INFLUENCE OF POPULATION DENSITY AND VARIETY ON GROWTH AND YIELD OF RAPESEED-MUSTARD

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INFLUENCE OF POPULATION DENSITY AND VARIETY ON GROWTH AND YIELD OF RAPESEED-MUSTARD

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CERTIFICATE

This is to certify that the thesis entitled, **"INFLUENCE OF POPULATION DENSITY AND VARIETY ON GROWTH AND YIELD OF RAPESEED-MUSTARD"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **FARHANA MAMUN,** Registration No. **06-02066** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated:

Place: Dhaka, Bangladesh

(Dr. Md. Hazrat Ali)
Professor
Research Supervisor

Dedicated to

My

Beloved Parents

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INFLUENCE OF POPULATION DENSITY AND VARIETY ON GROWTH AND YIELD OF RAPESEED-MUSTARD

ABSTRACT

The experiment was conducted at the field of the Sher-e-Bangla Agricultural University farm, Dhaka to evaluate the performance of population density and variety on growth and yield of Rapeseed-Mustard. The experiment consists of two factors (1) Variety and (2) Population density. Four varieties viz. (i) V_1 = BARI Sarisha-13, (ii) V_2 = BARI Sarisha-15, (iii) V_3 = BARI Sarisha-16 and (iv) V_4 = SAU Sarisha-3 were used and four population densities were used viz. (i) P_1 = 100000 plants ha^{-1}; i.e. 10 plants m^{-2} (ii) P_2 = 400000 plants ha^{-1}; i.e.40 plants m^{-2} (iii) P_3 = 700000 plants ha^{-1} i.e. 70 plants m^{-2} and (iv) P_4 = 1000000 plants ha^{-1} i.e. 100 plants m^{-2} .Significant variation was found in all parameters at different growth stages of rapeseed- mustard. Different varieties showed significant variation at different stages. Data also showed that V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) gave the tallest plant (170.90 cm) but the highest leaf length (29.79 cm), leaf breadth (9.16 cm), length of siliqua (7.94 cm), seeds siliqua^{-1} (26.03), 1000 seed weight (4.10 g), seed yield (1.60 t ha^{-1}) and harvest index (41.02%) were found from V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) where the highest dry weight plant^{-1} (22.70 g), branches plant^{-1} (7.56) and siliquae plant^{-1} (145.70) were found from V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}). Again, the maximum stover yield (2.93 t ha^{-1}) and biological yield (4.06 t ha^{-1}) were found from V_3P_3 (BARI Sarisha-16 × 70 plants m^{-2}) and V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) respectively. Considering individual effect, BARI Sarisha-13 (V_1) gave the highest seed yield (1.35 t ha^{-1}), biological yield (3.55 t ha^{-1}) and harvest index (37.65%) where P_3 (70 plants m^{-2}) gave the maximum seed yield (1.32 t ha^{-1}), stover yield (2.33 t ha^{-1}), biological yield (3.48 t ha^{-1}) and harvest index (36.14%). So, above all deliberation, the best result was achieved from the treatment combination of BARI Sarisha-13 × 70 plants m^{-2} (V_1P_3).

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg ha^{-1}	=	Kilogram per hectare
g	=	gram (s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t ha^{-1}	=	ton per hectare
%	=	Percent

Chapter 1

Introduction

INTRODUCTION

Rapeseed-mustard is one of the most important and widely grown oilseed crops of Bangladesh. Rapeseed and Mustard are commonly known as mustard in Bangladesh those belong to the family Cruciferae. Botanically it has mainly three species, *Brassica rapa* L. *Brassica napus* L. and *Brassica juncea* L. These are cultivated for edible oil. Among the species *Brassica rapa* and *Brassica napus* are regarded as “rapeseed” while *Brassica juncea* is regarded as “mustard”. 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). In Bangladesh, rapeseed and mustard are the most important among all oil seed crops. In the year 2011-12 it covered 4.83 lakhs ha and the production was 5.25 lakhs Mt and yield was 1.09 lakhs Mt ha $^{-1}$ (AIS, 2013).

Rapeseed- mustard occupies only 0.336 million hectare, (60%) among oil cropped area (Wahhab *et al.*, 2002). Oilseeds are important in the economy of Bangladesh. At present about 0.234 million hectares of land are under rapeseed-mustard cultivation in Bangladesh with oil yield in the order of 0.203 million tons per year (BARI, 2011) .It is an important source of cooking oil in Bangladesh and meets around one third of the edible oil requirement of the country (Ahmed, 2008).Bangladesh has been facing acute shortage of edible oil for the last several decades. Our internal production can meet only about 21% of total consumption. The rest 79 % is met by the import (Begum *et al.,* 2012). The import of oil and oilseeds to meet up the deficit every year requires huge foreign exchange.

The major reasons for low yield of rapeseed-mustard in our country are due to lack of high yielding variety, appropriate plant population and want of knowledge for sowing time with proper management practices etc.

Oils of plant origin constitute important component of human diet, ranking third after cereals and animal products and are nutritionally superior to animal oil (Singh, 2000). In Bangladesh, about ten oil seed crops are grown in the country of which, *Brassica* oil crop is the most importantoil crop that supplies major edible oil of the country.

It is mainly grown in winter season in Bangladesh. The average per hectare yield of mustard is alarmingly low in Bangladesh compared to other rapeseed growing countries like Germany, France, UK and Canada producing 6667 kg ha^{-1}, 5070 kg ha^{-1}, 3264 kg ha^{-1}, 3076 kg ha^{-1} respectively while its average yield of is 1575 kg ha^{-1} (FAO, 2003).

The area under mustard is declining due to late harvesting of high yielding T. aman rice and increasing boro rice acreage. Last ten years average of both area and production of rapeseed showed a have gradually declining to 104 thousand hectare and 68 thousand tons in the country (Anon. 2006). Domestic production of edible oil comes from rapeseed-mustard, groundnut and sesame.

Edible oils play a very vital role in human nutrition. As a high energy component of food, it is important for meeting the caloric requirement. Each gram oil/fat supplies 9 kilo calorie energy while each gram of carbohydrate/ protein furnishes 4 kilo calorie energy (Stryer, 1980). Vegetable fat is not only a high energy food but also it is provides collesterol free poly unsaturated essential fatty acids like linolenic and ilnoleic acid obtained only from plant sources for human beings.It is a carrier of fat soluble vitamins (A, D, E and K) in the body. On the nutritional point of view at least 15-20 % of total calorie intake in daily diet come from the fats and oils. It is also used from improving the taste of a number of foods and make palatable. Mustard seeds contain 40-45 % oil and 20-25 % protein. It also serves as an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc.

Rapeseed-mustard is grown more or less all over Bangladesh, but more particularly in the districts of Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur, Dhaka (BBS, 2012).

Yield and its development process depend on genetic, environmental and agronomic factors as well as the interaction between them. There is a scope to increase the yield level of mustard by using HYV seed and by adopting proper management practices such as spacing, population density, irrigation, fertilizer application and other cultural operations.

In recent years, Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University, Bangladesh Institute of Nuclear Agriculture (BINA) and Sher-e-Bangla Agricultural University (SAU) has released a number of new high yielding varieties of rapeseed/mustard for farmer's cultivation. The yield of HYV cultivars ranges from 1.4 to 2.5 t ha^{-1} (BARI, 2002). By introducing the high yielding varieties with better fertilizer management packages the yield of mustard can be increased manifold. But the yields in farmer's fields are still low compared to the potentialities due to lack of proper management practices. So there is a scope to increase the yield level of modern varities with proper management practices like spacing, irrigation, seed rate, fertilizer application etc. Cultivation of low yielder local varieties with poor fertilizer management are the major causes for poor yield of mustard in the country (Alam and Rahman. 2006). High yield potential of a crop variety is the prerequisite for increasing its production.

Optimum population plays an important role in producing higher yield. Establishment of optimum population density per unit area is a prerequisite for having increased grain yield. Population density thus influences yield and yield contributing characters in rapeseed production(Johnson *et al*., 2003). Rapeseed and mustard yield can be affected by competitive stress among individual plants. Competition occurs when two or more plants need a particular factor necessary for growth from same place and when the immediate supply of this factor falls below or fails to provide the combined demands of the plants to fulfil the requirement.

Establishment of an optimum population density is one of the important factors for securing good yield of a crop. It is well established that the crop environment with regard to light intensity and concentration of carbon dioxide can play a vital role in photosynthesis of the plant and thus increase dry matter accumulation as well as vegetative growth of the plant. Hence, plant density per unit area influences the crop yield considerably. Optimum population density ensures proper growth of both aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, land as well as air spaces and water.

Keeping in view the inter-plant competition for optimum plant nutrients, sun light, moisture and aeration, it may be required to find out a fair combination of population density to achieve optimum yield under certain agro-climatic conditions.

So, the experiment was under taken to find out the performance of rapeseed – mustard varieties and population density with the following objectives:

1. Examine the effect of variety on the growth, yield and yield contributing characters of rapeseed – mustard.
2. Identify the effect of population density on the growth,yield and yield contributing characters of rapeseed – mustard.
3. Find out interactions between variety and population density on the growth,yield and yield contributing characters of rapeseed – mustard.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Rapeseed – mustard is an important oil seed crop in Bangladesh which can contribute to large extent in the national economy. But the research works done on this crop with respect to agronomic practices are inadequate. Only some limited studies have so far been done in respect of agronomic management practices of the crop particularly the variety and population density. However, a number of such studies have been carried out in other parts of the world. Some of the studies relevant to the present piece of work have been reviewed following the parameters of plant growth and yield.

2.1 Effect of variety

2.1.1 Plant height

Fathy *et al*. (2009) conducted a study at the Agricultural Research Station, Hada El-Sham, King Abdul Aziz 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$^{-1)}$. In terms of varietal differences, the plant height data revealed that Sero-4 was the Plant height of taller, followed by Sero-6, and then Callypso and Pactole varieties.

Plant height of rapeseed and mustard differs among the varieties depending on their genetic makeup. There are three species of cruciferous *Brassica* viz. *Brassica campestris*, *Brassica juncea* and *Brassica napus* from one another with respect to plant growth, development and yield (Alam, 2004). 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 (Sana *et al*., 2003).

In addition, it was reported that different *brassica* varieties differed significantly regarding their plant heights (Reddy and Reddy, 1998).

Ahmed *et al*. (1999) stated 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.

Mondal *et al*. (1992) found that variety had significant effect on plant height. They found the highest plant height (134.4 cm) in the variety J-5004, which was identical with SS-75 and significantly taller than JS-72 and Tori-7.

2.1.2 Branches plant^{-1}

Sana, *et al*. (2003) concluded that the variation in the number of branches per plant is the result of combined effect of genetic make-up of the crop and environmental conditions, which play a remarkable role towards the final seed yield of the crop.

Hussain *et al*. (1996) stated that the varieties were statistically different with respect to number of primary branches. The maximum number was recorded in Semu-249/84.

Khaleque (1989) reported that 3.9 and 3.1 primary branches plant^{-1} produced in TS-72 and Sonali sarisha respectively. Mondal *et al*. (1992) noticed that most of the lower branches were unproductive in Sonali sarisha.

Variable number of branches per plant among different varieties, which have been related to be under genetic management control, has also been reported by Khehra and Singh (1988).

2.1.3 Siliquae plant^{-1}

Fathy *et al*. (2009) conducted 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.

Rana and Pachauri (2001) conducted an experiment at New Delhi at Indian Agricultural Research Institute in sandy loam soil and quoted that the highest number of siliquae per plant recorded in cultivar TERI (OE) R 15 (285) compared to cultivar Bio 902 (238).

Raj Singh *et al*. (2001) conducted an experiment in Jodhpur and observed that number of siliquae plant^{-1} recorded higher in cultivar Pusa Bold (257) compared to cultivar TS9 (198).

Significant differences in the number of siliquae plant^{-1} among different cultivars of brassica and significant differences in seed yield among different varieties of brassica species were reported (Reddy and Reddy, 1998).

Jahan and Zakaria (1997) reported that the highest number of siliquae plant^{-1} was recorded in BLN-900(130.9) which was identical with that Observed in BARI sarisha-6 (126.3). Tori-7 had the lowest (46.3) number of siliquae plant^{-1}.

Reddy and Avilkumar (1997) conducted a field experiment in Jagtial and concluded that mustard cultivar Divya recorded significantly higher number of siliquae plant^{-1} (132) over GM-2 (97).

In Kanpur, Yadav *et al*. (1994) also quoted that number of siliquae plant^{-1} were higher in cultivar Vaibhav (363) compared to cultivar Varuna (257).

Mondal *et al*. (1992) stated that maximum number of siliquae plant^{-1} was in the 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

Rana and Pachauri (2001) conducted an experiment at New Delhi at Indian Agricultural Research Institute in sandy loam soil and observed that length of siliquae recorded higher in cultivar TERI (OE) R 15 (4.6 cm) compared to cultivar Bio 902 (3.47 cm) and cultivar TERI (OE) R 15.

Hussain *et al*. (1996) stated 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 Hyola-101, Sampad, BARI sarisha-6 and Hyloa -51. The shortest siliqua length (4.62 cm) was found in the hybrid Semu-249/84 which was identical to those of Semu-DNK-89/218, AGH-7 and Tori-7. The longest siliqua (8.07 cm) was found in BLN -900 and Hyola -401.

Regression analysis revealed that siliqua weight significantly influenced the seed yield whereas; siliqua length and siliqua diameter had a marginal effect (Gangasaran *et al*. 1981). 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} contributes materially towards the final grain yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield attributes of rapeseed and mustard and population density is a vital factor in producing optimum number of seeds siliqua^{-1}.

Raj Singh *et al*. (2002) recorded that cultivar Laxmi recorded significantly higher number of seeds siliqua^{-1} (13) over BSH1 (11).

Raj Singh *et al*. (2001) conducted an experiment in Jodhpur and observed that cultivar Pusa Bold recorded higher number of seeds siliqua^{-1} (14.02) as compared to cultivar Local (11.15).

Jahan and Zakaria (1997) found 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).

Yadav *et al*. (1994) Kanpur conducted an experiment and reported that, number of seeds siliqua^{-1} recorded significantly higher in cultivar Rohini (14.6 seeds siliqua^{-1}) compared to cultivar Vardan (13.5 seeds siliqua^{-1}).

2.1.6 1000 seed 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. A good number of research works have been conducted on this character.

Fathy *et al*. (2009) conducted a study at the Agricultural Research Station, Hada El-Sham, King Abdul Aziz 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}). In terms of variety differences, Pactale and Sero-4 had the highest 1000-seed weights without significant differences between them, while Callypso variety was the lowest.

Significant differences for 1000-seed weight among different brassica varieties were also reported by Sana, *et al*., 2003.

Raj Singh *et al*. (2002) recorded significantly higher 1000-seed weight in cultivar RH 30 (6.2 g) over Varuna (5.6 g).

Rana and Pachauri (2001) conducted an experiment at New Delhi at Indian Agricultural Research Institute in sandy loam soil and quoted that cultivar Bio 902 recorded higher 1000-seed weight (3.16 g) compared to TERI (OE) R 15 (2.18 g).

Mondal and Wahab (2001) described that weight of 1000-seeds varied from variety to variety and species. They found 1000-seed weight 2.50-2.65 g in case of improved Tori-7 (*B. campestris*) and 1.50.80 g in case of Rai-5 (*B. juncea*).

