determine optimum seed rate and inter-row spacing for food barley production. The experiment involved a factorial combination of three seed rates (80, 100 and 120 kg ha^{-1}) and three inter-rows spacing (20, 30 and 40 cm). The experiment was conducted using a randomized complete block design with three replications. The results indicated the treatments had significant effect in all parameters except plant height and spike length. Based on the result of this study, use of 30 cm inter-row spacing and 120 kg ha^{-1} seed rate is superior in grain yield (4481 kg ha^{-1}) and total biomass (14.6 t ha^{-1}). Therefore, use of 30 cm inter row spacing with seeding rate of 120 kg ha^{-1} can be recommended for food barley production at Shama Bulket kebele and its vicinity.

Begum (2021) carried out a field experiment to study the effect of seed rate on yield performance of wheat under strip tillage. Wheat cv. BARI Gom-26 was sown under conventional tillage (CT) vs. strip tillage (ST), including four seeding rates viz. 100, 110, 120, and 130 kg ha^{-1}. The CT was done with a two-wheel tractor and consisted of two primary tillages followed by two secondary tillages. The ST was done using a Versatile Multi-crop Planter (VMP) machine in a single pass process. A pre-plant herbicide, glyphosate was applied 3 days before of ST operation @ 3.7 L ha^{-1}. The experiment was laid out in a randomized complete block design with four replications. The impact of tillage methods on the seed rate was found significant in the yield and economic profit of wheat. The longest spike with the highest number of grains $spike^{-1}$, the highest weight of 1000-grain, grain yield, and BCR was recorded when 120 kg seeds of wheat sown with strip tillage. This practice produced a 25% higher yield and earned 51% higher profit than the practice of seeding 100 kg seeds ha^{-1} with conventional tillage.

Roussis *et al.* (2017) carried out a field experiment was conducted to determine the effect of seed rate and fertilization on yield and yield components of *Nigella sativa* crop. The experiment was laid out according to a split-plot design with three replicates, two main plots (seed rates: 50 kg/ha and 60 kg/ha) and four sub-plots (fertilization treatments: untreated, compost, sheep manure, inorganic fertilizer). Plants were higher in plots sown at a rate of 60 kg/ha (18.2-22.7 cm). The highest number of capsules per plant (5.0-5.8) were found in sub-plots subjected to inorganic fertilization. Moreover, there were significant differences between fertilization treatment regarding seed yield and biological yield. The highest seed yield (911-1066 kg/ha) and biological yield (3864-4063 kg/ha) were found in inorganic treatments. The number of branches per plant, number of seeds per capsule, thousand-seed weight, and Harvest Index was not affected neither by seed rate nor by fertilization. Finally, there was not any significant interaction between seed rate and fertilization.

Akhter (2017) an experiment was conducted with three seed rates (100, 120 and 140 Kg ha^{-1}) and five varieties (BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28) in the rabi season to determine the optimum seed rate for newly released varieties. The highest grain yield was found in BARI Gom 26, which is medium sized seeded variety. The bolded seeded variety BARI Gom 24 and BARI Gom 25 failed to produce higher grain yield due to lower number of spikes per m^2 and lower number of grains per spike. A seed rate of 140 kg ha^{-1} produced the highest yield traits and grain yield across all the varieties, but there was no statistical difference with the seed rate of 120 kg ha^{-1}. The performance of yield traits and yield of the wheat varieties varied with the seeding rates. Therefore, the seed rate of the variety BARI Gom 24, BARI Gom 26 and BARI Gom 28 can be considered as 140 kg seed ha^{-1} and the variety BARI Gom 25 and BARI Gom 27 can be considered as 120 kg seed ha^{-1}.

Rahel and Fekadu (2016) who reported that maximum biomass yield was reported at seeding rate of 100 kg seed ha^{-1} than 125 and 150 kg ha^{-1}, maximum grain yield 2.78 t/ha was obtained in plots seeded with 100 kg seed ha^{-1} rather than a seed rate of 75, 125 and 150 kg ha^{-1}, maximum productive tiller was reported from lower seed rate than higher seed rate because of productive tiller per plant higher at lower seed rate than higher seed rate.

Alemayehu (2015) who reported that maximum productive tiller from minimum seed rate and vice versa and maximum grain yield recorded from a seed rate of 150 kg ha^{-1} and variety was not show significant effect on grain yield.

Aleminew *et al.* (2015) carried out a field experiment to determine the effect of Np fertilizers application and seeding rates on yield and yield components of noug Three seed rate levels (SR) of Fogera-1 variety were used as (5, 7.5 and 10 kg ha^{-1}) and as (7.5, 10 and 12.5 kg ha^{-1}) for row and broadcast planting methods, respectively. Five levels of Np (0-0, 10.25-23, 20.5-23, 41-23 and 41-46 kg of N and P_2O_5 ha^{-1}, respectively) were used Urea and DAP as a source. The analysis of variance for growth and yield parameters of noug revealed that there were highly significant ($P<0.01$) effects due to Np fertilizers and seed rate levels. Generally, 7.5 × 41-23 and 10 × 41-46 kg/ha seed rate levels and Np fertilizer combinations, respectively gave higher seed yield in case of drill planting methods; 10× 41-23 gave the highest seed yield of noug for broadcast planting methods. The present results highlight the practical importance of adequate Np fertilization and true seed rate levels for seed yield and oil content of noug and recommended that application of 7.5 and 10 kg/ha seed rates and 41 and 23 kg/ha N and P fertilizers will be meet crop Np requirements of noug for drill and broadcast planting methods, respectively.

Ali *et al.* (2010) explained that lower seeding rates significantly increased the number of grains and vice versa.

Seleiman *et al*. (2010) and Jemale *et al*. (2015) reported that increasing seeding rates from 250-400 m^{-2} and 100- 200 kg ha^{-1} grains prolong the number of days from sowing to maturity of wheat, respectively.

Baloch *et al*. (2010) reported that different seed rate had no significant effect on spike length. Furthermore, Zewdie *et al.* (2014) reported that plant height and spike length are negatively related. Shorter plant produces longer spike and long plant produce shorter spike.

Sarker *et al.* (2007) An experiment was conducted with three wheat varieties of varying seed sizes at five seed rates in medium and high management at rabi season to determine the appropriate seed rates for the varieties under different management practices. On an average, high management increased grain yield by 18.4%, but the benefit-cost ratio (BCR) was higher in medium management. Higher grain yield was obtained from varieties Shatabdi (medium sized seed) and Prodip (large sized seed) compared to Sufi (small sized seed) in high management, whereas in medium management, all the varieties produced similar grain yield. Considering yield performance and BCR analysis, the seed rates of Sufi and Shatabdi might be 100 and 120 kg/ha, respectively, for both the managements. Seed rates of Prodip might be 120 and 140 kg/ha for medium and high management, respectively.

Higher seeding rate caused to changing plant height and stem thickness because of the lower light penetrating in to the plants canopy bed and more inter specific competition to more absorption light. These factors (higher seeding rate and lower light penetration) increasing inter node length, reducing stem thickness and increasing plant height (Otteson *et al.,* 2007).

Begum *et al.* (2005) an experiment was conducted to study the effect of seed rate and row spacing on the yield and yield components of two varieties of mustard. The treatments included two varieties viz. BARI sorisha-6 and Sambal, two seed rates viz. 7 and 9 kg seeds/ha, and five row spacings viz. 10, 15, 20 25 and 30 cm. Higher seed yield was obtained by the variety BARI sorisha 6. The result showed that seed rate had a significant effect on plant height, no. of filled pods/plant, no. of seeds/pod, 1000-seed weight, seed yield and straw yield. Between two seed rates 9 kg seeds/ha produced higher seed yield (1.15t/ha). Yield and all yield contributing characters except harvest index were significantly influenced by row spacing. The highest seed yield (1.429 t/ha) was found in 30 cm row spacing. Among the yield contributing characters only 1000 seeds weight was significantly influenced by the interaction of variety and seed rate as well as the interaction of seed rate and row spacing. The interaction of variety and row spacing had significant influence on unfilled pods/plant, seed yield and straw yield. The highest seed yield (2.01 t/ha) was produced when the seeds of Sambal were sown at 30cm row spacing and the same variety with 10cm row spacing produced the lowest seed yield (0.60 t/ha). The interaction of variety, seed rate and row spacing had no significant influence on yield and yield contributing characters of mustard.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November, 2020 to March, 2021 to investigate on the influence of elicitors and seed rate on enhancing growth and yield of black cumin. This chapter includes a brief description of the experimental period, location, soil and climatic condition of the experimental area and materials that were used for conducting the experiment such as treatment and design of the experiment, growing of crops, intercultural operations, data collection procedure and procedure of data analysis that were used for conducting the experiment.

3.1 Experimental site

The research was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experiment was carried out during rabi season. The location of the experimental site is situated at 90° 22' E longitude and 23° 41' N latitude. The altitude of 8.6 meters above the sea level. Map of experimental site are presented in Appendix I.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI Farmgate, Dhaka and the results showed that the soil composed of 27% sand, 43% silt and 30% clay. The soil was having a texture of sandy loam with pH and organic matter 5.47 – 5.63 and 0.83%, respectively. The details soil characteristics are presented in Appendix II.

3.3 Climatic condition of the experimental site

The experimental area was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al.,* 1979). The climatic conditions during the period of experiment was collected from the Bangladesh Meteorological Department, Agargaon, Dhaka and the data are presented in Appendix III.

3.4. Agro-ecological region

The experimental field belongs to the agro-ecological region of the Madhupur Tract (AEZ-28). The landscape comprises level upland, closely or broadly dissected terraces associated with either shallow or broad, deep valleys.

3.5. Experimental details:

The experiment was conducted to study the effect of elicitors and seed rate on the growth and seed yield of black cumin. Different levels of two factors were as follows:

3.5.1 Experimental treatment

Factor A: **Elicitors (Different types)**

T_1= Control

T_2= Salicylic acid (50 ppm)

T_3= Gibberellic acid (100 ppm)

