INFLUENCE OF PHOSPHORUS FERTILIZATION AND SEED RATES ON GROWTH AND YIELD OF BLACK CUMIN (*Nigella sativa* L.)

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CERTIFICATE

*This is to certify that the thesis entitled **'INFLUENCE OF PHOSPHORUS FERTILIZATION AND SEED RATES ON GROWTH AND YIELD OF BLACK CUMIN (Nigella sativa L.)'** 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 (MS)** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **MD. RAFI KHAN**, Registration number: **18-09112,** 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 duly been acknowledged.

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Dedicated to My Beloved Parents

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The Author

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ABSTRACT

The experiment was carried out at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2019 to March 2020 to study influence of phosphorus fertilization and seed rates on growth and yield of black cumin. The experiment consisted of two factors. Factor A: Four levels of phosphorus *viz.*, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1} 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}. The experiment was laid out in a Randomized Complete Block Design with three replications. Data were recorded on growth, yield components and yield of black cumin and significant variation was observed for most of the studied characters. Growth related data was maximum on P_3 (45 kg P ha^{-1}) treatment but in case of seed yield, P_2 (40 kg P ha^{-1}) 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. In case of different levels of phosphorus, the highest seed yield (1.22 t ha^{-1}) was obtained from P_2 (40 kg P ha^{-1}) treatment whereas the lowest seed yield (0.98 t ha^{-1}) was obtained from P_0 (control) treatment. In case of different seed rates, the highest seed yield (1.14 t ha^{-1}) was obtained from R_2 (10 kg seeds ha^{-1}) treatment whereas the lowest seed yield (1.07 t ha^{-1}) was obtained from R_3 (12 kg seeds ha^{-1}) treatment. So, it was observed that the highest seed yield (1.27 t ha^{-1}) was obtained from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand, the lowest seed yield (0.94 t ha^{-1}) was obtained from of P_0R_3 (control + 12 kg seeds ha^{-1}) 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.

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LIST OF ACRONYMS

Acronym		Full meaning
AEZ	=	Agro-Ecological Zone
%	=	Percent
^0C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

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INTRODUCTION

Nigella (*Nigella sativa* L.) is well known as black cumin or kalojira. The name nigella derives from the Latin nigellus or niger, meaning black kalajira is an annual herbaceous plant belonging to the Ranunculaceae family. *Nigella* is an important seed spice has originated from Mediterranean region of Asia to North India. *Nigella* is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan, India and Turkey (Pal, 2012). In Bangladesh, it covers 14742 hectares of land, with total annual production of 16526 tons (DAE, 2017), over the Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kushtia, Bogra, Rangpur and Natore districts (Ali *et al.*, 2015; Noor *et al*., 2008).

The ripe seed of black cumin contains 7% moisture, 4.34% ash, 23% protein, 0.39% fat, 4.99% starch and 5.44% raw fiber (Mozaffarian *et al.*, 2000). The seeds are rich in fats, fiber, and minerals such as Fe, Na, Cu, Zn, P, Ca and vitamins such as ascorbic acid, thiamin, niacin, pyridoxine, and folic acid (Takruri and Dameh, 1998). *N. sativa* seeds contain 30-35% oil and 0.5-1.5% essential oil which have several uses for pharmaceutical and food industries (Ustun *et al*., 1990; Ashraf *et al*., 2006). Seed has essence and a bitter nigeline substance. Black cumin seeds contain protein, alkaloids (nigellicines and nigelledine), saponin (α-hederin) fixed and essential oil (Ozel *et al*., 2009). The fixed and essential oil of black cumin contain various bioactive molecules such as thymoquinone, thymol, tocopherol, *trans* retinol and selenium (Sultan *et al*., 2009). Seeds of this plant were used both as spice and medicine since a very long time. The seeds are bitter in taste and consumption of whole seed even in small quantity gives a feeling of constriction of throat. It is appropriately known as *seed of blessing* (*habbatul barakah*). The spice was attributed with numerous medicinal properties and is widely used in unani, ayurveda, siddha and other ethnomedicine systems across the world (Srivastava, 2014).

The medicinal value of the spice is immense and numerous workers appreciated its unique, varied and powerful pharmacological traits. The popularity of the plant was highly enhanced by the ideological belief in the herb as a cure for multiple diseases likes anti-tumour, anti-diabetic, cardio-protective, gastro-protective, anti-asthmatic, nephron-protective, hepato-protective, anti-inflammatory, immune-modulatory, neuro-protective, anti-convulsant, anxiolytic, antioxidant, anti-nociceptive, anti-oxytocic, contraceptive, anti-bacterial, anti-fungal and anthelmintic activities were immensely appreciated. The major medicinal components are *thymoquinone* and *nigellone* (a dimer of thymoquinone). These were attributed to impart anti-tumour, anti-inflammatory and anti-diabetic properties (Rimu *et al.,* 2020; Turkdogan *et al.,* 2001; Al-Jassir, 1992).

Now-a-days, nutrients content in soil is the most limiting factor for proper growth and yield of plants. The requirements of different plant nutrients vary with different crops. Phosphorus (P) is critical in plant metabolism which plays an important role in cellular energy transfer, respiration, photosynthesis and it is a key structural component of nucleic acids coenzymes, phosphorproteins and phospholipids. Phosphorus fertilization is a major input in crop production (Blackshaw *et al.,* 2004). Phosphorus is essential for the general health of the plant and root development and more stem strength. It improves flower formation and makes seed production more uniform. It also improves seed quality and resistant to plant disease. Plant growth and seed yield was increased when phosphorus was applied (Bairagi, 2014; Purbey and Sen, 2005). Sharma *et al.* (2014) obtained maximum number of primary branches per plant, pods per plant, seeds per pod, seed yield from optimum P application. It is also reported that an increase in seed yield was obtained with judicious application of phosphorous (Khiriya *et al*., 2001; Khiriya *et al*., 2003 and Sheoran *et al*., 1999). The vegetative growth in terms of plant height, number of leaves and number of branches and the yield parameters in respect to number of pods per plant, seeds per pod, seed yield per plant, seed yield per plot, seed yield per hectare and test weight were observed significantly maximum in due to an application of nitrogen and phosphorus. The maturity parameters like number of days required for first flower initiation, days required for 50% flowering, first pod formation, 50% pod formation and maturity of seed crop were found to be delayed with an increased level of nitrogen and phosphorus per hectare (Jagdale and Dalve, 2010).

Seed rate is one of the main key factors for obtaining high yield and quality in the production of crops. Seed rate is the key factor determining effecting the yield and yield components. Several studies carried out in countries where systematically cultivated, have demonstrated that suitable seed rate can increase the growth and yield of *N. sativa* (Toncer and Kizil, 2004; Tuncturk *et al.*, 2004). Seed rate significantly affected plant height, number of branch per plant, number of capsule per plant, seed yield per plant and seed yield. High seed rates reduced number of branch, number of capsule per plant, seed yield per plant and seed yield. Seed rate did not affect thousand seed weight, number of seed per capsule, essential oil and fatty oil rate (Toncer and Kizil, 2004). It was reported that 8 kg seed/ha would be the optimum seed rate and line sowing in raised bed would be the most effective method for higher seed yield of the black cumin. But for broadcasting seeds should be shown with 10 kg/ha (Fahim *et al.*, 2017).

Keeping the above facts in view the present experiment was undertaken with following objectives:

i. To investigate the effect of phosphorus fertilization on growth and seed yield of black cumin.

ii. To observe the influence of seed rates on growth and seed yield of black cumin.

iii. To find out the suitable combination of phosphorus fertilization and seed rates for better growth and higher seed yield of black cumin.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The yield of black cumin may be increased through appropriate combination of different levels of phosphorus and seed rates. Though black cumin is cultivated in many parts of our country, very little research work has so far been conducted on the appropriate levels of phosphorus with suitable seed rates. Research findings regarding the growth and seed yield of black cumin as influenced by different levels of phosphorus and seed rates under Bangladesh condition is very limited. With the above background, some of the pertinent works have been reviewed in this chapter.

2.1 Effect of different levels of phosphorus

Moradzadeh *et al.* (2021) carried out an experiment to find out the combined effect of combined bio-chemical fertilizers ameliorate agro-biochemical attributes of black cumin (*Nigella sativa* L.). Therefore, the combined effect of urea and biofertilizers was studied on the quantitative and qualitative traits of *N. sativa* L. in a randomized complete block design with 10 treatments and three replications. The treatments included control (no fertilization), U (100% chemical fertilizer as urea at 53.3 kg ha^{-1}, Nb (Biofertilizer, *Azotobacter vinelandii*), Pb (Biofertilizer, *Pantoea agglomerans* and *Pseudomonas putida*), Kb (Biofertilizer, *Bacillus spp.*), NPKb (NPK, biofertilizer), Nb + 50% U, Pb + 50% U, Kb + 50% U and NPKb + 50% U. The NPK(b) + U50% was related to the highest quantity of plant height, branch diameter, capsule (follicle) number per plant, auxiliary branches, seed yield per plant, thousand-seed weight, essential oil content, total phenolic compounds, flavonoid content, DPPH free radical scavenging, nitric oxide (NO) radical scavenging, superoxide radical scavenging, chain-breaking activity, phosphorus content, and potassium content, along with U for the highest biological yield and (Pb) + U50% for the highest essential oil percentage which is close to (NPKb) + U50%. The lowest value was observed in all traits related to the control treatment except for branch diameter that was related to (NPKb). Hence, the application of (NPKb) + U50% as bio-chemical fertilizers improved *N. sativa* L. Traits, so it can be recommended.

Rimu *et al.* (2020) conducted a research to investigate the effects of organic and inorganic fertilizer application on the yield and quality of black cumin. Among the inorganic fertilizer, mainly the dose of phosphorus was different. Other doses of inorganic fertilizers were constant. Cowdung and organic compost were used as organic fertilizer. The first emergence and the highest plant height at different days after sowing were recorded from treatment T_7 (N_{60} + P_{60} + K_{50} + S_{10} + Zn_3 (kg/ha) + cowdung @ 5 t/ha). The minimum period required for first flowering (67.89 days) was recorded in treatment T_7. However, the first capsule was formed in the plot at 85.48 days after sowing where treatment T_4 (N_{60} + P_{60} + K_{50} + S_{10} + Zn_3 (kg/ha) was imposed. The maximum days required for flowering and capsule formation was recorded in control plot. The highest number of primary branches (5.53), maximum fresh weight (30.73 g) of single plant was noted from treatment T_7. The highest number of capsules per plant (27.2), number of seeds per capsule (135) and seed yield per plant (5.24 g) were recorded from treatment T_7. While the highest oil content (24.59%) was recorded in T_5 (N_{60} +P_{50} + K_{50} + S_{10} + Zn_3 (kg/ha) + cowdung 5 t/ha, followed by T_8 (24.25%). Oil content was the lowest in control treatment. The highest amount of magnesium in black cumin seeds (0.065%) was noted in T_7 (N_{60} + P_{60} + K_{50} + S_{10} + Zn_3 (kg/ha) + cowdung @ 5 t/ha), while the maximum contents of nitrogen (5.68 %), potassium (0.141%) and iron (0.031 ppm) were noted in treatment T_8 (N_{60} + P_{50} + K_{50} + S_{10} + Zn_3 (kg/ ha + organic compost at 5 t/ha). On the contrary, the highest contents of phosphorus (0.0337%), calcium (0.396%) and the zinc (0.0195 ppm) were observed in treatment T_{10} (N_{60} + P_{60} + K_{50} + S_{10} + Zn_3 (kg/ha) + organic compost at 5 t/ha).

Sultana *et al.* (2019) carried out an investigation during *rabi* 2017 and 2018 in the Malda district on, optimum N and P application levels to get high yield and quality in nigella four levels of nitrogen (0, 20, 40 and 60 kg nitrogen ha^{-1}) and phosphorus (0, 15, 30 and 45 kg phosphorus ha^{-1}). The study on application of different levels of nitrogen and phosphorus revealed that all the traits were influenced by N and P application. There was interaction effect in the traits like plant height (60, 90 DAS and at harvest), capsule yield, husk yield. N and P application levels improved the plant height, number of leaves per plant and number of branches per plant at different stages of growth. Similar response was observed in fresh and dry matter accumulation. Minimum total chlorophyll content, The yield contributing characters like capsule weight at harvest, capsule length and diameter, number of capsules, number of seeds per capsule, test weight, capsule yield per plant and grain yield per plant increased with level of application of N and generally maximum values were observed in highest N application. Similar response was observed with P application. Seed yield and stalk yield were maximum at highest N application. Seed yield was maximum with the application of phosphorus 45 and 30 kg ha^{-1}. The uptake of N, P and K increased with the increase of N and P applications. Lower available nitrogen and potassium, and higher available phosphorus status was observed after harvest than initial soil status. The highest Benefit Cost Ratio (BCR) was recorded with the crop sown during the October. The application of 60 kg N ha^{-1} in two splits as basal and at 35 DAS with 30 kg P ha^{-1}.

