EFFECT OF DATE OF SOWING AND SPACING ON GROWTH AND SEED YIELD OF BLACK CUMIN (*Nigella sativa* L.)

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DHAKA -1207

JUNE, 2021

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Registration No.: 13 –05744

Semester: January-June, 2021

A Thesis

Submitted to the Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
SEED TECHNOLOGY

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF DATE OF SOWING AND SPACING ON GROWTH AND SEED YIELD OF BLACK CUMIN** *" submitted to the Institute of Seed technology, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in SEED TECHNOLOGY,*** *embodies the results of a piece of bona fide research work carried out by* **ABDULLA-AL-MASUD**, *Registration No.* **13-05744** *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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ACKNOWLEDGEMENTS

All praises to Almighty Allah, the Supreme Ruler of the universe Who enables the author to complete this thesis work successfully for MS degree.

The author would like to express his sincere appreciation and vast indebtedness to his supervisor ***Prof. Dr. Khaleda Khatun,*** *Professor****,*** *Department of horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for her proficient guidance, planning, valuable advice, continuous suggestions and all kinds of support and help for all the period of research work and preparation of this thesis. He regards it is a privilege to acknowledge his gratefulness, endless gratitude and best regards to his respectable co-supervisor,* ***Prof. Dr. Tahmina Mostarin,*** *Professor, Department of horticulture, Sher-e-Bangla Agricultural University, for her valuable suggestions, kind co- operation and scholastic guidance throughout the study and research work.*

It is a great pleasure and privilege to express his boundless gratitude and cordial regards to ***Prof. Dr. Md. Ismail Hossain****, Director, Institute of seed technology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his valuable advice and kind consideration. The author wishes to expand his special thanks and warmest gratitude to his other course teachers, Sher-e-Bangla Agricultural University, Dhaka, for their co-operations and constant encouragement. He also wishes to acknowledge his indebtedness to farm division of SAU and other staff for their great co-operation in the execution of research work.*

The author expresses his unfathomable respects, sincere gratitude and deep indebtedness from his core of heart to his beloved parents whose sacrifice, inspiration, encouragement and continuous blessings paved the way to his higher education.

June,2021
SAU, Dhaka

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EFFECT OF DATE OF SOWING AND SPACING ON GROWTH AND SEED YIELD OF BLACK CUMIN (*Nigella sativa* L.)

ABSTRACT

An experiment was conducted at the central research field of Sher-e-Bangla Agricultural University, Dhaka during November 2019 April 2020 to study the effect of date of sowing 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 consisted of four different sowing dates like T_1= 5th November, T_2= 20th November, T_3=5th December, T_4= 20th December., Factor B consisted of four levels of spacing like S_1= 20cm×10cm, S_2= 20cm×20cm, S_3= 25cm×10cm, S_4= 25cm×20cm. The experiment was laid out in a randomized complete block design (factorial) with three 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 sowing date the tallest plant (45.99 cm) ,the maximum primary branch plant^{-1} (8.4) and secondary branch plant^{-1} (15.20), flower plant^{-1} (20.15), capsules plant^{-1} (18.80), seeds capsules^{-1} (84.41), 1000 seed weight (2.49 g) ,the highest seed yield plant^{-1} (4.02 g), seed yield plot^{-1} (249.92 g), germination percentage (84.00%) and vigor index (1059.5) was observed from T_1 (5th November) treatment. In case of plant spacing the tallest plant (44.96 cm) was observed from S_1 (20cm×10cm) treatment. The maximum primary branch plant-1 (8.2) and secondary branch plant-1 (14.45), days to 50% flowering, maximum seeds capsules-1 (84.75), seed yield per plant(4.61), 1000 seed weight (2.92 g), germination percentage(82%), vigor index(1073.2) was observed from S4(25cm× 20cm) treatment. Flower plant-1 (19.3), capsules plant-1 (17.81) was observed from S_2 (20cm×20cm) treatment. Maximum seed yield plot-1 (316.83 g) was recorded from S_1 (20cm×10cm) treatment. Among the treatment combinations T_1S_4 (5th November sowing with 20cm×25cm spacing) treatment give highest seed yield plant^{-1} (4.96 g) and the lowest (3.03 g) was obtained from T_4S_1 (20th December sowing with 20cm×10 cm spacing) treatment. So the treatment combination T_1S_4 (5th November sowing with 20cm×25cm spacing) appeared to be the best for achieving the maximum growth and 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

g = gram (s)

ha^{-1} = Per hectare

HRC = Horticulture Research Centre

kg = Kilogram

LSD = Least Significant Difference

Max = Maximum

Min = Minimum

NS = Not significant

RCBD = Randomized Complete Block Design

SAU = Sher-e-Bangla Agricultural University

SRDI = Soil Resources and Development Institute

wt = Weight

% = Percent

^0C = Degree Celsius

CHAPTER I

INTRODUCTION

Black cumin (*Nigella sativa* L.) is an annual seed spices herb which belongs to the family of Ranunculaceae. It is also known as black seeds and in Bengali it is known as Kalojira. It is one of important spices with medicinal value in Bangladesh. Black cumin is native to the Mediterranean and in the Western parts of Asia continent. It is cultivated mostly all over the world along with Middle East, North Africa and Asia wherein most range is found. (Abu-Jadayil, 2002.). In Bangladesh it is cultivated in several districts like as Shariatpur, Madaripur, Jashore, Kushtia, Sirajganj and Natore. *Nigella sativa* and *Nigella damascena* species are commonly cultivated (Baydar, 2013). Black cumin seed has profound medicinal uses (Ali and Blunden, 2003). Black cumin seeds is comprised of high economic value and contain fixed oil, essential oil, protein and carbohydrates. Its medicinal value is diversified and most of the researchers acknowledged its unique, useful and powerful pharmacological characteristics. Seed of black cumin also contains alkaloids such as nigellidin, nigellisin and nigellimin (Baydar, 2013). *Nigella sativa* seeds are used in the ancient system of ayurvadic medicine and possess carminative, digestive, diuretic and antiseptic properties (Baytop, 1984; Siddiqui and Sharma, 1996).

The usual consumption of black cumin seed for medicinal purpose is identified as curative for various diseases and described in the Bible called itthe Gifth (Atta-ur-Rahman *et al*., 1985). Black Cumin seeds have an aromatic odor and is bitter in taste. Seeds are used as basic element in making soup, sausages, cheese, cakes and candies (Behera, *et al.,* 2004). The seeds are also effective for the treating various diseases like as cold, cough, fever, and several types of pains such as toothache, gastrointestinal problem, nausea, vomiting, urinary pathway infections and kidney or urine keeping bladder stones of human (Riaz *et al.,* 1996). As herb, black cumin has a wealthy dietary value; it includes monosaccharides. The seed is wealthy in fatty acids, proteins and carbohydrates.

It includes all important amino acids and wealthy supply of nutrients and minerals (Abu-Jadayil *et al.*, 1999). Extracts of black cumin are used as natural products for the

treatment of schistosomiasis, which is a widely prevalent disease in the third world countries. Black cumin plant oil is well known to play role as insecticidal, antibiotical, hypotensive, and immunopotentiating activities (Hader *et a*l., 1993; Siddiqui and Sharma, 1996). Another use of *N. sativa* seeds is as seasoning for foodstuffs like bread and pickles, especially widespread in Turkey (D'Antuono *et al*., 2001). It develops as 20 to 30 cm tall, uniformly separated, direct (yet not string like) leaves. The blossoms are fragile, and typically shaded light blue and white, with 5 to 10 petals. The organic product is an enormous and swelled case made out of 3 to 7 joined follicles, each containing various seeds. Seeds are used as spices and condiments and also used in making breads, biscuits, cake and other backery products. Desserts and within sidethe instruction of conventional candy dishes, pastry, pickles, and used as sweets and liquors (Thippeswamy and Naidu, 2005). Beside this black cumin oil is full with many medicinal usages (Ali and Blunden, 2003). Seed of black cumin is contained with 7% moisture, 4.34% ash, 23% protein, 0.39% fat,4.99% starch and 5.44% raw fiber (Zargari, 1990). Black cumin cultivation progress is expanding step by step in Bangladesh because of its various worth. Presently a people groups are cognizant about their wellbeing and therefore this sort of restorative flavor has the incredible interest to the ranchers.

Various factors can be helpful in improving the yield on the basis of per unit area, however sowing dates and spacing are most important. Delayed sowing date decreases seed weight and the number of umbrella per plant. Delayed sowing results in reduced vegetative growth leading to reduced number of umbrella per plant and plant height (Rahnavard *et.al.*, 2010; Sharratt and Gesch, 2004). Mohan *et al*. (2001) have also reported that decrease in plant height with later sowing. Significant loss in yield and decrease in plant height caused by delayed sowing owing to the unpromising sowing dates was quantified by Bianco *et al*. (1994) and Barros *et al*. (2004). Sadeghi *et al.* (2009) reported that early sowing as compared to late resulted in higher seed yield, number of capsule plant^{-1}, no. of seeds capsules^{-1} and plant height. In a study on the effect of sowing date with plant density on seed yield of fennel, Darzi *et al*. (2002) reported that they significantly affected seed yield and that the best sowing date was March 25 and the best density was 10 plants/m^2 .Yield loss due to unfavorable sowing date has been found in several crops such as sunflower (Barros *et al*., 2004) and fennel (Bianco *et al*., 1994; Kafi, 1990). However, the

optimum development among the variables that influence on yield and nature of black cumin seed, plant density is one of the main factors. (Ahmed and Haque, 1986).
Suitable plant dispersing can prompt ideal yield. In suitable plant density, plants can able to use completely environmental conditions (water, air, light and soil) and inter- or intra-specific competition is in minimum range. The number of plant per unit area is the most important among yield components (Kafi, 2003). Researchers accepted that the foundation of ideal spacing of solid plants in a field is responsible for the effective cultivating framework. An ideal plant spacing is a spacing at which every ecological element (water, air, light, soil) are completely used by the plants and simultaneously, intraspecies and extra-species rivalries are limited (Alizadeh and Koucheki, 1995). The number of seed per capsule is affected by environmental, field management and its number was reported from 11.3 to 16.8 under varying plant densities (Kafi, 2003). Growth and development and of black cumin seed is triggered by certain elements viz., sowing time, spacing, variety and nutrient elements.Various factors can play important role in improving the yield on the basis of per unit area, however sowing dates are most important. Early sowings were suitable for growth and yield of black cumin seed (Ahmad and Haq ,1986). Significant loss in yield owing to the unpromising sowing dates was quantified by Bianco *et al.* (1994). Sadeghi *et al*. (2009) reported that early sowing as compared to late is resulted in higher seed yield, number of capsule plant-1, no. of seeds capsule-1 and plant height. A suitable combination of sowing date and spacing spacing is essential for better yields performance (Miah *et al*.,1990). The aim of the research is to evaluate the growth and seed yield of black cumin influenced by date of sowing and plant spacing.
The main objectives of this research is as following:

- To identify the optimum sowing date for maximum yield of black cumin seed.
- To find out the suitable spacing for maximum growth and seed yield of black cumin.
- To determine the combined effect of sowing date and spacing on yield and quality of black cumin seeds.

