PLANTING GEOMETRIC EFFECT ON GROWTH AND YIELD OF RAPESEED AND MUSTARD

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CERTIFICATE

This is to certify that the thesis entitled **"PLANTING GEOMETRIC EFFECT ON GROWTH AND YIELD OF RAPESEED AND MUSTARD"** submitted to the Faculty of Agriculture**,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **MST. RIFAT JAHAN,** Registration. No. **15-06878** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

____
(Prof. Dr. H.M.M. Tariq Hossain)
Supervisor

Dedicated
To

My beloved parents
and
My family

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ABSTRACT

The field experiment was conducted at the farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the Rabi season (November - February) of 2015 - 2016 to study the planting geometric effect on growth and yield of rapeseed and mustard. The experiment was laid out in a split-plot design with three replications. Two factors of which were variety, (V_1= BARI Sarisha-11, V_2= BARI Sarisha-14 and V_3= BARI Sarisha-17) allocated to the main plots and the planting geometry, (S_1 = Random geometry, S_2 = 25 cm × 5 cm, S_3 = 30 cm × 5 cm, S_4 = 35 cm × 5 cm and S_5 = 40 cm × 5 cm) which were assigned to sub plots. Data were collected from the experimental field also recorded during the period from 30 to 75 DAS at 15 days interval and at harvest. Plant height was significantly influenced by different variety. As varietal effect, BARI Sarisha-11 produced the maximum plant height (127.36 cm), no. of branches plant^{-1} (13.74), siliquae plant^{-1} (179.58), 1000 seeds weight (3.46 g), seed yield (1.68 t ha^{-1}), stover yield (3.88 t ha^{-1}) and biological yield (5.51 t ha^{-1}) at harvest. Number of leaves plant^{-1} affected significantly due to planting geometry with variety. The planting geometry affected significantly on the number of seeds siliqua^{-1}, seed yield, 1000 seeds weight, stover yield, biological yield and harvest index but showed insignificant difference on siliqua length. The seed yield varied significantly among varieties. In the case of planting geometry S_3 (30 cm × 5 cm) showed the highest no. of siliquae plant^{-1} (141.13), 1000 seeds weight (3.43 g) and biological yield (4.28 t ha^{-1}) however S_2 (25 cm × 5 cm) resulted with the highest seed yield (1.52 t ha^{-1}) and harvest index (37.07 %) only. Although the wider spaced plants appeared with vigorous growth and yield but failed to produce maximum yield due to lack of optimum plant population. Among the combination of treatments, BARI Sarisha-11 ranked top in seed yield (2.15 t ha^{-1}), stover yield (4.29 t ha^{-1}) and biological yield (6.44 t ha^{-1}) when it was sown with S_4 (35 cm x 5 cm) planting geometry, where seed yield and stover yield statistically similar to S_3 (30 cm x 5 cm) geometric arrangement.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
Cm^2	Square centimeter
^0C	Degree Celsius (Centrigrade)
cv.	cultivars
CV(%)	Percentage of Co-efficient of Variance
DAS	Days after sowing
df	Degrees of freedom
et al.	and others (at elli)
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
HI	Harvest Index
hr	Hour
i.e.	In other words
Kg	Kilogram
Kg ha^{-1}	Kilogram per hectare
LSD	Least significant difference
MoP	Muriate of Potash
m	Meter
m^2	Square meter
no.	Numbers

LIST OF ACRONYMS

NS	Non significant
P^H	Hydrogen ion conc.
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
t	Ton
viz.	Videlicet (namely)
wt.	Weight
%	Percent

Chapter I
Introduction

CHAPTER I
INTRODUCTION

Rapeseed and Mustard (*Brassica spp*.) are commonly known as mustard belongs to the family *Brassicaceae*, which is one of the most important and widely grown oilseed crop of winter season in Bangladesh. Botanically it has three species, *Brassica campestris* L. *Brassica napas* L. and *Brassica juncea* L. Among the species *Brassica campestris* and *Brassica napus* are regarded as "rapeseed" while *Brassica juncea* is noted as "mustard". The adventages of *Brassica juncea* over *Brassica napus* include more vigorous seedling growth, quicker ground covering ability, greater tolerance to heat and drought and enhanced resistance to the blackleg fungus, *leptosphaeria maculans* (Woods *et al*., 1991; Burton *et al*., 1999). The pods of *Brassica juncea* shatter less readily and seeds potentially contain a higher percentage of oil plus protein because the yellow seed coat is thinner. In Bangladesh, *Brassica rapa* L. is the main oil yielding species of *Brassica spp*. (FAOSTAT, 2013).

Mustard (*Brassica spp*.) is one of the most important oil yielding crops of the world after soybean and groundnut (FAO, 2012). But it occupies the first position in respect of area and production among the oil crop grown in Bangladesh (DAE, 2015). In Bangladesh the edible oil production is 3,76,000 metric tons of which rapeseed *(Brassica spp*.) covers 62% of the total annual oil (MOA, 2006). Worldwide the total annual production of rapeseed along with mustard is 63.04 million tons of seed from an area of 34.33 million hectares (FAO, 2013). At present about 0.234 million hectares of land are under rapeseed-mustard cultivation in Bangladesh with oil yield of 0.203 million tons per year (BARI, 2011). Rapeseed-mustard represents an important source of cooking oil in Bangladesh and meets around one third of the edible oil requirement of the country (Ahmed, 2008). Our internal production can meet only about 21% of total demand and the rest other 79 % is met by the import (Begum *et al*., 2012). Due to insufficient production, a huge amount of foreign exchange involving over 160 million US Dollar is being spent every year for importing edible oils in Bangladesh (Rahman, 2002).

By using HYV seeds supported with improved agronomic practices including planting geometry plays a vital role in increasing the yield level of mustard. The yield of HYV cultivars ranges from 1400 to 2500 kg ha^{-1} (BARI, 2002). Though, the yield of rapeseed-mustard is increasing obviously with the introduction of HYVs with improved of management practices but the average yield per hectare of mustard in Bangladesh is much lower compared to Germany, France, UK and Canada producing 6667 kg ha^{-1}, 5070 kg ha^{-1}, 3264 kg ha^{-1}, 3076 kg ha^{-1} respectively (FAO, 2003).

However, in oilseed rape and mustard row spacing or plant density may vary considerably worldwide; depending on the environment, production system and cultivar. Previous studies have shown that plant geometry is an important factor that affects rapeseed-mustard yield. Population density, as a result of planting geometry also influences growth, yield and yield contributing characters in rapeseed production (Johnson *et al.*, 2003). Planting geometry is row to row and plant to plant distance, which play a vital role in the production of rapeseed and mustard. Suboptimal planting geometry, wider rows and plant spacing lead to low population which in turn fail to compensate the yield obtained in optimum plant stand while narrower row and plant spacing increase the inter and intra-plant competition leading to poor growth and development and dry matter accumulation resulting in poor yield (Singh and Dhilon, 1991). Verma (1990) reported closer row spacing of 30 cm for better yields. Whereas, Sierts and Geister (1987) suggested that plant density affects the plant population, number of pods $plant^{-1}$, number of seeds $plant^{-1}$ and hence seed yield $plant^{-1}$. Therefore, a uniform distribution of plants per unit area is a prerequisite for yield stability that securing good yield of a crop (Diepenbrock, 2000).

Keeping above facts in mind, an experiment was conducted to study the growth, yield and yield attributes of rapeseed-mustard varieties grown with different planting geometry with the following objectives:

Objectives:

1. To investigate the effect of plant population maintained by planting geometry in rapeseed-mustard;
2. To optimize a planting geometry for yield maximization of a variety under study;
3. To evaluate the varietal performance in terms of plant growth and yield of rapeseed-mustard and
4. To find out the interactions between variety and planting geometry on the growth and yield of rapeseed-mustard.

Chapter II
Review of Literature

CHAPTER II
REVIEW OF LITERATURE

Rapeseed and Mustard are the principle oilseed crop in Bangladesh which contributes to a large extent in the national economy. Among crop species the rapeseed-mustard complex is probably the one group of crop plants that has received the least attention from the physiologist and agronomist. The research findings in this regard are meagre. Only some limited studies have so far been done in respect of agronomic management practices of the crop particularly the variety and planting geometry. However, a number of such studies have been carried out in different parts of the world. Some of the pertinent works on these have been reviewed in this chapter.

2.1 Effect of variety

2.1.1 Plant height

Plant height of rapeseed and mustard differs among the varieties depending on their genetic makeup. Each varieties have different plant types.

Hossain *et al*. (2012) was carried out an experiment at the Regional Agricultural Research Station (RARS), Jessore (AEZ-11, High Ganges River Floodplain) during 2003-2006 to evaluate the response of different varieties of mustard to boron application. Boron application was made at 0 and 1 kg ha^{-1}. The varieties chosen from *B. campestris* were BARI Sarisha-6, BARI Sarisha-9 and BARI Sarisha-12. The *B. napus* varieties were BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha-13. Varieties BARI Sarisha-10 and BARI Sarisha-11 were from the *B. juncea* group. The seed yield was positively and significantly correlated with the yield contributing characters viz. siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and 1000 seeds weight, but not with plant height.

Alam (2004) reported that plant height of rapeseed and mustard differs among the varieties depending on their genetic makeup. There are three species of *Brassica* viz. *Brassica campestris, Brassica juncea* and *Brassica napus* differ from one another with respect to plant growth, development and yield. Sana *et al*. (2003) concluded that the final plant height reflects the growth behavior of a crop. Besides genetic characteristics, environmental factors also play a vital role in determining the height of the plants. Ahmed *et al*. (1999) observed that the tallest plant (102.56 cm) was recorded in the variety Daulat. No significant difference was observed in plant height of BARI sarisha-6 and Nap-8509. Ali *et al*. (1998) examined significant variation on plant height of different varieties of rape and mustard. In addition, it was reported that different *Brassica* varieties differed significantly regarding their plant heights (Reddy and Reddy, 1998).

Hussain *et al.* (1996) stated that the highest plant was in Narenda (175 cm), which was identical with AGA-95-21 (166 cm). The shortest variety was Tori-7. Mondal and Islam (1993) found that variety had significant effect on plant height. They found the highest plant height (134.4 cm) on the variety J-5004, which was identical with SS-75 and was significantly taller than JS-72 and Tori-7. Bhuiyan (1989) found significant variation in plant height due to different varieties of mustard and rape. According to Bhargava and Tomar (1982) the ideotype should combine the major yield attributes of varieties having plant height ranges between 1.00 - 1.25 m.

2.1.2 Branches plant^{-1}

The yield contributing character viz. no. of branches are very important determinant of the seed yield of rapeseed and mustard. Varieties among *Brassica* species showed a marked variation in the number of branches per plant and their arrangement.

Khanlou and Sharghi (2015) conducted an field experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety, where the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety has simple significant on the number of branches in plants ($P<0.05$). Aziz (2014) observed that numbers of primary branches were significantly affected by variety throughout the life cycle. At harvest, maximum numbers of primary branches were recorded at SAU Sarisha-2 which was statistically similar with BARI Sarisha-15 and the minimum numbers of primary branches were recorded at BARI Sarisha-11 which was statistically similar with BARI Sarisha-13.

Mamun *et al*. (2014) carried out a field experiment to evaluate the effect of variety and different plant densities on growth and yield of rapeseed mustard during Rabi 2011-12 under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities. BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15. Oad *et al*. (2001) conducted a study on rapeseed (*B. napus*) cv. P 53 and maintained 3 row spacing (30, 45 and 60 cm). They observed that branches plant^{-1} was affected significantly by 60 cm row spacing.

BARI (2000) observed under poor management, the number of primary branches plant^{-1} was higher (4.2) in the variety SS-75 and lower (2.1) in the variety BAR1 Sharisa-8. The higher number of primary branches plant^{-1} was found in BARI Sharisa-6 (5.5) and lower in BARI Sharisa-8 under medium management. Under proper management the highest number of primary branches plant^{-1} was with BARI Sharisa-6 (5.9) and lower (3.0) with Nap-248. Hussain *et al*. (1996) reported that the varieties were statistically different with respect to number of primary branches. The maximum number of primary branches was recorded in the Hyola-401(5.0) and the minimum number was recorded in Semu-249/84. Mondal *et al*. (1992) stated that most of the lower branches were unproductive in Sonali sarisha.

2.1.3 Siliquae plant^{-1}

Number of siliquae plant^{-1} is an important determinant of the seed yield of rapeseed and mustard.

Aziz (2014) found that number of siliquae plant^{-1} was significantly affected by variety. Maximum number of siliquae plant^{-1} was recorded at BARI Sarisha-11 and minimum number was observed at BARI Sarisha-15. Hossain *et al*. (2012) stated that BARI Sarisha-11 produced the highest number of siliquae plant^{-1} followed by BARI Sarisha-10. BARI Sarisha-7, BARI Sarisha-8, and BARI Sarisha-13 produced statistically similar number of siliquae plant^{-1} in the control plots.

Fathy *et al*. (2009) carried out a study at the Agricultural Research Station, Hada El-Sham, King Abdulaziz University. Four canola varieties, Callypso, Pactole, Sero-4 and Sero-6 varieties were tested under four nitrogen fertilizer rates (0.00, 92, 138 and 184 kg N ha^{-1}) and stated that Pactale and Sero-6 varieties produced the highest number of siliquae plant^{-1} significantly dominated over the Sero-4 and Callypso variety. Raj *et al*. (2001) conducted an experiment in Jodhpur and observed that number of siliquae plant^{-1} higher in cultivar Pusa Bold (257) compared to cultivar TS9 (198).

Reddy and Reddy (1998) reported that significant differences in the number of siliquae plant^{-1} among different cultivars of *Brassica* species. Mondal *et al.* (1992) stated that maximum no.

of siliquae plant^{-1} was variety J-5004, which was identical with siliquae plant^{-1} of Tori-7. The lowest number of siliquae plant^{-1} (45.9) was found in the variety SS-75.

2.1.4 Length of siliqua

The siliqua length varies due to differences in genotypes. Different variety produces different length of siliqua.

Aziz (2014) observed that siliqua length of mustard and rapeseed plant was significantly affected by variety. The biggest siliqua length was recorded at BARI Sarisha-13 and the smallest siliqua length was observed at BARI Sarisha-11. Masud *et al.* (1999) observed significant genetic variation in siliqua length among seven genotypes of *B. campestris* and a cultivar of *B. napus*. Similar result for siliqua length was found by Lebowiz (1989) and Olsson (1990).

Hussain *et al*. (1996) found that the varieties were statistically different with respect to length of siliqua. The longer siliqua (7.75 cm) was found in the hybrid BLN-900 which was identical to Sampad, BARI sarisha-6, Hyola-51 and Hyloa-101. The shortest siliqua length (4.62 cm) was found in the hybrid Semu-249/84 which was identical to those of AGH-7, Semu-DNK-89/218 and Tori-7. The longest siliqua (8.07 cm) was found in Hyola-401 and BLN-900. Gangasaran *et al*. (1981) stated that regression analysis revealed that siliqua weight significantly influenced the seed yield whereas; siliqua length and siliqua diameter had a marginal effect. They further noticed that siliqua length and number served as the most reliable index of selection for yield improvement in brown sarson (*B. campestris* var.sarson).

2.1.5 Seeds siliqua^{-1}

The number of seeds siliqua^{-1} also contributes materially towards the final seed yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield attributes of rapeseed and mustard.

Hossain *et al*. (2012) observed that the number of seeds siliqua^{-1} also varied significantly among the varieties due to B application. The average number of seeds siliqua^{-1} ranged from 12.00 to 20.67 and 13.22 to 27.44 in the B untreated and treated plots, respectively. The maximum average number of seeds siliqua^{-1} (27.44) was recorded in B treated BARI Sarisha-8. Akhter (2005) found that variations in number of seeds siliqua^{-1} among the varieties were found statistically significant. The highest number of seeds siliqua^{-1} (23.80) was found from

BARI sarisha-8 and the lowest was recorded as 10.78 from BARI Sarisha-11.The variety BARI Sarisha-10 and BARI Sarisha-7 showed the number of seeds siliqua^{-1} as 12.64 and 22.03, respectively. Jahan and Zakaria (1997) investigated that BARI Sarisha-6 produced the highest number of seeds siliqua^{-1} (26.13) which was at par with Sonali (23.5) and Jatarai (22.8). The lowest number of seeds siliqua^{-1} (18.0) was found in Tori-7 (205), AGA-95-21(20.7) and BARI sarisha-8 (21.6).

2.1.6 1000 seeds weight

It is also an important character which reflects the seed size. It varies from genotype to genotype and is influenced by some production factors.

Akhter (2005) stated that the highest weight of 1000 seeds (3.8 g) was recorded from BARI Sarisha-7 with harvesting the crop at 90 days. The lowest 1000 seeds weight (2.63 g) was recorded from BARI Sarisha-10 with harvesting at 100 days, which was similar with the same variety harvesting at 90 and 110 days. Sana *et al.* (2003) reported that significant differences for 1000 seeds weight among different *Brassica* varieties. Singh *et al*. (2002) observed that 1000 seeds weight ranged between 2.36 and 4.20 g in F_1 and 2.46, 4.30 g in F_2 population. Where significant genetic variations were observed among a large number of strains of *B. campestris*, *B. napus* and *B. juncea.* Singh (1986), Chowdhury and Malik (1987), Jain *et al*. (1988), Yin (1989), Yadav *et al*. (1993), Kudla (1993), Kumar and Singh (1994) and Hussain *et al*. (1998).

Raj Singh *et al*. (2002) showed significantly higher 1000 seeds weight in cultivar RH 30 (6.2 g) over Varuna (5.6 g). Rana and Pachauri (2001) investigated an experiment at New Delhi at Indian Agricultural Research Institute in sandy loam soil and quoted that cultivar Bio 902 recorded higher 1000 seeds weight (3.16 g) compared to TERI (OE) R 15 (2.18 g). Mondal and Wahab (2001) summerised that weight of 1000 seeds varied from variety to variety and species. They found 1000 seeds weight 2.50-2.65 g incase of improved Tori-7 (*B. campestris*) and 1.50.80 g in case of Rai-5 (*B. juncea*). BARI (2001) reported that significant variation in 1000 seeds weight of rapeseed and mustard in different variety and the highest weight of 1000 seeds was observed in variety Jamalpur-1 and the lowest in BARI sarisha-10.

Karim *et al*. (2000) observed that varieties showed significant variation in the weight of thousand seeds. They found higher weight of 1000 seeds in J 3023 (3.43 g) J 3018 (3.42 g) and J 4008 (3.50 g). Hussain *et al*. (1998) observed significant variation in case of 1000 seeds weight as influenced by different varieties. They found Hyola 401 had the highest 1000 seeds weight (3.4 g) and the lowest 1000 seeds weight was recorded in Tori 7 (2.l g). Jahan and Zakaria (1997) conducted an experiment to find out the performance of different varieties of rapeseed and mustard. They found variation in 1000 seeds weight and the highest seed weight in the variety BLN 900 (3.37 g) and the lowest in Tori 7 (2.27 g).

2.1.7 Seed yield

Seed yield is an important polygenic character which is highly influenced by other characters and production factors. A good number of reports revealed that there were variability among different genotypes of rapeseed and mustard.

Aziz (2014) examined an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Result indicated that seed yield of rapeseed plant was significantly affected by different variety. The highest seed yield (3.74 t ha^{-1}) was obtained at BARI Sarisha-11 and the lowest seed yield (2.54 t ha^{-1}) was found at BARI Sarisha-15. Islam and Mahfuza (2012) carried out an experiment at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2010-2011. BARI Sarisha-11 produced the highest seed yield (1472 kg ha^{-1}) while BARI Sarisha-14 the lowest (1252 kg ha^{-1}). The highest mean seed yield was recorded at maturity stage (1480 kg ha^{-1}).

Goyal *et al*. (2006) stated that the highest seed yield of variety varuna (6.13 g per plant) followed by Kranti (6.10 g per plant). The highest seed yield as recorded in 6th November sowing as compared to delayed sowings. Varuna observed to be a good yielder in all temperature region as compared to the varieties. Behera *et al.* (2002) carried out a field experiment to study the effect of plant population and sulfur levels on yield of mustard (*B. juncea*) and found interaction effects of variety and plant population significant on pooled seed yield and recorded the maximum seed yield at the intermediate population level. Rahman (2002) stated that yield variation existed among the varieties whereas the highest yield was observed in BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha-11 (2.00-2.50 t ha^{-1}) and the lowest yield in variety Tori-7 (0.95-1.10 t ha^{-1}).

Raj *et al.* (2001) conducted an experiment in Jodhpur and observed that seed yield recorded higher in cultivar Pusa Bold (1900 kg ha^{-1}) compared to cultivar Local (1470 kg ha^{-1}).

Significant differences in the seed yield among different varieties of *Brassica* species were reported (Reddy and Reddy, 1998). Mondal *et al*. (1995) reported that after continuation efforts of plant breeders of Oilseed Research Centre, BARI had developed several short duration genotypes of *B. napus* with high yield potential. The genotype, Nap-3 was one of these genotypes (Jahan and Zakaria, 1997). Mendham *et al*. (1990) quoted that seed yield was variable due to varietal difference in species of *B. napus*. Findings were similarly noticed by Chauhan *et al*. (1993).

2.1.8 Stover yield

Aziz, K.M.T. (2014) observed that stover yield of mustard and rapeseed plant was significantly affected by different variety. The highest stover yield (6.95 t ha^{-1}) was obtained at BARI Sarisha-13 and the lowest stover yield (3.77 t ha^{-1}) was found at BARI Sarisha-15. Hossain *et al*. (2012) examined that BARI Sarisha-8 (*Brassica napus*) had the maximum response to B application. On the other hand, BARI Sarisha-11 (*Brassica juncea*) showed the minimum response. The mean yields of *B. campestris* varieties were 2224-2702 kg ha^{-1}, *B. napus* varieties were 2850-3199 kg ha^{-1}, and yields of *B. juncea* varieties were 3080-3528 kg ha^{-1} for the B control plots.

