EFFECT OF MACRONUTRIENTS COMBINATION WITH PLANT SPACING ON THE GROWTH AND YIELD OF BLACK CUMIN (*Nigella sativa* L.)

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CERTIFICATE

This is to certify that the thesis entitled, "*EFFECT OF MACRONUTRIENTS COMBINATION WITH PLANT SPACING ON THE 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*** in ***HORTICULTURE****, embodies the result of a piece of bonafide research work carried out by* ***MD. IMRAN SARKAR****, Registration No. 13-05506 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

An experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during October 2019 to March 2020 to study the effect of macronutrients combination and plant spacing on growth and yield of black cumin (*Nigella sativa* L.). Black cumin variety BARI Kalozira 1 was used as planting material in this study. The experiment consisted of two factors: Factor-A: macro nutrient combinations (4 levels): T_1= $N_0P_0K_0$ kg ha^{-1} (control), T_2= $N_{45}P_{25}K_{20}$ kg ha^{-1}, T_3= $N_{135}P_{75}K_{60}$ kg ha^{-1}; Factor-B: plant spacing (3 levels): S_1= 20cm×10cm, S_2= 20cm×15cm and S_3= 20cm×20cm. The experiment was laid out in a randomized complete block design (factorial) with three (3) replications. Data on different growth, yield contributing and yield parameter of black cumin were recorded and significant variation was observed from different treatments. In case of nutrient combinations the tallest plant (54.86 cm) was observed from T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) treatment. The maximum primary branch plant^{-1} (8.62) and secondary branch plant^{-1} (12.18), flower plant^{-1} (22.20), capsules plant^{-1} (19.69), seeds capsules^{-1} (76.18), 1000 seed weight (2.99 g) and germination percentage (91.00%) was observed from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment. The highest seed yield plant^{-1} (3.36 g), seed yield plot^{-1} (170.4 g), seed yield ha^{-1} (1.18 t) and dry matter (11.29 g) were observed from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment. In case of plant spacing the tallest plant (48.34 cm) was observed from S_1 (20cm×10cm) treatment. The maximum primary branch plant^{-1} (7.80) and secondary branch plant^{-1} (11.23) flower plant^{-1} (20.26), capsules plant^{-1} (18.81), 1000 seed weight (2.99 g) , seed yield plant^{-1} (3.89 g) and germination percentage (89.85%) were observed from S_3 (20cm×20cm) treatment. The maximum seeds capsules^{-1} (71.77 g) and dry matter (10.03 g) were observed from S_2 (20cm×15cm) treatment. The seed yield plot^{-1} (156.66 g) and seed yield ha^{-1} (1.09 t) were recorded from S_1 (20cm×10cm) treatment. The highest BCR (2.80) was obtained from the T_2S_2 treatment combination where as the lowest BCR (2.24) was from T_0S_3 treatment combination. It may be concluded that, sowing of black cumin providing 90 kg N, 50 kg P and 40 kg K nutrient combination with 20 cm × 15 cm plant spacing was recorded to be more suitable practice for getting higher amount and quality of seed yield of black cumin.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ = Agro-Ecological Zone

BARI = Bangladesh Agricultural Research Institute

BBS = Bangladesh Bureau of Statistics

CV% = Percentage of Coefficient of Variance

DAS = Days after sowing

et al. = And others

FAO = Food and Agricultural Organization of United Nations

g = gram (s)

ha^{-1} = Per hectare

HRC = Horticulture Research Centre

kg = Kilogram

LSD = Least Significant Difference

Max = Maximum

Min = Minimum

MOP = Muriate of Potash

N = Nitrogen

NPK = Nitrogen, Phosphorous and Potassium

NS = Not significant

RCBD = Randomized Complete Block Design

SAU = Sher-e-Bangla Agricultural University

SRDI = Soil Resources and Development Institute

TSP = Triple Super Phosphate

wt = Weight

% = Percent

^{0}C = Degree Celsius

CHAPTER I

INTRODUCTION

Black cumin (*Nigella sativa* L.) is well known as a spice crop in Bangladesh as well as in the world. It is commonly known as 'Kalozira' belongs to family Ranunculaceae and is cultivated in the winter season. The crop is also known by many common names viz. black caraway, black-cumin, fennel- flower, nigella, nutmeg-flower and roman-coriander. It is believed to have originated in western Asia where it grows both wild and cultivated. It is widely cultivated in Southwest Asia, South Europe, Syria, Egypt, Pakistan, India, Iran, Japan, China and Turkey (Shewaye, 2011). In Bangladesh, it is grown well in Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kusthtia and Natore districts. It grows to 20 to 60 cm tall, with finely divided, linear (but not thread-like) leaves and plant has a developed taproot. The flowers are delicate, and usually coloured pale blue and white with 5 to 10 petals. The fruit is a large and inflated capsule composed of 3 to 7 united follicles, each containing throughout Black cumin is numerous seeds. The seed is used as a spice (Abadi *et al.,* 2015). Black Cumin has a long history of use as food flavors, perfumes and medicinal values. Essential oil has been used for bringing smell to some medicines, for sterilizing of surgical operation fiber, for producting of some veterinary and agricultural medicines and plastic (Simon *et al.*, 1984). The seed contain 30-35 % of oil which has several uses for pharmaceutical and food industries (Ustun *et al.,* 1990). It is appropriately known as seed of blessing (habbatul barakah) (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, cardioprotective, gastroprotective, anti-asthmatic, nephroprotective, hepato-protective, antiinflmmatory, immune-modulatory, neuroprotective, anticonvulsant, anxiolytic, antinociceptive, anti-oxidant, antioxytocic, contraceptive, antibacterial, antifungal and anthelmintic activities were immensely appreciated. The major medicinal components are thymo- quinone and nigellone (a dimer of thymoquinone). These were attributed to impart anti-tumour, anti-inflammatory and anti-diabetic properties (Woo *et al*., 2012). Multiple studies made in the last decades validate its health beneficial effects particularly in diabetes, dyslipidemia, hypertension, respiratory disorders, inflammatory diseases, and cancer. Nigella sativa seeds also possess immune stimulatory, gastroprotective, hepatoprotective, nephroprotective, and neuroprotective activities. (Srinivasan, 2018). Black Cumin seeds have an aromatic odor and bitter taste. They are used as an essential ingredient in soup, sausages, cheese, cakes and candies (Behera *et al.,* 2004). On Bangladesh black cumin was cultivated on 31 hectares of land and average yield 0.8-1.0 ton per hectares (BBS 2018).

Quality in medicinal plants is more important than other plant products. Environmental factors have an important role on plant growth. Some of these factors such as nutrient and spacing can be controlled by human. Both of them are essential to increase yield and quality of plants (Singh and Goswami, 2000). Because the need of increasing the medicinal plant production all over the world, its production became an ultimate goal to meet the great increase of population to avoid chemical therapy side effects on human health through utilization of the medical herbs. However, the use of the most suitable and recommended agricultural practices in growing such crops could provide the producers with higher income, in comparison with many other traditional crops (Hassan *et al.,* 2012).

Fertilizer application to the plant greatly effects their growth, production plant constituents. Nitrogen (N) has the largest effect on plant physiology and is probably the most important limiting nutrient for crop growth. Agricultural soils are often deficient in N and hence, to ensure adequate N supply to crops and to prevent from nutrient deficiencies, large amounts of inorganic N are applied (Shah, 2004). Nitrogen strongly stimulates growth expention of the plant canopy and ultimately increase yield contributing characters and yield. It is reported that application of 60-90 kg nitrogen per hectare is essential to achieve maximum performance of cumin (Champawat and Pathak, 1982; Ehteramian, 2002; Tuncturk *et al.,* 2012). Availability of nitrogen is of prime importance for growing plants as it is a major and indispensable constituent of protein and nucleic acid molecules (Troug, 1973). An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally lead to higher productivity.

Phosphorus (P) 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. The early supply of phosphorous to the crop is influenced by soil phosphorous and phosphorous application as well as by soil and environmental conditions that affect phosphorous phytoavailability and root growth. Roots absorb phosphorous ions from the soil solution. The ability of the plant to absorb phosphorous will depend on the concentration of phosphorous ions in the soil solution at the root surface and the area of absorbing surface in contact with the solution

(Barber, 1984). Application of phosphorus was found to increase plant height, number of branches, fresh and dry weight and essential oil content of black cumin (Sushama and Jose, 1994).

Potassium (K) fertilizer is another essential component to reduce the severity of disease of black cumin plants. Application of K ha along with N ha^{-1} decreased plant death due to disease and also increased yield in Cumin (Champawat and Pathak, 1982)

Very cool temperature and excessive use of fertilizer may cause reduction in growth and yield of black cumin and increase diseases infestation. Black cumin of different genotypes requires good combination of fertilizers for optimum growth and yield. The present study was undertaken to understand the growth and yield of black cumin genotypes under different levels of N-P-K fertilizer and also to determine the optimum fertilizer doses for black cumin production.

Population density is one of the major factors that affect yield and quality of black cumin seed (Ahmed and Haque, 1986). Appropriate plant spacing can lead to maximum yield. Agronomists believe that the establishment of optimum density of healthy plants in a field is the basis for the successful farming system. Optimum plant density is a density at which all environmental parameters (water, soil, air and light) are fully exploited by the plants and at the same time, intraspecies and extraspecies competitions are reduced (Alizadeh and Koucheki, 1995). When plant density is increased, most yield components of the plants are decreased such as number of $fruit^{-1}$ and number of seed $plant^{-1}$. However, there have some components that do not follow this pattern in some cases (Hashemi *et al.*, 1998).

Plant spacing plays an important role in growth and yield. Optimum plant spacing ensures the plant to grow properly with their aerial and underground parts by utilizing more sunlight and soil nutrients (Miah *et al.*, 1990). High plant spacing make difficult for various intercultural operations. In a densely populated crop, the interplant competition is very high for essential nutrients, light and air, which usually results in mutual shading, lodging and thus favors more vegetative growth than grain yield.

Black cumin lacks research recommendations on optimum plant density (seed rate) and row spacing that could lead to the poor yield of the crop. Hence, it is vital to identify the suitable seed rates and row spacing for black cumin production. Therefore, this study was initiated with the objective of finding out the optimum seed rate and inter- row spacing for better growth and yield attributes of black cumin.

In the world today, the traditional food, forage and fiber crops are not the only plants of key agricultural and trade significance, but they also include plants whose secondary metabolites are valued for their characteristic aromatic or therapeutic attributes, or as main natural inputs to the proliferating perfumery and chemical industries. In Bangladesh, not many farmers are growing black cumin crop on commercial basis. So, a very small quantity of yield obtained that is insufficient to meet the national requirements and there is a gap between its production and demand. So, there is a huge scope for improvement of the production potential of black cumin in Bangladesh. Black cumin lacks research recommendations on optimum macronutrient level and spacing that could lead to the poor yield of the crop. Hence, it is vital to identify the suitable Macronutrient level and spacing for black cumin production. Therefore, this study was initiated with the objective of finding out the optimum Macronutrient level and spacing for better growth and yield attributes of black cumin.

Keeping in view the above, the present piece of research was designed to achieve the following objectives –

- To investigate the effect of macronutrients (N, P & K) combination for maximum seed yield of black cumin;
- To identify the suitable spacing for maximum growth and yield of black cumin seed; and
- To determine the combined effect of macronutrient like N, P & K with plant spacing on the higher seed yield of black cumin.

CHAPTER II

REVIEW OF LITERATURE

Black cumin is one of the most important medicinal plants all over the world including Bangladesh. The yield of black cumin depends on many factors such as are land topography, soil fertility, soil productivity, environment (light, temperature, moisture, humidity and rainfall), and different cultural practices. Different types of chemical fertilizers play an important role on its growth, yield and quality. Nitrogen, phosphorus and potassium are the three major important macronutrients which are responsible for controlling growth and yield of black cumin. A number of research works have been done on different levels of macronutrients on the yield of black cumin in various parts of the world, which have been made in this regard in Bangladesh. Cultural practice spacing of plant also play an important role on yield and quality of black cumin. The present study has been taken to investigate the effect of macronutrient and spacing on growth and yield of black cumin (*Nigella sativa* L.). In the chapter an attempt has been made to research findings related to the present study have been reviewed here.

Vedantham *et al.* (2020) made an experiment in the Vegetable Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences. 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=152.17kg ha^{-1}, Single Super Phosphate = 406.25kg ha^{-1}, Murate of Pottash = 108.33kg ha^{-1}) was superior in terms of growth and yield viz. plant height (60.23), 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 $plant^{-1}$ (8.59g), seed yield $plot^{-1}$ (103.12g) and seed yield (7.20q ha^{-1}) of Black cumin.

Ozyazici (2020) studied effect of different levels of leonardite and nitrogen fertilizer applied to the soil on seed yield and some quality parameters of black cumin (*Nigella sativa* L.). In the study, 4 different doses of leonardite and nitrogen fertilizer were administered. In the study, the highest plant height and number of branches were found in L_2N_{90}, the highest number of capsules was found in L_2N_{60}, and the highest number of seed per capsule was found in L_2N_{60} and L_3N_{60}. As a result of the study, the highest seed yield was obtained from L_2 and L_3 doses of leonardite and from N_{60} dose of nitrogen. It was determined that the fixed oil ratio, essential oil ratio contained in the black cumin seeds, and essential oil components parallel with the increase in leonardite and nitrogen doses. It was concluded that leonardite, a soil conditioner, could be used in black cumin cultivation under semi-arid climate conditions and that 2000 kg ha^{-1} leonardite and 60 kg ha^{-1} nitrogen could be applied to improve the yield and quality of black cumin (*Nigella sativa* L.).

Rimu *et al.* (2020) was conducted an experiment 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. Cow dung 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^{-1}) + cow dung @5 t ha^{-1}). 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^{-1}) 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 T7. 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 T7. While the highest oil content (24.59%) was recorded in T_5 (N_{60} + P_{50} + K_{50} + S_{10} + Zn_3 (kg ha^{-1}) + Cow dung 5 t ha^{-1}, 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 T7 (N_{60} + P_{60} + K_{50} + S_{10} + Zn_3 (kg ha^{-1}) + cow dung @ 5 t ha^{-1}), 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^{-1} + organic compost at 5 t ha^{-1}). 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^{-1}) + organic compost at 5 t ha^{-1}).

Sen *et al.* (2019) was conducted a field experiment during rabi seasons of 2014–15 and 2015–16 to study the effects of various combination of different levels of organic inorganic, and biofertilizers (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 biofertilizer 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.

Khurshid *et al.* (2018) was conducted a field experiment at the Agricultural Scientific Research Center in Hama (Syria) during 2015-2016 season to study the effect of adding levels of nitrogen, phosphorus and potassium on the production of black seed according to the experimental design of complete randomized block design, with three replicates. With the addition of nitrogen levels 0-60-120 kg N ha^{-1} in the form of urea (46% N), phosphorus levels 0-30-60 kg P_2O_5 ha^{-1} in the form of triple superphosphate (46% P_2O_5) and potassium levels 0-30-60 kg K_2O ha^{-1}, in order to study and diagnose the nutritional status of black seed crop and determine the data of the integrated diagnostic system (DRIS). The DRIS data of the black seed crop was identified in the Syrian Arab Republic for the first time depending on the content of NPK in the leaves after 90 days of sowing according to the laws of Beaufils and Sumner. As well as to study of the effect of NPK factors on seed production of black seed (kg ha^{-1}). The results showed that there is a clear correlation between DRIS indicators and the physiological equilibrium of the three elements (NPK) in the leaves on the one hand, and with the seed production on the other hand. The best physiological equilibrium of (NPK) paralyzed with $N_{120}P_{30}K_{30}$ treatment (1630 kg ha^{-1}), which were statistically similar with $N_{120}P_{30}K_{60}$, that gave the highest yield (1609 kg ha^{-1}). The standard values of black bean plant were determined by n/p, n/k and k/p (6.19, 1.40 and 4.47) respectively.

Waliullah *et al.* (2021) was conducted a field experiment to find out a suitable sowing date and method to produce higher seed yield of black cumin. The two factor experiment comprised with four sowing dates (1st November, 15th November, 1st December and 15th December) and two sowing methods (line sowing and broadcast seeding). The experiment was carried out following randomized complete block design with three replicates. Results showed that plant growth, yield contributing traits and yield of black cumin significantly influenced by sowing dates and methods. It was observed that the line sowing method compared to broadcast seeding and 1st December sowing among the other sowing dates exhibited higher plant growth with greater production of seed. The combine effect of sowing time and sowing methods showed significantly influenced on black cumin seed production. It was observed that the 1st December sowing with line sowing method increased the seed yield as compared to other sowing dates and methods. From the findings of this study it can be concluded that 1st December following line sowing method would maximize plant growth, yield contributing traits and seed yield of black cumin in Bangladesh.

Sağlam *et al.* (2019) was carried out a study to determine the efficiency of nitrogen (N) doses (0, 30, 60, and 90 kg N ha^{-1}) under supplemental potassium (K) application (50 kg K_2O ha^{-1}) on black cumin in 2011 and 2012. The significant effects ($p < 0.01$) of N and K doses on seed yield and seed oil content were found. The highest seed yield was obtained from 60 kg N ha^{-1} in the first year and 90 kg N ha^{-1} in the second year. The seed yield was increased at a K application dose of 50 kg ha^{-1} compared to the control. The highest seed yield (1245.1 kg ha^{-1}) in the first year was obtained from 50 kg K ha^{-1} with 60 kg N ha^{-1}, whereas the highest seed yield (991.4 kg ha^{-1}) in the second year was obtained from 50 kg K ha^{-1} with 90 kg N ha^{-1}. Furthermore, the seed oil content ranged from 36.5 - 40.3% through N in two-year means. The results showed significant effects of N and K applications on seed oil content. The seed oil content increased with 50K kg ha^{-1} compared to control and decreased with N doses in both years. The highest seed oil content (40.3 %) was obtained from 50 kg K ha^{-1} with 30 kg N ha^{-1} when both years were combined.

Jebraeil *et al.* (2021) was conducted a field experiment using a randomized complete block design with three replications was performed in the crop years 2017–18 to analyze the effects of soil fertility management practices on essential oil and seed oil properties of medicinal plant black cumin (*Nigella sativa* L.). The fertility management treatments were various application rates of the chemical fertilizers, manure, combination of chemical–manure and chemical–manure–Azorhizobium. The results showed that combination of chemical–manure–Azorhizobium increased the plant yield components in the first year and second year. In the second year, some physiological characteristics were increased. Dry weight, seed yield, biological yield, percentages of seed oil and essential oil increased with the application of the chemical–manure–Azorhizobium. The combined application of manure at 30 t ha^{-1} together with Azorhizobium had the greatest positive effects on the improvement of vegetative and reproductive characteristics of black cumin. Low application of chemical fertilizers had a little effect on the plant characteristics. These results show that the integrated plant nutrition management (IPNM) reduced chemical fertilizer (NPK) application rates; thus, it was a step to sustainable agriculture and reduction of environmental impacts.

