GROWTH AND YIELD OF RAPESEED AND MUSTARD VARIETIES AS AFFECTED BY PLANTING METHOD

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CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND YIELD OF RAPESEED AND MUSTARD VARIETIES AS AFFECTED BY PLANTING METHOD"** submitted to the Faculty of Agriculture**,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRONOMY,** embodies the results of a piece of bonafide research work carried out by **SUDIPTA ROY,** Registration. No. **09-03691** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

TO

MY

GRANDPARENTS

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GROWTH AND YIELD OF RAPESEED AND MUSTARD VARIETIES AS AFFECTED BY PLANTING METHOD

ABSTRACT

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka in the Rabi season (November- February) of 2014-2015 to evaluate the performance of varieties on different planting methods of mustard. The treatment comprised of two planting methods and six varieties. The two planting methods were conventional method of sowing (M_1) and System of Mustard Intensification (SMI) (M_2). Six different varieties were BARI Sarisha-11 (V_1), BARI Sarisha-13 (V_2), BARI Sarisha-14 (V_3), BARI Sarisha-15 (V_4) BARI Sarisha-16 (V_5) and Tori-7 (V_6). The experiment was laid out in a Split-plot design with three replications. Planting methods was assigned in the main plot and varieties in the sub plot. The planting method affected significantly for the siliqua length, number of siliquae plant^{-1}, number of seed siliqua^{-1}, stover yield, biological yield and harvest index but statistically unaffected for 1000-seed weight and seed yield. It was found that SMI produced 2.28% higher seed yield compared to conventional method. The seed yield of mustard varied for different variety. BARI Sarisha-11 produced the highest seed yield (1386.50 kg ha^{-1}) whereas the lowest seed yield (733.10 kg ha^{-1}) was given BARI Sarisha-14. BARI Sarisha-11 in SMI method resulted the highest seed yield (1830.70 kg ha^{-1}) that might be due to higher number of siliquae (483.47) plant^{-1}. BARI Sarisha-14 in SMI showed the lowest seed yield (429.80 kg ha^{-1}). Thus it may be concluded that SMI was not effective for all varieties i.e the variety BARI Sarisha-11 performed better in SMI method.

LIST OF CONTENTS

LIST OF CONTENTS (Contd.)

LIST OF CONTENTS (Contd.)

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Rapeseed and Mustard (*Brassica spp.*) belongs to the family *Brassicaceae* is one of the most important and popular oil crop. The *Brassica* has three species that produce edible oil, namely *Brassica napus. B. campestris* and *B. juncea.* Brassica is one of the most important oilseed crops throughout the world after soybean and groundnut (FAO, 2004). It has a remarkable demand for edible oil in Bangladesh. It occupies first position in Bangladesh in respect of area and production among the oilseed crops grown in this country (DAE, 2015). This crop is currently ranked as the world's third important oil crop. Vegetable oils and fats (lipids) constitute an important component of human diet. Oils of plant origin are nutritionally superior to that of animal origin. Oils and fats also act as an important carrier of vitamins A and D. The essential fatty acids contained in oils and fats play an important role in several metabolic processes (Kaul and Das, 1986). Due to insufficient production, a huge amount of foreign exchange involving over 160 million US Dollar is being spent every year for importing edible oils in Bangladesh (Rahman, 2002). At present about 5.32 lac hectares of land are under mustard cultivation in Bangladesh with a production of 5.96 lac metric tons of mustard seed (DAE, 2015).

This quantity can meet only a fraction of the cooking oil, requirement for the country. Mustard seed contains about 40-45% oil and 20-25% protein. It is also important for improving the taste of a number of food items. Its oil is widely used as cooking and medicinal ingredients. Moreover, mustard oil cake is also used as a feed for cattle and fish and as a good manure. It also serves as an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Its oil is also used by the villagers for hair dressing and body massage before bath. Dry mustard straw is also used as fuel.

Variety plays an important role in mustard production. High yielding varieties (HYVs) can contribute to get optimum yield. There are some HYVs of mustard, which have been released by the Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA). The yields of these cultivars range between 1.4 to 2.1 t ha^{-1} (BARI, 2002). 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).