Akhter (2005) evaluated that the highest straw yield (3.68 t ha^{-1}) was found from BARI Sarisha-7 that was similar (3.42 t ha^{-1}) with the variety BARI Sarisha-11. The lowest straw yield was (3.08 t ha^{-1}) recorded from BARI Sarisha-10 that was similar to the variety BARI Sarisha-8 (3.09 t ha^{-1}). BARI (2001) reported that in case of poor management ISD local gave the highest stover yield (3779 kg ha^{-1}) and the lowest stover yield (1295 kg ha^{-1}) was found from Nap-248. In case of medium management highest weight (6223.3 kg ha^{-1}) was same variety and under high management conditions the lowest (3702.3 kg ha^{-1}) from PT-303. The highest stover yield 6400 kg ha^{-1} was obtained from the variety Rai-5 and the lowest stover yield 4413.3 kg ha^{-1} was obtained from Tori-7.

2.1.9 Biological yield

In Hissar, Raj *et al*. (2002) showed that biological yield recorded significantly higher in Laxmi cultivar (1370 kg ha^{-1}) over BJH-1 (1190 kg ha^{-1}). Rana and Pachauri (2001) were reported that the cultivar Bio 902 recorded higher biological yield of 7250 kg ha^{-1} compared to cultivar TERI (OE) M 21 (6850 kg ha^{-1}).

Khoshanazar *et al*. (2000) investigated that compared different mustard and rapeseed cultivars and reported that all cultivars differed significantly in biological yield and seed oil yields.

2.1.10 Harvest index (HI)

Sultana *et al*. (2009) observed that SAU Sarisha-1 exhibited the highest value (37.10%) of harvest index and Improved Tori-7 showed the lowest harvest index (37.34%). SAU Sarisha-1 and Kollania showed statistically similar values of harvest index. Akhter (2005) studied that variations in harvest index among the varieties were found statistically significant. The highest harvest index (31.73%) was recorded from BARI Sarisha-10 that was similar (30.18%) with the variety BARI Sarisha-8. The lowest harvest index (27.79%) was recorded from BARI Sarisha-7 that was also similar to BARI Sarisha-11 (28.90%) and BARI Sarisha-8.

Raj *et al.* (2002) carried out an experiment in Hissar in sandy loam soil and observed that harvest index was significantly higher in cultivar RH 10 (0.19) over Laxmi (0.17). Islam *et al*. (1994) observed that variety had significant effect on harvest index (%) of rapeseed and mustard. They found that the highest HI in the variety RS 72 which was identical to Dulat and the lowest in Sonali Sharisha (21.90%) followed by Sambal (26.7%).

2.2 Effect of planting geometry

2.2.1 Plant height

Khanlou and Sharghi (2015) conducted an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety, in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety has significant on height of plant, diameter of stem. The effect of planting distance has a significant effect on the plant height ($P<0.01$). Aziz (2014) carried out an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the Rabi period in 2013-14. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Sowing technique treatments were Broadcasting, Line Sowing, Raised Bed and System of Mustard Intensification (SMI). Result showed that plant height was significantly varied among the sowing techniques.

Hossain *et al*. (2013) conducted an experiment at Agronomy field laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, to study the effect of irrigation and sowing method on yield and yield attributes of mustard. Sowing method had significant effect on plant height. Line sowing produced the tallest plant (96.51 cm) and the shortest one (94.26 cm) was found at broadcast method. Oad *et al*. (200l) studied to determine the eftect of row spacing on growth and yield of rapeseed (*Brassica napus*). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing (30, 45 and 60 cm). They observed that plant height was affected significantly by 60 cm row spacing that produced the tallest plant. Sher *et al*. (2001) were studied on effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.) They found that number of plants (m^{-2}), plant height at maturity (cm), was significantly affected both by varying planting pattern and inter plant spacing.

Ahmed *et al*. (1999) quoted that the tallest plant was (102.56 cm) in the variety Daulat. No significant difference was observed in plant height BARI Sharisa-6 and Nap-8509. Butter and Aulakh (1999) were studied on Indian mustard cv. RLM 6l9 and maintained 3 row spacings l5, 22.5 and 30 cm. They observed that row spacing had no significant effect on plant height. Chauhan *et al*. (1993) observed no significant effect of row spacing on the plant height of toria. They evaluated three row spacing viz. 20, 30 and 40 cm. The maximum plant height was found at 20 cm row spacing which was similar to the plant height found at 30 cm row spacing and lowest at 40 cm row spacing. It showed that plant height decreased with the increase of row spacing. Sharma (1993) stated positive relationship between plant height and increasing row spacing of rapeseed. During 1988-1989 among three row spacing of 30, 37.5 and 45 cm for the sowing of rapeseed, they found the tallest plant with 45 cm row spacing which was heigher than 37.5 cm at 30 cm row spacing. Scarisbric *et al.* (1982) observed negative relationship between plant heights with higher plant density.

2.2.2 Branches plant^{-1}

Aziz (2014) carried out an experiment to evaluated the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. Result indicated that number of primary branches was not significantly affected by sowing technique at 30 DAS but significant at 45, 60 and 75 DAS and at harvest. At harvest, maximum numbers of primary branches were recorded at SMI technique and minimum numbers of primary branches were recorded at broadcast sowing technique which was statistically similar with line sowing. Hossain *et al.* (2013) suggested that sowing method had significant effect on the production of total branches plant^{-1}. Line sowing method produced the highest number of branches plant^{-1} (8.42). The lowest number of total branches plant^{-1} (8.03) was observed in the broadcast method.

Sam-Daliri *et al*. (2011) conducted a study on factorial experiment in randomized complete block design in three replicates in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including new lines (crossed two varieties of H19, oliath), Zarfam and Pahnab-e-joybar (Local varieties). The results showed that simple varieties has significant on the number of branches in plants ($P<0.05$). Oad *et al*. (2001) carried out an experiment in Pakistan to determine the effect of row spacing on growth and yield of rapeseed (*B. napus*). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing (30, 45 and 60 cm). They observed that branches plant^{-1} was affected significantly by row spacing and among them 60 cm row spacing proved the best.

Butter and Aulakh (1999) conducted a study on Indian mustard cv. RLM 619 and maintained 3 row spacings 15, 22.5 and 30 cm). They observed that row spacing had no significant effect on number of secondary branches plant^{-1}. Tomar and Namedo (1989) conducted a study on *Brassica campestris* var. Toria and observed increased number of branches plant^{-1} when seed rate of rapeseed was maintained 5 kg ha^{-1}.

2.2.3 Siliquae plant^{-1}

Planting geometry has a remarkable effect in producing more number of fertile siliquae plant^{-1}. Wider spacing facilitated favorable environment for producing more siliquae than closer spacing.

Hossain *et al*. (2013) reported that in the closer plant population at broadcasting method, there were competitions for light, space, nutrients and environments. The lowest number of branches plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1} were produced. Hasanuzzaman (2008) conducted an experiment at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh. Accumulation of dry matter in siliqua, number of siliquae plant^{-1}, length of siliqua and seeds per siliqua of rapeseed (*Brassica campestris* L.) plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm). Number of siliquae plant^{-1}

was affected by different irrigation levels and row spacing and the highest number of siliquae was produced by two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing. Siddiqui (1999) suggested that wider spacing facilitated favorable environment for producing more siliquae than closer spacing. Row spacing had remarkable effect in producing more number of fertile siliquae plant^{-1} and observed that number of siliquae plant^{-1} were higher in 30 cm row spacing (Thakur, 1999).

Gurjar and Chauhan (1997) carried out an experiment in Gwalior and observed that number of siliquae plant^{-1} recorded higher with 30 cm × 15 cm row spacing (444) as compared to 45 cm × 15 cm row spacing (356). Thakuria and Gogoi (1996) conducted a field experiment to evaluate *Brassica juncea* cv. TM 2, TM 4 and Varuna at 2 row spacing (30 and 45 cm). The effect of cultivars and row spacing on seed yield and yield attributes was significant increased at 45 cm row spacing but no. of siliquae plant^{-1} was decreased. Sharma (1992) carried out an experiment at College of Agriculture, Gwalior (Madhya Pradesh) and concluded that a row spacing of 30 cm recorded higher number of siliquae plant^{-1} (233.4) as compared to 45 cm row spacing (228.4).

2.2.4 Length of siliqua

Hossain *et al*. (2013) quoted that siliqua length was not significantly influenced by sowing method. Numerically, the longest siliqua (5.69 cm) was found at line sowing method and the shortest one was obtained from broadcasting method.

Singh and Verma (1993) observed that higher length of siliqua with 60 cm row spacing (4.26 cm) was found as compared to 30 cm row spacing (4.14 cm). Singh and Singh (1987) also observed an experiment with 3 row spacing (30, 45 and 60cm) in mustard found that length of siliqua however, remained unaffected by plant densities.

2.2.5 Seeds siliqua^{-1}

The number of seeds siliqua^{-1} is an important determinant of the seed yield in rapeseed-mustard. So, row spacing is a vital factor in producing optimum number of seeds siliqua^{-1}.

Hasanuzzaman (2008) conducted an experiment on rapeseed (*Brassica campestris* L.) plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm) and stated that number of seeds siliqua^{-1} were significantly affected by the combination of irrigation levels and 40 cm row spacing. Yadav *et al*. (1994) were reported that a row spacing of 45 cm × 20 cm recorded significantly higher number of seeds siliqua^{-1} (15) as compared to 45 cm × 10 cm (13.0).

Singh and Verma (1993) found that a row spacing of 60 cm recorded greater number of seeds siliqua^{-1} (11.55) compared to 30 cm row spacing (10.80). Mishra and Rana (1992) reported that a row spacing of 60 cm recorded higher number of seeds siliqua^{-1} (13.2) as compared to 30 cm or 45 cm row spacing (13.1). Sharma (1992) studied a field experiment at College of Agriculture, Gwalior (Madhya Pradesh) and concluded that row spacing of 45 cm recorded more number of seeds siliqua^{-1} (14.18) as compared to 30 cm row spacing (13.10).

2.2.6 1000 seeds weight

Hossain *et al*. (2013) were observed that the weight of 1000 seeds was not influenced by sowing method. The maximum weight of 1000 seeds (3.49 g) was obtained from line sowing method and the minimum weight of 1000 seeds (3.43 g) was found in broadcasting method. Atlassi *et al*. (2008) carried out an experiment in order to investigate the effect of planting pattern on morphology, yield and yield components of canola. The experiment was laid on split-plot design. The treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and RGS 003) as sub-plots. The effect of planting pattern on 1000 seeds weight was more significant.

Sher *et al*. (2001) found out on the effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.). They found that number of pods plant^{-1}, 1000 seeds weight and seed oil content were significantly affected both by varying planting pattern and inter plant spacing. Khan *et al*. (2000) revealed that one of the economically most important yield parameter of the crop, the 1000 seeds weight and seed yield as affected by sowing method. Crop grown with ridge sowing method showed significantly the highest 1000 seeds weight as compared to drill sowing and furrow sowing, while broadcast sown crop produced the lowest 1000 seeds weight. Chauhan *et al.* (1993) found a positive relation between row spacing and 1000 seeds weight. They found a significant effect of row spacing (20, 30 and 40 cm) on 1000 seeds weight of Toria. Among the row spacing 40 cm row spacing gave highest weight of 1000 seeds while 20 cm row spacing gave lowest weight.

Sharma (1992) stated a significant increasing rate of 1000 seeds weight with the increase of row spacing in different mustard varieties. He conducted an experiment with four row spacing viz. 30.0, 33.5, 37.5 and 45.0 cm. Among all row spacing maximum seed weight was found from 45 cm row spacing which was significantly higher and lowest seed weight was found from 33.5 cm row spacing. Tomar and Namedo (1989) reported a study on *Brassica campestris* var. Toria, when population density was maintained 22.2 plants m^{-2} there was increment in 1000 seeds weight conditions. Singh and Singh (1987) conducted an experiment with 3 row spacing (30, 45 and 60 cm) in mustard found that the weight increased with the increase of row spacing and the highest seed weight was found from 60 cm row spacing and 30 cm row spacing gave the lowest weight of 1000 seeds.

2.2.7 Seed Yield

There are three species of *Brassica* viz. *Brassica campestris*, *Brassica napus* and *Brassica juncea.* Each of which differs from one another with respect to plant development, growth and yield character and significantly influenced by geometric pattern.

Atlassi *et al.* (2008) concluded an experiment on canola, the experiment was done on split-plot design. Treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and RGS 003) as sub plots. They observed that both the effects of planting pattern and variety with narrower row spacing had maximum seed yield because of more evenly distributed plants and less plant competition on rows. At Shillongani, higher seed yield of toria (*Brassica rapa* var. toria) was harvested in broadcast sowing over other practices. Toria broadcast at dough stage along with 80 kg N ha^{-1} gave the significantly highest yield (AICRP-RM, 2007).

Mottalebipour and Bahrani (2006) found that increasing row spacing significantly increased the values of almost all yield attributes but it had no significant effect on branches $plant^{-1}$, seeds $siliqua^{-1}$, seed yield and oil yield. Parminder and Sidhu (2006) observed that the oil and protein content significantly decreased as sowing was delayed from 15 October to 15 December. The highest oil content (35.3%) was recorded for the crop sown in 15 October. A row spacing of 60 cm recorded a higher protein content and lower oil content than a row spacing of 45 or 30 cm.

Faraji (2004) recorded that a decrease in row spacing resulted in the increase in number of siliqua plant^{-1}, number of seed siliqua^{-1} and seed yield. Row spacing at 12 cm and the sowing rate of 6 kg seed ha^{-1} produced the highest seed yield of 5044 kg ha^{-1}. Bilgili *et al*. (2003) found a significant response between yield contributing characters and seed yield of *B. rapa* L. It is observed that heigher seed yield 14090 kg ha^{-1} was obtained from seeding rate 200 m^{-2} at 35 cm row spacing. Singh *et al.* (2003) carried out an experiment at C. S. Azad University of Agriculture and Technology, Kanpur and emphasized that a row spacing of 45 cm resulted in the higher seed yield (2064 kg ha^{-1}). It is suggested that closer row spacing of 20 cm produces the lower seed yield of 1343 kg ha^{-1} (Kumar and Singh, 1994).

Heidari *et al*. (2003) observed that the effect of row spacing was significant on plant height number of branches plant^{-1}, number of pods plant^{-1}, number of seeds siliqua^{-1} and 1000 seeds weight and was highly significant on seed yield. Ozer (2003) evaluated a study to observe the effects of spacing between or within rows on the yield and yield components of Tower and Lirawell, two cultivars of *Brassica napus* L., were studied for 2 years in Erzurum, Turkey. Rows were spaced at 15, 30 and 45 cm and within rows spacing were 5, 10 and 15 cm. The results suggested that seed yield was significantly affected by spacing between rows but not by spacing within rows. The rape yields were higher at the narrower (15 cm) row spacing compared to the middle (30 cm) and wider (45 cm) spacing. Similar findings revealed that seed yield was higher with 30 × 15 cm row spacing as compared to 60 cm row spacing (Singh *et al*., 2002). Chaniyara *et al.* (2002) summerised that seed yield was higher at 45 cm and 15 cm inter and intra row spacing respectively. Oad *et al*. (2001) conducted a field experiment in Pakistan to evaluted the effect of row spacing on growth yield and oil content of rape (*B. napus*). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing 30, 45 and 60 cm. They observed that seed yield and oil content were affected significantly by 60 cm row spacing.

Sher *et al*. (2001) examined on effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.). While, the inter-active effect of planting pattern and inter-plant spacing was only found to be significant on number of plants m^{-2}, seed yield (t ha^{-1}) and seed oil content (%). Sahoo *et al*. (2000) conducted an experiment on Indian mustard in kharif season at Bangalore, and reported that seed yield (669 kg ha^{-1}) was higher at closer spacing (30 × 15 cm). Khan and Muendal (1999) conducted an experiment on rape cv. Shiralee grown in rows 15, 30 and 45 cm. They found that row spacing of 15 cm produced the highest and the lowest seed yield respectively. Sharma *et al.* (1999) observed insignificant variation of spacing. While, mustard (*B. juncea* cv. RH 30 and Varuna were grown at 2 row spacing (20 cm and 30 cm).

Sanjeev Kumar *et al*. (1997) in Ludhiana, found that seed yield was higher under 30 cm row spacing (1647 kg ha^{-1}) as compared to 45 cm row spacing (1476 kg ha^{-1}). Shahidullah *et al.* (1997) reported that higher seed yield was obtained by 30 × 15 cm row spacing. Gurjar and Chauhan (1997) carried out an experiment in Gwalior and found that the seed yield higher with 30 × 15 cm rowing (1676 kg ha^{-1}) as compared to 45 × 15 cm row spacing (1119 kg ha^{-1}). In Assam, Sarmah (1996) conducted a field experiment at Regional Agricultural Research Station, Shillongani, and it was reported that a row spacing of 30 cm recorded greater yield than 40 cm row spacing. Similarly, higher seed yield produced at 30 cm row spacing compared to 40 and 50 cm spacing (Khan and Tak, 2002).

Shelke *et al*. (1995) conducted a field trial in Parbhani and suggested that seed yield was higher with 45 or 60 × 22.5 cm spacing of 45 × 22.5 cm (1260 kg ha^{-1}) followed by 60 × 22.5 cm (1230 kg ha^{-1}). Suraj *et al.* (1995) conducted a field experiment on Indian mustard (*B. juncea*) by maintaining 5 row spacing of 10 15, 20, 25 and 30 cm and row orientation of N-S or E-W. While row orientation has no significant affect on seed yield, the highest seed yields were found at 15 cm row spacing. Downey (1971) stated that optimum spacing per unit area plays an important role towards increased yield. Seed yield can be increased by raising plant population, but this relationship is parabolic. Several studies suggest that a higher number of siliquae $plant^{-1}$ has the greatest effect on seed yield on rape and mustard (Mendham *et al*., 1981; Thurling, 1974; Rahman *et al*., 1988).

2.2.8 Stover yield

In Ludhiana, Sanjeev Kumar *et al*. (1997) observed that 4,44,000 plants per ha resulted in higher stover yield (9870 kg ha^{-1}) as compared to 45 cm row spacing (8810 kg ha^{-1}).

Singh *et al.* (2003) stated that in Indian mustard gave the highest seed yield and total biomass produced maintaining 45 cm row spacing than 30 and 60 cm row spacing. Chauhan *et al*. (1993) concluded that row spacing greatly influenced the stover yield of mustard due to variation of the spacing area. Among three row spacing (20, 30 and 40 cm) 30 cm row spacing gave highest yield of stover and second highest yield was obtained from 40 cm which was statistically different with 30 cm row spacing of stover yield.

2.2.9 Biological yield

Aziz (2014) stated that biological yield of mustard and rapeseed plant was significantly affected by different sowing method. The highest biological yield was obtained at SMI technique and in broadcast sowing lowest biological yield was found. Thakuria and Gogoi (1996) studied a field experiment to determine the effect of *Brassica juncea* cv. TM 2, TM 4 and Varuna at 2 row spacing (30 and 45 cm). The effects of cultivars and row spacing seed yield and biological yield was significant which increased under 45 cm row spacing.

2.2.10 Harvest index

Ali *et al*. (1996) observed significant variation on the harvest index of rapeseed at different levels of plant density (Population of 70 and 100 plants m^{-2}) did not show significant difference in harvest index but 40 plants m^{-2} gave higher harvest index. Shrief *et al*. (1990) maintained population density of 30, 60 and 90 plants m^{-2} for raising rapeseed and claimed positive response of all yield contributing characters. When density was maintained as 30 plants m^{-2}, they found that higher harvest index.

2.3 Interaction of variety and planting geometry on different crop characters

Venkaraddi (2008) carried out an experiment to determine the response of mustard varieties on date of sowing and row spacing at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. Where 12 treatment combinations consisting of three varieties (Pusa Agram, Pusa Mahak and EJ-15), two sowing dates (II fortnight of September and I fortnight of October) and two row spacing (30 cm and 45 cm). The performance of mustard with respect to growth and yield parameters was significantly superior with variety Pusa Agram, II fortnight of September sowing and 30 cm row spacing. Significantly higher net returns and B : C ratio were recorded with variety Pusa Agram (16081 Rs. ha^{-1} and 2.14), early sowing during II fortnight of September (13079 Rs. ha^{-1} and 1.78) and 30 cm row spacing (12600 Rs. ha^{-1} and 1.68). It is summerised that mustard seed yield (1326 kg ha^{-1}), oil yield (570.03 kg ha^{-1}), net returns (23107 Rs. ha^{-1}) and B:C ratio (3.12) were higher with variety Pusa Agram sown during II fortnight of September at 30 cm row spacing.

Johnson *et al.* (2003) observed that population density and cultivar interaction were only significant for plant height. Shorter plants for the *Brassica rapa* cultivars was found when grown at the narrower row spacing, but *B. napus* cultivars had similar plant height at both population density and hybrid *B. napus* cultivar yielded greater than the open pollinated cultivars. Population density has no affect on the primary characters determining crop value, seed yield and oil content. Significant differences were found on pooled seed yield on interaction effect of mustard varieties (*Brassica juncea*) viz. “Sanjukta Asceh” and Varuna and plant populations under rainfed conditions during rabi season (Behera *et al*., 2002).

Behera *et al*. (2002) summerised the effect of plant population and sulfur levels on yield of mustard (*B. juncea*) and found that interaction effects of variety and plant population significant on pooled seed yield and observed maximum seed yield at the intermediate population level of 14.8 plants m^{-2}. Surya *et al*. (1998) revealed that yield and yield components were not affected by spacing. Laxmi (30 × 15 cm or 40 × 30 cm) recorded the highest yield, followed by RH-30 then Veruna.

From the above review of different experimental evidences related to this study it was noticed that different varieties of rapeseed-mustard differed among themselves due to their genetic makeup. Yield contributing characters are also influenced by row spacing. These experiment an attempt has been made to see the effect of rapeseed and mustard on yield and yield components are influenced by planting geometry.