Mousa *et al.* (2012) carried out an experiment during the 2004-2005 and 2005-2006 seasons at the Floriculture Nursery, Experimental Farm, Faculty of Agriculture, Assiut University to investigate the effects of plant spacing (15 and 30 cm) and various fertilizer treatments; cattle manure (15 m^3/feddan), NPK fertilization [ammonium nitrate (33.5% N) 60, calcium superphosphate (15.5% P_2O_5) 45, and potassium sulphate (48% K_2O) 48 kg/feddan] and bio-fertilizers [Biogen (500 g) and phosphorein (300 g/Kg seeds) were added either individually or in combination]. A complete randomized block design in a split-plot arrangement with four replicates was used in this experiment. Plant spacing was randomly distributed in the main plots and fertilizer treatments in the sub plots. Data obtained showed that significant increases were found in branch number, seed production, yields of volatile and fixed oil in seeds in relation to plant spacing of 30cm comparison to that of 15 cm. Moreover, leaf contents of carbohydrates, nitrogen, phosphorous and potassium recorded similar trend. All fertilizer treatments significantly increased plant height and branch number per plant compared to unfertilized plants. However, cattle manure was more effective in this concern. Cattle manure produced higher yields of seeds and volatile oil than other treatments. In addition, it significantly increased leaf contents of carbohydrates, N, P and K. The interaction among treatments cleared that the space of 30 cm along with cattle manure yielded the best results.

Vedantham *et al.* (2020) conducted an experiment in the Vegetable Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh). Thirteen treatments having one cultivar were laid out in Randomized Block Design (RBD) with three replications.

Find out the effect of nitrogen, phosphorus and Potassium (NPK) on growth, and yield of black cumin. On the basis of present investigation it is concluded that the application of treatment T_6= 70:65:65 (Urea=152.17 kg/ha, Single Super Phosphate= 406.25 kg/ha, Murate of Pottash= 108.33 kg/ha) was superior in terms of growth and yield *viz.* plant height (60.23 cm), number of primary branches per plant (8.25), number of primary branches per plant (14.96), days to flower bud appearance (63.48), days to 50% flowering (56.46), number of capsule plant^{-1} (37.47), seed yield plant^{-1} (8.59 g), seed yield plot^{-1} (103.12 g) and seed yield (7.20 q ha^{-1}) of Black cumin.

Sen *et al.* (2019) conducted a field experiment during rabi seasons of 2014–15 and 2015–16 to study the effects of various combination of different levels of inorganic, organic and bio-fertilizers (Azophos) on the vegetative growth, yield contributing attributes and quality of seeds of black cumin. The results showed that the combination of 100% RDF (Recommended Dose of Fertilizer) + 15 t ha^{-1} FYM (Farm Yard Manure) + 4 kg ha^{-1} Azophos significantly improved most of the parameters related to growth of plant, seed yield and net returns. However, for production of seed oil, 75% RDF of chemical fertilizers + FYM + bio-fertilizer was recorded was the best. Most of the soil properties were improved by application of 100% RDF + FYM. Therefore from the results, it could be suggested that inclusion of organic manure and bio-fertilizer along with 100% (RDF) is the best combination for seed production of black cumin whereas for better quality seed oil 25% RDF can be substituted with FYM and biofertilizer (Azophos) in terai region of West Bengal.

Kizil *et al.* (2008) carried out an experiment to evaluate the effects of sowing periods and P application rates on yield and oil composition of black cumin (*Nigella sativa* L.). The study reports effects of winter and spring sowings and 0, 40, 80, 120 and 160 kg ha^{-1} triple super phosphate (P) application on yield, yield components and fatty acid composition of black cumin during 2003-2004 and 2004-2005 at Diyarbakir, Turkey. The fatty acid methyl esters (FAMEs) were extracted from the reaction vials with hexane. The GC (gas chromatography) analysis was carried out by means of a Varian 3400 apparatus equipped with Supelcowax-10 fused silica capillary column. The results showed that vegetative growth period was the major and meteorological conditions and P doses were the minor factors controlling yield components; such that winter sowing resulted in maximum seed yield (1037 to 1534 kg ha^{-1}), fatty oil content (30.2 to 37.9%) and essential oil content (0.31 to 0.56%). Major constituents of fatty oil were determined as linoleic, palmitic and oleic acid. The percentage of linoleic acid was determined between 43.34 and 51.50%.

Yimam *et al.* (2015) conducted a field experiment at Duka, Konta district to determine the effect of nitrogen (N) and phosphorous (P) fertilizers on growth, yield and yield components of black cumin. Five levels of N (0, 15, 30, 45 and 60 kg ha^{-1} in the form of urea) and three levels of P (0, 20, 40 kg ha^{-1} in the form of TSP) arranged in RCB design with three replications. Results indicated that interaction of N and P highly significantly ($p<0.01$) influenced the different growth and yield parameters except for 1000 seed weight. The highest seed yield (1336.7 kg ha^{-1} was obtained from 60 kg N and 40 kg P ha^{-1}. Highest number of pods per plant (45.9) was obtained from 60 kg N ha^{-1} and 40 kg P ha^{-1} interactions. The tallest plants (72.50 cm) were measured on plots fertilized at the rate of 60 kg N and 40 kg P ha^{-1}. The highest number of branches (46.1) was obtained from the interaction effect of 60 kg N and 40 kg P ha^{-1}. The highest numbers of seeds per pod (91.6) was achieved at treatment combination of 60 kg N and 40 kg P ha^{-1} followed by 88.4 seeds by the treatment combination of 60 kg N and 20 kg P ha^{-1}. The highest harvest index (20.8%) was obtained from the treatment that received 60 kg N and 40 kg P ha^{-1} followed by 20.5%, which received 45 kg N and 20 kg P ha^{-1} interactions and the lowest harvest index (15.1%) was recorded from the treatment that received 15 kg N and 0 kg P interaction. The longest days to 50% flowering (86.7 days) were observed for the treatment that received 60 kg N and 40 kg P ha^{-1}. However, the shortest flowering days (75.5) days were for the control treatment. Partial budget analysis has shown that two treatment combinations of (NP ha^{-1}) were found to be economically viable with marginal rate of revenue beyond the minimum acceptable level (150%). The highest MRR (%) was obtained with the interaction effect of 45 kg N and 40 kg P ha^{-1} with marginal rate of revenue (1272.2%) for net benefit 15254.1 birr, followed by the interaction effect of 15 kg N and 20 kg P ha^{-1} with marginal rate of revenue (485%) for net benefit 10325 birr over the control with a net benefit 8595.0 birr. Since the experiment was conducted at one place and only for one cropping season, it will not be appropriate to arrive at a strong recommendation. However, as a recommendation, growers can be advised to use a combination of 45 kg N and 40 kg P ha^{-1} followed by 15 kg N and 20 Kg P ha^{-1} for black cumin production in the area.

Yousuf *et al.* (2018) conducted a field experiment at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during *rabi* (winter) season of 2016-17 to evaluate the effects of fertilizer treatments on black cumin (BARI Kalozira-1). The field belongs to Shallow red-brown terrace soil of Salna series under AEZ-28 (Madhupur Tract). The experiment was laid out in randomized complete block design (RCBD) with three replications. Results showed that the application of nutrient elements had positive effect on plant height, branches per plant, capsule setting, umbels per plant, capsules per plant, capsule size, seeds per capsule, 1000-seed weight and seed yield of black cumin. The highest seed yield (1277 kg ha^{-1}) was obtained from 75% RDCF + 25% cowdung-N treatment followed by 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg ha^{-1}) and the lowest seed yield (420 kg ha^{-1}) was recorded with 50% RDCF. Thus, the IPNS treatment 75% RDCF + 25% cowdung-N appeared to be the best suitable package for black cumin cultivation in this location.

Massoud *et al.* (2014) conducted a field experiment at Gemmeiza Agricultural Research Station, Agric. Res. Center, El- Gharbia Governorate during two successive winter seasons (2011/2012 and 2012/2013) to study the effect of natural sources of phosphorus (Phosphorien and Rock phosphate) at three levels (50, 75 and 100 %) of the recommended dose (RD) and foliar application of Super Mex or Power Mix on some vegetative growth parameters, seed yield, fixed oil yield and chemical compositions in seeds of black cumin (*Nigella sativa* L.) plant. The obtained results revealed that the highest values of plant height, capsules number/plant, seeds number/capsule, capsules weight/plant, 1000-seed weight, seed yield and fixed oil yield were achieved from the treatment of 50 % (Phosphorien plus Rock phosphate) + 50 % NPK in both seasons, while 75 % (Phosphorien plus Rock phosphate) resulted in the highest plant dry weight and chemical constituents content. Spraying with Super Mex (RD) + 50 % NPK resulted in the highest values of vegetative growth characters, seed yield, fixed oil of percentage, yield and chemical constituents in comparison with the foliar spray of Power Mix (RD) and the control treatments in both seasons. The interaction treatment of 75 % (Phosphorien plus Rock phosphate) + Super Mex + 50 % NPK augmented values of plant height, capsules number/plant, seeds number/capsule, capsules weight/plant, 1000-seed weight, seed yield, fixed oil yield and chemical constituents in both seasons, while Phosphorien plus Rock phosphate (50 %) induced in the highest plant weight.

Ali *et al.* (2015) carried out an experiment at the research farm of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh, during November 2013 to April 2014 to determine the growth and yield performance of four varieties of black cumin (Exotic variety, BARI kalozira-1, Faridpur local and Natore local) as influenced by three levels of fertilizers (40-20-30 Kg ha^{-1}, 80-30-45 Kg ha^{-1} and 120-40-60 Kg ha^{-1} N-P-K, respectively). The experiment was conducted in a randomized complete block design (RCBD) with three replications. First flower bud initiation day, capsule setting, and capsule ripening in 50% plant were not significantly influenced by N-P-K fertilizer levels. The secondary branch $plant^{-1}$, tertiary branch $plant^{-1}$, plant height at harvest, capsule length, capsule diameter and 1000 seed weight of black cumin were also not influenced significantly by the fertilizer levels. The dry matter weight $plant^{-1}$, primary branch $plant^{-1}$, fruit $plant^{-1}$, seed $capsule^{-1}$ and grain yield of black cumin genotypes were significantly influenced by different levels of N-P-K fertilizers. Natore local gave maximum dry matter production $plant^{-1}$ at 55 DAS with moderate N-P-K levels and at 70 DAS with higher N-P-K fertilizer levels (0.22 and 1.06 g, respectively), whereas Exotic black cumin genotype showed maximum dry matter $plant^{-1}$ at 85 and 100 DAS with higher N-P-K fertilizer levels (2.30 and 4.97 g, respectively). Exotic variety produced maximum grain yield (3.43 g $plant^{-1}$ and 2.30 t ha^{-1}) at higher level of N-P-K fertilizer, but BARI kalozira-1 (2.95 g $plant^{-1}$ and 1.95 t ha^{-1}), Faridpur local (2.80 g $plant^{-1}$ and 1.90 t ha^{-1}) and Natore local (2.69 g $plant^{-1}$ and 1.80 t ha^{-1}) showed maximum yields at moderate N-P-K fertilizer levels. Among the test varieties of black cumin, the exotic variety showed better yield performance than the others.

Shirmohammadi *et al.* (2014) conducted a field experiment at Nour Abad's research farm in Lorestan, Iran, in 2013 to assess the effect of biological phosphate and chemical phosphorus fertilizer on black cumin yield and yield components. The experiment was set up as a 6-factorial with three replications using a randomized complete block design. Biological phosphate (Pseudomonas putida) at two levels (inoculated and non-inoculated) and chemical phosphorus (P2O5) at three levels were used as treatments (0, 40 and 80 kg ha^{-1}). The effects of treatments on plant height, capsule number per plant, grain number per capsule, and grain yield were statistically significant, but there were no significant differences between treatments in terms of 1000 seed weight. The means revealed that a biological phosphate + chemical phosphorus treatment resulted in the greatest plant height (32.1 cm) and grain yield (735 kg ha^{-1}) (40 kg ha^{-1} P_2O_5). The results show that using a combined biological phosphate and chemical phosphorus fertilizer can be a useful and practical method for increasing black cumin yield, yield components, and reducing environmental pollution.

Tuncturk *et al.* (2013) conducted an experiment in 2006 and 2007 to determine the effects of different phosphorous doses (0, 20, and 40 kg ha^{-1}) on yield and yield components of black cumin (*Nigella sativa* L.) in Van ecological conditions. Field trials were designed using a Completely Randomized Block Design with three replications at Yuzuncu Yil University's Agricultural Faculty's experimental fields. Plant height (cm), number of branch $plants^{-1}$, number of capsule $plants^{-1}$, number of seeds $capsule^{-1}$, 1000-seed weight (g), and seed yield (kg ha^{-1}) were all measured in the study. Significant differences in the number of capsules, 1000-seed weight, and seed yield were found after statistical analysis of the phosphorous doses applications. Phosphorus doses were increased to increase seed yield. The application of 40 kg P ha^{-1} fertilizer resulted in the highest seed yield (597 kg ha^{-1}) and thousand-seed weight (2.48 g), according to the results. The highest mean values for the number of capsules (5.68 capsules $plant^{-1}$) resulted in an application of 20 kg P ha^{-1}.