CHAPTER II

REVIEW OF LITERATURE

Black cumin is of the the blessings of nature created by the Almighty. It is completely comprised with mediacative value. This plant is grown almost everywhere in the world. Its medicative price is in creasing day by day. The literature relating to growth and yield elements of black cumin as influenced by sowing date and spacing area unit terribly scanty. However, the relevant info accessible on this space generated from totally different studies has been reviewed during this character.

2.1 Effect of swoing date on seed yield

EL-Mkeway & M.A.M (2012) reported that early sowing date increased significantly the growth and yield parameters on the other hand late sowing date decreased them. Nawaz *et al.* (1995) stated that sowing dates have no significant influence on 1000-seed weight. The harvest index was decreased as the sowing time delays irrespective of varieties.

Bahrami *et al.* (2006) stated that the harvest index was highly significant between sowing dates and genotypes interaction that increased harvest index. Due to more partitioning of dry matter to reproductive parts resulted in the increased crop yield probably.

The optimum sowing time of each type of crop is regarded as basic requirements to yield. There are several experiments have been conducted regarding on sowing seeds and transplanting time, which concluded that the total crop yield is significantly affected by sowing times (Snoek 1981).

A month delay in sowing caused drastical reduction in the number of capsules per plant and hence early sowing was reported to becritical in Nigella reported by Giridha (2015); Jafari (2013); El-Mekawy (2012) which is also supported the present results.

Delayed showing showed the result in decreasing of capsule number and this was also reported by Haq *et al.* (2015); Vaseghi *et al.* (2013); Islam and Akhtar (2013); Meena *et al. (*2012).

Hafez (1998) stated that its growth parameters like as plant height, base and sides branches per plant, fresh weight of the plant greatly increased in black cumin seeds are sown in october. The maximum plant height was found in plants (32.12 cm) sown

in the middle of the week of october. Similarly, the same datum turned out to be better generate the maximum number of sheets. Maximum sowing date the number of branches was recorded at the time of sowing in mid-october (3 branches and 4 branches).

Datta *et al.* , (2008) also found increased plant height of black cumin advance sowing time to 15 days november and after it returns gradually. He also found an increasing trend in numbers primary and secondary branches per plant in a plant early sown with black cumin.

Gowda *et al.* , (2006) recorded similar species date-related observations in fenugreek. Malhotra and Vashishtha (2008) reavled that sowing during second fortnight of October was appropriate time for optimum growth and yield of nigella. Majumder *et al.*, (2012) conducted an experiment on the crop response to six dates of sowing and two spacings in Gangetic plains of West Bengal.

Sowing date had the significant effect on the number of umbrella per plant that related to high sensitivity of this yield component to photoperiod and temperature, which conforms to the finding. The highest number of umbrella per plant was reported under the first sowing date (give actual sowing dates). Three sowing dates were 3, 13 and 23 on March. Plants under second (13, March) and third (23, March) sowing dates had 25 and 18% lower umbrella number compared with the first sowing date (3rd March).

Yield loss due to unfavorable sowing date has been found in many crops such as sunflower (Barros *et al.*, 2004) and fennel (Bianco *et al.*, 1994; Kafi, 1990). Yield components of Basil include the number of plant in unit area, the number of umbrella per plant, the number of seed per umbrella and seed weight. Kafi,(2003) stated that the number of plant per unit area is the most important among yield components.

Ahmed and Haque (1986) studied the effect of row spacing (15, 20, 25 and 30 cm) and time of sowing (November 1, November 20, December 10 and December 30) on the yield of black cumin (*Nigella sativa*) in Bangladesh, they reported that closer row spacing (15 cm) and early sowing (November 1) was the best for higher seed yield of black cumin. The number of umbrella per plant has the second rank interms of importance in yield components.

Seed per umbrella number is inflenced by environmental, field management and its

number was reported from 11.3 to 16.8 under different plant densities (Kafi, 2003). Basil seed weight is varied in different experiments with different plant populations. Kafi (2003) reported that it was from 2.79 to 2.99 g under varying in different plant densities. Growth and development is accelerated with delayed sowing because the crops faced with higher temperatures during the vegetative growth (Datta *et al*., 1994).

Ehteramian (2003) reported that delayed sowing date showed positive result because of the occurrence, resulting to lack sudden winter chilling. late sowing date has influence on decreasing seed weight and the umbrella number per plant. Species such as *Nigella sativa* and *Nigella damascena* are generally cultivated . This study is aimed to determine the determination of the optimum sowing date and plant density of Basil for achievement of maximum seed yields under the conditions of the west of Iran.

2.2 Effect of spacing on yield and growth

Koocheki *et al.,* (2006) studied fennel densities of 40, 50, 60 and 100 plants/m^2 and stated that when the density was increased from 40 to 100 plants/m^2, yield of seed increased along with plant density.

Bahraininejad *et al.,* (2006) reported that the fennel density of 3.5 plants/m2 produced 2669.3 kg seeds/ha and other densities tested i.e. H. 5 and 10 plants/m2, was significantly superior.

A study was conducted to study the effect of sowing dates, nitrogen fertilization rates, and plant density on black seed productivity under the rain-fed semi-arid conditions of Jordan. The results at the Mushaqar site showed that sowing on December 2 yielded 25.1% and 54.1% more seed than sowing in late December and early January, respectively. Likewise, the biological yield at the first appointment (December 2nd) was 53.5% and 87% higher than at the 2nd and 3rd appointments, respectively. The harvest index behaved differently, with the highest harvest index being achieved on the 2nd and 3rd planting dates. At the Maru site, the highest harvest index value was reported on the second date with an increase of 29.2% and 33.5% over sowing on the 1st and 3rd dates, respectively. Seed yield at both locations correlated significantly with plant height and weight of 1000 seeds. Neither plant density treatments nor urea treatments applied at the time of cultivation showed a significant effect on seed yield

for the two sites.

To study the influence of N fertilization and plant density on the yield and yield parameters of fennel in Birjand, Iran, a study was conducted by Azita *et al.* (2012) in the research area of the Research Center for Agriculture and Natural Resources in Southern Khorasan in the year of 2010. The study was a spatial and temporal split-plot experiment based on a three-replicate randomized full block design. The main plot was the N fertilizer level on five levels of 0, 40, 80, 120 and 160 kg ha-1 and the secondary plot was the density on three levels of 10, 15 and 20 plants per m^2. Traits studied included cone count per plant, cone count per cone, fruit count per cone, cone count per m^2, 1000 seed weight and fruit yield measured at two cuts and compared. It was found that N content and plant density significantly affected all traits studied, but their interactions were statistically non significant for the traits.

Esmaeil and Behnaz (2014) reported that as plant density is more than optimal, the amount of light, food and water is insufficient for the plant. Then, if the plant density is under the optimum due to environmental factors, it will not be sufficient and resulted in the decrease of the grain yield. Components of *Nigella sativa* were evaluated in 1999-2000 and 2000-2001 under semi-arid conditions in Diyarbakr, Turkey. Seed rate significantly affected plant height, number of branches per plant, number of capsules per plant, seed yield per plant, and seed yield. High seed rates (40 & 50 kg ha-1) reduced the number of branches, number of capsules per plant, seed yield per plant and seed yield.

An study was executed to evaluate the influence of sowing date and plant density on yield and yield components of black cumin (*Cuminum carvi* L.) under drought conditions. Four planting densities (50, 100, 150 and 200 plants m^{-2}) and three sowing dates (March 3, 13 and 23) were applied. The result showed that seed yield was influenced by sowing date and the interaction of plant density. Early sowing time resulted in higher seed yields, as evidenced by higher aboveground biomass, number of umbrellas per plant, number of seeds per umbrella, and plant height. Harvest index and 1000 seed weight were unaffected by sowing date and planting density. Plants sown earlier at a density of 200 m^{-2} resulted in higher seed yields. (Sedigheh *et al*., 2009).

Maya *et al.* (1997) reported that plant height of peppers was significantly affected by

close spacing.

Kim *et al.* (1999) found that planting systems and spacing did not significantly alter plant height, main stem length, fruit length, fruit diameter, or pericarp thickness.

Norman (1992) stated that increasing in plant density has no significant effect on individual plants when plant density is below the level at which interplant competition can occurs.

Janick (1972) reported that increasing competition resembles a reduction in the concentration of growth factors. Yield per unit area tends to increase as plant density increases to a certain point and then decreases (Akintoye *et al.*, 2009). Mazumder *et al.* (2007) found that plants grown under normal spacing have suitable population density per unit area, providing optimal conditions for lush plant growth and better plant canopy area due to maximum light disruption, photosynthetic activity, assimilation and accumulation of more photosynthesis into the plant system and therefore they produce more seed yield with best quality characteristics.

Ameen *et al*. (1988) showed that the closest spacing of 45 x 20 cm had the tallest plant height of 110.06 cm, but was not significant. While a distance of 4530 cm had the highest number of branches per plant (8.45) in fennel.

Pandey *et al.* (1996) observed the tallest (108.71 cm) plant height at a narrow spacing of 60×45 cm in tomato hybrids, while a wider spacing of 90 x 45 cm had the highest number of primary branches per plant (7.91).

Kanwar *et al.* (2000) conducted an experiment to determine the effects of different population densities in onions and concluded that population densities registered no effects on days to flowering and maturity.

Bahadur and Singh (2005) stated that a narrower spacing of 60 x 40 cm recorded the tallest plant height of 176.1 cm. whereas; A larger spacing of 60 x 60 cm recorded the highest number of branches per plant (13.2) in tomatoes. According to Ameen, seed quality attributes such as test weight, germination percentage, and seedling vigor index were found to be better at larger spacings than at closer spacings. Distance between plants increased, the number of branches per main stem increased significantly.

Ghobadi and Ghobadi (2010) studied the effect of different coriander plant densities (10, 30, 50 and 70 plants per m^2) and concluded this number of umbels per plant and

number.The number of fruits per cone decreased with increasing plant density, but no significant difference in weight per 1000 fruits was observed.

Akbarinia *et al.* (2006) studied coriander densities of 20, 30, 40, 50 and 60 plants/m^2 and concluded that the yield of fruits and essential oils was higher at a density of 30 plants/m2.

Ahmed and Haque (1986) studied the effect of row spacing (15, 20, 25 and 30 cm) and timing of sowing (November 1, November 20, December 10 and December 30) on the yield of black cumin (Nigella sativa) in Bangladesh, they found closer row spacing (15 cm) and early sowing (November 1) was best for higher seed yield of black cumin. Hopper row spacing did not affect plant height, but the number of umbels and seed yield per plant increased with increased spacing.

Masood *et al.* (2004) studied the effect of row spacing (40, 50, 60 and 70 cm) on funnel morphological traits and seed yield and reported that the highest plant height, highest seed yield per umbel and highest seed yield per hectare achieved with the lowest were row spacing, but the lowest plant height, seed yield per umbel and seed yield per hectare were obtained with the largest row spacing.