T_4 = Pinching

Factor B: **Seed rate (Different levels)**

R_1= 8 kg/ha

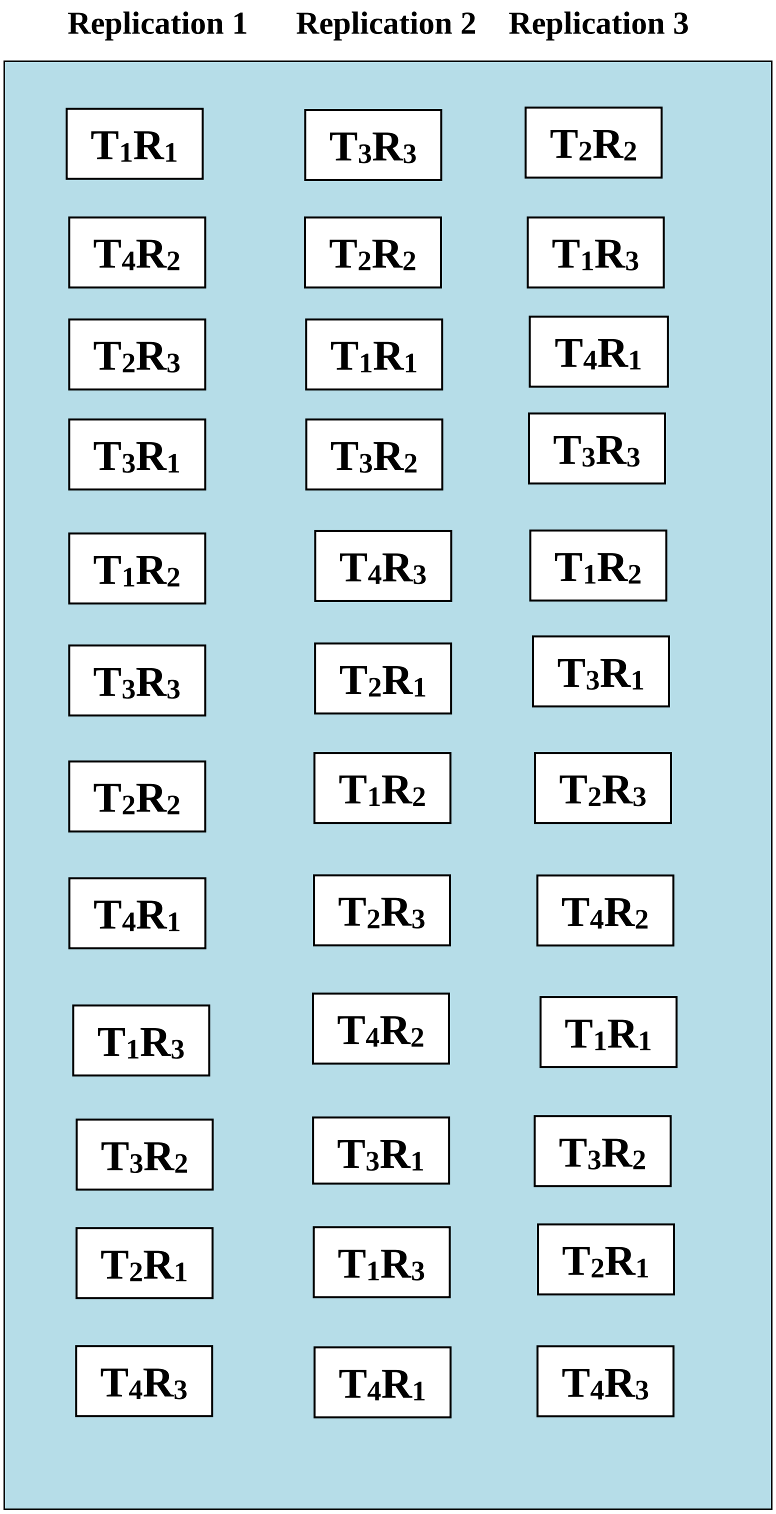
R_2= 10 kg/ha

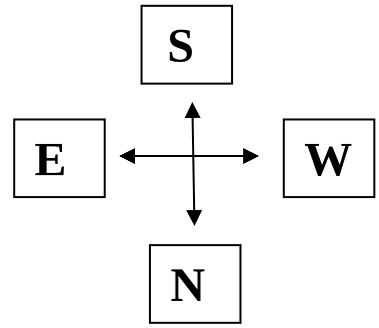
R_3= 12 kg/ha

The seed was sown at 8, 10, 12 g/ m^2 of the plot at seed rate of 8, 10, 12 kg/ha.

There are 12 treatment combinations such as T_1R_1, T_1R_2, T_1R_3, T_2R_1, T_2R_2, T_2R_3, T_3R_1, T_3R_2, T_3R_3, T_4R_1, T_4R_2, T_4R_3.

3.5.2 Design and layout of the experiment





Factor A: Elicitors (different types)
T_1= Control
T_2 = Salicylic acid 50 ppm
T_3 = Gibberellic acid 100 ppm
T_4 = Pinching

Factor B: Seed rate (different levels)
R_1 = 8 kg/ha
R_2 = 10 kg/ha
R_3 = 12 kg/ha

Plot size: 1 m x 1 m

Plot spacing: 0.50 m x 0.50 m

Block to block distance: 0.50 m
Row to row distance: 0.25 m x 0.25 m

Figure. 1. Layout of the experimental plot of Black cumin.

3.6 Planting Materials

In this experiment black cumin variety of BARI Kalozira 1 was used in the experiment as a planting material. BARI Kalozira-1 was developed by Bangladesh Agricultural Research Institute (BARI) in 2009. The seed was collected from the Regional Spice Research Centre, BARI, Joydebpur, Gazipur.

3.7 Land preparation

The experimental site was first opened with power tiller with successive cross-ploughed three times followed by laddering up to the desirable tilth. The stubbles, weeds and crops residues of last crop were removed from the field. Proper drainage channels were made in order to avoid water logging due to rainfall during the study period.

3.8 Manure and fertilizer application

Manure/Fertilizers	Dose (kg/ha)
Cowdung	10 tons
Urea	125 kg
Triple Super Phosphate (TSP)	95 kg
Muriate of potash (MP)	75 kg

Source: (Mondal *et al.,* 2011)

The entire amount of cowdung, 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.

3.9 Sowing of seed

To enhance germination, the 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. The soil was also treated with Furadan 5G @15 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm. The seeds were sown on 25 November, 2020 in rows continuously by hand. The seeds were mixed with loose soil to maintain the uniform sowing in rows.

A light irrigation was applied in soil before the sowing of seeds to maintain the proper moisture for better seed germination. The seeds were gently pressed by hands after sowing and covered with loose soil.

3.10 Application of the treatments

The solution was made at the rate of 100 mg of GA_3 solute dissolved in 1000 ml of water for the concentration of 100 ppm solution. The doses of gibberellic acid 100 ppm were applied twice on the standing crops at 40 and 60 days after sowing (DAS). The solution was made at the rate of 50 mg of salicylic acid solute dissolved in 1000 ml of water for the concentration of 50 ppm solution. The doses of salicylic acid 50 ppm were applied twice on the standing crops at 40 and 60 days after sowing (DAS). Pinching involves removal of the growing point of the shoot along with few leaves. It was done with sharp scissor at 40 days after sowing (DAS).

3.11 Intercultural operations

3.11.1 Weeding

Weeding with khurpi was done on 25 DAS.

3.11.2 Irrigation

Two irrigations were given as plants required. First irrigation was given immediately after topdressing and second irrigation were applied 60 DAS with watering can. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture.

3.12 Crop protection

The field was investigated time to time to detect visual differences among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. Diazinon 60 Ec was sprayed twice at 15 days interval @ 2 ml L^{-1} of water to control aphid. Some plots started to die after rotting in the basal portion of the plant. For controlling this disease, Autostin 50 WDG was sprayed thrice at 7 days interval @ 2 g L^{-1} water and Sulcox 50% WP was sprayed thrice at 7 days interval @ 1 g L^{-1}.

3.13 Harvesting and threshing

The crops were harvested when 80% of the pods were in terminal matures. After collecting sample plants, harvesting was started on March 15 and completed on March 28, 2021. Previous randomly selected five plants, those were considered for data recording was collected from each plot to analyze the yield and yield contributing characters. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.14 Drying and weighing

The seeds those were collected dried under the sun for 2-3 days. Dried seeds of each plot were weighed and subsequently converted into yield t/ha.

3.15 Parameters assessed

Data were collected on the following parameters:

3.15.1 Vegetative growth parameters

a) Plant height (cm)
b) Number of leaves per plant
c) Number of branches per plant

3.15.2 Yield and yield contributing parameters

a) Days to first flowering
b) Days to 50% flowering
c) Number of days need for harvesting
d) Number of capsules per plant at harvest
e) Single capsule weight (g)
f) Length of the capsule (cm)
g) Breadth of the capsule (cm)

h) Number of seed per capsule
i) Weight of seed per capsule (mg)
j) Weight of seed per plant (g)
k) 1000 seed weight (g)
l) Weight of seed per plot (g)
m) Seed yield (t/ha)
n) Weight of stover per plot (g)
o) Stover yield (t/ha)

3.16 Data collection procedure

Five plants from each plot were selected as random and were tagged for the data collection. Some data were collected from sowing to harvesting with 20 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun.

3.16.1 Vegetative growth parameters

3.16.1.1 Plant height (cm)

Plant height was measured with the help of a meter scale from the ground level of the root up to the tip of leaf at 40 DAS, 60 DAS, 80 DAS and after harvest of black cumin plants and their mean values were calculated and recorded.

3.16.1.2 Number of leaves per plant

Number of leaves per plant was counted four times such as 40 DAS, 60 DAS, 80 DAS and at harvest of black cumin plants and their mean values were calculated and recorded.

3.16.1.3 Number of branches per plant

The total number of primary, secondary and tertiary branch and its number was counted after final harvesting of crop and their mean values were calculated and recorded.

3.16.2 Yield and yield contributing parameters

3.16.2.1 Days to first flowering

All the plants were observed carefully and the days of first flowering were counted by deducting from the days of seed sowing.

3.16.2.2 Days to 50% flowering

All the plants were observed carefully and the days of 50 % flowering were counted by deducting from the days of seed sowing.

3.16.2.3 Number of days need for harvesting

The date of harvesting was considered to give total information of life span of BARI Kalojira-1 by the application elicitors and seed rate. The total number of days needed for final harvest from each treatment was counted from deducting the days of seed sowing.

3.16.2.4 Number of capsules per plant (at harvest)

After the harvest of black cumin plants the total number of capsules was counted from five randomly plants of each plot and the means were taken.

3.16.2.5 Single capsule weight (g)

After harvest, weight of single capsules (g) were recorded from randomly selected plants from plots and their mean values were calculated and recorded.

3.16.2.6 Length of the capsule (cm)

After harvest, length of the capsules (cm) were recorded with measuring scale from randomly selected plants and their mean values were calculated and recorded.

3.16.2.7 Breadth of the capsule (cm)

After harvest, breadth of the capsules (cm) were recorded with measuring scale from randomly selected plants. Mean values of data were calculated and recorded.

3.16.2.8 Number of seed per capsule

After harvest the total number of seeds per capsule was counted from five plants of each plot and the means were taken.

3.16.2.9 Weight of seeds per capsule (mg)

Five plants were randomly selected from each plot, the weight of all seeds of each capsule was taken with the help of electric balance and the mean values were considered for weight of seed per capsule in milligram.

3.16.2.10 Weight of seeds per plant (g)

After harvest the total number of capsules were counted and then the total weight of total number of seeds from the five randomly selected plants of each plot in gram was taken with the help of electric balance.

3.16.2.11 1000-seed weight (g)

One thousand seeds from each plot were counted and weighed in gram with the help of electric balance and their mean values were counted and recorded.

3.16.2.12 Weight of seed per plot (g)

Total weight of seeds from each plot was considered as seed yield per plot in gram.

3.16.2.13 Seed yield (t/ha)

Total weight of seed from each plot was considered as seed yield per plot in gram and then seed yield of per plot was converted to tons per hectare.

3.16.2.14 Weight of stover per plot (g)

The husk and dry plant parts other than seed were considered as stover and the total weight of stover per plot was measured in gram and their values were recorded.

3.16.2.15 Stover yield (t/ha)

The husk and dry plant parts other than seed were considered as stover and the total weight of stover per plot was measured in gram unit and then plot yield was converted to stover yield tons per hectare.

3.17 Statistical Analysis

The recorded data on different parameters were statistically analyzed using Statistic 10 software. The significance of the difference among the treatments means was estimated by least significant difference test (LSD) at 5% level of probability.

3.17.1 Economic Analysis

The cost of production was calculated to find out the most economic combination of elicitors and seed rate. All input cost like the cost for land lease and interests on running capital were computing in the calculation. The interests were calculated @ 13% in simple rate. The market price of black cumin was considered for estimating the return. Analyses were done according to the procedure of Alam *et al.* (1989).

3.17.2 Analysis for total cost of production of black cumin

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix section.

3.17.3 Gross income

Gross income was calculated on the basis of sale of black cumin. The price of black cumin was determined on the basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

3.17.4 Net return

Net returns were arrived after deducting the cost of cultivation from the gross returns of the marketable produce on hectare basis and expressed in taka per hectare

Net returns = Gross returns – cost of cultivation.