Ali *et al.* (2015) conducted an experiment to know the effect on 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} NPK, respectively). First flower bud initiation day, capsule setting, and capsule ripening in 50% plant were not significantly influenced by NPK 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 NPK fertilizers. Natore local gave maximum dry matter production $plant^{-1}$ at 55 DAS with moderate NPK levels and at 70 DAS with higher NPK 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 NPK 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 NPK fertilizer, but BARI $kalozira^{-1}$ (2.95 g $plant^{-1}$ and 1.95 t ha^{-1}), Faridpur local (2.80g $plant^{-1}$ and 1.90 t ha^{-1}) and Natore local (2.69 g $plant^{-1}$ and 1.80 t ha^{-1}) showed maximum.

Shirmohammadi *et al.* (2014) studied in a field experiment at the research farm of Nour Abad in Lorestan, Iran, during 2013. Experiment was arranged as a 6 factorial based on randomized complete block design in three replications. Treatments included biological phosphate (*Pseudomonas putida*) at two levels inoculated and non-inoculated and chemical phosphorus (P_2O_5) at three levels (0, 40 and 80 kg ha^{-1}). Results showed that effect of treatments on plant height, capsule number per plant, grain number per capsules and grain yield were statically meaningful, however, there were no significant differences between treatments in respect of 1000 seed weight. The means showed that the greatest plant highest (32.1 cm) and grain yield (735 kg ha^{-1}) were obtained by a treatment of biological phosphate and chemical phosphorus (40 kg ha^{-1} P_2O_5). Results indicate that applying the combined biological phosphate and chemical phosphorus fertilizer can be practical and helpful method to increase black cumin yield, yield components and reduce the environmental pollution.

Tuncturk *et al.* (2012) carried out an experiment to determine the effects of different nitrogen doses (0, 20, 40, 60 and 80 kg ha^{-1}) on the yield and some yield components of 5 black cumin (*Nigella sativa* L.) in Van ecological conditions in 2006 and 2007. Field trials were designed by Completely Randomized Block Design with three replications at the experimental fields of Agricultural Faculty of Yuzuncu Yil University. In the study, plant height (cm), number of branch plant^{-1}, number of capsule plant^{-1}, number of seeds capsule^{-1}, 1000 seed weight (g) and seed yield (kg ha^{-1}) were determined. In conclusion, the effects of nitrogen (N) doses on the yield and some yield components were statistically significant except for 1000 seed weight and number of seeds capsule^{-1}. Plant height, number of branch plant^{-1}, number of capsule plant^{-1} and seed yield were increased by increasing nitrogen doses. According to the results, the highest values were obtained in seed yield (575 kg ha^{-1}), the number of capsule (7.5 capsule plant^{-1}) and the number of branch (4.51 branch plant^{-1}) from 60 kg N ha^{-1} application.

Shah (2007) reported the effect of basal nitrogen (0, 176, 264, 352 or 442 mg N pot^{-1}) applied with or without 10^{-5} M kinetin (KIN) spray on *Nigella sativa* L. Although, N alone was found to significantly enhance all parameters, viz, nutrient (NPK) accumulation, number of capsules, seed yield plant^{-1}, essential oil yields plant^{-1}.

Khalid (2012) investigated with the main objective to study the effect of different levels of NP fertilizers, trace elements and their interactions on the morphological and biochemical contents of medicinal and aromatic plants including anise (*Pimpinella anisum* L.), coriander (*Coriandrum sativum* L.) and sweet fennel (*Foeniculum vulgare* var. Dolce). Plots were divided into two main groups. The first group was subjected to different levels of NP combinations: N_0P_0, N_1P_1, N_2P_2 and N_3P_3. N_0 = 0 kg N ha^{-1}, N_1 = 100 kg N ha^{-1}, N_2 = 150 kg N ha^{-1} and N_3 = 200 kg N ha^{-1}; P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 37.5 kg P_2O_5 ha^{-1}, P_2 = 56.3 kg P_2O_5 ha^{-1} and P_3 = 75 kg P_2O_5 ha^{-1}. The second group was subjected to the same NP treatments but foliar spray (trace elements) was added at 1 g L^{-1}. N source was ammonium sulphate [$(NH_4)_2SO_4$] (20% N). P_2O_5 source was calcium superphosphate (15% P_2O_5). Foliar spray source was commercial solution (Greenzite) which contains EDTA Na2 Mn (40%), EDTA Na2 Zn (48%), Fe (5.4 mg L^{-1}), Mg (0.54 mg L^{-1}), Mn (50.54 mg L^{-1}), Zn (570.27 mg L^{-1}), Cu (0.054 mg L^{-1}), Mo (0.027 mg L^{-1}), Ni (0.005 mg L^{-1}) and Co (0.005 mg L^{-1}). The most effective treatment was N_3P_3 [200 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1}] × trace elements interaction, resulting in a positive increase in vegetative growth characters. The highest values of vegetative growth characters i.e. plant height (89.8 cm), leaf number (32.6), branch number (7.8), umbel number (22.9), fresh weight (257.8 g $plant^{-1}$), dry weight (99.1 g $plant^{-1}$) and fruit yield per plant (27.8 g) for sweet fennel were recorded from N_3P_3 × trace elements interaction.

Valiki *et al.* (2015) carried out an experiment in order to investigate the influence of different level of vermicompost and NPK fertilizer fertilizers on yield, growth parameters and essential oil of fennel (Foeniculum vulgare Miller.). The experimental treatments were chemical fertilizer (150 kg N ha^{-1} + 150 kg phosphate ha^{-1} + 100 kg potash ha^{-1}), vermicompost (5, 10, 15 and 20 t ha^{-1}) and control (without fertilizer). Analysis of variance showed that plant height, number of main and lateral branches, number of umbrellas per plant, number of umbellets per umbrella, seed yield, biological yield and harvest index at different levels of vermicompost and NPK fertilizer statistically significant. Results indicated that using 15 t ha^{-1} of vermicompost showed more positive effect on recorded traits of fennel than other treatments.

Nataraja *et al.* (2003) conducted an experiment to study the influence of nitrogen, phosphorous and potassium on growth and seed yield of black cumin at Sanjivini Vatika, University of Agricultural Sciences, Bangalore during 2000-2001. The experiment consisted of twenty seven treatment combinations with three levels each of nitrogen (0, 50 and 100 kg ha^{-1}), phosphorous (0, 20 and 40 kg ha^{-1}) and potassium (0. 30 and 60 kg ha^{-1}), and was laid out in factorial randomized block design with three replications. The results revealed significant differences in growth and yield parameters among the treatments. Application of nitrogen at 100 kg ha^{-1} recorded the maximum values for plant spread (427.75 cm^{-2}) and number of seeds (57.52) per pod. Significant differences were also observed with the interaction of NPK at 50:40:30 kg ha^{-1} producing pods of good size (3.84 cm^{-2}), higher test weight of 1000 seeds (2.38 g) and seed yield (17.45 q ha^{-1}).

Girma and Taddesse (2013) conducted an experiment to find out effect of nitrogen and phosphorous rates on yield and yield components of Ethiopian cumin. The treatment consisted of four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}) and four levels of phosphorous (0, 25, 50 and 75 kg ha^{-1}in form of P_2O_5). Main and interaction effects of fertilizer significantly improved 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. Number of seeds $umbel^{-1}$ was influenced only by the main effect of fertilizer while number of primary branches and thousand seed weight were remained unaffected. Combined effect of 100 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} gave maximum significant total dry matter yield (3307 kg ha^{-1}), seed yield (1072 kg ha^{-1}) and essential oil yield (39.0 L ha^{-1}).

Moniruzzaman *et al.* (2009) conducted a study to find out the effect of nitrogen levels on quality of 'Bangladhonia'. They reported that the highest fresh yield of Bangladhonia was recorded from with the application of the highest dose of nitrogen.

Rana *et al.* (2012) was conducted a field experiment during rabi season of 2010-11 to find out the effect of nitrogen and phosphorus on growth, yield and quality of black cumin. Among the varieties, AN-1 recorded maximum value for number of capsules per plant (30.30), number of seeds per capsules (60.33), test weight (1.46 g), seed yield (4.88 q/ha), straw yield (12.48 q/ha), harvest index (27.89 %) and biological yield (17.36 q/ha) as compared to local cultivar of nigella. 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 recorded with the application of fertilizer 60: 120 kg ha^{-1} N, P followed by 45: 90 kg ha^{-1} N, P and lowest in control at all the growth stages. Therefore, the application of 60 kg ha^{-1} N and 120 kg ha^{-1} P fertilizer with the variety AN-1 gave the maximum growth, yield and quality of nigella with the highest net return per hectare.

Albukhder and Al-Refai (2019) conducted an experiment to study the effect of planting dates and the levels of NPK fertilizer and its interaction on some vegetative and fruits characters of *Foeniculum vulgare* L. The experiment including two factors; the first factor the planting dates were represented by four dates (1st November, 15th November, 30th November and 15th December) respectively, whereas the second factor included four levels of the NPK fertilizers ($N_0P_0K_0$), ($N_{60}P_{50}K_{30}$), ($N_{90}P_{75}K_{45}$) and ($N_{120}P_{100}K_{60}$) kg ha^{-1} respectively. The results showed that the planting of fennel plant in the first date (1st November) resulted in increase of all studied vegetative and fruits characters as compared with plants which was planted at fourth date (15th December). There was significant increment of the studied plant characters which was fertilized by the higher level of fertilizer ($N_{120}P_{100}K_{60}$) as compared with control treatment.

Moniruzzaman *et al.* (2014) conducted a study to find out the influence of different rates and methods of nitrogen application on foliage yield of coriander. They reported that the number of leaves $plant^{-1}$ increased with the increase of N dose up to 80 kg ha^{-1} in foliage coriander.

Yimam *et al.* (2015) was 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 60/40 kg N 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 (72.5 cm) were measured o plots fertilized at the rate of 60/40 NP kg ha^{-1}. The highest number of branches (46.1) was obtained from the interaction effect of 60/40 NP kg ha^{-1}. The highest numbers of seeds per pod (91.6) was achieved at treatment combination of 60/40 NP kg ha^{-1} followed by 88.4 seeds by the treatment combination of 60/20 NP kg ha^{-1}. The highest harvest index (20.8%) was obtained from the treatment that received 60/40 NP kg ha^{-1} followed by 20.5%, which received 45/20 NP kg ha^{-1} interactions and the lowest harvest index (15.1%) was recorded from the treatment that received 15 and 0 kg NP interaction. The longest days to 50% flowering (86.7 days) were observed for the treatment that received 60/40 kg N 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 45/40 kg NP ha^{-1} with marginal rate of revenue (1272.2%) for net benefit 15254.1 birr, followed by the interaction effect of 15/20 kg NP 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 45/40 kg NP ha^{-1} followed by 15/20 Kg N P_2O_5 ha^{-1} for black cumin production in the area.

Gulzar *et al.* (2011) were conducted a field experiments to evaluate the effects of nitrogen (N) and sulfur (S) levels and their methods of application on canola. Branches $plant^{-1}$, pods $plant^{-1}$ and biological yield significantly increased with increase in nitrogen level and no significant increase in seed pod^{-1} and seed and oil yields occurred beyond 120 kg N ha^{-1}. However, thousand seed weight consistently decreased with increasing level of nitrogen. Pods $plant^{-1}$ and biological yield continually increased with increase in sulfur level. Alternatively, significant increase in branches $plant^{-1}$, seed pod^{-1}, seed weight, seed and oil yields was noted with increase in sulfur level up to 40 kg ha^{-1}. Applications of sulfur and nitrogen in split significantly decreased seed yield as compared to sole applications. It is concluded that sulfur and nitrogen application as sole at the rate of 40 and 120 kg ha^{-1}, respectively performed better than the rest of their levels and method of application.

Zahoor A. *et al.* (2007) reported that the split dose of nitrogen might increase black cumin yield.

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, which was laid out in a randomized complete block design (RCBD). The combined 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. However, further research needs to be undertaken in different black cumin producing areas of the country on recent varieties to achieve the optimum seed rate and inter-row spacing with information related to cost of production for better recommendation.

Rahnavard *et al*. (2010) conducted an experiment to evaluate the effect of sowing date and plant density on yield and yield components of Black Cumin (*Cuminum carvi* L.) under dry farming conditions. Four plant densities (50, 100, 150 and 200 plants m^{-2}) and three sowing dates (3, 13 and 23 of March) were applied. Result showed that seed yield was influenced by sowing date and plant density interaction. Early sowing date resulted in higher seed yields as evident from higher aboveground biomass, the number of umbrella per plant, the number of seed per umbrella and plant height. Harvest index and 1000-seed weight were not affected by sowing date and planting density. Earlier sown plants with density of 200 m^{-2} resulted in higher seed yields.

Sedigheh *et al*. (2009) conducted an experiment to evaluate the effect of sowing date and plant density on yield and yield components of Black Cumin (*Cuminum carvi* L.) under dry farming 8 conditions. Four plant densities (50, 100, 150 and 200 plants m^{-2}) and three sowing dates (3, 13 and 23 of March) were applied. Result showed that seed yield was influenced by sowing date and plant density interaction. Early sowing date resulted in higher seed yields as evident from higher aboveground biomass, the number of umbrella per plant, the number of seed per umbrella and plant height. Harvest index and 1000-seed weight were not affected by sowing date and planting density. Earlier sown plants with density of 200 m^{-2} resulted in higher seed yields.

Fahim *et al*. (2017) conducted an experiment to evaluate the effect optimum seed rate and suitable sowing method for black cumin during rabi season, 2013-14 and 2014-15 at the research field of Spices Research Centre, Shibganj, Bogra. 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^{-1} 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^{-1} in 2013-14 & 1254 kg ha^{-1} in 2014-15) was recorded from treatment combination of 8 kg seed ha^{-1} x line sowing in raised bed, which was identical to 10 kg seed ha^{-1} x Line sowing in raised bed (976.9 kg ha^{-1} in 2013-14 & 1155 kg ha^{-1} in 2014-15) followed by 10 kg seed ha^{-1} x Line sowing without bed (959.7 kg ha^{-1} in 2013-14 & 1090 kg ha^{-1} in 2014-15). The lowest seed yield (218.8 kg ha^{-1} in 2013-14 & 254 kg ha^{-1} in 2014-15) was recorded from 4 kg seed ha^{-1} x Broadcasting without bed method. It was concluded that 8 kg seed ha^{-1} 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^{-1}.

Bahraminezhad and papzen (2006) were carried out an experiment in 2000 in the Faculty of Agriculture of the University of Razi, Kermanshah, Iran. To found out the effect of four row spacings (40, 50, 60 and 70 cm) were studied using randomized complete block design with four replications. The measured traits were as follows; plant height, the number of follicle per plant, the number of seeds per follicle, 1000 kernel weight, biological yield, grain yield, harvest index, oil, and essence percentage. Mean comparison for grain yield, using Duncan Multiple Range Test, revealed that when the seeds were planted in 40 centimeters row spacing, the grain yield was highest (660 kg ha^{-1}), and was significantly different when compared with means of the other treatments. The average oil and essence percentages of seeds in this study were 28% and 0.148%, respectively.

Kizil *et al*. (2005) conducted a field experiment was to determine suitable row spacing for *Nigella sativa*. According to results, row spacings were significantly affected plant height, number of branches, number of capsules, thousand seed weight, seed yield, essential oil yield and fatty oil yield. And also, correlation between seed yield and number of capsules per plant, number of seed per capsule, thousand seed weight and seed yield per plant was found significantly important.

Esmaeil and Behnaz (2014) stated that if amount of plant density is more than optimum, amount of light, foodstuffs and water will not be sufficient for plant. Then if plant density is lower than optimum as a result from environment factors won't be sufficiently and so grain yield will decrease.

Ahmed and Haque (1986) studied the effect of row spacing (15, 20, 25 and 30 cm) and time of sowing (1^{st} November, 20^{th} November, 10^{th} December and 30^{th} December) on the yield of black cumin (*Nigella sativa*), they found that higher row spacing (15 cm) and early sowing (1^{st} November) was the best for higher seed yield of black cumin.

Masood *et al.* (2004) studied the effect of row spacing (40, 50, 60 and 70 cm) on morphological characters and seed yield of funnel and reported that the highest plant height, seed yield $umbel^{-1}$ and seed yield ha^{-1} were obtained with the lowest plant spacing but the lowest plant height, seed yield per umbel, and seed yield per hectare were obtained with the greatest row spacing.

Khorshidi *et al*. (2009) was carried out an experiment in college of agriculture Karaj at 2008 to showed that the effect of different densities of planting on yield and essential oil components of Fennel (*Foeniculum vulgare* Mill.). This experiment was conducted based on completely randomized block design with three replication and five plant densities. Five plants spaces were 10, 15, 20, 25 and 30cm on the row. The distance between rows in all treatments was 40cm. The essential oil extracted by water distilled method from seeds and essential oil was analyzed by gas chromatography (GC). The higher essential oil percentage (%3.53) was obtained with the lowest densities of planting.The higher percentage of anethole (%83.07), estragol (%3.47), fenchone (%8.04), p-cymene (%4.45), Į-terpinene (%0.54), sabinene (%0.51), and Į-Pinene (%0.48) were obtained with space between plants 25, 10, 20, 20, 15, 20, and 25cm, respectively.

Akbarinia *et al.* (2006) studied the coriander densities of 20, 30, 40, 50 and 60 plants m^{-2} and concluded that fruit and essential oil yield were higher in 30 plants m^{-2} Ahmed and Haque (1986) studied the effect of row spacing (15, 20, 25 and 30cm) and time of sowing (November 1, November 20, December 10 and December 30) on the yield of black cumin (*Nigella sativa*) in Bangladesh, they found that closer row spacing (15 cm) and early sowing (November 1) was the best for higher seed yield of black cumin densities.

Norman (1992) reported that increasing plant density does not affect individual plants if the plant density is below the level at which competition occurs between plants.

Janick (1972) reported that increasing competition is similar to decreasing the concentration of growth factors.

Abdolrahimi *et al.* (2012) was conducted a study to found out effect of different inter row level, intra row level and three varieties black cumin Experiment was conducted based on 12completely random blocks with 4 replications. In this research the first factor (A) was the inter row level, at intervals of 20 and 40 cm; the second factor (B) was the intra row level, at three levels of 2, 4 and 6 cm; and the third factor (C) was the three varieties of *Nigella sativa* Baft, Bukan, and Arbil. Results showed that the effects of plant density and cultivation arrangement on weight of capsule, total weight of stem, leaf weight, seed weight, 1000-grain weight, seed efficiency and harvest index were significant. Baft cultivar had the best results for seed efficiency, but the Arbil variety had the best results for 1000-grain weight. Seed efficiencies at the inter row spacing of 20 cm, of intra row spacing of 2 cm, and Baft variety were 1920.3, 2336.9, and 2148.1 kg ha^{-1} respectively. Harvest Indexes of the intra row spacing of 6 cm, and for the Baft variety were 25.65%, and 25.84%

respectively. The Baft variety planted at 20 cm inter row and 2 cm intra row spacing was overall, the most efficient planting arrangement for *Nigella Sativa.*

Akintoye *et al.* (2009) Yield per unit area tends to increase as plant density increases up to a point and then declines.