Though, yield of rapeseed and mustard in Bangladesh has been increased obviously with the introduction of high yielding varieties and improvement of management practices but the average yield per hectare of mustard in this country is alarmingly very poor compared to that of advanced 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 (FAO, 2003). Annual requirement of edible oil is about 5 lakh metric tonnes. The internal production of edible oil can meet up only less than one-third of the annual requirement (Mondal and Wahhab, 2001). The major reasons for low yield of rapeseed-mustard in Bangladesh are due to lack of high yielding variety, appropriate population density and inadequate knowledge of sowing time, sowing methods and proper management practices etc (Mamun *et al.,* 2014). The area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of *boro* rice loosing in an area of 104 thousand hectare and production 68 thousand tons of mustard and rapeseed in last ten years (Anon., 2006). Yield and its development process depend on genetic, environmental and agronomic factors as well as the interaction between them. Therefore, there is a scope to increase the yield level of rapeseed-mustard by using HYV seed and by adopting proper management practices like spacing, seed rate and vice-versa (Bhuiyan *et al.,* 2011).

In Bangladesh, mustard is sown in early October to November. During winter a short cool season prevails in Bangladesh. The temperature in the country remains fairly high up to mid October which gradually comes down afterwards.

In oilseed rape and mustard row spacing or plant density vary considerably worldwide, depending on the environment, production system and cultivar. Previous studies have shown that plant density is an important factor affecting rapeseed yield. Plant density in rapeseed governs the components of yield, and thus the yield of individual plants. A uniform distribution of plants per unit area is a prerequisite for yield stability (Diepenbrock, 2000). Establishment of optimum plant density per unit area is a prerequisite for having increased seed yield. Mustard yield can be increased by following system of mustard intensification techniques suggested by many researchers (SRI-Rice, 2014; Aziz, 2014). The plant density can be adjusted by the use of different planting method and row spacing. Planting method thus may influence yield contributing characters of mustard. Rapeseed has generally slight or inconsistent seed yield responses to various row spacing's. Therefore, optimum densities for each crop and each environment should be determined by local research. However, there are very few researches on the SMI performance of rapeseed and mustard varieties of Bangladesh. With conceiving the above thinking in mind, the present research work has been undertaken in order to fulfilling the following objectives:

- To evaluate the varietal performance in terms of plant growth and yield of mustard;
- To assess the appropriate planting method for specific variety for increasing plant growth and yield of mustard and
- To find out the interaction between planting methods and variety for better plant growth and yield of mustard.

CHAPTER 2

REVIEW OF LITERATURE

Rapeseed and Mustard is an important oil crop of Bangladesh which contributes to a large extent in the national economy. But the research works done on this crop with respect to different planting methods are inadequate. Its growth and yield are determined by various factors of which planting technique is one of the most important. A very little work has been done involving the planting technique with the mustard varieties. Some of the work applicable to the present study has been reviewed below:

2.1 Effect of planting method on different crop characters

2.1.1 Plant height

Aziz (2014) conducted an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the Rabi period in 2013-14. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Sowing technique treatments were Broadcasting, Line Sowing, Raised Bed and System of Mustard Intensification (SMI). Result showed that plant height was significantly varied among the sowing techniques.

Atlassi *et al.* (2008) conducted an experiment in order to investigate the effect of planting pattern on morphology, yield and yield components of canola. The experiment was laid on split-plot design. The treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and RGS 003) as sub-plots. Results indicated that both the effects of planting pattern and variety on morphologic characters (plant height, stem diameter, height of the first lateral branch and number of lateral branches) were significant.

Khan *et al*. (2000) carried out an experiment on mustard in saline field at Agricultural Research Institute (ARI) Tamab during 1997-98. Canola (*Brassica napus*) was sown using four different sowing techniques included drill, broadcast, furrow and ridge. The highest plant height found in ridge planting method.

Khanlou and Sharghi (2015) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety has significant on height plant, diameter of stem. The effect of planting distance has a significant effect on the height plant and diameter of stem ($P<0.01$).

Sarkees (2013) conducted an experiment at Karda-Rasha College of Agriculture, Erbil to evaluate the effect of different seeding rates using drill-row and broadcasting sowing methods on growth, seed and oil yields of rapeseed (*Brassica napus* L.) cv. Pactol. The tallest plants were produced in the drill-row sown plots. (129.5 cm), while the shortest plants were produced with broadcasting sowing (115.2 cm), this result was in agreement with Khan *et al.* (2000) that the plants of broadcasting sowing were shorter (109.7 cm) than plants of drill sowing method (118.0 cm).

Sher *et al.* (2001) were studied on effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.) They found that number of plants

(m^{-2}), plant height at maturity (cm), was significantly affected both by varying planting pattern and inter plant spacing

Hossain *et al.* (2013) carried out an experiment at Agronomy field laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, to study the effect of irrigation and sowing method on yield and yield attributes of mustard**.** Sowing method had significant effect on plant height. Line sowing produced the tallest plant (96.51 cm) and the shortest one (94.26 cm) was found at broadcast method.