3.17.5 Benefit cost ratio (BCR)

It was obtained by dividing gross returns with cost of cultivation per hectare.

$$\text{Benefit Cost Ratio} = \frac{\text{Gross returns (Tk./ha)}}{\text{Total cost of production}}$$

CHAPTER IV

RESULTS AND DISCUSSION

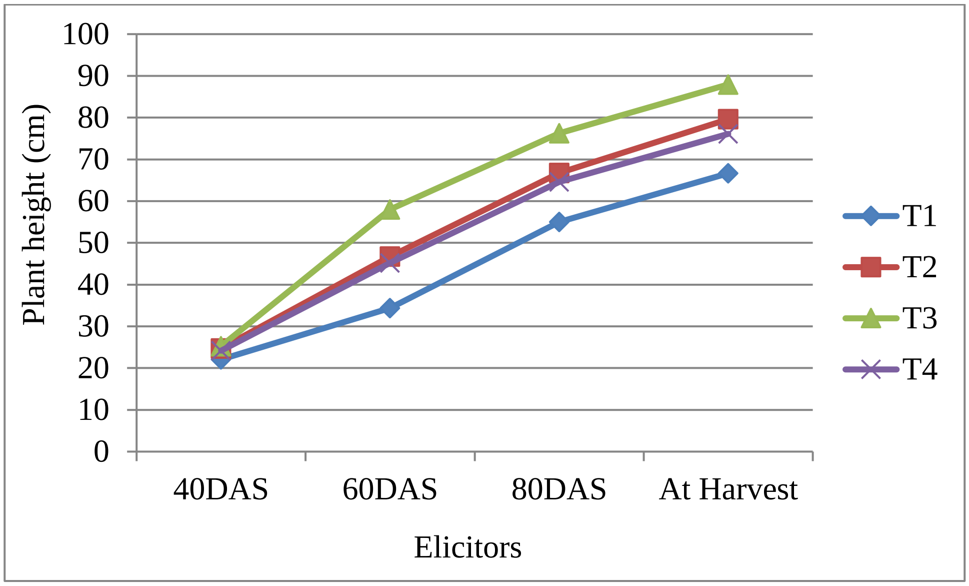
The experiment was conducted to study the growth, yield and economic benefit of Black cumin (*Nigella sativa* L.) as influenced by elicitors and seed rate. Data on different growth, yield attributes and economic benefit of black cumin were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix section. The results have been presented with the help of graphs and tables and possible interpretations given under the following headings**.**

4.1 Plant height

Plant height of black cumin plant was significantly varied due to the elicitors treatment (Figure 2 and Appendix: III). At harvest, the highest plant height (87.95 cm) was found from the T_3 (GA_3 100 ppm) treatment and the shortest plant height (66.66 cm) was produced from the control (T_1) treatment. Shah *et al*. (2006) and BARI (2007) reported that, plant height increases with the application of GA_3 application. The application of optimum doses of GA_3 increased the internode elongation of stem. So, the height of plant was increased under present study with significantly varied with the application of GA_3.

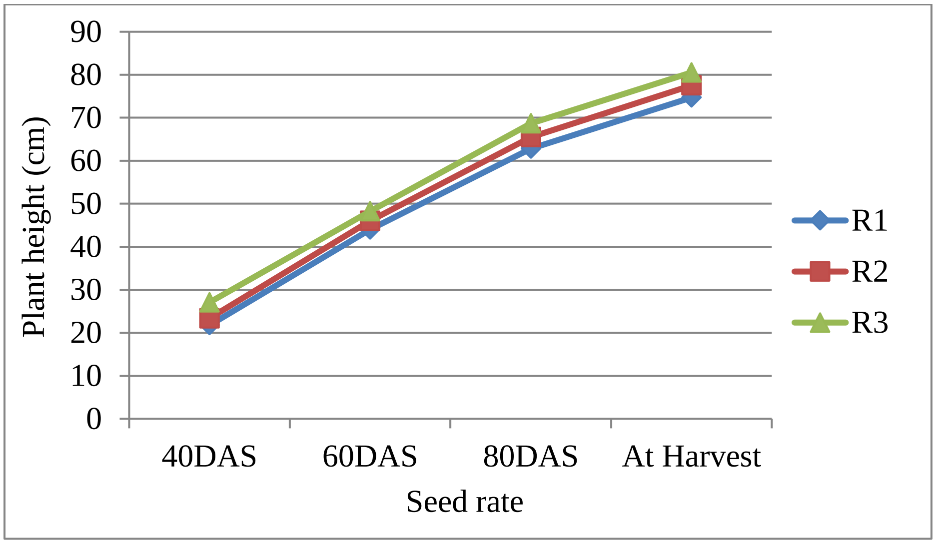
Seed rate had a significant influenced on plant height of black cumin plants at 40, 60, 80 DAS and at harvest (Figure 3) (Appendix: III). The highest plant height (80.54 cm) was observed from R_3 (12 kg/ha) seed rate and the lowest plant height (74.70 cm) was obtained from R_1 (8 kg/ha) seed rate at harvest. These findings on plant height were in accordance with Toncer and Kizil (2004); Tuncturk *et al*. (2005) and Roussis *et al.* (2017), Tuncturk *et al*. (2005) found that an increasing seed rate in black cumin increased plant height. Similar results also reported by Koli (2013), 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.

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 and Appendix: III). At harvest, the highest plant height (92.93 cm) was produced from T_3R_3 (GA_3 100 ppm and 12 kg/ha) treatment combination and the lowest plant height (63.80 cm) was found from T_1R_1 (control and 8 kg/ha) treatment combination.



Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching.

Fig. 2. 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.3. Effect of seed rate on plant height of black cumin.

4.2 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 and Appendix: IV). 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 T_4 (pinching) treatment, while the lowest number of leaves per plant (58.65) was obtained from T_1 (control) treatment. The findings of current study reveal that by pinching practice the number of branches per plant increased and thereby increased the number of leaves in pinched plants as compared to control. Increase in number of leaves per plant as a result of pinching has been observed previously in china aster, field bean and bottle gourd. Pinching boosts branch production that in turn increases young leaf production, thus a greater number of leaves is related to the number of branches.

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 and Appendix IV). From the observation of 80 DAS the highest number of leaves per plant (71.23) was recorded from the treatment R_1 (8 kg/ha) seed rate and the lowest number of leaves per plant (66.85) was recorded from the treatment R_3 (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 and Appendix. IV). At 80 DAS, the highest number of leaves per plant (80.23) was recorded from T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination and the lowest number of leaves per plant (56.37) was produced from T_1R_3 (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**
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	42.76 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**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

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

Table 2. Combined effect of elicitors and seed rate on plant height (cm), 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	
$T_1 R_1$	19.65 h	33.03 i	52.33 j	63.80 i	8.53 fg	36.90 g	61.17 h	27.13 i
$T_1 R_2$	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_1R_3	25.50 cd	36.53 h	57.90 h	68.53 h	7.60 ij	28.73 i	56.37 j	24.23 k
T_2R_1	22.76 fg	45.09 f	65.50 ef	77.57 ef	9.15 de	55.17 b	74.30 c	49.57 b
T_2R_2	23.90 def	46.83 e	66.53 e	79.77 de	8.13 gh	51.90 c	72.53 d	43.53 d
$T_2 R_3$	27.57 ab	48.16 d	68.16 d	81.56 cd	7.15 j	48.60 d	71.13 d	41.60 e
T_3R_1	22.30 fg	54.90 c	71.20 c	83.87 bc	9.27 d	44.43 e	69.23 e	37.35 f
T_3R_2	24.80 cde	58.36 b	75.50 b	87.06 b	8.73 ef	43.00 ef	65.87 f	33.53 g
T_3R_3	28.70 a	60.86 a	82.16 a	92.93 a	7.82 hi	41.53 f	63.70 g	31.77 h
T_4R_1	22.30 fg	42.93 g	62.13 g	73.57 g	13.27 a	57.90 a	80.23 a	51.63 a
$T_4 R_2$	23.70 ef	45.43 f	65.13 f	75.60 fg	11.83 b	54.10 b	77.67 b	49.93 b
T_4R_3	26.50 bc	47.33 de	66.63 e	79.15 de	10.23 c	52.17 c	76.23 b	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**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, 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

The variation in number of branches 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 in T_1 (control) treatment (Table 1).

A significant variation was found in the number of branches per plant was observed due to effect of different levels of seed rate in black cumin plant. At harvest, the highest number of branches per plant (41.42) was produced in R_1 (8 kg/ha seed rate) treatment while the lowest number of branches per plant (35.98) was found in R_3 (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 T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination while the lowest number of branches per plant (24.23) was observed from T_1R_3 (control and highest seed rate) treatment combination at harvest. (Table 2).

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 and Appendix V). Results revealed that, the longest days (60.67) were needed to reach the 1st flowering stage by the plant treated with T_4 (pinching) treatment and the shortest days (46.11) were needed by the plant treated with T_3 (GA_3 100 ppm) treatment. The application of GA_3 may improve the earlier development of flowering. So, application of GA_3 the earlier 1st flowering was observed under present study.

A significant variation was found in case of days to first flowering was observed due to effect different levels 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 R_3 (12 kg/ha seed rate) treatment and the shortest days (53.50) 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 flowering of black cumin plant (Table 4). The highest days (62.33) to needed first flowering obtained from T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination and lowest (45.33) days were observed from the T_3R_1 (GA_3 and lowest seed rate) treatment combination.

Table 3. Effect of elicitors and seed rate on days of first flowering, days to 50% flowering and number of capsules per plant of black cumin.

Treatment	Days to first flowering	Days to 50% flowering	Number of capsules per plant
Different types of elicitors			
T_1	58.78 b	64.56 b	19.98 d
T_2	52.78 c	54.22 c	39.21 b
T_3	46.11 d	52.56 d	30.15 c
T_4	60.67 a	67.33 a	40.42 a
$Lsd_{0.05}$	0.5378	0.6686	0.0723
CV%	8.75	8.45	5.26
Different level of seed rate			
R_1	53.50 c	58.58 c	36.10 a
R_2	54.58 b	59.83 b	32.49 b
R_3	55.67 a	60.58 a	28.74 c
$Lsd_{0.05}$	**0.4658**	**0.5790**	**0.0626**
CV%	**8.75**	**8.45**	**5.26**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

Table 4. Combined effect of elicitors and seed rate on days of first flowering, days to 50% flowering, days required for harvesting and number of capsules per plant of black cumin.

Treatment combination	Days to first flowering	Days to 50% flowering	Days required for harvesting	Number of capsules per plant
$T_1 R_1$	57.67 d	62.00 d	134.67 a	22.61 i
$T_1 R_2$	58.33 cd	65.67 c	132.33 b	19.73 j
T_1R_3	60.33 b	66.00 bc	133.67 a	17.62 k
T_2R_1	52.33 f	53.67 ef	120.67 f	42.63 b
T_2R_2	52.67 ef	54.33 ef	121.33 f	39.17 d
$T_2 R_3$	53.33 e	54.67 e	123.33 e	35.83 e
T_3R_1	45.33 h	52.00 h	115.67 h	34.94 f
T_3R_2	46.33 g	52.33 gh	118.00 g	29.80 g
T_3R_3	46.67 g	53.33 fg	118.67 g	25.71 h
T_4R_1	58.67 c	66.67 bc	125.33 d	44.23 a
$T_4 R_2$	61.00 b	67.00 b	127.00 c	41.25 c
T_4R_3	62.33 a	68.33 a	127.67 c	35.79 e
$Lsd_{0.05}$	**0.9315**	**1.1580**	**1.1234**	**0.1252**
CV%	**8.75**	**8.45**	**7.25**	**5.26**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

4.5 Days to 50% flowering

Elicitors had significant effect on days to 50% flowering (Table 3 and Appendix V). Results revealed that, the longest days (67.33) were needed to reach 50% flowering by the plant treated with T_4 (pinching) treatment and the shortest days (52.56) were obtained by the plant treated with T_3 (GA_3 100 ppm) treatment. The application of GA_3 may improve the earlier development of flowering. So, application of GA_3 the earlier 50 % flowering was observed under present study by inducing the more hormone and interacting with temperature and humidity.

