EFFECT OF VARIETY AND PLANT SPACING ON SEED YIELD AND YIELD ATTRIBUTES OF BLACK CUMIN (*Nigella sativa* L.)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF VARIETY AND PLANT SPACING ON SEED YIELD AND YIELD ATTRIBUTES OF BLACK CUMIN (*Nigella sativa* L.)"** *submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in AGRICULTURAL BOTANY,*** *embodies the results of a piece of bona fide research work carried out by* **SHARMEEN AKHTER KOLI**, *Registration No.* **05-01779** *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.

....

Dated: **(Prof. Asim Kumar Bhadra)**

Place: Dhaka, Bangladesh ***Supervisor***

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during Rabi season (November–February), 2012 to study the yield performance of Black cumin (*Nigella sativa* L.) in response to variety and population density. Two varieties and six levels of spacing were used in the experiment. The two varieties were V_1= Local (collected from Vikrampur), V_2= BARI Kalozira-1 and used spacings were as follows: S_1= 15 cm x10 cm, S_2= 20 cm x10 cm, S_3= 25 cm x10 cm, S_4= 15 cm x15 cm, S_5= 20 cm x15 cm and S_6= 25 cm x15 cm. The experiment was laid out in a randomized complete block (RCBD) design having twelve treatments with 3 replications. The variety BARI Kalozira-1 showed higher values for all the growth and yield attributes than local variety. BARI Kalozira-1 produced a seed yield of 1373.09 kg/ha where Local variety produced 1239.57 kg/ha. All of the growth and yield parameters except 1000-seed weight were significantly influenced by various spacing used in this experiment. The wider spacing of 25 cm × 15 cm provided maximum plant height at last harvest. The yield attributing factors like number of capsules plant^{-1}, number of seeds capsule^{-1}, single capsule weight (mg), weight of seeds capsule^{-1} (mg), weight of seeds plant^{-1} (g), 1000-seed weight (g) and seed yield (kg/ha) were found the highest either in 20 cm × 15 cm or 25 cm × 15 cm spacing. The interaction effect of variety and spacing was found significant for all of the growth and yield contributing factors as well as for seed yield. Number of plants m^{-2} was significantly higher in lower spacings for both of the varieties. Yield attributing factors like number of seeds capsule^{-1}, number of capsules plant^{-1}, single capsule weight (mg), weight of seeds capsule^{-1} (mg), weight of seeds plant^{-1} (g), 1000-seed weight (g) and seed yield (kg/ha) were found the highest either in 20 cm × 15 cm or 25 cm × 15 cm spacing treatment in case of BARI Kalozira-1. Highest seed yield was recorded (1458.19 kg/ha) in BARI Kalozira-1 with the spacing of 20 cm × 15 cm.

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ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
Anon.	Anonymous
@	At the rate of
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
cm^2	Centimeter square
cv.	Cultivar(s)
CV	Coefficient of Variance
DMRT	Duncan's Multiple Range Test
DAT	Days after transplanting
e.g.	example
et al.	and others
g	Gram
G	Granular
i.e	that is
IRRI	International Rice Research Institute
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2O	Potassium Oxide
LSD	Least Significant Difference
TSP	Triple Super Phosphate
m	Meter
mg	Miligram
MoP	Muriate of Potash
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
P_2O_5	Phosphorus Penta Oxide
^0C	Degree Celsius
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter

CHAPTER 1

INTRODUCTION

Black cumin (*Nigella sativa* L.) is an annual spicy herb and belongs to the *Ranunculaceae* family. Sometimes it is referred to as nigella or black seeds. It is native to the Mediterranean and Western Asia regions. It is cultivated in many parts of the world including the Middle East, North Africa and Asia where maximum diversity is found. (Abu-Jadayil, 2002; Donmez and Mutlu, 2004; Tierra, 2005). As herb**,** black cumin has a rich nutritional value; it contains monosaccharides. The seed is rich in fatty acids, proteins and carbohydrates. It contains all essential amino acids and rich source of vitamins and minerals (Abu-Jadayil *et al*., 1999; Atta, 2003). Seeds are used both as a condiment in bread and cakes and in the preparation of traditional sweet dishes, pastry, pickles, and used as candies and liquors (Luetijohann 1998; Thippeswamy and Naidu, 2005). In addition, black cumin oil has many medicinal usages (Ali and Blunden 2003). Very limited information is available in the literature about cumin cultivation and production practices.

Plant based functional foods are gaining popularity across the world due to an array of evidences for their safer therapeutic applications. The health claims associated with the consumption of plants are due to their rich phytochemistry (Tapsell *et al*., 2006). Phytochemicals like Ώ-3-fatty acids, dietary fibers, antioxidant, vitamins, plant sterols and flavonoids are helpful in maintaining the health of an individual thus reducing the risk of various maladies (Manach *et al*., 2005; Ramaa *et al*., 2006).

Black cumin (*Nigella sativa* L.) locally known as “Kalo jira” is a good source of nutritionally essential components. Black cumin seeds have been used as herbal medicine by various cultures and civilizations to treat and prevent a number of diseases. Recent research also witnessed the presence of *Nigella sativa* seeds some 3000 years ago at Uli

Burun, off the southwest coast of Turkey (Black *et al.*, 2006). It is also famous for the saying of the Prophet Muhammad (SAW) "Hold on to use of the black cumin seed, for it has a remedy for every illness except death" (Bukhari, 1985). The historical tradition of black cumin seed in medicine is also substantial; identified as curative black cumin in the Bible, and mentioned as Melanthion by Hippocrates and Dioscorides and Pliny called it as the Gith (Atta-ur-Rahman *et al*., 1985a).

Like most herbs, the composition of black cumin varies with geographic distribution, time of harvest and agronomic practices. Scientific investigations have depicted its composition i.e. moisture, oil, proteins, ash and total carbohydrates contents in the range of 3.8-7.0%, 22.0-40.35%, 20.85-31.2%, 3.7- 4.7% and 24.9-40.0%, respectively (Takruri and Dameh, 1998; Atta, 2003). Its health enhancing potential has been attributed to the active ingredients that are mainly concentrated in fixed or essential oil (Ramadan, 2007). Black cumin fixed oil is lipid fraction containing fatty acids, fat-soluble vitamins and meagure amounts of volatile constituents, whereas its essential oil comprises of only volatiles.

Among the factors that affect yield and quality of black cumin seed, population density is one of the major factors (Ahmed and Haque, 1986). Suitable plant spacing can lead to optimum 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, air, light, soil) are fully exploited by the plants and at the same time, intraspecies and extra-species competitions are minimized (Alizadeh and Koucheki, 1995). As plant density is increased, most yield components of the plants are decreased such as fruit number and seed number per plant. However, some components do not follow this pattern in some cases (Hashemi Dezfuli *et al.*, 1998).

Plant spacing plays an important role in growth and yield of rice. Optimum plant density ensures the plant to grow properly with their aerial and underground parts by utilizing more solar radiation and soil nutrients (Miah *et al.*, 1990). Closer spacing hampers intercultural operations. In a densely populated crop, the inter plant competition is very high for nutrients, air and light, which usually results in mutual shading, lodging and thus favors more straw yield than grain yield.

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. A suitable combination of cultivar and spacing of plant is necessary for better yield performance.

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

i) To find out the suitable variety for better growth and maximum seed yield of black cumin.

ii) To find out the suitable spacing for better growth and yield of black cumin.

CHAPTER 2

REVIEW OF LITERATURE

Black cumin is one of the important medicinal plants all over the world including Bangladesh. Its medicinal value is increasing day by day. The literature regarding growth and yield components of black cumin as influenced by variety and spacing are very scanty. However, the relevant information available on this area generated from different studies has been reviewed in this chapter.

2.1 Effect of genetic variability on plant growth and yield

Rajagopalan *et al*. (1996) evaluated thirteen *Coriandrum sativum* cultivars for seed and essential oil yield during 1990-91 and 1991-92 at the Tamil Nadu Agricultural University, Coimbatore, India. Seed yield was in the range of 359.2-683.4 kg/ha; Co.3 recorded the highest seed yield. Although no significant differences in essential oil content or yield were observed between the cultivars, JC.81 produced the highest essential oil yield (3.95 kg/ha).

Kalra *et al*. (2003) evaluated a set of 120 Indian accessions of coriander (*Coriandrum sativum* L.) screened under late planted conditions for time taken for flowering and fruit maturity, seed yield, seed size, percent content of essential oil in seeds, oil yield and susceptibility to powdery mildew and stem gall diseases. It was concluded that accession CIMAP 2053 and CIMAP 2096 would be suitable for cultivation of coriander under late sown conditions in Indo-Gangetic plains for higher yield of seeds and essential oil, respectively. Days to flowering ranged from 65-80, days to maturity ranged from 100-125, seed yield per plot (6 m^2 ranged from 0.17-1.39 kg, 1000- seed weight from 8.8-14.6 g.

Singh *et al*. (2005) evaluated seventy germplasm lines of coriander (*Coriandrum sativum* L.) of diverse eco-geographical origin. The 70 genotypes were grouped into 9 clusters depending upon the genetic architecture of genotypes and characters uniformity and confirmed by canonical analysis. The maximum inter cluster distance was between I and IV (96.20) followed by III and IV (91.13) and I and VII (87.15). The cluster VI was very unique having genotypes of high mean values for most of the component traits. The cluster VII had highest seed/umbel (35.3 ± 2.24), and leaves/plant (12.93 ± 0.55), earliest flowering (65.05 ± 1.30) and moderately high mean values for other characters.