Karim *et al*. (2000) stated that varieties showed significant variation in the weight of thousand seeds. They found higher weight of 1000-seed in J-3023 (3.43g), J-3018 (3.42g) J- 4008(3.50).

BARI (2001) reported that there was significant variation in 1000-seed 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.

Hussain *et al*. (1998) observed significant variation on 1000-seed weight as influenced by different varieties. They found Hyola- 401 had the highest 1000-seed weight (3.4 g) and the lowest 1000-seed weight was recorded in Tori-7 (2.1 g).

In Kanpur, Yadav *et al*. (1994) also quoted that 1000-seed weight recorded higher in cultivar Rohini (4.9 g) compared to cultivar Vaibhav (4.6 g).

2.1.7 Seed yield

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

Basak *et al*. (2007) conducted a field experiment on Non-Calcareous Dark Grey Floodplain Soil to find out the performance of three mustard varieties viz., i) BARI Sarisha-9, ii) BARI Sarisha-12 and iii) Tori-7 (Local) and three fertilizer doses as: F1= 120-34-64-32-1.5 kg ha^{-1} NPKSB (HYG), F2= 86-26-44-26-1.0 kg ha^{-1} NPKSB (MYG) and F3 = 54-60-15 kg ha^{-1} NPK. The variety BARI sarisha-9 produced the highest seed yield (892 kg ha^{-1}). The fertilizer level of HYG gave higher seed yield (956 kg ha^{-1}). BARI Sharisha-9 gave higher gross return (Tk. 21882 ha^{-1}) and gross margin (Tk.14936 ha^{-1}) under HYG fertilizer level but higher BCR (3.54) was recorded under MYG fertilizer level due to less fertilization cost.

Rahman (2002) observed higher seed yield in BARI sarisha-7, BARI Sharisha-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 Singh *et al*. (2002) recorded significantly higher seed yield in cultivar RH 30 (2390 kg ha^{-1}) over Varuna (2240 kg ha^{-1}).

Raj Singh *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).

In Hissar, Sharma *et al*. (1997) conducted an experiment in sandy loam soil and recorded significantly higher seed yield in cultivar RH-30 (1835 kg ha^{-1}) over RH 819 (1699 kg ha^{-1}).

Yadav *et al*. (1994) Kanpur conducted a experiment and reported that seed yield recorded higher in cultivar Vaibhav (1330 kg ha^{-1}) compared to cultivar Varuna and Rohini (980 and 1020 kg ha^{-1}), respectively.

2.1.8 Stover yield

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 the lowest (3702.3kg ha^{-1}) from PT-303 under high management conditions. The 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.

Reddy and Avilkumar (1997) conducted a field experiment in Jagtial and quoted that cultivar Varuna recorded significantly higher stover yield (2096 kg ha^{-1}) over GM-1 (1806 kg ha^{-1}).

In Kanpur, Yadav *et al*. (1994) also quoted that Stover yield recorded was higher in cultivar Vaibhav (4430 kg ha^{-1}) compared to cultivar Vardan (4000 kg ha^{-1}).

2.1.9 Biological yield

In Hissar, Raj Singh *et al*. (2002) observed that biological yield recorded significantly higher in Laxmi cultivar (1370 kg ha^{-1}) over BJH-1 (1190 kg ha^{-1}).

Rana and Pachauri (2001) 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}).

Several investigators (Khoshanazar et *al*., 2000) 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

Raj Singh *et al*. (2002) conducted 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).

Rana and Pachauri (2001) conducted an experiment at New Delhi at Indian Agricultural Research Institute in sandy loam soil. The cultivar TERI (OE) R 15 showed significantly higher harvest index of 24.5% compared to cultivar TERI (OE) M 21 (18.5%).

Islam *et al*. (1994) showed that variety had significant effect on harvest index (%) of rapeseed and mustard. They found that the highest harvest index 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 population density

2.2.1 Plant height

Meitei *et al*. (2001) conducted two years experiment to determine the effect of (23000 plants ha^{-1}, 40000 plants ha^{-1}, 50000 plants ha^{-1} ,62000 , 83000 plants ha^{-1}, 100000 plants ha^{-1} , 166000 plants ha^{-1}) spacing on the yield and yield components of *B. juncea* var. Rugosa cultivars (*Hanggam Amubi*, *Hanggam Angoubi* and *Hanggam Anganbi*). They observed that *Hanggam Angoubi* gave the highest plant height (52.25 and 48.29 cm) and 23000 plants ha^{-1} population density resulted on the tallest plants (55.00 and 48.38 cm).

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that plant height record was higher in 340000 plants ha^{-1} population (166 cm) as compared to 149000 plants ha^{-1}.

Chauhan *et al*. (1993) reported 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 and Thakur (1993) reported 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 higher than 37.5 cm and 30 cm row spacing. But the effect was not statistically influenced.

2.2.2 Branches plant^{-1}

Rana and Pachauri (2001) also observed that the number of secondary branches plant $^{-1}$ recorded higher in 340000 plants ha $^{-1}$ density (7.6 branches plant $^{-1)}$

Thakur (1999) conducted a field experiment at Himachal Pradesh Krishi Vishwavidyalaya, Kangra and observed that number of primary and secondary branches plant $^{-1}$ was higher in 30 cm row spacing as compared to 20 cm row spacing.

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and reported that primary and secondary branches plant $^{-1}$ recorded significantly higher with 30 × 15 cm row spacing (6.72 and 21.57 branches plant $^{-1}$) as compared to 45 × 15 cm (5.80 and 16.76 branches plant $^{-1}$) .

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. They found that number of branches plant^{-1} was significantly superior in the plant density of 30 plants m^{-2} compared to those from 60 and 90 plants m^{-2}.

Tomar and Namedo (1989) conducted a study on *Brassica campestris* var. Toria and found that when population density was maintained at 22.2 plants m^{-2} that increased the number of branches plant^{-1} when seed rate of rapeseed was maintained 5 kg ha^{-1}. *B. campestris* var. Toria, when population density was maintained 22.2 plants m^{-2} there was increment in the number of primary and secondary branches.

Gupta (1988) conducted a field experiment to determine the effects of spacing on rapeseed on using (330000 plants ha^{-1} , 400000 plants ha^{-1}, 200000 plants ha^{-1}, 250000 plants ha^{-1}, 166000 plants ha^{-1}, 266000 plants ha^{-1}) the mean population density and he found that wider spacing increased the number of branches plant^{-1}.

2.2.3 Siliquae plant^{-1}

Hasanuzzaman (2008) carried out 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 silique was produced by two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing.

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the number of siliquae plant^{-1} (272) recorded higher with 340000 plants ha^{-1} as compared to148000 plants ha^{-1} population density.

Butter and Aulakh (1999) conducted a study on Indian mustard cv. RLM 619 and maintained 3 rows spacing (15, 22.5 and 30 cm). They observed that row spacing had significant effect on number of siliquae plant^{-1} and found increased number of siliquae plant^{-1} with wider row spacing (40 cm).

Thakur (1999) conducted a field experiment at Himachal Pradesh Krishi Vishwavidyalaya, Kangra and observed that number of siliquae plant^{-1} were higher in 30 cm row spacing.

Row spacing had remarkable effect in producing more number of fertile siliquae plant^{-1}. Wider spacing facilitated favorable environment for producing more siliquae than closer spacing (Siddiqui, 1999).

Gurjar and Chauhan (1997) conducted a field 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 except siliquae plant^{-1} which increased at 45 cm row spacing.

Sharma (1992) conducted a field 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

Hasanuzzaman (2008) carried out an experiment at Sher-e-Bangla Agricultural University (SAU) Farm where 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). Length of siliquae as well as number of seeds per siliqua was significantly affected by the combination of irrigation levels and row spacing.

Rana and Pachauri (2001) also observed that the length of siliqua recorded was higher with 148000 plants ha $^{-1}$ (4.02 cm) as compared to 500000 plants ha^{-1} (3.73 cm).

Singh and Verma (1993) quoted that higher length of siliqua with 60 cm row spacing (4.26 cm) was observed as compared to 30 cm row spacing (4.14 cm).

Singh and Singh (1987) in 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} contributes materially towards the final grain yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield attributes of rapeseed and mustard and population density is a vital factor in producing optimum number of seeds siliqua^{-1}.

Hasanuzzaman (2008) carried out an experiment at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh and stated that number of seeds siliqua^{-1} were significantly affected by the combination of irrigation levels and row spacing.

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the number of seeds siliqua^{-1} recorded significantly higher under 220000 plants ha^{-1} (16.8) as compared to 500000 plants ha^{-1} (15.0).

Ali *et al*. (1996) found a significant difference in the number of seeds siliqua^{-1} with different population densities while working with rapeseed. They reported for the negative relation between the number of seeds siliqua^{-1} and population density. Rapeseed plant gave highest number of seeds siliqua^{-1} when population density was 100,000 plants ha^{-1} while lowest number of seeds siliqua^{-1} was found from the population density of 1,000,000 plants ha^{-1}.

In Kanpur, Yadav *et al*. (1994) revealed 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) quoted that a row spacing of 60 cm recorded greater number of seeds siliqua^{-1} (11.55) compared to 30 cm row spacing (10.80).

Sharma (1992) conducted 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).

Mishra and Rana (1992) also 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).

2.2.6 1000 seed 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. A good number research works have been conducted on this character.

Chauhan *et al*. (1993) reported a positive relation between row spacing and 1000-seed weight. They found a significant effect of row spacing (20, 30 and 40 cm) on 1000-seed 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) found a significant increasing rate of 1000-seed 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 from others. Lowest seed weight was found from 33.5 cm row spacing.

Tomar and Namedo (1989) conducted a study on *Brassica campestris* var. Toria when population density was maintained 22.2 plants m^{-2} there was increment in 1000 seed weight conditions. It was observed that interaction effect of variety and plant populations were found significant on pooled seed yield.

Singh and Singh (1987) in an experiment with 3 row spacing (30, 45 and 60cm) in mustard found that no significant effect of row spacing on 1000-seed weight of mustard However, 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

Angadi *et al*. (2003) reported that reducing plant population by half from 80 to 40 plants m^{-2} did not reduce seed yield but seed yield declined as population dropped below 40 plants m^{-2}.

Chaniyara *et al*. (2002) conducted a experiment in Gujarat at College of Agriculture and emphasized that seed yield was higher at 45 and 15cm inter and intra row spacing respectively. Row spacing of 30 cm produced higher seed yield than 40 and 50 cm spacing (Khan and Tak, 2002).

Seed yield was higher with 30 × 15 cm row spacing as compared to 60 cm row spacing (Shivani *et al*., 2002). In Kanpur, Singh and Prasad (2003) conducted a field experiment at C. S. Azad University of Agriculture and Technology and emphasized that a row spacing of 45 cm resulted in the higher seed yield (2064 kg $ha^{-1)}$. The closer row spacing of 20 cm recorded the lower seed yield of 1343 kg ha^{-1} (Kumar and Singh, 2003).

Behera *et al*. (2002) conducted 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 of 14.8 plants m^{-2}.

Rana and Pachauri (2001) conducted a field experiment in New Delhi, and reported that the higher seed yield (1670 kg ha$^{-1)}$ recorded higher with 333000 plants ha $^{-1}$ as compared to 148000 plants ha^{-1} (1280 kg ha^{-1}).

At Bangalore, Sahoo *et al*. (2000) conducted an experiment and reported seed yield was higher at closer spacing (30 × 15 cm, 669 kg ha$^{-1)}$.

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and reported that the seed yield recorded higher with 30 × 15 cm rowing (1676 kg ha $^{-1}$) as compared to 45 × 15 cm row spacing (1119 kg ha^{-1}).

In Dhaka, Shahidullah *et al*. (1997) conducted a field experiment and reported that higher seed yield was obtained by 30 × 15 cm row spacing.

Sanjeev Kumar *et al*. (1997) in Ludhiana, reported that seed yield was higher under 30 cm row spacing i.e., 333000 plants ha$^{-1,}$ (1647 kg ha $^{-1}$) as compared to 45 cm row spacing 2, 22,000 plants ha^{-1} (1476 kg ha $^{-1}$)

Pangarkar and Shelke (1995) conducted a field trial in Parbhani, and suggested that seed yield was higher with a spacing of 45 × 22.5 cm (1260 kg ha $^{-1}$) followed by 60 × 22.5 cm (1230 kg ha $^{-1}$). Similarly, Shelke *et al.* (1995) revealed that seed yield was higher with 45 or 60 × 22.5 cm spacing.

A field experiment was conducted at Regional Agricultural Research Station, Shillongani, Assam and it was reported that a row spacing of 30 cm recorded greater yield than 40 cm row spacing (Sarmah, 1996).

2.2.8 Stover yield

Sanjeev Kumar *et al*. (1997) in Ludhiana, reported that 4,44,000 plants per ha resulted in higher stover yield (9870 kg ha^{-1}) as compared to 45 cm row spacing i.e., 2,22,000 plants ha^{-1} (8810 kg ha^{-1}).

Ali *et al*. (1996) reported that, stover yield ha^{-1} significantly differed with different population density. They found maximum stover yield with the population density of 400,000 plant ha^{-1}. The lowest Stover yield was found from 100,000 plants ha^{-1}. The yield variation was due to lowest number of plants unit area and vice versa. It indicated that the improvement in yield attributes at lower plant density was not reflected by stover yield.

Chauhan *et al*. (1993) reported that stover yield of mustard was greatly affected by row spacing due to variation of the population per unit area. Among three rows spacing (20, 30 and 40 cm) 30 cm row spacing gave highest yield of stover. The second highest yield was obtained with row spacing of 40 cm which was statistically different with 30 cm row spacing yield.

2.2.9 Biological yield

Rana and Pachauri (2001) observed that biological yield recorded higher under 500000 plants ha^{-1} (7010 kg ha^{-1}) compared to 148000 plants ha^{-1} (6270 kg ha^{-1}).

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 effects of cultivars and row spacing on seed yield and biological yield was significant except siliquae $plant^{-1}$ which increased under 45 cm row spacing.

2.2.10 Harvest index

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the harvest index recorded higher with 330000 plants ha^{-1} (24.8%) as compared to 148000 plants ha^{-1} (20.4%).

Plant density at different levels increased the harvest index of rapeseed (Ali *et al*., 1996). 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. They found that higher harvest index where density was maintained as 30 plants m^{-2}.

2.3 Interaction effect of variety and population density

Venkaraddi (2008) conducted a field experiment at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the response of mustard varieties to date of sowing and row spacing. There were 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 mustard variety Pusa Agram recorded significantly higher seed yield (1028 kg $ha^{-1)}$ and oil yield (447.11 kg ha^{-1}). Early sowing during II fortnight of September recorded significantly higher seed yield (888 kg ha^{-1}) and oil yield (387.74 kg ha^{-1}). Row spacing of 30 cm recorded significantly higher seed yield (874 kg ha^{-1}) and oil yield (383.56 kg ha^{-1}). 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 can be concluded 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 and Hanson (2003) conducted a study to determine the interactions for commonly used spacing with canola (*Brassica napus*) performance using contemporary open-pollinated, hybrid and transgenic cultivars. They 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. napas* cultivar yielded greater than the open pollinated cultivars. Seed yield and oil content, the primary characters determining crop value were not affected by population density.