2.3 Interaction of sowing date and spacing

An experiment was conducted by Dutta *et al.* (1994) reported that significant effect of sowing date and plant density on seed yield of fennel. Grain yield loss of agricultural crops such as fennel (*Foeniculum vulgare* M.) was reported due to unsuitable sowing date. They reported that early sowing produced higher seed yield, while shortening of the growing cycle decreased the amount of radiation intercepted during the growing season and thus total dry weight of plant .On the other hand, the number of plants per unit area is the most important among yield components (Kafi, 2003). Applying optimum plant density, plants are completely adapted in environmental conditions such as water, air, light, soil and inter- or intra specific competition will be at the minimum level (Sadeghi *et al.*, 2009; Verzalova *et al.*, 1990) indicating that increasing plant density was found to produce taller plants, but thinner stems, lesser branches number in fennel. The weight of 1000 seeds was significantly affected by the planting dates and plant density at the two locations (Khaled *et al*, 2007). They conducted an experiment based on three sowing date,

nutrient and plant densities in Maru site and found that the highest 1000 seed weight at Mushaqar site was obtained under 35 kg seed ha-1, followed by 25, 30 and 40 kg ha-1. While Maru achieved the highest seed weight under 30 and 35 kg seed ha^{-1}. The first planting date produced the tallest plants at Mushaqar, while 25 kg seed ha^{-1} yielded the tallest plants at Maru.The information regarding interactive effect of planting date and plant spacing on growth and yield of fennel is lacking in Jordan. The present study was, therefore, carried out to evaluate the effect of different planting date and plant spacing on growth and yield of fennel under irrigated conditions of south Jordan valley area, Jordan.

Jafari (2013) stated that plant density with optimum sowing date showed increasing movement in growth parameters. In feenel and fenugreek total seed production per plant upturned with early sowing and comparatively more spacing. Hader *et al*,(1997) reported that combined effect of optimum sowing date and sowing distance in coriander resulted seed number and seed quality, where as late sowing decrese yield with minimum seed number per plant.

CHAPTER III

MATERIALS AND METHODS

Different materials used and methodologies followed in this experiment are presented here in detail. This chapter deals with a brief description of experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and analysis etc.

3.1 Experimental site and time

The experiment was conducted from 5th November, 2019 to 30th April, 2020 (*Robi* season) which comprised of seed collection, growing and experimentation, data collection and compilation etc. at the Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka-1207. It is located under the Agro-ecological zone of Madhupur Tract, AEZ-28 (23^0 $41^{'}$ N latitude and 90^0 $22^{'}$ E longitude) at an elevation of 8 m above the sea level.

3.2 Climate

The experimental area was flat having available irrigation and drainage system. Sufficient sunshine was available during the experimental period.The experimental area belongs to Modhupur Tract (Agro-Ecological Zone 28). Red-Brown Terrace soil type with silty clay in surface and silt clay loam in sub-surface region. As per USDA soil classification, the experimental soil was under Inceptisol order. The analysis was done at Soil Resources and Development Institute (SRDI), Dhaka.

3.3 Planting material

In this experiment Black cumin variety BARI kalojira1 was used. BARI kalojira1 was developed by Spices Research Centre, BARI in 2009. It's plant height is 55-60cm, number of primary branches is 5-7, number of capsule/plant is 20- 25, number of seeds/pod is 75-80, seed weight/pod is 0.20-0.27g, seed weight/plant is 5- 7g, 1000 seeds weight is 3.00 - 3.25 g.

3.4 Land preparation

The experimental land was prepared with the help of power tiller by three successive

ploughing and cross-ploughing followed by laddering. Weeds and crop residues of previous crop were removed from the field. The experimental area was laid out according to the design of the experiment. The unit plot was leveled before seed sowing.

3.5 Fertilizer management

At the time of first ploughing, cowdung was applied at the rate of 10 t ha^{-1}. The experimental area was fertilized with 125, 95 and 75 kg ha^{-1} urea, triple super phosphate (TSP) and muriate of potash (MP) ha^{-1} respectively. 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.

3.6 Seed sowing

Before seed sowing the seeds were soaked in water for 12 hours to enhance germination. The seeds were sown in rows according to the treatments by hand. To allow uniform sowing in rows seeds were mixed with loose soil. The seeds were covered with good pulverized soil just after sowing and gently pressed by hands with slight watering.. Four sowings were done in 5th Nov, 20th Nov, 5thDec and 20th Dec in 2019. After 15 days of seedling emergence, the seedlings were thinned to maintain required spacing treatments.

3.7 Experimental treatments

Treatments included in the experiment were as follows:

A) Sowing time(Different dates of sowing)

T_1 = 5th November
T_2 = 20th November
T_3 = 5th December
T_4 = 20th December

B) Spacing(Different spacing)

S_1 = 20 cm × 10 cm
S_2 = 20 cm × 20 cm
S_3 = 25 cm × 10 cm
S_4 = 25 cm × 20 cm

Treatments combinations:

There are 16 treatment combinations such as T_1S_1, T_1S_2 ,T_1S_3, T_1S_4, T_2S_1, T_2S_2, T_2S_3, T_2S_4, T_3S_1,T_3S_2,T_3S_3,T_3S_4, T_4S_1, T_4S_2, T_4S_3,T_4S_4

3.8 Experimental design

The experiment was laid out in randomized complete block design with three replications. The unit plot size was 2 m x 1 m. The spacing between block was 1 m and between plots 0.5 m.

3.9 Intercultural operations

Weeding

First weeding was done at 25 DAS and the 2nd and 3rd weeding was done at 40 DAS and 55 DAS respectively to keep the crop weed free.

Irrigation and drainage

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. Proper drainage facilities were developed to avoid stagnation of water.

3.10 Plant protection measures

The field was inspected from time to time to detect visual differences among the treatments and any kind of infestation attack by weeds, insects and diseases. So 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 showed symptoms of fungal attack. For control, Dithane M-45 was sprayed at 10 days interval @ 2 g/Litre water.

3.11 Harvesting and post harvest operation

Plants of all the plots were not harvested at the same date. Harvesting was done from 20 March to 22 April 2020 at fifteen days interval according spowing date with maturity. After uprooting the plants they were kept under the sun to dry naturally. Seeds were collected by beating with a stick. After cleaning, the seeds of different plots were also sun-dried and kept in separate plastic containers with tight covers

3.12 Data collection

The following data were recorded:

Plant height

Plant height was measured at 45 days after sowing , 90 days after sowing and finally 135 days after sowing before the time of harvesting. Plants for data collection from each plot were flowered.

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.

Days to first flowering and 50% flowering:

Days that need for first flowering and 50% flowering of the total plants are recorded in per plot according to experiment

Number of flower plant^{-1}

Number of flower per plant are recorded from different plant randomly in research plot. This is done after some days recording 50% flowering required days time.

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

Number of capsules plant-1 were recorded before harvesting plants and number of seeds per capsule were recorded after harvesting .

Length of capsule and breadth of capsule

Length of capsule and breadth of capsule are recorded after harvesting with slide calipers scale.

Seed yield plant^{-1} &Seed yield plot^{-1}

Seed yield per plant and yield per plot were recorded after harvesting.

Thousands seed weight

A composite sample was taken from the yield of ten plants. The 1000 seeds of each plot were counted and weighed with a digital balance.The 1000 seed weight was recorded in gram.

Germination%

Germination percentage is caculated through germination test in petridish method. 25 seed is placed in a petridish from each plot seed sample. After 15 days all the samples are observed and count the number of germinated seed. Than determine it in percentage.

Vigor index

vigor index are recorded after harvesting. Vigor index is determined through multiplying germination% with the sum of root and shoot length.

Vigor index = Germination percentage × (root length + shoot length)

3.13 Statistical analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the STATISTIX. 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 LSD test at 5% level of significance**.**

CHAPTER IV
RESULTS AND DISCUSSION

The results of effect of treatments of different sowing date, different spacing and their combined effect on achieving quality and higher seed yield of black cumin have been described and discussed below in details under the following headings:

4.1 Plant height (cm)

Different sowing date had significant influence on plant height of black cumin at different growth stages (Table. 1) appendix 6 . At 135 DAS, the highest plant height (45.99 cm) was obtained from T_1 (5^{th} November sowing) treatment which was statistically similar (44.7) to T_2 treatment. On the other hand the lowest plant height (41.17 cm) was recorded from the T_4 (20^{th} December sowing) treatment. Hence it may be inferred that the increase in plant height may be due to the favorable influence of climatic condition increased role of photosynthesis, reduced transpiration and stimulation of root system, increase cell division, cell enlargement and metabolic processes. Similar findings were also observed by reported by Meena *et al.,* (2012) in nigella, Giridhar *et al.,* (2017) in black cumin and Sowmya *et al.,* (2017) in fenugreek.

Different spacing had significant variation on plant height of black cumin at different growth stages **(**Table 2**).** Plant height increased with decreased plant spacing. At 135 DAS, the highest plant height (44.96 cm) was achieved from S_1 (20 cm × 10 cm) treatment which was statistically identical (44.11 cm) to S_3 treatment and similar (43.65 cm) to S_2 treatment. Again, the lowest plant height (42.02cm) was observed from S_4 (25 cm× 20 cm) treatment. The variation in plant height as influenced by spacing was perhaps due to proper utilization of nutrient, moisture and light. (Table. 2). 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. 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 & 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.

Table 1. Effect of sowing date on plant height at 45 DAS, 90 DAS and 135 DAS of black cumin.

Plant hight (cm) at different DAS			
Treatment	**45 DAS**	**90 DAS**	**135 DAS**
T_1	12.19 a	24.90 a	45.99 a
T_2	10.70 b	24.02 b	44.74 ab
T_3	10.60 bc	23.19 c	43.84 b
T_4	10.28 c	21.18 d	41.17 c
$LSD_{(0.05)}$	0.4020	0.6308	1.8004
CV%	4.40	3.24	4.91

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_1= 5th Nov sowing, T_2=20th Nov sowing, T_3=5th Dec sowing, T_4=20th Dec sowing

Table 2. Effect of spacing on plant height at 45 DAS, 90 DAS and 135 DAS of black cumin.

Plant hight (cm) at different DAS			
Treatment	**45 DAS**	**90 DAS**	**135 DAS**
S_1	10.76 b	24.94 a	44.96 a
S_2	11.02 ab	22.58 c	43.65 ab
S_3	11.25 a	24.21 b	44.11 a
S_4	10.75 b	21.56 d	42.02 b
$LSD_{(0.05)}$	0.4020	0.6308	1.8004
CV%	4.40	3.24	4.91

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 × 20 cm, S_3 = 25 cm × 10 cm and $S_{4=}$ 25 cm × 20 cm

Combined effect of different sowing date and spacing on plant height of black cumin was statistically significant at different (Table 3) days after sowing (DAS). At 135 DAS, the highest plant height (48.50 cm) was obtained from T_1S_1 (5th Nov sowing and 20 cm × 10 cm) treatment combination, which was statistically similar to T_1S_3 (5th Nov sowing and 25cm×10cm) treatment combination and the lowest plant height (38.70 cm) was observed from T_4S_4 (20th Dec and 25cm×20 cm) treatment combination which was statistically similar to T_4S_1. This might be due to the fact that environmental conditions with proper uses nutrient increase vegetative growth of plant. The result is similar with findings of Esmaeil and Behnaz (2014).