Chapter III
Materials and Methods

CHAPTER III
MATERIALS AND METHODS

A field experiment was conducted at the farm of Sher-e-Bangla Agricultural University with three rapeseed-mustard varieties with five levels of planting geometry grown in the rabi season (November 2015 - February 2016).

3.1 Experimental site

3.1.1 Geographical location

The experimental area was situated at $23^0 74'$ N latitude and $90^0 35'$ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.1.2 Agro-Ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as "islands" surrounded by floodplain (Anon., 1988b). The land was medium high with medium fertility level and well drained. The experimental site has been shown in the Map of AEZ of Bangladesh in Appendix- I.

3.2 Soil

The soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranges from 5.7-6.0 and had organic carbon 0.86% and 1.19 % before sowing and after harvest, respectively. The analyses were done by Soil Resources Development Institute (SRDI), Dhaka. The experimental area was flat having available irrigation and drainage system and above flood level. The physical and chemical characteristics of the soil have been presented in Appendix II & III.

3.3 Climate

The experimental area experiences a sub-tropical climate in this locality, characterized by three distinct seasons, the winter season from November to February, the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*., 1979). The kharif season starts with high temperature and it decreases when the season proceeds towards Rabi. The mean maximum temperature rises in the month of April, whereas in winter the mean maximum temperature downs in January. The Robi season is characterized with scanty rainfall associated with moderately low temperature with short day length. The relative humidity increases from June to September (80% or above) and declined to a minimum in the winter. Meterological data on rainfall, air temperature and relative humidity from November 2015 to February 2016 were obtained from the Department of Meterological center, Dhaka-1207, Bangladesh have been shown in Appendix IV.

3.4 Experimental materials

Seeds of three rapeseed and mustard varieties were used as planting materials and the test varieties were (i) BARI Sarisha-11 (mustard), (ii) BARI Sarisha-14 (rapeseed) and (iii) BARI Sarisha-17 (rapeseed).

These three rapeseed and mustard varieties seeds were collected from the Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90% for all the varieties.

3.5 Description of varieties

The important characteristics of these varieties are mentioned below:

BARI Sarisha-11: The variety BARI Sarisha-11 (*Brassica juncea*) was developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2001. It is a tall plant variety. Plant height of this variety is about 120-130 cm. Siliquae are two chambered, appressed in the inflorescence. Seeds are brown in colour and bold, resistant to orobanche. No. of siliquae plant^{-1} is 75-150 with 12-15 seeds siliqua^{-1}. The variety is drought & salinity tolerant. Suitable for late cultivation as a short duration variety which mature at 105-110 days. Seed yield is 2.0-2.4 t ha^{-1}.

BARI Sarisha-14: The variety BARI Sarisha-14 (*Brassica campestris*) was developed by Bangladesh Agricultural Research Institute (BARI) in 2006. Plant height is 75-85 cm. Siliquae are two chambered. No. of siliqua plant^{-1} are 80-100 with 22-26 seeds siliqua^{-1}. Thousand seeds weight 3.5-3.8 g. The crop matures within 75-80 days. Seed yield is 1.4-1.6 t ha^{-1}.

BARI Sarisha-17: BARI Sarisha-17 (*Brassica rapa*) is also a high yielding rapeseed variety was developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2013. Plant height of this variety is about 90-100 cm. No. of siliquae plant^{-1} are 61-62 with 32-33 seeds siliqua^{-1}. Seeds are yellow in color with 3-4% higher oil compared to the purple brownish seeds. The crop matures within 85-90 days and its yield varies from 1.7-1.8 t ha^{-1}.

3.6 Experimental treatments under investigation

There were two factors in the experiment as varieties and different levels of planting geometry as mentioned below:

3.6.1 Experimental factors

Factor A. Variety : 3

(i) BARI Sarisha-11 (V_1)

(ii) BARI Sarisha-14 (V_2)

(iii) BARI Sarisha-17 (V_3)

Factor B. Planting Geometry : 5 (created by varying row to row and constant plant to plant distance)

The line to line distances were maintained with 25 cm, 30 cm, 35 cm and 40 cm. The constant distance for plant to plant within the lines was maintained with 5 cm by thinning of plants after germination. However, the planting geometries were designated as follows :

(i) S_1 = Random geometry (By broadcasting of seeds)

(ii) S_2 = 25 cm x5 cm

(iii) S_3 = 30 cm x 5 cm

(iv) S_4 = 35 cm x 5 cm

(v) S_5 = 40 cm x 5 cm

3.6.2 Treatment combinations

The experiment consisted of the 15 combination of treatments represented as follows :

V_1S_1	V_2S_1	V_3S_1
V_1S_2	V_2S_2	V_3S_2
V_1S_3	V_2S_3	V_3S_3
V_1S_4	V_2S_4	V_3S_4
V_1S_5	V_2S_5	V_3S_5

3.7 Experimental design and layout

The experiment was laid out in Split-plot design with three replications. The experimental unit was divided into three blocks each of which was represented as a replication. Total land area was 300 m^2. There were altogether 45 (15x3) unit plots. In each replication, varieties and planting geometry were assigned randomly in main plots and sub-plots respectively. The unit plot size was 2 m × 2 m = 4 m^2. Distance between plot to plot was 0.50 m and replication to replication 0.75 m, respectively. The layout of the experimental design was presented in Appendix V.

3.8 Planting geometry

In the case of broadcast sowing, the calculated amount of seeds per unit plot 2.8 x 10^{-3} Kg were sown by hand.

In the case of line sowing, the geometric arrangements of plants were maintained by the following :

Row to row distance : 25 cm, 30 cm, 35 cm and 40 cm (respectively)

Plant to plant distance : 5 cm (after thinning)

3.9 Detail of experimental preparation

3.9.1 Land preparation

The experimental field was opened by a tractor drawn disc plough. Subsequent cross ploughing was done followed by laddering to make the land level to obtain a desirable tilth. The corners of the land were spaded out. All weeds stubble, debris and residues were removed from the field and the land was made ready for layout. The decomposed organic manure were applied seven days before laying out of plots. The basal doses of inorganic fertilizers were applied one day before sowing. Finally the plots were spaded well followed by levelling to make the plots ready for sowing.

3.9.2 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. From the soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis from Soil Resources Development Institute (SRDI), Farmgate, Dhaka-1215.

3.9.3 Fertilization

The experimental plots were fertilized with the recommended fertilizer dose of 115-85-57-27-5.8-5.0 kg ha^{-1} of N, P_2O_5, K_2O, S, Zn and Boron respectively from their sources of Urea, TSP, MoP, Gypsum and Zinc Sulphate and Cowdung 10 t ha^{-1} respectively. The half of urea and the whole amount of other fertilizers were applied as basal dose during final land preparation and the rest half urea were applied at 20-25 days after sowing (DAS) at 28 Nov, 2015 as top-dressing before flowering.

3.9.4 Germination test

Germination test was done before sowing the seeds in the field. Filter paper were placed on petridishes and the papers were soaked with water. Seeds were distributed randomly in petridish. Germination data were collected and converted to percentage by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds set for germination}} \times 100$$

The germination (%) were found 87%, 90% and 94% of the tested varieties of BARI Sarisha – 17, BARI Sarisha – 14 and BARI Sarisha – 11 respectively.

3.9.5 Sowing of seeds

Seeds of the 3 varieties of rape-mustard (BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-17) as per treatment were sown at the rate of 6-8 kg ha^{-1} on 07 November, 2015. Seeds were placed at around 2 cm depth and then rows were covered with loose soil properly and treated with Vitavex 200, Rovral 50 WP @ 2 and 4 g kg^{-1} seed respectively. Pre-sowing irrigation was given to ensure the maximum germination percentage.

3.10 Intercultural operations

3.10.1 Weeding and thinning

The crop was infested with some weeds during the early growth stage of crop establishment. The experimental plots were found infested with different kinds of weeds, viz. Bathua (*Chenopodium album* L.), Durba (*Cynodon dactylon*), Nut sedge (*Cyperus rotundus* L.), Biskatali (*Polygonum hydropiper* L.), Goose grass (*Eleusine indica*) etc. Weeding was done manually with 'nirani' in each of the plot. Thinning was done followed by first weeding at 15 days of emergence and second weeding was done at 30 days after emergence. Thinnings were done twice in all the unit plots with care to maintain a plant population density as per treatment.

3.10.2 Irrigation

Two irrigations were done at 25 days and 50 days after sowing in order to maintain adequate moisture in the field for ensuring the more yield.

3.10.3 Plant protection measure

The plants were attacked by aphids (*Lipaphis erysimi*. K) at the time of flowering. They were controlled by spraying Malathion 57 EC @ 2 ml L^{-1} and Ripcord 10 EC @ 1 ml L^{-1}. The spraying was done in the afternoon while the pollinating bees were away from the field.

3.10.4 General observations of experimental field

The experimental plots were visited frequently to observe the growth status and to provide the management pratices, if needed till harvest of crops.

3.10.5 Harvesting and post harvest operations

The crop maturity varied with different varieties. The experimental crop was harvested at maturity when 85-90% of the siliquae turned straw yellowish in color. BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-17 were harvested at maturity on 01, 05 and 16 February, 2016 respectively. Harvesting was done in the morning to avoid shattering. Before harvesting the whole plot, ten plants were sampled randomly from each plot, bundled separately, tagged and brought to a clean cemented threshing floor for collecting data on different yield attributes. One square meter area from the center of each plot was harvested for recording yield data. The sampled plants were uprooted prior to harvest and plants were tied into bundles and carried to the threshing floor. The crop was sun dried properly by spreading them over floor. Seeds were separated from the siliquae by beating the bundles with bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were further dried in the sun. Seed and stover yield were recorded separately. By summing of the seed yield and stover yield, the biological yield was calculated.

3.11 Sampling and data collection

The samples of ten plants were selected at random from each plot for recording data at 30 DAS and continued until harvest with 15 days interval. However, the following data were recorded during the experiment as follows :

Crop growth characters

i) Plant height (cm)

ii) Leaves plant^{-1} (no.)

Yield contributing characters

i) Branches plant^{-1} (no.)

ii) Siliquae plant^{-1} (no.)

iii) Length of siliqua (cm)

iv) Seeds siliqua^{-1} (no.)

v) 1000 seeds weight (g)

Yields

i) Seed yield (t ha^{-1})

ii) Stover yield (t ha^{-1})

iii) Biological yield (t ha^{-1})

iv) Harvest index (%)

3.12 Detailed procedures of recording data

3.12.1 Crop growth characters

3.12.1.1 Plant height (cm)

Plant height was measured from the ground level to the apex of the leaf or siliqua of the selected plants. The mean value of plant height was recorded in cm.

3.12.1.2 Leaves plant^{-1} (no.)

The numbers of leaves plant^{-1} were counted and calculated to average value by considering values of ten plants.

3.12.2 Yield contributing characters

3.12.2.1 Branches plant^{-1} (no.)

The total number of branches plant^{-1} was recorded from selected samples at the time of harvest. Then the average data were calculated.

3.12.2.2 Siliquae plant^{-1} (no.)

Siliquae of ten randomly sampled plants were counted and the mean number was recorded.

3.12.2.3 Siliqua length (cm)

The length of the siliqua was measured from the base to the tip of the siliqua and finally the lengths were recorded as per treatments.

3.12.2.4 Seeds siliqua^{-1} (no.)

The number of seeds was counted from sampled plants and the average value was calculated to express the no. of seeds per siliqua.

3.12.2.5 1000 seeds weight (g)

From the harvested seeds of each plot, 1000 seeds were randomly seperated and weighed (g) by an electric balance.

3.12.3 Harvesting of crops

In the case of broadcasting and line sowing method BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-17 were harvested at 102, 87 and 90 days, respectively.

3.12.4 Yields

3.12.4.1 Seed yield (t ha^{-1})

Seed yields were taken by threshing, cleaning and drying of the harvested seeds of the sampling area (1 m^2) from each plot and the harvested yields were expressed as t ha^{-1}.

3.12.4.2 Stover yield (t ha^{-1})

The stover weights were calculated after threshing of seeds from the plants of 1 m^2 area and then expressed as t ha^{-1} on dry weight basis.

3.12.4.3 Biological yield (t ha^{-1})

Biological yield (sun dried) was calculated by summing up of seed and stover yield per plot. Biological yield was calculated by using the following formula:

Biological yield = Seed yield + Stover yield (dry weight basis)

3.12.4.4 Harvest index (%)

Harvest index was calculated from the ratio of seed yield to biological yield (seed yield + stover yield) and expressed in terms of percentage. It was calculated by the following formula (Donald, 1963):

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield (t/ ha)}}{\text{Biological yield (t/ ha)}} \times 100$$

3.13 Statistical analysis of data

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique with the help of computer package STATISTIX 10 program. The mean differences among the treatments were adjudged by least significant difference (LSD) test at 5 % level of significance.

Chapter IV
Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

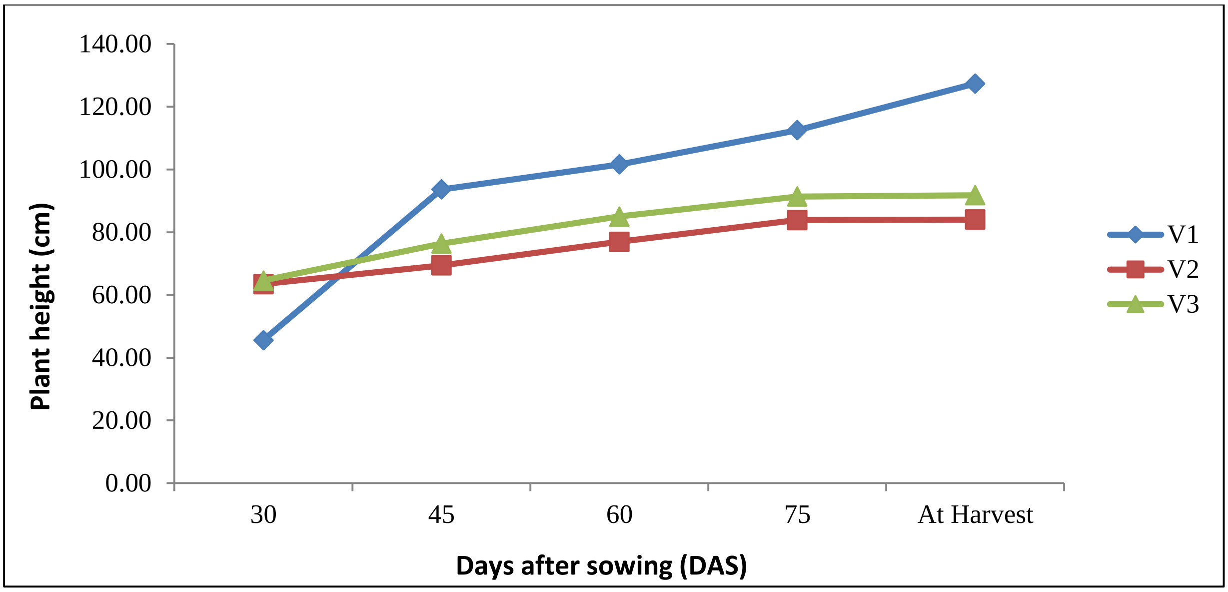
This chapter comprises of presentation and discussion of the results on different growth parameters, yield and yield contributing characters of rapeseed-mustard were shown. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix (VI-XI).

4.1 Crop growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of variety

The plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity. Plant height varied significantly at 30, 45, 60, 75 DAS (different days after sowing) and at harvest depending on varieties (Figure 1). At 30 DAS, the highest plant height (64.59 cm) was recorded from V_3 (BARI Sarisha-17) which was statistically similar with (63.47 cm) from V_2 (BARI Sarisha-14) but different (45.62 cm) from V_1 (BARI Sarisha-11). At 45, 60, 75 DAS and at harvest the plant height of V_1 (BARI Sarisha-11) was significantly highest (93.66, 101.61, 112.52 and 127.37 cm respectively) over the other varieties. On the other hand, the lowest plant heights were obtained from V_2 (BARI Sarisha-14) which were (69.46, 76.15, 83.91 and 84.06 cm) at 45, 60, 75 DAS and at harvest respectively. It was noted that initially V_3 (BARI Sarisha-17) appeared with the tallest plant but after 45 DAS and at maturity it scored 2^{nd} among the varieties under study. BARI (2002) reported that that BARI Sarisha-11 was taller (120-130 cm) than that of other varieties. Similar variation on plant height among rapeseed-mustard varieties was also reported by many researchers (Aziz, 2014; Alam, 2004; Ahmed *et al*., 1999; Ali *et al*., 1998; Jahan and Zakaria, 1997; Hussain *et al*., 1996 and Mondal *et al*., 1992). Yeasmin (2013) disagreed with this finding. She stated that varietal effect was insignificant on plant height of mustard.

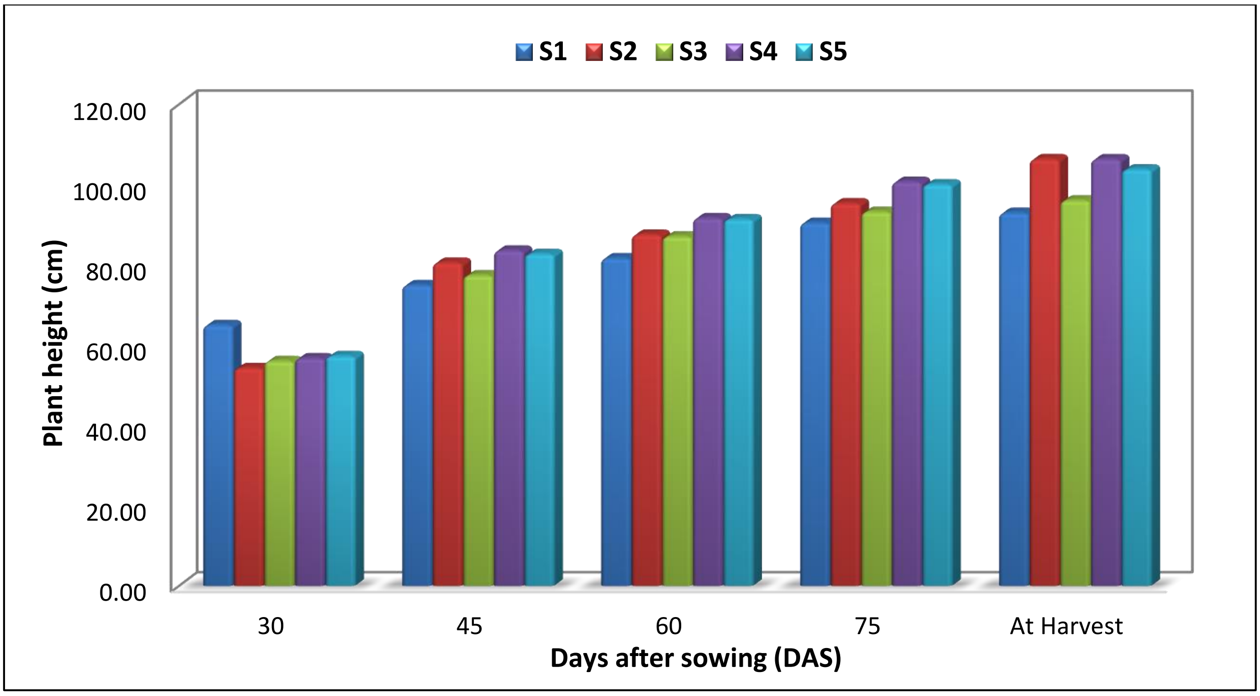


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

Figure 1. Effect of variety on plant height of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 3.33, 2.98, 6.60, 4.86 & 3.35 at 30, 45, 60, 75 DAS and at harvest, respectively).

4.1.1.2 Effect of planting geometry

Plant height was significantly affected by planting geometry i.e, plant population density at different days after sowing (DAS) and at harvest (Figure 2). Results under the present study revealed that the tallest plant (65.02 cm) at 30 DAS was noted with the S_1 (Random geometry) which was statistically different from those of other planting patterns viz. S_2 (25 cm x 5 cm), S_3 (30 cm x 5 cm), S_4 (35 cm x 5 cm) and S_5 (40 cm x 5 cm) respectively. But at 45, 60 and 75 DAS, S_1 showed the shortest plant (74.94, 81.54 and 90.47 cm, respectively) where S_3 statistically similar with S_1 (93.21 cm) at 75 DAS. Moreover, S_2 produced the tallest plant (106.31 cm) which was statistically simillar to S_4 and S_5 (106.30 and 103.80 cm) at harvest and highly significant and different from S_1 and S_3 respectively. Gupta (1988) and Scarisbric *et al.* (1982) recorded significant taller plant height of mustard with wider spacing. On the other hand, the shortest plant in the closest spacing might be due to more competition for nutrient, moisture, space and light among the plants (Hossain *et al.*, 2013 and Oad *et al.*, 2001) also observed similar justification.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 2. Effect of planting geometry on plant height of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 4.34, 2.30, 2.58, 3.73 & 4.39 at 30, 45, 60, 75 DAS and at harvest, respectively).