2.1.2 Number of primary branches plant^{-1}

Aziz (2014) conducted an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. Result indicated that number of primary branches was not significantly affected by sowing technique at 30 DAS but significant at 45, 60 and 75 DAS and at harvest. At harvest, maximum numbers of primary branches were recorded at SMI technique and minimum numbers of primary branches were recorded at broadcast sowing technique which was statistically similar with line sowing.

Hossain *et al.* (2013) reported that sowing method had significant effect on the production of total branches plant^{-1}. Line sowing method produced the highest number of branches plant^{-1} (8.42). The lowest number of total branches plant^{-1} (8.03) was observed in the broadcast method.

Sarkees (2013) conducted an experiment at Karda-Rasha College of Agriculture, Erbil to evaluate the effect of different seeding rates using drill-row and broadcasting sowing methods on growth, seed and oil yields of rapeseed (*Brassica napus* L.) cv. Pactol and found no significant differences in case of number of primary branches of plant due to different sowing methods.

Aiken *et al*. (2015) found that seeding with a hoe drill (HD) resulted in the best emergence and stand ratings, and earlier flowering. Emergence and stand ratings for seeding with a no-till drill (NT) were better than ratings for broadcast seeding (BC). Canola (*Brassica napus* L.) had better stand rating and earlier flowering than Indian mustard (*Brassica juncea* L.) Czernj. & Cosson) and Camelina (*Camelina sativa* L.) Crantz), which were similar.

2.1.3 Number of siliquae plant^{-1}

Aziz (2014) reported that number of siliquae plant^{-1} was significantly affected by sowing technique. Maximum number of siliquae plant^{-1} was recorded at SMI technique and minimum number of siliquae plant^{-1} was observed at broadcast sowing technique.

The number of siliqua per plant is an important yield contributing character of oil seed rape. Several studies suggest that a higher number of siliquae plant^{-1} has the greatest effect on seed yield on rape and mustard (Mendham *et al.*, 1981; Thurling, 1974; Rahman *et al.*, 1988).

Hossain *et al*. (2013) studied that in the closer plant population at broadcasting method, there were competitions for light, space, nutrients and environments and therefore, lowest number of branches plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1} and 1000-seed weight were produced, ultimately seed yield plant^{-1} was decreased .

Khan *et al*. (2000) studied number of siliqua per plant play a major role in yield which was significantly affected by sowing methods. Maximum siliqua per plant were produced by ridge sown plants. The results for the rest three methods (broadcast, furrow and drill) were statistically non significant.

Sarkees (2013) reported that individual plants of drill-row sowing produced a higher number of siliquae than those of broadcasting sowing (130.0) and (107.1) respectively.

2.1.4 Length of siliqua

Aziz (2014) reported that siliqua length of mustard and rapeseed plant was significantly affected by sowing technique. The biggest siliqua length was recorded at SMI technique and the smallest siliqua length was observed at line sowing which was statistically similar with broadcast sowing and raised bed technique.

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

2.1.5 1000-seed weight

Sarkees (2013) reported that crop grown with drill-row sowing method showed significantly the highest seed weight as compared to broadcasting which produced lowest seed weight.

Khan *et al.* (2000) reported that one of the economically most important yield parameter of the crop, the 1000 grain weight and grain yield as affected by sowing method. Crop grown with ridge sowing method showed significantly the highest 1000 grain weight as compared to drill sowing and furrow sowing, while broadcast sown crop produced the lowest 1000 grain weight.

Hossain *et al.* (2013) were found that the weight of 1000-seed was not influenced by sowing method. The maximum weight of 1000-seed (3.49 g) was obtained from line sowing method and the minimum weight of 1000-seed (3.43 g) was found in broadcasting method.

2.1.6 Seed yield

Aziz (2014) reported that seed yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing techniques. The highest grain yield (3.8 t ha^{-1}) was obtained at SMI technique and the lowest grain yield (2.11 t ha^{-1}) was found at broadcast sowing technique.

Khan *et al.* (2000) found that the maximum grain yield of 1119 kg ha^{-1} was obtained when crop was grown on ridges which were significantly higher than rest of sowing methods. There were no significant differences between furrow and drill sowing methods observed. The lowest yield was obtained when the seed was broadcasted.