Table 3. Combined effect of sowing date and spacing on plant height at 45 DAS, 90 DAS and 135 DAS of black cumin (*Nigella sativa* L.)

Plant hight (cm) at different DAS			
Treatment	**45 DAS**	**90 DAS**	**135 DAS**
T_1S_1	12.81 a	27.13 a	48.50 a
T_1S_2	11.76 bc	24.03 cd	45.24 a-d
T_1S_3	12.13 ab	25.73 b	47.10 ab
T_1S_4	12.06 ab	22.73 efg	43.13 c-f
T_2S_1	10.76 d	26.10 ab	46.53 abc
T_2S_2	10.93 d	22.93 def	46.33 abc
T_2S_3	10.56 de	25.06 bc	43.96 b-e
T_2S_4	10.56 de	22.00 fg	42.13 d-g
T_3S_1	9.76 efg	24.93 bc	41.10 efg
T_3S_2	11.10 cd	23.00 def	45.66 a-d
T_3S_3	10.50 def	22.23 fg	44.46 b-e
T_3S_4	11.06 cd	22.60 efg	44.13 b-e
T_4S_1	9.70 fg	21.60 gh	40.31 fg
T_4S_2	10.30 def	20.36 h	41.36 efg
T_4S_3	11.83 bc	23.83 cde	44.33 b-e
T_4S_4	9.30 g	18.93 i	38.70 g
LSD(0.5)	0.8040	1.2616	3.6008
CV%	4.40	3.24	4.91

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_1= 5th Nov sowing, T_2=20th Nov sowing, T_3=5th Dec sowing, T_4=20th Dec sowing and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 20 cm, S_3 = 25 cm × 10 cm and S_4= 25 cm × 20 cm

4.2 Number of primary branches plant^{-1}

Different sowing date had significant influence on number of primary branches plant^{-1}. It was observed that the highest number of primary branches plant^{-1} (8.4) was recorded from T_1 (5th Nov sowing) treatment and lowest (6.96) was recorded from T_4 (20th Dec sowing) treatment (Table 4). The reasons may be due to early sowing the plant got optimum temperature at growing period which increases growth parameters as cell division, cell elongation, cell enlargement metabolic process,. Datta *et al*., (2008) found that increasing in number of primary and secondary caused at early sowing.

Table 4. Effect of different sowing date on number of primary, secondary branch, days to first flowering and days to 50% flowering of black cumin(*Nigella sativa* L)

Treatment	Number of primary branch	Number of secondary branch	Days to first flowering	Days to 50% flowering
T1	8.40 a	15.20 a	56.61 a	65.83 a
T2	7.86 b	13.12 b	55.69 ab	65.33 a
T3	7.28 c	12.38 bc	55.36 b	63.33 b
T4	6.96 d	11.93 c	51.83 c	61.58 c
LSD(0.05)	0.2109	0.8289	1.0081	0.5409
CV%	3.31	7.55	2.20	1.01

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_1= 5th Nov sowing, T_2=20th Nov sowing, T_3=5th Dec sowing, T_4=20th Dec sowing

significant variation was found due to different spacing on number of primary branches plant^{-1}. It was observed that the lowest number of primary branches plant^{-1} (7.17) was recorded from S1 (20 cm × 10 cm) treatment and highest (8.22) from S4 (25 cm × 20 cm) treatment (Table 5). 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.

Table 5. Effect of different spacing on number of primary, secondary branch, days to first flowering and days to 50% flowering of black cumin (*Nigella sativa* L.)

Treatment	Number of primary branch	Number of secondary branch	Days to first flowering	Days to 50% flowering
S1	7.17 d	11.75 c	53.89 b	63.41 b
S2	7.43 c	12.70 b	54.78 ab	64.33 a
S3	7.68 b	13.73 a	55.64 a	63.50 b
S4	8.22 a	14.45 a	55.19 a	64.83 a
$LSD_{(0.05)}$	0.2109	0.8289	1.0081	0.5409
CV	3.31	7.55	2.20	1.01

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 × 20 cm, S_3 = 25 cm × 10 cm and S_4= 25 cm × 20 cm

Number of primary branches plant^{-1} showed significant variation among the treatments due to the combined effect of sowing time and plant spacing. Highest primary branches plant^{-1} (9.00) was found from the T_1S_4 (5th Nov sowing with 25cm × 20cm) treatment combination which was statistically similar(8.70) with T_2S_4 (20th Nov sowing with 25cm × 20 cm) treatment combination. On the other hand, lowest value (6.33) was recorded in T_4S_1 (20th Dec sowing with 20cm × 10 cm) treatment combination (Table 6). Generally earlier sowing time and higher spacing plant get more food and space for vigorous growth and produce more primary branches compared to late sowing time and spacing. Gowda *et al*.,(2006) found similar relation.

Table 6. Combined effect of sowing date and spacing on number of primary, secondary branch, days to first flowering and days to 50% flowering of black cumin (*Nigella sativa* L.)

Treatment ,	Number of primary branch	Number of Secondary branch ,	Days to 1st flowering	Days to 50% flowering
T_1S_1	8.33 bc	13.46 c-f	56.10 bcd	65.66 abc
T_1S_2	8.06 cd	14.26 cd	56.80 bc	66.33 a
T_1S_3	8.20 cd	16.06 ab	56.32 bc	64.66 cd
T_1S_4	9.00 a	17.00 a	59.20 a	66.66 a
T_2S_1	7.16 fgh	12.16 fgh	55.23 bcd	64.66 cd
T_2S_2	7.56 ef	13.10 d-g	55.89 bcd	65.66 abc
T_2S_3	8.03 cd	11.76 ghi	55.63 bcd	65.00 bc
T_2S_4	8.70 ab	12.50 efgh	57.21 ab	66.00 ab
T_3S_1	6.86 h	11.26 hi	53.11 efg	63.33 ef
T_3S_2	7.06 gh	12.23 fgh	54.23 def	63.00 ef
T_3S_3	7.36 fg	14.06 cde	56.02 bcd	63.33 ef
T_3S_4	7.83 de	14.93 bc	54.91 cde	63.66 de
T_4S_1	6.33 i	10.13 i	51.10 g	60.00 g
T_4S_2	7.03 gh	11.20 hi	52.21 g	62.33 f
T_4S_3	7.13 gh	13.03 d-g	51.42 g	61.00 g
T_4S_4	7.36 fg	13.36 cdefg	52.60 fg	63.00 ef
LSD(0.5)	0.4217	1.6577	2.0161	1.0817
CV%	3.31	7.55	2.20	1.01

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_1 = 5th Nov sowing, T_2 = 20th Nov sowing, T_3 = 5th Dec sowing, and T_4= 20th Dec sowing and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm S_4 = 25 cm × 20 cm.

4.3 Number of secondary branches plant^{-1}

It is reported from present experiment that different sowing date significantly influenced on the seconbdary branches per plant of black cumin (Table. 4).The maximum branches was (15.20) recorded from T_1(5^{th} Nov sowing) treatment while the lowest was (11.93) in T_4 (20^{th} Dec sowing) treatment. This might be due to plant got optimum temperature for completing vegetative growth which significantly influenced on secondary branches per plant. Hafez(1998) reported that growth parameters were positively increased ewhen black cumin seeds are sowing during mid October month.

Significant variation was found due to the effect of spacing on number of secondary branches plant^{-1}. The minimum (11.75) number of secondary branches plant^{-1} was recorded from S_1 (20 cm × 10 cm) spacing and the maximum (14.45) from S_4 (25 cm × 20 cm) spacing (Table 5). This finding was also reported in related works of Tuncturk *et al.* (2005) & 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 sowing date and spacing was statistically significant in respect of number of secondary branch per plant (Table 6). Maximum secondary branches plant^{-1} (17.00) was found from the T_1S_4 (5^{th} Nov sowing with 25cm × 20cm spacing) treatment combination which was statistically similar (16.06) to T_1S_3 (5^{th} Nov and 25cm × 10 cm) treatment combination. On the other hand, minimum was obtained (10.13) from T_4S_1 (20^{th} Dec sowing and 20cm×10 cm) treatment combination (Table 6). This might be due to earlier sowing time 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 various sowing date on the days to first flowering. T_1 treatment (5^{th} November sowing) took maximum days (56.61 days) to reach 1st flowering stage which was statistically similar (55.69) to T_2 (20^{th} Nov sowing) treatment. Treatment T_4 (20^{th} December sowing) was found the earliest in

flowering (51.83days) (Table 4). From the results of the present study indicated that earlier sowing induced plant to delay flowering. Sadeghi (2009) reported that in addition to environmental conditions influenced on flowering stages of plant.

Different plant spacing had significant effect on days to first flowering (Table 5). Higher plant spacing at S_3 (25 cm × 10 cm) treatment took maximum days (55.64 days) to reach 1st flowering stage which was statistically identical (55. 19 days) to S_4(25 cm × 20 cm) treatment and similar(54.78 days) to S_2 (20 cm× 20 cm) treatment. On other hand minimum plant spacing at S_1 (20 cm ×10 cm) treatment took minimum days (53.89 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 sowing date and spacing was statistically significant in respect of days to first flowering (Table 6). The maximum days (59.20 days) took to first flowering at T_1S_4 (5^{th} November sowing with 25cm × 20cm spacing) which was statistically similar (57.21 days) to T_2S_4 (20^{th} November and 25cm × 20cm) treatment combination. T_4S_1 (20^{th} December and 20cm×10 cm) treatment combination took minimum days (51.10 days) to first flowering which was statistically identical (51.42 days) with T_4S_3 (20^{th} December sowing with 25cm×10 cm spacing) treatment.

4.5 Days to 50% flowering

There was a significant variation due to different sowing date on the days required to 50% flowering. At T_1 (5^{th} November) sowing date took maximum days (65.83 days) to reach 50% flowering stage which was statistically identical (65.33 days) to T_2(20^{th} Nov sowing) treatment. The T_4 (20^{th} December sowing) treatment was found the earliest in flowering (61.58 days) (Table 4). The minimum number of days to reach 50% flowering date observed from 20^{th} December sowing date .

Different plant spacing had significant influence on days to 50% flowering (Table 5). Higher plant spacing at S_4 (25cm × 20cm) treatment took maximum days (64.83 days) to reach 50% flowering stage which was statistically identical (64.33 days) to S_2 treatment . On other hand minimum plant spacing at S_1 (20cm × 10cm) treatment took

minimum days (63.41 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 sowing date and spacing was statistically significant in respect of days to 50% flowering (Table 6). The maximum days (66.66 days) took to 50% flowering at T_1S_4 (5^{th} November sowing with 25cm × 20cm spacing) treatment combination which was statistically identical (66.33 days) to T_1S_2 (5^{th} November sowing with (20cm × 20cm spacing) treatment combination. On the other hand T_4S_1 (20^{th} December sowing with 20 cm×10 cm) treatment combination took minimum days (60.0 days) to reach 50% flowering which was statistically identical (61.0 days) to T_4S_3 (20^{th} December and 25 cm×10 cm) treatment combination. Meena *et al*,(2011 and 2012) conducted a two year experiment on *Nigella sp* and they reported that maximum yield parameter and yield among dates of sowing was obtained with sowing on 15^{th} October with a row spacing 25 cm.