4.1.1.3 Combined effect of variety and planting geometry

Combined effect of variety and planting geometry showed different result at different DAS and at harvest which presented in Table 1. At 30 DAS the tallest plant (72.69 cm) was found from V_3S_3 combination (BARI Sarisha-17 with 30 cm x 5 cm geometric pattern) which was statistically similar (67.02, 65.99 and 65.80 cm) with V_2S_1 (Random geometry, plant to plant 5 cm distance with BARI Sarisha-14), V_2S_2 (BARI Sarisha-14 with 25 cm x 5 cm) and V_2S_4 (BARI Sarisha-14 with 35 cm x 5 cm). At 30 DAS the lowest height (34.14 cm) was found from V_1S_2 which was statistically similar (35.94 cm) with V_1S_3 combination. At 45, 60 and 75 DAS the tallest plant (101.93, 111.23 and 125.26 cm respectively) was produced by V_1S_4 (BARI Sarisha-11 with 35 cm x 5 cm spacing) which was statistically similar (99.10, 108.90 and 120.76 cm) with V_1S_5 (BARI Sarisha-11 with 40 cm x 5 cm spacing). The lowest plant height was found from V_3S_1 (64.39 cm) which statistically similar (66.93 and 66.71 cm) V_2S_5 and V_2S_3 at 45 DAS; V_2S_2 (72.63 cm) was statistically similar to (75.70, 75.45, 75.41 and 73.02 cm, respectively) from V_2S_3, V_2S_4, V_2S_5 and V_3S_1, respectively at 60 DAS; and V_3S_1 (80.18 cm) was statistically similar to (83.11, 82.94, 81.60 and 81.31 cm) from V_2S_5, V_2S_4,

V_2S_3 and V_2S_2 at 75 DAS as well as with V_2S_2 (81.29 cm) was statistically similar to (87.42, 83.18, 83.17, 82.95 and 82.07 cm, respectively) with V_3S_3, V_2S_5, V_3S_1, V_2S_4 and V_2S_3 respectively, at harvest. The plant response in terms of height to the combined treatment was found higher at middle growth stage from 30 to 75 DAS considered as maximum growth stage. At harvest the highest plant height was (140.78 cm) found from V_1S_2 (BARI Sarisha-11 with 25 cm x 5 cm spacing) which were statistically similar (140.60 cm) with V_1S_4 combination (BARI Sarisha-11 with 35 cm x 5 cm spacing).

Table 1. Combined effect of variety and planting geometry on plant height of rapeseed-mustard at different days after sowing

Treatment Combination	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	63.72 bc	88.89 b	87.07 de	100.66 c	104.87 d
V_1S_2	34.14 e	90.35 b	96.05 bc	108.63 b	140.78 a
V_1S_3	35.94 e	88.03 b	98.03 b	107.29 b	118.67 c
V_1S_4	44.83 d	101.93 a	111.23 a	125.26 a	140.60 a
V_1S_5	49.47 d	99.10 a	108.90 a	120.76 a	131.91 b
V_2S_1	67.02 ab	71.55 e	81.55 e	90.58 d	90.83 ef
V_2S_2	65.99 a-c	72.37 e	72.63 f	81.31 e	81.29 g
V_2S_3	59.57 bc	66.71 fg	75.70 f	81.60 e	82.07 g
V_2S_4	65.80 a-c	69.74 ef	75.45 f	82.94 e	82.95 g
V_2S_5	58.97 c	66.93 fg	75.41 f	83.11 e	83.18 g
V_3S_1	64.31 bc	64.39 g	73.02 f	80.18 e	83.17 g
V_3S_2	62.85 bc	78.90 cd	86.41 de	96.04 cd	96.87 e
V_3S_3	72.69 a	77.44 d	87.50 de	90.73 d	87.42 fg
V_3S_4	59.64 bc	79.02 cd	88.23 de	93.83 cd	95.36 e
V_3S_5	63.48 bc	82.16 c	89.83 cd	96.31 cd	96.23 e
LSD $_{(0.05)}$	7.47	4.6	7.64	7.47	7.53
CV(%)	7.71	2.96	3.04	3.99	4.46

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

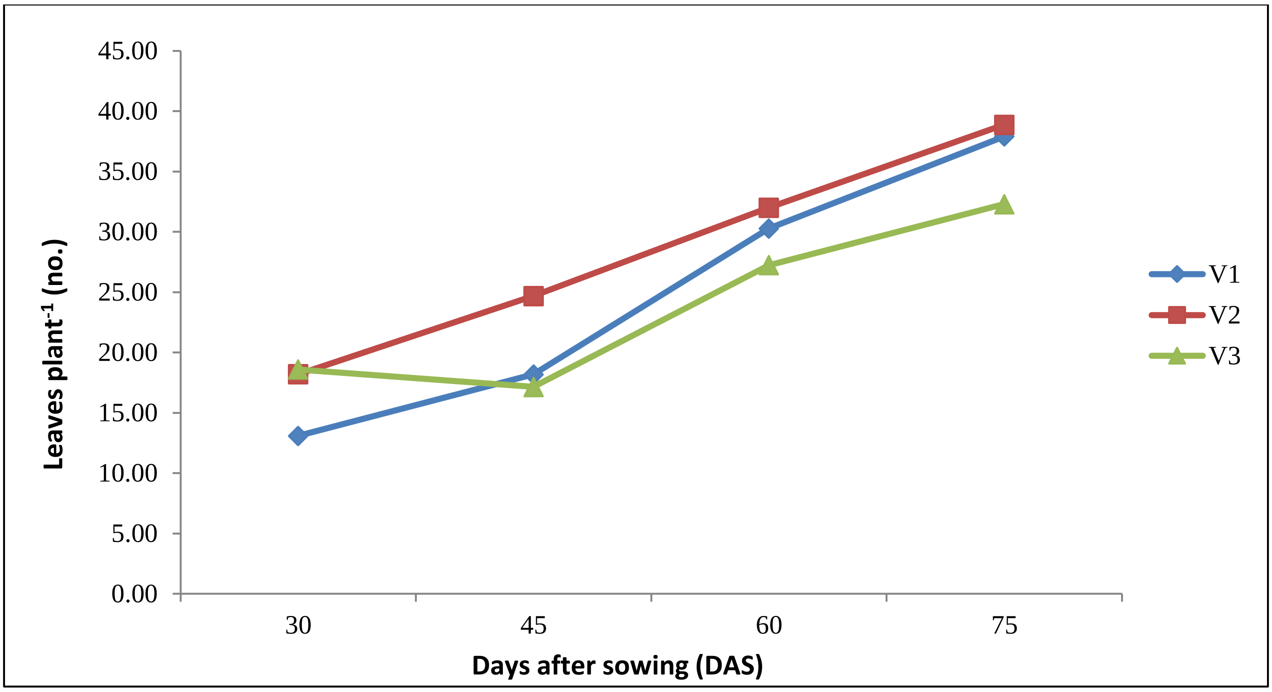
S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

4.1.2 Leaves plant^{-1} (no.)

4.1.2.1 Effect of vareity

There was marked differences among the three varieties of rapeseed and mustard on leaves plant^{-1} at different DAS. Effect of variety on leaves plant^{-1} is presented in Figure 3. At 30 DAS V_3 showed the highest numbers of leaves plant^{-1} (18.69) which was statistically similar (18.20) with V_2 whereas the lowest value (13.09) was from V_1. At 45, 60 and 75 DAS V_2 showed the highest numbers of leaves plant^{-1} (24.67, 32.01 and 38.88 respectively) where statistical similarity (30.28 and 37.91 respectively) observed with V_1 at 60 and 75 DAS. Number of leaves plant^{-1} increased from 30 to 45 DAS and then decreased from 75 DAS. Similar justification was found from Singh *et al.* (2003). He found that the highest number of leaves were produced by BARI Sarisha-11 (24.50) and BARI Sarisha-14 (22.48) which was statistically similar with Tori-6 (26.41) and BARI Sarisha-15 (27.71) at 50 DAS. Aziz (2014) evaluated that number of leaves was not significantly affected by variety at 30 DAS but at 45, 60 and 75 DAS and at harvest affected significantly.

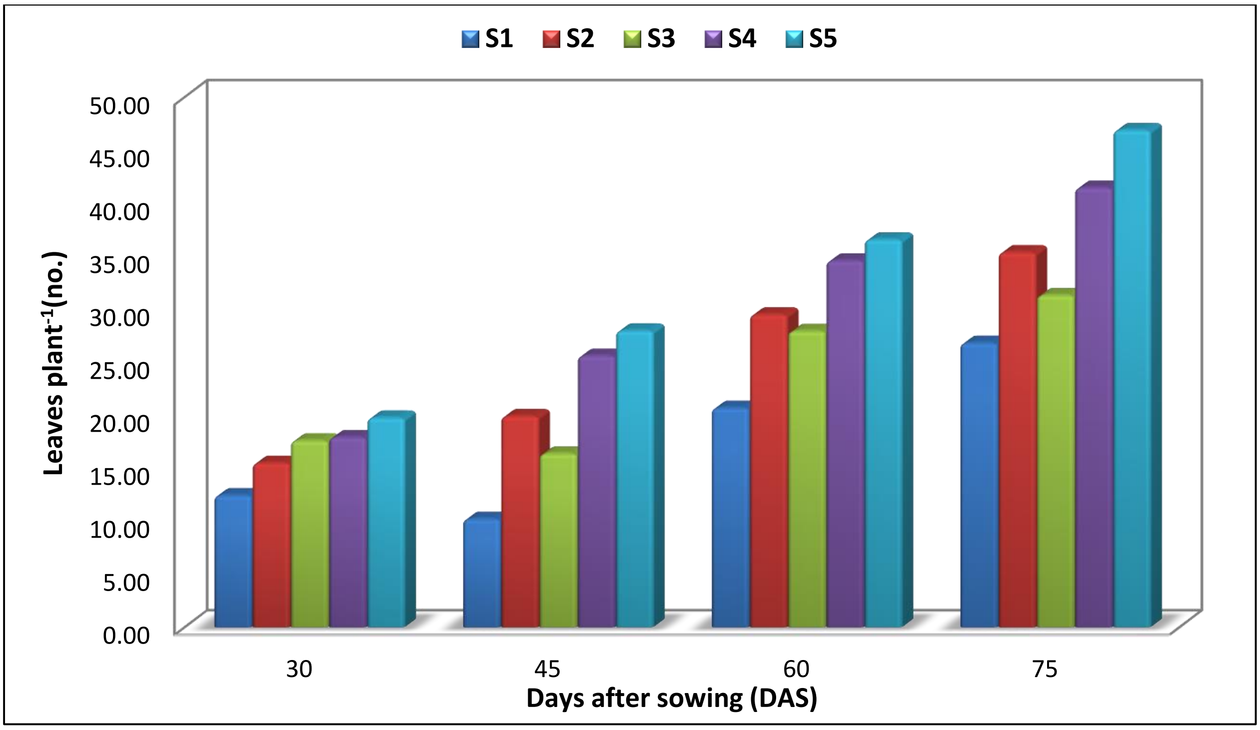


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

Figure 3. Effect of variety on number of leaves plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 0.95, 1.99, 3.33 & 2.92 at 30, 45, 60, and 75 DAS respectively).

4.1.2.2 Effect of planting geometry system

Planting geometric system was significant effect on leaves plant^{-1} at 30, 45, 60 and 75 DAS shown in Figure 4. At 30 DAS S_5 showed the highest leaves plant^{-1} (19.75) which showed statistical difference (17.90 and 15.48) with S_4 and S_2 respectively where S_3 (17.59) statistically similar with S_4 and the lowest (12.42) from S_1. The S_5 subsequently given the highest results (27.97, 36.57 and 46.89) at 45, 60 and 75 DAS, respectively; whereas the lowest result was found at 45, 60 and 75 DAS (10.19, 20.67 and 26.80, respectively) from S_1 which was statistically different (19.90, 29.49 and 35.36, respectively) with S_2. Here it was observed that the number of leaves plant^{-1} increased with the increase area of spacing. Similar justification was found from Aziz (2014). He found that leaf number was significantly affected by at 45, 60 and 75 DAS and at harvest.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 4. Effect of planting geometry on number of leaves plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 1.02, 1.25, 1.77 & 1.75 at 30, 45, 60 & 75 DAS respectively).

4.1.2.3 Combined effect of variety and planting geometry

There are significant differences in leaves number plant^{-1} with different treatments at different DAS. Combined effect of variety and planting geometry on leaves plant^{-1} is presented in Table 2. At 30 and 45 DAS V_2S_5 given the highest number of leaves plant^{-1} (24.90 and 37.10) which was statistically similar (23.33) with V_3S_4 at 30 DAS, respectively. Whereas the lowest number of leaves plant^{-1} was found at 30 DAS (11.30) from V_1S_2 which was statistically similar to (12.13 and 12.00) V_3S_1 and V_2S_1 which was statistically different from (20.07, 19.40, 17.80, 17.33, 16.90, 14.27, 13.47, 13.30 and 13.13) with V_3S_3, V_2S_3, V_2S_2, V_3S_2, V_2S_4, V_1S_5, V_1S_4, V_1S_3 and V_1S_1 respectively. During 45, 60 and 75 DAS V_3S_1 showed the lowest results (7.20, 14.33 and 18.20, respectively) where (18.13) from V_2S_1 was statistically similar to V_3S_1 at 60 DAS; while the highest were (37.10) from V_2S_5 at 45 DAS, (45.53) from V_2S_4 at 60 DAS and at 75 DAS the highest were (54.33) from V_2S_5 which was statistically similar (53.00) with V_2S_4.

Table 2. Combined effect of variety and planting geometry on number of leaves plant^{-1} of rapeseed-mustard at different days after sowing

Treatment Combination	Number of leaves plant^{-1}			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
V_1S_1	13.13 ef	10.30 h	29.53 ef	39.27 c
V_1S_2	11.30 g	22.60 d	33.67 cd	43.20 b
V_1S_3	13.30 ef	15.20 f	31.10 de	33.60 d
V_1S_4	13.47 ef	22.13 d	24.90 g	33.67 d
V_1S_5	14.27 e	20.70 de	32.20 de	39.80 c
V_2S_1	12.00 fg	13.07 fg	18.13 hi	22.93 f
V_2S_2	17.80 cd	18.20 e	25.53 fg	30.80 de
V_2S_3	19.40 bc	23.30 d	30.53 de	33.33 d
V_2S_4	16.90 d	31.70 b	45.53 a	53.00 a
V_2S_5	24.90 a	37.10 a	40.30 b	54.33 a
V_3S_1	12.13 fg	7.20 i	14.33 i	18.20 g
V_3S_2	17.33 d	18.90 e	29.27 ef	32.07 d
V_3S_3	20.07 b	10.57 gh	22.13 gh	27.00 e
V_3S_4	23.33 a	22.93 d	31.20 de	37.67 c
V_3S_5	20.07 b	26.10 c	37.20 bc	46.53 b
LSD (0.05)	1.83	2.75	4.26	3.94
CV(%)	6.33	6.44	6.11	4.96

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

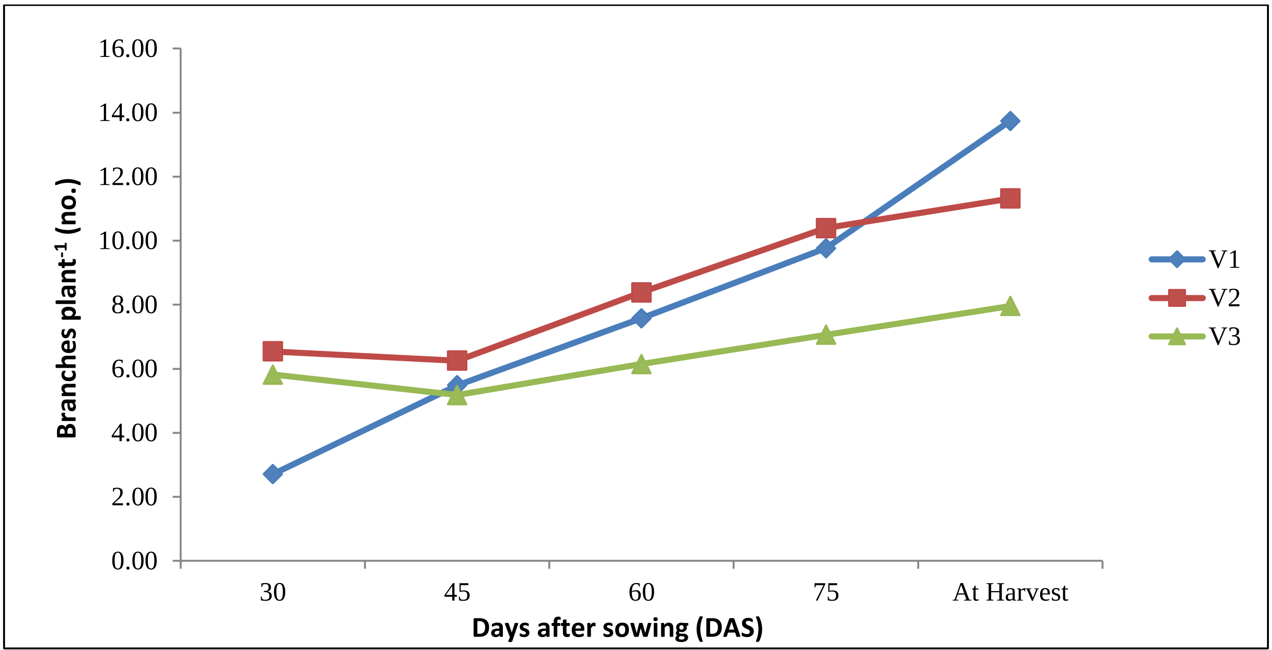
In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

4.2 Yield and other parameters

4.2.1 Branches plant^{-1} (no.)

4.2.1.1 Effect of variety

There are significant variation of number of branches plant^{-1} due to varietal variation with different treatments at different DAS and at harvest among the varieties of rapeseed-mustard (Figure 5). At 30 DAS, three varieties showed significant result, i.e. the highest number was (6.54) from V_2 which was statistically different (5.82) with V_3 and the lowest was (2.71) from $V_{1,}$ respectively. At 45 DAS the highest number was (6.25) showed from V_2 and the lowest was (5.18) from V_3 which was statistically similar (5.49) with V_1. At 60 and 75 DAS again given the highest result (8.39 and 10.39) from V_2 and the lowest was (6.15 and 7.06 respectively) from V_3. But at harvest V_1 given the highest result (13.74) and lowest observed (7.96) from V_3. Findings were related to observation of Aziz (2014). He observed that BARI Sarisha-11 produced the highest number of secondary branches throughout the growing period.

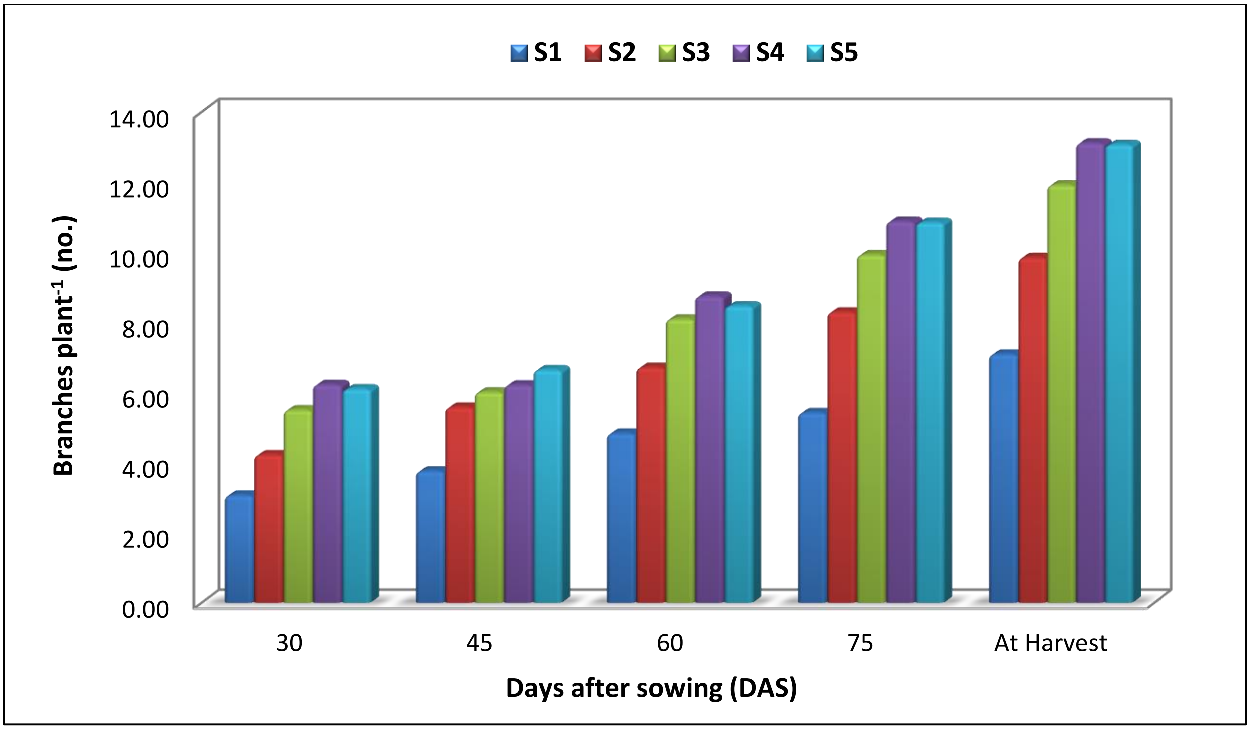


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

Figure 5. Effect of variety on number of branches plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 0.27, 0.51, 0.59, 0.56 & 1.43 at 30, 45, 60, 75 and at harvest, respectively).

4.2.1.2 Effect of planting geometry

Different planting geometry showed significantly variant result at different DAS and at harvest. Branches plant^{-1} increased with the increasing of spacing of planting. At 30 DAS the highest result was occupied (6.22) by S_4 which was statistically similar (6.10) with S_5 and the lowest was (3.07) from S_1 respectively (Figure 6). At 45 DAS the highest results were (6.64) obtained from S_5 which was statistically similar (6.21 and 6.01) with S_4 and S_3 where the lowest were at 45 DAS (3.76) from S_1. At 60, 75 DAS and at harvest the highest results were (8.74, 10.88 and 13.11 respectively,) from S_4 which was statistically similar (8.47 and 8.09) from S_5 and S_3 at 60 DAS, (10.85) from S_5 at 75 DAS and (13.07 and 11.91, respectively) from S_5 and S_3 at harvest. The lowest results were (4.83, 5.42 and 7.09 respectively,) from S_1 at 60, 75 DAS and at harvest. Wider spacing influenced the growth of higher number of lateral branches of a plant. Branch number was also increase with the increase of plant spacing. Khanlou and Sharghi (2015) also observed that effect of planting distance on number of branches per plant has been significant. Similar findings were reported by Sam-Daliri *et al*. (2011), Ozer (2003), Ali *et al.* (1996), Chauhan *et al*. (1993), Shrief *et al.* (1990) and Gupta (1988).