Hammo (2008) conducted a field experiment in Singar- Mosul city during the 2005-2006 season to investigate the effects of very high level (320 N, 300 P_2O_5) kg ha^{-1} and high level (280 N, 260 P_2O_5) kg ha^{-1} nitrogen and phosphorus fertilizer, pinch and without pinch, and plant seed rate sowing 0.6, 0.8, 1.0, 1.2 g/10m^2 by hand within 3, 4, 5, 6 rows respectively in (10)m^2 plot size on seed components of The experiment was set up in a randomized complete block design with three replications. Among the outcomes are the following. Very high nitrogen and phosphorus levels resulted in a significant increase in fixed oil, volatile oil, protein, and phosphorus; in contrast, carbohydrate was significantly decreased, while humidity and ash were unaffected by this factor. When nigella plants are pinched, the fixed oil, ash, and carbohydrate content of the seeds increase significantly, while the volatile oil, protein, and phosphorus content decreases significantly. When compared to 0.6 g/10m^2, increased seed rate sowing from 0.8 to 1.2 $g/10m^2$ resulted in significant increases in fixed oil, whereas decreased seed rate sowing 0.6, 0.8 $g/10m^2$ resulted in significant increases in volatile oil and ash when compared to 1.0, 1.2 $g/10m^2$. Protein levels increased significantly from 20.67 to 24.40 $g/10m^2$ when seed rate was reduced from 1.2 to 0.8 $g/10m^2$. While the medium rate results in a significant increase in phosphorus when compared to the lowest and highest rates, the lowest rate of see rate results in the highest percentage of carbohydrate when compared to the others.

Girma and Taddesse (2013) conducted an experiment to determine the effect of nitrogen and phosphorous rates on Ethiopian cumin yield and yield components. The treatment included four nitrogen levels (0, 50, 100, and 150 kg ha^{-1}) and four phosphorous levels (0, 50, 100, and 150 kg ha^{-1}) (0, 25, 50 and 75 kg ha^{-1} in form of P_2O_5). Plant height, number of secondary and tertiary branches $plant^{-1}$, number of umbels $plant^{-1}$, dry matter yield, seed yield, essential oil content, and essential oil yield all had a significant influence on fertilizer main and interaction effects. The main effect of fertilizer had the only effect on the number of seeds $umbel^{-1}$, while the number of primary branches and 1000- seed weight were unaffected. The combined effect of 100 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} resulted in the highest significant total dry matter yield (3307 kg ha^{-1}), seed yield (1072 kg ha^{-1}) and essential oil yield (39.0 L ha^{-1}).

Rana *et al.* (2012) conducted a field experiment during the 2010-11 rabi season to determine the effect of nitrogen and phosphorus on the growth, yield, and quality of black cumin. When compared to a local cultivar of nigella, AN-1 had the highest number of capsules per plant (30.30), number of seeds per capsule (60.33), test weight (1.46 g), seed yield (4.88 q/ha), straw yield (12.48 q/ha), harvest index (27.89 percent), and biological yield (17.36 q/ha). Maximum plant height at harvest (45.95 cm), number of branches per plant at harvest (17.30), fresh weight per plant at 60 DAS (13.08 g), and dry weight of shoot per plant at 60 DAS (3.21 g) were all recorded with fertilizer applications of 60: 120 kg ha^{-1} N, P, 45: 90 kg ha^{-1} N, P, and control at all growth stages. As a result, using 60 kg ha^{-1} N and 120 kg ha^{-1} P fertilizer with the variety AN-1 resulted in the greatest growth, yield, and quality of nigella, as well as the highest net return per hectare.

2.2 Effect of seed rates

Mengistu *et al.* (2021) conducted a field experiment with the objective to assess the influence of different seed rates and inter-row spacing on yield and yield attributes of black cumin at Kulumsa. This experiment was done in the cropping years of 2017, 2018 and 2019 at Kulumsa Agricultural Research Center, Southeast Ethiopia. Twelve treatment combinations of four seed rates (5 kg ha^{-1}, 10 kg ha^{-1}, 15 kg ha^{-1} and 20 kg ha^{-1}) and three inter-row spacing (20 cm, 30 cm and 40 cm) were studied on a black cumin variety – 'Aden', which was laid out in a randomized complete block design (RCBD) with factorial arrangement in three replications. The interaction effect of seed rate and inter-row spacing was not statistically significant (P >0.05) on all growth and yield parameters. However, the main effect of seed rate was significant (P < 0.05) on most of the parameters studied while inter-row spacing was significant only on days to emergence and plant height. Yield and yield attributing factors such as number of primary branch $plant^{-1}$, number of secondary branch $plant^{-1}$, number of pods $plant^{-1}$ and seed yield ha^{-1} (kg) were significantly influenced by the seed rate. Seed yield increased from 462 kg ha^{-1} to 634 kg ha^{-1} as seed rate increased from 5 kg ha^{-1} to 20 kg ha^{-1} and showed a decrease in yield from 601 kg ha^{-1} to 507 kg ha^{-1} as inter-row spacing increased from 20 cm to 40 cm although it was not significant. Hence, 15 kg ha^{-1} seed rate and 30 cm inter-row spacing could be recommended for optimum black cumin production in the study area.

Roussis *et al.* (2017) carried out a field experiment 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^{-1} and 60 kg ha^{-1}) 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^{-1} (18.2-22.7 cm). The highest numbers of capsule 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^{-1}) and biological yield (3864-4063 kg ha^{-1}) 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.

Fahim *et al.* (2017) carried out an experiment at the research field of Spices Research Centre, Shibganj, Bogra during rabi season, 2013-14 and 2014-15 to determine optimum seed rate and suitable sowing method for black cumin cultivation. The land was medium high and the soil was clay loam in texture. The experiment was laid out in a Randomized Complete Block Design (factorial) with three replications. Four different seed rates viz. 4, 6, 8 and 10 kg seed/ha and three sowing methods *viz.* Broadcasting without bed, Line sowing without bed and Line sowing in raised bed were compared. The highest seed yield (1063.0 kg/ha in 2013-14 and 1254 kg/ha in 2014-15) was recorded from treatment combination of 8 kg seed/ha × line sowing in raised bed, which was identical to 10 kg seed/ha × Line sowing in raised bed (976.9 kg/ha in 2013-14 and 1155 kg/ha in 2014-15) followed by 10 kg seed/ha × Line sowing without bed (959.7 kg/ha in 2013-14 and 1090 kg/ha in 2014-15). The lowest seed yield (218.8 kg/ha in 2013-14 and 254 kg/ha in 2014-15) was recorded from 4 kg seed/ha × Broadcasting without bed method. It was concluded that 8 kg seed/ha would be the optimum seed rate and line sowing in raised bed would be the most effective method for higher seed yield of the black cumin. But for broadcasting seeds should be shown with 10 kg/ha.

Toncer and Kizil (2004) researched to evaluate the effects of seed rate (10, 20, 30, 40 and 50 kg ha^{-1}) on seed yield and some yield components of *Nigella sativa* under semi-arid conditions in Diyarbakır, Turkey during 1999-2000 and 2000-2001. Seed rate significantly affected plant height, number of branch per plant, number of capsule per plant, seed yield per plant and seed yield. High seed rates (40 and 50 kg ha^{-1}) reduced number of branch, number of capsule per plant, seed yield per plant and seed yield. Seed rate did not affect thousand seed weight, number of seed per capsule, essential oil and fatty oil rate. The highest seed yield (828 kg ha^{-1}) was obtained from 10 kg ha^{-1}.

Hammo (2008) conducted a field experiment during the season 2005-2006 in Singar-Mosul city to investigate the effects of very high level (320 N, 300 P_2O_5) kg ha^{-1}, and high level (280 N, 260 P_2O_5) kg ha^{-1} of nitrogen and phosphorus fertilizer, pinch and without pinch, and plant seed rate sowing 0.6, 0.8, 1.0, 1.2 g/10m^2 was done by hand within 3, 4, 5, 6 rows respectively in (10)m^2 plot size on seed components of *Nigella sativa* L. The experiment was laid out in randomized complete block design with three replications. The results include the following. Very high levels of nitrogen and phosphorus caused a significant increase in fixed oil, volatile oil, protein, and phosphorus; in contrast carbohydrate was significantly decreased, while humidity and ash cannot be affected with this factor. Pinching nigella plants causes a significantly increasing in fixed oil, ash, and carbohydrate of seeds while volatile oil, protein, and phosphorus were decreased significantly when compared with non-pinched plants. Increased seed rate sowing from 0.8 to 1.2 g/10m^2 caused significant increasing in fixed oil when compared with 0.6 g/10m^2 while decreased seed rate sowing 0.6, 0.8 g/10m^2 caused significant increases in volatile oil and ash when compared with 1.0, 1.2 g/10m^2. Protein also increased significantly from 20.67 to 24.40 with decreased seed rate sowing from 1.2 to 0.8 g/10m^2. While medium rate cause significant increase in phosphorus when compared with lowest and highest rate, the lowest rate of see rate give the highest percentage of carbohydrate when compared with other.

Tuncturk *et al.* (2005) carried out an experiment to determine some important agronomical properties of the black cumin in Van, Turkey. The experiments were designed in a Randomized Complete Block Design with three replications. In the study, four different seed rates 5, 10, 15 and 20 kg ha^{-1} were applied. The seeds were sown as main crop in 3 April and 10 May in 2001 and 2002, respectively in 25 cm apart and given 30 and 60 kg ha^{-1} of N and P_2O_5, respectively. Data were tabulated on mean plant height, the number of branch, the number of capsule, the number of seeds in the capsule, thousand-seed weight, seed yield (kg ha^{-1}), essential oil content (%) and essential oil yield (kg ha^{-1}) in both years. It was showed that the analyzed features were generally affected by seed rate applications. Averaged over years, the highest seed yield 701.2 kg ha^{-1} and essential oil yield 3.5 kg ha^{-1} obtained from the 15 kg ha^{-1} seed rate application. It was concluded that the 15 kg ha^{-1} application were considered the optimum seed rate, having high essential oil and seed yield in the black cumin.

El-Hag (1996) carried out field experiment in Shambat area at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum and Horticultural Research Station for two growing seasons of 1993/94 and 94/95 respectively. The objectives of the study were to investigate and determine the optimun sowing date, seed rate and planting method of black cumin (*Nigella sativa*) under prevailing environmental conditions of Khartoum area. Three independent experiments were conducted to study the effect of these agronomic practices on plant growth, seed yield and yield components. In experiment (1) sowing date treatments were: l and 15 November; l and 15 December; l and 15 January in the season 1993/94 and the same treatments with the exception of 15 January in the season 1994/95. In experiment (2) seed rate treatments were: 3.2, 6.4 and 9.6 kg/fed in both seasons. In experiment (3) planting method treatment were: broadcasting holes 20 cm apart and drilling method in the two seasons. Data collected and analyzed were the same in the three experiments and included: number of days to start of seedling emergence, 50 flowering and harvest, plant height, fresh and dry weight per plant, number of branches per plant, number of flowers per plant, number of pods per plant, number of seeds per pods and aborted flowers percentage, thousand seed weight, seed yield per feddan and oil content of seed. The results indicated no consistent difference in days taken to beginning of seedling emergence among sowing dates in the two seasons. However, days to 50% of flowering were less in late sowing, and crop growth vigor was reduced with delayed sowing date. Percentage of empty pods and aborted flowers increased with delaying in sowing date. Results showed statistically significant effect of sowing date on seed yield. Fifteenth and first of November sowing gave the higher seed yield in the season 93/94 and 94/95, while non-significant reduction in seed yield was detected from l December till l January; however the results of season 93/94 were inconclusive due to missing data of seed yield for the sowing dates of 15 December, l and 15 January. Sowing date was not shown to affect the oil content of seed. Increasing seed rate inversely affected plant height, plant growth vigor and yield components per plant, whereas the seed yield per feddan responded positively to increasing seed rate. Drilling method produced longest plants in the two seasons, while the highest growth vigor and yield components per plant resulted from broadcasting method. Broadcasting method produced significantly the highest thousand seed weight and seed yield in the first season while in the second season drilling method gave the highest values which were not significant. Results indicated that suitable planting method depends to a large extent on the type and structure of soil.

Ozlem and Suleyman (2004) conducted an experiment to evaluate the effects of seed rate (10, 20, 30, 40 and 50 kg ha^{-1}) on seed yield and some yield components of

Nigella sativa under semi-arid conditions in Diyarbakır, Turkey during 1999-2000 and 2000-2001. Seed rate significantly affected plant height, number of branch per plant, number of capsule per plant, seed yield per plant and seed yield. High seed rates (40 and 50 kg ha^{-1}) reduced number of branch, number of capsule per plant, seed yield per plant and seed yield. Seed rate did not affect thousand seed weight, number of seed per capsule, essential oil and fatty oil rate. The highest seed yield (828 kg ha^{-1}) was obtained from 10 kg ha^{-1}.