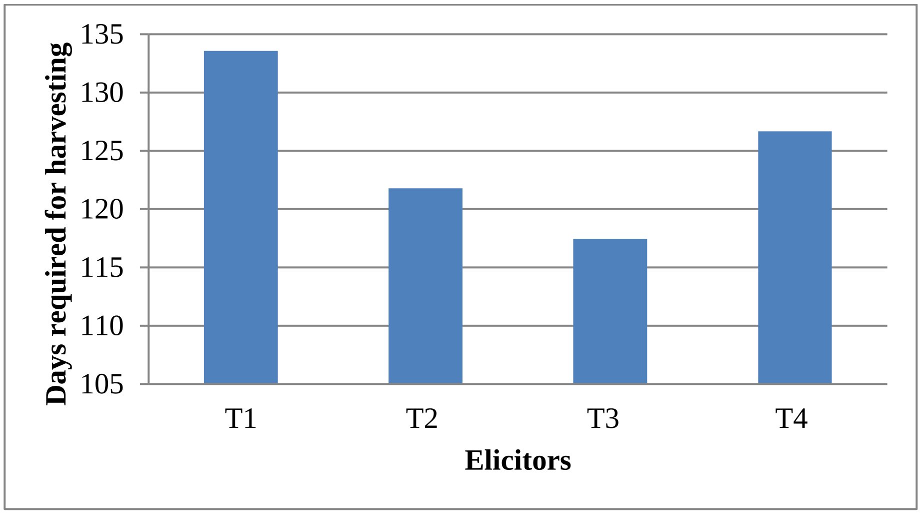
A significant variation was found in case of days to 50% flowering was observed due to effect different levels of seed rate in black cumin plant. The longest days (60.58) were needed to reach the 1^{st} flowering stage by the plant treated with R_3 (12 kg/ha seed rate) treatment and the shortest days (58.58) were observed 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 50% flowering of black cumin plant (Table 4). The highest days (68.33) was needed to obtain 50% flowering from T_4R_3 treatment combination (pinching and 12 kg/ha seed rate) and lowest (52.00) days was observed from the T_3R_1 (GA_3 100 ppm and 8 kg/ha seed rate) treatment combination which was statistically similar (52.33) days to the T_3R_2 (GA_3 100 ppm and 10 kg/ha seed rate) treatment combination.

4.6 Days required for harvesting

Significant variation was found among different types of elicitors effect on days required for harvesting of black cumin (Figure 4 and Appendix V). Days required for harvesting was decreased with the application of elicitors. Results revealed that, the later harvesting time (133.56 days) was exhibited by the plants treated with T_1 (control) treatment whereas the earlier harvesting time (117.44 days) was needed by the plants treated with T_3 (GA_3 100 ppm) treatment. The finding was nearly supported by BARI (2007) describing for early ripening. It might be due to comparatively high temperature and humid weather and the application of GA_3 may improve the earlier development of seed resulting earlier ripening for harvesting.

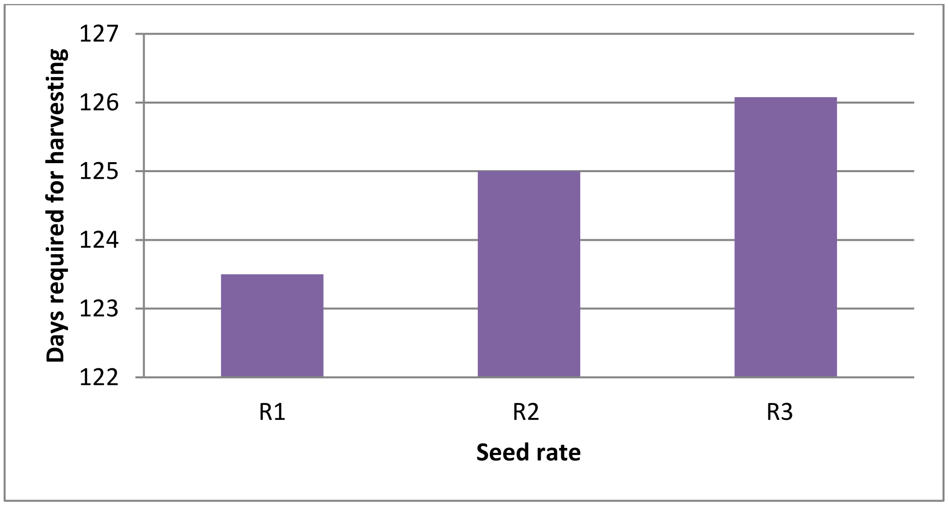
Effect of seed rate on days required for harvesting of black cumin plant was differed significantly. The treatment R_3 (12 kg/ha seed rate) showed the late harvesting (126.08 days) of black cumin, while the early harvesting (123.50 days) recorded from R_1 (8 kg/ha seed rate) treatment (figure 5 and Appendix V).

The combined effect of different elicitors and seed rate showed significant differences on days required for harvesting of black cumin (Table 4 and Appendix V). Combined effect of T_1R_1 (control and 8 kg K/ha seed rate) treatment combination gave the late harvesting (134.67 days) which was statistically identical to T_1R_3 (control and 12 kg K/ha seed rate) treatment combination. The early harvesting (115.67 days) was obtained from the T_3R_1 (GA_3 100 ppm and seed rate 8 kg/ha) treatment combination. Proper elicitor and seed rate helps to decrease harvesting days of black cumin.



Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching.

Fig.4. Effect of elicitors on days required of harvesting 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.5. Effect of seed rate on days required of harvesting of black cumin.

4.7 Number of capsules per plant at harvest

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 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 observed in pinched plants as compared to un- pinched plants. Plants having more 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 R_1 (8 kg/ha seed rate) treatment and the lowest number of capsules per plant (28.74) was obtained from (12 kg/ha seed rate) R_3 treatment. Angadi *et al*. (2003) reported that with the increase in seed rate, number of filled pods/ plant decreased. McVettey *et al*. (1988) reported that seed rate had negative correlation with the number of filled pods/ plant.

The combination of elicitors and seed rate gave the highest number of capsules per plant (44.23) was recorded from T_4R_1 (pinching and 8 kg/ha seed rate) (Table 4). The lowest number of capsules per plant (17.62) was obtained from the T_1R_3 (control and 12 kg/ha seed rate) treatment combination in black cumin.

4.8 Single capsule weight (g)

Single capsule weight (g) showed statistically significant variation due to the effect of elicitors. Higher single capsule weight (0.36 g) was observed from T_2 (salicylic acid 50ppm) treatment which was statistically identical (0.35g) to T_4 (pinching) treatment of black cumin while lowest value (0.19 g) was recorded from T_1 (control) treatment (Table 5).

Weight of single capsule (g) varied significantly due to the effect of seed rate. The highest weight of single capsule (0.32 g) was recorded in R_1 (8 kg/ha seed rate) treatment in black cumin. On the other hand, the lowest weight of single capsule (0.26g) was found in black cumin R_3 (12 kg K/ha seed rate) treatment which was statistically identical (0.28) to R_2 (10 kg/ha seed rate) treatment.

Paperi Moqaddam and Bohrani (2005) found that with decreasing plant density, number of capsules in plant and capsule weight increased.

Significant variation was found due to the combined effect of elicitors and seed rate on weight of single capsule. The highest weight of single capsule (0.40g) was recorded in T_2R_1 (salicylic acid and seed rate 8 kg/ha seed rate) treatment combination and it was statistically similar (0.38g) to T_4R_1 (pinching and 8 kg K/ha seed rate) treatment combination. The treatment combination T_1R_3 (control and 12 kg/ha seed rate) gave statistically the lowest result (0.17g) which was statistically similar (0.20g) to T_1R_2 (control and 10 kg K/ha seed rate) treatment combination in black cumin plant (Table 6).

Table 5. Effect of elicitors and seed rate on single capsule weight (g), length of capsule (cm), breadth of capsule (cm) and number of seeds per capsule of black cumin.

Treatments **Different types of elicitors**	**Single capsule weight (g)**	**Length of capsule (cm)**	**Breadth of capsule (cm)**	**Number of seeds per capsule**
$\mathbf{T_1}$	0.19 c	1.26 d	0.94 d	83.15 d
$\mathbf{T_2}$	0.36 a	1.60 a	1.34 a	119.55 a
$\mathbf{T_3}$	0.25 b	1.45 c	1.22 c	95.13 c
$\mathbf{T_4}$	0.35 a	1.55 b	1.29 b	116.24 b
$\mathbf{Lsd_{0.05}}$	0.0281	0.0277	0.0344	2.1926
CV%	7.95	6.32	5.21	7.45
Different level of seed rate				
$\mathbf{R_1}$	0.32 a	1.51 a	1.26 a	109.21 a
$\mathbf{R_2}$	0.28 b	1.48 b	1.21 b	104.60 b
$\mathbf{R_3}$	0.26 b	1.41 c	1.12 c	96.75 c
$\mathbf{Lsd_{0.05}}$	**0.0244**	**0.0240**	**0.0298**	**1.8989**
CV%	**7.95**	**6.32**	**5.21**	**7.45**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

Table 6. Combined effect of elicitors and seed rate on single capsule weight (g), length of capsule (cm), breadth of capsule (cm), number of seeds pre capsule of black cumin.

Treatment combination	Single capsule weight (g)	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule
$T_1 R_1$	0.22 ef	1.32 f	1.04 e	84.24 g
$T_1 R_2$	0.20 fg	1.29 f	0.92 f	83.02 g
$T_1 R_3$	0.17 g	1.19 g	0.85 g	82.20 g
$T_2 R_1$	0.40 a	1.65 a	1.39 a	127.29 a
$T_2 R_2$	0.35 bc	1.60 bc	1.39 a	120.07 b
$T_2 R_3$	0.33 c	1.56 c	1.24 c	111.30 c
$T_3 R_1$	0.28 d	1.47 d	1.28 bc	99.48 e
$T_3 R_2$	0.25 de	1.46 de	1.24 c	96.68 e
$T_3 R_3$	0.28 d	1.47 d	1.28 bc	99.48 e
$T_4 R_1$	0.38 ab	1.61 ab	1.32 b	125.81 a
$T_4 R_2$	0.35 bc	1.57 bc	1.31 b	118.63 b
$T_4 R_3$	0.33 c	1.46 de	1.23 c	104.28 d
$Lsd_{0.05}$	**0.0487**	**0.0480**	**0.0595**	**3.7977**
CV%	**7.95**	**6.32**	**5.21**	**7.45**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

4.9 Length of capsule (cm)

Length of capsule was significantly influenced by the elicitors. The longest capsule (1.60cm) was obtained from the T_2 (salicylic acid 50 ppm) treatment and the shortest capsule length (1.26cm) was found from the T_1 (control) treatment (Table 5 and Appendix: VI).

Length of capsule of black cumin plant showed significant difference in case of seed rate. The longest capsule (1.51cm) was obtained from the R_1 (8 kg/ha seed rate) treatment and the shortest capsule (1.41cm) from the R_3 (12 kg K/ha seed rate) treatment (table 5 and Appendix: VI) seed rate.

The length of capsule was significantly influenced by the combined effect of elicitors and seed rate treatment (table 6 and Appendix: VI). The longest capsule was (1.65 cm) obtained from the treatment combination T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) and it was statistically similar to T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination while the shortest (1.19 cm) was observed from the treatment combination of T_1R_3 (control and 12 kg/ha seed rate) in black cumin plant (Table 6).

4.10 Breadth of capsule (cm)

Significant variation was found among the elicitor treatments in case of breadth of the capsule of black cumin plant (Table 5 and Appendix: VI). The maximum breadth of capsule (1.34cm) was obtained from the T_2 (salicylic acid 50 ppm) treatment and the minimum breadth of capsule (0.94cm) was produced from the T_1 (control) treatment.