Sarkees (2013) reported that maximum total yield of 1091.9 kg ha^{-1} was obtained when crop was grown by drill-row sowing, which was significantly higher (140.9%) than broadcasting method.

Hossain *et al.* (2013) revealed that sowing method had significant influence on seed yield. The highest seed yield (1.69 t ha^{-1}) was found from line sowing. Whereas, the lowest seed yield (1.46 t ha^{-1}) was exhibited from the broadcasting method.

At Shillongani, broadcast method was found to be more successful. Significantly higher seed yield of toria (*Brassica rapa* var. toria) was harvested in broadcast sowing over other practices. Toria broadcast at dough stage along with 80 kg N ha^{-1} gave the highest yield (AICRP-RM, 2007).

Khan and Muendel (1999) reported that broadcast seeding appeared the worst treatment for seed yield and also resulted with heavy growth of *Avena sativa* (oats) in weed dry weights of 1274 and 1498 g m^{-2} respectively.

2.1.7 Stover yield

Hossain *et al.* (2013) found significant influence on stover yield due to sowing method. The line sowing method produced the highest stover yield (2.85 t ha^{-1}). The lowest stover yield (2.66 t ha^{-1}) was found in broadcasting method.

Aziz (2014) reported that stover yield of mustard and rapeseed plant was significantly affected by different sowing techniques. The highest stover yield was obtained at SMI technique and the lowest stover yield was found at broadcast sowing technique.

2.1.8 Biological yield

Khan *et al.* (2000) studied the result of biological yield as affected by different sowing methods. Maximum biological yield was observed in ridge sowing method (26390 kg ha^{-1}) which was at par to drill sowing method (27900 kg ha^{-1}). The lowest biological yield was found in furrow and broadcast method (25885 and 26065 kg ha^{-1} respectively).

Aziz (2014) reported that biological yield of mustard and rapeseed plant was significantly affected by different sowing technique. The highest biological yield was obtained at SMI technique and the lowest biological yield was found at broadcast sowing technique.

2.2 Effect of variety on different crop characters

2.2.1 Plant height

Varietal performance of a crop depends on its genetic makeup. Ali *et al.* (1998) observed significant variation on plant height of different varieties of rape and mustard.

Ahmed *et al*. (1999) stated that the tallest plant (102.56 cm) was recorded on the variety Daulat. No significant difference was observed on plant height between Dhali and Nap-8509.

Jahan and Zakaria (1997) observed that Dhali gave the tallest plant height (142.5 cm) which was similar with Sonali (139.5) and Japrai (138.6cm). The shortest plant height was observed in Tori-7 (90.97 cm) which was significantly shorter than other varieties.

Aziz (2014) conducted an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the Rabi period in 2013-14. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha -2. Sowing technique treatments were Broadcasting, Line Sowing, Raised Bed and System of Mustard Intensification (SMI). Result showed that plant height of mustard and rapeseed were significantly influenced by different varieties throughout the growing period.

An experiment was conducted at the Regional Agricultural Research Station (RARS), Jessore (AEZ11, High Ganges River Floodplain) during 2003-2006 to evaluate the response of different varieties of mustard to boron application. Boron application was made at 0 and 1 kg ha^{-1}. The varieties chosen from *B. campestris* were BARI Sarisha -6, BARI Sarisha -9 and BARI Sarisha -12. The *B. napus* varieties were BARI Sarisha -7, BARI Sarisha -8 and BARI Sarisha -13. Varieties BARI Sarisha -10 and BARI Sarisha -11 were from the *B. juncea* group. The seed yield was positively and significantly correlated with the yield contributing characters viz. pods $plant^{-1}$, seeds pod^{-1}, and 1000-seed weight, but not with plant height and pod length (Hossain *et al.*, 2012).

Hossain *et al.* (1996) observed that the highest plant was in Narenda (175 cm), which was identical with AGA-95-21 (166 cm). The shortest variety was Tori-7.

Mondal *et al.* (1992) reported 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 was significantly taller than JS-72 and Tori-7.

2.2.2 Primary branches plant^{-1}

The yield contributing characters such as number of primary, secondary and tertiary branches are important determinant of the seed yield of rapeseed and mustard. Varieties among *Brassica* species showed a marked variation in the arrangement of the branches and their number per plant.

Aziz (2014) reported that numbers of primary branches were significantly affected by variety throughout the life cycle. At harvest, maximum numbers of primary branches were recorded at BARI Sarisha-15 which was statistically similar with SAU Sarisha -2 and the minimum numbers of primary branches were recorded at BARI Sarisha-13 which was statistically similar with BARI Sarisha-11.

