GROWTH AND YIELD PERFORMANCE OF MUSTARD AND RAPESEED VARIETIES AS INFLUENCED BY DIFFERENT SOWING TECHNIQUES

A THESIS

BY

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD PERFORMANCE OF MUSTARD AND RAPESEED VARIETIES AS INFLUENCED BY DIFFERENT SOWING TECHNIQUES"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***KAZI MD. TAREQ AZIZ,*** ***Registration. No. 08-03004*** *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: 28/02/2016
Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)
Supervisor

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GROWTH AND YIELD PERFORMANCE OF MUSTARD AND RAPESEED VARIETIES AS INFLUENCED BY DIFFERENT SOWING TECHNIQUES

ABSTRACT

An experiment was done at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from Robi, 2013-14 to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There were 16 treatments (4 variety × 4 sowing technique). The variety treatments were V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2. Sowing technique treatments were S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= System of Mustard Intensification (SMI). Results showed that highest plant height (143.58 cm) was achieved at the combination of BARI Sarisha-11 and raised bed technique. Highest dry matter (39.93 g) was produced by the combination of BARI Sarisha-11 and SMI technique. Highest number of siliquae plant^{-1} (1179.67) was achieved at the BARI Sarisha-11 and SMI technique. Maximum siliqua length (8.99) and seeds siliqua^{-1} (30.33) was achieved with the combination of BARI Sarisha-13 and SMI technique. Highest grain yield (4.75 t ha^{-1}) and biological yield (16.06 t ha^{-1}) were obtained by the combination of BARI Sarisha-11 and SMI technique. Maximum harvest index (36.45%) was obtained at the combination of BARI Sarisha-15 and SMI technique. Highest weight of 1000-seed (4.26 g) was found at the combination of BARI Sarisha-11 and raised bed technique. Highest oil percentage (41.73%) was obtained from the plots with the combination of BARI Sarisha-15 and line sowing technique.

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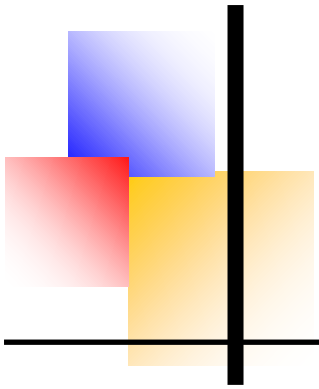
LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BARI	Bangladesh Agricultural Research Research Institute
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
et al.	And others
e.g.	*exempli gratia* (L), for example
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram (s)
HI	Harvest Index
i.e.	*id est* (L), that is
IRRI	International Rice Research Institute
kg	Kilogram (s)
kg ha^{-1}	kg per hectare
LSD	Least Significant Difference
m^2	Meter squares
MS	Master of Science
No.	Number
NS	Non significant
SAU	Sher-e-Bangla Agricultural University
SMI	System of mustard intensification
SRDI	Soil Resource and Development Institute
var.	Variety
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
°C	Degree Centigrade
%	Percentage



Chapter 1

Introduction

INTRODUCTION

Mustard and rapeseed (*Brassica spp*.) is an important oil seed crop in Bangladesh. It is the second most important edible oil in the world. About 13.2% of the annual edible oil comes from this crop (FAO, 2005). *Brassica* oil crop is the most important group that supplies major edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country (AIS, 2010). Bangladesh is running a short of 60-75% of the demand of edible oil (Rahman, 2002). In Bangladesh these crops cover less than 3% of the total cultivated land. Total area and annual production of mustard and rapeseed crops are 2.42 lac hectare and 2.22 lac metric tons respectively (BBS, 2010). The average grain yield of mustard is only 0.92 t ha^{-1} (BBS, 2010), which is very low as compared to those of mustard growing countries in the world. The major reasons for such poor yield is mainly due to use of indigenous variety and poor management as practiced at farmer's field. Therefore, attempts must be made to increase the per unit production by using HYV and by adopting better management practices such as appropriate sowing method and other cultural operations.

Generally two main methods of sowing are followed in Bangladesh for mustard cultivation. They are line sowing and broadcasting. In line sowing, seeds are sown in separate line by maintaining plant to plant distance. Line sowing can ensure optimum plant population per unit area thereby increasing the yield of mustard. In broadcasting, seeds are sown haphazardly. As a result, it is difficult to maintain desired plant population per unit area which is important to obtain higher yield. A suitable technique of sowing of mustard is to be found out for higher yield.