Ameen *et al.* (1988) stated that the narrowest spacing of 45 × 20 cm recorded the highest plant height of 110.06 cm but it was non-significant. While, 45 × 30 cm spacing recorded the highest number of branches per plant (8.45) in fennel.

Plant (2013) showed that with increase in inter-plants space significantly increased plant height, growth, fruit yield number of umbels/ plant and essential oil percentage /plant and oil production of fennel plants (*Foeniculum vulgare*).

Kumar *et al*. (2007) was conducted an experiment during rabi season of 2001-02 to study the effect of different levels of spacing, nitrogen and cycocel concentrations on growth, yield and quality of coriander *cv.* Hisar Anand. Maximum plant height was recorded under closer spacing of (20×20 cm, Row and Plant, respectively) and highest dose of nitrogen (80 kg ha^{-1}), whereas, number of branches and umbels per plant, umbellate per umbel, seed yield per plant, test weight and vigour index were found maximum under widest row and plant spacing of 50×20 cm, respectively with 80 kg N ha^{-1}. However, the seed yield per hectare was maximum under row and plant spacing (30×20 cm) when applied with 80 kg N/ha, which was at par of 30×20 cm spacing with 60 kg N ha^{-1}. Yield and quality of coriander seed was improved when single foliar spray of cycocel 100 ppm applied 40 days.

Diereichsen (1996) reported that maximum fruit yield of coriander was obtained with density of 50 plants per m^{-2} and decreasing plant density, the plant to some extent compensates the yield reduction by producing new branches.

Selim *et al.* (2013) carried out the field work to study the effect of sowing dates (15th Sep., 7th Oct. and 1st Nov.), sow spacing (25, 35 and 50 cm between hills with two plants on a hill) and bio-fertilization (spraying the plants with active dry yeast at 0, 2 and 5 g L^{-1} thrice per season) on growth, fruit yield and oil production of fennel plants (*Foeniculum vulgare*, Mill). The results showed that sowing fennel plants on 7th Oct. at 50 cm and spraying with 5 g L^{-1} of yeast gave the highest vegetative growth and fruit yield $plant^{-1}$. The highest number of branches plant^{-1} was obtained from sowing the plants on 15th Sept. at 50 cm spacing and sprayed with yeast at 5 g L^{-1}. As well as, the same treatment (sowing the plants on 15th Sept. and sprayed with yeast at 5 g L^{-1}.) and culture at a distance of 25 cm resulted in the highest values of plant height, number of umbels plant^{-1} and essential oil percentage plant^{-1}.

Al-Dalain *et al.* (2012) conducted a study to evaluate the effect of planting date and plant spacing and their interactive effects on yield, yield components and growth of fennel under irrigation. Three planting dates (Oct. 1st, Nov. 1st and Dec. 1st) and four plant spacings (10 cm, 20 cm, 30 cm and 40 cm with constant row width, 60 cm) were used. Fruit yield was significantly influenced by plant spacing, planting date and their interaction. Early planting significantly increased the fruit yield combined with higher number of branches per plant, number of umbrellas per plant, number of fruits per plant and plant height. The percentage of increases in Oct. 1st were 34.4% and 32.2% in fruit and biological yield respectively compared with Dec. 1st planting. Harvest index and thousand fruit weight was not significantly affected by planting date. The early planting date with 30 cm plant spacing resulted in· higher fruit (4136 kg ha^{-1}) and biological yield (10114 kg ha^{-1}).

Esmaeil *et al.* (2014) set up a field experiment to evaluate the effect of four sowing methods *viz*., broadcast, line sowing (45 cm), ridge sowing (45 cm) and bed sowing (45/45 cm) on growth and yield of fennel sown on 14th September, 14th October and 14th November. The fennel sown on 14th November produced significantly the lowest seed yield than 14th September and 14th October mainly due to lower stand density, number of umbels per plant and number of seeds per umbel. The line sowing of fennel in mid-October was recorded to be the best combination for getting higher fennel seed yield.

Das *et al.* (2020) conducted a field experiment to found out the effect of nitrogen and spacing on black cumin during the rabi (winter) season for two consecutive years i.e., 2015–16 and 2016–17 at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, The field was laid out in randomized block design with 9 treatments and 3 replications. N_2S_3 shows better performance in all growth parameter like plant height (42.76 cm at 90DAS and 50.63 cm in 105DAS), number of branches (6.66 and 7.30 number primary branches at 90 DAS and 105 DAS, 10.80 and 16.13 number secondary branches at 90 DAS and 105 DAS). But in number leaves better performance was recorded in N_2S_2 and N_1S_3 treatment with 63.70 and 68.90 number leaves in 90 DAS and 105 DAS respectively. With respect to time of flowering and fruiting, N_1S_1 shows early performance (with 67.63 DAS in initiation of flowering, 74.16 DAS in 50 percent flowering, 89.20 DAS in initiation of fruitset and 121.20 DAS in fruit maturity). Although in case of yield attributing parameters and yield, N_2S_3 treatment combination showed better performance like plant height at harvest (50.63cm), total plant weight (14.10 g), pods plant^{-1} (15.86), total pod weight (5.73 g), number of seeds pod^{-1} (96.93), breadth of pod (0.83cm), yield ha^{-1} (1.74ton), yield m^{-2} (17.50 g). From this experiment it can be concluded that N_2S_3 treatment combination with 50 kg nitrogen ha^{-1} and 25x20 cm^2 spacing is best for alluvial plains for black cumin.

Nimet *et al.* (2015) conducted a field experiment to found out the effect response of black cumin (*Nigella sativa* L.) to different seed rates growth, yield components and essential oil content. 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 PO, respectively. Data were tabulated on mean plant height, the mumber of branch, the number of capsule, the number. The experiment was carried out in two vegetation seasons of 2013 and 2014 at the Isparta and Eskisehir ecological conditions. The average seed yield varied between 201.0-407.1 kg ha^{-1} in 2013 and 458.9-790.3 kg ha^{-1} in 2014. In compared to locations; while yield components of black cumin populations significantly varied according to locations and years, seed yield in both years were higher in Isparta location on all populations due to higher rainfall than Eskisehir. In compared to populations; the highest seed yield was determined in Usak population and it was followed by E skisehir population. But the essential oil wasn’t detected in Usak population. The highest essential oil content was obtained from Tokat population in both locations and years, it was followed by E skisehir population. The fixed oil ratios were higher in Tokat, Usak and Antalya populations in both locations and years.

Gamal *et al.* (2012) was performed a field experiment on black cumin (*Nigella sativa* L.) during the 2004-2005 and 2005-2006 seasons at the Assiut University to investigate the effects of plant spacing (15 and 30 cm) and various fertilizer treatments; cattle manure ($15m^3$ feddan^{-1}), NPK fertilization [ammonium nitrate (33.5% N) 60, calcium super phosphate (15.5% P_2O_5) 45, and potassium sulphate (48% K_2O) 48kg feddan^{-1}] and bio-fertilizers [Biogen (500g) and phosphorein (300g kg^{-1} seeds) were added either individually or in combination]. 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 30 cm 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.

Mollafilabi *et al.* (2010) studied the effects of plant density and nitrogen on yield and yield components of Black cumin (*Nigella sativa* L.), an experiment in the form of factorial RCB design with 4 replications has been conducted at Ferdowsi University of Mashhad, Iran. In his study factors were plant density with 4 levels (60, 120, 180 and 240 plants m^{-2}) and nitrogen with for levels (0, 50, 100 and 150 kg ha^{-1}). Results showed that LAI, TDM and CGR increased by increasing plant density and nitrogen levels. LAI and CGR were highest in reproduction stage. Relative growth rate (RGR) was not affected by plant density and nitrogen and had a diminishing procedure during growing season. Number of flowering branches and follicles per plant were decreased by increasing plant density. However, plant density had no significant effect on plant height, 1000 seeds weight, seed yield, biological yield and harvest index. Seed yields were 779, 804, 809 and 502 kg ha^{-1} in plant density treatments, respectively. There were significant differences between nitrogen application treatments and without nitrogen application. Nitrogen increased plant height, no. of flowering branches, no. of follicle per plant, biological yield and seed yield. Seed yield was 590 kg ha^{-1} in no. nitrogen treatment. Application of 50, 100 and 150 kg ha^{-1} of nitrogen resulted in 815, 895 and 896 kg ha^{-1} seed yield, respectively. But, there were no significant differences among 50, 100 and 150 kg ha^{-1} nitrogen levels for above parameters. Number of seed per follicle was minimum at 0 and 150 kg ha^{-1} nitrogen levels and was maximum at 50 kg ha^{-1} nitrogen. Nitrogen had no significant effect on 1000 seeds weight. There was negative correlation between nitrogen level and harvest index.

Khaled *et al.* (2007) conducted a study to investigate the effect of sowing dates with nitrogen fertilization rates and plant density on black cumin (*Nigella sativa* L.) productivity. The factors were arranged in a split-split-plot in a RCB design. Results at Mushaqar location showed that planting on 2nd December gave 25.1% and 54.1% more seed yield over planting at the end of December or at early January, respectively. Similarly, biological yield at the first date (2nd December) was higher by 53.5% and 87% as compared to the 2nd and 3rd dates, respectively. Harvest index behaved differently, where the highest harvest index was obtained in 2nd and 3rd planting dates. At Maru location, highest harvest index value was obtained in second date with an increase of 29.21% and 33.53% over planting in 1st and 3rd date, respectively. Weight of thousand seed was significantly affected by planting dates with plant density at the two locations. The highest thousand seed weight at Mushaqar was obtained under 35 kg seed ha^{-1} followed by 25, 30 and 40 kg ha^{-1}. However at Maru, the maximum seed weight was obtained under 30 and 35 kg seed ha^{-1}. First planting date gave the tallest plants at Mushaqar and 25 kg seeds ha^{-1} gave the tallest plants at Maru. Seed yield was significantly effected by at both locations with plant height and weight of thousand seeds. Neither plant density treatments nor urea treatment applied at cultivation date showed significant effect on seed yield for the both locations.

Özel *et al.* (2009) conducted a study to determine the optimal row spacing and seeding rate of black cumin(*Nigella sativa* L.) at the conditions of Harran Plain during 2000-2001 and 2001-202 winter crop production periods in accordance with split plot design with 3 repetitions.

Pawar *et al.* (2007) conducted an experiment during the rabi season of 2003- 2004 to study effect of nitrogen rates (50, 75 and 100 kg ha^{-1}) and spacing on coriander. Application of nitrogen at a rate of 100 kg ha^{-1} resulted in the maximum plant height, number of leaves per plant, number of primary branches per plant, number of secondary branches per plant, east-west spread of the plant, fresh weight of plant and yield per hectare.

Ghobadi and Ghobadi (2010) reported the effect of nitrogen rates and plant densities on fruit yield, essential oil percent and yield of coriander fruits concluded that the highest fruit yield was obtained by using 60 kg N ha^{-1} while the highest essential oil percent and yield were obtained with 90 kg N ha^{-1} application stated that fruit yield was higher in 30 plants m^{-2} densities. Nevertheless). Dierchesen (1996) reported the highest fruit yield of coriander at density 50 plants m^{-2}.

Moosavi *et al.* (2013) carried out in research field of Islamic Azad University, Birjand Branch, Birjand, Iran in 2010 based on a randomized complete block design with three replications. The main plots were nitrogen rates at four levels (0, 40, 80 and 120 kg N ha^{-1}) and the sub-plots were plant densities at three levels (30, 40 and 50 plants m^{-2}). The results showed that nitrogen rate had 12 significant effect on fruit yield, essential oil percent and yield traits and interaction between nitrogen rate and plant density only affected fruit yield but change in plant density significantly affected all traits except essential oil percent. Means comparison showed that as N fertilization rate was increased from 0 to 80 kg N ha^{-1}, plant height and fruit yield were increased by 19.8 and 74.1 %, respectively. Moreover, means comparison showed that the increase in plant density from 30 to 50 plants m^{-2}, increased plant height, first fruit distance from ground and fruit respectively. Given the results of the study, the treatment of 80 kg N ha^{-1} application with the density of 50 plants m^{-2} recommended for the cultivation of coriander in Birjand, Iran.

Koocheki *et al.* (2006) studied the fennel densities of 40, 50, 60 and 100 plants m^{-2} and concluded that as the density was increased from 40 to 100 plants m^{-2}, seed yield increased with plant density. However, Bahreininejad *et al.* (2006) reported that the fennel density of 3.5 plants m^{-2} produced 2669.3 kg seed ha and was significantly superior over other studied densities, i.e. 5 and 10 plants m^{-2}.

Azita *et al.* (2012) was carried a study the effect of N fertilization and plant density levels on yield and yield components of fennel in Birjand, Iran, a study in research field of agriculture and natural resources research center of southern Khorasan in 2010. The study was a spatial and temporal split-plot experiment based on a randomized complete block design with three replications. The main plot was N fertilization level at five levels of 0, 40, 80, 120 and 160 kg ha^{-1} and the sub-plot was the density at three levels of 10, 15 and

20 plants per m^2. The studied traits included umbel number per plant, umbellet number per umbel, fruit number per umbel, umbel number per m^2, 1000-seed weight, and fruit yield which were measured and compared at two cuts. It was found that N level and plant density significantly influenced all studied traits, but their interactions were not statistically significant for the traits.

Jan *et al.* (2011) studied response of seed yield of corriander to phosphorus and row spacing was studied at Malakandhare, Horticulture Farm, Agricultural University, Peshawar, Pakistan during the year 2002-03. Four levels of phosphorus (0, 15, 30 and 45 kg ha^{-1}) were applied at four different row spacings (15, 25, 35 and 45 cm). The result indicated that different levels of phosphorus and row spacing had significant effect on all parameters, however, their interaction effect was non-significant in most parameters with the exception of the seed yield $hectare^{-1}$. Maximum numbers of umbels $plant^{-1}$ (47.00) and 1000 seed weight (10.32 g) were obtained with 45 kg P ha^{-1} at 45 cm row spacing. Whereas, the maximum days to first umbel maturity (30.0) and days to last umbel maturity (25.33) were recorded in control treatments. However, maximum seed yield (1360.0 kg ha^{-1}) was obtained when 45 kg P ha^{-1} was applied at row spacing of 25 cm.

Sharma *et al.* (2016) was conducted A field experiment during rabi 2012-13 at the Research Farm, College of Horticulture, Mandsaur (Madhya Pradesh) to study the response of coriander to different row spacing and nitrogen levels. The experiment was laid out in factorial RBD design with three replications including three row spacing and four levels of nitrogen. The different treatments significantly influenced the growth, yield and quality attributes of coriander. Application of 90-120 Kg N ha^{-1} and 30 cm row spacing significantly improved plant height, number of branches $plant^{-1}$, fresh weight of leaves (g) $plant^{-1}$, dry weight of plant (g) $plant^{-1}$, days to 50% flowering, number of umbels $plant^{-1}$, number of umbellets $plant^{-1}$, test weight, seed yield, straw yield, biological yield, harvest index, chlorophyll content in leaves (mg g^{-1}) and essential oil content (%) of seeds over their respective lower levels.

Garima *et al.* (2018) was carried out a investigation during Rabi season of 2017-2018 at the Horticulture complex, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. The treatment combinations consisting of five levels of nitrogen (50, 60, 70, 80 and 90 kg N ha^{-1}) and three row spacing (30, 40 and 50 cm) replicated thrice. Highest growth characters were higher in the treatment combination N_5S_3 (N: 90 kg N ha^{-1} , S: 50 x 10 cm) viz., number of branches, total biomass production of the plant on dry weight basis(g), days taken to 50% flowering, Days taken to maturity and yield attributes the treatment combination N_5S_3 (N: 90 kg N ha^{-1}, S: 50 x 10 cm) viz., umbels $plant^{-1}$, umbellets $plant^{-1}$, seeds $umbel^{-1}$, test weight (g), Seed yield $plant^{-1}$ (g). Maximum seed yield of 16.66 q ha^{-1} was obtained in coriander (Jawahar Dhaniya-2) with treatment combination N_5S_1 (N: 90 kg N ha^{-1}, S: 30 x 10 cm) and maximum net return of Rs 79,221.06 ha^{-1} and cost benefit ratio 1:3.11.

Nandal *et al.* (2010) carried out an experiment to study the response of spacing, phosphorus levels and cutting of leaves on growth and yield of coriander. The experiment was laid out in split plot design with three replication, having three levels of phosphorus (25, 50 and 75 kg P_2O_5 ha^{-1}), two spacing (20x20 and 40x10 cm) and three cutting of leaves (C_0-Control, C_1- One cutting at 30 days, C_2- two cutting at 30 and 50 days after sowing). The treatment combination 75 kg P_2O_5 ha^{-1} with a spacing 40x10 cm and without cutting resulted in maximum seed yield. It was closely followed by treatment 50 kg P_2O_5 ha^{-1} and 40x10 cm spacing without cutting. Significantly the higher green leaves yield was recorded in the treatment combination of highest levels of phosphorus (75 kg) and spacing (20x20 cm) and two cutting of green leaves treatment. Minimum seed yield was recorded in 25 kg P_2O_5 ha^{-1} and 20x20 cm spacing with two cutting of green leaves treatment combination.

CHAPTER III

MATERIALS AND METHODS

The present study was carried out to study the response of different macronutrients and spacing on the growth and yield of black cumin (*Nigella sativa* L.) during the period from October 2019 to April 2020. Materials and methods of the present study have been discussed by the following headings.

3.1 Experimental site

The experiment was carried out at Horticultural Farm in Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. It was located in the south western corner of the university and corner of the farm. It is located at 23^0 41' N latitude and 90^0 22' E longitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28 (Appendix I).

3.2 Climatic condition

The climate of the experimental field was sub-tropical and was characterized by high temperature, heavy rainfall during Kharif-1 season (March-June) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are presented in Appendix II.

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract under the AEZ-28 and Tejgoan soil series. The selected land was medium high land with adequate irrigation facilities. The physical and chemical properties of soil of the experimental site was sandy loam in texture having pH 5.47 - 5.63. Organic matter content ware very low (0.83). The physical composition such as sand, silt, clay content were 40%, 40% and 20% respectively. The physical and chemical characteristics of the soil have been presented in Appendix III.

3.4 Materials

3.4.1 Seed

In this experiment black cumin variety of BARI Kalozira 1 was used in the experiment as a planting material. BARI Kalozira 1 was developed by Bangladesh Agricultural Research

Institute (BARI) in 2009. The seed was collected from the Regional Spice Research Centre, BARI, Joydebpur, Gazipur.

3.4.2 Fertilizers

The recommended doses of micronutrient, organic mannure was added to the soil of experimental field along with different levels of Nitrogen (N), Phosphorous (P) and Potassium (K). However any fertilizer was not applied to control plot.

3.5 Methods

3.5.1 Treatments

Two factors were used in the experiment viz. four levels of nutrient combinations (T) and three levels of spacing (S).