Bhandari and Gupta (1993) reported that 200 hundred genotypes of *Coriandrum sativum* L exhibited genetic variability for plant height, primary and effective branches, days to flowering and maturity, umbels and umbellets per plant, seeds per umbellets, thousand seed weight, straw and grain yield per plant and harvest index. Plant height ranged from 11.8-86.1 cm, no. of primary branches from 1.4-8.6, days to flowering from 65.0-118.8, days to maturity from 112.0-145.0, umbels per plant from 3.2-39.3, umbellets per plant from 7.1-177.8, seeds per umbellet from 1.7-11.8, 1000-seed weight from 5.0-22.1 g, grain yield per plant from 0.2-7.8g and harvest index from 8.9-84.8.

Datta and Choudhuri (2006) evaluated and reported that 17 germplasm lines of coriander (*Coriandrum sativum* L.) showed significant variation for most of the character studied. Genotype RCr-41 produced the highest seed yield (1.51 t/ha) followed by DH-246 (1.43 t/ha). RCr-41 and ACR-69 were found free from wilt and stem gall disease incidence. In this experiment plant height ranged from 42.87-98.77 cm, primary branches/plant from 5.37-8.23, secondary branches/plant from 10.10-16.75, umbels/plant from 20.83-34.67, seeds/umbel from 33.47-35.57 and 1000-seed weight from 9.33-13.82 g seed yield ranged from 686-1506 g per hectare. Seed colour was classified as yellowish green and light yellowish while seed shape, as oblong, roundish oblong and round. 9 lines infested with stem gall disease.

2.2 Effect of spacing on plants

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.

A study was conducted by Khaled *et al.* (2007) to investigate the effect of sowing dates, nitrogen fertilization rates and plant density on black cumin productivity under the rainfed semi-arid conditions of Jordan. The factors were arranged in a split-split-plot in a randomized complete block design with three replicates and two locations. Results at Mushaqar location showed that planting on December 2 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 (December 2) 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 29.2% and 33.5% over planting in 1st and 3rd date, respectively. Weight of 1000 seed was significantly affected by planting dates and plant density at the two locations. The highest 1000 seed weight at Mushaqar was obtained under 35 kg seed ha^{-1} followed by 25, 30 and 40 kg ha^{-1}. Whereas at Maru, the highest seed weight was obtained under 30 and 35 kg seed ha^{-1}. First planting date gave the tallest plants at Mushaqar, whereas 25 kg seeds ha^{-1} gave the tallest plants at Maru. Seed yield was significantly correlated at both locations with plant height and weight of 1000 seeds. Neither plant density treatments nor urea treatment applied at cultivation date showed significant effect on seed yield for the two locations.

In order to study the effect of N fertilization and plant density levels on yield and yield components of fennel in Birjand, Iran, a study was carried out by Azita *et al.* (2012) 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.

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.

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

An experiment was conducted 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).

Maya *et al*. (1997) stated that, plant height of sweet pepper was significantly increased with close spacing. Manchanda *et al.* (1888) also expressed similar opinion on plant height of sweet pepper.

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

Norman (1992) and Foidl *et al*. (2001) 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.

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

Mazumder *et al. (*2007) stated that plants grown under normal spacing will have optimum population density per unit area which provides optimum conditions for luxuriant crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence they produce more seed yield with best quality traits.

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.

Pandey *et al.* (1996) observed the highest (108.71 cm) plant height in narrow spacing of 60×45 cm in tomato hybrids while, wider spacing of 90x45 cm recorded the highest number of primary branches per plant (7.91).

Kanwar *et al.* (2000) conducted an experiment to know the effect of different levels of population density in onion and concluded that population density failed to register any effect on days to flowering and maturity.

Bahadur and Singh (2005) stated that a closer spacing of 60x40 cm recorded the highest plant height of 176.1 cm. whereas; wider spacing of 60x60 cm recorded the highest number of branches per plant (13.2) in tomato.

Seed quality attributes like test weight, germination percentage and seedling vigour index were found to be better at wider spacing compared to narrower spacings in fennel, according to Ameen *et al.* (1988).

Khorshidi *et al.* (2009) showed that with increase in inter-plants space significantly increased branch number per main stem.

Ghobadi and Ghobadi (2010) studied the effect of different coriander plant densities (10, 30, 50 and 70 plant per m^2) and concluded that number of umbels per plant and number of fruit per umbel reduced with increasing plant density but no significant difference was observed in 1000-fruit weight.

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 densities.

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.

Verzalova *et al*. (1988) reported that row spacing of funnel did not effect on the plant height but number of umbel and seed yield per plant was increased at the wider spacing.

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

2.3 Interaction of variety and spacing

An experiment was conducted by Esmaeil and Behnaz (2014) to investigate changes range of oil yield and percentage attention to plant density on three varieties of black seed, in the form of factorial based on completely randomized block designs (RCBD) with 4 replications in Saat-Loui agricultural station of West Azerbaijan province. In this research, the first factor (A) contained two levels 20 and 40 cm inter rows, the second factor (B) contained three levels 2, 4 and 6 cm intra rows and the third factor (C) contained three different varieties of Baft, Bukan, and Arbil. The specimens were planted on April 22, 2009. The results showed that the effects of plant density and harvest arrangement on grain yield, oil yield and oil percentage were significant. The highest and least grain yield, oil yield and oil percentage obtained from varieties of Baft and Arbil respectively. Oil percentage of inter rows 20 cm and intra rows 6 cm was 31.26 and 33.77 percent respectively. The content of oil percentage in variety Baft was 32.33 percent. Overall, the best content of oil percentage obtained from inter rows 20 cm with intra rows 6 cm in variety Baft about 37.47 percent.

2.4 Medicinal value

Diet and health linkages are no more questionable as consumers are now more conscious toward their food selection (Hasler, 1998). Consumption patterns have been altered variably over the last two decades; attributed to various health policies and legislation implemented in many parts of the globe, particularly in US, Japan and the European Union, etc. to improve the quality and quantity of food (Krystallis *et al*., 2008). In the 20th Century, nutritionists of the western world mainly focused on identification and understanding of nutrients essential for human growth and development resulting in the formation of reference dietary guidelines (Harper, 1987). However, in the same epoch especially in China and Mediterranean countries, a major concerns were the exploration of non-nutritive phytochemicals for their medicinal worth (Tanaka *et al*., 2001). 21st century witnessed the merger of these ideas and functional, nutraceuticals and pharma foods led the changing trend to minimize risk of diseases through diet based strategies (Zock and Katan, 2008). Concept of functional foods often intermingles with nutraceuticals, chemopreventive agents, and phytochemicals. The American Dietetic Association (2005) put forward the definition of functional foods as “all those foods that provide health benefits beyond their nutrition”.

Black cumin (*N. sativa* L.) belongs to the family Ranunculaceae/buttercup. It is an annual flowering plant, native to Southwest Asia. It grows 20-30 cm tall, with finely divided, linear leaves. The flowers are usually pale blue and white, with 5-10 petals. The fruit is a large inflated capsule composed of 3-7 united follicles, each containing numerous seeds (Mozzafari *et al*., 2000). The different parts of the plant are used for medicinal purposes

(Salem, 2005). *Nigella* is used in India and Middle East as a spice & condiment, occasionally in Europe as pepper or spice. It is widely used in Indian cuisines, particularly in mildly braised lamb dishes such as “Korma” (Ramadan, 2007). It is used in Indian medicine to cure indigestion and bowel disorders. The historical tradition of black cumin seed use as medicine is substantial (Atta-ur-Rahman *et al*., 1985a).

In view of its wide range of medicinal uses, scientific investigations presented some conclusive evidences about its composition; moisture, oil, proteins, ash and total carbohydrates contents were in range of 3.8-7.0, 22.0 to 40.35%, 20.85-31.2, 3.7-4.7 and 24.9-40.0%, respectively (Atta, 2003; Salem, 2005). In another study, Cheikh- Rouhou *et al. (*2007) compared Tunisian and Iranian varieties for their quality attributes. Tunisian variety contains 8.65, 28.48, 26.7, 4.86 and 40.0% of moisture, oil, proteins, ash and carbohydrates, while Iranian variety contained 4.08, 40.35, 22.6, 4.41, and 32.7% of respective attributes.

Minerals such as calcium, phosphorus and iron were found to be in appreciable amounts, while zinc, calcium, magnesium, manganese and copper in meager quantities (Ali and Blunden, 2003). Iron, copper, sodium, potassium, calcium, zinc, phosphorous and magnesium contents lie in the range of 9.1-15.40, 1.5-3.75, 41.2-55.0, 442.3-675.0, 154.4-305.0, 3.36-6.6, 378.12-576.9 and 134.92-147.05mg/100g of seed, respectively (Cheikh-Rouhou *et al*., 2007). Likewise, Takruri and Dameh (1998) reported presence of iron, copper, sodium, potassium, calcium, zinc and phosphorous in quantities of 105, 18.4, 496.0, 5257, 1859, 60.4 and 5265mg/kg, respectively (Ashraf *et al*., 2006; Cheikh-Rouhou *et al*., 2007).

Furthermore, traces of alkaloids were also found belonging to two different types: isochinoline is represented by nigellimine and nigellimin-*N*oxide and pyrazol includes nigellidine and nigellicine (Nickavar *et al*., 2003). Subsequently, Morikawa *et al*. (2004) isolated new dolabellane-type diterpene alkaloids, Nigellamines A(3), A(4), A(5), and C, from the methanolic extract of black cumin. Afterwards, Singh *et al*. (2005) separated two new aliphatic compounds from hexane extract of *Nigella sativa*. The compounds were characterized as 16-triecosen-7-ol-1 and 6-nonadecanone-2. More recently, Mehta *et al*. (2009) identified new saponin from its ethanolic extract. Black cumin seed contains fixed and essential oil; health claims are often attributed to functional ingredients present in them (Ali and Blunden, 2003).