Production of any crops is influenced by several factors, of which sowing method is very important. Deep tillage improves the physical, chemical and biological properties of soil. 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. Highest plant height found in ridge

planting method. Abdel (1973) reported that planting radish in ridge method resulted in greater weight of individual root as well as total yield compared to that of flat method.

Of the agronomic practices, sowing technique is of considerable importance as proper adjustment of plants in the field not only ensures optimum plant population, but also enables the plants to utilize the land and other input resources more efficiently and resolutely towards growth and development (Ali *et al.*, 1998). The number of siliqua plant^{-1} is an important yield contributing character of oil seed rape. Several studies suggest that a higher number of siliqua plant^{-1} has the greatest effect on seed yield on rape and mustard (Mendham and Scott, 1975; Thurling, 1974; Rahman *et al.*, 1988). According to Hossain *et al.* (2013) sowing method had significant influence on seed yield. On his study, the highest seed yield was found from line sowing. Whereas, the lowest seed yield was exhibited from the broadcasting method. Khan *et al.* (2000) found that the maximum grain yield of 1.12 t ha^{-1} was obtained when crop was grown on ridges which was significantly higher than rest of sowing methods. There were no significant differences between furrow and drill sowing methods. The lowest yield was obtained when the seed was broad casted.

Brassica (genus of mustard) has three species that produce edible oil, they are *B. napus, B. campestris* and *B. juncea*. Of these, *B. napus* and *B. campestris* are of the greatest importance in the world's oil seed trade. In this subcontinent, *B. juncea* is also an important oil seed crop. Until recently, mustard varieties such as Tori-7, Sampad (both *Brassica campestris*) and Doulat (*Brassica juncea*) were mainly grown in this country. Recently several varieties of high yielding potential characteristics has been developed by BARI.

Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (1987) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. Singh *et al*. (1999) found oil content variation due to different varieties and different method. They estimated oil content of

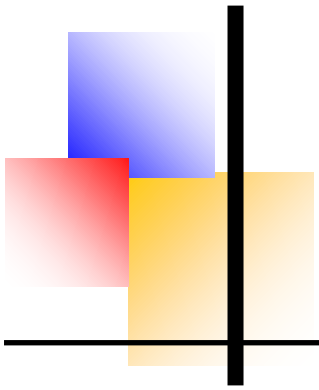
different varieties from different species and highest oil content (44.3%) from variety PYS841 (*B. campestries*) and lowest (40.8%) from Kranti (*B. juncea*) by Soxhlet method. In bold perculation method, they found highest oil content (44%) in the variety PYS841 (*B. campestries*) and lowest (40%) in PBC221 (*B. carinata*). Jahan and Zakaria (1997) observed the performance of seven local and three early varieties of rapeseed, mustard and canola. The varieties differed with respect to oil content of seeds. In general, local varieties had higher oil content compared to exotic varieties. The higher oil content of 41.85% was found in Sonali sarisha which was identical to that found in Sampad. The lowest oil content of 30.90% was found in BLN-900.

There are great scopes of increasing of mustard production by increasing cultivated area with choosing proper variety and sowing technique. The productivity and quality of mustard and rapeseeds can be improved by proper adjustment of variety and sowing technique. In spite of all favourable condition and better scope of mustard production, Bangladesh is running with acute shortage of edible oil since long time. As a result, a huge amount of foreign exchange has been spent every year for importing edible oil.

The above discussion suggests that in order to improve productivity of mustard, high yielding variety with appropriate sowing technique is needed to be identified.

Therefore, keeping the above points in view, the present work was undertaken to

I. evaluate the effect of variety on the growth & yield of mustard.
II. identify the best effect of sowing technique on the growth & yield of mustard.
III. find out the best combination effects of variety and sowing technique on the growth and yield of mustard.



Chapter 2
Review of literature

REVIEW OF LITERATURE

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

2.1 Effect of sowing technique on different crop characters

2.1.1 Plant Height

Plant height is a varietal character of rapeseed but environmental conditions and cultural operations may affect it. Planting technique has direct effect on plant height.

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. Highest plant height found in ridge planting 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. The tallest plants were produced in the drill-row sown plots. While the shortest plants were produced with broadcasting sowing, this result is in agreement with Khan *et al.* (2000) that the plants of broadcasting sowing are shorter than plants of drill sowing method.

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 and the shortest one was found at broadcast method.