Behera *et al*. (2002) stated that field experiment were conducted during rabi season to study the effect of plant population consumptive use productivity and moisture of mustard (*Brassica juncea*) varieties viz "Sanjukta Asceh" and Varuna under rainfed conditions. It was observed that interaction effect of variety and plant populations were found significant on pooled seed yield.

Behera *et al*. (2002) conducted 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 of 14.8 plants m^{-2}.

Surya *et al*. (1998) conducted a field experiment in the rabi (winter) season of 1996-97 in Hiser, where *Brassica juncea* cv. Varuna, RH-30 and Laxmi were sown 5 or at spacing of 30 × 15 cm or 40 × 30 cm. Yield and yield components were not affected by spacing, Laxmi gave 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 and population density had influence on yield contributing characters of mustard.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted at the Department of Agronomy field of Sher-e-Bangla Agricultural University. This experiment was conducted with four rapeseed varieties along with four population densities in the rabi season of November 2011- February 2012 to evaluate the performance of population density along with variety on growth and yield of Rapeseed-Mustard in respect of growth and yield performance.

3.1 Experimental Site

The research was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207. The experiment area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Soil

The soil of the experimental site belongs to the agro-ecological region of “Madhupur Tract” (AEZ No.28). It was Deep Red Brown Terrace soil and belonged to “Nodda” cultivated series. The top soil is clay loam in texture. Organic matter content was very low (0.78%) and soil pH was 5.6. The physical and chemical characteristics of the soil have been presented in Appendix II.

3.3 Climate

The experimental area experiences a sub-tropical climate where 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. Usually scanty rainfalls in Rabi season (October to March) and heavy rainfall during Kharif season (April to September). The relative humidity increases from June to September (80% or above) and declined to a minimum in the winter. The monthly average rainfall, air temperature and relative humidity of the site during the experimental work have been shown in Appendix III.

3.4 Experimental materials

Four varieties of rapeseed were used as planting materials and the test varieties were (i) BARI Sarisha-13, (ii) BARI Sarisha-15, (iii) BARI Sarisha-16 and (iv) SAU Sarisha-3.

Seed of BARI Sarisha-13, BARI Sarisha-15 and BARI Sarisha-16 were collected from the Oil Seed Research Center, Bangladesh Agricultural Research Institute, Gazipur and SAU sarisha-3 was collected from Department of Genetics and Plant Breeding, Sher-e- Bangla Agricultural University, Dhaka-1207.

The important characteristics of these varieties are mentioned below:

BARI Sarisha-13: BARI Sarisha-13 is a high yielding variety of rapeseed. It is a short duration variety. Siliqua of this variety are comparatively longer. Plant height of this variety is about 80-100cm. No. of siliquae plant^{-1} is 65-75 with 28-30 seeds siliqua$^{-1.}$ Seeds are purple in color with 42- 43% oil. The crop matures within 90-95 days and its yield varies from 2200-2800 kg ha^{-1}.

BARI Sarisha-15: BARI Sarisha-15 is also a high yielding variety of rapeseed. Plant height of this variety is about 90-100 cm. No. of siliqua plant^{-1} 70-80 with 20-22 seeds siliqua^{-1}. Seeds are yellow in color. The crop matures within 80-85 days and its yield varies from 1550-1650 kg ha^{-1}.

BARI Sarisha-16: BARI Sarisha-16 is also a high yielding variety of mustard. Plant height of this variety is about 175-195 cm. Seeds are purple in color. No. of siliqua plant^{-1} 180-200 with 9-11 seeds siliqua^{-1}. The crop matures within 105-115 days and its yield varies from 2000-2500 kg ha^{-1}.

SAU Sarisha-3: SAU Sarisha-3 is a high yielding variety of rapeseed. It is under yellow sarson group of *Brassica campestris*. Siliqua of this variety are medium. Plant height of this variety is about 80 cm. Seeds are dark grey in color. The crop matures within 110-115 days and its yield varies from 1.5-1.9 t ha^{-1}.

3.5 Experimental treatments

The treatments comprised of four varieties and four population densities.

3.5.1 Experimental factors

Factor-1: Variety

i. V_1 = BARI Sarisha-13
ii. V_2 = BARI Sarisha-15
iii. V_3 = BARI Sarisha-16
iv. V_4 = SAU Sarisha-3

Factor-2: Population density

i. P_1 = 100000 plants ha^{-1} i.e. 10 plants m^{-2}
ii. P_2 = 400000 plants ha^{-1} i.e. 40 plants m^{-2}
iii. P_3= 700000 plants ha^{-1} i.e. 70 plants m^{-2}
iv. P_4 = 1000000 plants ha^{-1} i.e. 100 plants m^{-2}

3.5.2 Treatment combinations

There were altogether 16 treatments combinations. The experiment consists of the following treatment combinations:

V_1P_1	V_2P_1	V_3P_1	V_4P_1
V_1P_2	V_2P_2	V_3P_2	V_4P_2
V_1P_3	V_2P_3	V_3P_3	V_4P_3
V_1P_4	V_2P_4	V_3P_4	V_4P_4

3.6 Experimental design and layout

The experiment was laid out in a Split plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. There were altogether 48 (16×3) unit plots, each plot measuring 2m × 2.50 m. Inter-block and Inter-plot spacing were 0.50 m and 0.75 m, respectively. The layout of the experiment was presented in Appendix IV.

3.7 Land preparation

The experimental field was opened by a tractor drawn disc plough and was ploughed and cross ploughed three times with power tiller followed by laddering to obtain a desirable tilth. The corners of the land were spaded out. Weeds stubble and residues were cleaned from the soil and the land was made ready for layout. Finally, the plots were laied out and the decomposed organic manure were applied seven days before while the basal doses of inorganic fertilizer that applied one day before sowing and were spaded well following proper levelling to make the plots ready for sowing.

3.8 Fertilizer application

The experimental plots were fertilized with the recommended fertilizer dose as given below:

i.	Cow dung	:	10 t ha^{-1}
ii.	N	:	115 kg ha^{-1}
iii.	P_2O_5	:	86.4 kg ha^{-1}
iv.	K_2O	:	60 kg ha^{-1}
v.	ZnO_2	:	5 kg ha^{-1}
vi.	S	:	27 kg ha^{-1}
vii.	Boric Acid	:	10 kg ha^{-1}

Half of the urea and full amount of other fertilizers were broadcasted during final land preparation. Rest half of urea was top-dressed before flowering of each sowing.

3.9 Germination test

Germination test was performed before sowing the seeds in the laboratory. Filter paper was placed on petridishes and the papers were soaked with water. Seeds were distributed at random in petridish. Data on emergence were collected on percentage basis by using the following formula:

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

3.10 Sowing of seeds

Seeds were sown in lines continuously and line to line distance was 30 cm. Seeds were placed 2 cm depth and then rows were covered with loose soil properly and maintained according to the treatments. Seeds were sown on different population densities according to treatment specification. Seeds were sown on 1st November 2011.

3.11 Weeding and thinning

The experimental plots were weeded twice in time. First weeding was followed by thinning which was done at 12 days of emergence and second weeding was done at 30 days after emergence. Thinning was done once in all the unit plots with care to maintain a plant population density in each row as per treatment.

3.12 Irrigation

Irrigation was done at 25 days and 45 days of sowing in order to maintain adequate moisture in the field.

3.13 Plant protection measure

There was light attack of insect-pests during the crop growth period. The plants were attacked by aphids at the time of flowering. It was controlled by spraying Malathion 57 EC at the rate of 2 ml L^{-1} of water. The spraying was done in the afternoon while the pollinating bees were away from the field.

3.14 General observations of experimental field

The plots under experiment were frequently observed to notice any change in plant growth and other characters were noted down immediately to make necessary measures.

3.15 Harvesting and post-harvest operations

The crop maturity varied with varieties. The maturity of crop was determined when 80% to 85% of siliqua become straw in color. BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3 were harvested at maturity on 13, 16, 18 and 21 February, 2012 respectively. One square meter area from the center of each plot was harvested for recording yield data.recorded. The harvested plants were tied into bundles and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the siliquae by beating with bamboo sticks and later were cleaned, dried, weighed and converted into t ha^{-1}. The weights of the dry straw were also taken.

3.16 Sampling and data collection

Ten sample plants were selected at random from each plot for taking plant and yield contributing data. The heights of plants were measured with a scale placed on the ground level to top of the leaves. Number of branches, number of siliqua, siliqua length, number of grain $siliqua^{-1}$ and weight of thousand seeds were recorded separately. From each plot the weight of the straw were taken. Biological yield and the harvest index were also calculated from this data.

The parameters studied in the experiment were as follows:

i) Plant height (cm)
ii) Leaf length (cm)
iii) Leaf breadth (cm)
iv) Dry weight $plant^{-1}$ (g)
v) Branches $plant^{-1}$ (number)
vi) Siliquae $plant^{-1}$ (number)
vii) Seeds $siliqua^{-1}$ (number)
viii) Length of siliquae (cm)
ix) Weight of 1000 seed (g)
x) Grain yield (t ha^{-1})
xi) Stover yield (t ha^{-1})
xii) Biological yield (t ha^{-1})
xiii) Harvest index (%)

3.17 Procedure for data collections after harvest

3.17.1 Plant height (cm)

Plant height was measured from the ground level to the apex of the leaf or siliqua in randomly selected 10 plants from specific rows of each plot at 25, 50, 75 DAS and at harvest and when from the mean plant height (cm) was recorded.

3.17.2 Leaf length (cm)

Leaf length was taken from randomly selected 10 leaves and then averaged. Leaf length was measured from base to top of the leaves.

3.17.3 Leaf width (cm)

Leaf breadth was taken from randomly selected 10 leaves and then averaged.

3.17.4 Dry weight plant^{-1} (g)

Five plants plot^{-1} were uprooted by random selection at different days after sowing. The samples were oven dried until a constant weight was recorded. The average weight was expressed as dry weight plant^{-1}.

3.17.5 Branches plant^{-1} (number)

The total number of branches plant^{-1} was counted from selected samples at the time of harvest and was recorded. Mean number of branches plant^{-1} was expressed as number of branches plant^{-1}.

3.17.6 Siliquae plant^{-1} (number)

Number of total siliquae of pre selected ten plants from each unit plot was noted and the mean number was recorded. The number of siliquae of each plant was counted and the mean was recorded.

3.17.7 Siliquae length (cm)

The length of the siliquae was measured from the base to the tip of the siliqua.

3.17.8 Seeds siliqua^{-1} (number)

The number of seeds was counted from randomly taking 10 siliquae per treatment. The average value is calculated as the number of seeds siliqua^{-1}.

3.17.9 1000-seed weight (g)

From the seed stock of each plot, 1000-seeeds were randomly collected and weighed by an electric balance. The 1000-seed weight was recorded in gram.

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

The mean weight were taken by threshing the plants of each sample area and then converted to t ha^{-1} in dry weight basis.

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

The weight of the plants containing grain was taken by subtracting the grain weight from the total weight. The stover weights were calculated after threshing and separation of grain from the plants of 1 m^{2} area and then expressed in t ha^{-1} on dry weight basis.

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

The summation of grain yield and stover yield were considered as biological yield. Biological yield was calculated by using the following formula,

Biological yield = Grain yield + stover yield; (dry weight basis).

3.17.13 Harvest index (%)

The 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 using the following formula (Donald, 1963):

$$\text{Harvest index} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

3.18 Statistical analysis

The collected data were analyzed statistically by using analysis of variance (ANOVA) technique with the help of computer package MSTAT-C program. The mean differences among the treatments were tested by least significance difference at 5% level of probability.

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

The experiment was conducted to study the performance of population density and variety on growth and yield of Rapeseed-Mustard. The results of the present investigation have been presented, discussed and compared as far as possible with the results of other research.

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

The plant height of the varieties was different at different days after sowing (DAS) (Fig 1). At 20 DAS, the highest plant stature of 10.71 cm was produced by the variety, SAU Sarisha-3 (V_4) which was highly significant and different from those of BARI Sarisha-13 (V_1), BARI Sarisha-15 (V_2) and BARI Sarisha-16 (V_3). But at 40, 60 DAS and at harvest, the plant height of the variety, BARI Sarisha-16 (V_3) was significantly highest of 75.79, 148.10 and 160.20 cm respectively which was statistically similar to SAU Sarisha-3 (V_4) at 40 DAS. Results also showed that, the shortest plant of 8.45 cm was found from BARI Sarisha-15 (V_2) at 20 DAS. But at 40, 60 DAS and at harvest, the plant height of the variety, BARI Sarisha-13 (V_1) was significantly lowest measuring of 63.86, 85.74 and 88.78 cm respectively and different from those of other tested varieties. It can be mentioned that initially SAU Sarisha-3 showed the tallest plant but after 40 DAS and at maturity BARI Sarisha-16 produced the highest plant height. Similar findings were reported by Alam (2004) who reported that plant height of rapeseed and mustard differed among the varieties due to different genetic makeup.

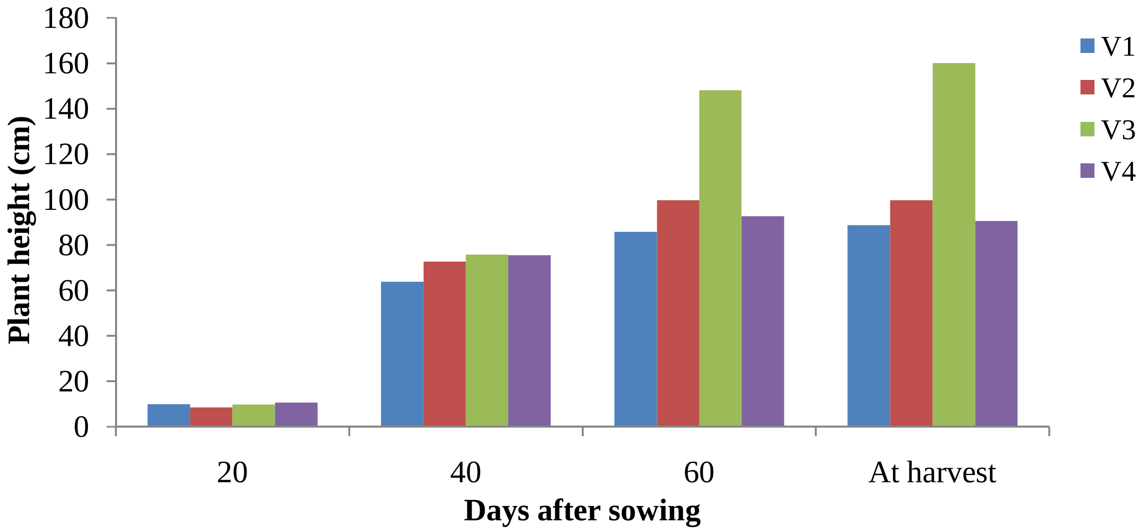

Fig. 1: Effect of variety on plant height at different days after sowing of rapeseed-mustard. (LSD $_{0.05}$= 0.592, 1.613, 1.196 and 1.665 at 20, 40, 60 DAS and at harvest, respectively)

Here,
V_1 = BARI Sarisha-13
V_2 =BARI Sarisha-15
V_3 = BARI Sarisha-16
V_4 = SAU Sarisha-3

4.1.1.2 Effect of population density

Plant height was significantly affected by plant population density and was observed at different days after sowing (DAS) (Fig. 2). Results under the present study revealed that the tallest plant of 10.27 cm was recorded from P_1 at 10 plants m^{-2} density which was closely followed by P_4 of 100 plants m^{-2} at 20 DAS. But at 40 and 60 DAS, P_3 at 70 plants m^{-2} produced the tallest plant of 76.20 and 108.40 cm respectively. Again, at the time of harvest, P_2 at 40 plants m^{-2} density gave the highest plant height of 113.40 cm followed by P_1 at 10 plants m^{-2} density. On the other hand, the lowest plant height was observed with P_4 at 100 plants m^{-2} at 60 DAS and at harvest it was 102.70 and 106.40 cm respectively. But at 20 and 40 DAS, P_3 with 70 plants m^{-2} and P_1 with 10 plants m^{-2} respectively produced the shortest plant. The results obtained from the present study was conformity to the findings of Sharma and Thakur (1999) and Chauhan *et al*. (1993).