Sam-Daliri *et al.* (2011) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** factorial experiment in randomized complete block design in three replicates in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including new lines (crossed two varieties of H19, oliath), Zarfam and Pahnab-e-joybar (Local varieties). The effect of planting distance has a significant effect on the number of branches and pods on main stem ($P<0.01$). In the mean interaction between varieties and sowing was found that the highest percentage of oil in this study Zarfam varieties with an average 41.8 % and 30 cm row spacing.

Ali and Rahman (1986) found significant variation in plant height of different varieties of rapes and mustard.

BARI (2000) found that the number of primary branches/plant was higher (4.02) in the variety SS-75 and lower (2.1) in the variety BARI Sharisa-5 under poor management under medium management, the higher number of primary branches plant^{-1} was found in BARI Sharisha-6 (5.5) and lower in BARI Sharisa-8 under higher management. The highest number of primary branches plant^{-1} was with BARI Sharisha-6 (5.9) and lower (3.0) with Nap-248.

Hossain *et al.* (1996) stated that the varieties were statistically different with respect to number of primary branches. The maximum number of primary branches was recorded in the Hyola-401(5.0) and the minimum number was recorded in Semu-249/84.

Khanlou and Sharghi (2015) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety Simple has significant on the number of branches in plants ($P<0.05$).

Jahan and Zakaria (1997) found that the local varieties Tori-7 and Sampad produced the highest number of primary branches plant^{-1} (4.07) which was at par with BLN-900. The minimum number of primary branches plant^{-1} (2.90) was found in Jatarai which was identical to those found in Hhole-401 and BARI sarisha-8 varieties.

Mamun *et al.* (2014) conducted a field experiment to evaluate the effect of variety and different plant densities on growth and yield of rapeseed mustard during Rabi 2011-12 under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-

15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities. BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15.

Sultana *et al*. (2009) carried out an experiment to evaluate the effect of irrigation and variety on yield and yield attributes of rapeseed. SAU Sarisha -1 produced the highest number of branches per plant (5.43) which was significantly higher than Kollania (4.80) and Improved Tori-7 (4.40).

Mondal and Islam (1993) reported that variety had significant effect on plant height. They found the highest plant height (134.4 cm) on the variety J-5004, which was identical with SS-75 and was significantly taller than JS-72 and Tori-7.

2.2.3 Number of siliquae plant^{-1}

Aziz (2014) reported that number of siliquae plant^{-1} was significantly affected by variety. Maximum number of siliquae plant^{-1} was recorded at BARI Sarisha-11 and minimum number of siliquae plant^{-1} was observed at BARI Sarisha-15.

Sultana *et al.* (2009) showed that Kollania produced the highest number of siliquae plant^{-1} (94.96) which was significantly higher than SAU Sarisha -1 and Improved Tori -7 (89.97 and 78.28, respectively.)

Khanlou and Sharghi (2015) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety has significant on the number of pods per branch, number of pods on main stem, seed oil Percent, pod number per plant.

Mamun *et al.* (2014) conducted an experiment and found that maximum siliqua plant^{-1} (126.90) was obtained in BARI Sarisha-13 which was more than three times higher than the minimum number of siliqua plant^{-1} (50.10) produced by SAU Sarisha-3.

Hossain *et al.* (2012) found that BARI Sarisha -11 produced the highest number of pods plant^{-1} followed by BARI Sarisha -10. BARI Sarisha -7, BARI Sarisha -8, and BARI Sarisha -13 produced statistically similar number of pods plant^{-1} in the control plots.

Jahan and Zakaria (1997) reported that in case of number of siliquae plant^{-1}, the highest number was recorded in BLN-900 (130-9) which was identical with that observed in Dhali (126.3). Tori-7 had the lowest (46.3) number of siliquae plant^{1}.

Mondal *et al.* (1992) stated that maximum number of siliquae plant^{-1} was in the variety J-5004 which was identical with the variety Tori-7. The lowest number of siliquae plant^{-1} (45.9) was found in the variety SS-75.

2.2.4 Siliqua length

Aziz (2014) reported that siliqua length of mustard and rapeseed plant was significantly affected by variety. The biggest siliqua length was recorded at BARI Sarisha-13 and the smallest siliqua length was observed at BARI Sarisha-11.

Jahan and Zakaria (1997) reported that the shortest pod 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 pod (8.07 cm) was found in BLN-900and Hyola-401

Masood *et al.* (1999) found significant genetic variation in pod length among seven genotypes of *B. campestris* and a cultivar of *B. napus*. Similar result for pod length was observed by Lebowitz (1989) and Olsson (1990).