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 6. Effect of planting geometry on number of branches plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 0.25, 0.87, 1.04, 0.87 & 1.43 at 30, 45, 60, 75 and at harvest, respectively).

4.2.1.3 Combined effect of variety and planting geometry

Combined effect of variety and planting geometry on branches plant^{-1} of rapeseed-mustard is given to the Table 3. At 30 DAS V_2S_5 given the highest number of branches plant^{-1} (7.80) which was statistically similar to (7.70, 7.47, 7.43 and 7.40) with V_2S_4, V_2S_3, V_2S_2 and V_3S_4, respectively and the lowest was (2.30) given by V_2S_1 which was statistically similar (2.43) with V_1S_3. At 45 DAS V_2S_5 was showed the highest results (7.74) which was statistically similar (7.03, 7.00, 6.90, 6.40, 6.33, 6.30 and 6.13) with V_1S_3, V_2S_2, V_2S_4, V_3S_4, V_1S_5, V_2S_3 and V_3S_5, respectively. The lowest branches plant^{-1} at 45 DAS (3.07) was found in V_3S_1 which was statistically similar (4.13 and 3.60) with V_1S_2 and V_2S_1, respectively. The highest was found (10.60) from V_2S_4 which was statistically similar to (10.13 and 9.80) with V_2S_5 and V_2S_3 at 60 DAS; at 60 and 75 DAS the lowest was (3.80 and 4.33) observed from V_3S_1 which was statistically similar (4.40 and 5.13) with V_2S_1. At harvest the highest no. observed (16.53) from V_1S_4 which was statistically similar (15.93, 15.27 and 14.20) with V_1S_5, V_1S_3 and V_2S_3, respectively and the lowest no. observed (4.73) from V_3S_1 which was statistically similar (6.27 and 5.47) with V_3S_3 and V_2S_1, respectively. According to Khanlou and Sharghi (2015) interaction between cultivars and planting was found the highest number of branches per plant in 50 cm row spacing. The increasing density reduced the number of branches per plant. Aziz (2014) observed similarities with the findings.

Table 3. Combined effect of variety and planting geometry on number of branches plant^{-1} of rapeseed-mustard at different days after sowing

Treatment Combination	Number of branches plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	3.47 e	4.60 e-g	6.30 de	6.80 hi	11.07 c
V_1S_2	0.70 g	4.13 f-h	6.07 d-f	8.67 ef	9.90 c
V_1S_3	2.43 f	7.03 a	8.80 bc	10.87 cd	15.27 ab
V_1S_4	3.57 e	5.33 c-f	9.03 a-c	11.80 c	16.53 a
V_1S_5	3.37 e	6.33 a-c	7.67 cd	10.67 cd	15.93 ab
V_2S_1	2.30 f	3.60 gh	4.40 fg	5.13 j	5.47 d
V_2S_2	7.43 ab	7.00 ab	7.00 de	7.80 f-h	9.30 c
V_2S_3	7.47 ab	6.30 a-c	9.80 ab	13.30 ab	14.20 ab
V_2S_4	7.70 a	6.90 ab	10.60 a	13.73 a	13.80 b
V_2S_5	7.80 a	7.47 a	10.13 ab	12.00 bc	13.80 b
V_3S_1	3.43 e	3.07 h	3.80 g	4.33 j	4.73 d
V_3S_2	4.53 d	5.60 b-e	7.07 de	8.40 e-g	10.33 c
V_3S_3	6.60 c	4.70 d-g	5.67 ef	5.60 ij	6.27 d
V_3S_4	7.40 ab	6.40 a-c	6.60 de	7.10 g-i	9.00 c
V_3S_5	7.13 b	6.13 a-d	7.60 cd	9.87 de	9.47 c
LSD $_{(0.05)}$	0.47	1.43	1.71	1.46	2.62
CV(%)	5.2	15.84	14.54	9.89	13.37

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

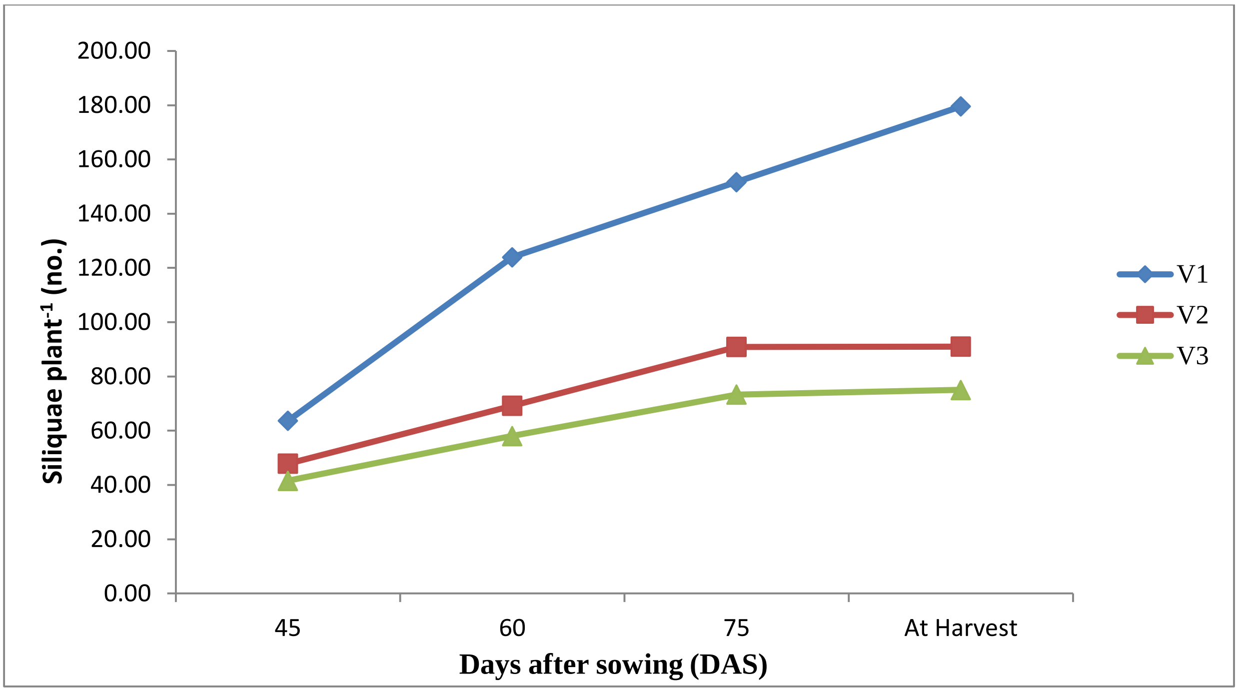
S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

4.2.2 Siliquae plant^{-1} (no.)

4.2.2.1 Effect of variety

Number of siliquae plant^{-1} was significantly varied among the varieties of rapeseed and mustard at different DAS and at harvest shown in Figure 7. The highest no. of siliquae plant^{-1} observed at 45, 60, 75 and at harvest was (63.70, 123.99, 151.66 and 179.58) from V_1 which statistically differ from other varieties. The lowest no. was observed (41.56, 58.04, 73.34 and 75.03 respectively) from V_3. Where V_3 of 45 DAS statistically similar to (47.85) from V_2. Aziz (2014) observed that number of siliquae plant^{-1} was significantly affected by variety. He found that BARI Sarisha-11 produced the highest number of siliquae plant^{-1} and BARI Sarisha-13 produced secound higher number of siliquae plant^{-1} than BARI Sarisha-15. Similar observation was also reported by Hossain *et al.* (2012), Jahan and Zakaria (1997), Islam *et al.* (1994) and Mondal *et al.* (1992).

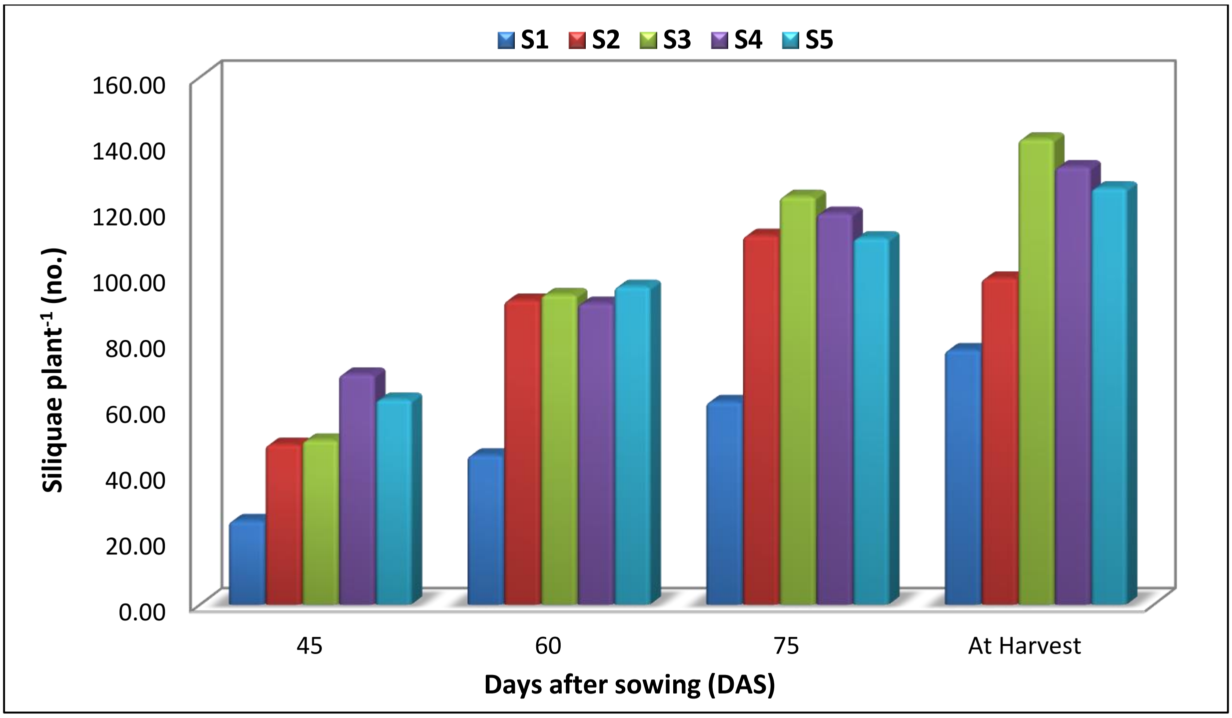


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

Figure 7. Effect of variety on number of siliquae plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 7.17, 3.74, 4.62 & 5.32 at 30, 45, 60, 75 and at harvest, respectively).

4.2.2.2 Effect of planting geometry

At 45 DAS the highest number of siliquae plant^{-1} was observed (69.71) by S_4 which was statistically similar (62.11) with S_5 and the lowest was (25.27) from S_1, respectively (Figure 8). At 60 DAS the highest results were (96.36) obtained from S_5 which was statistically similar (93.88, 92.17 and 91.21) with S_3, S_2 and S_4. At 75 DAS and at harvest the highest results were (123.68 and 141.13, respectively) from S_3 which was statistically similar (118.53 and 132.69, respectively) with S_4. Where the lowest results were (45.17, 61.37 and 77.10, respectively) from S_1 at 60, 75 DAS and at harvest. The result obtained from the present study was similar with the findings of Gupta (1988) and Hasanuzzaman (2008). Thakur (1999) observed the highest number of siliquae plant^{-1} with 30 cm row spacing. Al Barzinjy *et al.* (1999) and Momoh and Zoah (2001) stated that the number of siliquae per branch decreased with increasing plant density.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 8. Effect of planting geometry on number of siliquae plant^{-1} of rapeseed-mustard at different ages (LSD $_{(0.05)}$ = 8.01, 5.69, 5.43 & 8.77 at 30, 45, 60, 75 and at harvest, respectively).

4.2.2.3 Combined effect of variety and planting geometry

There was a significant variations observed in number of siliquae plant^{-1} due to interaction of varieties and planting geometry is given in Table 4. At 45 DAS V_2S_4 given the highest number of siliquae plant^{-1} (79.20) which was statistically similar (77.73 and 74.13) with V_1S_5 and V_1S_4, respectively and the lowest was (9.80) given by V_3S_1 which was statistically similar (12.30) with V_2S_1. At 60, 75 DAS and at harvest V_1S_3 was showed the highest results (163.37, 191.53 and 238.90, respectively,) and the lowest no. was observed (18.50, 29.00 and 34.50) from V_3S_1 which was statistically similar (21.70, 33.10 and 38.30) with V_2S_1. Several studies suggested that a higher number of siliquae plant^{-1} had the greatest effect on seed yield on rapeseed and mustard (Thurling, 1974; Rahman *et al.*, 1988).

Table 4. Combined effect of variety and planting geometry on number of silliquae plant^{-1} of rapeseed-mustard at different days after sowing

Treatment Combination	Number of silliquae plant^{-1}			
	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	53.70 cd	95.30 d	122.00 d	158.50 c
V_1S_2	48.90 de	137.20 b	182.07 b	136.25 d
V_1S_3	64.03 bc	163.37 a	191.53 a	238.90 a
V_1S_4	74.13 ab	104.03 d	134.20 c	181.20 b
V_1S_5	77.73 ab	120.03 c	128.50 cd	183.03 b
V_2S_1	12.30 f	21.70 j	33.10 i	38.30 i
V_2S_2	47.20 de	74.50 g	91.60 f	86.47 gh
V_2S_3	50.33 cd	70.50 gh	106.60 e	110.90 ef
V_2S_4	79.20 a	94.70 d	121.90 d	118.67 e
V_2S_5	50.20 cd	84.80 e	101.20 e	100.80 fg
V_3S_1	9.80 f	18.50 j	29.00 i	34.50 i
V_3S_2	49.10 d	64.80 h	61.80 h	73.90 h
V_3S_3	34.70 e	47.77 i	72.90 g	73.60 h
V_3S_4	55.80 cd	74.90 fg	99.50 ef	98.20 fg
V_3S_5	58.40 cd	84.25 ef	103.50 e	94.95 g
LSD $_{(0.05)}$	14.23	9.53	9.53	14.54
CV(%)	16.13	6.98	5.30	7.83

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

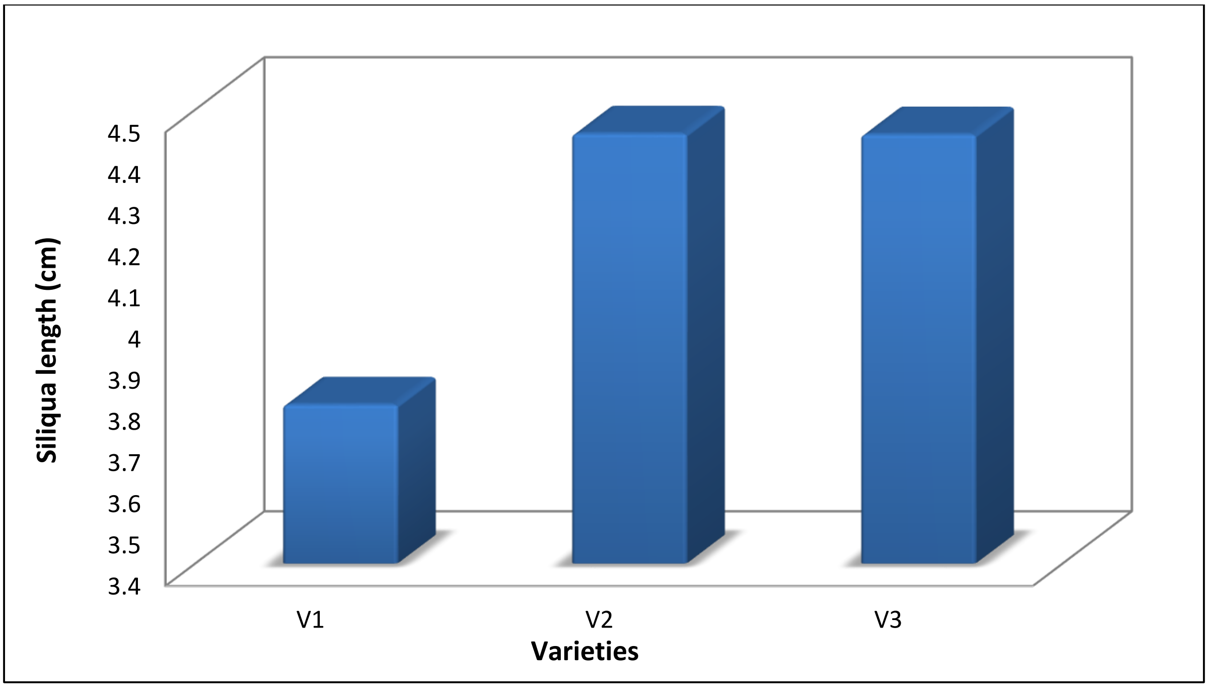
S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

4.2.3 Length of siliqua (cm)

4.2.3.1 Effect of variety

The length of siliqua was significantly differences among the varieties of rape-mustard (Figure 9). The result revealed that highest siliqua length was (4.44 cm) observed from the variety V_2 (BARI Sarisha-14) which was statistically similar (4.44 cm) with V_3 (BARI Sarisha-17) and lowest length (3.79 cm) was obtained from V_1 (BARI Sarisha-11). Similar variation in this character was also reported by Masud *et al.* (1999), Jahan and Zakaria (1997), Olsson (1990) and Lebowitz (1989), in several genotypes of rapeseed and mustard. Aziz (2014) also observed significant variation in siliqua length of mustard and rapeseed plant for different variety. He found the biggest siliqua length (8.24 cm) from BARI Sarisha-13 and the smallest siliqua length (4.21 cm) from BARI Sarisha-11.



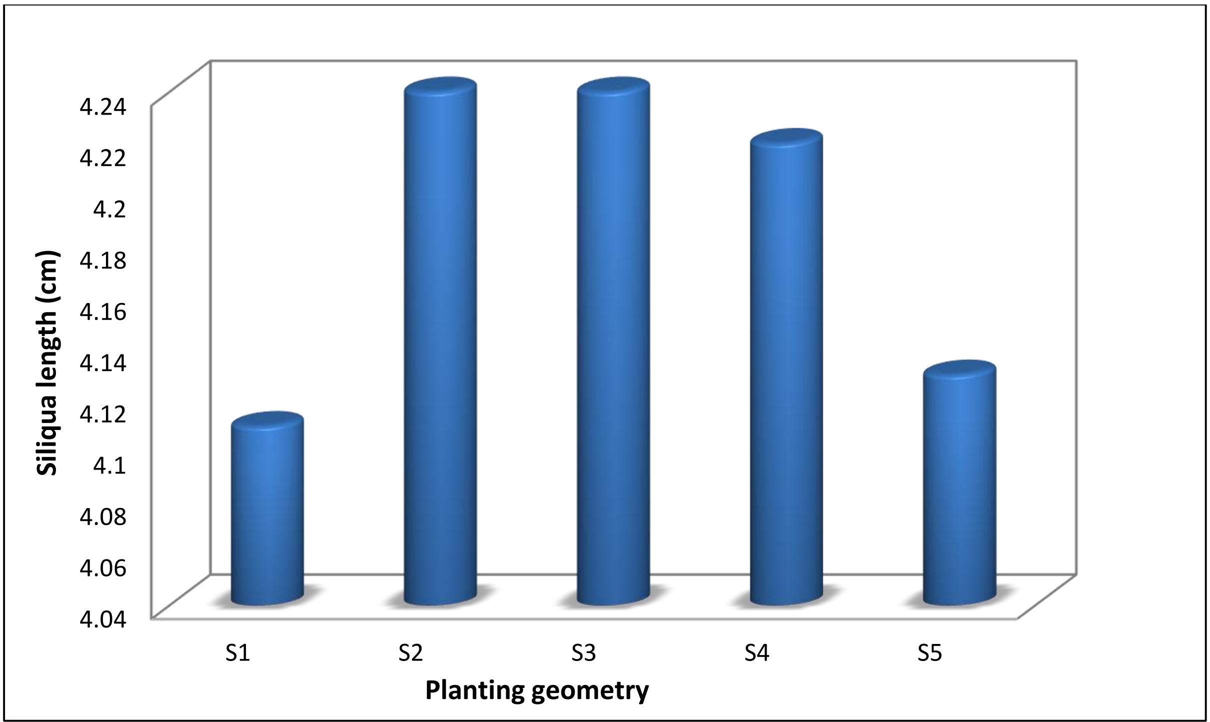
V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 9. Effect of variety on siliqua length of rapeseed-mustard (LSD $_{(0.05)}$ = 0.19).

4.2.3.2 Effect of planting geometry

Planting geometry was statistically insignificant on the length of siliqua (Figure 10). The highest siliqua length was (4.31 cm) observed from S_5 which was statistically similar (4.24, 4.24, 4.22 and 4.11 cm) with S_2, S_3, S_4 and S_1. Similar findings observed by Singh and Singh

(1987). Shrief *et al.* (1990) disagree with this findings. He observed lower plant density increased the pod length.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 10. Effect of planting geometry on siliqua length of rapeseed-mustard (LSD $_{(0.05)}$ = NS).