From the above review of literature it is evident that different levels of phosphorus fertilizers have a significant influence on growth and seed yield of black cumin. The literature suggests that lower or higher doses of phosphorus fertilization than optimum doses could reduce the seed yield of black cumin. From the above review of literature it is evident that seed rates itself influenced the growth and seed yield of black cumin plant. The literature revealed that accurate knowledge of the optimum levels of seed rates for any particular black cumin variety at a particular area is critical to achieve a higher seed yield of black cumin.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials and methods which were used in the field to conduct the experiment entitled "Influence of phosphorus fertilization and seed rates on growth and yield of black cumin (*Nigella sativa* L.)" during the period from November 2019 to March 2020. The materials and methods that were used for conducting the experiment have been presented in this chapter. It comprises a short description of experimental site, soil and climate, variety, growing of the crops, experimental design and treatments and collection of data presented under the following headings:

3.1 Description of the experimental site

The research work was conducted at "Horticulture Farm" of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2019 to March 2020. The location of the site was 23°74′ N Latitude and 90°35′ E Longitude with an elevation of 8.2 meters from the sea level (Anon, 1987) and presented in Appendix I.

3.2 Soil characteristics

The texture of the soil in the experimental field was silty loam. The soil in the experimental area is part of the Modhupur Tract (UNDP, 1988) and belongs to AEZ No. 28. Before conducting the experiment, a soil sample from the experimental plot was obtained from a depth of 0-30 cm and examined at the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka which is shown in Appendix II.

3.3 Climate and weather

The climate of the experimental site was under the subtropical climate with three distinct seasons: winter from November to February, pre-monsoon or hot season from March to April, and monsoon season from May to October (Edris *et al.*, 1979). The Bangladesh Meteorological Department, Agargoan, Dhaka, provided details of the meteorological data collected during the experiment, which are presented in Appendix III.

3.4 Crop/plating material

In this experiment black cumin variety, BARI Kalozira-1 was used. BARI Kalozira-1 was developed by Spices Research Centre, BARI in 2009. It's average plant height is 55-60 cm, number of primary branches is 5-7, number of pods/plant is 20-25, number of seeds/pod is 75-80, seed weight/pod is 0.20-0.27 g, seed weight/plant is 5-7 g, 1000 seeds weight is 3.00 - 3.25 g.

3.5 Treatments under the investigation

The experiment consisted of two factors *viz.* different levels of phosphorus and seed rates.

Factor A: Phosphorus fertilizer (4 levels)

$P_{0=}$ control

P_1= 35 kg P ha^{-1}

P_2= 40 kg P ha^{-1}

P_3= 45 kg P ha^{-1}

Factor B: Seed rates (3 levels)

R_1= 8 kg seeds ha^{-1}

R_2= 10 kg seeds ha^{-1}

R_3= 12 kg seeds ha^{-1}

There are 12 treatment combinations such as P_0R_1, P_0R_2, P_0R_3, P_1R_1, P_1R_2, P_1R_3, P_2R_1, P_2R_2, P_2R_3, P_3R_1, P_3R_2 and P_3R_3.

3.6 Design and layout of the experiment

The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were distributed randomly. There were 36 unit plots altogether in the experiment. The size of each plot was 1.2 m × 1.2 m. The distance maintained between two blocks and two plots were 50 cm and 50 cm, respectively. The plots were raised up to 10 cm.

3.7 Land preparation

The land was ploughed thoroughly four times with a power tiller. Ploughed soil was then laddered into a desirable fine tilth and leveled. The weeds were thoroughly cleaned. The final ploughing and land preparation were completed on November 12, 2019. The entire experimental area was divided into blocks and subdivided into plots for the sowing of black cumin seed, according to the experiment layout. Irrigation and drainage channels were also installed around the plot.

3.8 Application of manures and fertilizers

The source of N, P and K were urea, triple super phosphate and muriate of potash. Half of urea and total amount of muriate of potash fertilizers of each plot were applied and incorporated into soil during final land preparation. Rest of the urea was top dressed after 30 days of sowing (DAS). Triple super phosphate was applied as per treatment. Cowdung @ 5 t per hectare was applied during the land preparation.

3.9 Seed sowing

Sowing was done on 19 November, 2019 in rows 10 cm apart. Seeds were sown continuously in rows at the rate of 8 kg ha^{-1}, 10 kg ha^{-1} and 12 kg ha^{-1} (1.15 g, 1.44 g and 1.73 g of seeds per plot as per treatment). After sowing the seeds were covered with soil and slightly pressed by hand.

3.10 Intercultural operations

3.10.1 Weeding

First weeding was done at 20 DAS and the 2^{nd} and 3^{rd} weeding at 35 DAS and 55 DAS respectively to keep the crop weed free.

3.10.2 Thinning

The optimum plant population was maintained by thinning excess number of plants from the row at 15 days after sowing (DAS). The plant to plant and row to row distance was maintained as per treatment.

3.10.3 Irrigation and drainage

When the land appeared to be too dry, light irrigation was applied. Irrigation was done every 15 days until flowering. Two irrigations were performed following flowering. To avoid water stagnation, proper drainage facilities were developed.

3.10.4 Crop protection

The field was investigated on a regular basis to detect visual differences between treatments and any kind of infestation by weeds, insects, and diseases, in order to minimize significant pest losses. With normal green plants, the field looked nice. There was no evidence of insect attack, but some plots showed signs of fungal attack. Dithane M-45 was sprayed at 2 g/Litre water at 10-day intervals for control.

3.11 Harvesting and threshing

Previous data was collected from each plot on five randomly selected plants that were considered for data recording in order to analyze the yield and yield contributing characters. The remaining crops were harvested when 80% of the pods in the terminal matured. Harvesting started on March 15, 2020, following the collection of sample plants, and was completed on March 25, 2020. Crops were tied into bundles and carried to the threshing floor. Sun drying the crop bundles was accomplished by spreading them on the threshing floor. By pounding the bundles with bamboo sticks, the seeds were separated from the plants.

3.12 Drying and weighing

The seeds thus collected were dried in the sun for couple of days. Dried seeds of each plot were weighed and subsequently converted into yield kg/ha.

3.13 Data collection

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 45 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 was recorded after cleaning and drying those properly in the sun.

3.14 Detailed procedures of data recording

3.14.1 Plant height

Plant height was measured three times at 45 days interval such as 45, 90 and 135 DAS. The height of the plant was determined by measuring scale considering the distance from the soil surface to the tip of the randomly five selected plants and mean value was calculated for each treatment. The height of the plant was expressed in centimeter.

3.14.2 Primary branches per plant

The number of primary branches per plant was counted at harvest of black cumin plants. Mean value of data were calculated and recorded.

3.14.3 Secondary branches per plant

The number of secondary branches per plant was counted at harvest of black cumin plants.

3.14.4 Days to first and 50% flowering

The date of first and 50% flowering on the sample plants were recorded and the period required in days from the date of sowing was calculated. The date of opening of the first germination of fifty percent was considered as the date of 50% germination.

3.14.5 Number of capsules per plant

The number of capsules from five plants were counted and calculated as per plant basis.

3.14.6 Capsule length

Capsule length was measured in centimeter by randomly selected five capsules per plant and then the average was calculated.

3.14.7 Capsule breadth

Capsule breadth was measured in centimeter by randomly selected five capsules per plant and then the average was calculated.

3.14.8 Number of seeds per capsule

The number of seed from five capsules were counted and calculated as per capsule basis.

3.14.9 1000-seeds weight

A composite sample was taken from the yield of five plants. The weight of 200 seeds was taken first and then the result was converted into 1000-seeds. The 1000-seeds of each plot were counted and weighed with a digital electric balance. The 1000-seeds weight was recorded in gram.

3.14.10 Seed yield per plot

The separated seeds of plot were collected, cleaned, dried and weighed properly. The seed weight per plot was then recorded in gram.

3.14.11 Seed yield

Each plot’s total yield (g) was recorded first and then they were converted to tons per hectare by using the plot size.

3.15 Data analysis technique

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

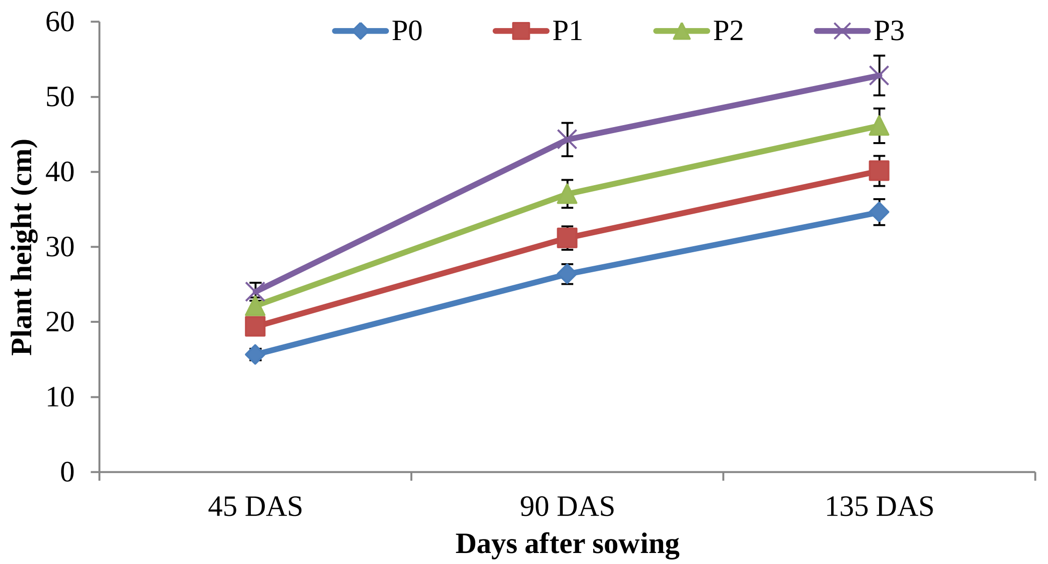
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to observe the influence of phosphorus fertilization and seed rate on growth and yield of black cumin under the soil and agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameters were recorded. The Analysis of Variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix V-XII. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1 Plant height (cm)

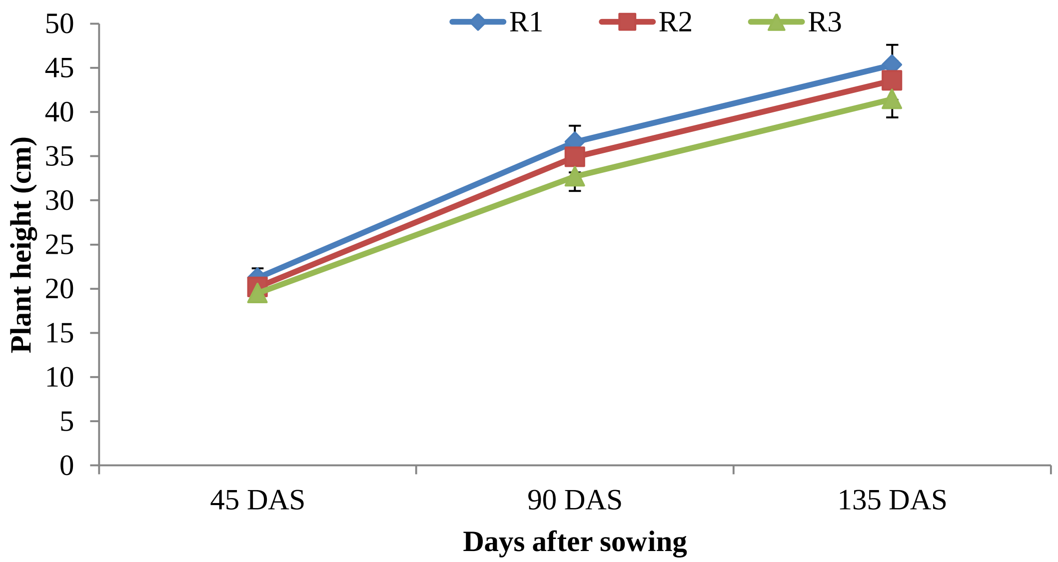
Statistically significant variation was observed on plant height at 45, 90 and 135 DAS due to different levels of phosphorus under the experiment (Fig. 1 and Appendix IX). At 135 DAS, the highest plant height (52.84 cm) was obtained from P_3 (45 kg P ha^{-1}) treatment and the lowest plant height (34.64 cm) was revealed from P_0 (control) treatment. It was revealed that the plant height increased with the increase in days after sowing (DAS) i.e., 45, 90 and 135 DAS. It also revealed that the plant height increased with different levels of phosphorus as well. Similar results were also observed by Moradzadeh *et al.* (2021), Rimu *et al.* (2020) and Sultana *et al.* (2019). They reported that phosphorus fertilizer increases the plant height.



Here, P_{0}= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Fig. 1. Effect of different levels of phosphorus on plant height at different days after sowing of black cumin

Seed rates showed significant influence on the height of black cumin plants at 45, 90 and 135 DAS (Fig. 2 and Appendix X). At 135 DAS, the highest plant height (45.33 cm) was observed from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the lowest plant height (41.45 cm) was observed from R_3 (12 kg seeds ha^{-1}) treatment. The result of the study was in coincided with the findings of Ozlem and Suleyman (2004) who reported that seed rate significantly affected plant height.



Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Fig. 2. Effect of seed rates on plant height at different days after sowing of black cumin

Significant influence was observed on plant height due to the combined effect of different levels of phosphorus and seed rates (Table 1 and Appendix V). From the results of the experiment showed that the highest plant height at 135 DAS (55.18 cm) was observed from the treatment combination of P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}). On the other hand the lowest plant height at 135 DAS (32.81 cm) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

Table 1. Combined effect of different levels of phosphorus and seed rates on plant height at different days after sowing of black cumin

Treatment Combinations	Plant height (cm) at		
	45 DAS	**90 DAS**	**135 DAS**
P_0R_1	16.75 h	28.15 hi	36.19 gh
P_0R_2	15.67 i	26.53 i	34.92 hi
P_0R_3	14.55 j	24.48 j	32.81 i
P_1R_1	20.52 f	32.41 f	42.27 ef
P_1R_2	19.15 g	31.33 fg	40.53 f
P_1R_3	18.47 g	29.85 gh	37.62 g
P_2R_1	22.81 cd	39.13 d	47.67 c
P_2R_2	22.00 de	37.28 d	46.19 cd
P_2R_3	21.62 e	34.81 e	44.63 de
P_3R_1	24.83 a	46.75 a	55.18 a
P_3R_2	23.91 ab	44.50 b	52.60 b
P_3R_3	23.33 bc	41.67 c	50.75 b
$LSD_{(0.05)}$	**0.94**	**1.89**	**2.47**
CV%	**2.75**	**3.22**	**3.36**

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

Here, $P_{0=}$ control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

4.2 Number of primary branches per plant

Significant variation was observed on number of primary branches per plant of black cumin due to different levels of phosphorus under the experiment (Table 2 and Appendix VI). At 135 DAS, the maximum number of primary branches per plant

(8.39) was obtained from P_3 (45 kg P ha^{-1}) treatment where minimum number of primary branches per plant (5.43) was observed from P_0 (control) treatment. It was revealed that the number of primary branches per plant increased with the increase in days after sowing (DAS). It also revealed that the number of primary branches per plant increased with different levels of phosphorus as well. Moradzadeh *et al.* (2021) observed the similar trends.

Statistically seed rates showed significant variation on number of primary branches per plant of black cumin (Table 3 and Appendix VI). At harvest, the maximum number of primary branches per plant (7.26) was observed from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the minimum number of primary branches per plant (6.64) was observed from R_3 (12 kg seeds ha^{-1}) treatment. El-Hag (1996) found the similar results.

Combined effect of different levels of phosphorus and seed rates significantly influenced by number of primary branches per plant (Table 4 and Appendix VI). At harvest, the maximum number of primary branches per plant (8.67) was achieved from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination which was statistically similar (8.40) to P_3R_2 treatment. On the other hand the minimum number of primary branches per plant (4.92) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.3 Number of secondary branches per plant

Significant variation was observed on number of secondary branches per plant of black cumin due to different levels of phosphorus under the experiment (Table 2 and Appendix VI). At harvest, the maximum number of secondary branches per plant (12.43) was obtained from P_3 (45 kg P ha^{-1}) treatment where minimum number of secondary branches per plant (8.70) was obtained from P_0 (control) treatment. It was revealed that the number of secondary branches per plant increased with the increase in days after sowing (DAS). It also revealed that the number of secondary branches per plant increased with different levels of phosphorus as well. Similar results also reported by Rimu *et al.* (2020).

Statistically seed rates showed significant variation on number of secondary branches per plant of black cumin (Table 3 and Appendix VI). At harvest, the maximum number of secondary branches per plant of black cumin (11.00) was obtained from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the minimum number of secondary branches per plant (10.11) was observed from R_3 (12 kg seeds ha^{-1}) treatment which was statistically similar (10.53) to R_2 treatment. The result was in agreement with the findings of Mengistu *et al.* (2021). They reported that yield and yield attributing factors such as number of primary branch $plant^{-1}$, number of secondary branch $plant^{-1}$, number of pods $plant^{-1}$ and seed yield ha^{-1} (kg) were significantly influenced by the seed rates.

Combined effect of different levels of phosphorus and seed rates significantly influenced by number of secondary branches per plant (Table 4 and Appendix VI). At harvest, the maximum number of secondary branches per plant (13.00) was achieved from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination which was statistically similar (12.47) to P_3R_2 treatment. On the other hand the minimum number of secondary branches per plant (8.27) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

Table 2. Effect of different levels of phosphorus on number of primary and secondary branches per plant of black cumin

Treatments	Number of primary branches per plant	Number of secondary branches per plant
P_0	5.43 d	8.70 d
P_1	6.53 c	9.95 c
P_2	7.56 b	11.09 b
P_3	8.39 a	12.43 a
$LSD_{(0.05)}$	**0.21**	**0.56**
CV%	**3.13**	**5.49**

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

Here, $P_{0=}$ control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Table 3. Effect of different levels of seed rates on number of primary and secondary branches per plant of black cumin

Treatments	Number of primary branches per plant	Number of secondary branches per plant
R_1	7.26 a	11.00 a
R_2	7.03 b	10.53 ab
R_3	6.64 c	10.11 b
$LSD_{(0.05)}$	**0.18**	**0.49**
CV%	**3.13**	**5.49**

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

Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Table 4. Combined effect of different levels of phosphorus and seed rates on number of primary and secondary branches per plant of black cumin

Treatment Combinations	Number of primary branches per plant	Number of secondary branches per plant
P_0R_1	5.81 h	9.15 hij
P_0R_2	5.55 h	8.67 ij
P_0R_3	4.92 i	8.27 j
P_1R_1	6.75 f	10.33 efg
P_1R_2	6.51 fg	9.92 fgh
P_1R_3	6.33 g	9.61 ghi
P_2R_1	7.81 cd	11.50 bcd
P_2R_2	7.67 d	11.07 cde
P_2R_3	7.20 e	10.72 def
P_3R_1	8.67 a	13.00 a
P_3R_2	8.40 ab	12.47 ab
P_3R_3	8.11 bc	11.83 bc
$LSD_{(0.05)}$	**0.37**	**0.98**
CV%	**3.13**	**5.49**

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

Here, $P_{0=}$ control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

4.4 Days to first flowering

Significant variation on days to first flowering of black cumin was observed due to different levels of phosphorus (Table 5 and Appendix VI). The minimum days to first flowering of black cumin (51.31) was obtained from P_3 (45 kg P ha^{-1}) treatment. On the other hand the maximum days to first flowering of black cumin (57.52) was obtained from P_0 (control) treatment. It was revealed that the days to first flowering of black cumin increased with the different levels of phosphorus as well. Rimu *et al.* (2020) observed the similar results.

Statistically significant difference on days to first flowering of black cumin was observed due to varied seed rates (Table 6 and Appendix VI). It was revealed that the minimum days to first flowering of black cumin (53.61) was obtained from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the maximum days to first flowering of black cumin (55.23) was observed from R_3 (12 kg seeds ha^{-1}) treatment which was statistically similar (54.50) to R_2 treatment. El-Hag (1996) reported that days to flowering were significantly influenced by the seed rate.

Combined effect of different levels of phosphorus and seed rates significantly influenced by days to first flowering of black cumin (Table 7 and Appendix VI). From the results of the experiment revealed that the minimum days to first flowering of black cumin (50.15) was observed from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination. On the other hand the maximum days to first flowering of black cumin (58.45) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination which was statistically similar to P_0R_2, P_0R_1 and P_1R_3 treatment combination, respectively.

4.5 Days to 50% flowering

Days to 50% flowering of black cumin significantly influenced by different levels of phosphorus (Table 5 and Appendix VI). The minimum days to 50% flowering of black cumin (61.60) was obtained from P_3 (45 kg P ha^{-1}) treatment. On the other hand the maximum days to 50% flowering of black cumin (67.34) was obtained from P_0 (control) treatment. It was revealed that the days to 50% flowering of black cumin increased with the different levels of phosphorus as well. Vedantham *et al.* (2020) found the similar trends.

Statistically significant variation on days to 50% flowering of black cumin was observed due to varied seed rates (Table 6 and Appendix VI). It was observed that the minimum days to 50% flowering of black cumin (63.58) was obtained from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the maximum days to 50% flowering of black cumin (65.10) was observed from R_3 (12 kg seeds ha^{-1}) treatment which was statistically similar (64.36) to R_2 treatment. The result of the experiment was in coincided with the findings of Tuncturk *et al.* (2005).

Combined effect of different levels of phosphorus and seed rates significantly influenced by days to 50% flowering of black cumin (Table 7 and Appendix VI). From the results of the experiment revealed that the minimum days to 50% flowering of black cumin (60.85) was observed from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination. On the other hand the maximum days to 50% flowering of black cumin (68.25) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination which was statistically similar to P_0R_2, P_0R_1 and P_1R_3 treatments, respectively.

Table 5. Effect of different levels of phosphorus on days to first and 50% flowering of black cumin

Treatments	Number of days to first flowering	Number of days to 50% flowering
P_0	57.52 a	67.34 a
P_1	55.44 b	65.16 b
P_2	53.52 c	63.28 c
P_3	51.31 d	61.60 d
$LSD_{(0.05)}$	**1.36**	**1.59**
CV%	**2.56**	**2.53**

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

Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Table 6. Effect of different levels of seed rates on days to first and 50% flowering of black cumin

Treatments	Days to first flowering	Days to 50% flowering
R_1	53.61 b	63.62 b
R_2	54.50 ab	64.36 ab
R_3	55.23 a	65.10 a
$LSD_{(0.05)}$	**1.18**	**1.37**
CV%	**2.56**	**2.53**

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

Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Table 7. Combined effect of different levels of phosphorus and seed rates on days to first and 50% flowering of black cumin

Treatment Combinations	Days to first flowering	Days to 50% flowering
P_0R_1	56.80 abc	66.09 abc
P_0R_2	57.30 ab	67.67 ab
P_0R_3	58.45 a	68.25 a
P_1R_1	54.67 c-f	64.67 cde
P_1R_2	55.50 b-e	65.00 bcd
P_1R_3	56.15 a-d	65.81 abc
P_2R_1	52.82 fg	62.70 d-g
P_2R_2	53.75 efg	63.00 d-g
P_2R_3	54.00 def	64.15 c-f
P_3R_1	50.15 h	60.85 g
P_3R_2	51.45 gh	61.75 fg
P_3R_3	52.33 fgh	62.20 efg
$LSD_{(0.05)}$	**2.36**	**2.76**
CV(%)	**2.56**	**2.53**

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

Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

4.6 Capsules per plant

Statistically significant variation on capsules per plant of black cumin was observed due to different levels of phosphorus (Table 8 and Appendix VII). The maximum capsules per plant (20.69) was observed from P_2 (40 kg P ha^{-1}) treatment while the minimum capsules per plant (16.32) was obtained from P_0 (control) treatment. It was observed that the number of capsules per plant increased with the different levels of phosphorus. Rimu *et al.* (2020) reported that highest number of capsules per plant was obtained when judicious applying of phosphorus fertilizer. Sultana *et al.* (2019) also observed the similar results.

Significant difference on capsules per plant of black cumin was observed due to varied seed rates (Table 9 and Appendix VII). It was revealed that the maximum capsules per plant (19.20) was obtained from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the minimum number of capsules per plant (17.86) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Tuncturk *et al.* (2005) reported that number of capsule and the number of seeds in the capsule were generally affected by seed rate applications.

Combined effect of different levels of phosphorus and seed rates significantly influenced by capsules per plant of black cumin (Table 10 and Appendix VII). From the results of the experiment revealed that the maximum number of capsules per plant of black cumin (21.80) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand the minimum number of capsules per plant of black cumin (15.37) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.7 Length of capsule (cm)

Statistically significant variation on length of capsule of black cumin was observed due to varied levels of phosphorus (Table 8 and Appendix VII). The maximum length of capsule (1.51 cm) was observed from P_2 (40 kg P ha^{-1}) treatment while the minimum length of capsule (1.11 cm) was obtained from P_0 (control) treatment. It was observed that the length of capsule per plant increased with the different levels of phosphorus. Sultana *et al.* (2019) found the similar result.

Significant difference on length of capsule per plant of black cumin was observed due to varied seed rates (Table 9 and Appendix VII). It was revealed that the maximum length of capsule (1.35 cm) was obtained from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the minimum length of capsule (1.25 cm) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Mengistu *et al.* (2021) observed the similar trends.

Combined effect of different levels of phosphorus and seed rates significantly influenced by length of capsule per plant of black cumin (Table 10 and Appendix VII). From the results of the experiment revealed that the maximum length of capsule (1.59 cm) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand the minimum length of capsule (1.07 cm) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.8 Breadth of capsule (cm)

Significant variation on breadth of capsule of black cumin was observed due to varied levels of phosphorus (Table 8 and Appendix VII). The maximum breadth of capsule (1.05 cm) was obtained from P_2 (40 kg P ha^{-1}) treatment while the minimum breadth of capsule (0.77 cm) was obtained from P_0 (control) treatment. It was revealed that the breadth of capsule per plant increased with the different levels of phosphorus. Mousa *et al.* (2012) revealed the similar result.

Marked difference on breadth of capsule per plant of black cumin was observed due to varied seed rates (Table 9 and Appendix VII). It was revealed that the maximum breadth of capsule (0.94 cm) was obtained from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the minimum breadth of capsule (0.87 cm) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Ozlem and Suleyman (2004) reported that increase the seed rate decreased the breadth of capsule relate to the yield.