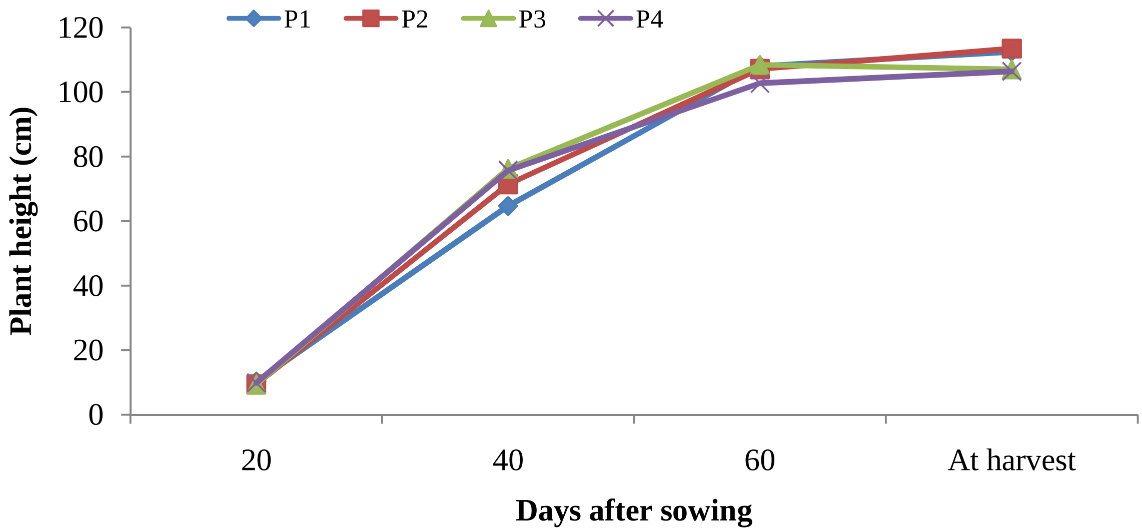

Fig. 2: Effect of population density on plant height at different days after sowing of rapeseed-mustard. ($LSD_{0.05}$ = 0.594, 1.591, 1.070 and 1.837 at 20, 40, 60 DAS and at harvest ,respectively)

Here,
P_1 = 100000 plants ha^{-1}
P_2 = 400000 plants ha^{-1}
P_3 = 700000 plants ha^{-1}
P_4 = 1000000 plants ha^{-1}

4.1.1.3 Interaction effect of variety and population density

The interaction effect of variety and population density had a significant effect on the plant height (Table 1). Significant differences of plant heights were found in every stages of plant growth. Maximum plant height at 20 and 40 DAS of 11.06 and 84.12 cm respectively was observed in the interaction of V_4P_4 of SAU Sarisha-3 and at 100 plants m^{-2} and V_3P_3 of BARI Sarisha-16 and at 70 plants m^{-2} respectively. But at 60 DAS and at harvest V_3P_1 of the variety BARI Sarisha-16 with 10 plants m^{-2} gave the tallest plant height of 156.10 and 170.90 cm respectively. The lowest plant height was found from V_2P_3 at 20 DAS, V_3P_1 at 40 DAS, V_1P_2 at 60 DAS as well as with V_4P_4 at harvest respectively produced 7.78, 60.56, 86.55 and 81.23 cm respectively). The plant response in terms of height to the combined treatment was found higher at middle growth stage from 40 to 60 DAS considered as maximum growth stage. The maximum plant height of 170.90 cm at harvest was obtained from the treatment V_3P_1 (BARI Sarisha-16 × 10 plants

m^{-2}) followed by V_3P_2 (BARI Sarisha-16 × 40 plants m^{-2}). Similar result was obtained by Meitei *et al*. (2001).

Table 1. Interaction effect of variety and population density on plant height at different days after sowing of rapeseed-mustard

Treatments	Plant height (cm)			
	20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Interaction effect of variety and population density				
V_1P_1	10.72 a	61.33 g	91.52 j	90.89 g
V_1P_2	9.93 cd	61.56 g	86.55 k	87.89 g-i
V_1P_3	9.15 ef	64.56 f	91.94 j	89.23 g-i
V_1P_4	9.92 cd	68.00 e	72.95 l	87.11 hi
V_2P_1	8.98 e-g	68.34 e	93.78 hi	97.99 f
V_2P_2	8.45 g	71.67 d	100.80 f	97.32 f
V_2P_3	7.78 h	76.56 c	101.10 f	101.80 e
V_2P_4	8.61 fg	74.56 c	103.40 e	101.60 e
V_3P_1	10.57 ab	60.56 g	156.10 a	170.90 a
V_3P_2	8.98 e-g	80.78 b	144.00 c	164.30 b
V_3P_3	9.48 de	84.12 a	152.10 b	150.00 d
V_3P_4	9.90 cd	76.67 c	140.20 d	155.50 c
V_4P_1	10.82 a	68.39 e	92.19 ij	90.11 gh
V_4P_2	10.08 bc	71.55 d	97.07 g	104.20 e
V_4P_3	10.90 a	79.56 b	87.36 k	86.78 i
V_4P_4	11.06 a	83.67 a	94.19 h	81.23 j
$LSD_{0.0.5}$	0.538	2.202	1.714	2.882
CV (%)	12.63	10.18	8.90	9.11

Here,
V_1 = BARI Sarisha-13 — P_1 = 100000 plants ha^{-1}
V_2 = BARI Sarisha-15 — P_2 = 400000 plants ha^{-1}
V_3 = BARI Sarisha-16 — P_3 = 700000 plants ha^{-1}
V_4 = SAU Sarisha-3 — P_4 = 1000000 plants ha^{-1}

4.1.2 Leaf length

4.1.2.1 Effect of variety

Leaf length of different varieties was different at different days after sowing (DAS) (Fig 3). At 20 DAS, the highest leaf length of 4.94 cm was produced by the variety, BARI Sarisha-16 (V_3) where BARI Sarisha-13 (V_1) showed the highest leaf length of 26.67 cm at 40 DAS which was significantly different from all other tested varieties. But at 60 DAS and at harvest, the leaf length of the variety, BARI Sarisha-16 (V_3) was significantly highest of 25.25 and 25.09 cm respectively which was statistically identical with BARI Sarisha-13 (V_1) at 60 DAS and at harvest and significantly different from those of BARI Sarisha-15 (V_2) and SAU Sarisha-3 (V_4). Results also showed that, the lowest leaf length of 3.56 cm was found from BARI Sarisha-13 (V_1) at 20 DAS. But at 40, 60 DAS and at harvest, the lowest leaf length of 15.64, 17.31 and 15.61 cm respectively was obtained from BARI Sarisha-15 (V_2) and different from those of other tested varieties. Here, it can be noted that at initial stage BARI Sarisha-16 showed the higher leaf length but after 40 DAS and at maturity BARI Sarisha-13 and BARI Sarisha-16 gave highest leaf length. This result might be due to cause of varietal performance i.e. genotypic character and also in association with population density.

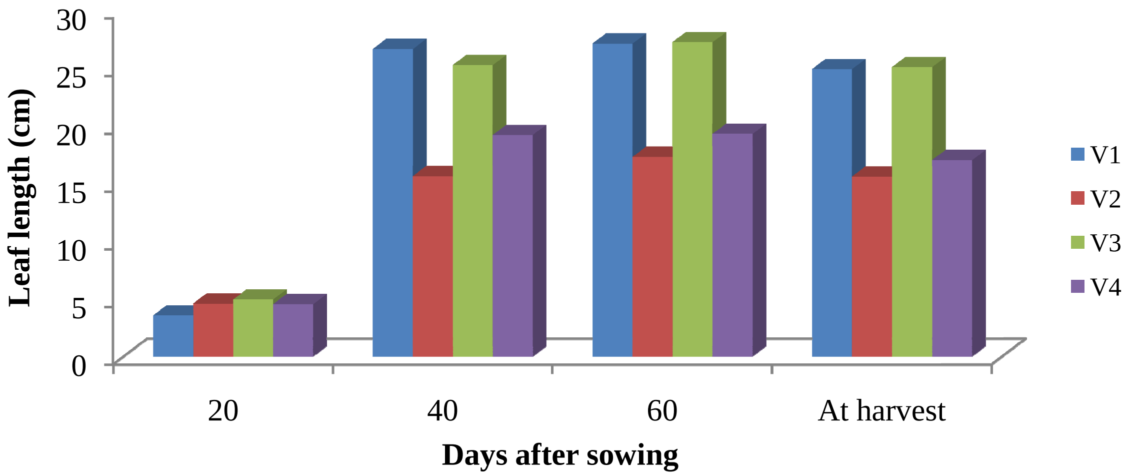

Fig. 3: Effect of variety on leaf length at different days after sowing of rapeseed-mustard. ($LSD_{0.05}$= 0.260, 0.911, 1.108 and 0.269 at 20, 40, 60 DAS and at harvest, respectively)

Here
V_1 = BARI Sarisha-13

V_2 = BARI Sarisha-15
V_3 = BARI Sarisha-16
V_4 = SAU Sarisha-3

4.1.2.2 Effect of population density

Leaf length was significantly affected by population density and variations were observed at different days after sowing (DAS) (Fig. 4). Results under the present study revealed that the highest leaf length of 4.70 cm was recorded from P_1 (10 plants m^{-2}) which was closely followed by P_2 (40 plants m^{-2}) at 20 DAS. But at 40, 60 DAS and at harvest the highest leaf length of 23.11, 24.11 and 21.89 cm respectively was found from P_2 (40 plants m^{-2}) which was statistically identical with P_1 (10 plants m^{-2}) at 40 DAS. On the other hand, the lowest leaf length of 4.08 cm was observed with P_3 (70 plants m^{-2}) at 20 DAS. But at 40, 60 DAS and at harvest P_4 (100 plants m^{-2}) showed the lowest leaf length of 20.00, 21.26 and 19.05 cm respectively which was significantly different from all other treatments of population densities. This result might be an indicative due to built in genetic characters of different entries expressed whenand larger plant spacing facilitates were provided by getting more nutrient, light and water.

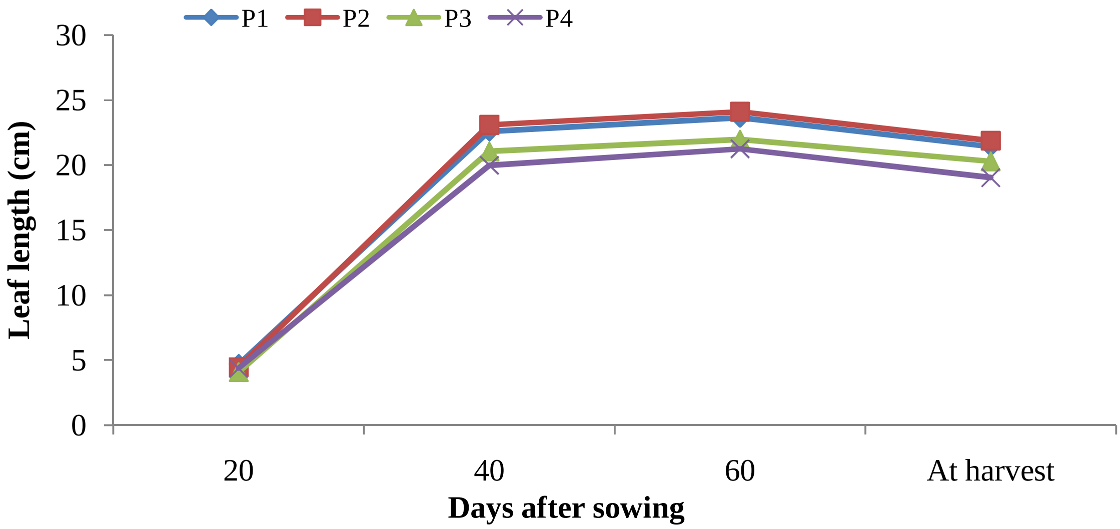

Fig. 4: Effect of population density on leaf length at different days after sowing of rapeseed-mustard. (LSD $_{(0.05)}$ = 0.231, 0.873, 0.339 and 0.284 at 20, 40, 60 DAS and at harvest respectively)

Here,

P_1 = 100000 plants ha^{-1}
P_2 = 400000 plants ha^{-1}
P_3 = 700000 plants ha^{-1}
P_4 = 1000000 plants ha^{-1}

4.1.2.3 Interaction effect of variety and population density

The interaction effect of variety and population density had a significant effect on the leaf length (Table 2). Significant differences on leaf length were found in every stages of growth. Maximum leaf length of 5.40 cm was observed in the interaction of V_3P_4 (BARI Sarisha-16 × 100 plants m^{-2}) which was closely followed by V_4P_1 (SAU Sarisha-3 × 10 plants m^{-2}) at 20 DAS. But at 40, 60 DAS and at harvest V_3P_1 (BARI Sarisha-16 and 10 plants m^{-2}) gave the highest leaf length of 30.34, 31.89 and 29.79 cm respectively. The lowest leaf length was producd by V_1P_4 at 20 DAS of 3.35 cm and V_2P_4 at 40 DAS of 14.22 cm. But at 60 DAS and at harvest the lowest leaf length of 14.01 and 13.99 cm respectively was produced by V_2P_3 (BARI Sarisha-15 × 70 plants m^{-2}). The maximum leaf length of 29.79 cm at harvest was obtained from the treatment V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) followed by V_3P_2 (BARI Sarisha-16 × 40 plants m^{-2}).