The world Health Organization (WHO) enumerated standards that dietary fat should be rich in polyunsaturated fatty acids (more than 33%) and with reduced contents of saturated fatty acids (less than 33%) to boost human health. Fatty acid composition of *N. sativa* L. fulfill the WHO standards as it contains around 80-84% unsaturated fatty acids and 14-20% saturated fatty acids (Ashraf *et al*., 2006).

CHAPTER 3

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 14th November, 2012 to 24th March, 2013 (*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. Thus the climatic factors were agreeable to grow the hybrid rice.

3.3 Soil

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.

3.4 Planting material

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

3.5 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.

3.6 Fertilizer management

At the time of first ploughing, cowdung was applied at the rate of 5 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. 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.

3.7 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 per kg of seeds before sowing. 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. The sowing was done in 14th November 2012 with slight watering. After 10 days of seedling emergence, the seedlings were thinned to maintain required spacing treatments.

3.8 Experimental treatments

Treatments included in the experiment were as follows:

A. Varieties

i) V_1 =Local

ii) V_2 =BARI Kalozira-1

B. Spacing

i) S_1 – 15 cm × 10 cm

ii) S_2 - 20 cm × 10 cm

iii) S_3 - 25 cm × 10 cm

iv) S_4 - 15 cm × 15 cm

v) S_5 - 20 cm × 15 cm

vi) S_6 - 25 cm × 15 cm

C. Treatments combinations:

Local (V_1)	×	S_1 – 15 cm × 10 cm
		S_2 - 20 cm × 10 cm
		S_3 - 25 cm × 10 cm
		S_4 - 15 cm × 15 cm
		S_5 - 20 cm × 15 cm
		S_6 - 25 cm × 15 cm
BARI Kalozira-1 (V_2)	×	S_1 – 15 cm × 10 cm
		S_2 - 20 cm × 10 cm
		S_3 - 25 cm × 10 cm
		S_4 - 15 cm × 15 cm
		S_5 - 20 cm × 15 cm
		S_6 - 25 cm × 15 cm

3.9 Experimental Design

The experiment was laid out in randomized complete block design with three replications. The unit plot size was 3 m x 1.2 m. The spacing between block was 1 m and between plots 0.5 m.

3.10 Intercultural operations

3.10.1 Weeding

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

3.10.2 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.

3.10.3 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 showed symptoms of fungal attack. For control, Dithane M-45 was sprayed at 10 days interval @ 2 g/Litre water.

3.10.4 Harvesting and post harvest operation

Plants of all the plots were not harvested at the same date. Harvesting was done from 11 March to 24 March 2013. 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.

3.11 Data collection

The following data were recorded:

Yield attributes and yield parameters

- Plant height at first flowering (cm)
- Plant height at 50% flowering (cm)
- Plant height at last harvest (cm)
- Number of primary branches plant^{-1}
- Number of secondary branches plant^{-1}
- Number of plants m^{-2}
- Number of seeds capsule^{-1}
- Number of capsules plant^{-1}
- Single capsule weight (mg)
- Weight of seeds capsule^{-1} (mg)
- Weight of seeds plant^{-1} (g)
- 1000-seed weight (g)
- Seed yield (kg/ha)

3.12 Detailed procedures of data recording

i) Plant height at first flowering, 50% flowering and at harvest (cm) :

Plant height at first flowering was measured when the selected and tagged plants for data collection from each plot were flowered. Plant height at 50% flowering was recorded when 50% of the tagged plants was flowered. At harvest, the height of the selected plants were measured again.

ii) 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.

iii) Number of plants m^{-2}

Before harvest, number of plants of some selected plots of each treatment combination were recorded. These data were then converted to number of plants m^{-2} by dividing with the plot size**.**

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

The number of seeds $capsule^{-1}$ and capsules $plant^{-1}$ were recorded from the tagged plants during harvest.

v) Weight of single capsules (mg), seeds $capsule^{-1}$ (mg) and seeds $plant^{-1}$ (g)

During harvest, weight of single capsules (mg) and seeds $capsule^{-1}$ (mg) as well as weight of seeds $plant^{-1}$ (g) were recorded from selected plants from plots of each combination of variety and spacing.

vi) 1000-seed weight (g)

1000-seed weight of each plot's selected plants were recorded by weighing 200 seeds first and then the results were converted into 1000 seeds.

vii) Seed yield (kg/ha)

Each plot's total yield (kg) were recorded first and then they were converted to kg ha^{-1} by using the plot size.

3.13 Statistical analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-C (Russell, 1986) 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 4

RESULTS AND DISCUSSION

The results of the study regarding the effect of variety and spacing on growth and yield related traits of black cumin (*Nigella sativa* L.) have been presented and possible interpretations have been made as follows:

4.1 Plant height at first flowering

4. 1. 1. Effect of variety

Plant height at first flowering was varied insignificantly among the two black cumin varieties. Higher plant height at first flowering was recorded in Local variety (28.12 cm) and lower from BARI Kalozira-1 (27.18 cm) (Table 1). Esmaeil and Behnaz (2014) found that the highest and lowest values for plant height were obtained from Baft and Arbil variety respectively. Bhandari and Gupta (1993) reported 200 hundred genotypes of *Coriandrum sativum* L exhibited genetic variability for plant height.

Table 1. Effect of variety on plant height at first flowering, at 50% flowering and at last harvest

	Plant height		
Variety	At first flowering (cm)	At 50% flowering (cm)	At last harvest (cm)
V_1	28.12	35.78	53.79 b
V_2	27.18	37.22	57.94 a
LSD	2.11	3.22	3.717
CV%	7.61	6.52	3.31
Level of Significance	NS	NS	*

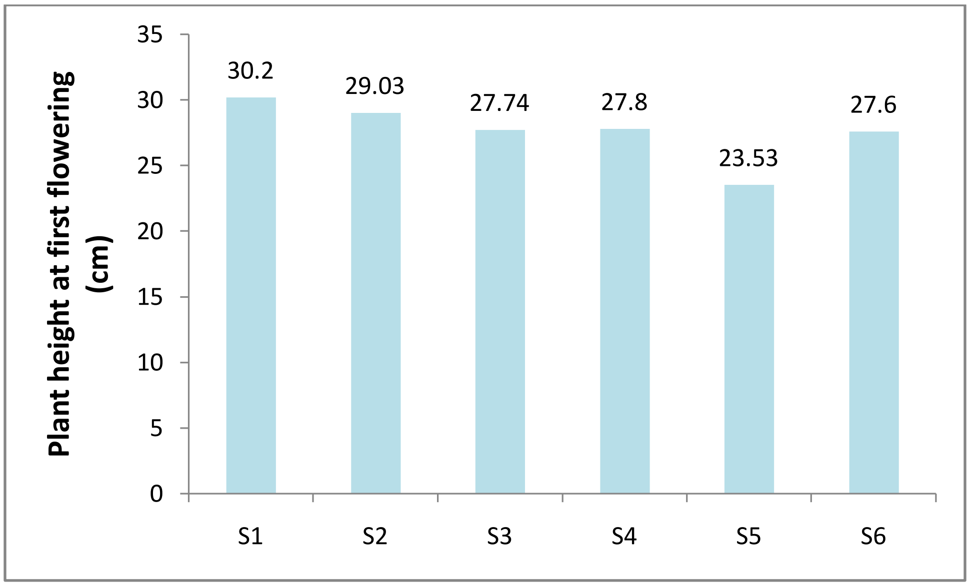
Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

4. 1. 2. Effect of spacing

Significant variation was found due to the effect of spacing on plant height at first flowering. The lowest plant height (23.53 cm) at first flowering was recorded from S_5 (20 cm × 15 cm spacing) and highest (30.20 cm) from S_1 (15 cm × 10 cm spacing). The treatment S_1 was statistically same to S_2 which gave plant height of 29.03 cm at first flowering (Figure 1 and Appendix I). Özlem and Süleyman (2004) found that seed rate significantly affected plant height.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 1. Effect of spacing on plant height at first flowering.

4. 1. 3. Interaction effect of variety and spacing

Plant height at first flowering was varied significantly due to the interaction effect of variety and spacing. The highest (31.27 cm) plant height at first flowering was recorded from V_1S_1 while lowest from V_2S_5 (23.07 cm). The result found from V_1S_1 was statistically similar with the results of V_1S_2 (29.40 cm), V_1S_4 (28.33 cm), V_1S_6 (28.93 cm), V_2S_1 (29.13 cm), V_2S_2 (28.67 cm), V_2S_3 (28.67 cm) and V_2S_4 (27.27 cm) (Table 2).

Table 2. Interaction effect of variety and spacing on plant height at first flowering, at 50% flowering and at last harvest

Treatments	Plant height at first flowering (cm)	Plant height at 50% flowering(cm)	Plant height at last harvest (cm)
V_1S_1	31.27 a	38.53 ab	53.40 cd
V_1S_2	29.40 ab	37.07 abc	56.73 abc
V_1S_3	26.80 bcd	34.20 bc	52.87 d
V_1S_4	28.33 ab	35.53 abc	45.93 e
V_1S_5	24.00 cd	33.13 c	54.53 cd
V_1S_6	28.93 ab	36.20 abc	59.27 ab
V_2S_1	29.13 ab	38.93 a	59.80 a
V_2S_2	28.67 ab	38.33 ab	58.47 ab
V_2S_3	28.67 ab	37.67 abc	55.00 cd
V_2S_4	27.27 abc	37.47 abc	56.00 bcd
V_2S_5	23.07 d	35.27 abc	58.53 ab
V_2S_6	26.27 bcd	35.67 abc	59.87 a
LSD	3.564	4.028	3.132
CV%	7.61	6.52	3.31
Level of Significance	*	*	*

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

4.2 Plant height at 50% flowering

4. 2. 1. Effect of variety

Plant height at 50% flowering was also varied insignificantly among the two black cumin varieties. Higher plant height at 50% flowering was recorded in BARI Kalozira-1 (37.22 cm) and lower from Local variety (35.78 cm) (Table 1).