Factor A: Four levels of macronutrients

$T_0 = N_0P_0K_0$ kg ha^{-1} (control)

$T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}

$T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}

$T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

Factor B: Three levels of spacing

S_1 = 20 cm×10 cm

S_2 = 20 cm×15 cm

S_3 = 20 cm×20 cm

3.5.2 Treatment combination

There were 12 treatment combinations of different levels of macro nutrient and plant spacing used in the experiment which are as follows:

T_0S_1, T_0S_2, T_0S_3, T_1S_1, T_1S_2, T_1S_3, T_2S_1, T_2S_2, T_2S_3, T_3S_1, T_3S_2, T_3S_3

3.5.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 12 x 3 =

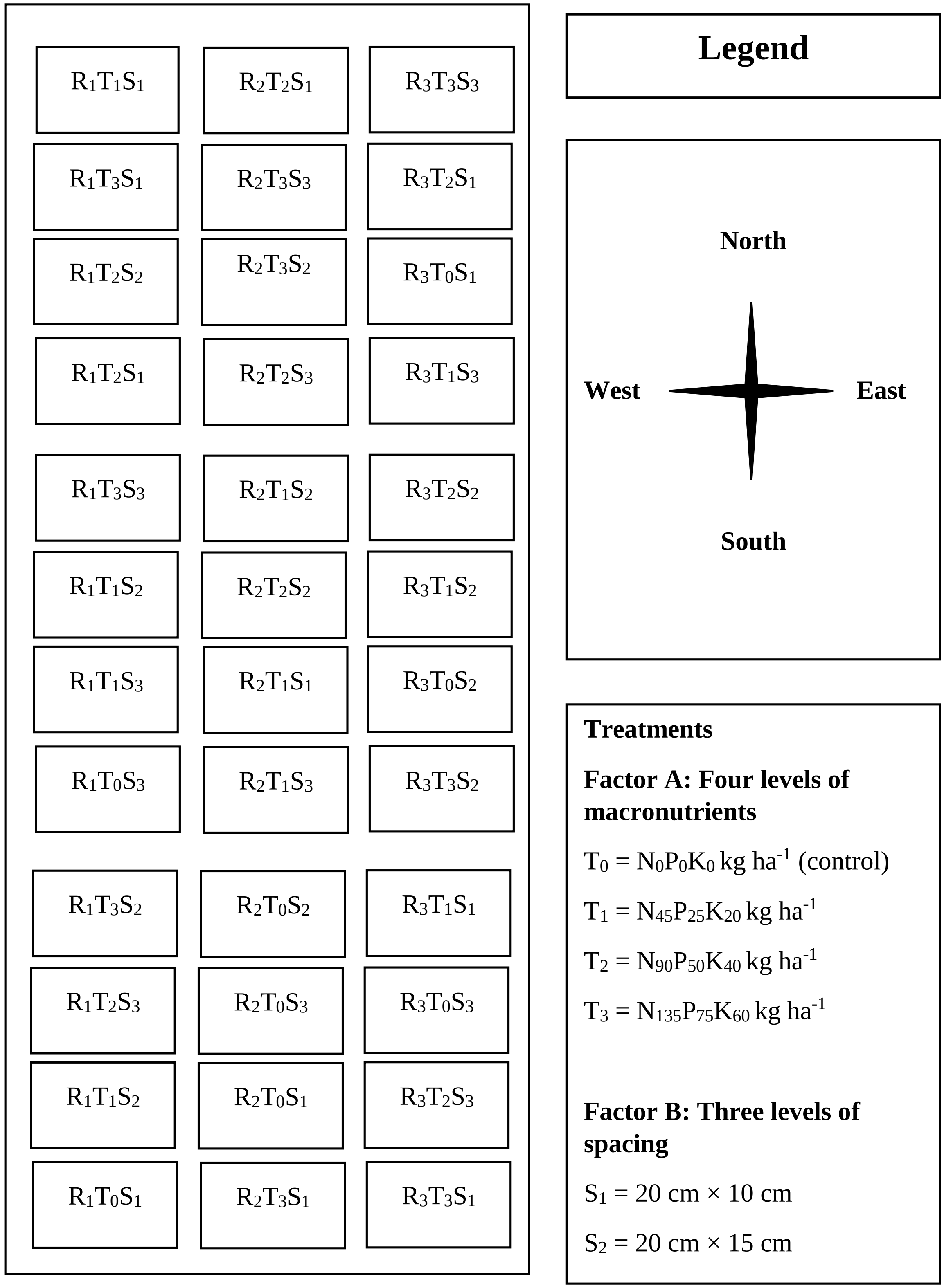

Fig. 1. Layout of the experimental field

36. The unit plot size was 1.2 m x 1.2 m (1.44 m^2). The distance between block to block was 0.5 m and distance between plot to plot was 0.5 m.

3.5.4 Land preparation

The experimental land was prepared with the help of power tiller by three successive ploughing and cross-ploughing followed by laddering, one month before planting. The corners of the plots were trimmed by spade. The clodes were broken into friable soil and the surface of the soil was leveled. Weeds and crop residues of previous crop were removed from the field. The weeds were cleaned properly. The final ploughing and land preparation were done on 15 November, 2019. The experimental area was laid out according to the design of the experiment. The unit plot was leveled before seed sowing.

3.5.5 Fertilizer management

At the time of first ploughing, cowdung and kitchen compost was applied at the rate of 10 and 5 t ha^{-1} respectively. The experimental area was fertilized as follow

Fertilizers		Doses/ha	Nutrients	Sources
Cow dung		10 t	-	Nature
Kitchen compost		5 t	-	Nature
Urea	T_1	98 kg	45 kg N	$CO(NH_2)_2$
	T_2	196 kg	90 kg N	
	T_3	293 kg	135 kg N	
TSP	T_1	125 kg	25 kg P	$Ca(H_2PO_4)_2$
	T_2	250 kg	50 kg P	
	T_3	375 kg	75 kg P	
MP	T_1	40 kg	20 kg K	KCl
	T_2	80 kg	40 kg K	
	T_3	120 kg	60 kg K	
Gypsum		112 kg	20 kg S	$CaSO_4.H_2O$
Boron		24 kg	4 kg B	H_3BO_3

The full amounts of triple super phosphate and muriate of potash and half of the urea were applied at final land preparation as a basal dose. Rest half of the Urea was applied in two equal splits at 25 and 50 days after seed sowing.

3.5.6 Seed sowing

Before seed sowing the seeds were soaked in water for 12 hours to enhance germination. Seeds were also treated with Bavistin @ 2 g kg^{-1} of seeds before sowing. Sowing was done on 19 November, 2019. Seeds were sown according to treatment in rows at the rate of 3 kg ha^{-1}. After sowing; the seeds were covered with soil and slightly pressed by hand. Seed were also sowed around the experimental plot area to check border effect. After 10 days of seedling emergence, the seedlings were thinned to maintain required spacing treatments.

3.5.7 Gap filling

The ungerminated black cumin were replaced by healthy seedling taken from border plants within two weeks after planting. The damaged plants were also replaced by healthy border plants.

3.5.7 Thinning and weeding

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. One weeding with khurpi was done on 25 DAS to keep the crop weed free.

3.5.8 Irrigation

When the land seemed too dry, then light irrigation was given. Irrigations were given at 15 days interval up to flowering. After flowering two irrigations were applied. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture. Proper drainage facilities were developed to avoid stagnation of water.

3.5.9 Plant protection measures

The field was investigated time to time to detect visual differences among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of insect attack was not found but some plots started to die after rotting in the basal portion of the plant which is symptoms of fungal attack. For control, Dithane M-45 was sprayed at 10 days interval @ 2 g L^{-1} water.

3.5.10 Harvesting and threshing

Harvesting was carried out by hand following at 80% maturity. First, the border row plants were harvested manually from all sides of each plot and subsequent plants of the net plot harvested excluding the earlier five randomly selected and tagged plants for recording various observations on **yield components** of parameters. The harvested plants were dried in the open air for five days and weighted as biological yield data. Threshing was done manually by beating the capsules with wooden stick on a clean and dried floor. Then seeds were cleaned and further dried in well-ventilated shady room for three days. The mean weight of seeds from each treatment was recorded in grams for computation of yield data.

3.5.11 Data collection

Five healthy plants were randomly selected in each plot as per treatment. Plastic coated labels were tagged for identification and recording of various observations. The following data were recorded:

3.6 Detailed procedures of data recording

i) Plant height

Plant height at 45, 90 and 135 DAS was measured from the 45, 90 and 135 days after sowing the. The height of the plant was determined by measuring scale considering the distance from the soil surface to the tip of the plants and mean value was calculated for each treatment and express in centimeter.

ii) Days to first and 50% flowering

The date of first and 50% flowering on the sample plants was recorded, and the period required in days from the date of sowing was calculated.

iii) Number of primary branches and secondary branches plant^{-1}

Number of primary branches and secondary branches plant^{-1} were counted from the selected plants during harvest and mean value of data were calculated and recorded for each treatment.

iv) Number of seeds capsule^{-1} and capsules plant^{-1}

Number of seeds capsule^{-1} and capsules plant^{-1} seeds capsule counted and calculated as per plant basis from the tagged plants during harvest.

v) 1000 seed weight

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

vi) Seed weight plot^{-1}

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

vii) Yield

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to tones per hectare

viii) Dry matter

After separated seeds five plant selected from each plot were oven dried and took the dry weight and mean value of data were calculated and recorded for each treatment

ix) Percent (%) seed germination

The number of sprouted and germinated seeds was counted daily commencing. Germination was recorded at 24 hrs interval and continued up to 10 days. More than 2 mm long plumule and radicle was considered as germinated seed. The germination rate was calculated using the following formula:

Rate of germination (%) = $\frac{\text{Total number of germinated seeds}}{\text{Total seed placed for germination}}$ x 100

x) Economic analysis

The cost of production was analyzed in order to find out the most economic combination different macro nutrient and plant spacing. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interest were calculated @ 14% in simple rate. The wholesale market price of black cumin was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\textbf{Benefit cost ratio (BCR)} = \frac{\textbf{Gross return per hectare (Tk.)}}{\textbf{Total cost of production per hectate (TK)}}$$

3.7 Data analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the Statistx 10 computer package program. Analysis of variance was done following two factors randomized complete block design. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The results on effectiveness of various treatments of levels of macro nutrients and plant spacing including untreated control for achieving quality and higher yield of black cumin have been described and discussed below in details under the following head:

4.1 Plant height

Different macro nutrients (N, P, K) had significant influence on plant height of black cumin at different growth stages (Fig. 2 and Appendix IV). At 135 DAS, the highest plant height (54.86 cm) was obtained from T_3 ($N_{135kg}P_{75kg}K_{60kg}$) treatment. Similarly, the lowest plant height (32.89 cm) was recorded from the T_0 (control) treatment. Hence it may be inferred that the increase in plant height may be due to the favorable influence and balanced absorption of nutrients, increased role of photosynthesis, reduced transpiration and stimulation of root system, increase cell division, cell enlargement and metabolic processes. It is also observed that plant height increased with macronutrient doses. Similar findings were also observed by Shaalan (2005), Tuncturk *et al*. (2012).

Different spacing had significant variation on plant height of black cumin at different growth stages **(**Fig. 3 and Appendix IV**).** Plant height increased with decreased plant spacing. At 135 DAS, the highest plant height (48.34 cm) was achieved from S_1 (20 cm × 10 cm) treatment. Again, the lowest plant height (45.72cm) was observed from S_3 (20 cm × 20 cm) treatment. The treatment S_1 was statistically identical to S_2 which gave plant height of 18.13 cm at 45 DAS. The variation in plant height as influenced by spacing was perhaps due to proper utilization of nutrient, moisture and light. (Fig. 3 and Appendix IV). Gamal *et al*. (2012) was observed that plant height was increased by decreasing plant spacing an antagonistic relationship was found between vegetative growth and plant spacing. Mengistu *et al*. (2021) reported the smallest inter-row spacing (20 cm) produced the highest average plant heights while the lowest values were obtained at the largest inter-row spacing (40 cm) respectively. These findings on plant height were in accordance with Toncer and Kizil (2004); Tuncturk *et al.* (2005) and Koli (2013). Roussis *et al.* (2017) also obtained similar results, although did on a different genotype and environment.

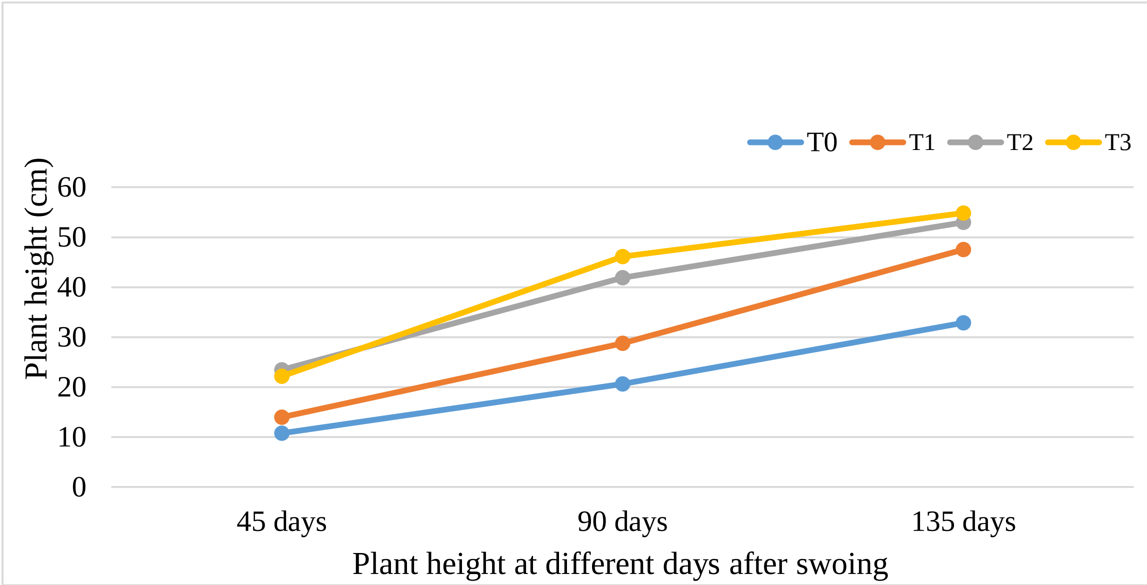

Fig. 2. Effect of nutrients combination on plant height of black cumin (*Nigella sativa* L.) (LSD value= 0.4479, 1.1080 and 0.5814 at 45, 90 and 135 DAS respectively), Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

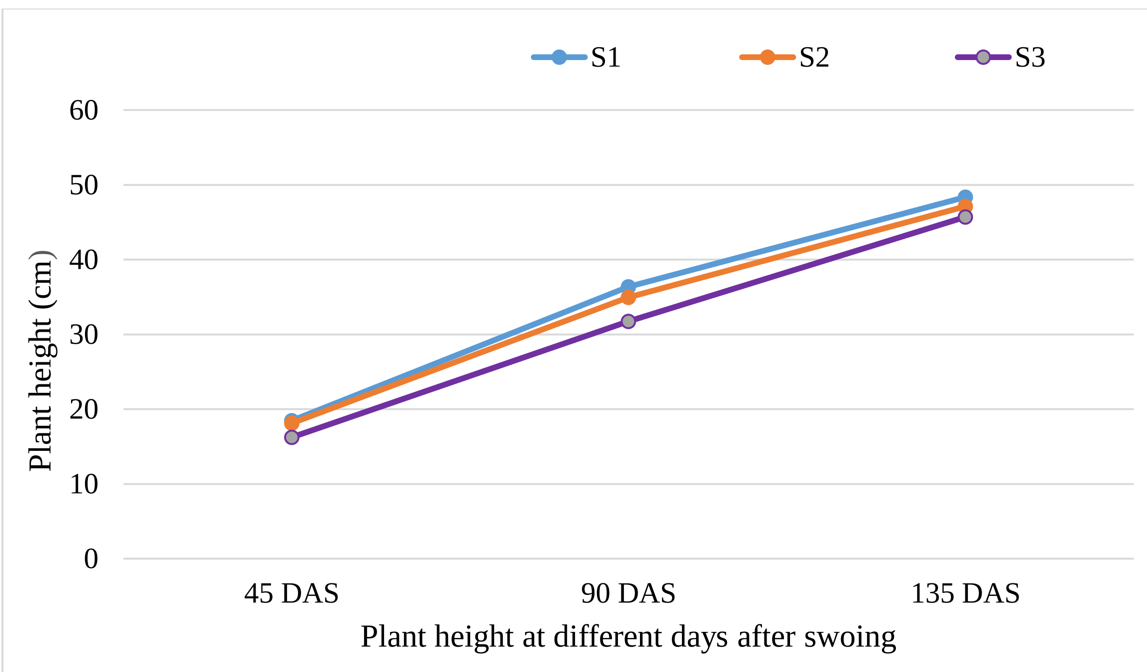

Fig. 3. Effect of plant spacing on plant height of black cumin (*Nigella sativa* L.) (LSD value= 0.3879, 0.9596 and 0.5035 at 45, 90 and 135 DAS respectively) Note: S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm and S_3 = 20 cm × 20 cm.

Combined effect of different nutrients and spacing on plant height of black cumin was statistically significant at different days after sowing (DAS). At 135 DAS, the highest plant height (56.36 cm) was obtained from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination, which was statistically similar to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm×15cm) treatment combination and the lowest plant height (32.20 cm) was observed from T_0S_3 (control and 20cm×20 cm) treatment combination which was statistically identical to T_2S_1.

Table 1. Combined effect of nutrients combination and plant spacing on plant height at 45 DAS, 90 DAS and 135 DAS of black cumin (*Nigella sativa* L.)

Treatments	**Plant height (cm)**		
	45 DAS	**90 DAS**	**135 DAS**
T_0S_1	10.49 h	20.71 f g	33.87 g
T_0S_2	11.55 g	21.75 f	32.60 h
T_0S_3	10.30 h	19.42 g	32.20 h
T_1S_1	14.20 e	32.27 d	48.33 e
T_1S_2	14.33 e	27.47 e	47.67 e
T_1S_3	13.40 f	26.53 e	46.53 F
T_2S_1	25.27 a	50.27 a	56.36 a
T_2S_2	24.62 ab	48.96 a	55.63 ab
T_2S_3	20.57 d	39.13 c	52.60 c
T_3S_1	23.91 b	42.27 b	54.81 b
T_3S_2	22.00 c	41.67 b	52.53 cd
T_3S_3	20.60 d	41.87 b	51.53 d
LSD(0.05)	0.7758	1.9191	1.0070
CV%	2.60	3.30	1.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1} and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

4.2 Number of primary branches plant^{-1}

There was a significant variation due to effect of nutrient in the number of primary branches plant^{-1}. The maximum number of primary branches plant^{-1} (8.62) was observed at T_2

($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment while controlled treatment showed comparatively lower (5.50) number of primary branch plant^{-1}. (Table 2). From the results of the present study indicated that optimum levels of macro nutrients combination might have induced better growing condition, perhaps due to supply of adequate plant nutrients which ultimately led to the production of more primary branch per plant. Ali *et al.* (2015) found that the number of primary branch plant^{-1} of black cumin was influenced significantly under different level of fertilizer, whereas secondary and tertiary branch plant^{-1} were not influenced significantly. This finding was also reported in related works of Tuncturk *et al*. (2005) & Roussis *et al.* (2017).