Combined effect of different levels of phosphorus and seed rates significantly influenced by breadth of capsule per plant of black cumin (Table 10 and Appendix VII). From the results of the experiment revealed that the maximum breadth of capsule (1.10 cm) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand the minimum breadth of capsule (0.74 cm) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.9 Number of seeds per capsule

Number of seeds per capsule of black cumin significantly influenced by the different levels of phosphorus (Table 8 and Appendix VII). The maximum number of seeds per capsule (80.07) was observed from P_2 (40 kg P ha^{-1}) treatment while the minimum number of seeds per capsule (66.24) was obtained from P_0 (control) treatment. It was revealed that the number of seeds per capsule increased with the increase of phosphorus. Similar results were also observed by Sultana *et al.* (2019), Yimam *et al.* (2015), Yousuf *et al.* (2018). They reported that number of capsules and number of seeds per capsule increased with level of application of P and generally maximum values were observed in highest P application.

Statistically significant influence on number of seeds per capsule of black cumin was observed due to varied seed rates (Table 9 and Appendix VII). It was revealed that the maximum number of seeds per capsule of black cumin (74.18) was achieved from R_2 (10 kg seeds ha^{-1}) treatment which was statistically identical (72.64) to R_1 treatment. On the other hand the minimum number of seeds per capsule (70.92) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Increasing seed rate inversely affected yield components per plant, whereas the seed yield per feddan responded positively to increasing seed rate. El-Hag (1996) observed the similar result.

Combined effect of different levels of phosphorus and seed rates significantly influenced by number of seeds per capsule of black cumin (Table 10 and Appendix VII). From the results of the experiment observed that the maximum number of seeds per capsule of black cumin (82.15) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination which was statistically similar (79.93) to P_2R_1 treatment combination. On the other hand the minimum number of seeds per capsule (64.71) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

Table 8. Effect of different levels of phosphorus on number of capsules per plant, length of capsule, breadth of capsule and number of seeds per capsule of black cumin

Treatments	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule
P_0	16.32 d	1.11 d	0.77 d	66.24 d
P_1	17.93 c	1.24 c	0.85 c	69.59 c
P_2	20.69 a	1.51 a	1.05 a	80.07 a
P_3	19.14 b	1.35 b	0.95 b	74.42 b
$LSD_{(0.05)}$	**0.43**	**0.04**	**0.02**	**1.87**
CV%	**2.42**	**3.37**	**2.54**	**2.65**

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

Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Table 9. Effect of different levels of seed rates on number of capsules per plant, length and breadth of capsule and number of seeds per capsule of black cumin

Treatments	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule
R_1	18.51 b	1.30 b	0.91 b	72.64 a
R_2	19.20 a	1.35 a	0.94 a	74.18 a
R_3	17.86 c	1.25 c	0.87 c	70.92 b
$LSD_{(0.05)}$	**0.37**	**0.03**	**0.01**	**1.62**
CV%	**2.42**	**3.39**	**2.54**	**2.65**

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

Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Table 10. Combined effect of different levels of phosphorus and seed rates on capsules per plant, length of capsule, breadth of capsule and number of seeds per capsule of black cumin

Treatment Combinations	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule
P_0R_1	16.48 h	1.12 hi	0.78 g	66.77 hi
P_0R_2	17.11 gh	1.15 h	0.80 g	67.25 hi
P_0R_3	15.37 i	1.07 i	0.74 h	64.71 i
P_1R_1	18.00 ef	1.25 fg	0.85 f	69.52 fgh
P_1R_2	18.33 e	1.27 f	0.88 f	70.81 fg
P_1R_3	17.47 fg	1.19 gh	0.81 g	68.44 gh
P_2R_1	20.40 b	1.51 ab	1.04 b	79.93 ab
P_2R_2	21.80 a	1.59 a	1.10 a	82.15 a
P_2R_3	19.87 bc	1.43 c	1.01 bc	78.12 bc
P_3R_1	19.15 cd	1.35 de	0.95 de	74.33 de
P_3R_2	19.56 c	1.39 cd	0.98 cd	76.50 cd
P_3R_3	18.72 de	1.30 ef	0.93 e	72.42 ef
$LSD_{(0.05)}$	**0.75**	**0.07**	**0.03**	**3.25**
CV(%)	**2.42**	**3.39**	**2.54**	**2.65**

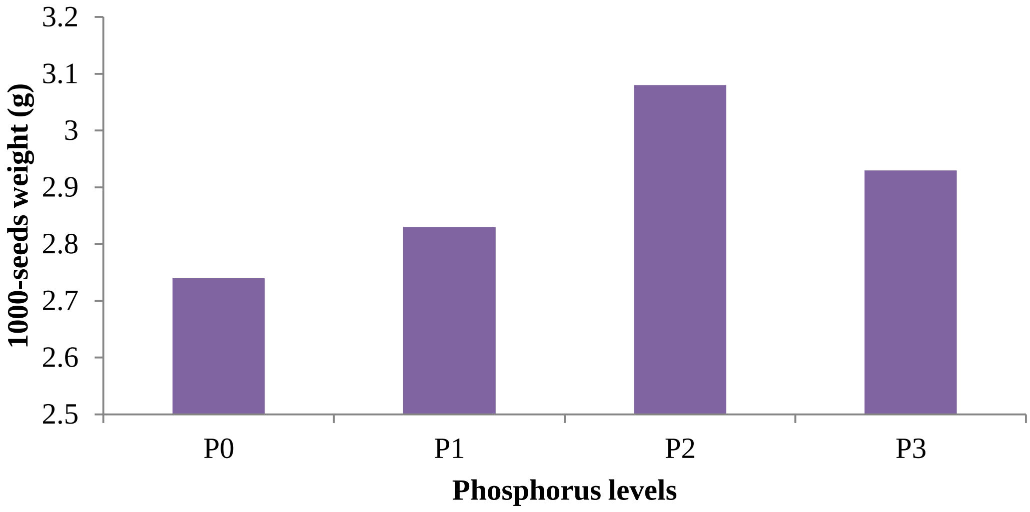
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

4.10 1000-seeds weight (g)

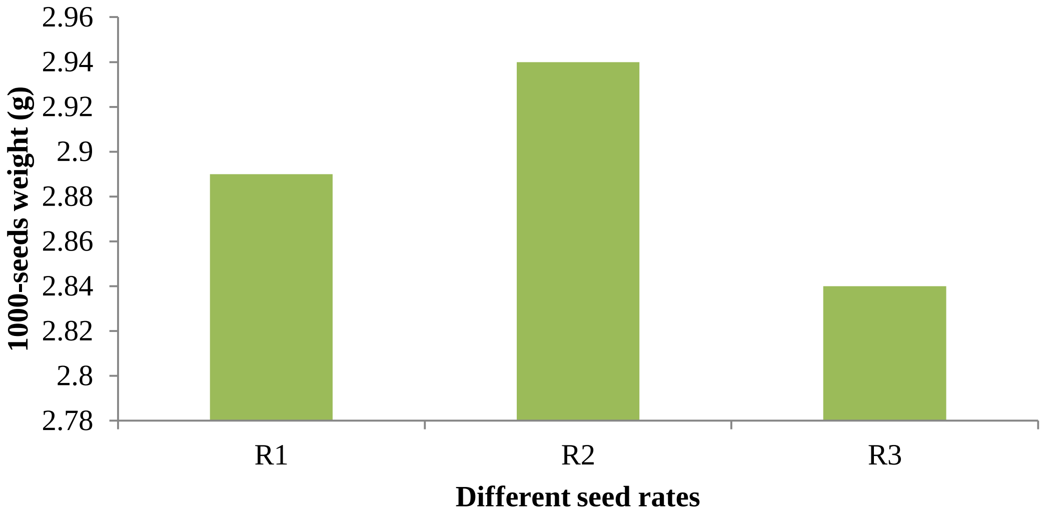
Significant variation on 1000-seeds weight was observed due to different levels of phosphorus (Fig. 3 and Appendix XI). From the results of the experiment showed that the maximum 1000-seeds weight (3.08 g) was obtained from P_2 (40 kg P ha^{-1}) treatment. On the other hand the minimum 1000-seeds weight (2.74 g) was obtained from P_0 (control) treatment. Yousuf *et al.* (2018) reported that the application of nutrient (NPK) elements had positive effect on plant height, branches per plant, capsule setting, umbels per plant, capsules per plant, capsule size, seeds per capsule, 1000-seed weight and seed yield of black cumin.



Here, P_{0}= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Fig. 3. Effect of different levels of phosphorus on 1000-seeds weight of black cumin

Statistically significant influence on 1000-seeds weight was observed due to different seed rates under the present experiment (Fig. 4 and Appendix XII). The maximum 1000-seeds weight (2.94 g) was obtained from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the minimum 1000-seeds weight (2.84 g) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Fahim *et al.* (2017) and Tuncturk *et al.* (2005) observed the similar results.



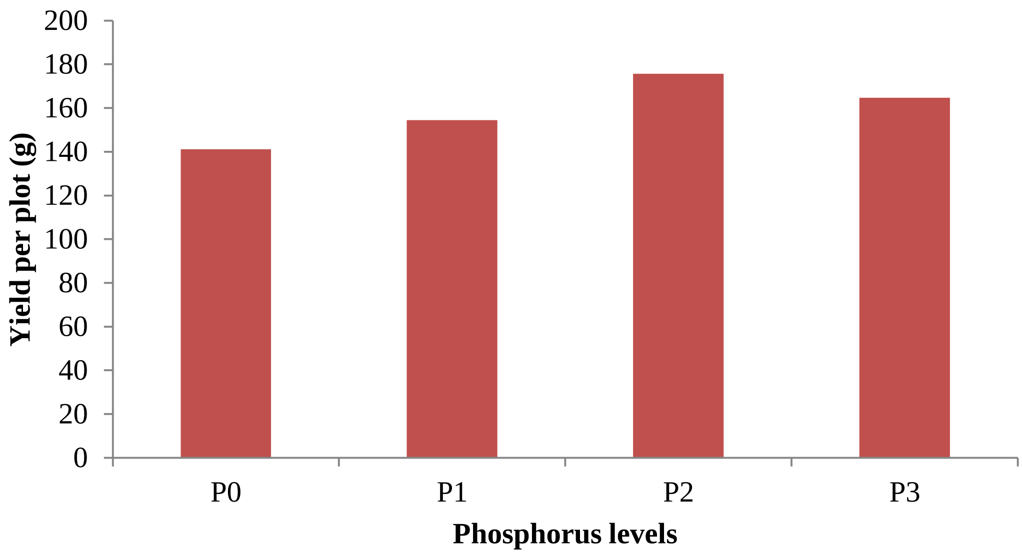
Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Fig. 4. Effect of different seed rates on 1000-seeds weight of black cumin

Combined effect of different levels of phosphorus and seed rates significantly influenced by 1000-seeds weight (Table 11 and Appendix VIII). From the results of the experiment revealed that the maximum 1000-seeds weight (3.15 g) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination which was statistically similar (3.08 and 3.02) to treatment combination of P_2R_1 and P_2R_3. On the other hand the minimum 1000-seeds weight (2.68 g) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.11 Yield per plot (g)

Significant variation on yield per plot was observed due to varied levels of phosphorus (Fig. 5 and Appendix XI). From the results of the experiment showed that the highest yield per plot (175.68 g) was obtained from P_2 (40 kg P ha^{-1}) treatment. On the other hand the lowest yield per plot (141.08 g) was obtained from P_0 (control) treatment. Moradzadeh *et al.* (2021), Rimu *et al.* (2020), Sultana *et al.* (2019), Mousa *et al.* (2012), Vedantham *et al.* (2020) and Sen *et al.* (2019) observed the similar results. Yimam *et al.* (2015) reported that use a combination of 45 kg N and 40 kg P ha^{-1} followed by 15 kg N and 20 kg P ha^{-1} for black cumin production in the area.

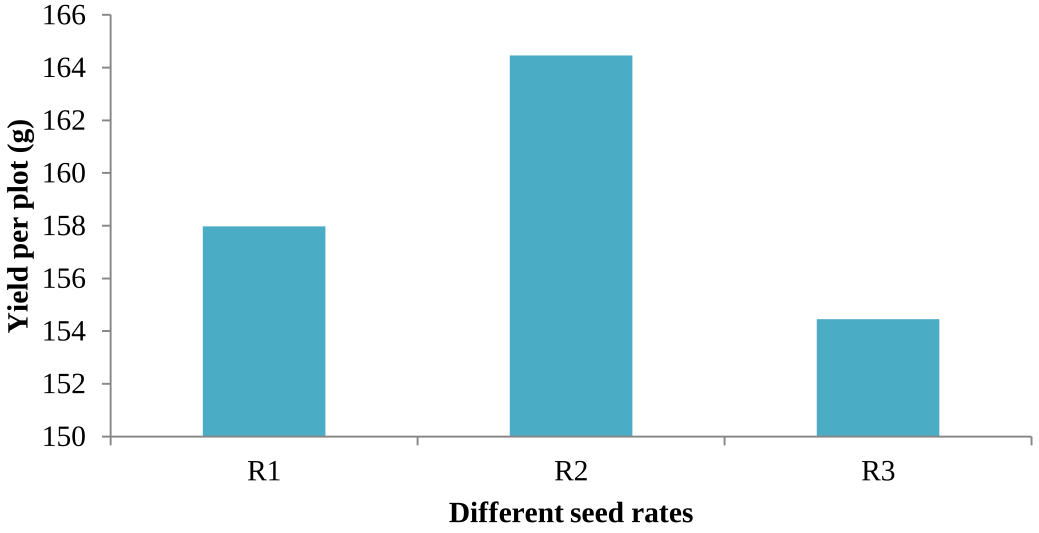


Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Fig. 5. Effect of different levels of phosphorus on yield per plot of black cumin

Statistically significant influence on yield per plot was observed due to varied seed rates during the experimentation (Fig. 6 and Appendix XII). It was observed that the highest yield per plot (164.46 g) was obtained from R_2 (10 kg seeds ha^{-1}) treatment.