4. 2. 2. Effect of spacing

Significant variation was found due to the effect of spacing on plant height at 50% flowering. The lowest plant height (34.20 cm) at 50% flowering was recorded from S_5 (20 cm × 15 cm spacing) and highest (38.73 cm) from S_1 (15 cm × 10 cm spacing)

(Figure 2 and Appendix I). The treatment S_1 was statistically similar to S_2 that gave plant height of 37.70 cm at 50% flowering. Maya *et al*. (1997) stated that, plant height of sweet pepper was significantly increased with close spacing.

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 2. Effect of spacing on plant height at 50% flowering

4. 2. 3. Interaction effect of variety and spacing

Plant height at 50% flowering was varied significantly due to the interaction effect of variety and spacing. The highest plant height (38.93 cm) at 50% flowering was recorded from V_2S_1 while the lowest from V_1S_5 (33.13 cm). The result found from V_2S_1 was statistically similar to the results of V_1S_1 (38.53 cm), V_1S_2 (37.07 cm), V_1S_4 (35.53 cm), V_1S_6 (36.20 cm), V_2S_2 (38.33 cm), V_2S_3 (37.67 cm), V_2S_4 (37.47 cm), V_2S_5 (35.27 cm) and V_2S_6 (35.67 cm) (Table 2).

4.3 Plant height at last harvest

4. 3. 1. Effect of variety

Plant height at last harvest (cm) showed significant variation between the two black cumin varieties. Statistically higher plant height at last harvest was shown by BARI Kalozira-1(57.94 cm) while the Local cultivar showed lower plant height (53.79 cm) between the two (Table 1).

4. 3. 2. Effect of spacing

Significant variation was found due to the effect of spacing on plant height at final harvest. The lowest plant height (50.97 cm) at final harvest was recorded from S_4 (15 cm × 15 cm spacing) and the highest (59.57 cm) from S_6 (25 cm × 15 cm spacing). The treatment S_6 was followed by S_2 which showed plant height of 57.60 cm at final harvest (Figure 3 and Appendix I). This may be due to lower competition among the plants. Sedigheh *et al.* (2009) stated that in suitable plant density, plants completely use environmental conditions (water, air, light and soil) and inter- or intra-specific competition is minimum.

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 3. Effect of spacing on plant height at harvest.

4. 3. 3. Interaction effect of variety and spacing

Plant height at harvest was varied significantly due to the interaction effect of variety and spacing. The highest (59.87 cm) plant height at harvest was recorded from V_2S_6 which was closely followed by V_2S_1 (59.80 cm) while the lowest was recorded from V_1S_4 (45.93 cm). The result found from V_2S_6 and V_2S_1 was statistically similar to the results of V_1S_2 (56.73 cm), V_1S_6 (59.27 cm), V_2S_2 (58.47 cm) and V_2S_5 (58.53 cm) (Table 2). These results do not contain with the findings of Esmaeil and Behnaz (2014) who found that interaction effect of variety and spacing was not significant on plant height.

4.4 Number of primary branches plant^{-1}

4. 4. 1. Effect of variety

Due to varietal difference, there was a significant variation in the number of primary branches plant^{-1}. BARI Kalozira-1 showed statistically higher number of primary branches plant^{-1} (7.89) while Local cultivar showed comparatively lower (7.16). (Table 3). Esmaeil and Behnaz (2014) found that the highest and the lowest values for number of stem were obtained from Baft and Arbil variety respectively.

Table 3. Effect of variety on number of primary branches plant^{-1}, secondary branches plant^{-1} and number of plants m^{-2}

Variety	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Number of plants m^{-2}
V_1	7.16 b	14.18 b	34.78
V_2	7.89 a	17.09 a	34.92
LSD	0.481	1.423	1.533
CV%	3.73	4.65	4.84
Level of Significance	*	*	NS

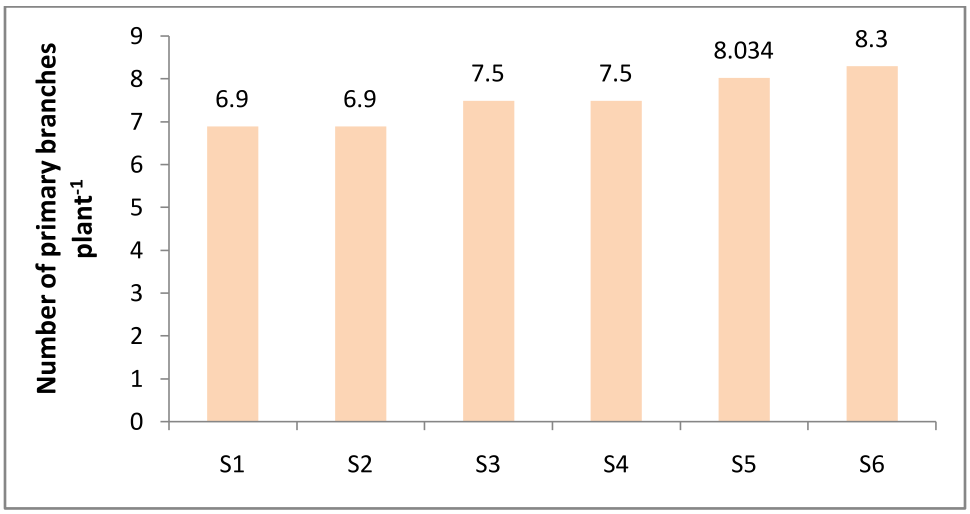
Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

4. 4. 2. Effect of spacing

Significant variation was found due to the effect of spacing on number of primary branches plant^{-1}. The lowest number of primary branches plant^{-1} (6.9) was recorded from S_1 (15 cm × 10 cm spacing) and S_2 (20 cm × 10 cm spacing) while highest (8.3) from S_6 (25 cm × 15 cm spacing). The treatment S_6 was statistically same to S_5 which gave 8.03 primary branches plant^{-1} (Figure 4 and Appendix II). Özlem and Süleyman (2004) found that seed rate significantly affected number of branch per plant of *Nigella sativa*. They mentioned that high seed rates (40 and 50 kg ha^{-1}) reduced number of branch per plant of *Nigella sativa*. Pandey *et al*. (1996) observed that wider spacing of 90x45 cm gave the highest number of primary branches per plant (7.91) in tomato. Khorshidi *et al.* (2009) showed that with increase in inter-plants space significantly increased branch number in main stem.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 4. Effect of spacing on number of primary branches plant^{-1}.

4. 4. 3. Interaction effect of variety and spacing

Number of primary branches plant^{-1} showed significant variation among the treatments due to the interaction effect of variety and spacing. Highest primary branches plant^{-1}

(8.867) was found from the V_2S_6 treatment which was followed by V_2S_5 (8.267). V_2S_3 (8.000) also showed better performance. On the other hand, lowest value for primary branches plant^{-1} was recorded in V_1S_1 (5.867) which was followed by the results of V_1S_2 (6.867) and V_1S_3 (7.000) (Table 4).

Table 4. Interaction effect of variety and spacing on primary branches plant^{-1}, secondary branches plant^{-1} and number of plants m^{-2}

Treatments	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Number of plants m^{-2}
V_1S_1	5.867 f	10.40 f	40.00 ab
V_1S_2	6.867 e	12.40 e	39.00 ab
V_1S_3	7.000 e	14.40 d	37.22 abc
V_1S_4	7.667 cd	16.53 b	34.00 cd
V_1S_5	7.800 bcd	16.40 b	31.39 de
V_1S_6	7.733 cd	14.93 cd	27.09 e
V_2S_1	7.933 bc	16.93 b	41.81 a
V_2S_2	6.933 e	16.60 b	39.20 ab
V_2S_3	8.000 bc	17.33 ab	36.04 bcd
V_2S_4	7.333 de	16.00 bc	33.30 cd
V_2S_5	8.267 b	17.20 ab	31.30 de
V_2S_6	8.867 a	18.47 a	27.90 e
LSD	0.4759	1.232	4.782
CV%	3.73	4.65	4.84
Level of Significance	**	**	**

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

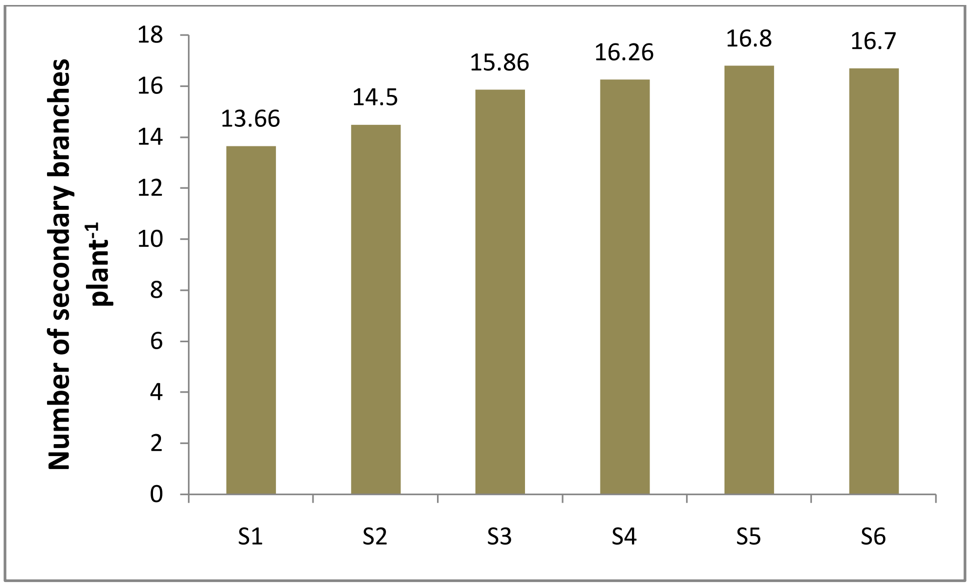
4.5 Number of secondary branches plant^{-1}

4. 5. 1. Effect of variety

There was a significant variation in the number of secondary branches plant^{-1} for the effect of variety. BARI Kalozira-1 produced statistically higher number of secondary branches plant^{-1} (17.09) while Local cultivar produced comparatively lowers (14.18) (Table 3).