Application of different levels of seed rate significantly affect the breadth of capsule of black cumin plant (Table 5 and Appendix: VI). The maximum breadth of capsule (1.26cm) was found from the R_1 (8 kg/ha) seed rate treatment and minimum (1.12cm) was obtained from the R_3 seed rate (12 kg/ha) treatment.

Combined application of elicitors and seed rate significantly influenced the breadth of capsule (Table 6 and Appendix: VI). The maximum breadth of capsule (1.39cm) was found from the T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) treatment combination which was statistically identical to T_2R_2 (salicylic acid 50 ppm and 10 kg/ha seed rate) treatment combination and the minimum (0.85cm) was observed from the T_1R_3 (control and 12 kg/ha seed rate) treatment combination.

4.11 Number of seeds per capsule

Significant variation was found due to the effect of elicitors on number of seeds per capsule per plant. The lowest number of seed per capsule (83.15) was recorded from T_1 (control) treatment. The T_2 (salicylic acid 50 ppm) treatment produced statistically highest number of seed per capsule (119.55) in black cumin plant (Table 5 and Appendix VII).

The number of seed per capsule differed significantly due to variation of seed rate (Table 5). Higher number of seed per capsule (109.21) was found in R_1 (8 kg seeds/ha) treatment and lower number of seed per capsule (96.75) was found R_3 (12 kg seeds/ha) treatment. McVetty *et al*. (1988) reported that seed rate positive correlation with the number of seeds per pod.

Significant variation was found due to the combined effect of elicitors and seed rate on number of seed per capsule. The lowest number of seed per capsule (82.20) was recorded from T_1R_3 (control and 12 kg/ha seed rate) treatment combination and it was statistically identical to (83.02) T_1R_2 and (84.24) T_1R_1 treatment combinations. The T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) treatment combination produced statistically the highest number of seed per capsule (127.29) which was statistically identical to (125.81) T_4R_1 (pinching and seed rate 8 kg/ha) treatment combination (Table 6).

4.12 Weight of seed per capsule (mg)

Different types of elicitors had significant effect on weight of seeds per capsule of black cumin (Table 7). Maximum weight of seeds per capsule (288.13 mg) was recorded from T_2 (salicylic acid 50 ppm) treatment and the lowest one (192.99 mg) was given by T_1 (control) treatment.

Seed rate had significant effect on weight of seeds per capsule of black cumin plant (Table 7). R_1 (8 kg/ ha seed rate) treatment gave the highest weight of seeds per capsule (265.63 mg) of black cumin where the R_3 (12 kg/ ha seed rate) treatment gave the lowest (255.71 mg) weight of seeds per capsule.

The treatment combination of elicitors and seed rate had significant effect on weight of seeds per capsule of black cumin under the present study (Table 8). However, the treatment combination T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) supported plants to produce maximum weight of seeds per capsule (291.81 mg) which was statistically similar (289.33 mg) to T_4R_1 (pinching and 8 kg/ ha seed rate) treatment combination of black cumin plant where the lowest one (188.02 mg) was achieved from T_1R_3 (control and 12 kg/ha seed rate) treatment combination.

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 7 and Appendix VII). Weight of seeds per plant was increased with the application of different elicitors. Results revealed that, the highest weight of seeds per plant (8.07 g) was obtained from the plants treated with T_2 (salicylic acid 50 ppm) treatment and the lowest weight of seeds per plant (4.68 g) was observed from the plants treated with T_1 (control) treatment.

Significant variation in weight of seeds per plant was observed among the application of different levels of seed rate represented in (Table 7). Application of R_1 treatment (seed rate 8 kg/ha) gave the highest weight of seeds per plant (7.37 g). The lowest weight of seeds per plant (6.26 g) was obtained from R_3 (12 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 T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) gave the maximum weight of seeds per plant (8.59g) which was statistically similar (8.15 g) to T_4R_1 (pinching and 8 kg/ha seed rate) (Table 8). But the treatment combination T_1R_3 (control and 12 kg/ha seed rate) gave the lowest weight of seeds per plant (4.04g).

Table 7. Effect of elicitors and seed rate on weight of seeds per capsule (mg), weight of seeds pre plant (g), 1000 seed weight (g) of black cumin.

Treatments	Weight of seeds per capsule (mg)	Weight of seeds per plant (g)	1000 seeds weight (g)
Different types of elicitors			
T_1	192.99 d	4.6833 d	2.30 d
T_2	288.13 a	8.0678a	3.04 b
T_3	274.92 c	6.9344 c	2.63 c
T_4	286.18 b	7.65 b	3.24 a
$Lsd_{0.05}$	1.6869	0.3055	0.0747
CV%	5.26	7.25	4.20
Different level of seed rate			
R_1	265.63 a	7.3683a	3.01 a
R_2	260.32 b	6.8733 b	2.79 b
R_3	255.71 c	6.26 c	2.62 c
$Lsd_{0.05}$	**1.4609**	**0.2646**	**0.0647**
CV%	**5.26**	**7.25**	**4.20**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

Table 8. Combined Effect of elicitors and seed rate on weight of seeds per capsule (mg), weight of seeds per plant (g), 1000 seeds weight (g) of black cumin.

Treatment combinations	Weight of seeds per capsule (mg)	Weight of seeds per plant (g)	1000 seeds weight (g)
T_1 R_1	198.77 g	5.23 g	2.42 ef
T_1 R_2	192.17 h	4.78 g	2.33 f
T_1 R_3	188.02 i	4.04 h	2.15 g
T_2 R_1	291.81 a	8.5933a	3.25 b
T_2 R_2	289.33 ab	8.01 bc	3.00 c
T_2 R_3	284.72 cd	7.6 cd	2.87 d
T_3 R_1	267.60 f	7.5 cde	2.95 cd
T_3 R_2	274.56 e	7.0033 e	2.54 e
T_3 R_3	282.61 d	6.3 f	2.41 f
T_4 R_1	289.33 ab	8.15ab	3.40 a
T_4 R_2	286.69 bc	7.7 bc	3.28 ab
T_4 R_3	282.52 d	7.1 de	3.04 c
Lsd $_{0.05}$	**2.9217**	**0.5292**	**0.1294**
CV%	**5.26**	**7.25**	**4.20**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

4.14 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 T_4 (pinching) treatment while lower value (2.30g) was recorded from T_1 (control) treatment (Table 7).

1000-seeds weight (g) varied significantly due to the effect of seed rate. The highest 1000-seeds weight (3.01 g) was given by R_1 (8 kg/ha seed rate) treatment. The lowest 1000-seed weight (2.62 g) was given by R_3 (12 kg/ha seed rate) treatment (Table 7 and Appendix: VII).

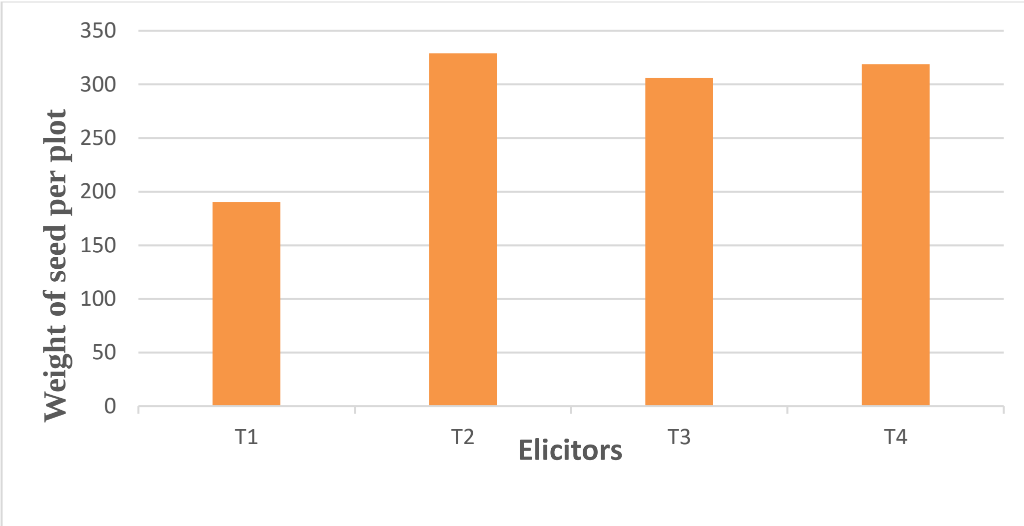
Due to the combined effect of elicitors and seed rate, 1000-seeds weight (g) varied significantly. The maximum 1000-seeds weight (3.40 g) was recorded in T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination and it was statistically similar to T_4R_2 (pinching and 10 kg/ha seed rate) treatment combination. The treatment combination T_1R_3 (control and 12 kg/ha seed rate) which produced the lowest 1000-seeds weight (2.15 g) (Table 8).

4.15 Weight of seed per plot (g)

Weight of seed per plot significantly differed with the application of different types of elicitors (Figure 6 and Appendix VIII). The maximum weight of seed per plot of black cumin (328.99 g) was recorded from T_2 (salicylic acid 50 ppm) treatment and it was statistically similar (319 g) to T_4 (pinching) treatment. However, the T_1 (control) treatment gave the lowest weight of seed per plot (190.47g). Jeyakumar *et. al.* (2008) and Dursun and Yildirim (2009) reported the same findings that salicylic acid increases the flower production rate by enhancing the growth regulators.

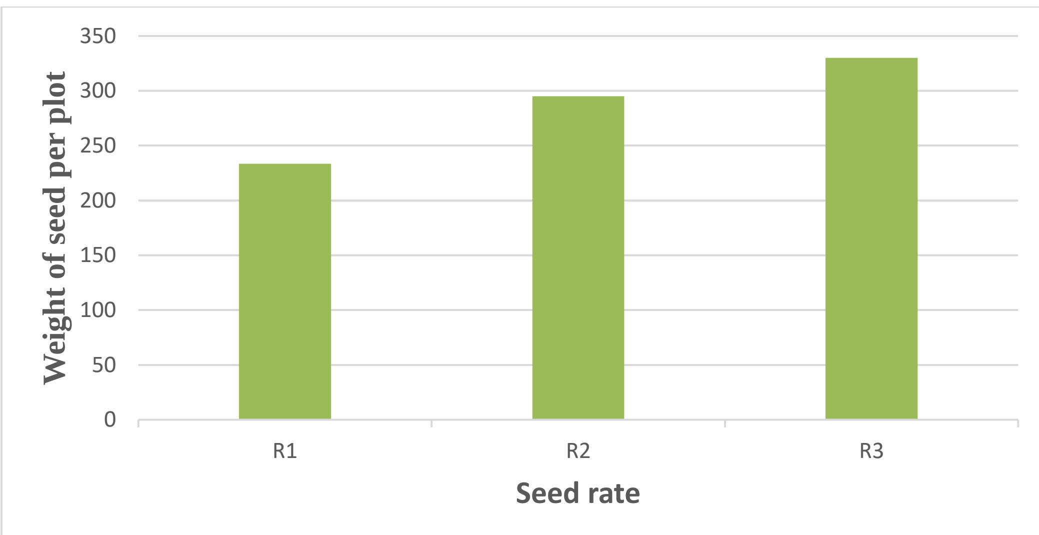
The weight of seed per plot of black cumin significantly differed due to different levels of seed rate (Figure 7 and Appendix VIII). The highest weight of seed per plot (330.01 g) was recorded from R_3 (12 kg/ha seed rate) treatment and R_1 (8 kg/ha seed rate) treatment gave the lowest weight of seed per plot (233.37 g).