Significant variation was found due to the effect of spacing on number of primary branches plant^{-1}. It was observed that the lowest number of primary branches plant^{-1} (7.09) was recorded from S_1 (20 cm × 10 cm) treatment and highest (7.80) from S_2 (20 cm × 20 cm) treatment (Table 3). Generally lower number of plants was provided more nutrients compared to higher population with same nutrient status in the soil that was provided and caused more number of primary branches per plant from higher plant spacing. These findings are in agreement with those of Fekadu *et al.*, (2021). Toncer *et al.*, (2004) found that seed rate significantly affected number of branch per plant of *Nigella sativa*. Kandeel *et al.* (2001) attributed the increments in vegetative characteristics to less competition among plants for the environmental conditions necessary for building up more metabolites and producing more lateral branches at wider spaces.

Number of primary branches plant^{-1} showed significant variation among the treatments due to the combined effect of macronutrients and plant spacing. Highest primary branches plant^{-1} (8.80) was found from the T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 20cm) treatment combination which was statistically similar T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 15 cm) and T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 10cm) treatment combination. On the other hand, lowest value for primary branches plant^{-1} (4.96) was recorded in T_0S_1 (control and 20cm × 10 cm) treatment combination which was statistically identical to T_0S_2 (control and 20cm × 15 cm) treatment combination (Table 4). Generally more nutrients and higher spacing plant get more food and space for vigorous growth and produce more primary branches compared to lower nutrients and spacing.

Table 2. Effect of nutrients combination on number of primary branches plant^{-1}, secondary branches plant^{-1}, days to first flowering and days to 50% flowering of black cumin (*Nigella sativa* L.)

Treatments	**Number of Primary branches plant^{-1}**	**Number of Secondary branches plant^{-1}**	**Days to first flowering**	**Days to 50% flowering**
T_0	5.50 d	8.60 d	51.88 c	61.78 c
T_1	7.42 c	10.98 c	53.00 b	63.53 b
T_2	8.62 a	12.18a	55.55 a	66.68 a
T_3	8.09 b	11.51 b	52.71 b	63.40 b
LSD(0.05)	0.2077	0.1622	0.4946	0.5672
CV%	2.87	1.53	2.95	3.91

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

Table 3. Effect of plant spacing on number of primary branches plant^{-1}, secondary branches plant^{-1}, days to first flowering and days to 50% flowering of black cumin (*Nigella sativa* L.)

Treatments	**Number of Primary branches plant^{-1}**	**Number of Secondary branches plant^{-1}**	**Days to first flowering**	**Days to 50% flowering**
S_1	7.09 c	10.35 c	52.47 c	63.24 b
S_2	7.34 b	10.87 b	53.45 b	63.69 b
S_3	7.80 a	11.23 a	53.92 a	64.61 a
LSD(0.05)	0.1799	0.1404	0.4283	0.4912
CV%	2.87	1.53	2.95	3.91

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Table 4. Combined effect of nutrients combination and plant spacing on number of primary branches plant^{-1}, secondary branches plant^{-1}, days to first flowering and 50% flowering of black cumin (*Nigella sativa* L.)

Treatments	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Days to first flowering	Days to 50% flowering
T_0S_1	4.96 g	8.20 h	51.03 f	61.09 f
T_0S_2	5.22 g	8.40 h	51.67 ef	61.44 f
T_0S_3	6.33 f	9.20 g	52.93 c	62.80 e
T_1S_1	7.20 e	10.67 f	52.40 cde	63.00 de
T_1S_2	7.67 d	11.07 e	52.53 cd	63.00 de
T_1S_3	7.40 de	11.20 e	54.07 b	64.27 c
T_2S_1	8.47 abc	11.80 cd	54.40 b	65.80 b
T_2S_2	8.60 ab	12.29 ab	55.80 a	66.66 ab
T_2S_3	8.80 a	12.47 a	56.45 a	67.57 a
T_3S_1	7.73 d	10.73 f	52.07 de	63.07 de
T_3S_2	8.13 c	11.73 d	53.80 b	63.33 cde
T_3S_3	8.40 bc	12.06 bc	52.27 cde	63.80 cd
LSD(0.05)	0.3598	0.2809	0.8566	0.9824
CV%	2.87	1.53	2.95	3.91

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1} and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

4.3 Number of secondary branches plant^{-1}

There was a significant variation due to effect of nutrient in the number of secondary branches plant^{-1}. Treatment T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) showed statistically higher number of secondary branches plant^{-1} (Table 2). Effect of nutrient on number of secondary branches plant (12.18) while T_0 (control) treatment showed comparatively lower (8.60) number of secondarry branch plant^{-1}. (Table 2). Tuncturk *et al.* (2012) found significant influence of nitrogen levels on the number of branch $plant^{-1}$ in black cumin. Shaalan (2005) reported that the combination of Biogein, Nitrobein and Phosphorein was the most effective treatment for increasing plant height and branch number of *Nigella sativa* L.

Significant variation was found due to the effect of spacing on number of secondary branches $plant^{-1}$. The lowest (10.35) number of secondary branches $plant^{-1}$ was recorded from S_1 (20 cm × 15 cm) spacing and the highest (11.23) from S_3 (20 cm × 20 cm) spacing (Table 3). This finding was also reported in related works of Tuncturk *et al.* (2005) and Roussis *et al.* (2017). Kızıl *et al.* (2008) reported that as inter row spacing increased, number of branch per plant decreased. Also this is probably because high inter row spacing created higher interplant competition.

Combined effect of different macronutrient and spacing was statistically significant in respect of number of secondary branch per plant (Table 4). Highest secondary branches $plant^{-1}$ (12.47) was found from the T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 20cm) treatment combination which was statistically similar (12.29) to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 15cm) treatment combination. On the other hand, lowest value for secondary branches $plant^{-1}$ (8.20) was recorded in T_0S_1 (control and 20cm×10 cm) treatment combination which was statistically identical (8.40) to T_0S_2 (control and 20cm×15 cm) (Table 1). Generally more nutrients and higher spacing plant get more food and space for vigorous growth and produce more primary branches compared to lower nutrients and spacing.

4.4 Days to first flowering

There was a significant variation due to effect of macronutrient in the days to first flowering. Application of 90 kg N, 50 kg P and 40 kg K ha^{-1} at T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment took maximum days (55.55) to reach 1st flowering stage. The T_0 (control) treatment was found the earliest in flowering (51.88 days) (Table 2). From the results of the present study indicated that scarcity of nutrients induced plat to early flowering. Yimam *et al.* (2015) reported that days to flowering decrease with increase micronutrients doses. This could be because of excessive nitrogen and phosphorous resulting in prolonged vegetative growth of the plant.

Different plant spacing had significant effect on days to first flowering (Table 3). Higher plant spacing at S_3 (20 cm × 20 cm) treatment took maximum days (53.92 days) to reach

1st flowering stage. On other hand lower plant spacing at S_1 (20 cm ×10 cm) treatment took minimum days (52.47 days) to reach 1st flowering stage. Mollafilabi *et al.* (2010) found that number of flowering branches per plant were decreased by increasing plant density. Giridhar *et al.* (2017) reported that days to first flowering increased with inter row spacing increased.

Combined effect of different macronutrient and spacing was statistically significant in respect of days to first flowering (Table 4). The maximum days (56.45 days) took to first flowering at T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 20cm) which was statistically identical (55.80 days) to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 15cm) treatment combination. T_0S_1 (control and 20cm×10 cm) treatment combination took minimum days (51.03 days) to first flowering which was statistically similar (51.67 days) to T_0S_2 (control and 20cm×15 cm) treatment combination.

4.5 Days to 50% flowering

There was a significant variation due to effect of nutrient in the days to 50% flowering. Application of 90 kg N, 50 kg P and 40 kg K ha^{-1} at T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment took maximum days (66.68) to reach 50% flowering stage. The T_0 (control) treatment was found the earliest in flowering (61.78 days) (Table 2). The minimum number of days to reach 50% flowering date observed from control of nitrogen and phosphorous. This could be because of excessive nitrogen and phosphorous resulting in prolonged vegetative growth of the plant. This result is in close conformity Ozguven and Sekeroglu (2007).

Different plant spacing had significant effect on days to 50% flowering (Table 3). Higher plant spacing at S_3 (20cm × 20cm) treatment took maximum days (64.61 days) to reach 1st flowering stage. On other hand lower plant spacing at S_1 (20cm × 10cm) treatment took minimum days (63.24 days) to reach 50% flowering stage. This could be because of higher plant spacing reduce the competition for resource and that provide plant proper nutrition resulting in prolonged vegetative growth of the plant. Giridhar *et al.* (2017) reported that days to 50% flowering increased with inter row spacing increased.

Combined effect of different macronutrient and spacing was statistically significant in respect of days to 50% flowering (Table 4). The maximum days (67.57 days) took to 50% flowering at T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 20cm) treatment combination which was statistically similar (66.66 days) to T_2S_2 (($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20cm × 20cm) treatment combination. Treatment T_0S_1 (control and 20 cm×10 cm) treatment combination took minimum days (61.09 days) to 50% flowering which was statistically identical (61.44 days) to T_0S_2 (control and 20 cm×15 cm) treatment combination.

4.6 Number of flowers per plant

The number of flowers $plant^{-1}$ was significantly affected by different levels of nutrient combinations (Figure 4 and Appendix IV). Number of flowers $plant^{-1}$ increased with the increase level of nutrients. The highest number of flowers $plant^{-1}$ (22.20) was recorded at T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment. The lowest number of flowers $plant^{-1}$ was recorded from T_0 (control) treatment (17.56). From the results of the present study indicated that number of flowers $plant^{-1}$ increased with the increase in nutrient doses. These findings are in agreement with those of Tuncturk *et al.* (2012).

Significant variations were clearly evident in case of number of flowers $plant^{-1}$ with different plat spacing (Fig. 5 and Appendix V). The highest number of flowers $plant^{-1}$ (20.26) resulted from S_3 (20 cm × 20 cm) treatment and the lowest (19.90) was obtained from S_1 (20 cm × 10 cm) treatment which was statistically identical (19.96) to S_2 (20 cm × 15 cm) treatment. From the results of the present study indicated that increase in plant density decreased number of flowers $plant^{-1}$.

Combined effect of different macronutrient and spacing was statistically significant in respect of number of flowers $plant^{-1}$ (Table 7). The highest number of flower $plant^{-1}$ (22.87) obtained from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination. The lowest number of flower $plant^{-1}$ (17.20) obtained from T_0S_1 (control and 20 cm×10 cm) treatment combination which was statistically identical (17.35) to T_0S_2 (control and 20 cm×15 cm) treatment combination.

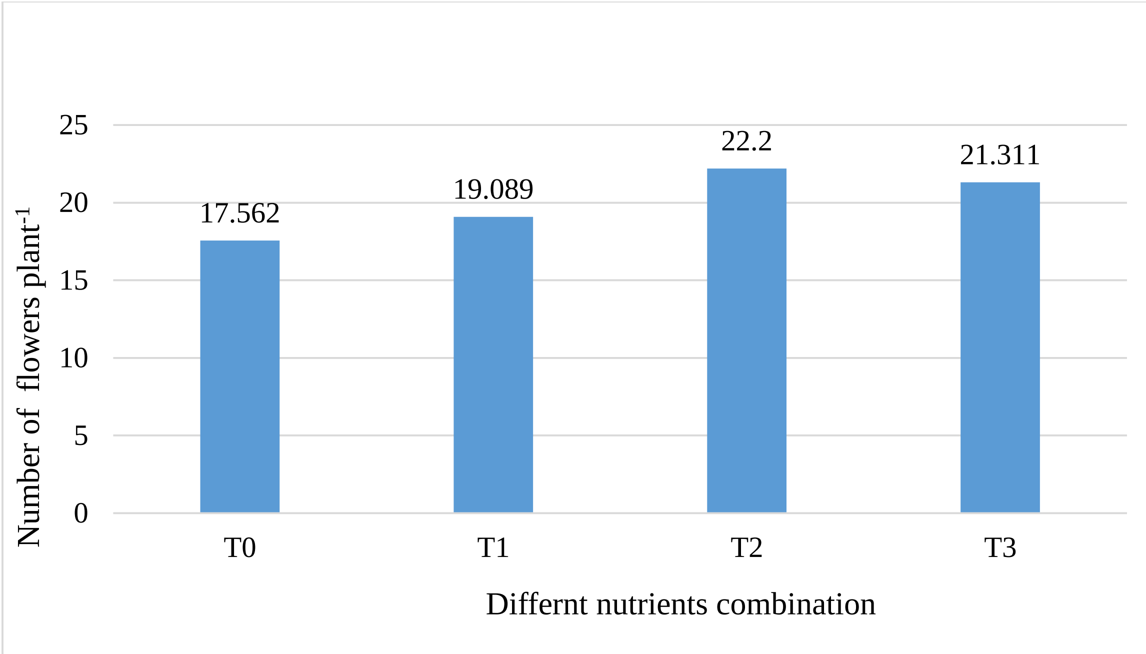

Fig. 4. Effect of nutrients combination on number of flowers plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value= 0.2007) Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

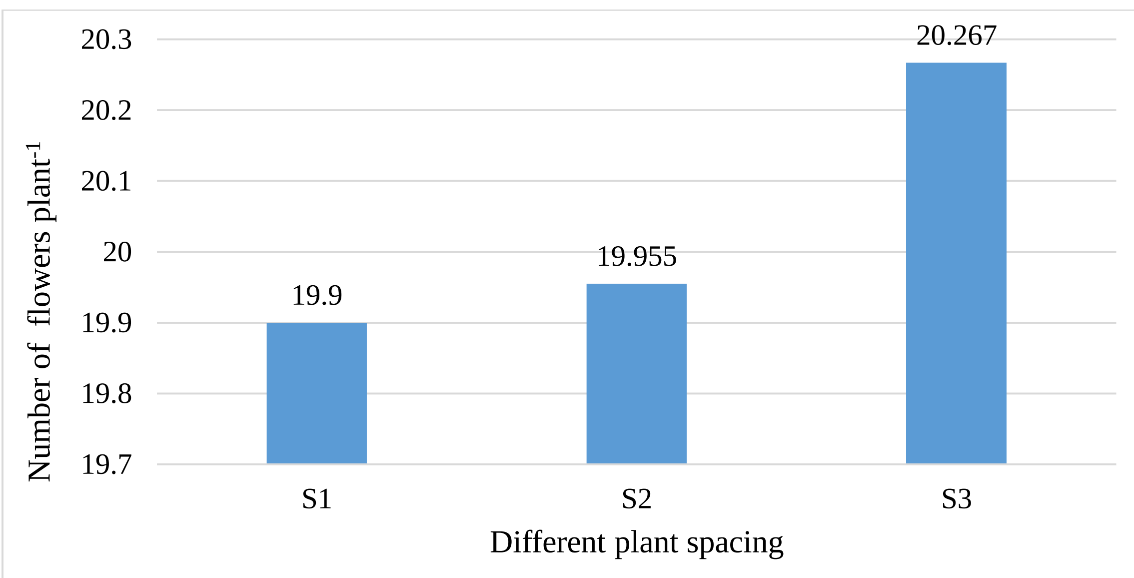

Fig. 5. Effect of plant spacing on number of flowers plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value= 0.1738) S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

4.7 Number of capsules per plant

The number of capsules plant^{-1} was significantly affected by different levels of nutrient combinations (Fig. 6 and Appendix IV). Number of capsules plant^{-1} increased with the increase level of macronutrients. The highest number of capsules plant^{-1} (19.81) was recorded at T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment which was statistically identical (19.69) to T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) treatment. The lowest number of capsules plant^{-1} (16.17) was recorded from T_0 (control) treatment. From the results of the present study number of capsules plant^{-1} increased with the increase in nutrient doses. Rimu *et al.* (2020), Hammo and Al-Atrakchii (2006) and Tuncturk *et al*. (2012) also reported increased capsule number plant^{-1} of black cumin with increased fertilizer levels. These findings are also supported by Shah (2007) Bommi *et al*. (2012). Generally environmental conditions during pollination at the first stage of seed set, determine the number of capsule (Sadeghi, 2009).

Significant variations were clearly evident in case of number of capsules plant^{-1} with different plat spacing (Figure 7 and Appendix IV). The highest number of capsules plant^{-1} resulted from S_3 (20 cm × 20 cm) treatment (18.81) and the lowest (17.62) was obtained from S_1 (20 cm × 10 cm) treatment. From the results of the present study indicated that increase in plant density decreased number of capsules plant^{-1}. Fekadu *et al.* (2021) found not significant number of capsules plant^{-1} with spacing, it may due to different climatic condition and variety. Giridhar *et al.* (2017) found that number of capsules plant^{-1} increased with inter row spacing increased.

Combined effect of different macronutrient and spacing was statistically significant in respect of number of flowers plant^{-1} (Table 7). The highest number of capsules plant^{-1} (20.80) obtained from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination which was statistically identical (20.40) to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination. The lowest number of capsules plant^{-1} (15.33) obtained from T_0S_1 (control and 20cm×10 cm) treatment combination.