On the other hand the lowest yield per plot (154.45 g) was observed from R_3 (12 kg seeds ha^{-1}) treatment. Mengistu *et al.* (2021) reported that yield and yield attributing factors such as seed yield per plot and seed yield ha^{-1} (kg) was significantly influenced by the seed rate. Seed yield increased from 462 kg ha^{-1} to 634 kg ha^{-1} as seed rate increased from 5 kg ha^{-1} to 20 kg ha^{-1} and showed a decrease in yield from 601 kg ha^{-1} to 507 kg ha^{-1} as inter-row spacing increased from 20 cm to 40 cm.



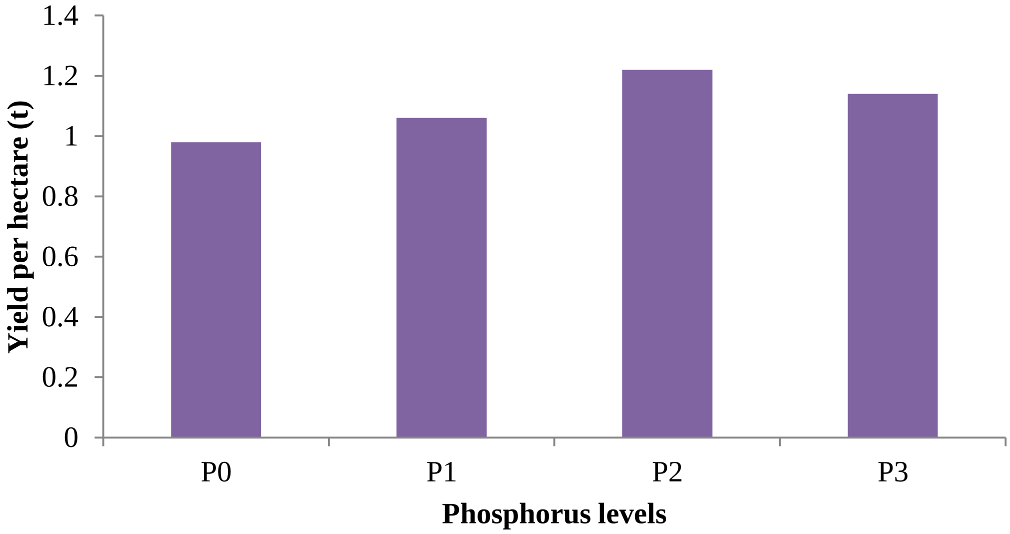
Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Fig. 6. Effect of different seed rates on yield per plot of black cumin

Yield per plot showed significant influence due to the combined effect of different levels of phosphorus and seed rates (Table 11 and Appendix VIII). From the results of the experiment observed that the highest yield per plot (182.88 g) was obtained from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand the lowest yield per plot (139.27 g) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.12 Yield per hectare (t)

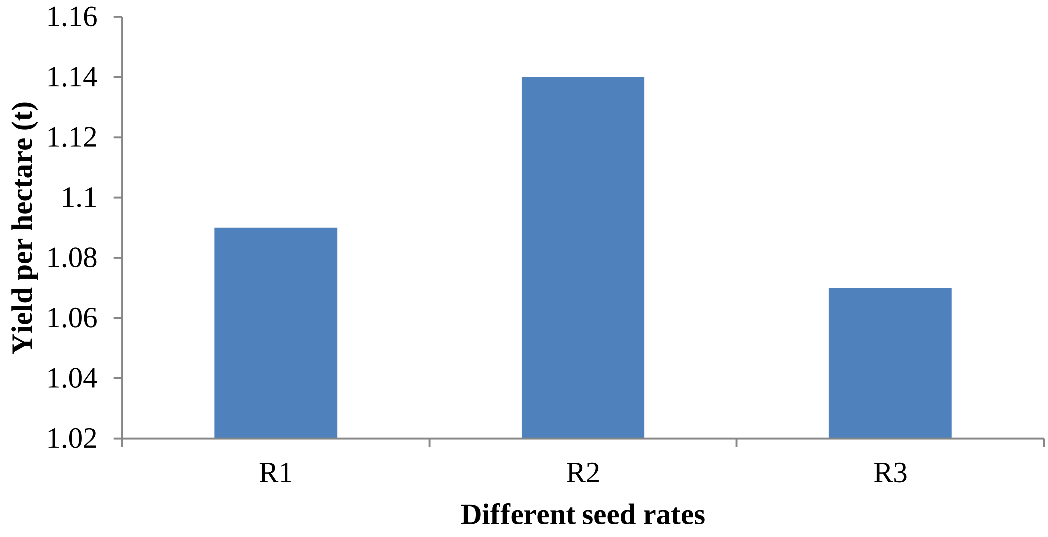
Significant variation was observed on yield per hectare due to different levels of phosphorus under the present study (Fig. 7 and Appendix XI). From the results of the experiment showed that the highest yield per hectare (1.22 t) was obtained from P_2 (40 kg P ha^{-1}) treatment. On the other hand the lowest yield per hectare (0.98 t) was obtained from P_0 (control) treatment. The result of the experiment were in coincided with the findings of Vedantham *et al.* (2020), Sen *et al.* (2019), Kizil *et al.* (2008), Tuncturk *et al.* (2013) and Yimam *et al.* (2015). Yousuf *et al.* (2018) reported that The highest seed yield (1277 kg ha^{-1}) was obtained from 75% RDCF + 25% cowdung-N treatment followed by 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg ha^{-1}) and the lowest seed yield (420 kg ha^{-1}) was recorded with 50% RDCF.



Here, P_0= control, P_1= 35 kg ha^{-1}, P_2= 40 kg ha^{-1} and P_3= 45 kg ha^{-1}

Fig. 7. Effect of different levels of phosphorus on yield per hectare of black cumin

Statistically significant influence on yield per hectare was observed due to different seed rates (Fig. 8 and Appendix XII). It was revealed that the highest yield per hectare (1.14 t) was revealed from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the lowest yield per hectare (1.07 t) was obtained from R_3 (12 kg seeds ha^{-1}) treatment. Mengistu *et al.* (2021) observed the similar result. They reported that seed yield ha^{-1} (kg) was significantly influenced by the seed rate. Fahim *et al.* (2017) reported that 8 kg seed/ha would be the optimum seed rate and line sowing in raised bed would be the most effective method for higher seed yield of the black cumin. But for broadcasting seeds should be shown with 10 kg/ha.



Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Fig. 8. Effect of different seed rates on yield per hectare of black cumin

Combined effect of different levels of phosphorus and seed rates significantly influenced by yield per hectare of black cumin (Table 11 and Appendix VIII). From the results of the experiment revealed that the highest yield per hectare (1.27 t) was observed from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination which was statistically similar (1.21 t) to P_2R_1 treatment combination. On the other hand the lowest yield per hectare (0.94 t) was obtained from P_0R_3 (control + 12 seeds kg ha^{-1}) treatment combination.

Table 11. Combined effect of different levels of phosphorus and seed rates on 1000-seeds weight, yield per plot and yield per hectare of black cumin

Treatment Combinations	1000-seeds weight (g)	Yield per plot (g)	Yield per hectare (t)
P_0R_1	2.75 fg	141.12 h	0.98 fg
P_0R_2	2.78 fg	146.75 g	1.01 fg
P_0R_3	2.68 g	135.36 i	0.94 g
P_1R_1	2.83 def	152.40 f	1.05 def
P_1R_2	2.85 def	161.18 e	1.11 cde
P_1R_3	2.80 efg	149.81 fg	1.04 ef
P_2R_1	3.08 ab	174.24 b	1.21 ab
P_2R_2	3.15 a	182.88 a	1.27 a
P_2R_3	3.02 abc	169.92 c	1.18 bc
P_3R_1	2.93 cde	164.16 de	1.14 bc
P_3R_2	2.97 bcd	167.04 cd	1.16 bc
P_3R_3	2.89 c-f	162.72 e	1.13 bcd
$LSD_{(0.05)}$	**0.14**	**3.95**	**0.08**
CV(%)	**2.92**	**1.47**	**4.52**

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

Here, P_0= control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

CHAPTER IV

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2019 to March 2020 to study the effect of different levels of phosphorus and seed rates on growth and yield of black cumin. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Madhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Four levels of phosphorus *viz.*, P_0= control, P_1= 35 kg ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1} 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}. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 1.44 m^2 (1.2 m × 1.2 m). Data on different growth, yield contributing characters and yield were recorded to find out the best levels of phosphorus fertilization and optimum seed rates for the potential yield of black cumin.

Data revealed that in case of different phosphorus levels, at 135 DAS, the tallest plant height (52.84 cm), maximum number of primary branches per plant (8.39), number of secondary branches per plant (12.43) was obtained from P_3 (45 kg P ha^{-1}) treatment while the shortest plant height (34.64 cm), minimum number of primary branches per plant (5.43) and number of secondary branches per plant (8.70) were revealed from P_0 (control) treatment. The minimum days to first flowering of black cumin (51.31) and days to 50% flowering of black cumin (61.60) was obtained from P_3 (45 kg ha^{-1}) treatment. On the other hand the maximum days to first flowering of black cumin (57.52) and days to 50% flowering of black cumin (67.34) was obtained from P_0 (control) treatment. In case of yield attributes and yield, the maximum number of capsules per plant (20.69), length of capsule (1.51 cm), breadth of capsule (1.05 cm), number of seeds per capsule (80.07), 1000-seeds weight (3.08 g), yield per plot (175.68 g) and yield per hectare (1.22 t) were obtained from P_2 (40 kg P ha^{-1}) treatment while the minimum number of capsules per plant (16.32), length of capsule (1.11 cm), breadth of capsule (0.77 cm), number of seeds per capsule (66.24), 1000-

seeds weight (2.74 g), yield per plot (141.08 g) and yield per hectare (0.98 t) was revealed from P_0 (control) treatment.

Seed rates significantly influence the growth, yield contributing characters and yield of black cumin. Data revealed that at 135 DAS, the tallest plant height (45.33 cm), maximum number of primary branches per plant (7.26) and number of secondary branches per plant (11.00) were observed from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the shortest plant height (41.45 cm), minimum number of primary branches per plant (6.64) and number of secondary branches per plant (10.11) were obtained from R_3 (12 kg seeds ha^{-1}) treatment. The minimum days to first flowering of black cumin (53.61) and days to 50% flowering of black cumin (63.58) were obtained from R_1 (8 kg seeds ha^{-1}) treatment. On the other hand the maximum days to first flowering of black cumin (55.23) and days to 50% flowering of black cumin (65.10) were obtained from R_3 (12 kg seeds ha^{-1}) treatment. In terms of yield components and yield, the maximum number of capsules per plant (19.20), length of capsule (1.35 cm), breadth of capsule (0.94 cm), number of seeds per capsule of black cumin (74.18), 1000-seeds weight (2.94 g), yield per plot (164.46 g) and yield per hectare (1.14 t) were obtained from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the minimum number of capsules per plant (17.86), length of capsule (1.25 cm), breadth of capsule (0.87 cm), number of seeds per capsule (70.92), 1000-seeds weight (2.84 g), yield per plot (154.45 g) and yield per hectare (1.07 t) was obtained from R_3 (12 kg seeds ha^{-1}) treatment.

Combined effect of different levels of phosphorus and seed rates significantly influenced by growth, yield attributes and yield of black cumin. Data obtained from the experiment revealed that at 135 DAS, the tallest plant height (55.18 cm), maximum number of primary branches per plant (8.67) and number of secondary branches per plant (13.00) were obtained from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination. On the other hand the shortest plant height (32.81 cm), minimum number of primary branches per plant (4.92) and number of secondary branches per plant (8.27) were obtained from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination. The minimum days to first flowering of black cumin (50.15) and days to 50% flowering of black cumin (60.85) was observed from P_3R_1 (45 kg P ha^{-1} + 8 kg seeds ha^{-1}) treatment combination. On the other hand the maximum days to first flowering of black cumin (58.45) and days to 50% flowering of black cumin

(68.25) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination. In terms of yield attributes and yield, the maximum number of capsules per plant (21.80), length of capsule (1.59 cm), breadth of capsule (1.10 cm), number of seeds per capsule (82.15), 1000-seeds weight (3.15 g), yield per plot (182.88 g) and yield per hectare (1.27 t) were obtained from P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination. On the other hand the minimum number of capsules per plant (15.37), length of capsule (1.07 cm), breadth of capsule (0.74 cm), number of seeds per capsule (64.71), 1000-seeds weight (2.68 g), yield per plot (135.36 g) and yield per hectare (0.94 t) were obtained from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

CONCLUSION

This study observed that different levels of phosphorus and seed rates have a positive effect on growth and yield of black cumin. In case of yield of black cumin, P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) treatment combination was given the better performance of all the yield contributing parameters and yield (1.27 t per ha) of black cumin than the other treatment combinations. So, the treatment combination of P_2R_2 (40 kg P ha^{-1} + 10 kg seeds ha^{-1}) can be repeated in different agro ecological zones of Bangladesh for better yield of black cumin.