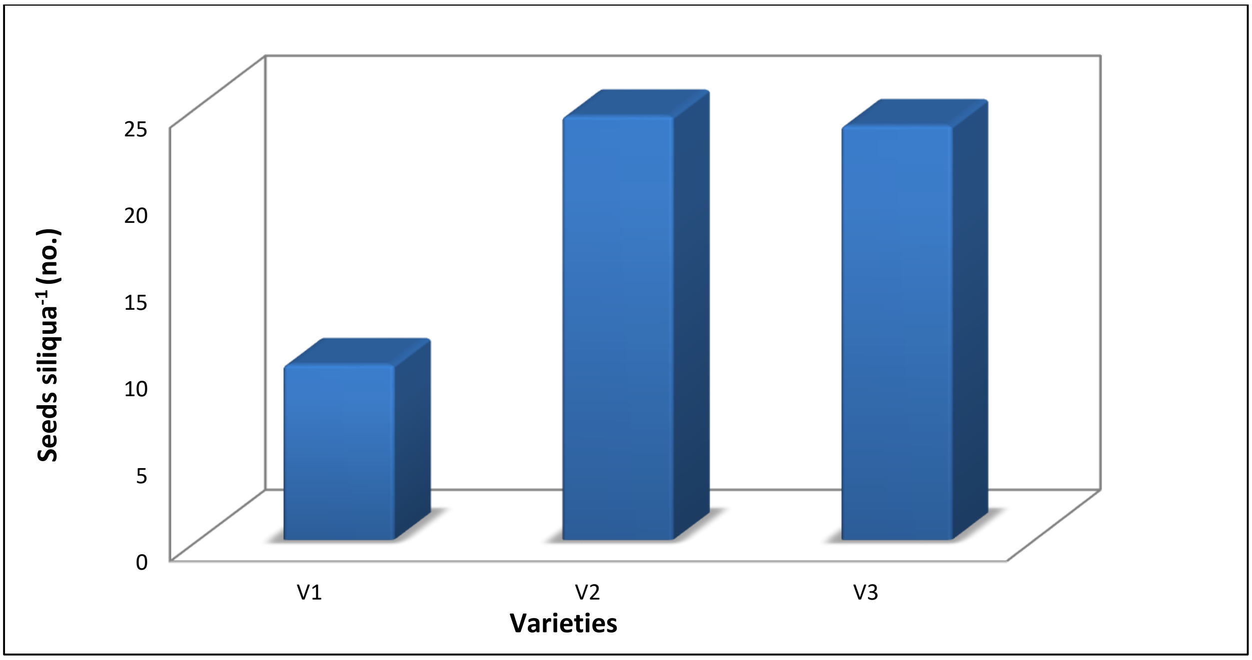
4.2.3.3 Combined effect of variety and planting geometry

There was a significant variation in length of siliqua observed due to interaction between varieties and planting geometry in rapeseed-mustard is given in Table 5. Where V_2S_2 achieved the highest (4.78 cm) length and which was statistically similar (4.57, 4.51, 4.51, 4.44, 4.42 and 4.36 cm, respectively), with V_3S_4, V_3S_3, V_2S_5, V_3S_5, V_2S_3 and V_3S_2.

4.2.4 Seeds siliqua^{-1} (no.)

4.2.4.1 Effect of variety

Varietal effect on seeds siliqua^{-1} varied significantly due to the test varieties in this experiment (Figure 11). The result revealed that the highest number of seeds siliqua^{-1} (24.43) was obtained from V_2 (BARI Sarisha-14) which was significantly higher than that of (23.88) from V_1 (BARI Sarisha-11) and (10.13) from V_3 (BARI Sarisha-17) but both are statistically similar. The result obtained from the present study was conformity with the findings of Aziz (2014) and Akhter (2005). They observed significant variation on the number of seeds siliqua^{-1} affected by variety of mustard and rapeseed. They also found maximum number of seeds siliqua^{-1} (24.00) from BARI Sarisha-13 and minimum number of seeds siliqua^{-1} (10.75) from BARI Sarisha-11.

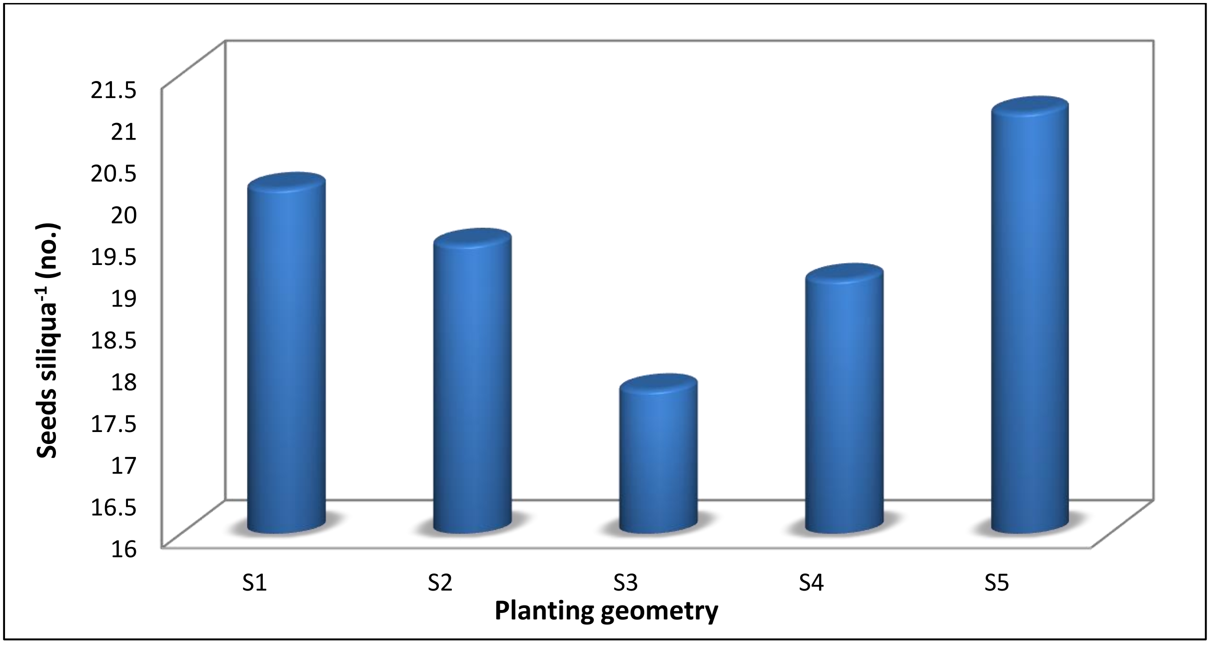


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 11. Effect of variety on seeds siliqua^{-1} of rapeseed-mustard (LSD $_{(0.05)}$ = 1.18).

4.2.4.2 Effect of planting geometry

Planting geometry has significant effect on the number of seeds siliqua^{-1}. The highest seeds siliqua^{-1} was (21.04) observed from S_5 which was statistically similar (20.13) with S_1 is given in Figure 12. The lowest no. of seeds siliqua^{-1} was (17.72) obtained from S_3 which was statistically similar (19.04) with S_4. Hossain *et al.* (2013) and Sharma (1992) also observed an increase in row spacing resulted in consistent increases in the number of seeds siliqua^{-1} in different cultivars of rape-mustard. Different evidence was also found (Singh and Singh, 1984). He reported that the seeds siliqua^{-1} increased as the plant density decreased.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 12. Effect of planting geometry on seeds siliqua^{-1} of rapeseed-mustard (LSD $_{(0.05)}$ = 1.49).

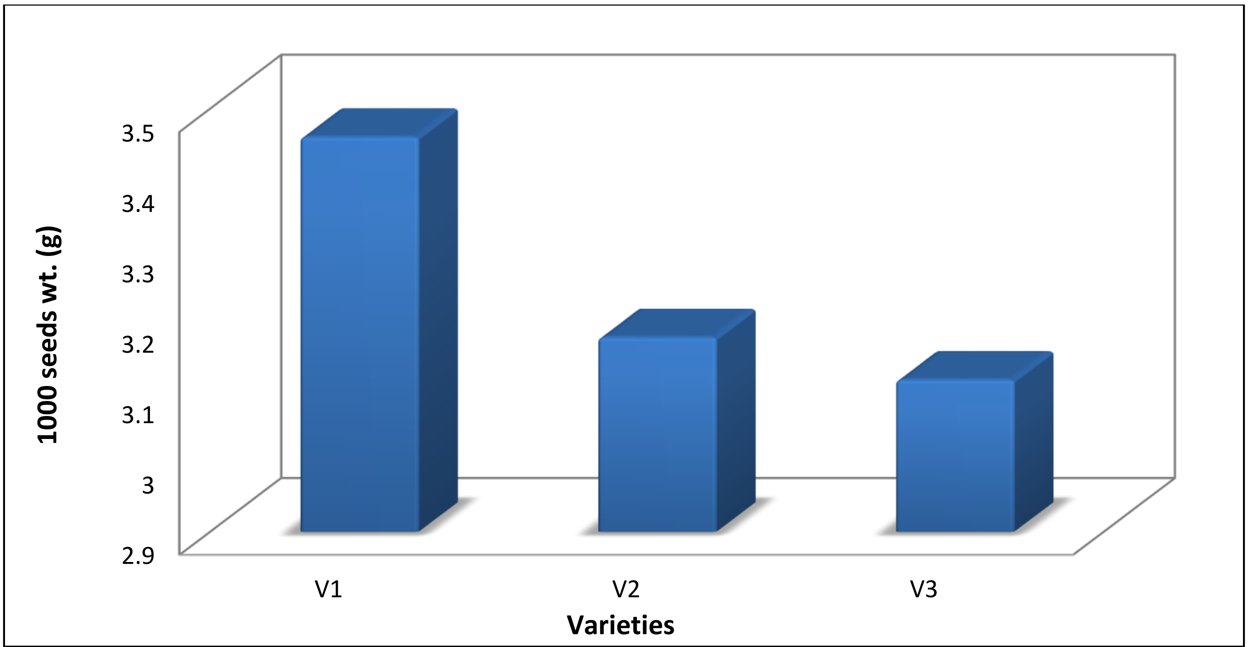
4.2.4.3 Combined effect of variety and planting geometry

There was a significant variation on the number of seeds siliqua^{-1} observed due to interaction between varieties and planting geometry in rapeseed-mustard is presented in Table 5. V_3S_5 achieved the highest (27.42) number of seeds siliqua^{-1} and which was statistically similar (25.01, 25.09 and 27.09 respectively) with V_2S_3, V_2S_5 and V_3S_1. The lowest no. of seeds siliqua^{-1} was (9.53) obtained from V_1S_1 which was statistically similar (9.83, 10.08, 10.60 and 10.60 respectively) with V_1S_2, V_1S_4, V_1S_3 and V_1S_5.

4.2.5 1000 seeds weight (g)

4.2.5.1 Effect of variety

The 1000 seeds weight was statistically significant among the varieties (Figure 13). The highest 1000 seeds weight of (3.46 g) from V_1 and the lowest 1000 seeds weight of (3.12 g) was found in V_3 which was statistically identical (3.18 g) to V_2. The result obtained from the present study was not similar with the findings of Ozer (2003) and he found no significant differences for 1000 seeds weight between the cultivars. The increase in row spacing did not significantly affect 1000 seeds weight. Mondal and Wahab (2001) observed that the weight of 1000 seeds varied from variety to variety. Sana *et al.* (2003) and Karim *et al.* (2000) also reported that the varieties showed significant difference in weight of thousand seeds.

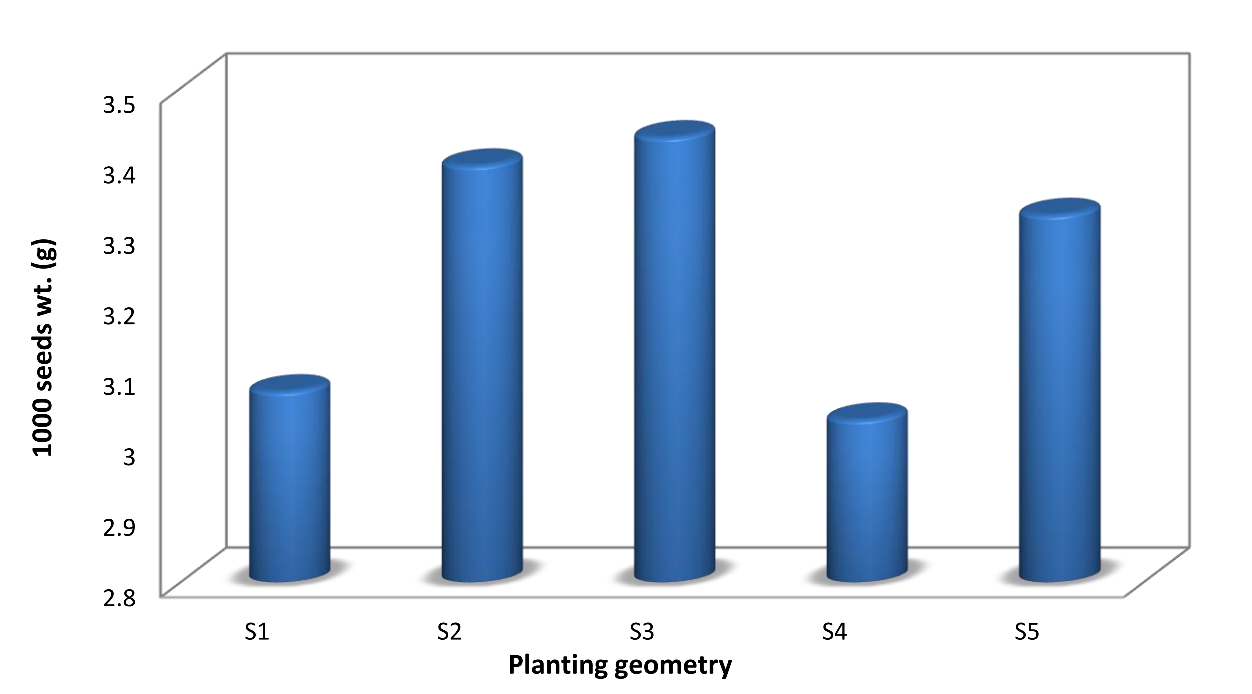


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 13. Effect of variety on 1000 seeds wt. of rapeseed-mustard (LSD $_{(0.05)}$ = 0.14).

4.2.5.2 Effect of planting geometry

Different planting geometry significant effect on 1000 seeds weight (Figure 14). The highest 1000 seeds weight was (3.43 g) observed from S_3 which was statistically similar (3.39 and 3.32 g) with S_2 and S_5 respectively. The lowest 1000 seeds weight was (3.03 g) from S_4 statistically similar (3.07 g) with S_1. Atlassi *et al.* (2008) found significant variation on 1000 seeds weight for different planting pattern and inter plant spacing. This agreed with previous papers which found that the varieties showed significant difference in weight of thousand seeds from Sher *et al.* (2001) and Karim *et al*. (2000). But difference also found from O'Donovan (1996) and Kudla (1993) and they observed that 1000 seeds weight was not significantly affected by plant densities.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 14. Effect of planting geometry on 1000 seeds wt. of rapeseed-mustard (LSD $_{(0.05)}$ = 0.17).

4.2.5.3 Combined effect of variety and planting geometry

There was a significant variation on weight of 1000 seeds with the interaction effect of variety and planting geometry. Combined effect of variety and planting geometry on weight of 1000 seeds is given in Table 5. It was found that the highest 1000 seeds weight (3.63 g) was found from the interactions of V_1S_2 which was statistically identical to (3.54, 3.49, 3.47, 3.42, 3.41, 3.39 and 3.35gm respectively) from V_1S_3, V_1S_1, V_3S_2, V_1S_5, V_3S_3, V_2S_5 and V_2S_3. On the other hand, the lowest 1000 seeds weight (2.60 g) was found from the treatment combination of V_3S_1.

Table 5. Combined effect of variety and planting geometry on siliqua length, seeds silliqua^{-1} and 1000 seeds wt. of rapeseed-mustard at harvest

Treatment Combination	Siliqua length (cm)	Seeds silliqua^{-1} (no.)	1000 seeds wt. (g)
V_1S_1	3.81 de	9.53 e	3.49 ab
V_1S_2	3.59 e	9.83 e	3.63 a
V_1S_3	3.79 de	10.60 e	3.54 a
V_1S_4	3.77 de	10.08 e	3.22 b-e
V_1S_5	3.97 c-e	10.60 e	3.42 a-c
V_2S_1	4.19 b-d	23.77 c	3.13 c-e
V_2S_2	4.78 a	24.41 bc	3.08 de
V_2S_3	4.42 ab	25.01 a-c	3.35 a-d
V_2S_4	4.31 bc	23.86 c	2.93 e
V_2S_5	4.51 ab	25.09 a-c	3.39 a-c
V_3S_1	4.32 bc	27.09 ab	2.60 f
V_3S_2	4.36 a-c	24.13 c	3.47 ab
V_3S_3	4.51 ab	17.56 d	3.41 a-c
V_3S_4	4.57 ab	23.19 c	2.94 e
V_3S_5	4.44 ab	27.42 a	3.16 c-e
$LSD_{(0.05)}$	0.44	2.91	0.29
CV(%)	6.25	7.88	5.29

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

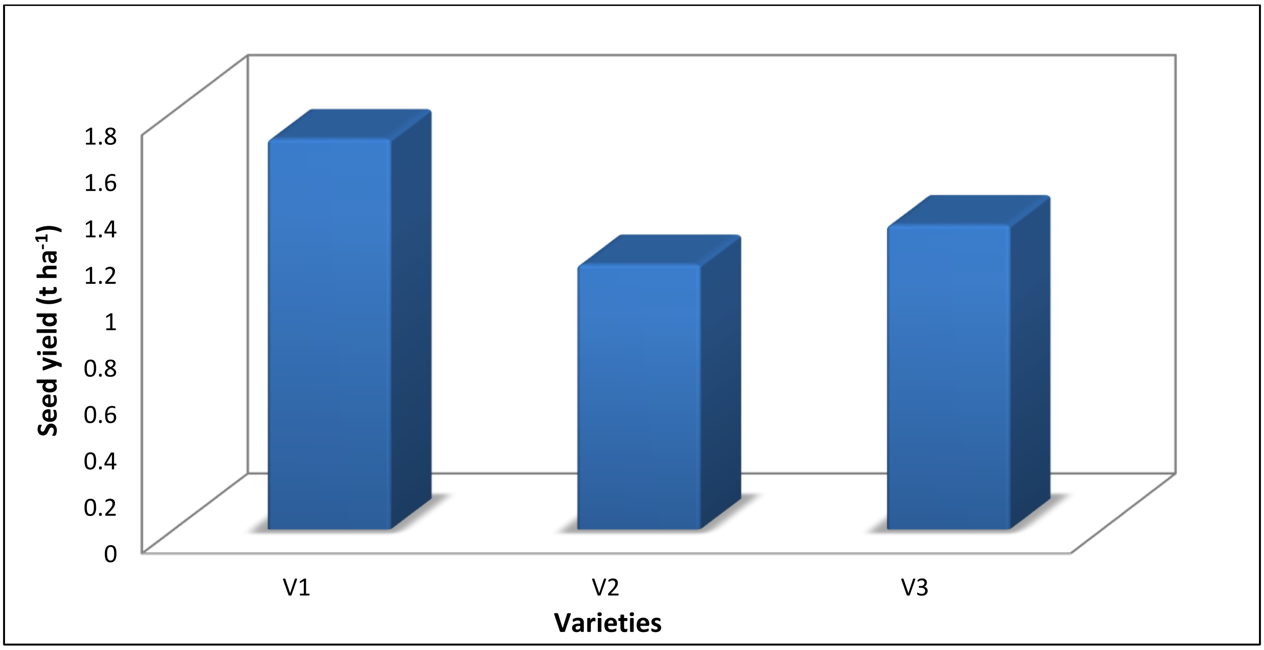
In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

4.3 Yield parameters

4.3.1 Seed yield (t ha^{-1})

4.3.1.1 Effect of variety

Seed yield is measured how much seeds are being developed to siliqua. There was a significant variation on seed yield of rapeseed-mustard varieties from each other shown in Figure 15. The results under the present study indicated that the variety V_1 (BARI Sarisha-11) produced seed yield (1.68 t ha^{-1}) which was significantly highest than those of (1.31 and 1.14 t ha^{-1}) obtained from V_2 and V_3 (BARI Sarisha-14 and BARI Sarisha-17). The lowest seed yield (1.14 t ha^{-1}) was found with the variety V_2 (BARI Sarisha-14). Khanlou and Sharghi (2015) found significant variation in seed yield among the cultivars. Aziz (2014) also indicated the yield variation due to varietal differences. He observed that highest grain yield (3.74 t ha^{-1}) from BARI Sarisha-11 and the lowest grain yield (2.54 t ha^{-1}) from BARI Sarisha-15. This result is match with the findings of Islam and Mahfuza (2012), Rahman (2002) and Islam *et al*. (1994).

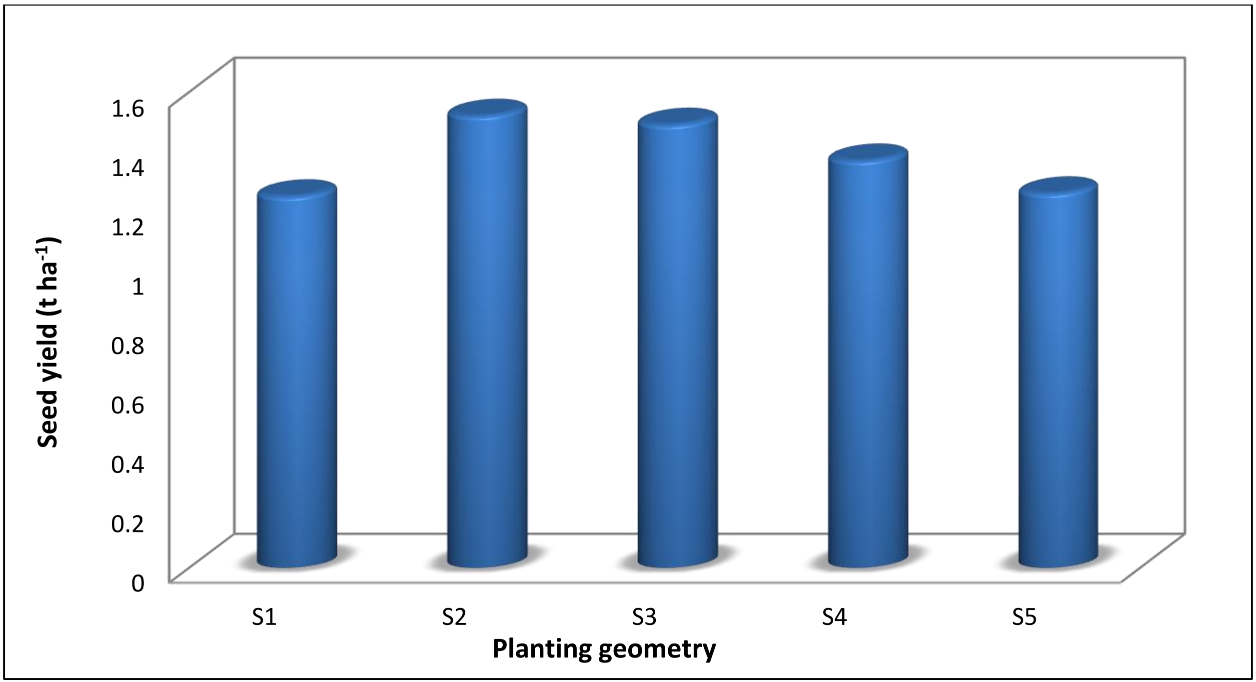


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 15. Effect of variety on seed yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.004).