2.1.2 Number of primary branches plant^{-1}

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}. The lowest number of total branches plant^{-1} 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. Growth, seed and oil yields of rapeseed (*Brassica napus* L.) cv. Pactol in Erbil/Kurdistan Region. Here he found no significant differences in case of no. of primary branches of plant due to different sowing methods.

According to Aiken *et al.* (2015), 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}

The number of siliquae plant^{-1} 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 and Scott, 1975; 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}, siliquae 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 plant^{-1} play a major role in yield which were significantly affected by sowing methods. Maximum siliqua plant^{-1} 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 siliques than those of broadcasting sowing.

2.1.4 Length of siliqua

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

2.1.5 Thousand Seed Weight

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

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

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

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

Khan *et al.* (2000) found that the maximum grain yield of 1.12 t ha^{-1} was obtained when crop was grown on ridges which was significantly higher than rest of sowing methods. There were no significant differences between furrow and drill sowing methods. The lowest yield was obtained when the seed was broad casted.

Sarkees (2013) reported that maximum total yield of 1.09 t ha^{-1} was obtained when crop was grown by drill-row sowing, which was significantly higher than broadcasting of 140.9%.

According to Hossain *et al.* (2013) sowing method had significant influence on seed yield. The highest seed yield was found from line sowing. Whereas, the lowest seed yield 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 of toria over other practices. Toria broadcast at dough stage along with 80 kg N ha^{-1} gave the highest yield (AICRP-RM, 2006).

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

Hossain *et al.* (2013) was found significant influence on stover yield due to sowing method. The line sowing method produced the highest stover yield. The lowest stover yield was found in broadcasting method.

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

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 which was at par to drill sowing method. The lowest biological yield was found in furrow and broadcast method.

2.2 Effects of variety

Varietal performance of a crop depends on its genetic make-up. There are several species of Oleiferous *Brassica* out of which *B. campestries*, *B. juncea*, *B. napus* and *B. carinata*, every one of which differs from one another with respect to growth, yield, yield components and oil contents.

2.2.1 Plant height

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

Ali and Rahman (1988) found significant variation on plant height of different varieties of rapes and mustard.

Jahan *et al*. (1997) observed that Dhali was the tallest plant which was similar with Sonali and Jatarai. The shortest plant was observed in Tori-7, which was significantly shorter than other varieties. The exotic varieties were of intermediate types of plants.

Mondal *et al*. (1992) observed significant variation in plant among different genotype of *Brassica*. They found the highest plant height in the variety J-5004, which was identical with SS-75 and significantly taller than JS-72 and Tori-7.

2.2.2 Number of branches plant^{-1}

It was stated that under poor management condition, number of branches plant^{-1} was higher in the variety SS-75 and lower in the variety BARI Sarisha-8. Under medium management, best performance was done by Dhali and worst performance by BARI Sarisha-8. Under higher management, highest number of branches per plant showed by Dhali and lowest by Nap-248 (BARI, 2000).

Jahan and Zakaria (1997) reported that the local varieties, Tori and Sampad produced the highest number of primary branches plant^{-1}. The minimum number of primary branches plant^{-1} was found in Jatarai that was identical with BARI Sarisha-8.

Hossain *et al.* (1996) found that the rapeseed and mustard varieties were statistically different with respect to the number of branches plant^{-1}. The maximum number of primary branches was recorded in the Hyola-401 (5.0) and the minimum number was recorded in Semu-249/84.

Mondal *et al*. (1992) reported the highest number of primary branches in rapeseed and mustard; there were no significant differences among the varieties for primary number of branches.

2.2.3 Number of siliquae plant^{-1}

Jahan and Zakaria (1997) reported that in case of number of siliquae plant^{-1}, the highest number was recorded in BLN-900 (130.9) that was identical with that observed in Dhali (126.3). Tori-7 had the lowest (46.3) number of siliquae plant^{-1}.
Hossain *et al.* (1996) stated that there was marked statistical variation in number of siliquae plant^{-1}. BLN-900 had the highest number of siliquae plant^{-1} (187.3) and the lowest in Semu-249/84 (150.4).

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

Shamsuddin and Rahman (1977) reported that the number of siliquae plant^{-1} was significantly varied for rapeseed and mustard varieties and the highest number of siliquae was found from mustard varieties.

2.2.4 Siliqua length

BARI (1999) reported that rapeseed and mustard varieties showed significant variations in respect of siliquae length. Highest siliquae length was found from Daulat and lowest from Dhali.