Table 2. Interaction effect of variety and population density on leaf length at different days after sowing of rapeseed-mustard

Treatments	**Leaf length (cm)**			
	20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Interaction effect of variety and population density				
V_1P_1	3.53 ij	24.56 cd	27.45 c	25.19 c
V_1P_2	3.77 gh	29.56 b	27.13 c	24.97 c
V_1P_3	3.59 hi	26.33 c	26.85 c	24.61 c
V_1P_4	3.35 j	26.23 c	27.08 c	24.90 c
V_2P_1	4.93 cd	16.78 jk	16.21 i	14.00 k
V_2P_2	5.08 bc	16.22 jk	20.58 fg	18.29 g
V_2P_3	4.04 f	15.34 kl	14.01 j	13.99 k
V_2P_4	4.32 e	14.22 l	18.47 h	16.15 j
V_3P_1	5.06 bc	30.34 a	31.89 a	29.79 a
V_3P_2	4.48 e	25.56 c	29.05 b	26.89 b
V_3P_3	4.82 d	22.89 de	24.80 d	22.55 d
V_3P_4	5.40 a	22.23 ef	23.26 de	21.11 e
V_4P_1	5.28 ab	18.68 hi	19.05 gh	16.71 i
V_4P_2	4.55 e	21.11 fg	19.69 gh	17.39 h
V_4P_3	3.89 fg	19.67 gh	22.23 ef	20.01 f
V_4P_4	4.45 e	17.33 ij	16.23 i	14.03 k

$LSD_{(0.05)}$	0.217	1.672	1.721	0.563
CV(%)	12.37	12.33	12.28	6.062

Here,

V_1 = BARI Sarisha-13 P_1 = 100000 plants ha^{-1}
V_2 = BARI Sarisha-15 P_2 = 400000 plants ha^{-1}
V_3 = BARI Sarisha-16 P_3 = 700000 plants ha^{-1}
V_4 = SAU Sarisha-3 P_4 = 1000000 plants ha^{-1}

4.1.3 Leaf width

4.1.3.1 Effect of variety

Leaf width of different varieties was different at different days after sowing (DAS) (Fig 5). At 20 DAS, the highest leaf width of 2.74 cm was produced by the variety, BARI Sarisha-13 (V_1). But at 40, 60 DAS and at harvest, the highest leaf width of the variety were 7.29cm, 8.52cm and 7.50 cm respectively and was obtained from the variety BARI Sarisha-16 (V_3) which was significantly different from those of BARI Sarisha-15 (V_2) and SAU Sarisha-3 (V_4). Results also showed that, the lowest leaf width was found from BARI Sarisha-15 (V_2) at all growth stages varieng from 2.31cm, 4.18cm, 4.69cm and 3.68 cm at 20, 40, 60 DAS and at harvest respectively which was significantly different from the other tested varieties. Here, it can be mentioned that at initial stage BARI Sarisha-13 had the higher leaf width but after 40 DAS to at maturity BARI Sarisha-16 produce the highest leaf width where BARI Sarisha-15 produced the lowest leaf width at all growth stages. This result indicated the differences due to differences in varietal characteristics happened due to genotypic variation and also in association with population densities.

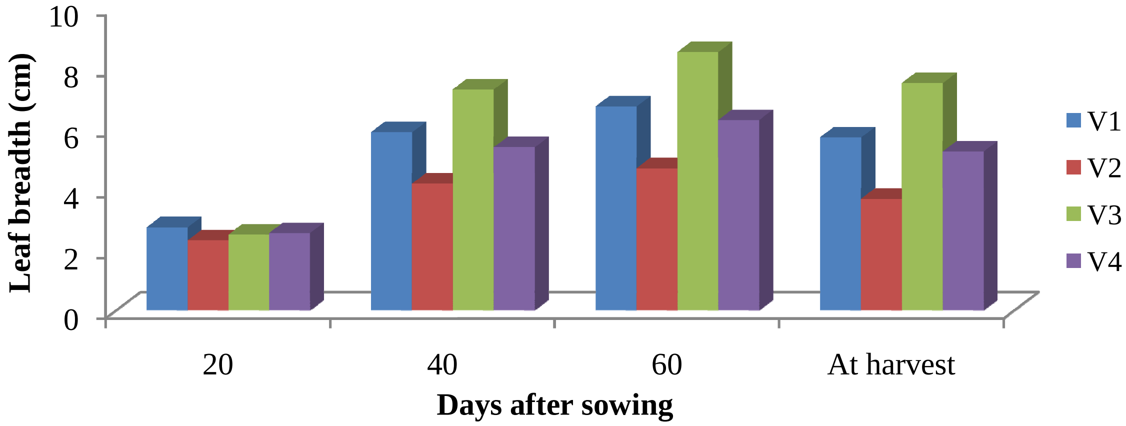

Fig. 5: Effect of variety on leaf width at different days after sowing of rapeseed-mustard. (LSD $_{(0.05)}$ = 0.139, 0.692, 0.841 and 0.211s at 20, 40, 60 DAS and at harvest, respectively)

Here,
V_1 = BARI Sarisha-13
V_2 = BARI Sarisha-15
V_3 = BARI Sarisha-16
V_4 = SAU Sarisha-3

4.1.3.2 Effect of population density

Leaf width was significantly affected by different population densities and variations were observed at different days after sowing (DAS) (Fig. 6). Results under the present study revealed that the highest leaf width of 2.64 cm was recorded from P_3 (70 plants m^{-2}) which was closely followed by P_1 (10 plants m^{-2}) at 20 DAS. But at 40, 60 DAS and at harvest the highest leaf width of 6.73, 7.11 and 6.08 cm respectively was found from P_1 (10 plants m^{-2}) which was statistically identical with P_2 (40 plants m^{-2}) at 60 DAS. On the other hand, the lowest leaf width was observed with P_4 (100 plants m^{-2}) at 20, 40, 60 DAS and at harvest were 2.45, 5.03, 5.82 and 4.78 cm respectively which was significantly different from all other treatments of the population densities. This result might be due to cause of genotypic differences expressed when larger plant spacing facilitates were provided to obtain more nutrient, light and water by plant.

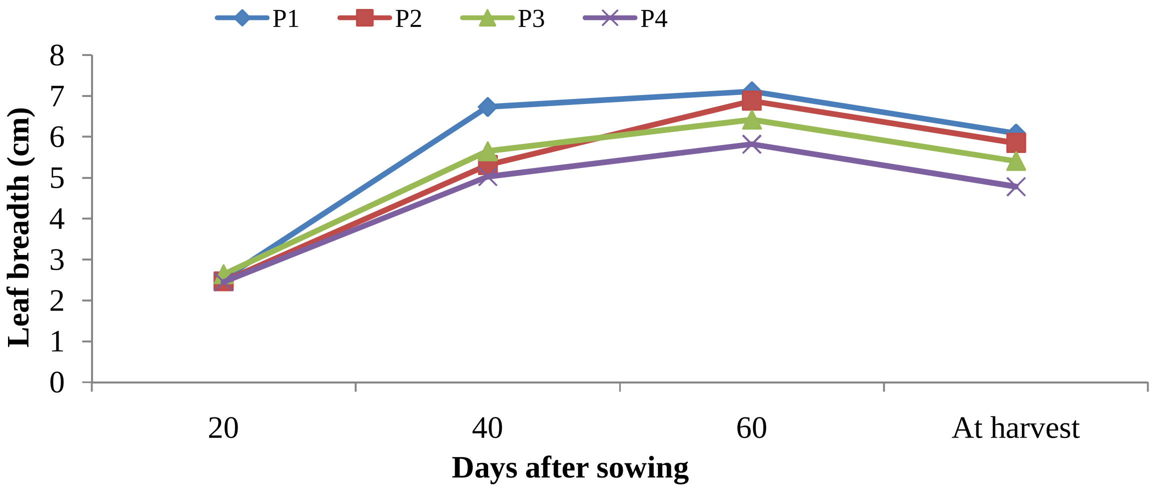

Fig. 6: Effect of population density on leaf breadth at different days after sowing of rapeseed-mustard. (LSD $_{(0.05)}$ = 0.139, 0.249, 0.286 and 0.112 at 20, 40, 60 DAS and at harvest ,respectively)

Here,
P_1 = 100000 plants ha^{-1}
P_2 = 400000 plants ha^{-1}
P_3 = 700000 plants ha^{-1}
P_4 = 1000000 plants ha^{-1}

4.1.3.3 Interaction effect of variety and population density

The interaction effect of variety and population density had a significant variation on leaf width at all growth stages (Table 3). Results reveal that the maximum leaf width of 2.87 cm was observed in the interaction of V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) which was closely followed by V_1P_2 (BARI Sarisha-13 × 40 plants m^{-2}) and V_3P_4 (BARI Sarisha-16 × 100 plants m^{-2}) at 20 DAS. But at 40, 60 DAS and at harvest V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) produced the highest leaf width of 7.66, 10.20 and 9.16 cm respectively which was statistically identical with V_1P_1, V_3P_2, V_3P_3 and V_4P_1 at 40 DAS. On the other hand, the lowest leaf width at 20, 60 DAS and at harvest of 1.99, 4.18 and 3.21 cm respectively was observed with V_2P_4 (BARI Sarisha-15 × 70 plants m^{-2}). But at 40 DAS V_2P_2 (BARI Sarisha-15 × 40 plants m^{-2}) showed the lowest leaf width of 3.54 cm. The results obtained from all other treatment combinations gave significantly different leaf width compared to highest and lowest leaf width.

Table 3. Interaction effect of variety and population density on leaf breadth at different days after sowing of rapeseed-mustard

Treatments	Leaf breadth (cm)			
	20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Interaction effect of variety and population density				
V_1P_1	2.87 a	7.22 a	6.63 de	5.60 f
V_1P_2	2.78 a-c	5.75 bc	7.72 bc	6.66 d
V_1P_3	2.64 cd	5.71 bc	6.60 de	5.59 f
V_1P_4	2.66 cd	4.84 c-e	5.96 e	4.98 g
V_2P_1	2.22 gh	5.16 cd	5.59 ef	4.54 h
V_2P_2	2.34 fg	3.54 f	4.66 fg	3.61 i
V_2P_3	2.67 b-d	4.08 ef	4.33 g	3.34 j
V_2P_4	1.99 i	3.92 ef	4.18 g	3.21 j
V_3P_1	2.45 ef	7.66 a	10.2 a	9.16 a
V_3P_2	2.11 hi	7.58 a	8.52 b	7.49 b
V_3P_3	2.62 cd	7.32 a	8.04 bc	7.03 c
V_3P_4	2.82 ab	6.62 ab	7.34 cd	6.32 e
V_4P_1	2.59 de	6.89 a	6.02 e	5.01 g
V_4P_2	2.57 de	4.37 d-f	6.63 de	5.65 f
V_4P_3	2.64 cd	5.50 c	6.69 de	5.69 f
V_4P_4	2.41 f	4.75 c-e	5.78 e	4.61 h
$LSD_{(0.05)}$	0.149	0.926	0.980	0.197
CV(%)	8.94	12.87	9.39	8.19

Here,

V_1 = BARI Sarisha-13 | P_1 = 100000 plants ha^{-1}

V_2 = BARI Sarisha-15 | P_2 = 400000 plants ha^{-1}

V_3 = BARI Sarisha-16 | P_3 = 700000 plants ha^{-1}

V_4 = SAU Sarisha-3 | P_4 = 1000000 plants ha^{-1}

4.1.4 Dry weight plant^{-1}

4.1.4.1 Effect of variety

Different varieties showed different dry weight plant^{-1} at different days after sowing (DAS) (Fig 7). At 20 DAS, there was a non significant difference was observed on dry weight plant^{-1} among the varieties. But at 40, 60, 80 DAS and at harvest BARI Sarisha-13 (V_1) produced the highest dry weight plant^{-1} of 5.25, 12.12, 14.62 and 17.58 g respectively which was statistically identical with BARI Sarisha-16 (V_3) at 60 DAS. Results also showed that, the lowest dry weight plant^{-1} was found from BARI Sarisha-15 (V_2) at all growth stages were 3.17, 7.92, 9.60 and 8.83 g at 40, 60, 80 DAS and at harvest respectively which was significantly different from the other test varieties. These results might be due to cause of genetic makeup and also nutrient availability, water and sunlight in association with plant spacing.

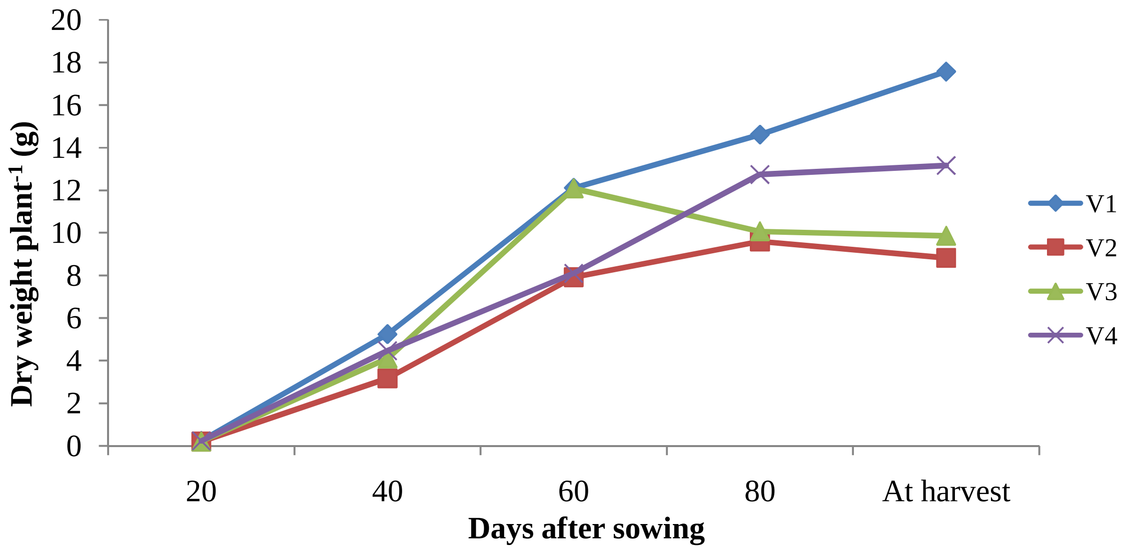

Fig. 7: Effect of variety on dry weight of plant at different days after sowing of rapeseed-mustard (LSD $_{(0.05)}$ = NS, 0.211, 1.155, 0.937 and 1.132 at 20, 40, 60, 80 DAS and at harvest ,respectively)

Here,
V_1 = BARI Sarisha-13
V_2 = BARI Sarisha-15
V_3 = BARI Sarisha-16
V_4 = SAU Sarisha-3

4.1.4.2 Effect of population density

Dry weight plant^{-1} was significantly affected by different population densities and variations were observed at different days after sowing (DAS) (Fig. 8). Results under the present study exposed that there was no significant variation at 20 DAS, but at 40 DAS and at harvest.The significant variation was obtained. The highest dry weight plant^{-1} of 5.08 g was recorded from P_2 (40 plants m^{-2}) at 40 DAS. But at 60, 80 DAS and at harvest the highest dry weight plant^{-1} of 13.85, 14.47 and 17.50 g respectively was found from P_1 (10 plants m^{-2}) which was significantly different from all other treatments of population densities. On the other hand, the lowest dry weight plant^{-1} was observed with P_4 (100 plants m^{-2}) at 40, 60, 80 DAS and at harvest were 3.52, 6.66, 9.58 and 8.65 g respectively which was significantly different from all other treatments of population densities. The result obtained from the present study also similarity with the findings of Mudholkar and Ahlawat (1981).