4.3.1.2 Effect of planting geometry

Different planting pattern had significant influence on the seed yield shown in Figure 16. It was observed that the maximum seed yield (1.52 t ha^{-1}) was found from S_2 (25 cm x 5 cm) which was statistically identical to (1.49 t ha^{-1}) was found from S_3 (30 cm x 5 cm). On the other hand, the lowest seed yield (1.25 t ha^{-1}) was found from S_1 (Random geometry) which was statistically similar (1.26 t ha^{-1}) was found from S_5 (40 cm x 5 cm). It can be mentioned that lower plant spacing i.e. higher plant population increase seed yield to a certain level but excess plant population is a reason of decreased seed yield. The result obtained from the present study was similar with the findings of Ozer (2003) and Sahoo *et al*. (2000). He observed that seed yield was significantly affected by spacing between rows and rape yield were higher at narrower row spacing compared to middle and wider spacing. Whereas it is differed from Bilgili *et al.* (2003) and Sher *et al.* (2001). They found that varying inter-plant spacing had non-significant effect on seed yield.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 16. Effect of planting geometry on seed yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.008).

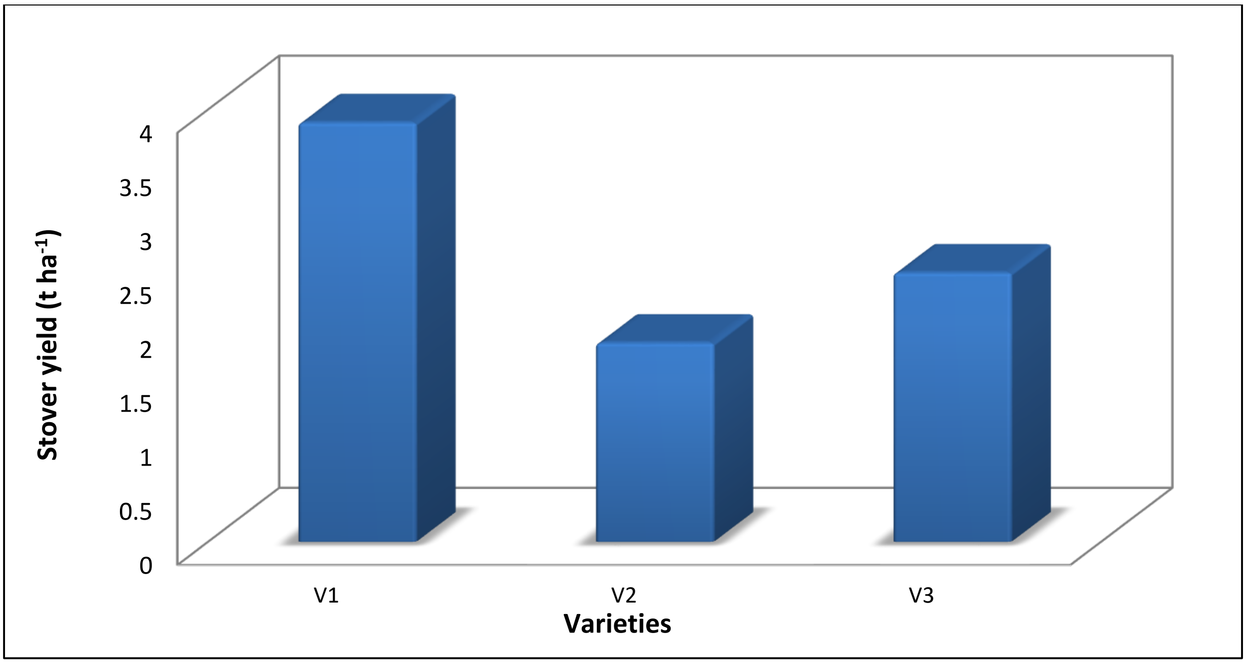
4.3.1.3 Combined effect of variety and planting geometry

Combination of variety and planting geometry played an important role for promoting the seed yield. Seed yield exposed inequality due to different interaction effect of variety and planting geometry. Results showed that the maximum seed yield (2.15 t ha^{-1}) was found from the interactions of V_1S_4 which was statistically identical to (2.09 t ha^{-1}) from V_1S_3 but statistically different from all other treatment combinations presented in Table 6. The lowest seed yield (0.77 t ha^{-1}) was found from the treatment combination of V_3S_4 which was closely followed by V_2S_5 (0.83 t ha^{-1}).

4.3.2 Stover yield (t ha^{-1})

4.3.2.1 Effect of variety

Stover yield of rapeseed-mustard varieties were significantly different from one another (Figure 17). The results under the present study indicated that the variety V_1 (BARI Sarisha-11) produced stover yield (3.88 t ha^{-1}) which was statistically different with (1.84 t ha^{-1}) from V_2 (BARI Sarisha-14) and was significantly highest than those of (2.49 t ha^{-1}) from V_3 (BARI Sarisha-17). The lowest stover yield of (1.84 t ha^{-1}) was found with the variety V_2 (BARI Sarisha-14). The result obtained from the present study had similarity with the findings of Akhter (2005) reported that stover yield of mustard and rapeseed plant was significantly affected by different variety. He found the highest stover yield (3.68 t ha^{-1}) was obtained from BARI Sarisha-7 was statistically similar with (3.42 t ha^{-1}) with the variety BARI Sarisha-11.

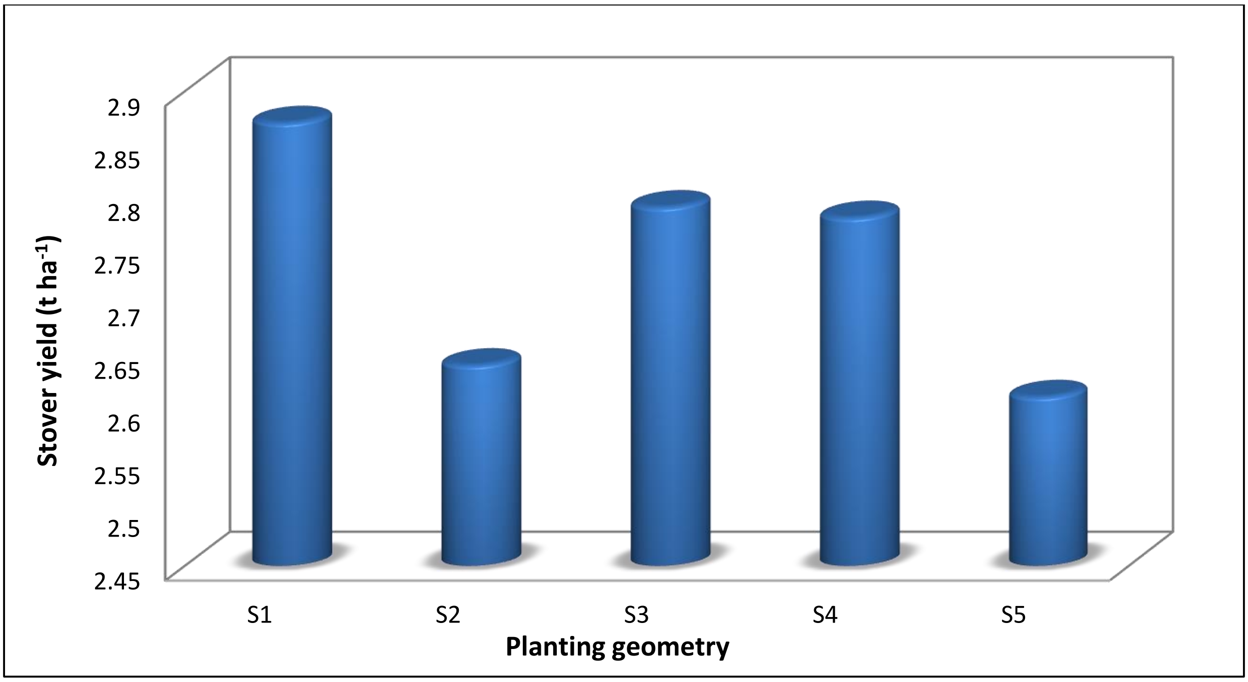


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 17. Effect of variety on stover yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.03).

4.3.2.2 Effect of planting geometry

Planting geometry had significant influence on the stover yield (Figure 18). It was observed that the highest stover yield (2.87 t ha^{-1}) was found from S_1 which was statistically similar with (2.79 and 2.78 t ha^{-1}) from S_3 and S_4. On the other hand, the lowest stover yield (2.61 t ha^{-1}) was found from S_5 which was statistically similar to (2.64 t ha^{-1}) from S_2. It is mention that lower plant spacing i.e. higher plant population increased stover yield to at a certain level but excess plant population was one of the reason of decreased stover yield. It might be due to accommodation of more number of plants/m^2 in closer row spacing. The result obtained from the present study had similarity with the findings of Singh *et al.* (2003) and Chauhan *et al.* (1993). They concluded that row spacing greatly influenced the stover yield of mustard due to variation of the spacing area. Among three rows spacing (20, 30 and 40 cm) 30 cm row spacing gave highest yield of stover and second highest yield was obtained from 40 cm which was statistically different with 30 cm row spacing of stover yield.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 18. Effect of planting geometry on stover yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.02).

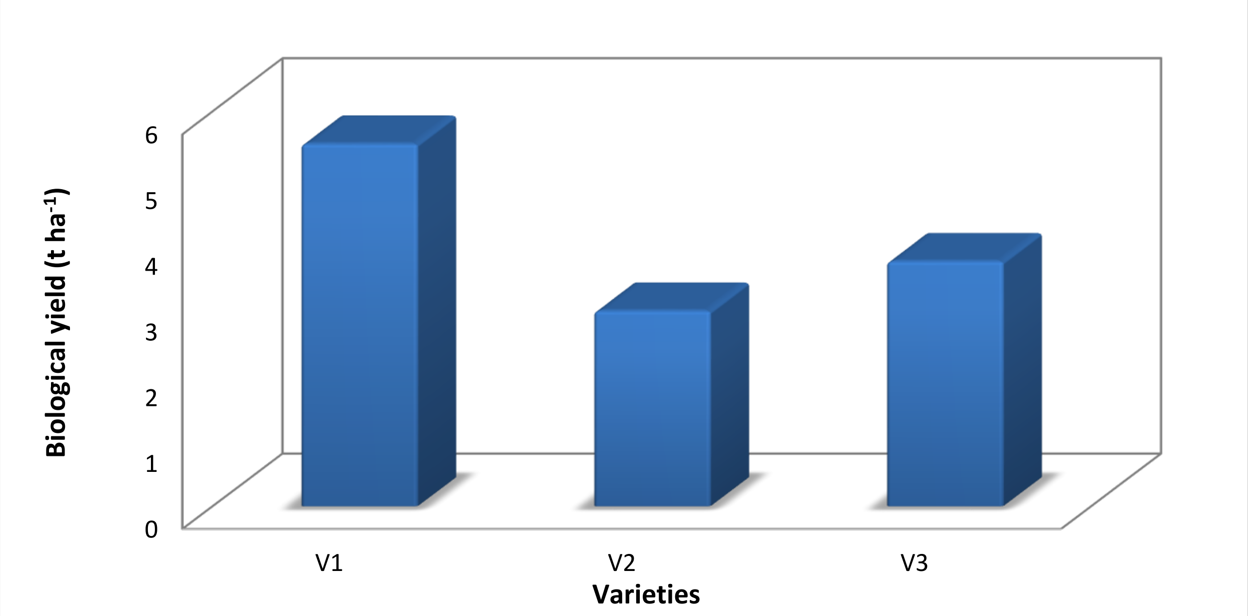
4.3.2.3 Combined effect of variety and planting geometry

Stover yield was significantly increased by the interaction effect of variety and planting geometry is presented in Table 6. Results showed that the maximum stover yield (4.29 t ha^{-1}) was found from the interactions of V_1S_4 which was statistically similar to (4.07 and 4.05 t ha^{-1}) V_1S_5 and V_1S_3 and different from all other treatment combinations. On the other hand, the lowest stover yield (1.51 t ha^{-1}) was found from the treatment combination of V_2S_5 which was statistically identical with V_2S_4 (1.76 t ha^{-1}).

4.3.3 Biological yield (t ha^{-1})

4.3.3.1 Effect of variety

Biological yield of rapeseed-mustard varieties were significantly different from one another (Figure 19). The top scorer variety V_1 (BARI Sarisha-11) produced biological yield (5.51 t ha^{-1}) which was statistically different from all other test varieties. The lowest biological yield (2.98 t ha^{-1}) was found with the variety of V_2 (BARI Sarisha-14). The middle most biological yield (3.73 t ha^{-1}) was found with the variety of V_3 (BARI Sarisha-17). The result obtained from the present study was match with the findings of Aziz (2014). Who found the highest biological yield from BARI Sarisha-11.

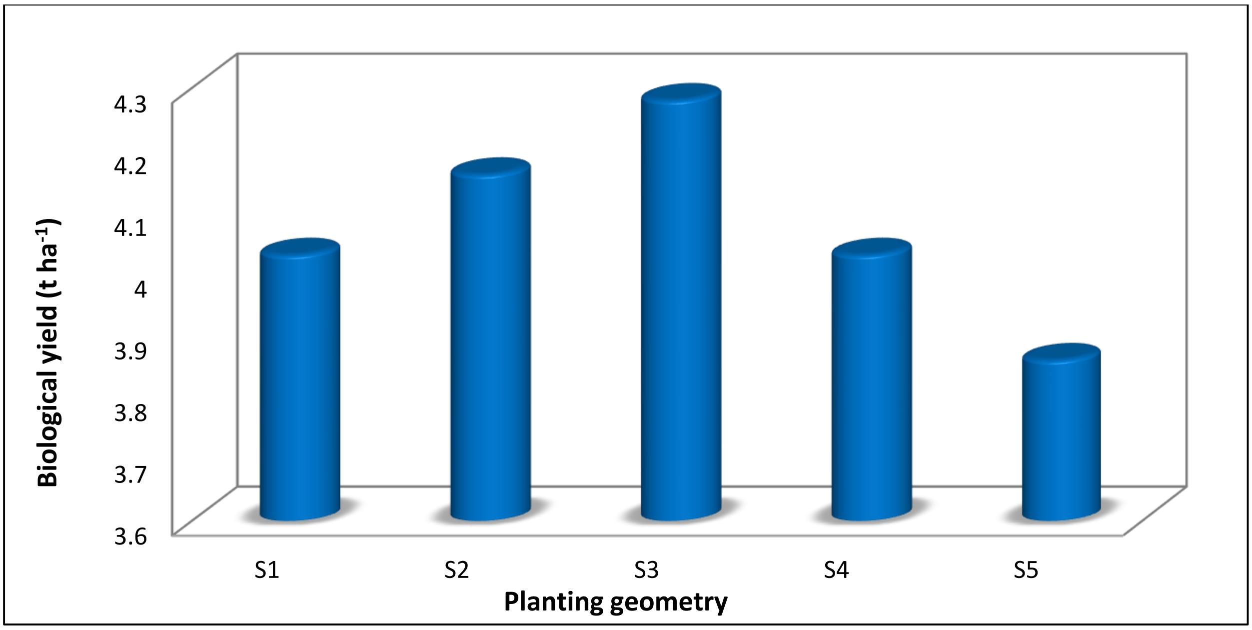


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 19. Effect of variety on biological yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.31).

4.3.3.2 Effect of planting geometry

Planting geometry had significant influence on the biological yield (Figure 20). It was observed that the highest biological yield (4.28 t ha^{-1}) was found from S_3 (30 cm x 5 cm) which was statistically identical with (4.17 t ha^{-1}) from S_2 (25 cm x 5 cm). The lowest biological yield (3.87 t ha^{-1}) was found from S_5 (40 cm x 5 cm). The result obtained from the present study was similar with the findings of Singh *et al*. (1986). They observed that increasing row spacing of all the varieties increased the biological yield.



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 20. Effect of planting geometry on biological yield of rapeseed-mustard (LSD $_{(0.05)}$ = 0.02).

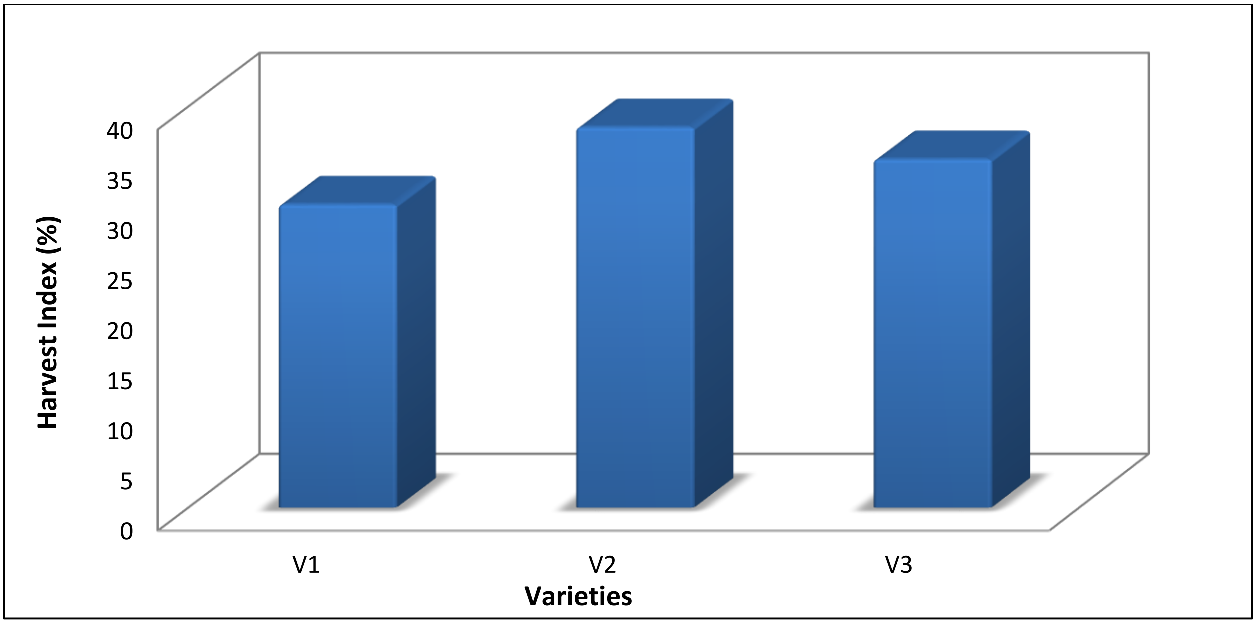
4.3.3.3 Combined effect of variety and planting geometry

There was significantly increased of biological yield by the interaction effect of variety and planting geometry is given in Table 6. Results showed that the maximum biological yield (6.44 t ha^{-1}) was found from the interactions of V_1S_4 which was statistically different from all other treatment combinations. On the other hand, the lowest biological yield (2.34 t ha^{-1}) was found from the treatment combination of V_2S_5 which was statistically identical with V_3S_4 (2.70 t ha^{-1}).

4.3.4 Harvest index (%)

4.3.4.1 Effect of variety

Harvest index was significantly varied among the varieties rapeseed-mustard (Figure 21). The highest harvest index (37.93 %) was obtained from V_2 (BARI Sarisha-14) and the lowest harvest index (30.22 %) obtained from V_1 (BARI Sarisha-11). The result obtained from the present study was similar with the findings of Akhter (2005) and Islam *et al*. (1994). Mehrota *et al.* (1976) recorded that harvest index values ranging from 25 to 40 % in *B. juncea* and that for *B. campestris* from 27 to 42 %.

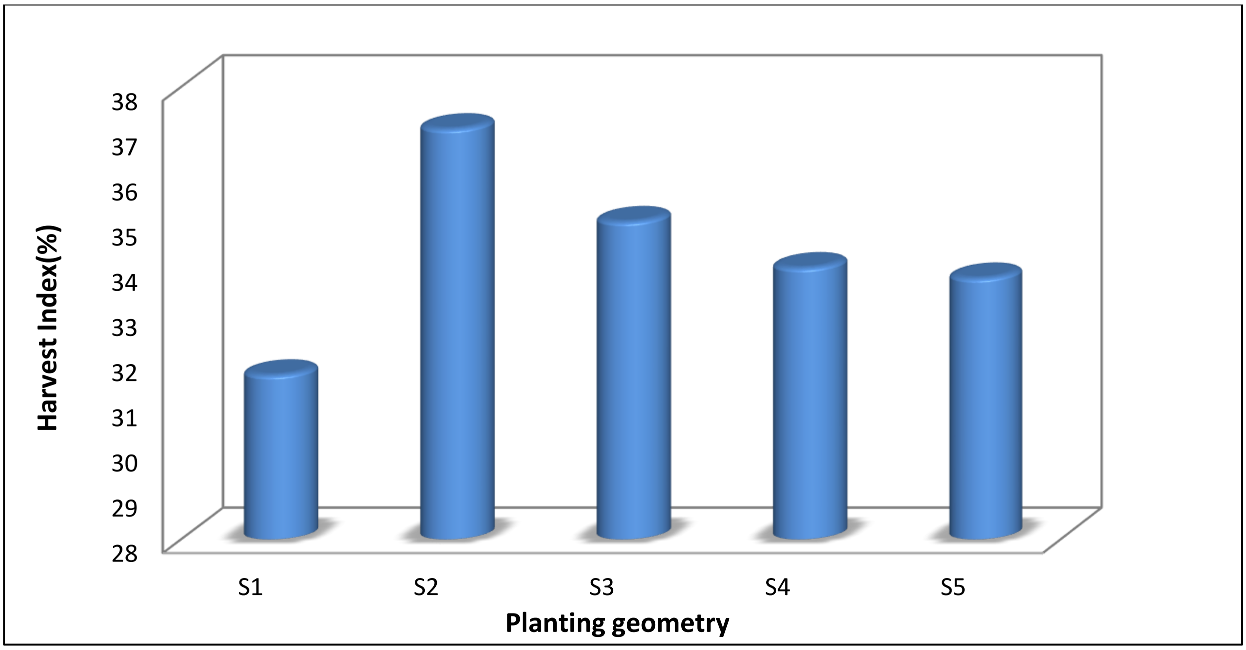


V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 & V_3 = BARI Sarisha-17

Figure 21. Effect of variety on harvest index of rapeseed-mustard (LSD $_{(0.05)}$ = 2.24).