4.6 Number of flowers per plant

The number of flowers plant^{-1} was significantly affected by different sowing dates(Figure 1 and Appendix IV). Number of flowers plant^{-1} increased with earlier sowing dates. The maximum number of flowers plant^{-1} (20.15) was recorded at T1 (5^{th} November sowing) treatment. The minimum number of flowers plant^{-1}(16.06) was recorded from T_4 treatment (20^{th} December sowing). These findings are in agreement with those of Fahim *et al.* (2017).

Significant variations were clearly evident in case of number of flowers plant^{-1} with different spacing (Fig. 2 and Appendix V). The maximum number of flowers plant^{-1} (19.30) resulted from S_4 (25 cm × 20 cm spacing) treatment and the minimum (16.76) was obtained from S_1 (20 cm × 10 cm) treatment. Results of the present study indicated that increase in plant density decreased number of flowers plant^{-1}.

Combined effect of different sowing date and spacing was statistically significant in respect of number of flowers plant^{-1} (Table 9). The maximum number of flower plant^{-1} (21.66) obtained from T_1S_4 (5th November and 25 cm×20 cm) treatment combination. The lowest number of flower plant^{-1} (15.06) obtained from T_4S_1 (20th December and 20cm×10 cm) treatment combination which was statistically identical (15.2) to T_4S_3 (20th December and 25 cm×10 cm) treatment combination

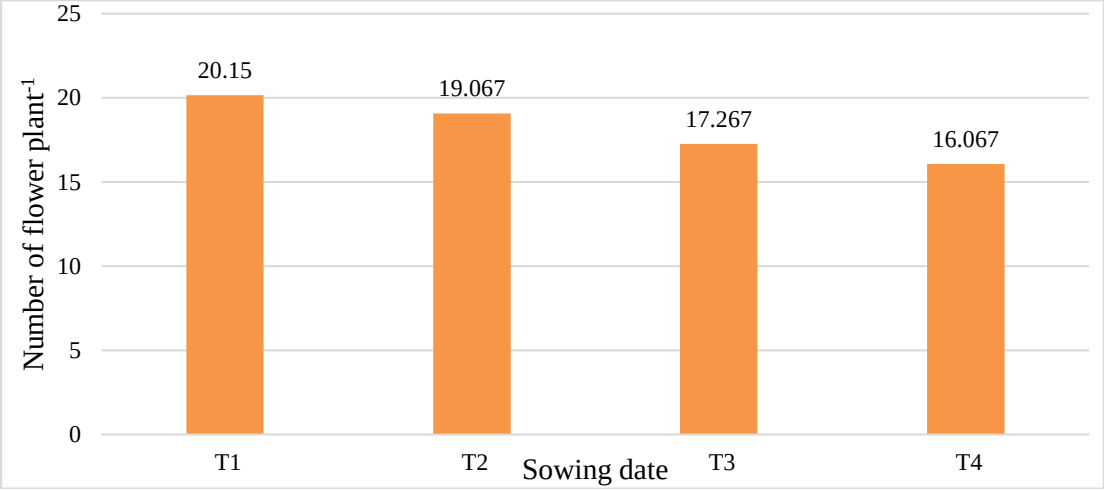

Fig 1: Effect of sowing date on number of flower plant^{-1} of black cumin (*Nigella sativa* L.)
Note: T_1= 5th Nov sowing, T_2= 20th Nov sowing, T_3= 5th Dec sowing, T_4= 20th Dec sowing

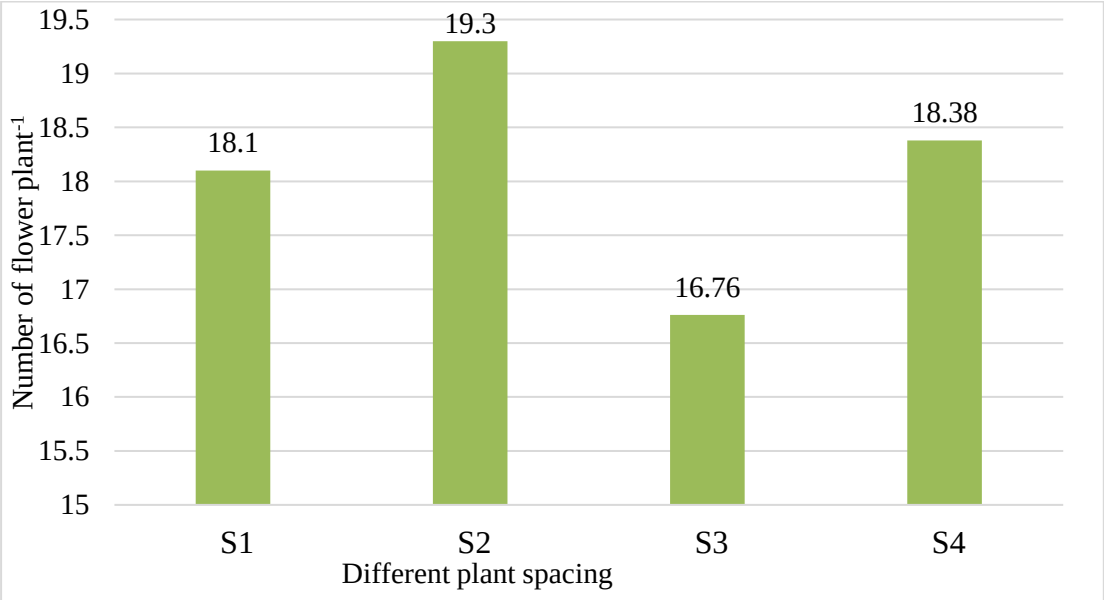

Fig 2: Effect of plant spacing on number of flower plant^{-1} of black cumin (*Nigella sativa* L.) Note: S_1= 20cm×10cm, S_2= 20cm×20cm, S_3= 25cm×10cm, S_4= 25cm×20cm

4.7 Number of capsules per plant

The number of capsules plant^{-1} was significantly affected by different sowing date (Fig. 3 and Appendix V). Number of capsules plant^{-1} decreased with the increase of sowing date. The highest number of capsules plant^{-1} (18.80) was recorded at T_1 (5th Nov) treatment. The lowest number of capsules plant^{-1} (15.06) was recorded from T_4 (20th Dec) treatment. From the results of the present study number of capsules plant^{-1} deccreased with the increase in nutrient doses. 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 plant spacing (Figure 4 and Appendix V). The maximum number of capsules plant^{-1} resulted from S_2 (20 cm × 20 cm) treatment (17.81) and the lowest (15.63) was obtained from S_3 (25 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 sowing date and spacing was statistically significant in respect of number of flowers plant^{-1} (Table 9). The maximum number of capsules plant^{-1} (20.33) obtained from T_1S_4 (5th Nov sowing and 25 cm × 20 cm) treatment combination. The minimum number of capsules plant^{-1} (14.26) was obtained from T_4S_1 (20th Dec sowing and 20cm×10 cm) treatment combination.

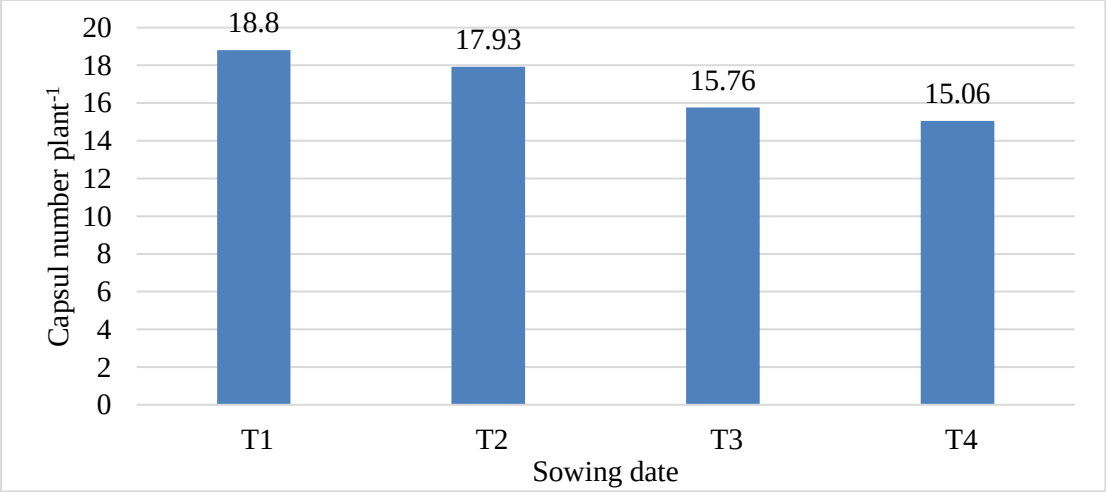

Fig 3. Effect of sowing date on number of capsule plant^{-1} of black cumin(LSD value=0.4577) Note: T_1= 5th Nov sowing, T_2= 20 th Nov, T_3= 5th Dec, T_4= 20th Dec sowing

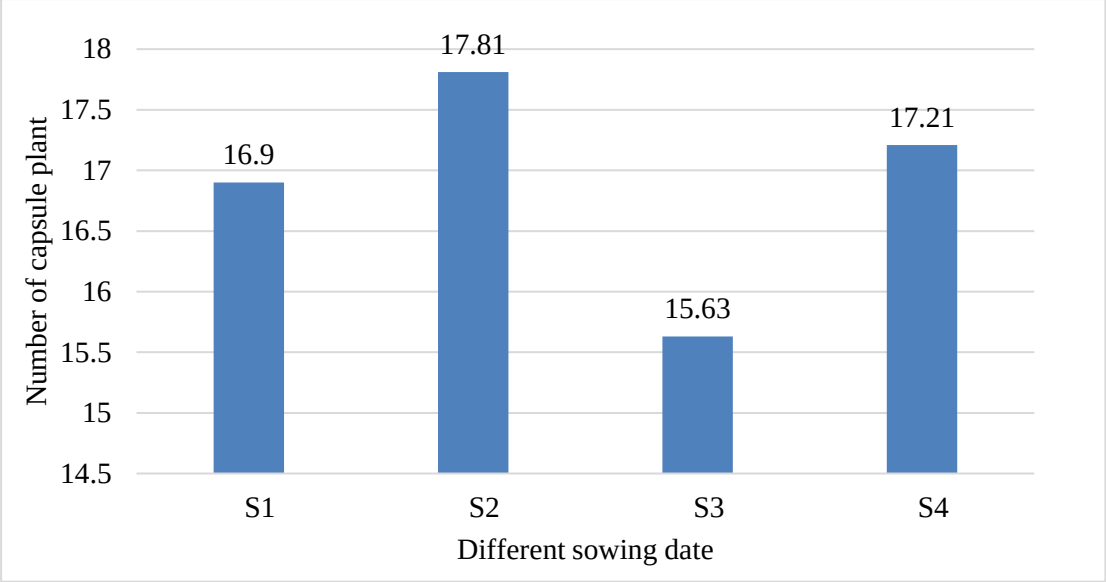

Fig 4. Effect of spacing on number of capsule plant^{-1} of black cumin(LSD value=0.4577) Note: S_1= 20cm×10cm, S_2= 20cm×20cm, S_3= 25cm×10cm, S_4= 25cm×20cm

4.8 Length of capsule

There was no significant variation due to effect of sowing date in the length of capsule. From the results of the present study (Table.7) indicated that the sowing date has no impact on length of capsule.