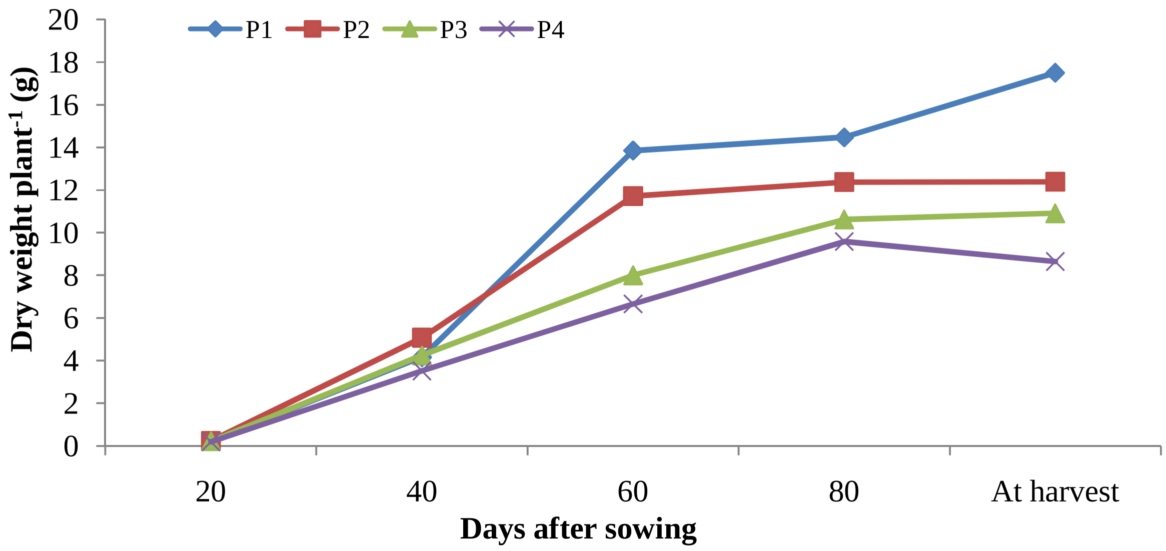

Fig. 8: Effect of population density on dry weight of plant at different days after sowing of rapeseed-mustard (LSD $_{(0.05)}$ = NS, 0.183, 0.799, 0.428 and 1.132 at 20, 40, 60, 80 DAS and at harvest, respectively)

Here,
P_1 = 100000 plants ha^{-1}
P_2 = 400000 plants ha^{-1}
P_3 = 700000 plants ha^{-1}
P_4 = 1000000 plants ha^{-1}

4.1.4.3 Interaction effect of variety and population density

The interaction effect of variety and population density had a significant effect on dry weight $plant^{-1}$ at all growth stages except at 20 DAS (Table 4). No significant effect was found at 20 DAS. Results exposed that the maximum dry weight $plant^{-1}$ of 6.43 g was observed in the interaction of V_1P_2 (BARI Sarisha-13 × 40 plants m^{-2}) at 40 DAS. But at 60, 80 DAS and at harvest V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) gave the highest dry weight $plant^{-1}$ of 19.13, 16.23 and 22.70 g respectively which was statistically identical with V_1P_2 at 60 DAS and V_1P_3 and V_4P_1 at 80 DAS. On the other hand, the lowest dry weight $plant^{-1}$ at 40, 80 DAS and at harvest of 2.64, 7.05 and 6.01 g respectively was observed with V_2P_3 (BARI

Sarisha-15 × 70 plants m^{-2}). But at 60 DAS V_1P_2 (BARI Sarisha-13 × 40 plants m^{-2}) showed the lowest dry weight plant^{-1} of 5.13 g. The results obtained from all other treatment combinations gave significantly different dry weight plant^{-1} compared to highest and lowest dry weight plant^{-1}.

Table 4. Interaction effect of variety and population density on dry weight of plant at different days after sowing of rapeseed-mustard

Treatments	**Dry weight plant^{-1} (g)**				
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**	**At harvest**
Interaction effect of variety and population density					
V_1P_1	0.25	4.65 de	19.13 a	16.23 a	22.70 a
V_1P_2	0.25	6.43 a	18.75 a	15.10 ab	16.10 c
V_1P_3	0.23	5.22 c	5.13 i	15.53 a	19.13 b
V_1P_4	0.23	4.70 de	5.48 hi	11.63 d	12.37 d
V_2P_1	0.19	3.67 hi	9.56 de	11.54 d	12.01 de
V_2P_2	0.23	3.58 h-j	6.55 gh	11.21 d	10.91 ef
V_2P_3	0.25	2.64 k	8.96 e	7.05 g	6.01 i
V_2P_4	0.16	2.81 k	6.61 gh	8.60 ef	6.38 hi
V_3P_1	0.20	4.41 ef	16.20 b	14.24 bc	15.07 c
V_3P_2	0.24	4.52 ef	13.17 c	9.42 e	9.95 f
V_3P_3	0.21	4.20 fg	10.49 d	7.53 fg	6.02 i
V_3P_4	0.21	3.34 ij	8.49 ef	9.15 e	8.43 g
V_4P_1	0.25	3.91 gh	10.52 d	15.87 a	20.20 b
V_4P_2	0.26	5.78 b	8.40 ef	13.80 c	12.60 d
V_4P_3	0.22	4.95 cd	7.46 fg	12.38 d	12.47 d
V_4P_4	0.21	3.24 j	6.06 g-i	8.96 e	7.43 gh
$LSD_{0.0.5}$	NS	0.349	1.296	1.135	1.135
CV (%)	4.38	10.45	9.32	24.43	43.45

Here,
V_1 = BARI Sarisha-13 — P_1 = 100000 plants ha^{-1}
V_2 = BARI Sarisha-15 — P_2 = 400000 plants ha^{-1}
V_3 = BARI Sarisha-16 — P_3 = 700000 plants ha^{-1}
V_4 = SAU Sarisha-3 — P_4 = 1000000 plants ha^{-1}

4.2 Yield contributing parameters

4.2.1 Branches plant^{-1}

4.2.1.1 Effect of variety

Numbers of branches plant^{-1} differed significantly due to different varieties (Table 5). Data showed that BARI Sarisha-13 produced the highest number of branches plant^{-1} of 6.14 which was significantly higher than BARI Sarisha-15 (4.59), BARI Sarisha-16 (4.87) and SAU Sarisha-3 (4.78). On the other hand, BARI Sarisha-15 gave the lowest number of branches plant^{-1} of 4.59. Numerical value indicates that BARI Sarisha-13 produced 33.77%, 26.07% and 28.45% higher branches plant^{-1} than BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3 respectively. The results obtained from the present study were similar with the findings of Hussain *et al*. (1996) and Khaleque (1989).

4.2.1.2 Effect of population density

Population density exerted influence on the number of branches plant^{-1} (Table 5). Results indicated that higher population density produced lower number of branches plant^{-1}. The maximum number of branches plant^{-1} of 6.84 was found from P_1 (10 plants m^{-2}). On the other hand, the lowest numbers of branches plant^{-1} of 3.75 was found from P_4 (100 plants m^{-2}). The maximum increases of 82.40% branches plant^{-1} was observed with P_1 (10 plants m^{-2}) compared to lowest performance of producing branches plant^{-1} (100 plants m^{-2}). Branch number was also increase with the increase of plant spacing. Similar findings were reported by Shrief *et al*. (1990), Chauhan *et al*. (1993) and Gupta (1988).

4.2.1.3 Interaction effect of variety and population density

Numbers of branches plant^{-1} were significantly influenced by the interaction effect of variety and population density (Table 5). The maximum number of branches plant^{-1} of 7.56 was found from the interactions of V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) which was statistically identical with V_2P_1 (BARI Sarisha-15 × 10 plants m^{-2}) and closely followed by $V_4P_1$and V_4P_2. The lowest number of branches plant^{-1} of 2.23) was found from the treatment combination of V_2P_4 (BARI Sarisha-15 × 100 plants m^{-2}) followed by V_4P_1 and V_4P_2. The result obtained from the present study was similar with the findings of Tomar and Namedo (1989) and Kumar and Gangwar (1985).

4.2.2 Siliquae plant^{-1}

4.2.2.1 Effect of variety

Number of siliquae plant^{-1} varied significantly due to varieties (Table 5). The result revealed that the highest number of siliquae plant^{-1} of 126.90 was obtained from BARI Sarisha-13 (V_1) which was significantly higher than that of BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3. Again, the lowest number of siliquae plant^{-1} of 42.13 was found from SAU Sarisha-3 (V_4) which was also significantly different from all other tested varieties. Similar observation was also reported by Islam *et al*. (1994) that siliquae plant^{-1} varied from variety to variety. Similar result was also reported by Jahan and Zakaria (1997) and Mondal *et al*. (1992).

4.2.2.2 Effect of plant population density

Plant population density had significant influence on the number of siliquae plant^{-1} (Table 5). The maximum number of siliquae plant^{-1} of 95.04 was found from P_1 (10 plants m^{-2}). On the other hand, the lowest number of siliquae plant^{-1} of 61.08 was found from P_4 (100 plants m^{-2}). The maximum increases of 55.60% of siliquae plant^{-1} was observed with P_1 (10 plants m^{-2}) compared to lowest performance of producing siliquae plant^{-1} (100 plants m^{-2}). Siliquae plant^{-1} was also increased with the increase of plant spacing. The result obtained from the present study was similar with the findings of Singh *et al*. (1986) and Mustapic *et al*. (1987).

4.2.2.3 Interaction effect of variety and plant population density

Number of siliquae plant^{-1} was significantly increased by the interaction effect of variety and population density (Table 5). The maximum number of siliquae plant^{-1} of 145.70 was found from the interactions of V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) which was statistically different from all other treatment combinations.V_1P_2, V1P3, V_3P_1 and V_3P_2 also showed comparatively higher number of siliquae plant^{-1} but significantly different from V_1P_1. On the other hand, the lowest number of siliqua plant^{-1} of 24.67 was found from the treatment combination of V_4P_3 (SAU

Sarisha-3 × 70 plants m^{-2}) followed by V_2P_3, V_2P_4 and V_4P_4. Similar findings also reported by Butter and Aulakh (1999).

4.2.3 Length of siliquae

4.2.3.1 Effect of variety

Length of siliquae was varied significantly with the test varieties (Table 5). The result revealed that the highest length of siliqua of 7.67 cm was obtained from BARI Sarisha-13 (V_1) which was significantly higher than that of BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3. Again, the lowest length of siliqua of 4.59 cm) was found from BARI Sarisha-16 (V_3) which was also significantly different from all other tested varieties. The result obtained from the present study was similar with the findings of Hussain *et al*. (1996) and Gangasaran *et al*. (1981).

4.2.3.2 Effect of population density

Population density exerted no significant influence on the length of siliqua (Table 5). But it was observed that the highest length of siliqua of 5.90 cm was found from P_3 (70 plants m^{-2}) where the lowest length of siliqua 5.74 cm was found from P_2 (40 plants m^{-2}).

4.2.3.3 Interaction effect of variety and population density

Length of siliqua was significantly varied by the interaction effect of variety and population density (Table 5). The maximum length of siliqua of 7.94 cm was found from the interactions of V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) which was statistically identical with V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) and followed by V_1P_1 and V_1P_2. On the other hand, the lowest length of siliqua of 4.53 cm was found from the treatment combination of V_3P_4 (BARI Sarisha-16 × 100 plants m^{-2}) which was statistically identical with V_3P_3, V_3P_2 and V_3P_1.

4.2.4 Seeds siliqua^{-1}

4.2.4.1 Effect of variety

Number of seeds siliqua^{-1} varied significantly due to the test varieties (Table 5). The result revealed that the highest number of seeds siliqua^{-1} of 25.36 was obtained from BARI Sarisha-13 (V_1) which was significantly higher than that of BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3. Again, the lowest number of seeds siliqua^{-1} (14.95) was found from BARI Sarisha-16 (V_3) which was also significantly different from all other test varieties. The result obtained from the present study was conformity with the findings of Jahan and Zakaria (1997) and Gurjar and Chauhan (1997).

4.2.4.2 Effect of population density

Population density exerted no significant influence on the number of seeds siliqua^{-1} (Table 5). But it was observed that the highest number of seeds siliqua^{-1} of 20.26 was found from P_3 (70 plants m^{-2}) where the lowest number of seeds siliqua^{-1} of 19.70 was found from P_2 (40 plants m^{-2}). The result obtained from the present study was not similar with the findings of Singh and Singh (1987) and he reported that the number of seeds siliqua^{-1} increased as the population density decreased.

4.2.4.3 Interaction effect of variety and population density

Number of seeds siliqua^{-1} was significantly varied by the interaction effect of variety and population density (Table 5). The maximum number of seeds siliqua^{-1} of 26.03 was found from the interaction of V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) which was statistically similar with V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) and closely followed by V_1P_2 and V_1P_4. On the other hand, the lowest number of seeds siliqua^{-1} of 14.20 was found from the treatment combination of V_3P_2 (BARI Sarisha-16 × 40 plants m^{-2}) which was statistically similar with V_3P_3 and closely followed by V_3P_1, V_3P_4 and V_4P_4.

4.2.5 Weight of 1000 seeds

4.2.5.1 Effect of variety

Weight of 1000 seed differed significantly among the varieties (Table 5). The result revealed that BARI Sarisha-13 (V_1) had the highest 1000 seeds weight of 4.00 gm which was statistically higher from that of BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3. On the other hand, the lowest 1000 seed weight of 2.82 g was found in SAU Sarisha-3 (V_4) which was statistically identical with BARI Sarisha-15 (V_2). Similar findings were reported by Mondal and Wahab (2001) that weight of 1000 seeds varied from variety to variety.

4.2.5.2 Effect of population density

Different levels of population density had no significant effect on 1000 seed weight (Table 5). But results also showed that the highest 1000 seed weight of 3.39 gm was obtained with P_3 (70 plants m^{-2}) where the lowest of 3.24 was with P_2 (40 plants m^{-2}). The result obtained from the present study was not similar with the findings of Chauhan *et al.* (1993), Sharma (1992) and Patel *et al.* (1980) and they observed that wider spacing gave higher 1000 seed weight.