4. 5. 2. Effect of spacing

Significant variation was found due to the effect of spacing on number of secondary branches plant^{-1}. The lowest (13.66) number of secondary branches plant^{-1} was recorded from S_1 (15 cm × 10 cm spacing) and the highest (16.80) from S_5 (20 cm × 15 cm spacing) (Figure 5 and Appendix II). The treatment S_5 was statistically similar to S_6 which produced 16.70 secondary branches plant^{-1}. Bahadur and Singh (2005) stated that wider spacing of 60x60 cm recorded the highest number of branches per plant (13.2) in tomato. Some researches (Degenhardt and Kondra, 1981; Roy and Paul, 1991 and Kızıl, 2002) reported that as seed rate increased, number of branch per plant decreased. Also this is probably because high seed rate created higher interplant competition.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 5. Effect of spacing on number of secondary branches plant^{-1}.

4. 5. 3. Interaction effect of variety and spacing

Number of secondary branches plant^{-1} showed significant variation among the treatments due to the interaction effect of variety and spacing. The highest secondary branches plant^{-}

[1] (18.47) was found in V_2S_6 treatment which was statistically similar with V_2S_5 (17.20) and V_2S_3 (17.33). On the other hand, lowest value for secondary branches plant^{-1} (10.40) was recorded in V_1S_1 which was followed by the results of V_1S_2 (12.40) and V_1S_3 (14.40) (Table 4).

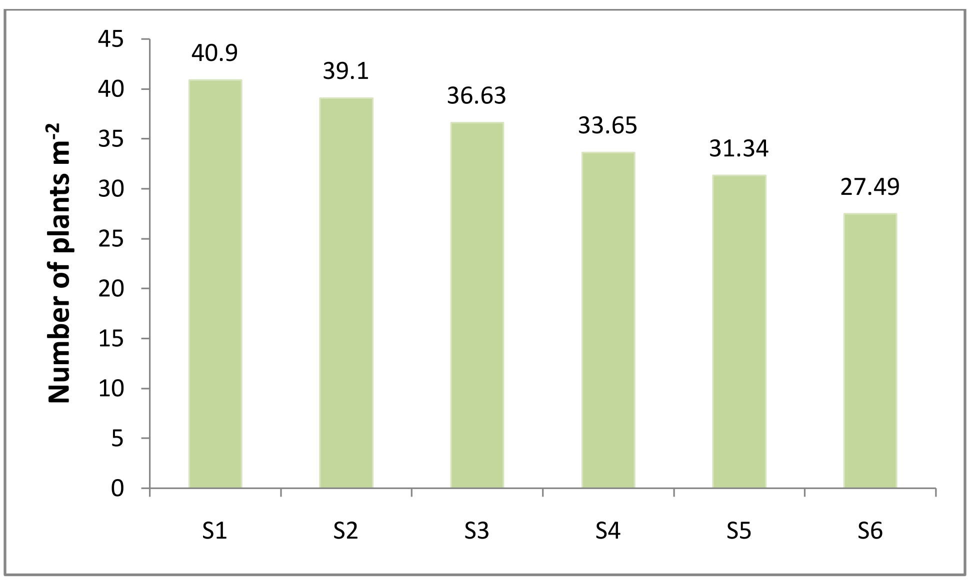
4.6 Number of plants m^{-2}

4. 6. 1. Effect of variety

Number of plants m^{-2} was varied insignificantly due to varietal effect. Though comparatively higher number of plants m^{-2} was given by Local variety (34.92) which was closely followed by BARI Kalozira-1 (34.78) (Table 3).

4. 6. 2. Effect of spacing

Number of plants m^{-2} varied significantly due to the effect of spacing. The highest number of plants m^{-2} (40.90) was given by S_1 (15 cm × 10 cm spacing) while the lowest (27.49) was from S_6 (25 cm × 15 cm spacing). It was observed that number of plants m^{-2} decreased as the spacing increased (Figure 6 and Appendix II).



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 6. Effect of spacing on number of plants m^{-2}.

4. 6. 3. Interaction effect of variety and spacing

Significant variation was found due to the interaction effect of variety and spacing for the parameter number of plants m^{-2}. Highest number of plants m^{-2} (41.81) was given by V_2S_1 which was very close and statistically similar with V_1S_1 (40.00), V_2S_2 (39.20) and V_1S_2 (39.00). On the other hand, the lowest result was recorded from V_1S_6 (27.09) which was statistically similar with V_2S_6 (27.90). It was observed that as spacing increased, number of plants m^{-2} was decreased for both the variety (Table 4).

4.7 Weight of seeds capsule^{-1} (mg)

4. 7. 1. Effect of variety

Due to the effect of variety, a significant variation was found between the two varieties for the parameter weight of seeds capsule^{-1} (mg). BARI Kalozira-1 (232.6 mg) showed better result than the Local variety (206.5 mg) (Table 5). Bhandari and Gupta (1993) reported that genotypes of *Coriandrum sativum* L exhibited genetic variability for seeds per umbellets.

Table 5. Effect of variety on weight of seeds capsule^{-1}, weight of seeds plant^{-1}, number of capsules plant^{-1}, single capsule weight and number of seeds capsule^{-1}

Variety	Weight of seeds capsule^{-1} (mg)	Weight of seeds plant^{-1} (g)	Number of capsules plant^{-1}	Single capsule weight (mg)	Number of seeds capsule^{-1}
V_1	206.5 b	3.662 b	21.61 b	267.3 b	89.39 b
V_2	232.6 a	4.033 a	23.92 a	279.2 a	100.1 a
LSD	7.798	0.3569	1.28	9.574	8.588
CV%	5.05	8.26	5.55	3.48	5.28
Level of Significance	*	*	*	**	*

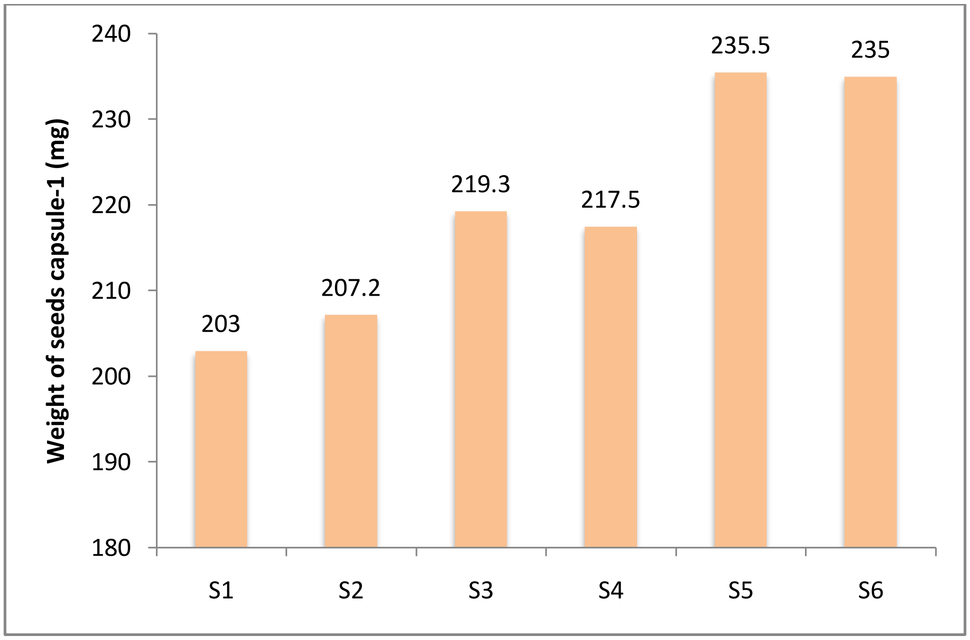
Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

4. 7. 2. Effect of spacing

Weight of seeds capsule^{-1} (mg) varied significantly due to the effect of spacing. The highest weight of seeds capsule^{-1} (235.5 mg) was recorded in S_5 (20 cm × 15 cm spacing) which was close and statistically similar to S_6 (25 cm × 15 cm spacing) (235.0 mg). On the other hand, the lowest weight of seeds capsule^{-1} (203.0 mg) was found in S_1 (15 cm × 10 cm spacing) (Figure 7 and Appendix III).



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 7. Effect of spacing on weight of seeds capsule^{-1} (mg).

4. 7. 3. Interaction effect of variety and spacing

Significant variation was found due to the interaction effect of variety and spacing for weight of seeds capsule^{-1} (mg). The highest weight of seeds capsule^{-1} was recorded in V_2S_5 (257.2 mg) which was close and statistically similar to V_2S_6 (243.6 mg). The lowest weight of seeds capsule^{-1} (187.8 mg) was found in V_1S_1 which was statistically similar to V_1S_2 (192.7 mg) (Table 6).