There was a significant variation due to effect of spacing in the length of capsule. The longest capsule length (1.5 cm) was obtained from S_4 (25 cm × 20 cm) treatment and the smallest capsule length (1.45 cm) from S1 (20 cm × 10 cm) treatment which was statistically similar (1.47 cm) to S_3 (25 cm × 10 cm) treatment (Table 8). It might be due to the fact that in treatment S_4 (25cm × 20 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 sowing date and spacing proved significant differences on length of capsule (Table 9). The longest capsule length (1.56 cm) was obtained from T_1S_4 (5^{th} Nov and 25 cm × 20 cm) treatment combination and the smallest capsule length(1.42 cm) from T_4S_1 (20^{th} Dec sowing and 20cm×10 cm) treatment combination (1.42 cm) which was statistically identical (1.46 cm) to T_2S_1 (20^{th} Nov sowing and 20cm×10 cm) and T_1S_1, T_1S_2 treatment combination respectively.

4.9 Breath of capsule

There was no significant variation due to effect of sowing date in the breath of capsule (Table.7).

Table .7 Effect of sowing date on length, breadth of capsule and number of seeds per capsule of black cumin (*Nigella sativa* L.)

Treatment	Length of capsule(cm)	Breadth of capsule(cm)	Number of seeds capsule^{-1}
T_1	1.49	0.94	84.41 a
T_2	1.47	0.95	83.18a
T_3	1.47	0.94	80.83 b
T_4	1.47	0.93	80.50 b
$LSD_{(0.05)}$	-	-	1.7275
CV%	1.79	3.66	2.52

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_1= 5th Nov sowing, T_2=20th Nov sowing, T_3=5th Dec sowing, T_4=20th Dec sowing

There was a significant variation due to effect of spacing in the breath of capsule. The maximum capsule breath (0.95 cm) was obtained from S_4 (25 cm × 20 cm) and S_2 (20 cm × 20 cm) treatments and the minimum capsule breath (0.92 cm) from S_1 treatment (20 cm × 10 cm) (Table 8). 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 sowing date and spacing proved significant differences on breath of capsule (Table 9). The maximum capsule breath (0.98 cm) was obtained from T_1S_4 (5th Nov sowing and 25 cm × 20 cm) treatment combination which was statistically similar (0.95cm) to T_2S_2 (20th Nov and 20 cm × 20 cm) treatment combination and the smallest capsule breath (0.89 cm) from T_4S_1 treatment.

Table 8. Effect of spacing on length, breadth of capsule and number of seeds per capsule of black cumin (*Nigella sativa* **L.)**

Treatment	Length of capsule(cm)	Breadth of capsule(cm)	Number of seeds capsule^{-1}
S_1	1.45 c	0.92 b	79.96 c
S_2	1.48 ab	0.95 a	82.86 b
S_3	1.47 bc	0.94 ab	81.35 bc
S_4	1.50 a	0.95 a	84.75 a
$LSD_{(0.05)}$	0.0220	0.0289	1.7275
CV%	1.79	3.66	2.52

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 × 20 cm, S_3 = 25 cm × 10 cm and S_4= 25 cm × 20 cm

Table 9. Combined effect of sowing date and spacing on number of flower, capsule number plant^{-1}, length and breadth of capsule and number of seed capsule^{-1} of black cumin (*Nigella sativa* L.)

Treatment ,	Number of flower plant^{-1}	Number of capsule plant^{-1}	Length of capsule(cm)	Breadth of capsule(cm)	Number of seeds capsule^{-1}
T_1S_1	19.00 de	17.86 cd	1.46 cd	0.92 abc	82.26 bc
T_1S_2	20.93 b	19.40 b	1.46 cd	0.95 ab	88.86 a
T_1S_3	19.00 de	17.60 d	1.47 c	0.92 bc	82.86 bc
T_1S_4	21.66 a	20.33 a	1.56 a	0.98 a	89.80 a
T_2S_1	19.06 d	17.86 cd	1.46 cd	0.94 abc	81.20 cd
T_2S_2	20.40 b	19.33 b	1.52 b	0.96 ab	82.86 bc
T_2S_3	17.13 gh	15.86 ef	1.45 cd	0.94 abc	81.60 cd
T_2S_4	19.66 c	18.66 bc	1.47 c	0.95 ab	85.33 b
T_3S_1	17.73 f	16.40 e	1.48 bc	0.94 abc	81.53 cd
T_3S_2	18.46 e	16.26 ef	1.46 cd	0.94 abc	80.46 cd
T_3S_3	15.86 i	14.80 gh	1.47 c	0.95 ab	79.66 cd
T_3S_4	17.00 gh	15.60 efg	1.48 bc	0.94 abc	82.06 cd
T_4S_1	16.60 h	14.26 h	1.42 d	0.89 c	78.73 d
T_4S_2	17.40 fg	15.46 fg	1.49 bc	0.95 ab	79.46 cd
T_4S_3	15.06 j	14.26 h	1.48 bc	0.95 ab	78.73 d
T_4S_4	15.20 j	16.26 ef	1.49 bc	0.96 ab	80.26 cd
LSD(0.5)	0.5360	0.9154	0.0441	0.0577	3.4551
CV%	1.77	3.25	1.79	3.66	2.52

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_1 = 5th Nov sowing, T_2 = 20th Nov sowing, T_3 = 5th Dec sowing, and T_4= 20th Dec sowing and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 15 cm, S_3 = 25 cm × 10 cm S_4 = 25 cm × 20 cm

4.10 Number of Seeds per capsule

Different sowing date had significant effect on number of seeds capsule^{-1} of black cumin (Table 7). Number of seeds capsule^{-1} increased with earlier sowing than late sowing. Maximum number of seeds capsule^{-1} (84.41) was recorded from T_1 (5th Nov sowing) which was statistically identical (83.18) to T_2 treatment and the T_4 (20th Dec sowing) treatment gave the lowest one (80.50).

There had significant variation due to the effect of spacing on number of seeds capsule^{-1}. The maximum number of seeds capsule^{-1} (84.75) was recorded in S_4(25 cm × 20 cm) treatment, while the lowest number of seeds capsule^{-1} (79.96) was recorded in S_1 (20 cm × 10 cm) (Table 8). 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 sowing date and spacing was statistically significant in respect of seed capsule^{-1}. The highest seed capsule^{-1} (89.80) obtained from T_1S_4 (5th Nov sowing and 25cm × 20cm) treatment combination. The lowest seed capsule^{-1} (78.73) obtained from T_4S_3 (20th Dec and 25cm × 10cm) treatment combination (Table 9).

4.11 1000 seed weight

Different sowing date had influence on 1000 seed weight of black cumin (Table 10). Earlier sowing date T_1 (5th Nov sowing) treatment significantly increased the 1000 seed which produced maximum seed weight (2.94 g) at harvest where T_4 (20th Dec sowing) treatment gave the lowest 1000 seed weight (2.77 g).

1000 seed weight of black cumin was significantly influenced by different level of spacing (Table 11). It was observed that higher spacing gave maximum yield. The maximum 1000 seed weight (2.92 g) was recorded from S_4 (25 cm × 20 cm) treatment where the lowest 1000 seed weight (2.76 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).

Table 10. Effect of sowing date on thousands seed weight, seed yield plot^{-1}, vigor index and germination percentage of black cumin

Treatment	Thousand seed weight(g)	Seed yield plot^{-1}(g)	Vigor Index	Germination%
T_1	2.94 a	249.92 a	1059.5 a	84.0 a
T_2	2.86 b	237.92 b	982.5 b	78.66 b
T_3	2.81 c	224.08 c	899.1 c	77.00 b
T_4	2.77 d	215.33 d	717.7 d	72.33 c
$LSD_{(0.05)}$	0.0170	1.0741	41.811	1.7445
CV%	0.71	0.56	5.48	2.68

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_1= 5th Nov sowing, T_2=20th Nov sowing, T_3=5th Dec sowing, T_4=20th Dec sowing

Table 11. Effect of spacing on thousands seed weight, seed yield plot-1, vigor index and germination percentage of black cumin

Treatment	Thousand seed weight(g)	Seed yield plot^{-1}(g)	Vigor Index	Germination%
S_1	2.76 d	316.83 a	879.0 b	74.00 d
S_2	2.89 b	173.08 d	786.3 c	77.00 c
S_3	2.82 c	261.50 b	920.2 b	79.00 b
S_4	2.92 a	175.83 c	1073.2 a	82.00 a
$LSD_{(0.05)}$	0.0170	1.0741	41.811	1.7445
CV%	0.71	0.56	5.48	2.68

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 × 20 cm, S_3 = 25 cm × 10 cm and $S_{4=}$ 25 cm × 20 cm

Combined effect of different sowing date and spacing showed significant differences on 1000 seed weight of black cumin (Table 12). Results revealed that the highest 1000 seed weight (3.06 g) was obtained from T_1S_4 (5^{th} Nov with 25 cm× 20 cm) treatment combination and followed by (3.02 g) T_1S_2 (5^{th} Nov and 20 cm×20 cm) treatment combination. The minimum 1000 seed weight (2.74 g) was recorded from T_4S_1 (20^{th} Dec sowing and 20 cm×10 cm) treatment combination which was statistically similar to T3S1 (5^{th} Dec 20 cm×10 cm). Rest of the treatment combination performed intermediate results in terms of 1000 seed weight compared to all other treatments.

4.12 Yield per plant

Yield per plant was significantly influenced due to different sowing date (Figure 5 and Appendix V). Yield was increased with increasing plant earlier sowing date. Results showed that the maximum yield per plant (4.02 g) was recorded from T_1 (5^{th} Nov sowing) treatment and the minimum yield per plant (3.50 g) was recorded from T_4 (20^{th} Dec sowing) treatment.