4.2.3.3 Interaction effect of variety and population density

Weight of 1000 seeds varied significantly with the interaction effect of variety and population density (Table 5). It was found that the highest 1000 seed weight of 4.10 g was found from the interactions of V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) which was closely followed by V_1P_1, V_1P_3 and V_1P_4. On the other hand, the lowest 1000 seed weight of 2.74 was found from the treatment combination of V_2P_4 (BARI Sarisha-15 × 100 plants m^{-2}) which was statistically identical with V_3P_3 and closely followed by V_2P_2, V_2P_3, V_4P_1, V_4P_2, V_4P_3 and V_4P_4

Table 5. Effect of variety and population density and their interaction on yield contributing parameters of Rapeseed-Mustard

Treatments	Branches plant^{-1} (No.)	Siliqua plant^{-1} (No.)	Length of siliqua (cm)	Seeds siliqua^{-1} (No.)	1000 seed weight (g)
Effect of variety					
V_1	6.14 a	126.90 a	7.67 a	25.36 a	4.00 a
V_2	4.59 c	53.17 c	5.06 c	22.76 b	2.87 c
V_3	4.87 b	96.59 b	4.59 d	14.95 d	3.61 b
V_4	4.78 b	42.13 d	6.04 b	16.95 c	2.82 c
$LSD_{0.0.5}$	0.794	1.597	0.2983	1.342	0.204
Effect of population density					
P_1	6.84 a	95.04 a	5.88	20.19	3.30
P_2	5.75 b	92.76 b	5.74	19.70	3.24
P_3	4.03 c	69.91 c	5.90	20.26	3.39
P_4	3.75 d	61.08 d	5.83	19.87	3.37
$LSD_{0.0.5}$	0.650	1.552	NS	NS	NS
Interaction effect of variety and population density					
V_1P_1	7.56 a	145.70 a	7.68 b	25.53 a	4.03 ab
V_1P_2	6.23 b	127.10 c	7.18 c	24.87 ab	3.83 a-c
V_1P_3	5.11 cd	136.60 b	7.94 a	26.03 a	4.10 a
V_1P_4	5.67 bc	98.11 f	7.87 a	25.01 ab	4.03 ab
V_2P_1	7.45 a	69.45 i	5.07 f	22.63 c	3.20 e
V_2P_2	5.11 cd	73.11 hi	5.10 f	22.25 c	2.75 f
V_2P_3	3.56 ef	33.23 l	5.14 f	22.89 c	2.78 f
V_2P_4	2.23 g	36.89 l	4.91 g	23.27 bc	2.74 f
V_3P_1	5.78 bc	106.40 e	4.61 h	15.40 ef	3.50 d
V_3P_2	5.00 cd	119.10 d	4.56 h	14.20 f	3.57 cd
V_3P_3	4.45 de	85.09 g	4.64 h	14.53 f	3.62 cd
V_3P_4	4.23 de	75.78 h	4.53 h	15.67 ef	3.77 b-d
V_4P_1	6.56 ab	58.56 j	6.17 d	17.20 de	2.76 f
V_4P_2	6.67 ab	51.78 k	6.12 d	17.47 d	2.83 f
V_4P_3	3.01 fg	24.67 m	5.94 e	17.59 d	2.75 f
V_4P_4	2.89 fg	33.53 l	5.92 e	15.53 ef	2.94 ef
$LSD_{(0.05)}$	0.924	4.124	0.149	1.669	0.258
CV (%)	8.70	10.78	6.12	8.05	7.37

Here,

V_1 = BARI Sarisha-13 | P_1 = 100000 plants ha^{-1}
V_2 = BARI Sarisha-15 | P_2 = 400000 plants ha^{-1}
V_3 = BARI Sarisha-16 | P_3 = 700000 plants ha^{-1}
V_4 = SAU Sarisha-3 | P_4 = 1000000 plants ha^{-1}

4.3 Yield parameters

4.3.1 Seed yield

4.3.1.1 Effect of variety

Grain yield of rapeseed- mustard varieties varied significantly from each other (Table 6). The results under the present study indicated that the variety BARI Sarisha-13 (V_1) produced seed yield of 1.35 t ha^{-1}, which was significantly highest than those of BARI Sarisha-15 (0.92 t ha^{-1}), BARI Sarisha-16 (1.16 t ha^{-1}) and SAU Sarisha-3 (1.19 t ha^{-1}). The lowest seed yield (0.92 t ha^{-1}) was found with the variety BARI Sarisha-15 (V_2). This result is in conformity with the findings of Islam *et al.* (1994) and Rahman (2002) who indicated the yield variation due to varietal differences.

4.3.1.2 Effect of population density

Population density had significant influence on the seed yield (Table 6). It was observed that the maximum seed yield of 1.32 t ha^{-1}) was found from P_3 (70 plants m^{-2}). On the other hand, the lowest seed yield of 0.82 t ha^{-1} was found from P_4 (100 plants m^{-2}). The maximum increases of 60.98% of seed yield was observed with P_3 (70 plants m^{-2}) compared to lowest performance of producing seed yield P_1 (10 plants m^{-2}). Here, 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 cause of decreased seed yield. The result obtained from the present study was similar with the findings of Angadi *et al*. (2003) ..

4.3.1.3 Interaction effect of variety and population density

Seed yield was significantly increased by the interaction effect of variety and population density (Table 6). Results showed that the maximum seed yield of 1.60 t ha^{-1}) was found from the interactions of V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) which was closely followed by V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) but statistically different from all other treatment combinations. V_1P_2, V_3P_2, V_3P_3, V_4P_2, V_4P_3 and V_4P_4 also showed comparatively higher seed yield but significantly different from V_1P_3. On the other hand, the lowest seed yield of 0.60 t ha^{-1} was found from the treatment combination of V_2P_1 (BARI Sarisha-15 × 10 plants m^{-2})

followed by V_1P_1, V_3P_1 and V_4P_1. The result obtained from the present study was similar with the findings of Behera *et al*. (2002) and Surya *et al*. (1998).

4.3.2 Stover yield

4.3.2.1 Effect of variety

Stover yield of rapeseed mustard varieties were significantly different from one another (Table 6). The results under the present study indicated that the variety BARI Sarisha-16 (V_3) produced stover yield of 2.27 t ha^{-1}, which was statistically identical with the variety BARI Sarisha-13 (V_1) and was significantly highest than those of BARI Sarisha-15 of 1.78 t ha^{-1} and SAU Sarisha-3 of 2.04 t ha^{-1}. The lowest stover yield of 1.78 t ha^{-1} was found with the variety BARI Sarisha-15 (V_2). The result obtained from the present study had similarity with the findings of BARI (2001) and Ali *et al*. (1996).

4.3.2.2 Effect of population density

Population density had significant influence on the stover yield (Table 6). It was observed that the highest stover yield of 2.33 t ha^{-1} was found from P_3 (70 plants m^{-2}). On the other hand, the lowest stover yield of 1.53 t ha^{-1} was found from P_1 (10 plants m^{-2}). The maximum increases of 52.28% of stover yield was observed with P_3 (70 plants m^{-2}) compared to lowest performance producing stover yield of P_1 (10 plants m^{-2}). Here, it can be concluded 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 causes of decreased stover yield.

4.2.3.3 Interaction effect of variety and population density

Stover yield was significantly increased by the interaction effect of variety and population density (Table 6). Results showed that the maximum stover yield of

2.93 t ha^{-1} was found from the interactions of V_3P_3 (BARI Sarisha-16 × 70 plants m^{-2}) which was statistically different from all other treatment combinations. On the other hand, the lowest stover yield of 1.57 t ha^{-1} was found from the treatment combination of V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) which was statistically identical with V_1P_1 and V_4P_1.

4.3.3 Biological yield

4.3.3.1 Effect of variety

Biological yield of rapeseed -mustard varieties were significantly different from one another (Table 6). The results under the present study indicated that the variety BARI Sarisha-13 (V_1) produced biological yield of 3.55 t ha^{-1}, which was statistically different from all other test varieties. The lowest biological yield of 2.70 t ha^{-1} was found with the variety of BARI Sarisha-15 (V_2).

4.2.3.2 Effect of population density

Population density had significant influence on the biological yield (Table 6). It was observed that the highest biological yield of 3.48 t ha^{-1} was found from P_3 (70 plants m^{-2}) which was statistically identical with P_4 (100 plants m^{-2}). On the other hand, the lowest biological yield of 2.35 t ha^{-1} was found from P_1 (10 plants m^{-2}). The result obtained from the present study was similar with the findings of Singh *et al*. (1986).

4.2.3.3 Interaction effect of variety and population density

Biological yield was significantly increased by the interaction effect of variety and population density (Table 6). Results showed that the maximum biological yield of

4.06 t ha^{-1} was found from the interactions of V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) which was statistically different from all other treatment combinations. On the other hand, the lowest biological yield of 1.93 t ha^{-1} was found from the treatment combination of V_2P_1 (BARI Sarisha-15 × 10 plants m^{-2}) which was also significantly different from all other treatment combinations.

4.3.4 Harvest index

4.3.4.1 Effect of variety

Harvest index of rapeseed -mustard varieties were significantly different from one another (Table 6). The results under the present study indicated that the variety BARI Sarisha-13 (V_1) produced harvest index of 37.65%, which was statistically different from all other test varieties. The lowest harvest index of 33.73% was found with the variety of BARI Sarisha-15 (V_2). The result obtained from the present study was similar with the findings of Islam *et al*. (1994).

4.3.4.2 Effect of population density

Population density had significant influence on the harvest index (Table 6). It was observed that the highest harvest index of 36.14% was found from P_3 (70 plants m^{-2}) which was statistically different from all other treatments of plant population. On the other hand, the lowest harvest index of 34.51% was found from P_1 (10 plants m^{-2}). The result obtained from the present study was similar with the findings of Scarisbric *et al*. (1982) and Shrief *et al*. (1990).

4.3.4.3 Interaction effect of variety and population density

Harvest index was significantly increased by the interaction effect of variety and population density (Table 6). Results showed that the maximum harvest index of 41.02% was found from the interactions of V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) which was statistically different from all other treatment combinations. V_1P_2, V_4P_3 and V_4P_4 also showed comparatively higher harvest index but significantly different from V_1P_3. On the other hand, the lowest harvest index of 31.21% was found from the treatment combination of V_3P_3 (BARI Sarisha-16 × 70 plants m^{-2}) which was also significantly different from all other treatment combinations. V_1P_1 and V_3P_4 also showed comparatively lower harvest index but significantly different from V_3P_3. The result obtained from the present study was similar with the findings of Singh and Singh (1987).

Table 6. Effect of variety and population density and their interaction on seed and Stover yield, biological yield and harvest index of Rapeseed-Mustard

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	Effect of variety			
V_1	1.35 a	2.20 a	3.55 a	37.65 a
V_2	0.92 c	1.78 c	2.70 d	33.73 d
V_3	1.16 b	2.27 a	2.93 c	34.15 c
V_4	1.19 b	2.04 b	3.23 b	36.93 b
$LSD_{0.0.5}$	0.112	0.091	0.071	0.095
SE	0.133	0.083	0.214	0.203
	Effect of population density			
P_1	0.82 c	1.53 c	2.35 c	34.51 c
P_2	1.23 b	2.22 b	3.48 a	35.97 b
P_3	1.32 a	2.33 a	3.15 b	36.14 a
P_4	1.22 b	2.20 b	3.43 a	35.85 b
$LSD_{0.0.5}$	0.094	0.081	0.09133	0.134
	Interaction effect of variety and population density			
V_1P_1	0.83 h	1.63 f	2.46 h	33.74 i
V_1P_2	1.47 b	2.30 cd	3.77 c	38.99 b
V_1P_3	1.60 a	2.30 cd	3.90 b	41.02 a
V_1P_4	1.50 ab	2.57 b	4.06 a	36.86 d
V_2P_1	0.60 i	1.33 g	1.93 j	31.09 k
V_2P_2	1.00 fg	2.00 e	3.00 fg	33.32 ij
V_2P_3	1.00 fg	1.90 e	2.91 g	34.49 h
V_2P_4	1.07 ef	1.90 e	2.98 fg	36.02 f
V_3P_1	0.90 gh	1.57 f	2.48 h	36.44 d-f
V_3P_2	1.23 cd	2.17 d	3.41 e	36.19 ef
V_3P_3	1.33 c	2.93 a	2.26 i	31.21 k
V_3P_4	1.17 de	2.40 c	3.58 d	32.76 j
V_4P_1	0.93 gh	1.60 f	2.52 h	36.76 de
V_4P_2	1.33 c	2.43 bc	3.76 c	35.36 g
V_4P_3	1.34 c	2.20 d	3.54 d	37.85 c
V_4P_4	1.17 de	1.93 e	3.11 f	37.74 c
$LSD_{(0.05)}$	0.106	0.149	0.129	0.5728
CV (%)	10.77	10.19	7.50	9.03

Here

V_1 = BARI Sarisha-13 | P_1 = 100000 plants ha^{-1}

V_2 = BARI Sarisha-15 | P_2 = 400000 plants ha^{-1}

V_3 = BARI Sarisha-16 | P1 = 700000 plants ha-1

V_4 = SAU Sarisha-3 | P2 = 1000000 plants ha-1

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

The experiment was conducted at the field of Sher-e-Bangla Agricultural University farm, Dhaka to evaluate the performance of population density and variety on growth and yield of Rapeseed-Mustard. The experiment consists of two factors (1) Variety and (2) Population density. Four varieties were viz. (i) V_1 = BARI Sarisha-13, (ii) V_2 = BARI Sarisha-15, (iii) V_3 = BARI Sarisha-16 and (iv) V_4 = SAU Sarisha-3 were used and four population densities were used viz. (i) P_1 = 100000 plants ha^{-1}, (ii) P_2 = 400000 plants ha^{-1}, (iii) P_3 = 700000 plants ha^{-1} and (iv) P_4 = 1000000 plants ha^{-1}. There were sixteen treatment combinations under the present study. Data were collected from the experimental field and analyzed statically.

Data were collected on Plant height (cm), Leaf length (cm), Leaf width (cm), Dry weight $plant^{-1}$, Branches $plant^{-1}$, Siliquae $plant^{-1}$, Seeds $siliqua^{-1}$, Length of siliqua (cm), Weight of 1000 seed (g), Grain yield (t ha^{-1}), Stover yield (t ha^{-1}), Biological yield (t ha^{-1}) and Harvest index (%).

Significant variation was found in all parameters at different growth stages of rapeseed-mustard. Different varieties showed significant variation at different stages.

Plant height at 40, 60 DAS and at harvest BARI Sarisha-16 (V_3) gave highest plant height of 75.79, 148.10 and 160.20 cm respectively where BARI Sarisha-13 (V_1) showed the lowest plant height of 63.86, 85.74 and 88.78 cm respectively. Again, BARI Sarisha-16 (V_3) also showed highest leaf length of 25.25 and 25.09 cm at 60 DAS and at harvest respectively and leaf width of 7.29, 8.52 and 7.50 cm at 40, 60 DAS and at harvest respectively where BARI Sarisha-15 (V_2) showed lowest leaf length of 15.64, 17.31 and 15.61 cm at 40, 60 DAS and at harvest respectively and leaf width of 2.31, 4.18, 4.69 and 3.68 cm at 20, 40, 60

DAS and at harvest respectively. In terms of dry weight plant^{-1}, BARI Sarisha-13 (V_1) showed the highest dry weight plant^{-1} of 5.25, 12.12, 14.62 and 17.58 g at 40, 60, 80 DAS and at harvest respectively where BARI Sarisha-15 (V_2) gave the lowest weight plant^{-1} of 3.17, 7.92, 9.60 and 8.83 g at 40, 60, 80 DAS and at harvest respectively.

Considering yield contributing parameters, BARI Sarisha-13 produced the highest number of branches plant^{-1} of 6.14, siliquae plant^{-1} of 126.90, length of siliquae of 7.67 cm, number of seeds siliqua^{-1} of 25.36 and 1000 seeds weight of 4.00 gm where BARI Sarisha-15 (V_2) gave the lowest number of branches plant^{-1} of4.59. But the lowest number of siliquae plant^{-1} of 42.13 and 1000 seed weight of 2.82 g were found from SAU Sarisha-3 (V_4) and the lowest length of siliquae of 4.59 cm and number of seeds siliqua^{-1} of 14.95 were found from BARI Sarisha-16 (V_3).

Considering yield parameters, it was observed that BARI Sarisha-13 (V_1) gave the highest seed yield of 1.35 t ha^{-1}, biological yield of 3.55 t ha^{-1} and harvest index of 37.65% but BARI Sarisha-16 (V_3) produced highest stover yield of 2.27 t ha^{-1} where the lowest seed yield of 0.92 t ha^{-1}, stover yield of 1.78 t ha^{-1}, biological yield of 2.70 t ha^{-1} and harvest index of 33.73%) were found with the variety of BARI Sarisha-15 (V_2).