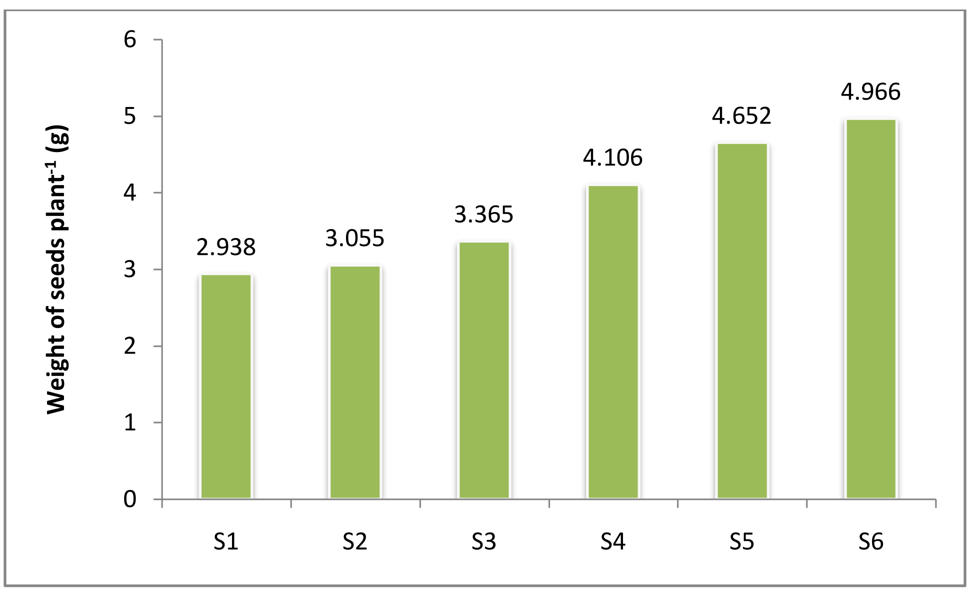
4.8 Weight of seeds plant^{-1} (g)

4. 8. 1. Effect of variety

Weight of seeds plant^{-1} (g) showed statistically significant variation due to varietal difference. BARI Kalozira-1 has produced greater weight of seeds plant^{-1} (5.25 g) than the local variety (4.85 g) (Table 5). The weight of *Cuminum carvi* seed varied in different experiments. Kafi (2003) reported that it was from 2.79 to 2.99 g under varying plant densities.

4. 8. 2. Effect of spacing

Weight of seeds plant^{-1} (g) varied significantly due to the effect of spacing. The highest weight of seeds plant^{-1} (6.637 g) was recorded in S_5 (20 cm × 15 cm spacing) which was followed by S_6 (25 cm × 15 cm spacing) (5.432 g). On the other hand, the lowest weight of seeds capsule^{-1} (4.115 g) was found in S_1 (15 cm × 10 cm spacing) (Figure 8 and Appendix III). Özlem and Süleyman (2004) found that seed rate significantly affected seed yield per plant in *Nigella sativa*. They reported that high seed rates (40 & 50 kg ha^{-1}) reduced the seed yield per plant.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 8. Effect of spacing on weight of seeds plant^{-1}.

4. 8. 3. Interaction effect of variety and spacing

Significant variation was found due to the interaction effect of variety and spacing for weight of seeds plant^{-1} (g). The highest weight of seeds plant^{-1} was recorded in V_2S_5 (6.693 g) which was closely followed by and statistically similar to V_2S_6 (6.580 g). The lowest weight of seeds plant^{-1} (3.767 g) was found in V_1S_1 which was statistically similar to V_1S_4 (3.960 g), V_2S_1 (4.270 g) and V_2S_2 (4.320 g) (Table 6).

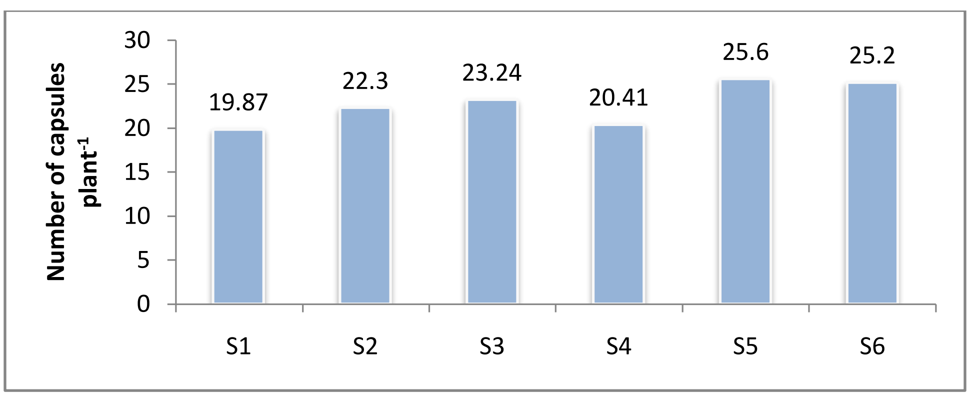
4.9 Number of capsules plant^{-1}

4. 9. 1. Effect of variety

Due to the effect of variety number of capsules plant^{-1} showed significant variation. BARI Kalozira-1 gave higher number of capsules plant^{-1} (23.79) than the local variety (21.75) (Table 5).

4. 9. 2. Effect of spacing

Significant variation was found due to the effect of spacing on number of capsules plant^{-1}. The lowest (19.87) number of capsules plant^{-1} was recorded from S_1 (15 cm × 10 cm spacing) and it was statistically similar to S_4 (15 cm × 15 cm) (20.41). The treatment S_6 (25 cm × 15 cm spacing) produced statistically highest number of capsules plant^{-1} (26.53) which was followed by S_5 (20 cm × 15 cm spacing) (24.26) (Figure 9 and Appendix III).



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 9. Effect of spacing on number of capsules plant^{-1}.

Kafi (1990) reported that the number of umbrella per plant under varying plant densities was from 18.9 to 31.3. Özlem and Süleyman (2004) found that the highest number of capsule per plant was obtained from 10 kg ha^{-1} (10.2 pieces/plant). Bianco *et al.* (1994) found significant effect of plant density on the number of umbrella per plant of fennel.

4. 9. 3. Interaction effect of variety and spacing

Significant variation was found due to the interaction effect of variety and spacing on number of capsules $plant^{-1}$. The lowest (17.87) number of capsules $plant^{-1}$ was recorded from V_1S_1 and it was statistically similar to V_1S_4 (18.02). The treatment V_2S_5 produced statistically the highest number of capsules $plant^{-1}$ (27.47) which was followed by V_2S_6 (25.60) (Table 6).

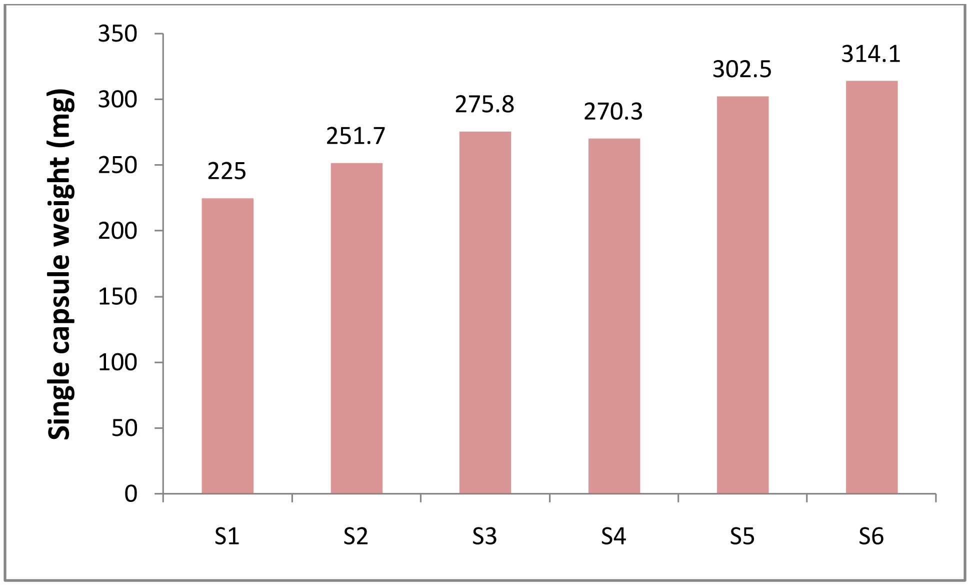
4.10 Single capsule weight (mg)

4.10.1. Effect of variety

Single capsule weight (mg) showed statistically significant variation due to the effect of variety. Higher single capsule weight (296.39 mg) was given by BARI Kalozira-1 while lower value was recorded from Local variety (250.11 mg) (Table 5).

4.10.2. Effect of spacing

Weight of single capsule (mg) varied significantly due to the effect of spacing. The highest weight of single capsule (291.5 mg) was recorded in S_5 (20 cm × 15 cm spacing) which was statistically similar to S_4 (15 cm × 15 cm) (290.8 mg) and S_6 (25 cm × 15 cm spacing) (289.2 mg). On the other hand, the lowest weight of single capsule (228.3 mg) was found in S_1 (15 cm × 10 cm spacing) (Figure 10 and Appendix III). Paperi Moqaddam and Bohrani (2005) found that with decreasing plant density, number of capsule in plant and capsule weight increased.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 10. Effect of spacing on single capsule weight (mg).

4.10.3. Interaction effect of variety and spacing

Significant variation was found due to the interaction effect of variety and spacing on weight of single capsule. The highest weight of single capsule (326.7 mg) was recorded in V_2S_5 and it was statistically similar to V_1S_6 (318.0) and V_2S_6 (310.0). The treatment V_1S_1 gave statistically the lowest result (200.0) which was followed by V_1S_2 (246.7) (Table 6).