4.8 Length of capsule (cm)

There was a significant variation due to effect of nutrients in the length of capsule. Application of 90 kg N, 50 kg P and 40 kg K ha^{-1} at T_2 treatment had longest capsule length (1.44 cm) which was statistically identical (1.39) to T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) smallest capsule

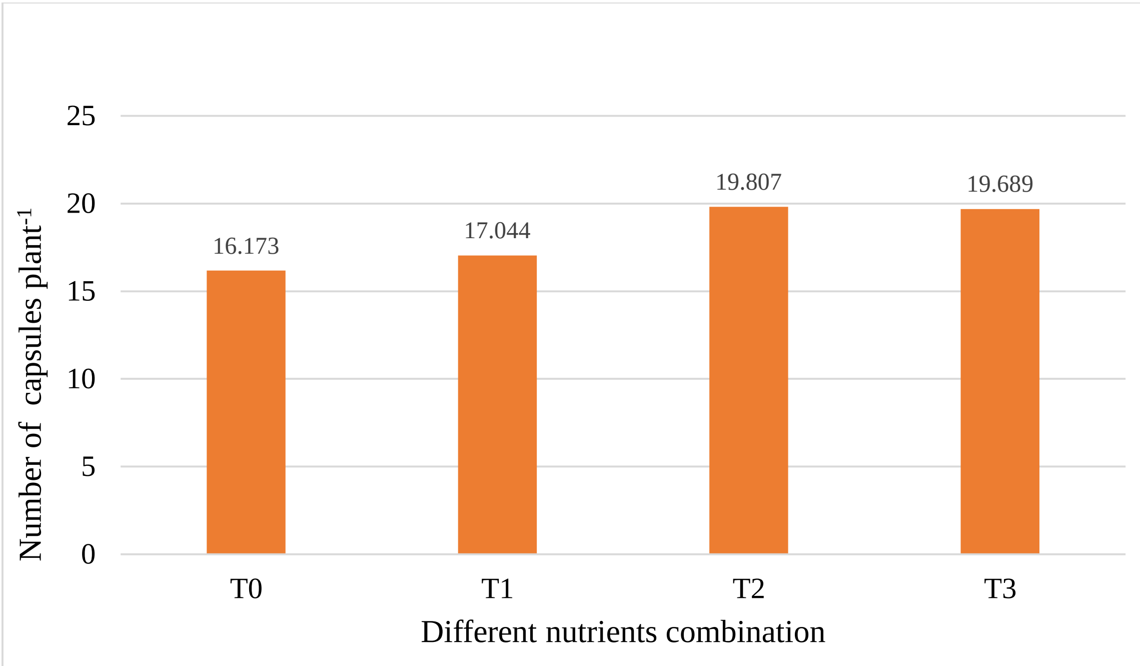

Fig. 6. Effect of nutrients combination on number of capsules plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value= 0.2773) Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

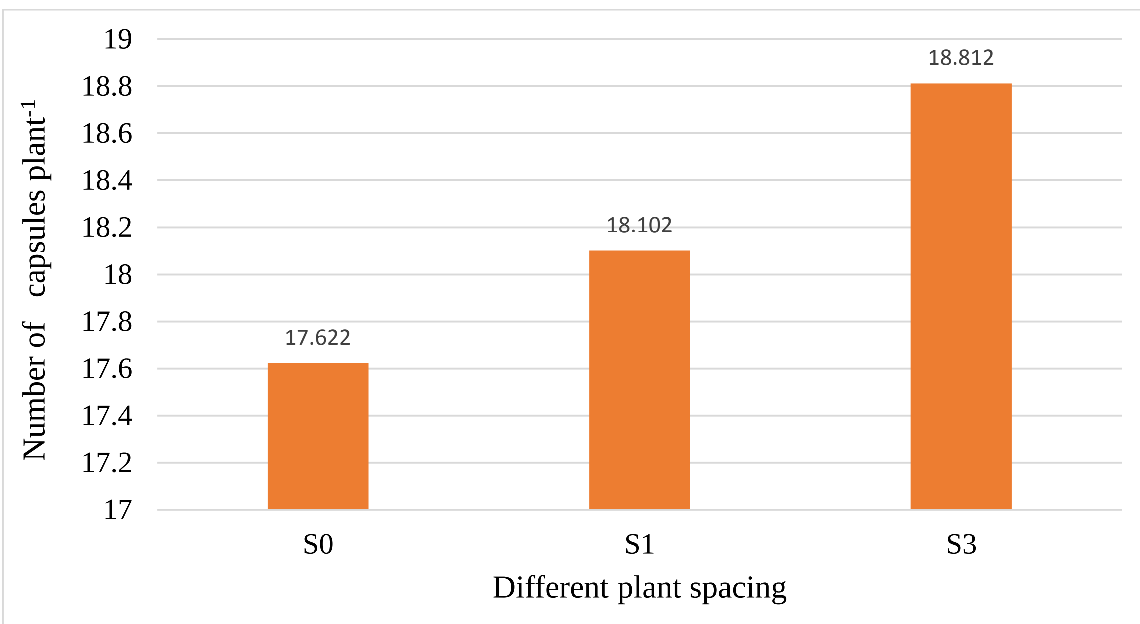

Fig 7. Effect of plant spacing on number of capsules plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value= 0.2402) Note: S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm and S_3 = 20 cm × 20 cm.

length (1.07 cm) was obtained from T_0 (control) treatment (Table 5). From the results of the present study indicated that increase nutrient doses increase the length of capsule. These findings are also supported by Ali *et al.* (2015) who found capsule lengths of the blackcumin were significantly influenced by the levels of fertilizer. He found maximum capsule length at harvest (1.17 cm), whereas the lowest capsule length at harvest (0.98 cm) that support present study.

There was a significant variation due to effect of plant spacing in the length of capsule. The longest capsule length (1.34 cm) was obtained from S_2 (20 cm × 15 cm) treatment and the smallest capsule length (1.23 cm) from S_1 (20 cm × 10 cm) treatment which was statistically identical (1.25 cm) to S_3 (20 cm × 20 cm) treatment (Table 6). It might be due to the fact that in treatment S_2 (20cm × 15 cm) treatment received adequate plant nutrients, no inter competition among plants, favorable growing atmosphere which contributed to longest capsule length. This finding was also reported in related works of Giridhar *et al.* (2017).

Combined effect of different levels of micronutrient and spacing proved significant differences on length of capsule (Table 7). The longest capsule length (1.53 cm) was obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination which was statistically identical (1.49 cm) to T_3S_2 ($N_{135}P_{75}K_{60}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and the smallest capsule length from T_0S_1 (control and 20cm×10 cm) treatment combination (1.04 cm) which was statistically identical (1.07 cm) to T_0S_3 (control and 20cm×20 cm) treatment combination and also statistically similar (1.09) to T_0S_2 (control and 20cm×15 cm) treatment combination.

4.9 Breath of capsule (cm)

There was a significant variation due to effect of nutrients in the breath of capsule. Application of 90 kg N, 50 kg P and 40 kg K ha^{-1} at T_2 treatment longest capsule breath (1.04 cm) which was smallest capsule breath (0.79 cm) was obtained from T_1 (ontrol) treatment (Table 5). From the results of the present study indicated that increase nutrient doses increase the breath of capsule. Ali *et al.* (2015) breath of capsule of different black cumin genotypes were significantly influenced by nutrient levels.

Table 5. Effect of nutrients combination on length of capsule, breath of capsule and number of seeds per capsule of black cumin (*Nigella sativa* L.)

Treatments	Length of capsule (cm)	Breath of capsule (cm)	Number of seeds per capsule
T_0	1.07 c	0.79 d	64.52 d
T_1	1.19 b	0.97 b	69.40 c
T_2	1.44 a	1.04 a	76.18 a
T_3	1.39 a	0.89 c	73.08 b
LSD(0.05)	0.0478	0.0300	0.7321
CV%	3.84	3.32	1.06

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

Table 6. Effect of different plant spacing on length of capsule, breath of capsule, and number of seeds per capsule of black cumin (*Nigella sativa* L.)

Treatments	Length of capsule (cm)	Breath of capsule (cm)	Number of seeds per capsule
S_1	1.23 b	0.88 b	69.55 b
S_2	1.34 a	0.94 a	71.77 a
S_3	1.25 b	0.94 a	69.55 b
LSD(0.05)	0.0414	0.0260	0.6340
CV%	3.84	3.32	1.06

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Table 7. Combined effect of nutrients combination and plant spacing on number of flowers plant^{-1}, number of capsules plant^{-1}, length of capsule, breath of capsule and number of seeds per capsule of black cumin (*Nigella sativa* L.)

Treatments	Number of flowers plant^{-1}	Number of capsules plant^{-1}	Length of capsule (cm)	Breath of capsule (cm)	No of seeds per capsule
T_0S_1	17.20 g	15.33 f	1.04 f	0.76 h	63.61 g
T_0S_2	17.35 g	16.00 e	1.09 ef	0.82 g	65.53 f
T_0S_3	18.13 f	17.19 d	1.07 f	0.80 gh	64.42 fg
T_1S_1	19.20 e	17.47 d	1.15 de	0.93 e	67.12 e
T_1S_2	18.87 e	16.27 e	1.24 c	0.99 bcd	69.97 d
T_1S_3	19.20 e	17.40 d	1.18 cd	0.98 cde	71.09 d
T_2S_1	21.53 c	18.22 c	1.39 b	1.02 bc	74.96 b
T_2S_2	22.20 b	20.40 a	1.53 a	1.08 a	78.12 a
T_2S_3	22.87 a	20.80 a	1.41 b	1.03 ab	75.46 b
T_3S_1	21.67 c	19.47 b	1.35 b	0.83 fg	72.51 c
T_3S_2	21.40 c	19.74 b	1.49 a	0.88 f	73.44 c
T_3S_3	20.87 d	19.86 b	1.34 b	0.95 de	73.29 c
LSD(0.05)	0.3476	0.484	0.0828	0.0519	1.2680
CV%	2.02	2.56	3.84	3.32	1.06

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

Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1} and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

There was a significant variation due to effect of plant spacing in the breath of capsule. The longest capsule breath (0.94 cm) was obtained from S_2 (20 cm × 15 cm) and S_3 (20 cm × 20 cm) treatment and the smallest capsule breath (0.88 cm) from S_1 treatment (20 cm × 10 cm) (Table 6). It might be due to the fact that in treatment S_2 and S_3 treatment received adequate plant nutrients, no inter competition among plants, favorable growing atmosphere which contributed to longest capsule breath.

Combined effect of different levels of micronutrient and spacing proved significant differences on breath of capsule (Table 7). The longest capsule breath (1.08 cm) was obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination which was statistically similar (1.03 cm) to T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination and the smallest capsule breath (0.76 cm) from T_0S_1 treatment which was statistically similar (0.80 cm) to T_0S_3 (control and 20 cm × 20 cm) treatment combination.

4.10 Seeds per capsule

Different levels of NPK fertilizer had significant effect on number of seeds $capsule^{-1}$ of black cumin (Table 5). Number of seeds $capsule^{-1}$ increased with the increase of NPK levels. Maximum number of seeds $capsule^{-1}$ (76.18) was recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) and the T_0 (control) treatment gave the lowest one (64.52). This result was in partial conformity with the findings of Toncer and Kizil (2004) who reported that, number of seed $capsule^{-1}$ varied from 90.7 to 92.8. Rimu *et al.* (2020), Rai *et al.* (2002) and Rana *et al.* (2012) also support the present study.

There was significant variation due to the effect of plant spacing on number of seeds $capsule^{-1}$. The maximum number of seeds $capsule^{-1}$ (71.77) was recorded in S_2 (20 cm × 15 cm) treatment. When the lowest number of seeds $capsule^{-1}$ (69.55) was recorded in S_1 (20 cm × 10 cm) and S_3 (20 cm × 20 cm) treatment (Table 6). These did not support the findings of Toncer *et al.,* (2004) who found that seed rate did not affect number of seed $capsule^{-1}$. Sadeghi *et al.* (2009) found that number of seed $umbrella^{-1}$ had an increasing trend with decreases in plant densities in *Cuminum carvi*. Because seed set depends on providing the adequate nutrients and environmental conditions while developed vegetative to reproductive stage, increased plant densities result in limited availability of nutrients, light and water so the number of reproductive units decrease; at total yield decreases.

Combined effect of different macronutrient and spacing was statistically significant in respect of seed $capsule^{-1}$. The highest seed $capsule^{-1}$ (78.12) obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination. The lowest seed $capsule^{-1}$ (63.61) obtained from T_0S_1 (control and 20 cm × 10 cm) treatment combination which was statistically similar (64.42) to T_0S_3 (control and 20 cm × 20 cm) treatment combination (Table 7).

4.11 1000 seed weight (g)

Different levels of NPK fertilizer had significant effect on 1000 seed weight of black cumin (Table 8). Application of macronutrients at different levels significantly increased the 1000 seed which produced maximum seed weight (2.99 g) at T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment where T_0 (control) treatment gave the lowest 1000 seed weight (2.80 g). Ozguven and Sekeroglu (2007) stated that there were no statistical differences among the different nitrogen doses in black cumin. In different studies, thousand seed weight of black cumin was reported as 3.50 g.

1000 seed weight of black cumin was significantly influenced by different level of spacing (Table 9). It was observed that higher spacing gave maximum yield. The maximum 1000 seed weight (2.96 g) was recorded from S_3 (20 cm × 20 cm) treatment where the lowest 1000 seed weight (2.82 g) was recorded from S_1 (20 cm × 10 cm) treatment. Similar findings were also obtained by Tuncturk *et al.* (2012), Giridhar *et al.* (2017).

Combined effect of different levels of macronutrient and spacing proved significant differences on 1000 seed weight of black cumin (Table 10). Results revealed that the highest 1000 seed weight (3.06 g) was obtained from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} with 20 cm × 20 cm) treatment combination which was statistically similar to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm×15 cm) treatment combination. The lowest 1000 seed weight (2.75 g) was recorded from T_0S_1 (control and 20 cm×10 cm) treatment combination which was statistically similar to T_0S_2 (control and 20 cm×15 cm) and T_1S_1 ($N_{45}P_{25}K_{20}$ kg ha^{-1} and 20 cm×10 cm) treatment combination. Rest of the treatment combination performed intermediate results in terms of 1000 seed weight compared to all other treatments. Rana *et al.* (2012) and Kaheni *at el.* (2013) also found significant effect of fertilizer levels on thousand seed weight of black cumin.

4.12 Yield per plant (g)

Yield per plant was significantly influenced due to different levels of macronutrient (Figure 8 and Appendix IV). Yield was increased with increasing plant nutrients. Results showed that the maximum yield per plant (3.36 g) was recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and the lowest yield of per plant (2.51 g) was recorded from T_0 (control)

Table 8. Effect of nutrients combination on 1000 seed weight, yield plot^{-1}, yield ha^{-1}, dry matter and germination percentage of black cumin (*Nigella sativa* L.)

Treatments	1000 seed weight (g)	Yield plot^{-1} (g)	Yield ha^{-1} (t)	Dry matter (g)	Germination percentage (%)
T_0	2.80 c	127.14 d	0.88 d	7.90 d	88.50
T_1	2.90 b	144.52 c	1.00 c	8.93 c	89.48
T_2	2.99 a	170.40 a	1.18 a	11.29 a	91.00
T_3	2.89 b	154.30 b	1.07 b	10.70 b	88.28
LSD(0.05)	0.0347	6.2480	0.0434	0.2528	5.5845 ^{NS}
CV%	0.91	4.29	4.29	2.66	6.40

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

Table 9. Effect of plant spacing on 1000 seed weight, yield plot^{-1}, yield ha^{-1}, dry matter and germination percentage of black cumin (*Nigella sativa* L.)

Treatments	1000 seed weight (g)	Yield plot^{-1} (g)	Yield ha^{-1} (t)	Dry matter (g)	Germination percentage (%)
S_1	2.82 c	156.66 a	1.09 a	9.30 c	88.54
S_2	2.91 b	150.57 b	1.05 b	10.03 a	89.56
S_3	2.96 a	140.04 c	0.97 c	9.79 b	89.85
LSD(0.05)	0.0272	5.4109	0.0376	0.2189	4.8363 ^{NS}
CV%	0.91	4.29	4.29	2.66	6.40

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm, NS= Not significant

Table 10. Combined effect of nutrients combination and plant spacing on 1000 seed weight, yield plant^{-1}, yield plot^{-1}, yield ha^{-1}, dry matter, and germination percentage of black cumin (*Nigella sativa* L.)

Treatments	1000 seed weight (g)	Yield per plant (g)	Yield per plot (g)	Yield per ha (t)	Dry matter (g)	Germination percentage (%)
T_0S_1	2.75 h	1.87 j	134.40 fg	0.93 fg	7.64 h	88.38
T_0S_2	2.81 fgh	2.38 gh	128.34 gh	0.89 gh	7.97 gh	88.33
T_0S_3	2.85 efg	3.30 d	118.68 h	0.82 h	8.08 g	88.77
T_1S_1	2.79 gh	2.12 i	152.40 bcd	1.06 bcd	8.553 f	89.11
T_1S_2	2.93 cd	2.66 ef	143.64 def	0.99 def	9.25 e	89.03
T_1S_3	2.98 bc	3.82 c	137.52 efg	0.96 efg	8.99 e	90.29
T_2S_1	2.90 cde	2.48 fg	178.32 a	1.24 a	10.14 d	91.11
T_2S_2	3.02 ab	3.27 d	176.76 a	1.23 a	12.13 a	90.92
T_2S_3	3.06 a	4.34 a	156.12 bc	1.08 bc	11.61 b	90.97
T_3S_1	2.84 efg	2.24 hi	161.52 b	1.12 b	10.85 c	85.55
T_3S_2	2.88 def	2.84 e	153.54 bcd	1.07 bcd	10.76 c	89.94
T_3S_3	2.96 bc	4.11 b	147.84 cde	1.03 cde	10.50cd	89.34
LSD(0.05)	0.0786	0.2097	10.822	0.0752	0.4379	9.6727 ^{NS}
CV%	0.91	4.20	4.29	4.29	2.66	6.40

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 levels of probability. Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1} and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm. NS= Not significant

treatment. From the above results, it was noted that NPK when used the nutrients become available to plants and much seed formation was occurred. The available soil nutrients supported proper vegetative growth with more protoplasm in the cells in comparison to less available nutrient in black cumin. The results found from the findings of Datta (2004) and Weiss (2002) were similar with the present study.

Yield plant^{-1} was significantly influenced by different level of spacing (Figure 9 and Appendix V). It was observed that higher spacing gave maximum yield. The maximum yield plant^{-1} (3.36 g) was recorded from S_3 (20 cm × 20 cm) treatment where the lowest yield plant^{-1} (2.51 g) was recorded from S_1 (20 cm × 10 cm) treatment. It might be due to the fact that in treatment S_3 (20 cm × 20 cm) treatment received adequate plant nutrients, no inter competition among plants, favorable growing atmosphere which contributed yield plant^{-1} (g). The result achieved from the present study was conformity with the findings of Kizil & Toncer (2005), Giridhar *et al.* (2017) who observed higher yield plant^{-1} from wider spacing.

Combined effect of different levels of macronutrient and spacing proved significant differences on yield plant^{-1} of black cumin (Table 10). Results revealed that the highest yield plant^{-1} (4.34 g) was obtained from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination. The lowest yield plant^{-1} (1.87 g) was recorded from T_0S_1 (control and 20 cm × 10 cm) treatment combination. Rest of the treatment combination performed intermediate results in terms of yield plant^{-1} compared to all other treatments.

4.13 Yield per plot (g)

Yield per plot of black cumin was significantly affected by different levels of macronutrient (Table 8). Higher application of plant nutrients gave higher seed yield per plot. Results specified that the highest yield per plot of black cumin (170.40 g) was recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment where the lowest yield per plot of black cumin (127.14 g) was recorded from T_0 (control) treatment. The results obtained from the present study was similar with the findings of Valabadi and Aliabadi (2011), Tuncturk *et al.* (2012).