Akhter (2005) reported that the variety BARI sarisha-8 showed longest siliqua length (7.30 cm) with harvesting at 100 days which was similar with the same variety harvested at 90 days (7.13 cm).

Hossain *et al*. (1996) stated that the varieties of rapeseed differed significantly in respect of siliqua length. The longer siliqua was found in hybrid BGN-900 (7.75 cm) that was similar to Hyole-101, Sampad, Dhali and Hyola-51.

2.2.5 Number of seeds siliqua^{-1}

Sam-Daliri *et al.* (2011) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** factorial experiment in randomized complete block design in three replicates in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including new lines (crossed two varieties of H19, oliath), Zarfam and Pahnab-e-joybar (Local varieties). The results showed that Simple varieties has significant on the number of branches in plants ($P<0.05$), number of pods per branch, number of pods on main stem and seed oil Percent ($P<0.01$).

Akhter (2005) reported that variations in number of seeds siliqua^{-1} among the varieties were found statistically significant. The highest number of seeds siliqua^{-1} (23.80) was found from BARI sarisha-8 and the lowest was recorded as 10.78 from BARI Sarisha-11 .The variety BARI Sarisha-10 and BARI Sarisha-7 showed the number of seeds siliqua^{-1} as 12.64 and 22.03, respectively.

Mamun *et al.* (2014) found that the number of seeds siliqua^{-1} contributes considerably towards the final seed yield. The number of seeds siliqua^{-1} differed significantly among varieties but not for plant densities, while the interaction effect of variety × plant density was significant. Highest number of seeds siliqua^{-1} (25.36) was obtained from BARI Sarisha-13 and BARI Sarisha-16 obtained the lowest (14.95).

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

2.2.6 1000-seed weight

Al-Barzinjy *et al.* (1999) investigated yield/density relationships of two spring cultivars of oilseed rape under five different plant densities. Densities ranged from 20 to 130 plants m^{-2}. Three response variables, number of pods per plant, seed weight per plant and dry matter per plant, were studied using different regression models to examine their relationship with density. Transformations were used to improve the fit of the models. Pods per plant, seed weight and dry matter per plant decreased as plant density increased. Seed weight and dry matter m^{-2} responded similarly to varying plant density for the two cultivars.

Mondal and Wahab (2001) found that weight of 1000 seeds of rapeseed and mustard varied from variety to variety and species to species. They found thousand seed weight 2.50-2.65 g in case of improved Tori-7 (*B. campestris*) and 1.50-1.80 g in case of Rai 5 (*B. napus*).

Atlassi *et al.* (2008) conducted an experiment in order to investigate the effect of planting pattern on morphology, yield and yield components of canola. The experiment was laid on split-plot design. The treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and

RGS 003) as sub-plots. The effect of planting pattern on number of pods per plant and 1000-seed weight was significant.

Sher *et al*. (2001) studied on the effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.). They found that number of pods plant^{-1}, 1000-seed weight and seed oil content were significantly affected both by varying planting pattern and inter plant spacing.

Yeasmin (2013) studied that the significantly highest yield was showed by BARI Sarisha-9 (1448.20 kg ha^{-1}). The significantly lowest yield was with BARI Sharisa -15 (1270.10 kg ha^{-1})

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

Akhter (2005) reported that the highest weight of 1000 seeds (3.8 g) was recorded from BARI Sarisha-7 with harvesting the crop at 90 days. The lowest 1000 seed weight (2.63 g) was recorded from BARI Sarisha-10 with harvesting at 100 days, which was similar with the same variety harvesting at 90 and 110 days.

2.2.7 Seed yield

Aziz (2014) conducted an experiment to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Sowing technique treatments were Broadcasting, Line Sowing, Raised Bed and System of Mustard Intensification (SMI). Result indicated that grain yield of rapeseed plant was significantly affected by different variety. The highest grain yield (3.74 t ha^{-1}) was obtained at BARI Sarisha-11 and the lowest grain yield (2.54 t ha^{-1}) was found at BARI Sarisha-15.