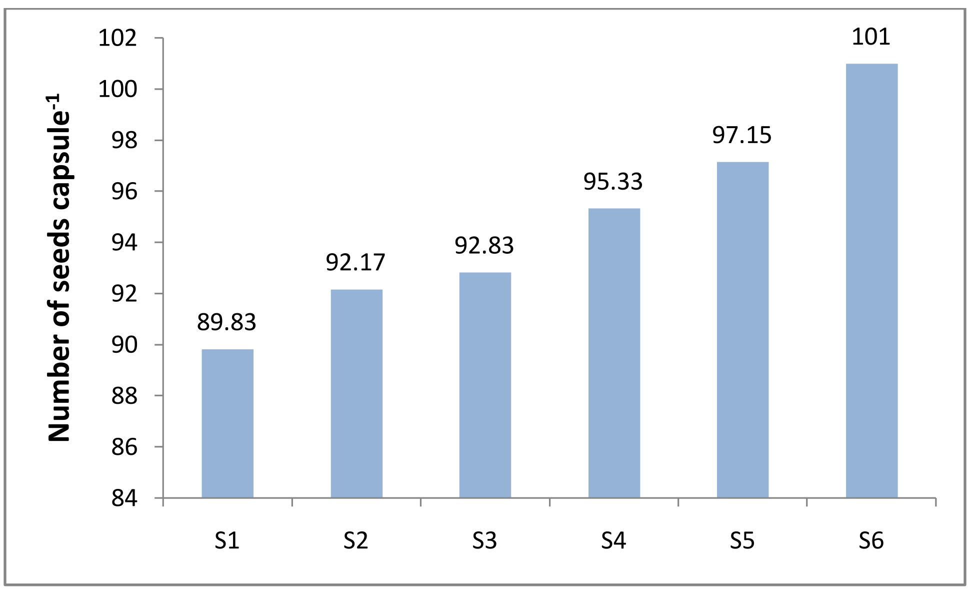
4.11 Number of seeds capsule^{-1}

4.11.1. Effect of variety

Number of seeds capsule^{-1} showed statistically insignificant variation due to the effect of variety. BARI Kalozira-1 produced numerically higher number of seeds capsule^{-1} (96.11) than the Local variety (93.33) (Table 5).

4.11.2. Effect of spacing

Number of seeds capsule^{-1} showed statistically significant variation due to the effect of spacing. The highest number of seeds capsule^{-1} (99.17) was recorded in S_5 (20 cm × 15 cm spacing) which was statistically similar to S_6, S_4 and S_3 which gave 97.33, 95.50 and 93.83 seeds capsule^{-1}. On the other hand, the lowest number of seeds capsule^{-1} (91.17) was recorded in S_1 (15 cm × 10 cm spacing) (Figure 11 and Appendix III). These are not in contain with the findings of Özlem and Süleyman (2004) who found that seed rate did not affect number of seed per capsule. Sedigheh *et al.* (2009) found that number of seed per umbrella showed an increasing trend with decreases in plant densities in *Cuminum carvi*. Because seed set depends on providing the sufficient nutrients and environmental conditions while shift from vegetative to reproductive stage, increased plant densities result in limited availability of nutrients, light and water so the number of reproductive units decrease; at last seed number decreases.



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 11. Effect of spacing on number of seeds capsule^{-1}.

4.11.3. Interaction effect of variety and spacing

Number of seeds capsule^{-1} showed statistically significant variation due to the interaction effect of variety and spacing. The highest number of seeds capsule^{-1} was recorded in V_2S_6 (107.0) and it was statistically similar to V_2S_5 (103.3), V_2S_4 (100.0) and V_2S_3 (98.00). On the other hand, the lowest number of seeds capsule^{-1} (84.67) was recorded in V_1S_1 which was followed by V_1S_2 (87.33) (Table 6).

Table 6. Interaction effect of variety and spacing on weight of seeds capsule^{-1}, weight of seeds plant^{-1}, number of capsules plant^{-1}, single capsule weight and number of seeds capsule^{-1}

Treatments	Weight of seeds capsule^{-1} (mg)	Weight of seeds plant^{-1} (g)	Number of capsules plant^{-1}	Single capsule weight (mg)	Number of seeds capsule^{-1}
V_1S_1	187.8 e	2.767 e	17.87 e	200.0 f	84.67 f
V_1S_2	192.7 de	2.840 e	22.20 d	246.7 e	87.33 ef
V_1S_3	209.7 cd	3.140 de	23.07 cd	288.3 b	87.67 d-f
V_1S_4	208.8 cd	3.960 bcd	18.02 e	272.3 b-d	90.67 c-f
V_1S_5	213.7 c	4.510 abc	23.73 bcd	278.3 bc	91.00 c-f
V_1S_6	226.4 bc	4.753 ab	24.80 bc	318.3 a	95.00 b-e
V_2S_1	218.1 c	3.110 de	21.87 d	250.0 e	95.00 b-e
V_2S_2	221.7 c	3.270 de	22.40 cd	256.7 de	97.00 b-d
V_2S_3	228.8 bc	3.590 cde	23.40 b-d	263.3 c-e	98.00 a-c
V_2S_4	226.1 bc	4.253 abc	22.80 cd	268.3 cd	100.0 a-c
V_2S_5	257.2 a	4.793 ab	27.47 a	326.7 a	103.3 ab
V_2S_6	243.6 ab	5.180 a	25.60 ab	310.0 a	107.0 a
LSD	18.76	0.9363	2.141	16.12	8.464
CV%	5.05	8.26	5.55	3.48	5.28
Level of Significance	*	**	*	**	*

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

4.12 1000-seed weight (g)

4.12.1. Effect of variety

Due to the effect of variety, 1000-seed weight (g) varied significantly. Higher 1000-seed weight (2.414 g) was given by BARI Kalozira-1 while lower value was recorded from Local variety (2.337 g) (Table 7).

Table 7. Effect of variety on 1000-seed weight and seed yield

Variety	1000-seed weight (g)	Seed yield (kg/ha)
V_1	2.337 b	1239.57 b
V_2	2.414 a	1373.09 a
LSD	0.07457	30.34
CV%	4.72	5.01
Level of Significance	*	**

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

4.12.2. Effect of spacing

1000-seed weight (g) varied non-significantly due to the effect of spacing. The highest 1000-seed weight (2.425 g) was given by S_5 (20 cm × 15 cm spacing) which was statistically similar to S_4, S_6 and S_2 who gave 2.403, 2.392 and 2.365 g 1000-seed weight. The lowest 1000-seed weight (2.335 g) was given by S_1 (15 cm × 10 cm spacing) (Figure 12 and Appendix III). Sedigheh *et al.* (2009) found that effect of sowing date and plant density on 1000-seed weight was not significant in *Cuminum carvi*.

4.12.3. Interaction effect of variety and spacing

Due to the interaction effect of variety and spacing, 1000-seed weight (g) varied significantly. The maximum 1000-seed weight was recorded in V_2S_5 (2.44 g) and it was statistically similar to all the other combinations except V_1S_1 which produced the lowest 1000-seed weight (2.23 g) (Table 8).

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 12. Effect of spacing on 1000-seed weight (g).

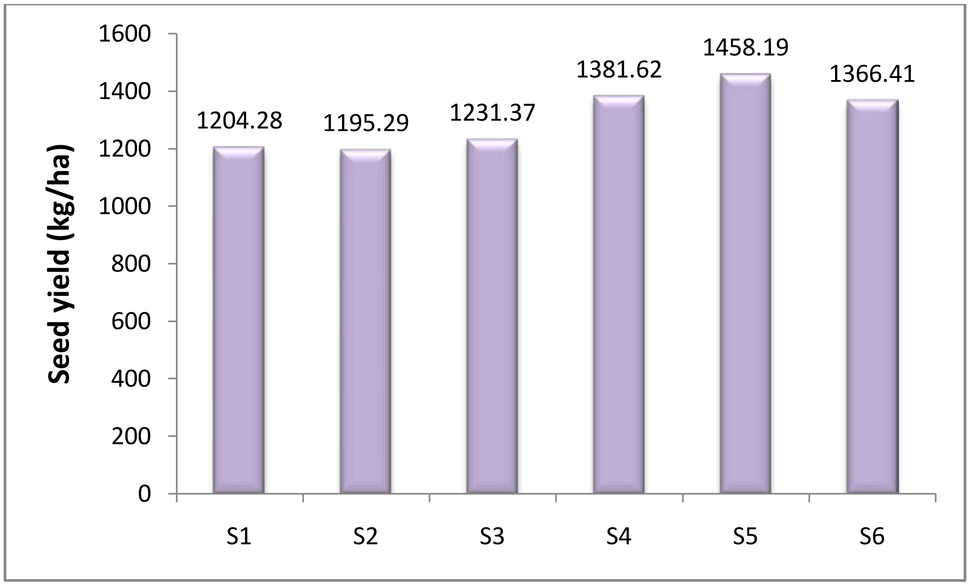
4.13 Seed yield (kg/ha)

4.13.1. Effect of variety

There was a statistically significant variation among the varieties in case of seed yield (kg/ha). Statistically higher seed yield was recorded in BARI Kalozira-1 (1086.00 kg/ha) while the Local variety gave lower value (1292.12 kg/ha) (Table 7).

4.13.2. Effect of spacing

Seed yield (kg/ha) showed statistically significant variation among the different spacing treatments. The maximum seed yield (1346.57 kg/ha) was recorded in S_5 (20 cm × 15 cm spacing) which was closely followed by S_6 (25 cm × 15 cm spacing) (1245.28 kg/ha). The lowest seed yield (1017.56 kg/ha) was recorded from S_1 (15 cm × 10 cm spacing) (Figure 13 and Appendix III).



S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Figure 13. Effect of spacing on seed yield (kg/ha).