The combined effect of elicitors and seed rate showed significant variation on weight of seed per plot of black cumin plant (Table 10 and Appendix VIII). The maximum weight of seed per plot (388.84 g) was recorded from the treatment combination of T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) and which was statistically similar (363.76 g) to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination and the minimum weight of seed per plot (161.67 g) was observed from the T_1R_1 (control and 8 kg/ha seed rate) treatment combination.



Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching.

Fig.6. Effect of elicitors on weight of seed per plot 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.7. Effect of seed rate on weight of seed per plot of black cumin.

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 highest seed yield (3.29 t/ha) was recorded in T_2 (salicylic acid 50 ppm) treatment which was statistically similar (3.19 t/ha) to T_4 (pinching) treatment while the T_1 (control) treatment gave lower value (1.90 t/ha) (Table 9) in black cumin.

Seed yield (t/ha) showed statistically significant variation among the different levels of seed rate treatments. The maximum seed yield (3.30 t/ha) was recorded in R_3 (12 kg/ha seed rate) treatment in black cumin. The lowest seed yield (2.33 t/ha) was obtained from R_1 (8 kg/ha seed rate) treatment (Table 9 and Appendix VIII).

Seed yield (t/ha) showed statistically significant variation due to the combined effect of elicitors and seed rate. Statistically the maximum seed yield (3.89 t/ha) was recorded in T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination and it was statistically similar (3.64 t/ha) to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination. The lowest seed yield (1.62 t/ha) was produced from T_1R_1 (control and 8 kg/ha seed rate) treatment combination (Table 10).

Table 9. Effect of elicitors and seed rate on seed yield (t/ha), weight of stover per plot (g), stover yield (t/ha) of black cumin.

Treatment	**Seed Yield (t/ha)**	**Weight of stover per plot (g)**	**Stover yield (t/ha)**
Different types of elicitors			
T_0	1.9047 c	277.67 c	2.78 c
T_1	3.2899a	390.68 a	3.91 a
T_2	3.0613 b	312.00 b	3.12 b
T_3	3.19 ab	389.67 a	3.89 a
$Lsd_{0.05}$	0.1749	8.6572	0.0866
CV%	5.28	6.75	4.25
Different level of seed rate			
R_1	2.3337 c	315.34 c	3.15 c
R_2	2.9507 b	344.75 b	3.45 b
R_3	3.3001a	367.42 a	3.67 a
$Lsd_{0.05}$	**0.1514**	**7.4973**	**0.0750**
CV%	**5.28**	**6.75**	**4.25**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

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.

Table 10. Combined effect of elicitors and seed rate on weight of seeds per plot (g), seed yield (t/ha), weight of stover per plot (g), stover yield (t/ha) of black cumin.

Treatment combination	Weight of seeds per plot (g)	Seed Yield (t/ha)	Weight of stover per plot (g)	Stover Yield (t/ha)
T_1 R_1	161.67 i	1.6167 i	246.00 h	2.46 h
T_1 R_2	193 h	1.93 h	278.00 g	2.78 g
T_1 R_3	216.74 gh	2.1674 gh	309.00 f	3.09 f
T_2 R_1	265.01 f	2.6501 f	367.37 d	3.67 d
T_2 R_2	333.13 cd	3.3313 cd	391.00 c	3.91 c
T_2 R_3	388.84a	3.8884a	413.67 a	4.14 a
T_3 R_1	225.03 g	2.2503 g	281.00 g	2.81 g
T_3 R_2	342.67 bc	3.4267 bc	304.00 f	3.04 f
T_3 R_3	350.71 bc	3.5071 bc	351.00 e	3.51 e
T_4 R_1	281.78 ef	2.8178 ef	367.00 d	3.67 d
T_4 R_2	311.47 de	3.1147 de	396.00 bc	3.96 bc
T_4 R_3	363.76ab	3.6376ab	406.00 ab	4.06 ab
Lsd $_{0.05}$	**30.287**	**0.3029**	**14.995**	**0.1499**
CV%	**7.25**	**5.28**	**6.75**	**4.25**

Here in a column means having similar letters are statistically similar and within those columns having different letters are differ significantly at 0.05 level of probability.

Here, T_1= Control, T_2= Salicylic acid 50 ppm, T_3= Gibberellic acid 100 ppm, T_4= Pinching,

R_1= 8 kg/ha seed rate, R_2= 10 kg/ha seed rate, R_3= 12 kg/ha seed rate.

4.17 Weight of stover per plot (g)

Weight of stover per plot (g) of black cumin due to different types of elicitors was found remarkably significant (Table 9 and Appendix VIII). The weight of stover per plot (g) was increased with the application of different elicitors. Results demonstrated that, the highest weight of stover per plot (390.68 g) was obtained by the plants treated with T_2 (salicylic acid 50 ppm) treatment which was statistically similar (389.67 g) to T_4 (pinching) treatment and the lowest weight of stover per plot (277.67 g) was produced by the plants treated with T_1 (control) treatment. The higher vegetative growth and higher dry weight per plant may be the main reason of higher weight of stover per plot (g) under present study.

Significant variation was found in weight of stover per plot (g) at different levels of seed rate (Table 9). At R_3 (12 kg/ha seed rate) treatment produced the highest weight of stover per plot (369.92 g) and R_1 (8 kg/ha seed rate) treatment gave the lowest weight of stover per plot (315.34 g).

Elicitors and seed rate in combination influenced weight of stover per plot (g) (Table 10). The treatment combination T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) produced the maximum weight of stover per plot (413.67 g) which was statistically similar (406.00g) to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination. But the T_1R_1 (control and 8 kg/ha seed rate) treatment combination gave the lowest weight of stover per plot (246.00 g).

4.18 Stover yield (t/ha)

Stover yield (t ha^{-1}) of black cumin was found remarkably significant due to the application of different types of elicitors (Table 9 and Appendix VIII). Results demonstrated that, the highest stover yield per hectare (3.91 t ha^{-1}) was produced by the plants treated with T_2 (salicylic acid 50 ppm) treatment which was statistically identical (3.89 t ha^{-1}) to T_3 (pinching) treatment and the lowest yield (2.78 t ha^{-1}) was produced by the plants treated with T_1 (control) treatment. Valadabadi and Aliabadi (2011) reported that, stover yield ranged from 3.49 to 4.23 t ha^{-1}.

In the present study, significant variation was found in stover yield per hectare at different levels of seed rate (Table 9). At 12 kg ha^{-1} seed rate R_3 treatment produced the highest stover yield per hectare (3.70 t/ha) and 8 kg/ha seed rate R_1 treatment gave the lowest stover yield per hectare (3.15 t/ha).

Elicitors and seed rate in combination put significant effect on stover yield per hectare and it was significantly superior (4.14 t/ha) at T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination which was statistically similar (4.70 t/ha) to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination. The T_1R_1 (control and 8 kg/ha seed rate) treatment combination gave the lowest stover yield per hectare (2.46 t/ha) (Table 10).

4.19 Economic analysis:

Economic analysis is the major criteria 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 11).

4.19.1 Cost of cultivation

The total cost of cultivation was observed to range from Tk. 264518 T_1R_1 (control and 8 kg/ha seed rate) treatment combination to Tk. 371648 T_3R_3 (GA_3 100 ppm and 12 kg/ha seed rate) treatment combination. Among all the inputs used in the present investigation, labor and plant hormones contributes more to the cost of cultivation (Table 11 and Appendix IX).

4.19.2 Gross return

Gross returns for different treatment combinations in the present investigation ranged from Tk. 485010 to Tk. 1166520. Among all the treatment combinations studied, T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination gave the highest gross returns of Tk. 1166520 and the lowest gross returns of Tk. 485010 from T_1R_1 (control and 8 kg/ha seed rate) treatment combination (Table 11).

4.19.3 Net return

Highest net returns per hectare of Tk. 832522 in black cumin cultivation under different treatment combinations of elicitors and seed rate studied was obtained from the T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination, whereas lowest net returns of Tk. 220500 obtained from T_1R_1 (control and 8 kg/ha seed rate) treatment combination (Table 11).

4.19.4 Benefit cost ratio (BCR)

From all the treatment combinations studied in the present investigation, T_4R_3 (pinching and 12 kg K/ha seed rate) treatment combination resulted in highest benefit cost ratio of 3.57 and the lowest benefit cost ratio 1.83 was obtained from T_1R_1 (control and 8 kg/ha seed rate) treatment combination (Table 11).

Table 11. Economic analysis of black cumin influenced by elicitors and seed rate

Treatments combination	Total cost of production (A + B)	Yield (Ton/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	BCR
T_1R_1	264518	1.6167	485010	220500	1.83
T_1R_2	266798	1.93	579000	312202	2.17
T_1R_3	294998	2.1674	650220	355222	2.20
T_2R_1	303518	2.6501	795030	461512	2.52
T_2R_2	318758	3.3313	999390	680632	3.14
T_2R_3	333998	3.8884	1166520	832522	3.49
T_3R_1	341168	2.2503	675090	303922	1.89
T_3R_2	356408	3.4267	1028010	671602	2.88
T_3R_3	371648	3.5071	1052130	680482	2.83
T_4R_1	275318	2.8178	845340	570022	3.07
T_4R_2	290558	3.1147	934410	643852	3.22
T_4R_3	305798	3.6376	1091280	785482	3.57

Here,

T_1= Control
T_2= Salicylic acid 50 ppm
T_3 = Gibberellic acid 100 ppm
T_4 = Pinching

R_1= 8 kg/ha Seed rate
R_2= 10kg/ha Seed rate
R_3= 12 kg/ha Seed rate

Selling Price = 300 Tk/Kg seeds

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from November, 2020 to March, 2021 to study the influence of elicitors and seed rate on enhancing the growth, yield and economic benefit of black cumin. The experiment consisted of two factors. Factor A: Elicitors, *viz*. T_1 = control, T_2 = salicylic acid 50 ppm, T_3 = gibberellic acid 100 ppm and T_4 = pinching; Factor B: Seed rate, *viz*. R_1 = 8 kg/ha, R_2 = 10 kg/ha and R_3 = 12 kg/ha. Levels of these two factors made 12 (4×3) treatment combinations and the numbers of plots were 36. The size of the unit plot was 1.00 m × 1.00 m following row to row distance 25 cm. The recorded data on different parameters were statistically analyzed using Statistic 10 software.

Data on different growth parameters and yield contributing characters and yield of black cumin were recorded. Considerable influence was found due to variation of elicitors. Results revealed that in terms of growth parameters, at harvest the highest plant height (87.95 cm) was found in GA_3 100ppm(T_3) treatment, number of leaves per plant (78.04), number of branches per plant (49.29) were found from T_4 (pinching) treatment, on the other hand the lowest plant height (66.66 cm), number of leaves per plant (58.65), number of branches plant^{-1} (25.74) were found from the treatment T_1 (control). In case of yield contributing parameters and yield, at harvest the highest days to first flowering (60.67), days to 50% flowering (67.33) were found from T_4 (pinching) treatment, days required for harvesting (133.56) were found in (T_1) control treatment, on the other hand the lowest days to first flowering (46.11), days to 50% flowering (52.56), days required for harvesting (117.44) were found in GA_3 100 ppm(T_3), at harvest the maximum number of capsule per plant (40.42) was found in T_4 (pinching) treatment, single capsule weight (g) (0.36 g), length of the capsule (1.60 cm), breadth of the capsule (1.34 cm), number of seed per capsule (119.55), weight of seed per capsule (288.13 mg), weight of seed per plant (8.0678 g) were found from(T_2) salicylic acid 50 ppm treatment, 1000 seed weight (3.24 g) was found from T_4 (pinching) treatment, weight of seed per plot (328.99 g), seed yield (3.8884 t/ha) were found from T_2 (salicylic acid 50 ppm) treatment, weight of stover per plot (390.68g), stover yield (3.91 t/ha) were found from (T_2) salicylic acid 50 ppm treatment, on the other hand the lowest number of capsule per plant (19.98), single capsule weight (0.19 g), length of the capsule (1.26 cm), breadth of the capsule (0.94 cm), number of seed per capsule (83.15), weight of seed per capsule (192.99 mg), weight of seed per plant (4.6833 g), 1000 seed weight (2.30 g), weight of seed per plot (190.47 g), seed yield (1.9047 t/ha), weight of stover per plot (277.67 g)**,** stover yield (2.78 t/ha) were found from the treatment T_1 (control).