Velicka *et al.* (2007) determined optimal density of spring rape (*Brassica napus* L.) crop stand by plant photosynthetic characteristics at the beginning of flowering. As crop density increased from 100 to 350 plants/m^2, leaf surface index (LSI) of the crop was found to increase by 18.2–80.2%, and LSI decreased by 38.8–67.3% as compared with the sparsest crop (50–100 plants/m^2). LSI depended on the rate of incident PAR reaching 0.5 and 0.25 heights of the crop stand and to the soil surface. When crop density increased from 100 to 350 plants/m^2, the photosynthetic potential (PP) of the crop increased 1.8 times as compared with the sparsest crop. PP of the densest rape crop stand was 3 times lower than in the sparsest crop. When the crop density increased from 100 to 250 plants/m^2, the daily increment in biomass calculated per leaf surface unit increased by 27.0% as compared with the sparsest crop and depended on LSI. When leaf area decreased, the daily increment in biomass calculated per leaf surface unit declined; in the densest stand, this characteristic was by 58.3% lower than in the sparsest crop. Rape productivity at the flowering stage depended on the crop density, LSI of plants, rate of PAR reaching 0.5 and 0.25 heights of the crop stand and to the soil surface, PP, and the daily increment in biomass calculated per leaf surface unit. Crop productivity at the flowering stage and the rape seed yield were associated by a significant parabolic relationship. When crop density increased from 100 to 350 plants/m^2, seed yield per plant considerably decreased (by 33.1–78.5%) as compared with the sparsest crop. The greatest influence on seed yield per plant was exerted by LSI and the daily increment in biomass calculated per leaf surface unit. When crop density increased to 250–300 plants/m^2, the seed yield considerably rose (by 28.6–58.8%) as compared with the sparsest crop; when this index reached 300–350 plants/m^2, the seed yield decreased because plant growth was suppressed, with the productivity reduced. The results thus obtained suggest that the photometric characteristics of spring rape were at optimum at crop density of 100–250 plants/m^2. The agro climatic conditions of Lithuania ensure potential for rapid accumulation of total biomass and high seed yield.

Rahman (2002) stated that yield variation existed among the varieties whereas the highest yield was observed in BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha-11 (2.00-2.50 t ha^{-1}) and the lowest yield in variety Tori-7 (0.95-1.10 t ha^{-1}).

Islam and Mahfuza (2012) conducted an experiment at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2010-2011. BARI Sarisha-11 produced the highest seed yield (1472 kg ha^{-1}) while BARI Sarisha-14 the lowest (1252 kg ha^{-1}). The highest mean seed yield was recorded at maturity stage (1480 kg ha^{-1}) and decreased towards green siliqua stage.

Ozer (2003) initiated a study to investigate the effects of spacing between rows and spacing within rows on the yield and agronomic characteristics of two genotypes of spring rapeseed (Tower and Lirawell) in Erzurum, eastern Anatolia, during 1994 and 1995. The effects of spacing between or within rows on the yield and yield components of Tower and Lirawell, two cultivars of *Brassica napus* L., were studied for 2 years in Erzurum, Turkey. Rows were spaced at 15, 30 and 45 cm. Spacing within rows were 5, 10 and 15 cm. The results of this study suggested that seed yield was significantly affected by spacing between rows but not by spacing within rows, and that rape yields were higher at the narrow (15 cm) row spacing compared to the middle (30 cm) and wider (45 cm) spacing.

Mamun *et al.* (2014) conducted an experiment and they indicated the result that variety, plant density and their interaction had significant effect on seed yield. Means comparison showed that the most (1.35 t ha^{-1}) and the least seed yield (0.92 t ha^{-1}) were belonged to the plots having BARI Sarisha-13 and BARI Sarisha-15, respectively.

Khanlou and Sharghi (2015) carried out an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety**,** in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety has significant on seed yield ($P<0.01$). The effect of planting distance has also a significant effect on grain yield ($P<0.05$) has significant.

Atlassi *et al.* (2008) conducted an experiment in order to investigate the effect of planting pattern on morphology, yield and yield components of canola. The experiment was laid on split-plot design. The treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and RGS 003) as sub-plots. The effect of cultivar on all of yield components was significant. Finally, the seed yield was affected by the planting pattern and cultivar. Planting patterns with narrower row spacing had maximum yield because of more evenly distributed plants and less plant competition on rows.

Sher *et al.* (2001) studied on effects of different planting patterns (30 cm apart single rows, 45 cm apart single rows, 40/20 cm apart paired rows, 60/30 cm apart paired rows) and inter-plant spacings (10, 15 and 20 cm) on growth, seed and oil yield of Raya (*Brassica juncea* L.). They found that varying inter-plant spacing had non-significant effect on seed yield ha^{-1}. While, the inter-active effect of planting pattern and inter-plant spacing was only found to be significant on number of plants m-2, seed yield (t ha^{-1}) and seed oil content (%).