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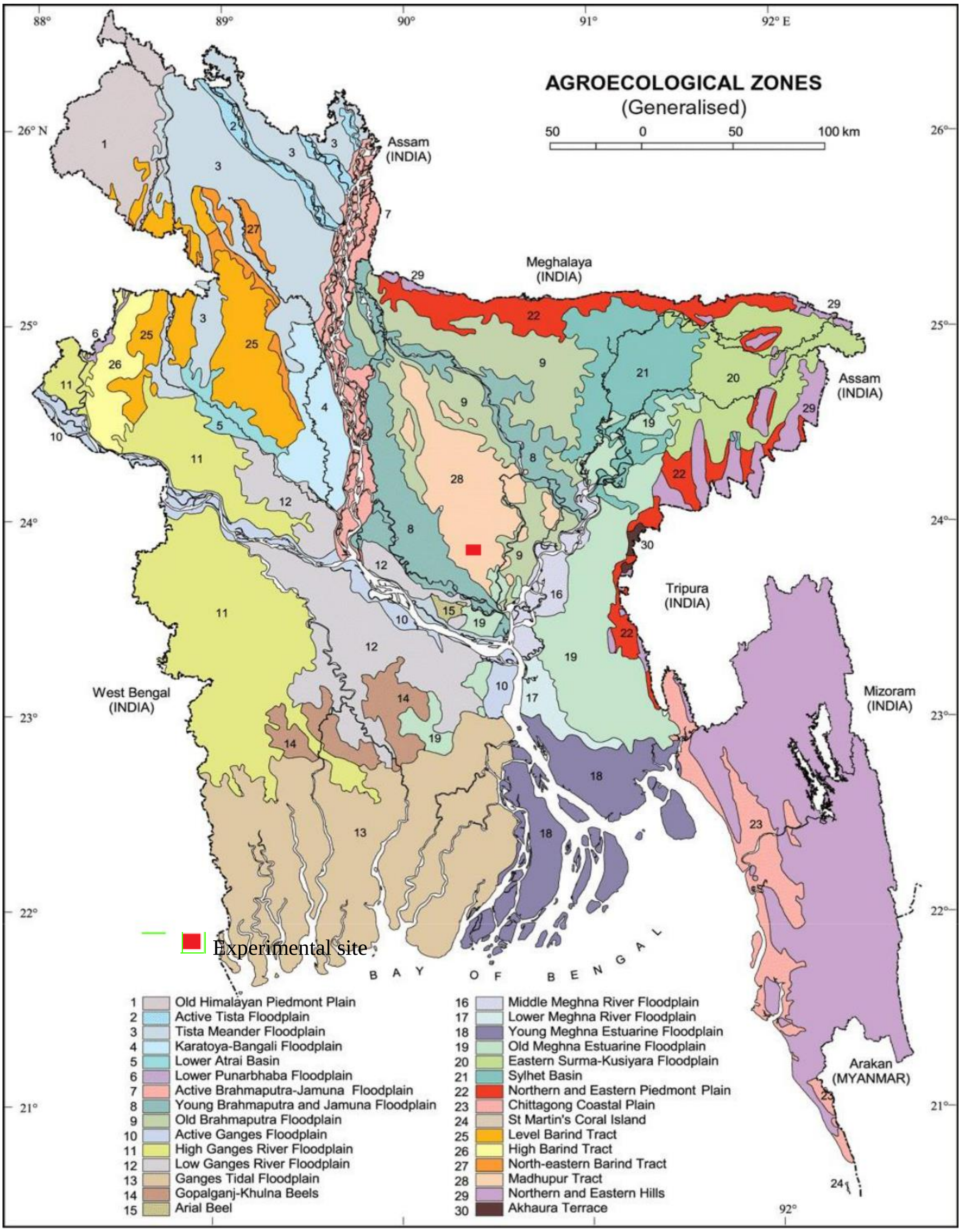
APPENDICES

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2019 to March 2020

Month and year	RH (%)	Air temperature (°C)			Rainfall
		Max.	*Min.*	*Mean*	(mm)
November, 2019	56.25	28.70	8.62	18.66	14.5
December, 2019	51.75	26.50	9.25	17.87	12.0
January, 2020	46.20	23.70	11.55	17.62	0.0
February, 2020	37.95	22.85	14.15	18.50	0.0
March, 2020	35.75	21.55	15.25	18.40	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University, Dhaka
AEZ	Modhupur 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	Not Applicable

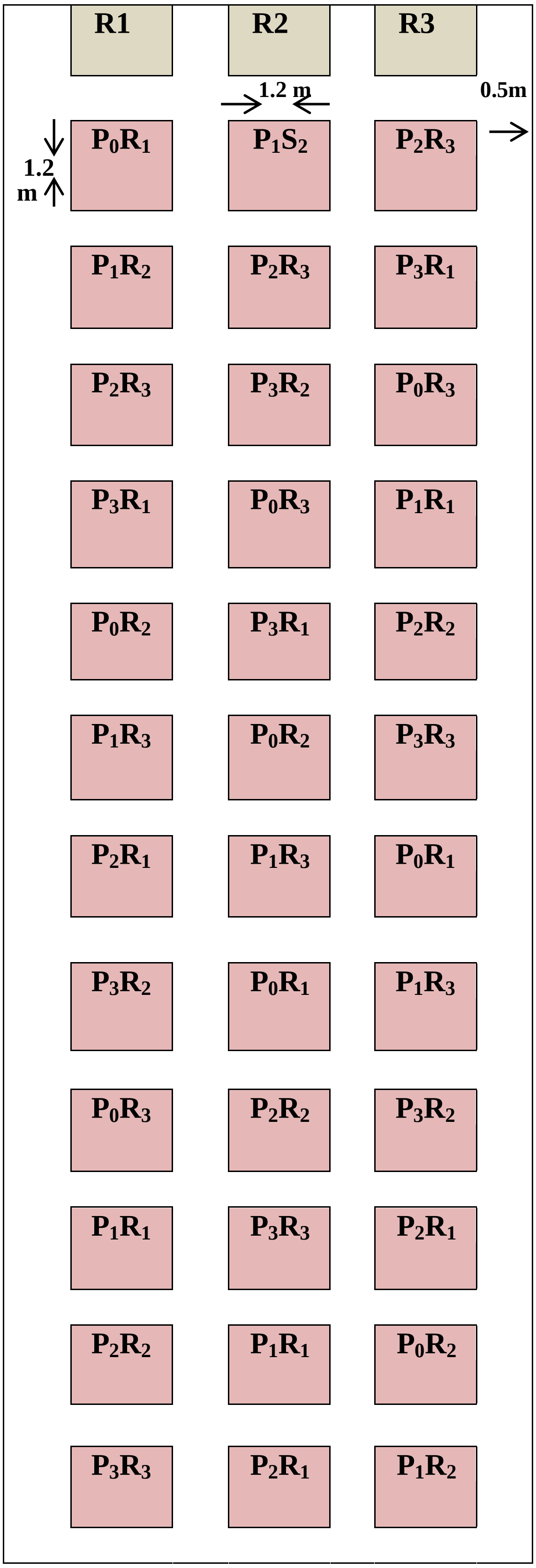
Source: Soil Resource Development Institute (SRDI)

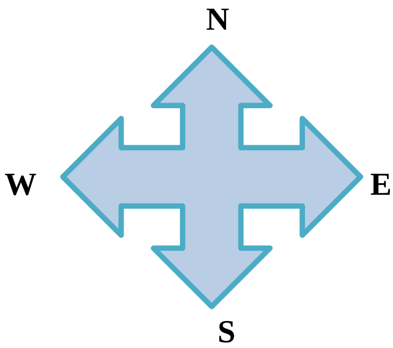
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	6.2
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experimental field





Plot size: 1.2 m × 1.2 m

Factor A: Different phosphorus (4)

P_0= 0 kg P ha^{-1} (control)

P_1= 35 kg P ha^{-1}

P_2= 40 kg P ha^{-1}

P_3= 45 kg P ha^{-1}

Factor B: Seed rates (3)

R_1= 8 kg seeds ha^{-1}

R_2= 10 kg seeds ha^{-1}

R_3= 12 kg seeds ha^{-1}

Appendix V. Mean square values of plant height at different days after sowing of black cumin growing under the experiment

Sources of variation	Degrees of freedom	Mean square of plant height at		
		45 DAS	90 DAS	135 DAS
Replication	2	67.403	72.865	169.488
Factor A	3	119.004**	537.897**	552.507**
Factor B	2	9.157**	46.063**	45.162**
A × B	6	0.190*	0.857*	0.642*
Error	22	0.311	1.252	2.136

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of number of primary and secondary branches per plant, days to first and 50% flowering per plant of black cumin growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Number of primary branches per plant	Number of secondary branches per plant	Days to first flowering	Days to 50% flowering
Replication	2	3.488	15.436	244.352	314.675
Factor A	3	14.847**	22.909**	63.308**	54.829**
Factor B	2	1.180**	2.364**	7.922*	6.978*
A × B	6	0.041*	0.032*	0.215*	0.326*
Error	22	0.048	0.335	1.946	2.657

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VII. Mean square values of number of capsule per plant, length of capsule, breadth of capsule and number of seeds per capsule of black cumin growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Number of capsule per plant	Length of capsule	Breadth of capsule	Number of seeds per capsule
Replication	2	40.407	0.0546	0.0126	256.610
Factor A	3	30.844**	0.2553**	0.1322**	325.551**
Factor B	2	5.408**	0.0318**	0.0137**	31.816**
A × B	6	0.332*	0.0011*	0.0003*	0.865*
Error	22	0.201	0.0019	0.0005	3.689

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of 1000 seeds weight, yield per plot and yield per hectare of black cumin growing during experimentation

Sources of variation	Degrees of freedom	Mean square of		
		1000 seeds weight	Yield per plot	Yield per hectare
Replication	2	0.7500	653.870	0.0498
Factor A	3	0.1992**	1955.560**	0.0977**
Factor B	2	0.0244*	309.330**	0.0130*
A × B	6	0.0009*	13.220*	0.0006*
Error	22	0.0071	5.450	0.0025

* significant at 5% level of significance
** significant at 1% level of significance

Appendix IX. Effect of different levels of phosphorus on plant height at different days after sowing of black cumin

Treatments	Plant height (cm)		
	45 DAS	**90 DAS**	**135 DAS**
P_0	15.66 d	26.39 d	34.64 d
P_1	19.38 c	31.20 c	40.14 c
P_2	22.14 b	37.07 b	46.16 b
P_3	24.02 a	44.31 a	52.84 a
$LSD_{(0.05)}$	**0.54**	**1.09**	**1.42**
CV%	**2.75**	**3.22**	**3.36**

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

Here, $P_{0=}$ control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Appendix X. Effect of different seed rates on plant height at different days after sowing of black cumin

Treatments	Plant height (cm)		
	45 DAS	90 DAS	135 DAS
R_1	21.23 a	36.61 a	45.33 a
R_2	20.18 b	34.91 b	43.56 b
R_3	19.49 c	32.70 c	41.45 c
$LSD_{(0.05)}$	**0.47**	**0.94**	**1.23**
CV%	**2.75**	**3.22**	**3.36**

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

Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}

Appendix XI. Effect of different levels of phosphorus on 1000-seeds weight, yield per plot and yield per hectare of black cumin

Treatments	1000-seeds weight (g)	Yield per plot (g)	Yield per hectare (t)
P_0	2.74 d	141.08 d	0.98 d
P_1	2.83 c	154.46 c	1.07 c
P_2	3.08 a	175.68 a	1.22 a
P_3	2.93 b	164.64 b	1.14 b
$LSD_{(0.05)}$	**0.08**	**2.28**	**0.04**
CV%	**2.92**	**1.47**	**4.51**

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

Here, $P_{0=}$ control, P_1= 35 kg P ha^{-1}, P_2= 40 kg P ha^{-1} and P_3= 45 kg P ha^{-1}

Appendix XII. Effect of different seed rates on 1000-seeds weight, yield per plot and yield per hectare of black cumin

Treatments	1000-seeds weight (g)	Yield per plot (g)	Yield per hectare (t)
R_1	2.89 ab	157.98 b	1.09 b
R_2	2.94 a	164.46 a	1.14 a
R_3	2.85 b	154.45 c	1.07 b
$LSD_{(0.05)}$	**0.07**	**1.97**	**0.04**
CV%	**2.92**	**1.47**	**4.51**

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

Here, R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1} and R_3= 12 kg seeds ha^{-1}