Different levels of spacing had significant effect on yield per plot of black cumin (Table 9). It was found that the highest yield per plot of black cumin (156.66 g) was recorded from S_1 (20 cm × 10 cm) treatment where the lowest yield per plot of black cumin (140.04 g) was recorded from S_3 (20 cm × 20 cm) treatment. The obtained results represented that maximum yield contributing characters was best with higher spacing but in case of yield closer spacing gave maximum yield and this result might be due to cause of higher plant

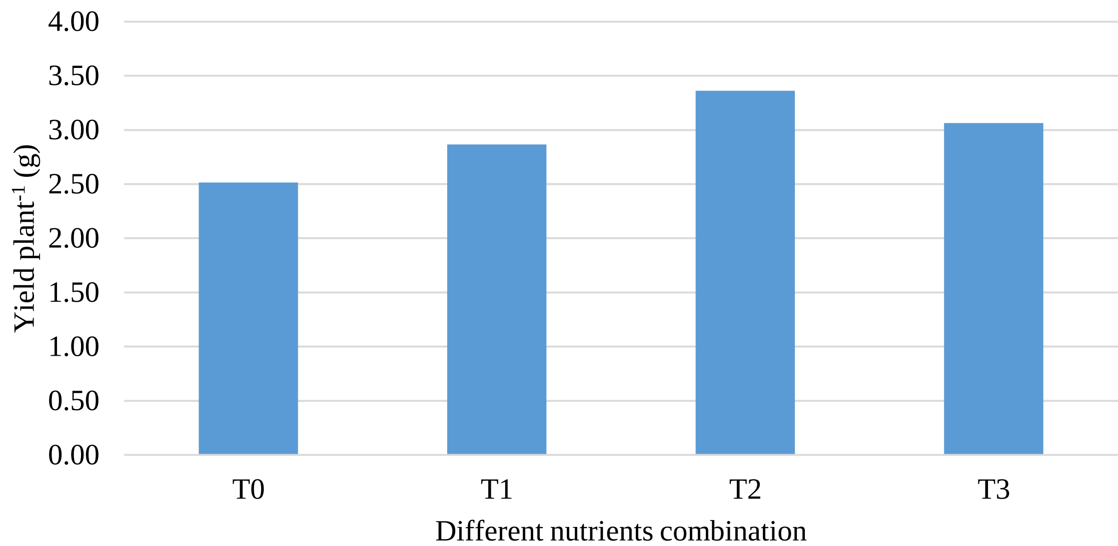

Fig. 8. Effect of nutrients combination on yield plant^{-1} of black cumin (*Nigella sativa* L.) (LSD) value= 0.1211) Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

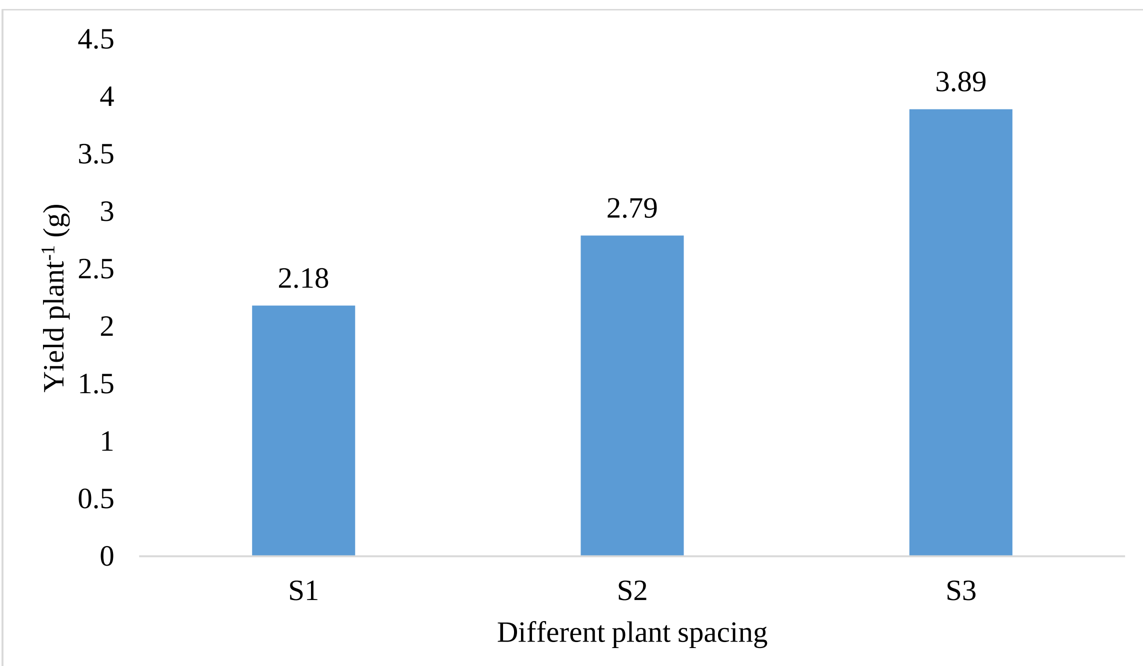

Fig. 9. Effect of plant spacing on yield plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value= 0.1049). Note: S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

population from closer spacing. Kizil and Toncer (2005) studied the effect of row spacing on seed yield and yield components of black cumin and found similar results on seed yield per plot with the present study. Abdolrahimi *et al.* (2012) studied the effect of inter and intra-row spacing on three black cumin varieties and found that, both factors affected different growth and yield parameters. Compared with our findings, the narrow inter-row spacing was found to be the best as it yielded better results and the yield particularly reduced when the raw spacing increased.

Yield per plot of black cumin was significantly affected by combined effect of different levels of macronutrient and spacing (Table 10). It was observed that the highest yield per plot (178.32 g) was obtained from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination which is statistically identical to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm×15 cm) combination. Results also revealed that the lowest yield per plot of black cumin (118.68 g) was recorded from T_0S_3 (control and 20 cm × 20 cm) treatment combination, which was statistically similar to T_0S_2 (control and 20 cm × 15 cm) treatment combination. The results obtained from all other treatment combination gave intermediate results compared to highest and lowest results. Higher number of plant population need higher amount of nutrients. Under the present study, closer spacing with higher nutrient doses gave the higher yield and this type of achievement might be due to higher plant population.

4.14 Yield per ha (t)

Different macronutrient showed significant variation on yield (t ha^{-1}) of black cumin (Table 8). Results represented that the highest yield of black cumin (1.18 t ha^{-1}) was recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment. Again, the lowest yield of black cumin (0.88 t ha^{-1}) was recorded from T_0 (control) treatment. Valabadi and Aliabadi (2011) found yield of up to 1.43 t/ha that was due to different cultiver. Tuncturk *et al.* (2012) reported that increasing phosphorus doses positively influenced seed yields in black cumin. The increment in **seed yield** under interaction of fertilizer might be associated with synthesis of more chlorophyll for photosynthesis resulting in promotion of plant development Ashraf *et al.*, (2005).

There was significant variation on yield (ton per hectare) of black cumin due to the effect of different spacing (Table 9). Results specified that the highest yield of black cumin (1.09 t ha^{-1}) was recorded from S_1 (20 cm × 10 cm) treatment where the lowest yield of black cumin (0.97 t ha^{-1}) was recorded from S_3 (20 cm × 20 cm) treatment. The results obtained from the present study was similar with the findings of Kizil & Toncer (2005). Mazumder *et al.* (2007) stated that plants grown under normal spacing could have optimum population density per unit area which provides optimum conditions for luxuriant crop growth due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence produce more seed yield with best quality traits.

Yield of black cumin was significantly affected by combined effect of different micronutrient and spacing (Table 10). Results identified that the highest yield of black cumin (1.24 t ha^{-1}) was obtained from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination which is statistically identical to T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination. The lowest yield of black cumin (0.82 t ha^{-1}) was recorded from T_0S_3 (control and 20 cm × 20 cm) treatment combination which was statistically similar to T_0S_2 (control and 20 cm ×15 cm) treatment combination. This result might be due to presence of favorable nutrient present in soil and higher population also contributed in the formation of the higher yield of black cumin. The seed yield obtained from this research result is in line with the yields reported by Datta (2004) and Weiss (2002) who reported highest value 1200 and lowest value 1000 kg ha. Yield per unit area tends to increase as plant density increases up to a point and then declines (Akintoye *et al.,* 2009).

4.15 Dry matter (g)

Significant influence was noted on dry matter affected by different macro nutrients (N, P, K) (Table 8). The highest dry matter at harvest (11.29 g) was obtained from the T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment where the lowest dry matter at harvest (7.90 g) was obtained from the T_0 (control) treatment. These findings are also supported by Ali *at el.* (2015) dry matter weight $plant^{-1}$ was increased gradually with the higher level of applied fertilizer.

Significant variations were clearly evident in case of dry matter with different plat spacing (Table 9). The highest dry matter resulted from S_3 (20 cm × 20 cm) treatment (18.81) and the lowest (17.62) was obtained from S_1 (20 cm × 10 cm) treatment. From the results of the present study indicated that increase in plant density dry matter.

Combined effect of different levels of macronutrient and spacing proved significant differences on dry matter weight of black cumin (Table 10). Results revealed that the highest dry matter weight (12.13 g) was obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination. The lowest dry matter weight (7.64 g) was recorded from T_0S_1 (control and 20 cm × 10 cm) treatment combination which was statistically similar to T_0S_2 treatment combination. Rest of the treatment combination performed intermediate results in terms of dry matter weight compared to all other treatments.

4.16 Percent (%) seed germination

Different macronutrients (N, P, K) treatment combination had no significant effect on percent (%) seed germination of black cumin (Table 8). However, the highest percent (%) seed germination (91.00%) was observed in T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment produced seeds whereas the minimum percent (%) seed germination (88.28%) was recorded from the seeds of treatment T_0 (control).

Seeds of black cumin obtained from different spacing treatment showed non-significant influence on percent (%) seed germination (Table 9). However, results indicated that the highest percent (%) seed germination (89.56%) was recorded from the seeds of was found in S_2 (20 cm × 15 cm) treatment whereas the lowest percent (%) seed germination (88.54%) was recorded from the seeds of was found in S_1 (20 cm × 10 cm) treatment.

Non-significant variation was recorded on percent (%) seed germination affected by combined effect of different macronutrient and plant spacing (Table 10). However, the highest percent (%) seed germination (91.11%) was recorded from seeds which were produced from the treatment combination of T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination the lowest percent (%) seed germination (85.55%) was found from the seeds achieved from the treatment combination T_0S_1 (control and 20 cm × 10 cm) treatment combination.

4.17 Cost benefit analysis

In the combination of nutrient and plant spacing maximum gross return (Tk. 310000) was obtained from the T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination of and the second highest gross return (Tk. 307500) was obtained in T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm). The lowest gross return (Tk. 205000) was obtained in the combination of T_0S_3 (control and 20 cm × 20 cm) (Table11).

Table 11. Cost and return analysis of black cumin considering nutrients combination and plant spacing

Treatments	Cost of production (Tk)	Yield (t ha^{-1})	Gross income (Tk)	Net income (Tk)	BCR
T_0S_1	99358	0.93	232500	133142	2.34
T_0S_2	94823	0.89	222500	127677	2.35
T_0S_3	91367	0.82	205000	113633	2.24
T_1S_1	107908	1.06	265000	157092	2.46
T_1S_2	103373	0.99	247500	144127	2.39
T_1S_3	98837	0.96	240000	141163	2.43
T_2S_1	114298	1.24	310000	195702	2.71
T_2S_2	109763	1.23	307500	197737	2.80
T_2S_3	105228	1.08	270000	164772	2.57
T_3S_1	120671	1.12	280000	159329	2.32
T_3S_2	117216	1.07	267500	150284	2.28
T_3S_3	112680	1.03	257500	144820	2.29

Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1} and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm.

Different treatment combination gives different types of net return. In combination of nutrient and plant spacing highest net return (Tk. 197737) was obtained from the T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and second highest net return (Tk. 195702) was obtained in T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm). The lowest net return (Tk. 113633) was obtained in the combination of T_0S_3 (control and 20 cm × 20 cm).

In combination of nutrient and plant spacing the highest benefit cost ratio (2.80) was attained from the T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and the closest benefit cost ratio (2.71) was acquired T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm). The lowest benefit cost ratio (2.24) was obtained from combination of T_0S_3 (control and 20 cm × 20 cm) (Table 11).

CHAPTER V
SUMMARY AND CONCLUSION

An experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of macro nutrient and spacing on morphological parameters and yield of black cumin. The experiment was conducted during the period from November 2019 to April 2020. Seeds of BARI Kalojira 1 variety was used for the present study and collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment comprised of four levels of macro nutrient viz. $N_0P_0K_0$ kg ha^{-1} (control), $N_{45}P_{25}K_{20}$ kg ha^{-1}, $N_{90}P_{50}K_{40}$ kg ha^{-1}, $N_{135}P_{75}K_{60}$ kg ha^{-1} and three level of spacing viz. 20 cm × 10 cm, 20 cm × 15 cm and 20 cm × 20 cm. The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 12 treatment combinations in all.

Data on different growth and yield parameters such as percent (%) seed germination, plant height, number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$, days to first flowering, days to 50% flowering, length of capsule, breath of capsule, number of seeds $capsule^{-1}$, number of capsules $plant^{-1}$, weight of seeds plant, weight of seeds plot, 1000 seed weight, seed yield, dry matter of plant were recorded and analyzed statistically.

The result of the experiment revealed that all the parameters studied were significantly influenced by different nutrient levels. There had significant effect on plant height, number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$. At 30 DAS, highest plant height (23.49 cm) were achieved from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and the lowest plant height (10.78 cm) were observed from control T_0 (control) treatment. But in case of 90 and 135 DAS highest plant height (46.12 cm) and (54.86 cm) were achieved from T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) treatment respectively and the lowest plant height (20.62 cm) and (32.89 cm) were observed from control T_0 (control) treatment respectively. The maximum number of primary branches (8.62) and number of secondary branches (12.18) were achieved from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and the minimum number of primary branches (5.50) and number of secondary branches (8.60) were achieved from control T_0 (control) treatment. The highest days to first flowering (55.55 DAS) and 50% flowering

(66.68 DAS) recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and the lowest days to first flowering (51.88 DAS) and 50% flowering (61.78 DAS) recorded from control T_0 (control) treatment. The highest number of flower (22.20), number of capsule (19.81), length of capsule (1.44 cm) and breath of capsule (1.04 cm) were recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and lowest number of flower (17.56), number of capsule (16.17), length of capsule (1.07 cm) and breath of capsule (0.79 cm) were recorded from control T_0 (control) treatment. The maximum number of seed per capsule of black cumin (76.18), thousand seed weight (2.99 g), yield per plant (3.36 g) were achieved from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and the minimum number of seed per capsule of black cumin (64.52), thousand seed weight (2.80 g), yield per plant (2.51 g) were achieved from control T_0 (control) treatment. The highest yield per plot (170.40 g), yield per hector (1.18 t) and dry matter weight (11.29 g) were recorded from T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment and lowest yield per plot (127.14 g), yield per hector (0.88 t) and dry matter weight (7.90 g) were recorded from control T_0 (control) treatment. There was no significant effect on the germination percentage. However, the highest percent (%) seed germination (91.00%) was observed in T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) produced seeds whereas the minimum percent (%) seed germination (88.28%) was recorded from the seeds of T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) treatment.

Different plant spacing showed significant effect on growth parameters of black cumin. There had significant effect on plant height, number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$. The highest plant height at 45, 90 and 135 DAS were (18.47 cm), (36.38 cm) and (48.34 cm) were achieved from S_1 (20 cm × 10 cm) treatment respectively and the lowest plant height (16.22 cm), (31.74 cm) and (45.78 cm) were observed from S_3 (20 cm × 20 cm) treatment respectively. The maximum number of primary branches (7.80) and number of secondary branches (11.23) were achieved from S_3 (20 cm × 20 cm) treatment and the minimum number of primary branches (7.09) and number of secondary branches (10.35) were achieved from S_1 (20 cm × 10 cm) treatment. The highest days to first flowering (53.92 DAS) and 50% flowering (64.61 DAS) recorded from S_3 (20 cm × 20 cm) treatment and the lowest days to first flowering (52.47 DAS) and 50% flowering (63.24 DAS) recorded from S_1 (20 cm × 10 cm) treatment. The highest number of flower (20.26) and number of capsule (18.81) were recorded from S_3 (20 × 20 cm) treatment and lowest number of flower (19.90) and number of capsule (17.62) were recorded from S_1 (20 cm × 10 cm) treatment. The highest length of capsule (1.34 cm) and breath of capsule (0.94 cm) were obtained from S_2 (20 cm × 15 cm) treatment and lowest length of capsule (1.23 cm) and breath of capsule (0.88 cm) were obtained from S_1 (20 cm × 10 cm) treatment. The maximum number of seed per capsule of black cumin (71.77) was obtained from S_2 (20 cm × 15 cm) treatment and the minimum number of seed per capsule (69.55) were obtained from both S_1 (20 cm × 10 cm) and S_3 (20 cm × 20 cm) treatment. The highest thousand seed weight (2.96 g) and yield per plant (3.89 g) were recorded from S_3 (20 cm × 20 cm) treatment and the lowest thousand seed weight (2.82 g) and yield per plant (2.18 g) were recorded from S_1 (20 cm × 10 cm) treatment. The highest yield per plot (156.66 g) and yield per hector (1.09 t) were recorded from S_1 (20 cm × 10 cm) treatment and lowest yield per plot (140.04 g), yield per hector (0.97) were recorded from S_3 (20 cm × 20 cm) treatment. The highest dry matter weight (10.03 g) of black cumin was found from S_2 (20 cm × 15 cm) treatment and the lowest highest dry matter weight (9.30 g) was found from S_1 (20 cm × 10 cm) treatment. There was no significant effect of spacing on the germination percentage. However, the highest percent (%) seed germination (89.85%) was observed in S_3 (20 cm × 20 cm) treatment produced seeds whereas the minimum percent (%) seed germination (88.54%) was recorded from the seeds of S_1 (20 cm × 10 cm) treatment.

Combined effect of micronutrients and spacing showed significant effect on growth parameters of black cumin. There had significant effect on plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}. The highest plant height at 45, 90 and 135 DAS were (25.27 cm), (50.27 cm) and (56.36 cm) were achieved from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination respectively and the lowest plant height (10.30 cm), (19.42 cm) and (32.20 cm) were observed from T_0S_3 (control and 20 cm × 20 cm) treatment combination respectively. The maximum number of primary branches (8.80) and number of secondary branches (12.47) were achieved from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination and the minimum number of primary branches (4.96) and number of secondary branches (8.20) were achieved from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The highest days to first flowering (56.45 DAS) and 50% flowering (67.57 DAS) recorded from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination and the lowest days to first flowering

(51.03 DAS) and 50% flowering (61.09 DAS) recorded from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The highest number of flower (22.87) and number of capsule (20.81) were recorded from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination and lowest number of flower (17.20) and number of capsule (15.33) were recorded from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The highest length of capsule (1.53 cm) and breath of capsule (1.08 cm) were obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and lowest length of capsule (1.04 cm) and breath of capsule (0.76 cm) were obtained from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The maximum number of seed per capsule of black cumin (78.12) was obtained from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and the minimum number of seed per capsule (63.61) were obtained from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The highest thousand seed weight (3.06 g) and yield per plant (3.34 g) were recorded from T_2S_3 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 20 cm) treatment combination and the lowest thousand seed weight (2.75 g) and yield per plant (1.87 g) were recorded from T_0S_1 (control and 20 cm × 10 cm) treatment combination. The highest yield per plot (178.32 g) and yield per hector (1.24 t) were recorded from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination and lowest yield per plot (118.68 g) and yield per hector (0.82) were recorded from T_0S_3 (control and 20 cm × 20 cm) treatment combination. The highest dry matter weight (12.13 g) of black cumin was found from T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination and the lowest highest dry matter weight (7.64 g) was found from T_0S_1 (control and 20 cm × 20 cm) treatment combination. There was no significant effect of macro nutrient and spacing on the germination percentage. However, the highest percent (%) seed germination (91.11%) was observed in T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm) treatment combination produced seeds whereas the minimum percent (%) seed germination (88.33%) was recorded from the seeds of T_0S_2 (control and 20 cm × 15 cm) treatment combination.