4.13.3. Interaction effect of variety and spacing

Seed yield (kg/ha) showed statistically significant variation due to the interaction effect of variety and spacing. Statistically the maximum seed yield (1458.19 kg/ha) was recorded in V_2S_5 and it was closely followed by V_2S_6 (1445.79 kg/ha). The lowest seed yield (1107.11 kg/ha) was recorded from V_1S_1 and it was closely followed by V_1S_2 (1108.23 kg/ha) (Table 8).

Özlem and Süleyman (2004) found that the highest seed yield was obtained from the lowest seed rate (10 kg ha^{-1}).

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.

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

Mazumder *et al. (*2007) stated that plants grown under normal spacing will have optimum population density per unit area which provides optimum conditions for luxuriant crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence they produce more seed yield with best quality traits.

Verzalova *et al*. (1988) reported that row spacing of funnel did not effect on the plant height but number of umbel and seed yield per plant was increased at the wider spacing.

Boroomand Rezazadeh *et al.* (2009) conducted an experiment to study the effect of planting date and plant density on morphologic traits and oil percentage of Ajowan and reported that with increasing leaves weight, number of capsule, number of stem, 1000-seed weight increased. Because with increasing number of stems, number of leaf increase and levels of chlorophyll increase also, consequently photosynthesis process and food manufacturing are well done and grain size and weight increase as a result.

Table 8. Interaction effect of variety and spacing on 1000-seed weight and seed yield

Treatments	1000-seed weight (g)	Seed yield (kg/ha)
V_1S_1	2.230 c	1107.11 f
V_1S_2	2.340 a-c	1108.23 f
V_1S_3	2.390 ab	1169.07 e
V_1S_4	2.310 bc	1346.59 c
V_1S_5	2.397 ab	1416.67 b
V_1S_6	2.357 ab	1288.37 d
V_2S_1	2.360 ab	1300.19 d
V_2S_2	2.410 ab	1282.17 d
V_2S_3	2.430 ab	1294.78 d
V_2S_4	2.427 ab	1416.21 b
V_2S_5	2.440 a	1458.19 a
V_2S_6	2.420 ab	1445.79 b
LSD	0.1071	37.19
CV%	4.72	5.01
Level of Significance	*	**

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

V_1 = Local, V_2 = BARI Kalozira-1

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

CHAPTER 5

SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during rabi season of November 2012 to March 2013 to study the yield performance of Black cumin (*Nigella sativa* L.) in response to variety and population density. Two varieties and six levels of spacing were used in the experiment. The two varieties were V_1= Local (collected from Vikrampur), V_2= BARI Kalozira-1 and six spacings were as follows: S_1= 15cm x10 cm, S_2= 20cm x10 cm, S_3= 25cm x10 cm, S_4= 15cm x15 cm, S_5= 20cm x15 cm and S_6= 25cm x15 cm. The experiment was laid out in randomized complete block (RCBD) design having twelve treatments with 3 replications. The size of unit plot was 3 m x 1.2 m. The total number of treatments was 12 and the number of plots were 36. Data were collected on the following parameters-plant height (at first flowering, at 50% flowering and at harvest), number of primary and secondary branches plant^{-1}, number of plants m^{-2}, number of seeds capsule^{-1}, number of capsules plant^{-1}, single capsule weight (mg), weight of seeds capsule^{-1} (mg), weight of seeds plant^{-1} (g), 1000-seed weight (g) and seed yield (kg/ha). The data were analyzed statistically by F-test to examine whether the treatment effects were significant. The mean comparisons of the treatments were evaluated by DMRT (Ducan's Multiple Range Test).

Most of the parameters were significantly affected by the varietal differences except plant height at first flowering, at 50% flowering and number of plants m^{-2}. Number of primary and secondary branches plant^{-1}, number of plants m^{-2}, number of seeds capsule^{-1}, number of capsules plant^{-1}, single capsule weight (mg), weight of seeds capsule^{-1} (mg), weight of seeds plant^{-1} (g), 1000-seed weight (g) and seed yield (kg/ha) were significantly higher in BARI Kalozira-1 compared to Local variety. BARI Kalozira-1 produced a seed yield of 1373.09 kg/ha where Local variety produced 1239.57 kg/ha.

All of the yield parameters except 1000-seed weight were significantly influenced by various spacing used in this experiment. At initial stage plant height was higher at lower plant spacings but later this pattern was changed. Wider spacings found to be beneficial for number of primary and secondary branches plant^{-1} also. On the other hand, though at higher densities plants faced competition for nutrient, water and other components; their yield was not too far behind of those of lower densities due to higher number of plants m^{-2}. As expected, number of plants m^{-2} was significantly higher in lower spacings than the higher ones. The yield attributing factors like number of seeds capsule^{-1}, number of capsules plant^{-1}, single capsule weight (mg), weight of seeds capsule^{-1} (mg), weight of seeds plant^{-1} (g), 1000-seed weight (g) and seed yield (kg/ha) were found highest either in 20 cm × 15 cm or 25 cm × 15 cm spacing treatment.

The interaction effect of variety and spacing was found significant for all of the growth and yield contributing parameters as well as for seed yield. It was observed from the results that plant height at first flowering was the highest in Local variety treated with lowest (15 cm × 10 cm) spacing while plant height at 50% flowering was found highest in BARI Kalozira-1 combined with 15 cm × 10 cm. but at harvest plant height was recorded highest in BARI Kalozira-1 combined with 25 cm × 15 cm spacing. BARI Kalozira-1 combined with wider spacings gave significantly higher number of primary and secondary branches plant^{-1} also. Number of plants m^{-2} was significantly higher in lower spacings for both of the varieties. yield attributing factors like number of seeds capsule^{-1}, number of capsules plant^{-1}, single capsule weight (mg), weight of seeds capsule^{-1}, weight of seeds plant^{-1}, 1000-seed weight and seed yield were found highest either in 20 cm × 15 cm or 25 cm × 15 cm spacing treatment in BARI Kalozira-1. Seed yield was recorded highest (1500.29 kg/ha) in BARI Kalozira-1 with the spacing 20 cm × 15 cm.

Based on the above results the following conclusions might be drawn-

i) BARI Kalozira-1 performed better than local variety in respect of growth, yield and yield contributing parameters.

ii) The spacing of 20 cm x 15 cm produced significantly maximum yield components and thus gave the highest seed yield.

iii) BARI Kalozira-1 in combination with 20 cm x 15 cm spacing gave the maximum seed yield of black cumin.

The following recommendations can be made from the above results-

- For black cumin cultivation, BARI Kalozira-1 with 20 cm x 15 cm spacing may be adopted.
- The findings of the present investigation should be confirmed by conducting similar types of experiments in different AEZs of Bangladesh.
- Oil content and other quality parameters can be studied in further researches.

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APPENDICES

Appendix I. Effect of spacing on plant height at first flowering, at 50% flowering and at last harvest

Spacing	Plant height at first flowering (cm)	Plant height at 50% flowering (cm)	Plant height at last harvest (cm)
S_1	30.20 a	38.73 a	56.60 b
S_2	29.03 ab	37.70 ab	57.60 b
S_3	27.74 b	35.93 bc	53.93 c
S_4	27.80 b	36.50 b	50.97 d
S_5	23.53 c	34.20 c	56.53 b
S_6	27.60 b	35.93 bc	59.57 a
LSD	1.578	1.871	1.564
CV%	7.61	6.52	3.31
Level of Significance	*	*	*

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Appendix II. Effect of spacing on primary branches plant^{-1}, secondary branches plant^{-1} and number of plants m^{-2}

Spacing	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}	Number of plants m^{-2}
S_1	6.900 c	13.66 e	40.90 a
S_2	6.900 c	14.50 d	39.10 b
S_3	7.500 b	15.86 c	36.63 c
S_4	7.500 b	16.26 b	33.65 d
S_5	8.034 a	16.80 a	31.34 e
S_6	8.300 a	16.70 a	27.49 f
LSD	0.3355	0.2617	0.1564
CV%	3.73	4.65	4.84
Level of Significance	*	*	**

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm

Appendix III. Effect of spacing on weight of seeds capsule^{-1}, weight of seeds plant^{-1}, number of capsules plant^{-1}, single capsule weight, number of seeds capsule^{-1}, 1000-seed weight and seed yield

Spacing	Weight of seeds capsule^{-1} (mg)	Weight of seeds plant^{-1} (g)	Number of capsules plant^{-1}	Single capsule weight (mg)	Number of seeds capsule^{-1}	1000-seed weight (g)	Seed yield (kg/ha)
S_1	203.0 d	2.938 e	19.87 c	225.0 d	89.83 c	2.335	1204.28 cd
S_2	207.2 c	3.055 e	22.30 b	251.7 c	92.17 bc	2.365	1195.29 d
S_3	219.3 b	3.365 d	23.24 b	275.8 b	92.83 bc	2.39	1231.37 c
S_4	217.5 b	4.106 c	20.41 c	270.3 b	95.33 b	2.403	1381.62 b
S_5	235.5 a	4.652 b	25.60 a	302.5 a	97.15 ab	2.425	1458.19 a
S_6	235.0 a	4.966 a	25.20 a	314.1 a	101.0 a	2.392	1366.41 b
LSD	3.496	0.2617	1.492	13.20	5.120	1.492	27.84
CV%	5.05	8.26	5.55	3.48	5.28	4.72	5.01
Level of Significance	*	**	*	*	*	NS	**

Means within a column having different letters are significantly different by DMRT

* - Significant at 5% level, ** - Significant at 1% level, NS- not significant

S_1 = 15 cm × 10 cm, S_2 = 20 cm × 10 cm, S_3 = 25 cm × 10 cm, S_4 = 15 cm × 15 cm, S_5 = 20 cm × 15 cm and S_6 = 25 cm × 15 cm