Mondal *et al*. (1995) reported that after continuous efforts of plant breeders of Oilseed Research Centre, BARI had developed several short duration genotypes of *B. napus* with high yield potential. The genotype, Nap-3 was one of these genotypes (Biswas and Zaman, 1990).

Mendham *et al*. (1990) showed that seed yield was variable due to varietal difference in species of *B. napus*. Similar findings were noticed by Chay and Thurling (1989), and Sharaan and Gowad (1986).

Afroz *et al.* (2011) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from November 2007 to March 2008 to study the effect of sowing date and seed rate on the yield and yield components of two mustard varieties. The highest seed yield (1.53 t ha-1) was recorded in 10 November sowing and the lowest one was achieved in 30 November sowing. Seed rate had also significant effect on plant height, branches $plant^{-1}$, pods $plant^{-1}$, effective pods $plant^{-1}$, pod length, no. of seeds pod^{-1} and seed yield.

2.2.8 Stover yield

Aziz, K. M. T. (2014) reported that stover yield of mustard and rapeseed plant was significantly affected by different variety. The highest stover yield (6.95 t ha^{-1}) was obtained at BARI Sarisha-13 and the lowest stover yield (3.77 t ha^{-1}) was found at BARI Sarisha-15.

Hossain *et al.* (2012) reported that BARI Sarisha-8 (*Brassica napus*) had the maximum response to B application. On the other hand, BARI Sarisha-11 (*Brassica juncea*) showed the minimum response. The mean yields of *B. campestris* varieties were 2224-2702kg ha^{-1}, *B. napus* varieties were 2850-3199 kg ha^{-1}, and yields of *B. juncea* varieties were 3080-3528 kg ha^{-1} for the B control plots.

Sultana *et al.* (2009) studied that stover yield for different varieties of rapeseed under study differed significantly. Kollania produced higher stover yield (2159.0 kg ha^{-1}) which was statistically at par with SAU Sarisha-1 (2156.0 kg ha^{-1}) and higher than Improved Tori -7 (1681.0 kg ha^{-1}).

Akhter (2005) observed that the highest straw yield (3.68 t ha^{-1}) was found from BARI Sarisha-7 that was similar (3.42 t ha^{-1}) with the variety BARI Sarisha-11. The lowest straw yield (3.08 t ha^{-1}) was recorded from BARI Sarisha-10 that was similar to the variety BARI Sarisha-8 (3.09 t ha^{-1}).

2.2.9 Harvest index

Mamun *et al.* (2014) conducted an experiment and data revealed that harvest index showed significant difference due to variation in varieties, plant densities and their interactions. BARI Sarisha-13 produced the highest harvest index of 37.65%, which was statistically different from all other test varieties and the lowest (33.73%) was incurred from BARI Sarisha-15.

Akhter (2005) observed that variations in harvest index among the varieties were found statistically significant. The highest harvest index (31.73%) was recorded from BARI Sarisha-10 that was similar (30.18%) with the variety BARI Sarisha-8. The lowest harvest index (27.79%) was recorded from BARI Sarisha-7 that was also similar to BARI Sarisha-11 (28.90%) and BARI Sarisha-8.

Sultana *et al.* (2009) showed that SAU Sarisha -1 exhibited the highest value (37.10%) of harvest index and Improved Tori -7 showed the lowest harvest index (37.34%). SAU Sarisha-1 and Kollania showed statistically similar values of harvest index.

2.3 Interaction of planting techniques and variety on different crop characters

Khan and Agarwal (1985) conducted an experiment and found that ridge and furrow sowing was superior to conventional flat sowing for growth parameters and yield of *Brassica juncea*.

Shekhwat *et al*. (2012) conducted an experiment at Bhubaneshwar, line sowing of yellow sarson after land preparation produced maximum seed yield (870 kg ha^{-1}) with 40kg N ha^{-1}. Paira or utera is a method of cropping in which the sowing of next crop is done in the standing previous crop without any tillage operation. Mustard sowing under paira/utera in the rice field has shown its edge over line sowing and broadcasting (Sowing of seeds by broad casting the seeds in the field) in eastern parts of India. At Dholi, mustard sown with paira cropping recorded significantly higher seed yield (1212 kg ha^{-1}) over line sown and broadcast method, while these 2 methods yielded at par. At Bhubaneswar, significantly higher yield (887 kg ha^{-1}) of mustard was recorded when sown as utera crop over line and broadcast sown crop (AICRP-RM, 1999).