Considerable influence was found due to the effect of different levels of seed rate. Results obtained that in terms of growth parameters, maximum plant height (80.54 cm) was found from 12 kg/ha seed rate (R_3) treatment, number of leaves per plant (71.23), number of branches plant^{-1} (41.42) were found from 8 kg/ha seed rate (R_1) treatment, on the other hand the lowest plant height (74.70 cm) was found from 8 kg/ha seed rate (R_1) treatment, number of leaves per plant (66.85), number of branches plant^{-1} (35.98) were found from 12 kg/ha seed rate (R_3) treatment. In case of yield contributing parameters and yield, at harvest the highest days to first flowering (55.57), days to 50% flowering (60.58), days required for harvesting (126.08) were found from 12 kg/ha seed rate (R_3) treatment, on the other hand the lowest days to first flowering (45.80), days to 50% flowering (58.58), days required for harvesting (123.50) were found from 8 kg/ha seed rate (R_1) treatment, at harvest the maximum number of capsule per plant (36.10) was found from 8 kg/ha seed rate (R_1) treatment, single capsule weight (g) (0.32), length of the capsule (1.51cm), breadth of the capsule (1.26 cm), number of seed per capsule (109.21), weight of seed per capsule (265.63 mg), weight of seed per plant (7.3683 g), 1000 seed weight (3.01g) were found from 8 kg/ha seed rate (R_1) treatment, weight of seed per plot (330.01 g), seed yield (3.3001 t/ha), weight of stover per plot (369.92 g)**,** stover yield (3.70 t/ha) were found from 12 kg/ha seed rate (R_3) treatment, on the other hand the lowest number of capsule per plant (28.74), single capsule weight (0.26 g), length of the capsule (1.41 cm), breadth of the capsule (1.12 cm), number of seed per capsule (96.75), weight of seed per capsule (255.71 mg), weight of seed per plant (6.26 g), 1000 seed weight (2.62 g) were found from 12 kg/ha seed rate (R_3) treatment, weight of seed per plot (233.37 g), seed yield (2.3337 t/ha), weight of stover per plot (315.34 g)**,** stover yield (3.15 t/ha) were found from the treatment R_1 (8 kg/ha seed rate).

In case of combined effect of elicitors and seed rate the highest plant height (92.93 cm) at harvest was observed from T_3R_3 (GA_3 100 ppm and 12kg/ha seed rate) treatment combination, number of leaves per plant (80.23) was observed from T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination, while shortest plant height (63.80 cm) was recorded from T_1R_1 (control and 8kg/ha seed rate), number of leaves (58.40) was found fromT_1R_2 (control and 10kg/ha seed rate) treatment combination. Maximum number of branches plant^{-1} (51.63) was recorded from T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination, where minimum number of branches plant^{-1} (24.23) was recorded from T_1R_3 (control and 12 kg/ha seed rate) treatment combination. The highest days to first flowering (62.33), days to 50% flowering (68.33) were observed from T_3R_3 (pinching and 12 kg/ha seed rate) treatment combination, days required for harvesting (134.67) was found from T_1R_1 (control and 8kg/ha seed rate) treatment combination, the lowest days to first flowering (45.33), days to 50% flowering (52.00), days required for harvesting (115.67) were found from T_3R_1 (GA3 100ppm and 8kg/ha seed rate) treatment combination. The maximum number of capsule per plant (44.23) was found from T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination, single capsule weight (g) (0.40 g), length of the capsule (1.65cm), breadth of the capsule (1.39 cm), number of seed per capsule (127.29), weight of seed per capsule (291.81 mg) and weight of seed per plant (8.5933 g) were observed from T_2R_1 (salicylic acid 50 ppm and 8 kg/ha seed rate) treatment combination, 1000 seed weight (3.40g) was found from T_4R_1 (pinching and 8 kg/ha seed rate) treatment combination, weight of seed per plot (388.84 g), seed yield (3.8884 t/ha), weight of stover per plot (413.67 g), stover yield (4.14 t/ha) were found from T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination, while the minimum number of capsule per plant (17.62), single capsule weight (0.17 g), length of the capsule (1.19 cm), breadth of the capsule (0.85 cm), number of seed per capsule (82.20), weight of seed per capsule (188.02 mg), weight of seed per plant (4.04 g), 1000 seed weight (2.15 g) was found from T_1R_3 (control and 12 kg/ha seed rate) treatment combination, weight of seed per plot (161.67 g), seed yield (1.6167 t/ha), weight of stover per plot (246.00 g), stover yield (2.46 t/ha) were found from T_1R_1 (control and 8 kg/ha seed rate) treatment combination.

The highest gross return (Tk. 1166520) was obtained from T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) treatment combination and the lowest gross return (Tk. 485010) was recorded from T_1R_1 (control and 8 kg/ha seed rate). The lowest net return (Tk. 220500) was recorded from T_1R_1 (control and 8 kg/ha seed rate) treatment combination and the highest net return (Tk. 832522) was obtained from T_2R_3 (salicylic acid 50 ppm and 12 kg/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 8 kg/ha seed rate) treatment combination.

Conclusion:

Considering the above result of the present experiment, the following conclusion
can be drawn:

- Elicitor T_2 (salicylic acid 50 ppm) treatment showed better performance and which is statistically similar to T_4 (pinching) treatment.
- Seed rate R_3 (12 kg/ha) treatment was superior than other seed rate.
- The treatment combination of T_2R_3 (salicylic acid 50 ppm and 12 kg/ha seed rate) showed the best potentiality which is statistically similar to T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination.
- From economic consideration, the highest BCR was obtained from T_4R_3 (pinching and 12 kg/ha seed rate) treatment combination. So, it can be concluded that the treatment combination T_4R_3 (pinching and 12 kg/ha seed rate) was given better performance and highest profitability than other treatment combination.

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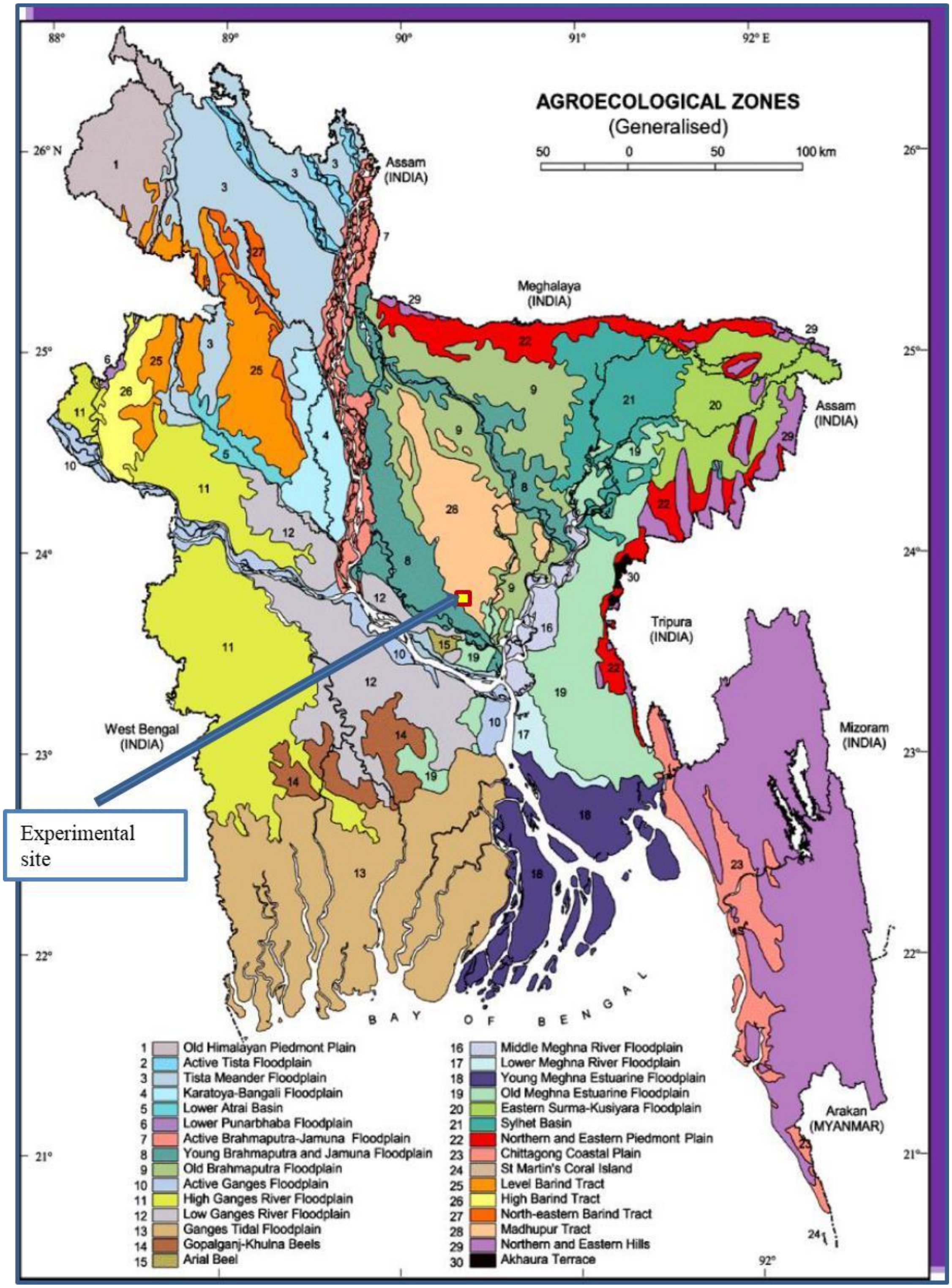
APPENDICES

Appendix I. **Map showing the experimental site under the study**



Appendix II. Characteristics of Sher-e-Bangla Agricultural University soil is analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka A. Morphological characteristics of the experimental field.

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural
AEZ	Madhupur Tract (28)
General soil type	Shallow Red Brown Terrace Soil
Land Type	High land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fellow-Tomato

B. Physical composition of the soil

Soil separates	%
Sand	27
Silt	43
Clay	30
Texture class	Sandy loam

C. Chemical composition of the soil

Soil characteristics	Analytical data
PH	5.47 – 5.63
Organic carbon (%)	0.46
Organic matter (%)	0.83
Total N (%)	0.05
Available P (ppm)	20.00
Available S (ppm)	46
Exchangeable K (me/ 100 gm soil)	0.12

Source: Soil Resources Development Institute (SRDI)

Appendix III. Analysis of variance of the data on plant height at different days after sowing (DAS) of black cumin as influenced by elicitors and seed rate.

Source of variation	Degree of freedom	Plant height (cm) at different days after sowing			
		40DAS	60DAS	80DAS	At Harvest
Replication	2	2.6938	1.059	0.163	3.533
Elicitors(A)	3	17.6701**	842.626**	682.897**	699.999**
Seed rate (B)	2	89.0718**	53.731**	105.437**	102.419**
Interaction(AxB)	6	0.9095**	1.809**	10.165**	5.294**
Error	22	0.8675	0.54	0.534	4.202

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix IV. Analysis of variance of the data on number of leaves at different days after sowing (DAS) of black cumin as influenced by elicitors and seed rate.