4.3.4.2 Effect of planting geometry

Planting geometry had significant influence on the harvest index (Figure 22). It was observed that the highest harvest index of (37.07%) was found from S_2 which was statistically similar to (35.02 %) from S_3 and different from all other treatments of plant population. On the other hand, the lowest harvest index of (31.63%) was found from S_1 which was statistically similar to (34.00 % and 33.77 %) from S_4 and S_5. The result obtained from the present study was similar with the findings of Shrief *et al.* (1990) and Scarisbric *et al.* (1982).



S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

Figure 22. Effect of planting geometry on harvest index of rapeseed-mustard (LSD $_{(0.05)}$ = 2.66).

4.3.4.3 Combined effect of variety and planting geometry

Harvest index was significantly increased by the interaction effect of variety and population density is given in Table 6. The maximum harvest index (43.21 %) was found from the interactions of V_2S_2 which was statistically similar to (40.04 %) from V_2S_4 whereas V_3S_2, V_3S_5, V_3S_3 V_2S_1 and V_2S_5 were also showed comparatively higher harvest index but significantly different from V_2S_2 and V_2S_4. On the other hand, the lowest harvest index (25.55 %) was found from the treatment combination of V_1S_1 which was also significantly similar to (29.90, 28.56 and 28.16 %) from V_1S_2, V_3S_4 and V_1S_5 combinations respectively. The result obtained from the present study was similar with the findings of Mamun *et al.* (2014) and Shrief *et al*. (1990).

Table 6. Combined effect of variety and planting geometry on seed yield , stover yield, biological yield and harvest index of rapeseed-mustard

Treatment Combination	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
V_1S_1	1.21 f	3.79 b	4.73 d	25.55 h
V_1S_2	1.36 de	3.19 c	4.55 de	29.90 f-h
V_1S_3	2.13 a	4.05 ab	6.14 b	34.09 c-f
V_1S_4	2.15 a	4.29 a	6.44 a	33.39 d-f
V_1S_5	1.60 c	4.07 ab	5.67 c	28.16 gh
V_2S_1	1.15 fg	1.98 de	3.13 g	36.73 b-e
V_2S_2	1.48 cd	1.93 de	3.41 f	43.21 a
V_2S_3	1.05 g	2.03 de	3.08 gh	33.99 c-f
V_2S_4	1.18 f	1.76 ef	2.94 gh	40.04 ab
V_2S_5	0.83 h	1.51 f	2.34 i	35.67 b-e
V_3S_1	1.38 de	2.85 c	4.27 e	32.60 e-g
V_3S_2	1.72 b	2.81 c	4.53 de	38.09 bc
V_3S_3	1.33 e	2.28 d	3.61 f	36.99 b-e
V_3S_4	0.77 h	2.28 d	2.70 hi	28.56 gh
V_3S_5	1.35 e	2.25 d	3.60 f	37.48 b-d
LSD (0.05)	0.02	0.05	0.04	4.65
CV(%)	5.61	7.82	3.85	7.96

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-17

S_1 = Random geometry, S_2 = 25 cm x 5 cm, S_3 = 30 cm x 5 cm, S_4 = 35 cm x 5 cm and S_5 = 40 cm x 5 cm

In each column, figures having similar letters or without letters do not differ significantly, where as figures bearing dissimilar letter differ significantly at 5% level of probability.

Chapter V
Summary and Conclusion

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SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, in the Rabi season (November - February) of 2015 - 2016 to evaluate the performance of the planting geometric effect on growth and yield of rapeseed-mustard varieties. The experiment was comprised of two factors. Factor A: Variety and Factor B: Planting Geometry. Three different varieties were (i) V_1 = BARI Sarisha-11, (ii) V_2 = BARI Sarisha-14 and (iii) V_3 = BARI Sarisha-17 used with five planting geometry (row spacing) viz. (i) S_1 = Random geometry, (ii) S_2 = 25 cm x 5 cm, (iii) S_3 = 30 cm x 5 cm, (iv) S_4 = 35 cm x 5 cm and (v) S_5 = 40 cm x 5 cm. The experiment was laid out in split-plot design with three replications having variety in the main plots and planting geometry in the sub plots. The size of the individual plot was 2 m x 2 m and total numbers of plots were 45. There were 15 treatment combinations. The data on crop growth characters like Plant height (cm), Leaves plant^{-1} (no.), Branches plant^{-1} (no.), Siliquae plant^{-1} (no.), Length of siliqua (cm), Seeds siliqua^{-1} (no.), Weight of 1000 seeds (g), Seed yield (t ha^{-1}), Stover yield (t ha^{-1}), Biological yield (t ha^{-1}) and Harvest index (%). Data were collected from the experimental field also recorded during the period from 30 to 75 DAS at 15 days interval and at harvest. Analysis was done by using the STATISTIX 10 package. The mean differences among the treatments were compared by least significant difference test at 5 % level of significance. Significant variation was found in all parameters at different growth stages of different varieties of rapeseed-mustard.

Considering crop growth parameters, results of the experiment showed that plant height was significantly influenced by different variety. At harvest V_1 gained the highest plant height was (127.36 cm) and the lowest value (84.06 cm) was from V_2. Planting geometry S_2 given the tallest plant (106.31 cm) and S_1 given the smallest (92.96 cm). The largest plant height (140.78 cm) was recorded from V_1S_2 combination whereas the lowest (81.29 cm) was from V_2S_2 at harvest.

Number of leaves plant^{-1} affected significantly due to planting geometry with variety. The maximum no. of leaves plant^{-1} (38.88) was obtained from V_2 and the minimum (32.29) was recorded from V_3 at 75 DAS. S_5 scored the highest leaves plant^{-1} (46.89) whereas S_1 gained the lowest leaves plant^{-1} (26.80) at 75 DAS. Combination V_2S_5 scored the maximum leaves plant^{-1} (54.33) and combination V_3S_1 scored the minimum leaves plant^{-1} (18.20) at 75 DAS.

Considering yield contributing parameters, the highest number of branches plant^{-1} (13.74) and were found from V_1 and the lowest value (7.96) was from V_3. S_4 treatment at harvest given the highest branches plant^{-1} (13.11) whereas the S_1 given the lowest (7.09). V_1S_4 showed the highest no. of branches plant^{-1} (16.53) and V_3S_1 given the lowest (4.73) at harvest.

At harvest V_1 showed the highest no. of siliquae plant^{-1} (179.58) and V_3 given the lowest siliquae plant^{-1} (75.03). S_3 given the highest siliquae plant^{-1} (141.13) and the lowest number (77.10) from S_1. V_1S_3 treatment combination showed the highest siliquae plant^{-1} (238.90) at harvest and V_3S_1 given the lowest number (34.50).

On rapeseed-mustard non significant result was found on the length of siliqua with planting geometry at harvest. The highest length of siliqua (4.44 cm) was attained from V_2 and V_3 where the lowest was recorded (3.79 cm) from V_1. S_5 showed the highest length of siliqua (4.31 cm) and the lowest length of siliqua (4.11 cm) was recorded from S_1. V_2S_2 combination was the top scorer in length of siliqua (4.78 cm) and V_1S_2 was the lowest scorer (3.59 cm) at harvest.

The number of seeds siliqua^{-1} was significantly influenced by different variety at harvest. The highest number seeds siliqua^{-1} (24.43) was found V_2 and V_1 given the lowest (10.13). S_5 given the highest seeds siliqua^{-1} (21.04) and the lowest number (17.72) from S_3. V_3S_5 treatment combination showed the highest seeds siliqua^{-1} (27.42) at harvest and V_1S_1 given the lowest number of seeds siliqua^{-1} (9.53).

The three varieties had significance on 1000 seeds weight. The highest 1000 seeds weight (3.46 g) was recorded by V_1 and the lowest result (3.12 g) by V_3. S_3 (3.43 g) produced the highest 1000 seeds weight and S_4 (3.03 g) produced the lowest 1000 seeds weight. Treatments combination V_1S_2 given the highest 1000 seeds weight (3.63 g) while the lowest weight was (2.60 g) from V_3S_1.

Considering yield parameters, the top most seed yield (1.68 t ha^{-1}) was shown by V_1 and that was lower (1.14 t ha^{-1}) in V_2. In addition the best yield (1.52 t ha^{-1}) was shown by S_2 and that was lowest (1.25 t ha^{-1}) in S_1. V_1S_4 treatment scored the maximum seed yield (2.15 t ha^{-1}) but V_3S_4 showed the minimum (0.77 t ha^{-1}) among the combination of treatments.

The highest stover yield (3.88 t ha^{-1}) was obtained from V_1 and the lowest stover yield (1.84 t ha^{-1}) was recorded from V_2. S_1 scored the highest stover yield (2.87 t ha^{-1}) and S_5 gained the lowest stover yield (2.61 t ha^{-1}). Combination V_1S_4 ranked above stover yield (4.29 t ha^{-1}) and combination V_2S_5 scored the lower stover yield (1.51 t ha^{-1}).

The maximum biological yield (5.51 t ha^{-1}) was obtained from V_1 and the minimum biological yield (2.98 t ha^{-1}) was recorded from V_2. S_3 scored the highest biological yield (4.28 t ha^{-1}) and S_5 gained the lowest biological yield (3.87 t ha^{-1}). Combination V_1S_4 scored the maximum biological yield (6.44 t ha^{-1}) and combination V_2S_5 attained the minimum biological yield (2.34 t ha^{-1}).

The maximum harvest index (HI) (37.93 %) was obtained from V_2 and the minimum HI (30.22 %) was recorded from V_1. S_2 scored the highest HI (37.07 %) and S_1 gained the lowest HI (31.63 %). Combination V_2S_2 attained the maximum HI (43.21 %) and combination V_1S_1 received the minimum HI (25.55 %).

By summarizing this chapter conclusion may be that, the performance among varieties V_1 (BARI Sarisha-11) was better in respect of growth, yield and yield components when sown at S_4 (35 cm x 5 cm) geometric pattern. With this treatment combination the yield was (2.15 t ha^{-1}). Whereas the combination of V_1S_3 (BARI Sarisha-11 with 30 cm x 5 cm) showed very close yield of (2.09 t ha^{-1}). As wider row spacing was significant with the maximum growth and yield contributing parameters of rape-mustard varieties. From the economic point of view, V_1S_4 (BARI Sarisha-11 with 35 cm x 5 cm) was the best combination.

Recommendations

This study was done for one year and found some interesting results. However, it is not wise to recommend with a single experimental findings of a single location and hence the repetition of this work at different AEZs may alter this finding due to the location variation. Therefore, further trial is necessary to reach a conclusion for sustainable practice among the farmers of Bangladesh.

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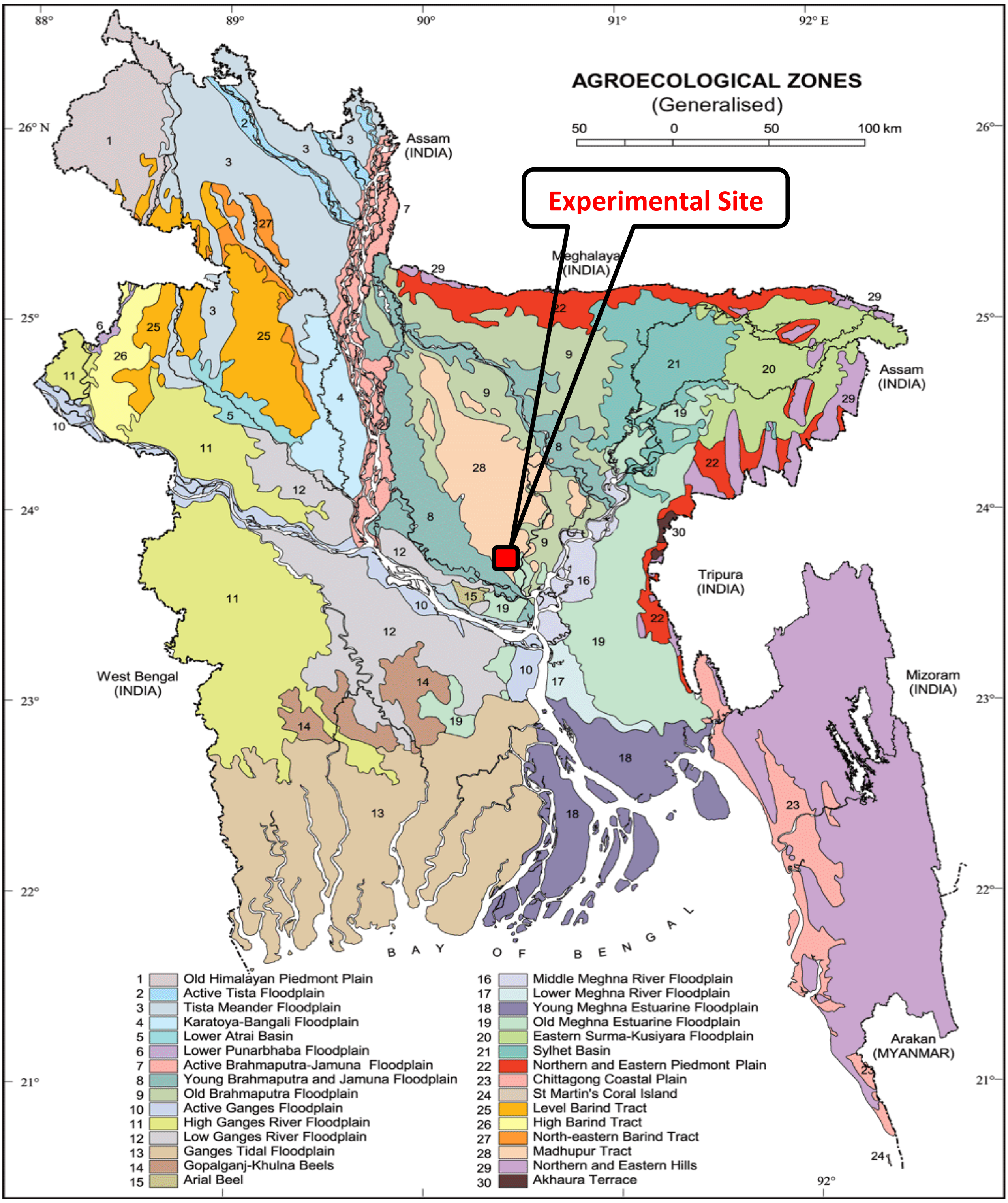
Appendices

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Physical characteristics of the soil of experimental field before seed sowing

Characteristics	Value
Sand (%) (0.2~0.02 min)	10
Silt (%) (0.02~0.002 min)	60
Clay (%) (<0.002 min)	30
Soil textural class	Silty clay loam
Particle density (g/cc)	2.6
Bulk density (g/cc)	1.35
Porosity (%)	46.67

Source: *Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka.*

Appendix III. Chemical properties of the soil of experimental field before seed sowing

Characteristics	Value
pH	5.70
Organic matter (%)	2.35
Total N (5)	0.12
K (mg/100g soil)	0.17
P (mg/g soil)	8.90
S (mg/g soil)	30.55
B (mg/g soil)	0.62
Fe (mg/g soil)	310.40
Zn (mg/g soil)	4.82

Source: *Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka.*

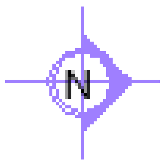
Appendix IV. Monthly average air temperature, relative humidity, total rainfall & sunshine hours of the experimental site during November, 2015 to February, 2016.

Month	Air Temperature (^0C)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hrs)
	Maximum	Minimum			
November, 2015	28.10	6.88	58.18	1.56	5.8
December, 2015	25.36	5.21	54.30	0.63	7.9
January, 2016	21.17	15.46	64.02	0.00	3.9
February, 2016	24.30	19.12	53.07	2.34	5.7

Source: *Bangladesh Meteorological Department (Climate & Weather Division), Agargaon, Dhaka-1207.*

Appendix V. Layout of the experimental design

V_1S_1	V_1S_2	V_1S_3	V_1S_4	V_1S_5
V_2S_4	V_2S_1	V_2S_5	V_2S_3	V_2S_2
V_3S_3	V_3S_5	V_3S_2	V_3S_1	V_3S_4
V_2S_2	V_2S_3	V_2S_4	V_2S_5	V_2S_1
V_3S_5	V_3S_4	V_3S_1	V_3S_2	V_3S_3
V_1S_1	V_1S_5	V_1S_3	V_1S_4	V_1S_2
V_3S_3	V_3S_1	V_3S_5	V_3S_2	V_3S_4
V_2S_1	V_2S_2	V_2S_3	V_2S_4	V_2S_5
V_1S_5	V_1S_4	V_1S_1	V_1S_3	V_1S_2



Number of Plots: 45
Plot size: 2 m x 2 m (4 m^2)
Block to block distance: 0.75 m
Plot to Plot distance: 0.5 m

Variety:

(i) V_1 = BARI Sarisha-11
(ii) V_2 = BARI Sarisha-14
(iii) V_3 = BARI Sarisha-17

Planting geometry:

(i) S_1 = Random geometry
(ii) S_2 = 25 cm x 5 cm
(iii) S_3 = 30 cm x 5 cm
(iv) S_4 = 35 cm x 5 cm
(v) S_5 = 40 cm x 5 cm

Appendix VI. Analysis of variance of the data on plant height of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square of plant height at days after sowing				
		30	45	60	75	At harvest
Replication	2	21.39	3.79	2.01	6.64	3.85
Variety (A)	2	1699.50*	2330.00*	2230.73*	3299.14*	7997.34*
Error I	4	10.79	8.63	42.39	22.95	10.95
Planting geometry (B)	4	153.96*	118.51*	193.90*	173.36*	344.87*
Variety (A) x Planting geometry (B)	8	194.12*	83.94*	135.59*	156.74*	265.99*
Error II	24	19.94	5.58	7.03	14.69	20.32

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on leaves plant^{-1} of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square of leaves plant^{-1} at days after sowing			
		30	45	60	75
Replication	2	0.29	1.37	4.11	5.41
Variety (A)	2	141.01*	249.81*	104.35*	189.60*
Error I	4	0.87	3.86	10.76	8.28
Planting geometry (B)	4	70.35*	459.57*	336.17*	572.86*
Variety (A) x Planting geometry (B)	8	25.40*	52.87*	148.57*	207.39*
Error II	24	1.11	1.67	3.29	3.25

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on branches plant^{-1} of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square of branches plant^{-1} at days after sowing				
		30	45	60	75	At harvest
Replication	2	0.36	1.78	1.92	0.09	0.11
Variety (A)	2	62.26*	4.58*	19.29*	47.43*	126.36*
Error I	4	0.07	0.25	0.34	0.30	1.99
Planting geometry (B)	4	16.41*	11.31*	23.57*	47.92*	58.93*
Variety (A) x Planting geometry (B)	8	7.02*	2.78*	4.79*	10.68*	14.80*
Error II	24	0.07	0.80	1.15	0.81	2.17

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on siliquae plant^{-1} of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square of siliquae plant^{-1} at days after sowing			
		45	60	75	At harvest
Replication	2	56.63	14.9	42.2	56.3
Variety (A)	2	1952.57*	18677.7*	25339.7*	47567.5*
Error I	4	50.07	13.6	20.8	27.5
Planting geometry (B)	4	2574.54*	4222.8*	5667.3*	6342.6*
Variety (A) x **Planting geometry (B)**	8	393.72*	1198.9*	1885.2*	1512.5*
Error II	24	67.78	34.2	31.1	81.3

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on length of siliqua, seeds siliqua^{-1} and 1000 seeds weight of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square values		
		Length of siliqua	Seeds siliqua^{-1}	1000 seeds weight
Replication	2	0.04	0.10	0.006
Variety (A)	2	2.14*	984.78*	0.51*
Error I	4	0.04	3.20	0.02
Planting geometry (B)	4	0.05 ^{NS}	13.78*	0.31*
Variety (A) x **Planting geometry (B)**	8	0.09*	17.78*	0.13*
Error II	24	0.07	2.36	0.03

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Analysis of variance of the data on seed yield, stover yield, biological yield and harvest index of rapeseed-mustard varieties as influenced by different planting geometry and their combinations

Sources of variation	Degrees of freedom (df)	Mean square values			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.00003	0.0007	0.0004	8.13
Variety (A)	2	0.0116*	0.1623*	0.2527*	225.44*
Error I	4	0.00002	0.0012	0.0009	4.88
Planting geometry (B)	4	0.0015*	0.0011*	0.0022*	35.28*
Variety (A) x **Planting geometry (B)**	8	0.0046*	0.0042*	0.0193*	46.92*
Error II	24	0.00006	0.0005	0.0003	7.46

*Significant at 5% level of significance

^{NS} Non significant

Plate no. 1. Image of experimental plot

Plate no. 2. Image of different planting geometry

Plate no. 3. Image of flowering stages of rapeseed-mustard varieties

Plate no. 4. Image of highest branching of BARI Sarisha-11 compared to other varieties

Plate no. 5. Image of siliquae bearing rapeseed-mustard varieties

Plate no. 6. Image of different time maturity stages of rapeseed-mustard varieties