Different population densities also showed significant variation at different stages. Plant height at the time of harvest, P_2 (40 plants m^{-2}) gave best result of 113.40 cm where lowest plant height was observed with P_4 (100 plants m^{-2}) at 60 DAS and at harvest of 102.70 and 106.40 cm respectively. Again, the highest leaf length was achieved from P_2 (40 plants m^{-2}) at 40, 60 DAS and at harvest of 23.11, 24.11 and 21.89 cm respectively where P_4 (100 plants m^{-2}) showed the lowest leaf length of 20.00, 21.26 and 19.05 cm s at 40, 60 DAS and at harvest respectively. But in case of leaf width, P_1 (10 plants m^{-2}) showed the highest result of 6.73, 7.11 and 6.08 cm at 40, 60 DAS and at harvest respectively, where the lowest leaf width was with P_4 (100 plants m^{-2}) at 20, 40, 60 DAS and at harvest of 2.45, 5.03, 5.82 and 4.78 cm respectively. But in terms of dry weight $plant^{-1}$, P_1 (10 plants m^{-2}) also gave the best result of 13.85, 14.47 and 17.50 g at 60, 80 DAS and at harvest respectively where as P_4 (100 plants m^{-2}) showed the lowest dry weight $plant^{-1}$ of 3.52, 6.66, 9.58 and 8.65 g at 40, 60, 80 DAS and at harvest respectively.

Considering yield contributing parameters, the maximum number of branches $plant^{-1}$ of 6.84 and siliquae $plant^{-1}$ of 95.04 were found from P_1 (10 plants m^{-2}). But there was no significant effect was found in case of length of siliqua, number of seeds $siliqua^{-1}$ and 1000 seed weight.

Considering yield parameters, the maximum seed yield of 1.32 t ha^{-1}, stover yield of 2.33 t ha^{-1}, biological yield of 3.48 t ha^{-1} and harvest index of 36.14% were found from P_3 (70 plants m^{-2}) where the lowest seed yield of 0.82 t ha^{-1} was found from P_4 (100 plants m^{-2}) but the lowest stover yield of 1.53 t ha^{-1}, biological yield of 2.35 t ha^{-1} and harvest index of 34.51% were found from P_1 (10 plants m^{-2}).

In case of combined effect of variety and population density, V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) gave the tallest plant of 156.10 and 170.90 cm at 60 DAS and at harvest respectively where the shortest plant height was found from V_4P_4 at harvest of 81.23 cm. But the interaction effect of V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) gave the highest leaf length of 30.34, 31.89 and 29.79 cm at 40, 60 DAS and at harvest respectively where V_2P_3 (BARI Sarisha-15 × 70 plants m^{-2}) showed the lowest leaf length of 14.01 and 13.99 cm at 60 DAS and at harvest respectively. Again, V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) gave the highest leaf width of 7.66, 10.20 and 9.16 cm at 40, 60 DAS and at harvest respectively where the lowest leaf width was observed with V_2P_4 (BARI Sarisha-15 × 70 plants m^{-2}) at 60 DAS and at harvest of 4.18 and 3.21 cm respectively. In case of dry weight $plant^{-1}$ V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) gave the highest dry weight $plant^{-1}$ of 19.13, 16.23 and 22.70 g at 60, 80 DAS and at harvest respectively where V_2P_3

(BARI Sarisha-15 × 70 plants m^{-2}) gave the lowest dry weight $plant^{-1}$ of 7.05 and 6.01 g at 80 DAS and at harvest respectively.

Considering yield contributing parameters, The maximum number of branches $plant^{-1}$ of 7.56 and siliquae $plant^{-1}$ of 145.70 were found from V_1P_1 (BARI Sarisha-13 × 10 plants m^{-2}) but the maximum length of siliqua of 7.94 cm, number of seeds $siliqua^{-1}$ of 26.03 and 1000 seed weight of 4.10 g were found from V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}). The lowest number of branches $plant^{-1}$ of 2.23 and 1000 seed weight of 2.74 were found from V_2P_4 (BARI Sarisha-15 × 100 plants m^{-2}) but the lowest number of siliquae $plant^{-1}$ of 24.67, length of siliqua of 4.53 cm and number of seeds $siliqua^{-1}$ of 14.20 were found from V_4P_3 (SAU Sarisha-3 × 70 plants m^{-2}), V_3P_4 (BARI Sarisha-16 × 100 plants m^{-2}) and V_3P_2 (BARI Sarisha-16 × 40 plants m^{-2}) respectively.

Considering yield parameters, the maximum seed yield of 1.60 t ha^{-1} and harvest index of 41.02% were found from V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) but the maximum stover yield of 2.93 t ha^{-1} was found from V_3P_3 (BARI Sarisha-16 × 70 plants m^{-2}) and the maximum biological yield of 4.06 t ha^{-1} was found from V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) where the lowest seed yield of 0.60 t ha^{-1} and biological yield of 1.93 t ha^{-1} were found from V_2P_1 (BARI Sarisha-15 × 10 plants m^{-2}) but the lowest stover yield of 1.57 t ha^{-1} was found from V_3P_1 (BARI Sarisha-16 × 10 plants m^{-2}) and the lowest harvest index of 31.21%of was found from V_3P_3 (BARI Sarisha-16 × 70 plants m^{-2}).

From the results obtained, it may be concluded that the performance of rapeseed cv. BARI Sarisha-13 was better in respect of growth, yield and yield components when sown at plant population of 70 plants m^{-2}. With this combination the yield was 1.60 t ha^{-1}. But with the treatment combination of V_1P_4 (BARI Sarisha-13 × 100 plants m^{-2}) showed very close yield of 1.50 t ha^{-1}. So, from economic point of view, V_1P_3 (BARI Sarisha-13 × 70 plants m^{-2}) was the best treatment combination.

However, this result has made a basis for further study that in different region involving different factors of production of rapeseed mustard to make make a remarkable conclusion. Further research is, therefore, necessary to reach a conclusion.

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Appendices

APPENDICES

Appendix I. Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207

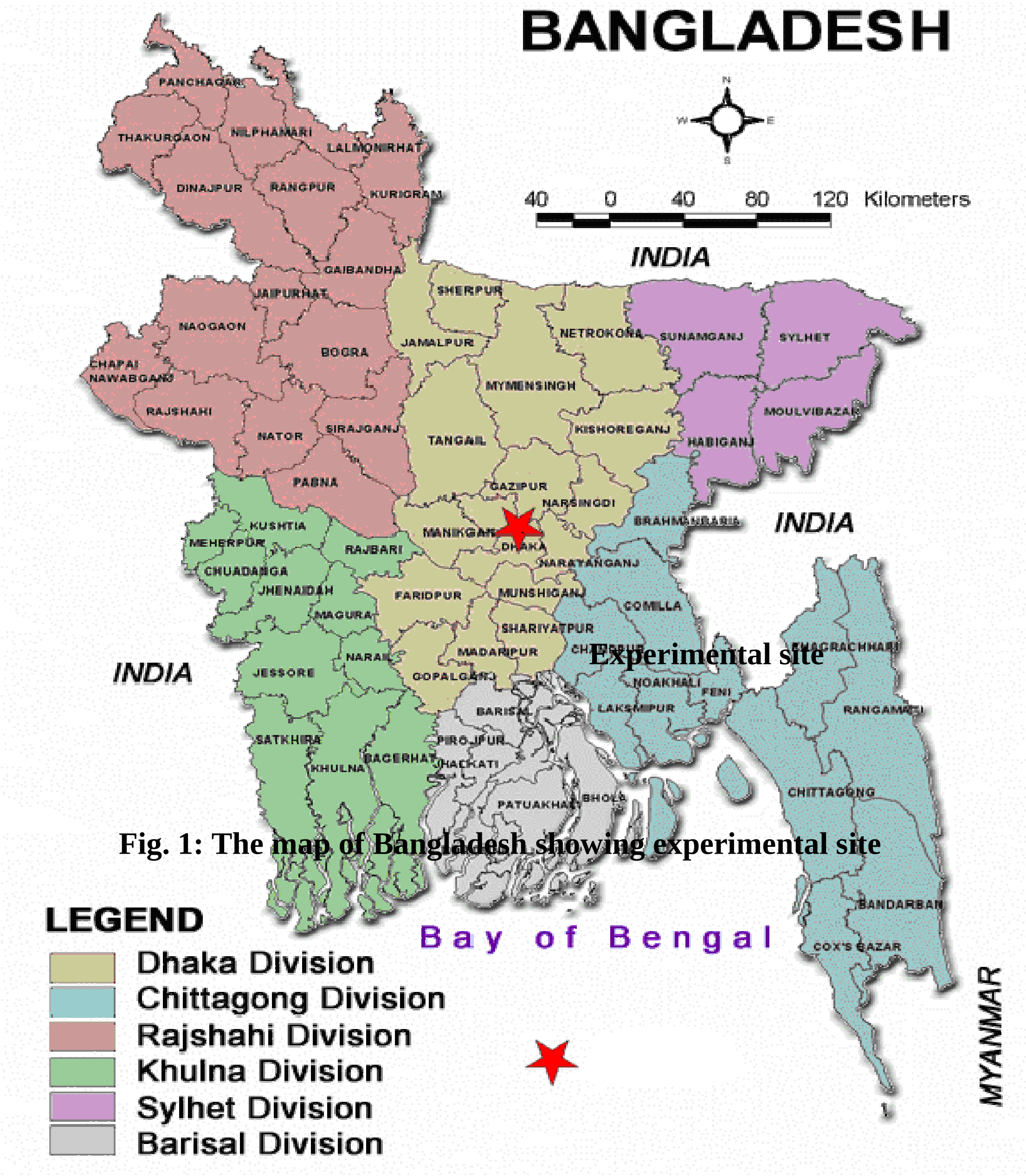


Fig. 1: The map of Bangladesh showing experimental site

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

A. Morphological characteristics of the experimental field

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	***Value***
Particle size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

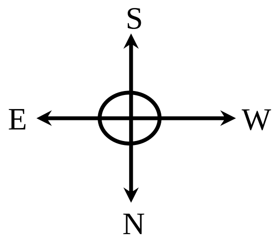
Appendix III. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from November 2011 to February 2012.

Month	**RH (%)**	**Max. Temp. (ºC)**	**Min. Temp. (ºC)**	**Rain fall (mm)**
November	50.26	24.80	16.40	0
December	48.36	24.52	14.18	0
January	69.53	25.00	13.46	0
February	50.31	29.50	18.49	0

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

Appendix IV: Layout of the experimental design.

$V_1 P_1$	$V_3 P_1$	$V_4 P_4$
$V_3 P_2$	$V_2 P_3$	$V_1 P_1$
$V_2 P_4$	$V_1 P_2$	$V_2 P_3$
$V_1 P_2$	$V_4 P_4$	$V_3 P_3$
$V_4 P_1$	$V_1 P_1$	$V_2 P_1$
$V_1 P_4$	$V_4 P_2$	$V_3 P_2$
$V_4 P_3$	$V_2 P_2$	$V_1 P_4$
$V_3 P_3$	$V_3 P_3$	$V_4 P_2$
$V_1 P_3$	$V_4 P_3$	$V_3 P_1$
$V_4 P_2$	$V_1 P_4$	$V_2 P_2$
$V_3 P_1$	$V_3 P_2$	$V_4 P_1$
$V_2 P_2$	$V_2 P_1$	$V_1 P_2$
$V_3 P_4$	$V_2 P_4$	$V_3 P_4$
$V_2 P_3$	$V_1 P_3$	$V_2 P_4$
$V_4 P_4$	$V_3 P_4$	$V_4 P_3$
$V_2 P_1$	$V_4 P_1$	$V_1 P_3$



Number of plots: 48
Plot size: 2m × 2.5m ($5m^2$)
Block to block distance: 0.75m
Plot to plot distance: 0.5m

Variety

(i) V_1 = BARI sarisha-13
(ii) V_2 = BARI Sarisha-15
(iii) V_3 = BARI Sarisha-16
(iv) V_4 = SAU sarisha-3

Population density

(i) P_1 = 100000 plants ha^{-1} i.e. 10 plants m^{-2}
(ii) P_2 = 400000 plants ha^{-1} i.e. 40 plants m^{-2}
(iii) P_3 = 700000 plants ha^{-1} i.e. 70 plants m^{-2}
(iv) P_4 = 1000000 plants ha^{-1} i.e. 100 plants m^{-2}

Appendix V: Effect of variety and population density on plant height at different days after sowing of rapeseed – mustard.

Source of variation	Degrees of freedom	Mean square of plant height (cm) at different days after sowing			
		20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Replication	2	1.35	2.80	2.05	1.86
Factor A	3	3.53*	3.68*	9.35*	3.44*
Factor B	3	2.44*	3.21*	8.74*	4.56*
AB	9	0.48**	6.73*	1.78**	6.39*
Error	30	1.504	2.80	2.05	3.98

*Significant at 5% level

Appendix VI: Effect of variety and population density on leaf length at different days after sowing of rapeseed – mustard.

Source of variation	Degrees of freedom	Mean square of leaf length (cm) at different days after sowing			
		20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Replication	2	1.65	1.48	2.91	1.00
Factor A	3	4.19*	3.41*	3.57*	5.67*
Factor B	3	0.78**	6.28*	6.32*	1.01*
AB	9	0.48*	6.58*	6.10*	1.75*
Error	30	0.097	1.19	1.76	0.28

*Significant at 5% level

Appendix VII: Effect of variety and population density on leaf width at different days after sowing of rapeseed – mustard.

Source of variation	Degrees of freedom	Mean square of leaf breadth (cm) at different days after sowing			
		20 DAS	**40 DAS**	**60 DAS**	**At harvest**
Replication	2	0.92	2.05	1.22	0.84
Factor A	3	0.37**	9.83*	9.99*	2.68*
Factor B	3	0.09**	3.92*	2.52*	3.91*
AB	9	0.16**	1.30**	2.07*	1.26*
Error	30	0.12	1.01	0.68	0.54

*Significant at 5% level

Appendix VIII: Effect of variety and population density on dry weight of plant at different days after sowing of rapeseed – mustard.

Source of variation	Degrees of freedom	Mean square of dry weight plant^{-1} at different days after sowing				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.01	1.34	1.78	2.53	2.32
Factor A	3	NS	8.90*	6.89*	6.65*	4.61*
Factor B	3	NS	4.88*	8.51*	5.04*	2.86*
AB	9	NS	0.87**	5.30*	7.28*	4.45*
Error	30	0.00	0.06	1.92	1.26	1.84

*Significant at 5% level

Appendix IX: Effect of variety and population density on yield contributing parameters of rapeseed-mustard.

Source of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Branches plant^{-1}	Siliqua plant^{-1}	Length of siliqua (cm)	Seeds siliqua^{-1}	1000 seed weight (g)
Replication	2	6.83	0.71	0.26	0.76	0.02
Factor A	3	6.66*	5.40*	9.28*	8.68*	4.02*
Factor B	3	4.26*	4.72*	NS	NS	NS
AB	9	1.47*	3.85*	1.13*	1.58*	1.07**
Error	30	0.91	1.67	0.14	2.59	0.26

*Significant at 5% level

Appendix X: Effect of variety and population density on seed yield, stover yield, biological yield and harvest index of rapeseed- mustard.

Source of variation	Degrees of freedom	Mean square of yield parameters			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.32	0.40	0.01	0.14
Factor A	3	0.55**	0.39**	1.62*	4.30*
Factor B	3	1.59*	1.62*	3.30*	6.71*
AB	9	0.17**	1.03*	0.44**	1.74*
Error	30	0.02	0.06	0.20	1.04

*Significant at 5% level

LIST OF PLATES

Plate 1: Field view of BARI Sarisha- 1

Plate 2: Field view of BARI Sarisha- 15

Plate 3: Field view of BARI Sarisha- 16

Plate 4: Field view of SAU Sarisha- 3