Source of variation	Degree of freedom	Number of leaves at different days after sowing		
		40DAS	60DAS	80DAS
Replication	2	0.0833	0.466	0.988
Elicitors(A)	3	28.2316**	853.492**	629.328**
Seed rate (B)	2	10.3341**	102.379**	58.173**
Interaction(AxB)	6	0.6216**	4.287**	0.814**
Error	22	0.0852	0.974	0.715

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix V. Analysis of variance of the data on number of branches per plant, days of first flowering, days to 50% flowering, number of days need for harvesting of black cumin as influenced by elicitors and seed rate.

Source of variation	Degree of freedom	Number of branches per plant	Days of first flowering	Days to 50% flowering	Number of days need for harvesting
Replication	2	0.37	0.083	1.333	0.194
Elicitors (A)	3	1015.8**	388.917**	488.667**	430.102**
Seed rate(B)	2	89.64**	14.083**	12.25**	20.194**
Interaction(AxB)	6	4.98**	1.417**	2.361**	0.491**
Error	22	0.15	0.326	0.394	0.467

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix VI. Analysis of variance of the data on number of capsules per plant, single capsule weight, length of single capsule, breadth of single capsule of black cumin as influenced by elicitors and seed rate.

Source of variation	Degree of freedom	Number of capsules per plant	Single capsule weight	Length of the capsule (cm)	Breath of the capsule (cm)
Replication	2	0.02	0.00046	0.0006	0.00501
Elicitors (A)	3	809.681**	0.05689**	0.19855**	0.28552**
Seed rate(B)	2	162.748**	0.00918**	0.0362**	0.06003**
Interaction(AxB)	6	3.292**	0.00014**	0.00182**	0.00314**
Error	22	0.004	0.00087	0.00083	0.00091

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix VII. Analysis of variance of the data on number of seeds per capsule, weight of seeds per capsule (g), weight of seeds per plant (g), 1000 seeds weight (g) of black cumin as influenced by elicitors and seed rate

Source of variation	Degree of freedom	Number of seeds per capsule	Weight of seeds per capsule (g)	Weight of seeds per plant (g)	1000 seed weight
Replication	2	1.1	2.1	0.0013	0.01082
Elicitors (A)	3	2712.28**	18610**	19.1606**	1.5868**
Seed rate(B)	2	475.56**	342.7**	2.9278**	0.45272**
Interaction(AxB)	6	54.83**	20.3**	0.1337**	0.01833**
Error	22	5.44	1.3	0.0033	0.00545

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix VIII. Analysis of variance of the data on weight of seeds per plot (g), seed yield (t/ha), weight of stover per plot (g), stover yield (t/ha) of black cumin as influenced by elicitors and seed rate

Source of variation	Degree of freedom	Weight of seeds per plot (g)	Seed Yield (t/ha)	Weight of stover per plot (g)	Stover yield (t/ha)
Replication	2	40.3	0.00403	71.6	0.00716
Elicitors (A)	3	24835**	2.4835**	29038.2**	2.90382**
Seed rate(B)	2	6783.3**	0.67833**	8180.9**	0.81809**
Interaction(AxB)	6	190.3**	0.01902**	484.7**	0.04847**
Error	22	54.3	0.00543	79.9	0.00799

* Significant at 0.05 level of probability; **Significant at 0.01 level of probability and ^{ns}Non-significant

Appendix IX. Production cost of black cumin per hectare

A. Material cost (Tk./ha)

Treatment combinations	Black cumin Seed cost	Plant Hormone	Fertilizers and manures				Pesticides	Sticking	Sub Total
		GA$_3$ and Salicylic acid (cost)	Urea	TSP	MoP	Cow dung		Bamboo and thread	(A)
T_1R_1	4800	0	2750	2090	1125	40000	4000	30000	84765
T_1R_2	6000	0	2750	2090	1125	40000	6000	35000	92965
T_1R_3	7200	0	2750	2090	1125	40000	8000	40000	101165
T_2R_1	4800	15000	2750	2090	1125	40000	4000	30000	102265
T_2R_2	6000	15000	2750	2090	1125	40000	6000	35000	110465
T_2R_3	7200	15000	2750	2090	1125	40000	8000	40000	118665
T_3R_1	4800	50000	2750	2090	1125	40000	4000	30000	133640
T_3R_2	6000	50000	2750	2090	1125	40000	6000	35000	141840
T_3R_3	7200	50000	2750	2090	1125	40000	8000	40000	150040
T_4R_1	4800	0	2750	2090	1125	40000	4000	30000	84765
T_4R_2	6000	0	2750	2090	1125	40000	6000	35000	92965
T_4R_3	7200	0	2750	2090	1125	40000	8000	40000	101165

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

Labor cost: 300 Tk. per person

Black cumin seed @ Tk. 600 kg^{-1}

Urea @ Tk. 22 kg^{-1}

TSP @ Tk. 22 kg^{-1}

MoP @ Tk. 15 kg^{-1}

GA$_3$ @ Tk. 500 g^{-1}

Salicylic acid @ Tk. 300 g^{-1}

Cowdung @ Tk. 5000 t^{-1}

B. Non-material cost (Tk./ha)

Treatment combinations	Cultivation with labour	Seed sowing cost	Spray and Pinching (labour cost)	Sticking with labour	Intercultural operation	Harvesting cost	Sub-total (B)	Total input cost (A+B)
T_1R_1	15000	6000	0	12000	24000	12000	69000	153765
T_1R_2	15000	7500	0	12000	24000	15000	73500	155665
T_1R_3	15000	9000	0	12000	24000	18000	78000	179165
T_2R_1	15000	6000	15000	12000	24000	12000	84000	186265
T_2R_2	15000	7500	15000	12000	24000	15000	88500	198965
T_2R_3	15000	9000	15000	12000	24000	18000	93000	211665
T_3R_1	15000	6000	15000	12000	24000	12000	84000	217640
T_3R_2	15000	7500	15000	12000	24000	15000	88500	230340
T_3R_3	15000	9000	15000	12000	24000	18000	93000	243040
T_4R_1	15000	6000	9000	12000	24000	12000	78000	162765
T_4R_2	15000	7500	9000	12000	24000	15000	82500	175465
T_4R_3	15000	9000	9000	12000	24000	18000	87000	188165

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

Labor cost: 300 Tk. per person

C. Overhead cost (Tk./ha)

Treatments combination	Overhead cost (Tk./ha)				Total cost of production
	Cost of leased land for 6 months (13% value of land tk-6,00000)	Miscellaneous cost (Tk-5% of the input cost)	Interest on running capital for 6 months (15% of cost per year)	Sub total (B)	
T_1R_1	80000	7688	23065	110753	264518
T_1R_2	80000	7783	23350	111133	266798
T_1R_3	80000	8958	26875	115833	294998
T_2R_1	80000	9313	27940	117253	303518
T_2R_2	80000	9948	29845	119793	318758
T_2R_3	80000	10582	31750	122332	333998
T_3R_1	80000	10882	32646	123528	341168
T_3R_2	80000	11517	34551	126068	356408
T_3R_3	80000	12152	36456	122608	371648
T_4R_1	80000	8138	24415	112553	275318
T_4R_2	80000	8773	26320	115093	290558
T_4R_3	80000	9408	28225	117633	305798

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

Plate 1. The pictorial view of the land layout of the experimental field.

Plate 2. Pictorial presentation of measuring the plant height of black cumin.

Plate 3. Pictorial presentation of pinched plant of black cumin.

Plate 4. Pictorial presentation of flowers of black cumin.

Plate 5. Pictorial presentation of control condition (T_1) treatment plot of black cumin.

Plate 6. Pictorial presentation of salicylic acid (T_2) treatment plot of black cumin.

Plate 7. Pictorial presentation of gibberellic acid (T_3) treatment plot of black cumin.

Plate 8. Pictorial presentation of pinching (T_4) treatment plot of black cumin.

Plate 9. Pictorial presentation of highest plant height of T_3 (Gibberellic acid) treatment then other treatment of black cumin plant.

Plate 10. Pictorial presentation of branches of black cumin plant of different treatment.

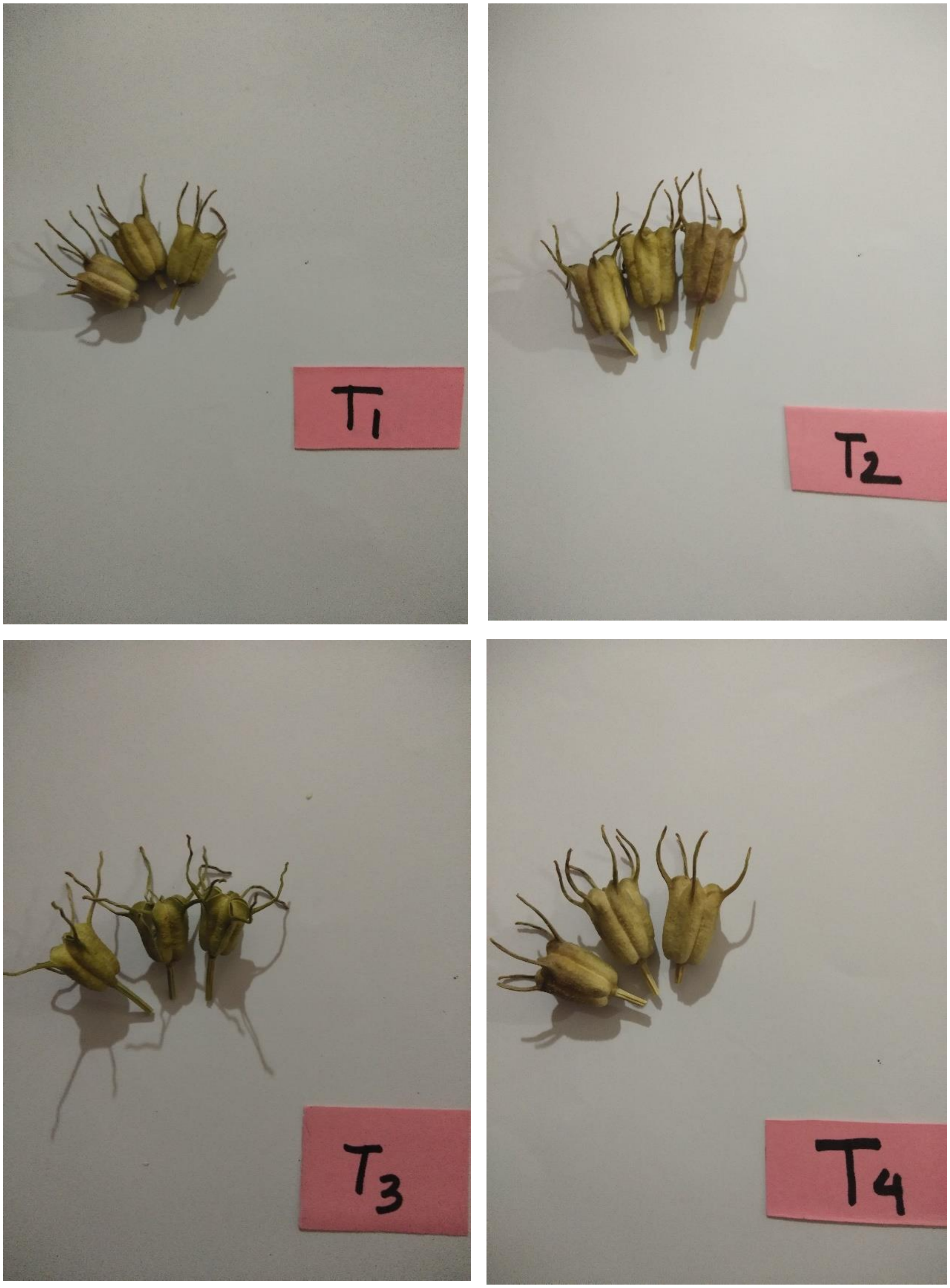


Plate 11. Pictorial presentation of capsules with different treatment of black cumin.