Considering economic analysis, it was found that the highest gross return (Tk 310000) was obtained from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 10 cm) treatment combination. The highest net return (Tk 197737) and highest benefit cost ratio (2.80) were obtained from the treatment combination of T_2S_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1} and 20 cm × 15 cm). Again, the lowest gross return (Tk. 205000), lowest net return (Tk. 113633) and lowest Benefit cost ratio (2.24) were obtained from T_0S_3 (control and 20 cm × 20 cm) treatment combination.

Conclusion:

Considering the above results of this experiment; the following conclusion and recommendations may be drawn:

- In the experiment T_2 ($N_{90}P_{50}K_{40}$ kg ha^{-1}) treatment was more effective than without nutrient T_0 (control)
- The spacing S_3 (20 cm × 20 cm) gave higher seed yield per plant but the spacing S_1 (20 cm ×10 cm) gave maximum yield per hectare
- During the investigation, the best treatment combination was obtained from T_2S_1 ($N_{90}P_{50}K_{40}$ kg ha^{-1} with 20 cm × 10 cm) having yield potentiality of 1.24 t/ha.

Recommendation:

Considering the above observations of the present study could be made the following recommendations.

1. Further study may be needed for ensuring the different macronutrients combination and plant spacing in relation to growth and seed yield and quality performance of black cumin in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

2. More another doses of macronutrients combination and plant spacing may be needed to include for future study as sole or different combination.

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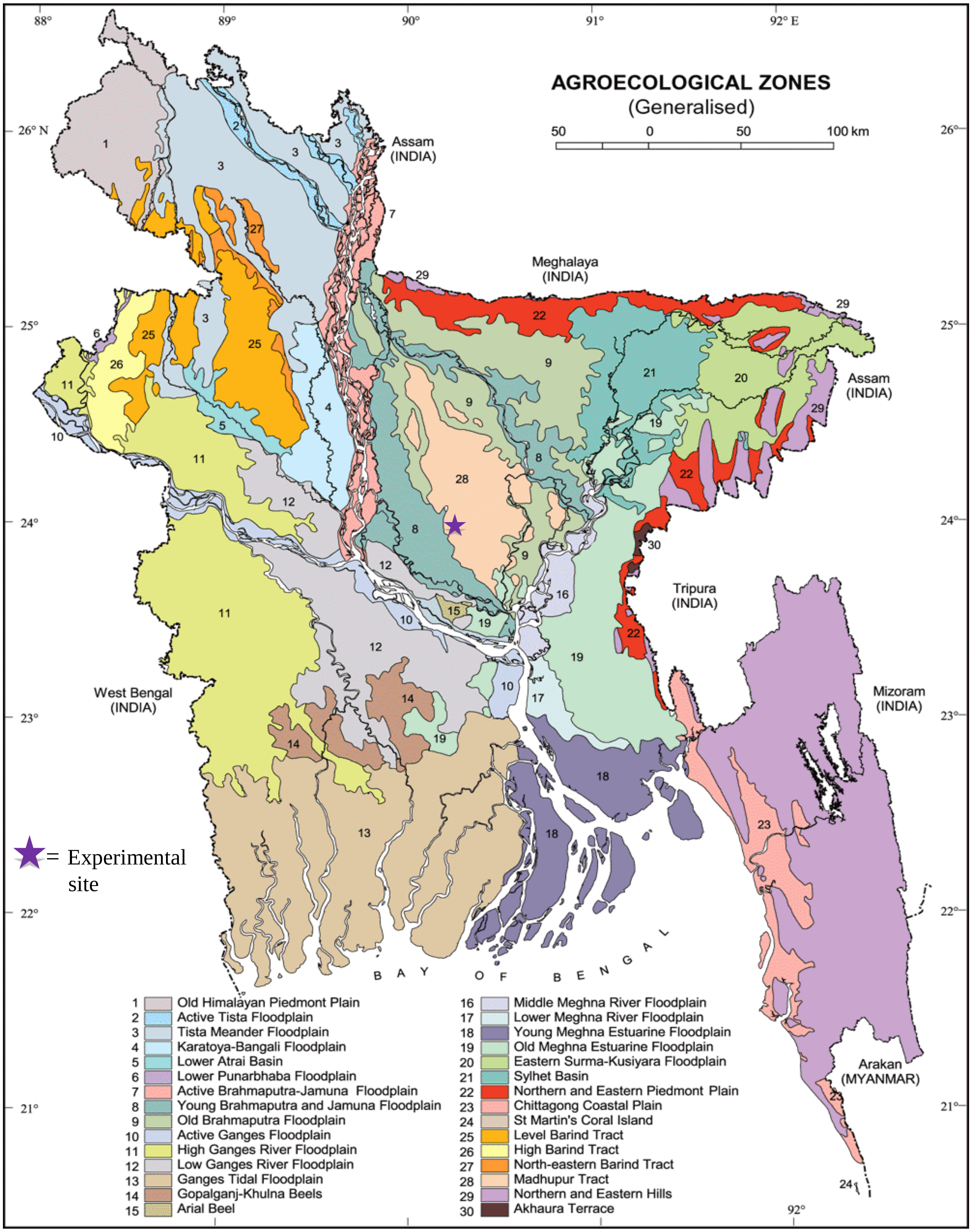
APPENDICES

Appendix I: Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II. Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period from November 2019 to April 2020

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	28.10	14.83	67.18	33
	December	25.00	16.46	60.53	0
2020	January	22.18	13.70	53.82	0
	February	26.10	18.83	45.18	19
	March	28.18	21.56	65.53	25
	April	32.15	23.45	67.23	85

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

Appendix III. The Morphological, physical and chemical characteristics of soil of the experimental site as observed prior to experimentation

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General Soil Type	Shallow red brown
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Drainage	Well drained
Flood level	Above flood level
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	28
%Silt	41
% Clay	31
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.46
Organic matter (%)	0.78
Total N (%)	0.033
Available P (ppm)	20.0
Exchangeable K (meq/100 g soil)	0.11
Available S (ppm)	45.0

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Effect of different nutrients of plant height, number of flowers plant^{-1}, number of capsules plant^{-1} and yield plant^{-1} of black cumin (*Nigella sativa* L.)

Treatments	Plant height			Number of flowers plant^{-1}	Number of capsules plant^{-1}	Yield plant^{-1}
	45 DAS	90 DAS	135 DAS			
T_0	10.78 d	20.62 d	32.89 d	17.56 d	16.17 c	2.51 d
T_1	13.98 c	28.76 c	47.51 c	19.09 c	17.04 b	2.87 c
T_2	23.49 a	41.93 b	52.96 b	22.20 a	19.81 a	3.36 a
T_3	22.17 b	46.12 a	54.86 a	21.31b	19.69 a	3.06 b
LSD(0.05)	0.4479	1.1080	0.5814	0.2007	0.2773	0.1211
CV%	2.60	3.30	1.26	2.02	2.56	4.20

Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}

Appendix V. Effect of plant spacing on plant height, number of flowers plant^{-1}, number of capsules plant^{-1} and yield plant^{-1} of black cumin (*Nigella sativa* L.)

Treatments	Plant height			Number of flowers plant^{-1}	Number of capsules plant^{-1}	Yield Plant^{-1}
	45 DAS	90 DAS	135 DAS			
S_1	18.47 a	36.38 a	48.34 a	19.90 b	17.62 c	2.18 c
S_2	18.13 a	34.96 b	47.11 b	19.96 b	18.10 b	2.79 b
S_3	16.22 b	31.74 c	45.78 c	20.26 a	18.81 a	3.89 a
LSD(0.05)	0.3879	0.9596	0.5035	0.1738	0.2402	0.1049
CV%	2.60	3.30	1.26	2.02	2.56	4.20

Note: S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Appendix VI. Analysis of variance of the data of plant height, number of primary branches plant^{-1} and number of secondary branches plant^{-1} affected by combined effect of nutrients combination and plant spacing of black cumin

Source of variation	Degree of freedom	Mean square				
		Plant height			Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}
		45 DAS	90 DAS	135 DAS		
Replication	2	0.03	1.68	0.19	0.08	0.02
Different nutrient dose (A)	3	345.31*	1247.00*	890.19*	16.69*	21.87*
Different spacing (B)	2	17.67*	67.81*	20.71*	1.56*	2.36*
Interaction (AxB)	6	4.07*	25.36*	1.48*	0.21*	0.17*
Error	22	0.210	1.28	0.354	0.0452	0.0275

* Significant at 5% level, ** Significant at 1% level, ^{NS} Not significant

Appendix VII. Analysis of variance of the data of days to first flowering, days to 50% flowering, number of flowers plant^{-1} and number of capsules plant^{-1} affected by combined effect of nutrients combination and plant spacing of black cumin

Source of variation	Degree of freedom	Mean square			
		Days to 1st flowering	Days to 50% flowering	Number of flowers plant^{-1}	Number of capsules plant^{-1}
Replication	2	0.25	0.32	0.10	0.07
Different Nutrient dose(A)	3	22.57*	37.76*	39.98*	30.72*
Different spacing (B)	2	6.59*	5.83*	0.47*	4.30*
Interaction (AxB)	6	1.59*	0.22*	0.74*	1.87*
Error	22	0.2559	0.3366	0.0421	0.0805

* Significant at 5% level, ** Significant at 1% level, ^{NS} Not significant

Appendix VIII. Analysis of variance of the data of length of capsule, breath of capsule, seeds capsule^{-1}, 1000 seed weight and seed yield plant^{-1} affected by combined effect of nutrients combination and plant spacing of black cumin

Source of variation	Degree of freedom	Mean square				
		Length of capsule	Breath of capsule	Seeds capsule^{-1}	1000 seed weight	Seed yield plant^{-1}
Replication	2	0.002	0.00071	0.12	0.167	0.009
Different Nutrient dose (A)	3	0.281*	0.10311*	226.69*	0.122	1.142*
Different spacing (B)	2	0.039*	0.01300*	15.40*	0.003*	9.054*
Interaction (AxB)	6	0.003*	0.00268*	3.13*	0.013*	0.039*
Error	22	0.00239	0.00094	0.561	0.015	0.01534

* Significant at 5% level, ** Significant at 1% level, ^{NS} Not significant

Appendix IX. Analysis of variance of the data of seed yield plot^{-1}, seed yield ha^{-1}, dry matter and germination rate affected by combined effect of different nutrients combination and plant spacing of black cumin

Source of variation	Degree of freedom	Mean square			
		Seed yield plot^{-1}	Seed yield ha^{-1}	Dry matter	Germination rate
Replication	2	21.43	0.001	0.02	43.84
Different Nutrient dose (A)	3	2951.84*	0.142*	22.17*	13.84^{NS}
Different spacing (B)	2	848.39*	0.040	1.68*	5.66^{NS}
Interaction (AxB)	6	36.76*	0.0018*	0.71*	4.35^{NS}
Error	22	40.84	0.00197	0.0669	32.6303

* Significant at 5% level, ** Significant at 1% level, ^{NS} Not significant

Appendix X. Cost of production of black cumin influenced by nutrients combination and plant spacing

A. Input cost (Tk/ha)

Treatments	Labour cost	Ploughing cost	Cost of seed	Cost of irrigation	Cost of manure and fertilizers							Insecti-cide	Sub Total
					Cowdung	Kichen compost	Urea	TSP	MOP	Gypsum	Boric Acid		
T_0S_1	15000	8000	4800	5000	20000	10000	0	0	0	2240	3360	2500	70900
T_0S_2	12000	8000	3600	5000	20000	10000	0	0	0	2240	3360	2500	66700
T_0S_3	10000	8000	2400	5000	20000	10000	0	0	0	2240	3360	2500	63500
T_1S_1	18000	8000	4800	5000	20000	10000	1568	2750	600	2240	3360	2500	78818
T_1S_2	15000	8000	3600	5000	20000	10000	1568	2750	600	2240	3360	2500	74618
T_1S_3	12000	8000	2400	5000	20000	10000	1568	2750	600	2240	3360	2500	70418
T_2S_1	19000	8000	4800	5000	20000	10000	3136	5500	1200	2240	3360	2500	84736
T_2S_2	16000	8000	3600	5000	20000	10000	3136	5500	1200	2240	3360	2500	80536
T_2S_3	13000	8000	2400	5000	20000	10000	3136	5500	1200	2240	3360	2500	76336
T_3S_1	20000	8000	4800	5000	20000	10000	4688	8250	1800	2240	3360	2500	90638
T_3S_2	18000	8000	3600	5000	20000	10000	4688	8250	1800	2240	3360	2500	87438
T_3S_3	15000	8000	2400	5000	20000	10000	4688	8250	1800	2240	3360	2500	83238

T_0 = Control; T1 = $N_{45}P_{25}K_{20}$ kgha^{-1}; T_2 = $N_{90}P_{50}K_{40}$ kgha^{-1}; T_3 = $N_{135}P_{75}K_{60}$ kgha^{-1}

S_1 = 20 cm × 10 cm; S_2 = 20 cm × 15 cm; S_3 = 20 cm × 20 cm

Labor cost =400 TK/day; Ploughing (4 times) = 2000 TK/cultivation; Seed rate = S_1=8 kg/ha, S_2=6 kg/ha, S_3=4 kg/ha

Urea=16 tk/kg; TSP=24 tk/kg; MOP=30 tk/kg; Gypsum=20 tk/kg; Boric acid=140 tk/kg

B. Overhead cost (Tk/ha)

Treatment	Cost of lease of land (Tk.8% of value of land cost/4 months)	Miscellaneous cost (Tk. 7% of the input cost)	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)
T_0S_1	20000	4963	3495	28458	99358
T_0S_2	20000	4669	3454	28123	94823
T_0S_3	20000	4445	3422	27867	91367
T_1S_1	20000	5517	3572	29090	107908
T_1S_2	20000	5223	3531	28755	103373
T_1S_3	20000	4929	3490	28419	98837
T_2S_1	20000	5932	3630	29562	114298
T_2S_2	20000	5638	3589	29227	109763
T_2S_3	20000	5344	3548	28892	105228
T_3S_1	20000	6345	3688	30033	120671
T_3S_2	20000	6121	3657	29778	117216
T_3S_3	20000	5827	3616	29442	112680

Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{45}P_{25}K_{20}$ kg ha^{-1}, $T_2 = N_{90}P_{50}K_{40}$ kg ha^{-1}, $T_3 = N_{135}P_{75}K_{60}$ kg ha^{-1}, S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Plate 1. Plot preparation

Plate 2. Seed sowing

Plate 3.Watering on seedbed

Plate 4.Seed germination

Plate 5. Plant height at 45 DAS

Plate 6. Weeding on experiment plot

Plate 7. Flower initiation on black cumin

Plate 8. Flower of black cumin

Plate 9. Experiment plot

Plate 10. Flowering stage of black cumin plant

Plate 11. Harvest of black cumin

Plate 12. Drying of harvested capsule

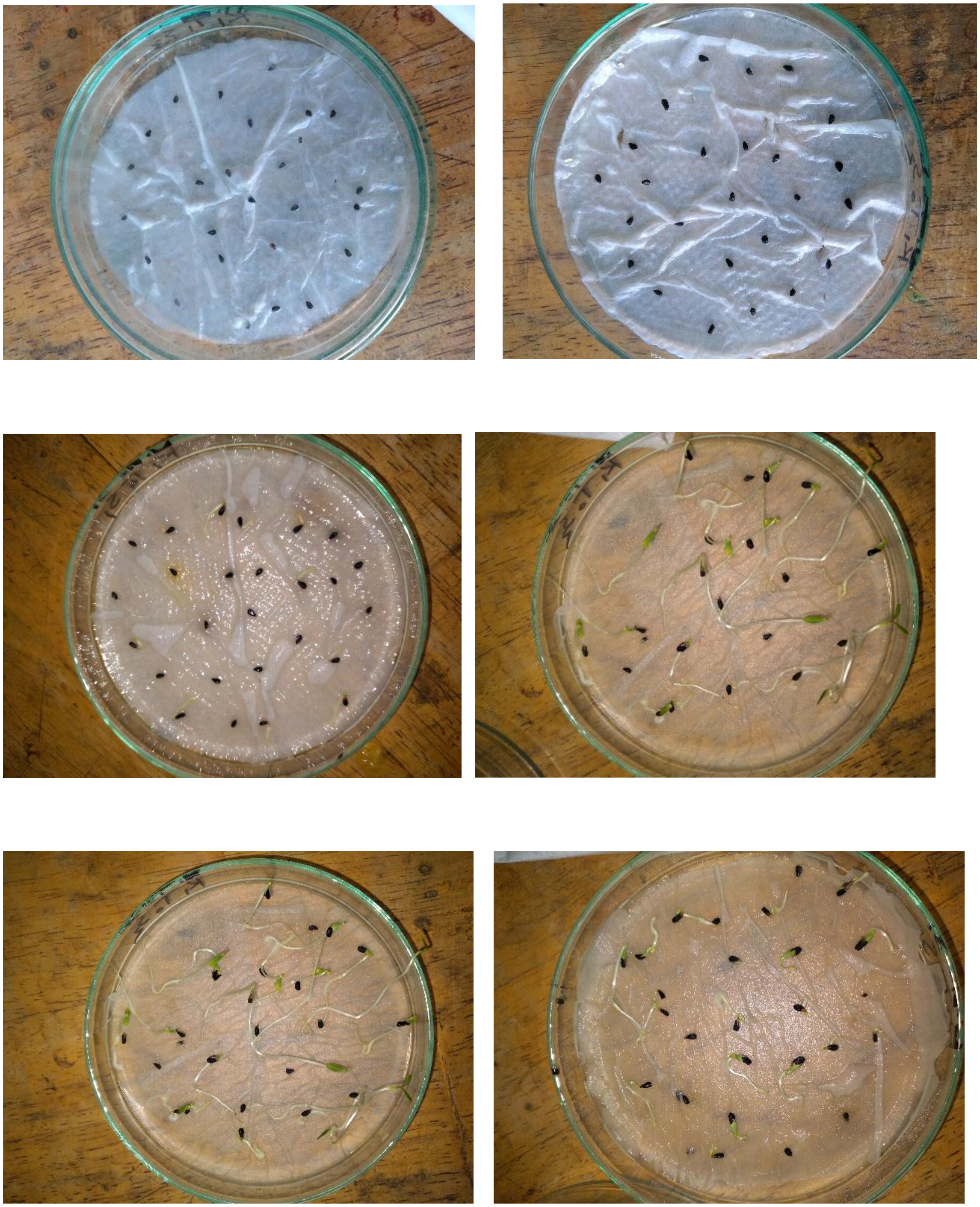


Plate 13. Germination test of harvested seed of black cumin