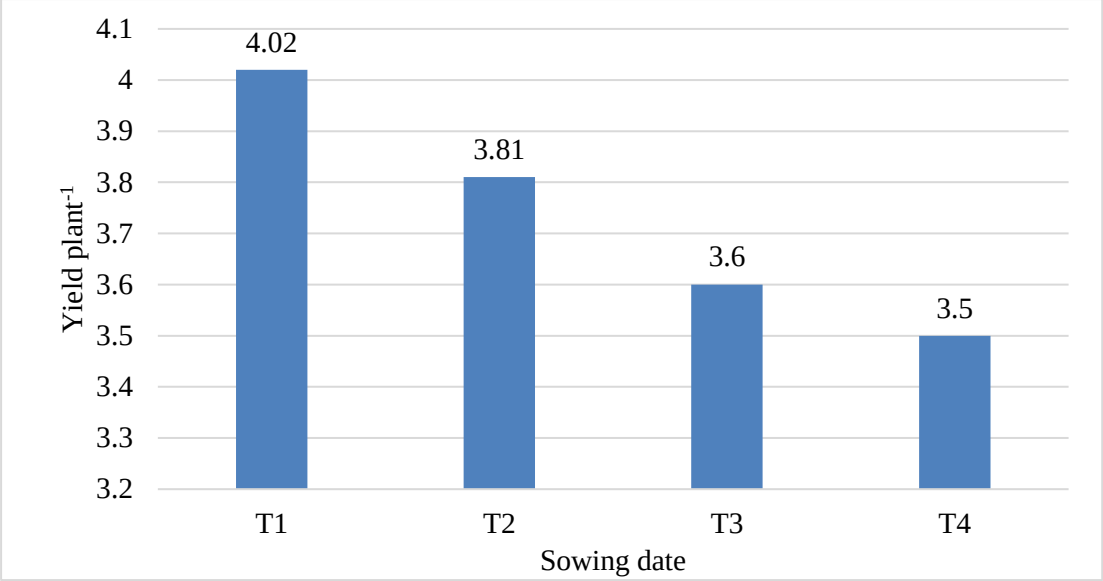

Fig 5: Effect of sowing date on yield plant^{-1} of black cumin(*Nigella sativa* L.) (LSD value = 0.0677) Note: T_1= 5th Nov sowing, T_2= 20th Nov sowing, T_3= 5th Dec sowing, T_4= 20th Dec sowing

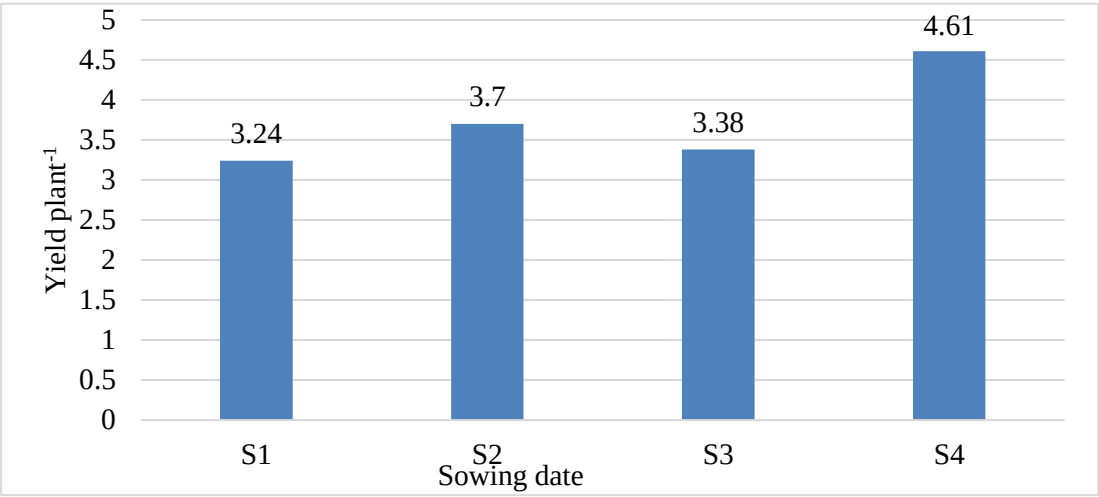

Fig 6. Effect of plant spacing on yield plant^{-1} of black cumin (*Nigella sativa* L.) (LSD value = 0.0677) Note:S_1= 20cm×10cm, S_2= 20cm×20cm, S_3= 25cm×10cm, S_4= 25cm×20cm

Yield plant^{-1} was significantly influenced by different level of spacing (Figure 6 and Appendix V). It was observed that higher spacing gave maximum yield. The maximum yield plant^{-1} (4.61 g) was recorded from S_4 (25 cm × 20 cm) treatment where the lowest yield plant^{-1} (3.24 g) was recorded from S_1 (20 cm × 10 cm) treatment. It might be due to the fact that in treatment S_4 (25 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 sowing date and spacing proved significant differences on yield plant^{-1} of black cumin (Table 12). Results revealed that the highest yield plant^{-1} (4.96 g) was obtained from T_1S_4 (5th Nov and 20 cm × 10 cm) treatment combination. The lowest yield plant^{-1} (3.03 g) was recorded from T_4S_1 (20th Dec and 20 cm × 10 cm) treatment combination.

4.13 Yield per plot

Yield per plot of black cumin was significantly affected by different sowing date(Table 10). Results specified that the highest yield per plot of black cumin (249.92 g) was recorded from T_1 (5th Nov) treatment where the lowest yield per plot of black cumin (215.33 g) was recorded from T_4 (20th Dec) treatment. Mjumder *et al*,(2012) reported that sowing dates have significant effect on number of pod per plant, number of seeds per pod and seed yield.

Different levels of spacing had significant effect on yield per plot of black cumin (Table 11). It was found that the highest yield per plot of black cumin (316.83 g) was recorded from S_1 (20 cm × 10 cm) treatment where the lowest yield per plot of black cumin (173.08 g) was recorded from S_4 (25 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 population from closer spacing. Kizil & 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.

Table 12. Combined effect of sowing date and spacing on thousands seed weight, seed yield plant^{-1}, seed yield plot^{-1}, germination percentage and vigor index and of black cumin

Treatment	Thousand seed weight (g)	Seed yield plant^{-1}(g)	Seed yield plot^{-1}(g)	Germination %	Vigor Index %
T_1S_1	2.81 f	3.49 ef	340.00 a	80.00 cd	1005.3 de
T_1S_2	3.02 b	3.89 d	184.33 j	84.00 b	859.1 fg
T_1S_3	2.90 d	3.75 d	284.67 e	84.00 b	1100.4 bc
T_1S_4	3.06 a	4.96 a	190.67 i	88.00 a	1273.1 a
T_2S_1	2.75 ghi	3.35 g	320.67 b	76.00 ef	937.3 ef
T_2S_2	2.94 c	3.85 d	177.33 l	76.00 ef	848.7 g
T_2S_3	2.79 f	3.40 fg	272.67 f	80.00 cd	1002.7 de
T_2S_4	2.97 c	4.63 b	181.00 k	82.66 bc	1141.3 b
T_3S_1	2.74 hi	3.11 hi	307.00 c	73.33 fg	892.7 fg
T_3S_2	2.84 e	3.61 e	170.00 m	77.33 de	817.9 gh
T_3S_3	2.80 f	3.21 h	248.67 g	77.33 de	840.4 g
T_3S_4	2.85 e	4.49 c	170.67 m	80.00 cd	1045.3 cd
T_4S_1	2.74 i	3.03 i	299.67 d	66.66 h	680.7 ij
T_4S_2	2.78 fg	3.47 efg	161.67 n	70.66 g	619.6 j
T_4S_3	2.78 fgh	3.16 h	240.00 h	74.66 ef	737.5 hi
T_4S_4	2.80 f	4.36 c	160.00 n	77.33 de	832.9 g
LSD(0.5)	0.0340	0.1353	2.1483	3.4890	83.622
CV%	0.71	2.17	0.56	2.68	5.48

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_1 = 5th Nov sowing, T_2 = 20th Nov sowing, T_3 = 5th Dec sowing, and T_4= 20th Dec sowing and S_1 = 20 cm ×10 cm, S_2 = 20 cm × 20 cm, S_3 = 25 cm × 10 cm S_4 = 25 cm × 20 cm

Yield per plot of black cumin was significantly affected by combined effect of different sowing date and spacing (Table 12). It was observed that the highest yield per plot (340.00 g) was obtained from T_1S_1 (5th Nov and 20 cm × 10 cm) treatment combination. Results also revealed that the lowest yield per plot of black cumin (160.67 g) was recorded from T_4S_2 (20th Dec and 20 cm × 20 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 Percent (%) seed germination

Different sowing date had significant effect on percent (%) seed germination of black cumin (Table 10). The highest percent (%) seed germination (84.00%) was observed

in T_1 (5^{th} Nov) treatment produced seeds whereas the minimum percent (%) seed germination (72.33%) was recorded from the seeds of treatment T_4 (20^{th} Dec).

Seeds of black cumin obtained from different spacing treatment showed influence on percent (%) seed germination (Table 11). Results indicated that the highest percent (%) seed germination (82%) was recorded from the seeds of was found in S_4 (25 cm × 20 cm) treatment whereas the lowest percent (%) seed germination (74%) was recorded from the seeds of was found in S_1 (20 cm × 10 cm) treatment.

Variation was recorded on percent (%) seed germination affected by combined effect of sowing date and plant spacing (Table 12). The highest percent (%) seed germination (88%) was recorded from seeds which were produced from the treatment combination of T_1S_4 (5^{th} Nov and 25 cm × 20 cm) treatment combination the lowest percent (%) seed germination (66%) was found from the seeds achieved from the treatment combination T_4S_1 (20^{th} Dec and 20 cm × 10 cm) treatment combination.

4.15 Vigor index%

Different sowing date had significant influence on vigor index of seedling (Table10). Maximum vigor index(1059.5) was reported from T_1(5^{th} Nov sowing) treatment and minimum (717.7) was recorded from T_4 (20^{th} Dec sowing) treatment.

Plant spacing had significant effect on vigor index (Table 11). In this experiment maximum vigor index(1073.2) was recorded from S_4 (25cm×20cm spacing) treatment and minimum vigor index was found in S_1 (20cm ×10cm spacing) treatment.

Variation was recorded on vigor index of seedling is affected by combined effect of sowing date and plant spacing (Table 12). The highest seedling vigor index (1273.1) was recorded from seeds which were produced from the treatment combination of T_1S_4 (5^{th} Nov and 25 cm × 20 cm) treatment combination and the lowest vigor index (619.6) was found from the seeds achieved from the treatment combination T_4S_2 (20^{th} Dec sowing and 20 cm × 20 cm) treatment combination.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomic research field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of different sowing date and spacing on seed 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 sowing date viz. T_1(5^{th} November), T_2(20^{th} November), T_3(5^{th} December) and T_4(20^{th} December) and four spacing viz. 20 cm × 10 cm, 20 cm × 20 cm, 25× 10 cm and 25 cm × 20 cm. The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 16 treatment combinations in all.

Data on different growth and yield parameters such as 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, percent (%) seed germination, vigor index were recorded and analyzed statistically.

The result of the experiment revealed that all the parameters studied were significantly influenced by differentsowing date. There had significant effect on plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}. At 45 DAS, highest plant height (12.19 cm sowing) were achieved from T_1 (5^{th} Nov sowing) treatment and the lowest plant height (10.28 cm) were observed from control T_4 (20^{th} December sowing) treatment. In 135 DAS highest plant height (45.99 cm) was achieved from T_1 (5^{th} Nov sowing) treatment respectively and the lowest plant height (41.77 cm) was observed from T_4 (20^{th} December sowing) treatment respectively. The maximum number of primary branches (9) and number of secondary branches (17) were achieved from T_1S_4 treatment. The maximum days to first flowering (56.61 DAS) and 50% flowering (65.83 DAS) recorded from T_1 (5^{th} Nov sowing) treatment and the lowest days to first flowering (51.83 DAS) and 50% flowering (61.58 DAS) recorded from control T_4 (20^{th} Dec sowing) treatment. The

highest number of flower (20.15), number of capsule (18.80), were recorded from T_1 (5^{th} Nov) treatment and lowest number of flower (16.06), number of capsule (15.06), were recorded from control T_4 (20^{th} Dec sowing) treatment. The maximum number of seed per capsule of black cumin (84.41), thousand seed weight (2.94 g), yield per plant (4.02 g) were achieved from T_1 (5^{th} Nov) treatment and the minimum number of seed per capsule of black cumin thousand seed weight, yield per plant were achieved from control T_4 (20^{th} December) treatment. The highest yield per plot (249.92 g), and Vigor index(1059.5), germination% (84) were recorded from T_1 (5^{th} Nov sowing) treatment and lowest yield per plot, and vigor index were recorded from T_4 (20^{th} Dec sowing) treatment. There was no significant effect on the length and bredth of capsule.

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 (11.02 cm), (24.94 cm) and (44.96 cm) were achieved from S_2 (20 cm × 10 cm) and S_1 treatment respectively and the lowest plant height were observed from S_4 (25 cm × 20 cm) treatment respectively. The maximum number of primary branches and number of secondary branches were achieved from S_4 (20 cm × 20 cm) treatment and the minimum number of primary branches and number of secondary branches were achieved from S_1 (20 cm × 10 cm) treatment. The highest days to first flowering and 50% flowering recorded from S_4 (25 cm × 20 cm) treatment and the lowest days to first flowering and 50% flowering recorded from S_1 (20 cm × 10 cm) treatment. The maximum number of flower and number of capsule were recorded from S_4 (25 × 20 cm) treatment and lowest number of flower and number of capsule were recorded from S_1 (20 cm × 10 cm) treatment. The maximum number of seed per capsule of black cumin (84.75) was obtained from S_4 (25 cm × 20 cm) treatment and the minimum number of seed per capsule were obtained from both S_1 (20 cm × 10 cm) treatment. The highest thousand seed weight (2.94 g) and yield per plant (4.61 g) were recorded from S_4 (25 cm × 20 cm) treatment and the lowest thousand seed weight and yield per plant were recorded from S_1 (20 cm × 10 cm) treatment. The highest yield per plot (316.13 g) and yield were recorded from S_1 (20 cm × 10 cm) treatment and lowest yield per plot, were recorded from S_4 (25 cm× 20 cm) treatment. The highest germination percentage (84.5%) of black cumin was found from S_4 (25

cm × 20 cm) treatment and the lowest germination % was found from S_1 (20 cm × 10 cm) treatment. There was no significant effect of spacing on the length and breadth of capsule.

Combined effect of sowing date 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 12.81 cm, 27.13 cm and 48.50 cm were achieved from T_1S_1 (5th Nov sowing and 20 cm × 10 cm) treatment combination respectively and the lowest plant height were observed from T_4S_3 (20th Dec and 25 cm × 10 cm) treatment combination respectively. The maximum number of primary branches and number of secondary branches were achieved from T_1S_4 (5th Nov sowing and 25 cm × 20 cm) treatment combination and the minimum number of primary branches and number of secondary branches were achieved from T_4S_1 (20th Dec sowing and 20 cm × 10 cm) treatment combination. The highest days to first flowering and 50% flowering recorded from T_1S_4 (5th Nov sowing and 25 cm × 20 cm) treatment combination and the lowest days to first flowering and 50% flowering recorded from T_4S_1 (20th Dec sowing and 20 cm × 10 cm) treatment combination. The highest number of flower and number of capsule were recorded from T_1S_4 (20th Nov and 25 cm × 20 cm) treatment combination and lowest number of flower and number of capsule were recorded from T_4S_1 (20th Dec and 20 cm × 10 cm) and T_4S_4 treatment combination. The maximum number of seed per capsule of black cumin was obtained from T_1S_4 (5th Nov and 25 cm × 20 cm) treatment combination and the minimum number of seed per capsule were obtained from T_4S_3 (5th Nov and 25 cm × 10 cm) treatment combination. The highest thousand seed weight and yield per plant (3.34 g) were recorded from T_1S_4 (5th Nov and 25 cm × 20 cm) treatment combination and the lowest thousand seed weight and yield per plant were recorded from T_4S_1 (5th Nov and 20 cm × 10 cm) treatment combination. The highest yield per plot (340 g) and were recorded from T_1S_1 (5th Nov sowing with 20 cm × 10 cm spacing) treatment combination and lowest yield per plot (160 g) were recorded from T_4S_3 (20th Dec sowing with 25 cm × 10 cm spacing) treatment combination. The maximum vigor index (1273.1) of black cumin was recorded from T_1S_4 (5th Nov sowing and 25 cm × 20 cm) treatment combination and the lowest vigor index (619.6) was found from T_4S_2 (20th Dec sowing and 20 cm × 20 cm) treatment combination. There was no

significant difference in length and breadth of capsule with sowing date and spacing .

Conclusion:

Considering the above result of this experiment; the following conclusion and recommendations can be drawn:

- In the experiment T_1 (5^{th} November sowing) treatment was more effective than other sowing date
- The spacing S_4 (25 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_1S_4 (5^{th} November sowing with 25 cm × 20 cm spacing) having yield potentiality.

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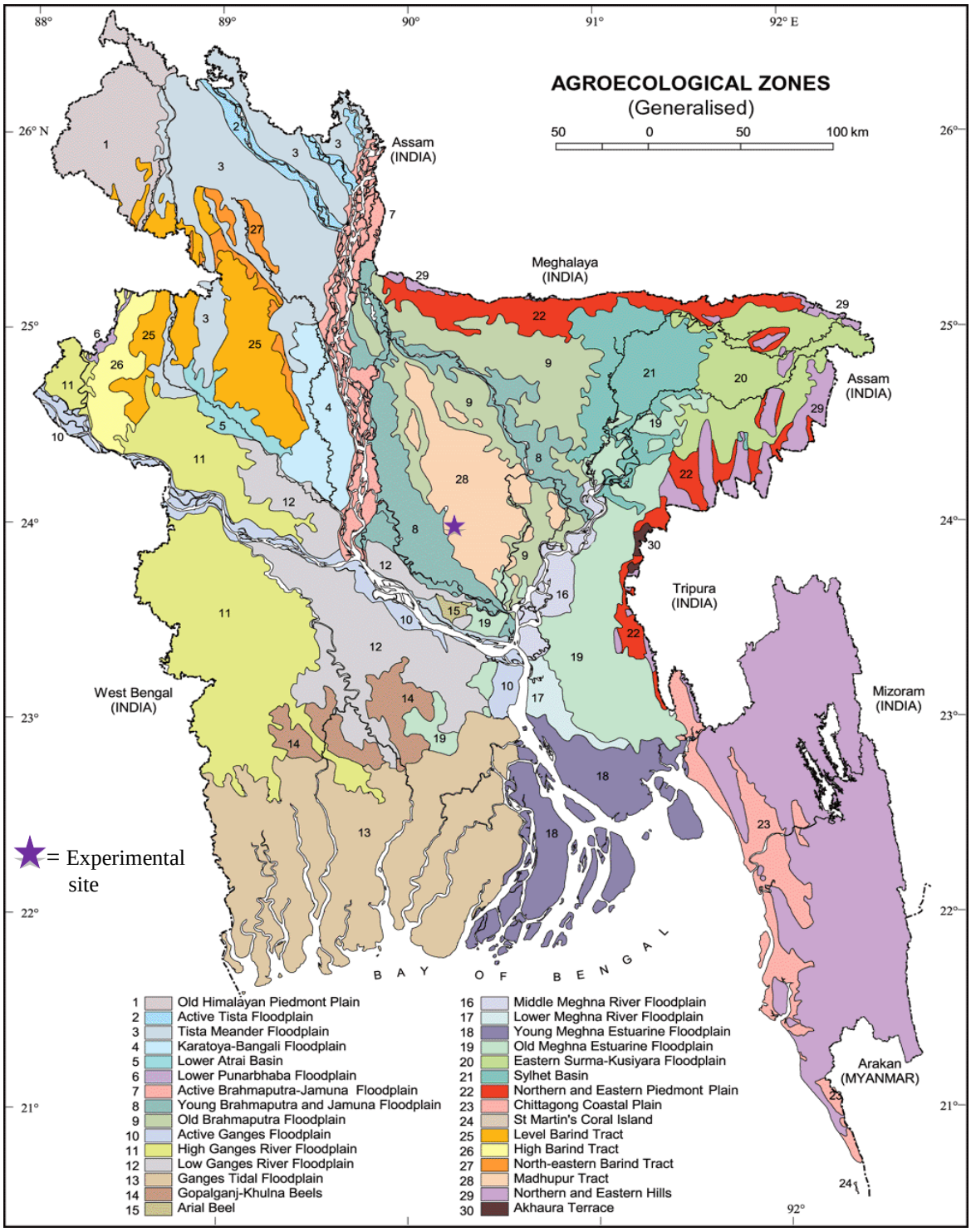
APPENDICES

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: Analysis of variance on effect of sowing date and spacing on plant height of Black cumin at different days after sowing

Source of variation	Deg. of freedom	Mean square				
		Plant hight			No. of pri.brnch	No. of sec.brnch
		45 DAS	90 DAS	135 DAS		
Replication	2	0.0663	0.11	3.58	0.003	2.255
Factor A(sowing time)	3	8.6784*	30.40*	50.00*	4.836*	25.08*
Factor B(spacing)	3	0.7046*	28.20*	21.04*	2.410**	16.67*
AB	9	1.6191*	3.62*	12.17*	0.176*	2.530**
Error	30	0.2325	0.57	4.663	0.063	0.988

** indicates significant at 5% level of significance*

Appendix V: Analysis of variance of data of effect of sowing date and spacing on different parameter of Black cumin.

Source of variation	DF	Mean square			
		Dys 1st flwring	Dys 50% flwring	No. capsl plant^{-1}	No. seed capsul^{-1}
Replication	2	1.60	0.02	0.06	3.41
Factor A(sowing time)	3	52.72*	45.68*	37.29*	42.53*
Factor B(spacing)	3	6.67*	5.57*	10.17	50.61*
AB	9	5.70*	1.16*	2.03*	22.08*
Error	30	1.46	0.42	0.30	4.29

** indicates significant at 5% level of significance*

Appendix VI: Analysis of variance of data of effect of sowing date and spacing on different parameter of Black cumin

Source of variation	DF	Mean square				
		1000 seed wt	Yld plant^{-1}	Yld plot^{-1}	Germition%	Vigor index
Replication	2	0.0004	0.00	6.4	9.00	4388
Factor A(sowing time)	3	0.0649*	0.63*	2785.3*	278.22*	258483*
Factor B(spacing)	3	0.0642	4.52*	58770.7*	136.00*	171613*
AB	9	0.0064*	0.01	82.5*	5.33*	6833*
Error	30	0.0004	0.00	1.7	4.378	2515

**indicates significant at 5% level of significance*