Hossain et *al*. (1996) reported that the varieties differed significantly in respect of siliqua length. The longer siliqua length was found in the hybrid BGN-900 of 7.75 cm which was identical to Hyole-101, Sampad, Dhali and Hyola-51. The shortest siliqua length was found in the hybrid Semu-DNK-89/218, AGH 95-7 and Tori-7.

The longest siliqua (8.07 cm) was found in BLN-900, which was superior to all other varieties. The shortest siliqua length (4.83cm) was obtained in Hyola-401 (Jahan and Zakaria, 1997).

2.2.5 Number of seeds siliqua^{-1}

Jahan and Zakaria (1997) observed that among the entries, Dhali produced the highest number of seeds siliqua^{-1}, which was at statistically similar with Sonali and Jatarai. The lowest number of seeds siliqua^{-1} was found in Tori-7, which was at par with that in Samapad, Hyole-401, BARI Sarisha-7, AGA-95-21 and BARI Sarisha-8.

Hossain *et al.* (1996) reported that there was significant difference among the varieties with respect to number of seeds siliqua^{-1}. The maximum number of seeds siliqua^{-1} was produced in the hybrid BLN-900 and the minimum number was recorded in Tori-7 as well as in Semu-249/84.

Zakaria and Jahan (1996) reported that the variety Sonali sarisha (SS-75) had produced the highest number of seeds per siliqua.

Mondal *et al.* (1992) stated that the highest number of seeds siliqua^{-1} in SS-75 which was significantly different from all other varieties. The lowest number of seeds siliqua^{-1} was found in J-5004.

2.2.6 Weight of 1000 seeds

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. campestries*) and 1.50 to 1.80 g in case of Rai 5 (*B. napus*).

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

Hussain *et al*. (1998) observed significant variation in case of 1000 seed weight as influence by different varieties. They found Hyda-401 had the highest thousand seed weight and the lowest thousand seed weight was recorded in Tori-7.

Zakaria and Jahan (1996) found lower thousand seed weight in Tori-7. BARI (2001) found significant variation in thousand seed weight of among different varieties of mustard and highest weight of thousand seeds was in Jamalpur-1 variety and lowest in BARI Sarisha-10.

2.2.7 Grain 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}).

Mondal *et al*. (1995) reported that after continuous efforts plant breeders of Oilseed Research Centre, BARI have developed several short duration genotypes of *B. napus* with high yield potential.

The genotype, Nap-3 is one of these genotypes (Biswas and Zaman, 1990), which is under active consideration for recommendation as a variety. It is likely to be a good variety for Bangladesh, but it has a problem of high shattering tendency.

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

Malik (1989) observed *B. carinata* produced 49% higher yield than each of *B. juncea* and *B. campestries*.

BARI (2001) showed that seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard.

Monir and Mc Neillly (1987) reported that there was no significant yield difference between cultivars of *Brassica napus.*

Halva *et al.* (1986) stated that seed yield of mustard varied widely among the species but the variation was little within the species. They observed that seven varieties of *Sinapis alba*, eight varieties of *B. juncea* and one variety of *B. nigra* produced an average yield of 2.2, 1.6 and 0.7 t ha^{-1} respectively.

Uddin *et al.* (1987) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species.

Shamsuddin and Rahman (1977) stated that yields were different among the varieties within the species.

Bhagot and Singh (1989) conducted an experiment and found that there was a significant yield differences among the varieties of mustard with the same species.

Jahan and Zakaria (1997) stated that yield variation was present in different rapeseed and mustard varieties.

Appleqvist and Ohlson (1972) reported that *Brassica napus* gives higher yield than the other two species of *B. juncea* and *B. campestries*.

2.2.8 Harvest index

Islam *et al.* (1994) reported that varieties had significant effect on harvest index (%) of mustard. They found highest harvest index in the variety TS-72 which was identical to Daulat and lowest in Sonali sarisha.

Mendham *et al.* (1981) stated that a low harvest index of rapeseed might be due to excessive siliquae and seed losses during flowering.

Thurling (1974) reported that in *Brassica* species, harvest index was strongly influenced by environment and was positively correlated to higher seed yield of *B. campestries* than *B. napus*. However, TDM and harvest index were found to contribute significantly to yield in both species. The value of harvest index ranged from 10 to 23 percent in both the species.

2.2.9 Oil content

BARI (2001) grew 13 varieties/genotypes under three different management level viz. poor, medium, high and found variation of oil content among them. At poor management, higher oil content (41.8%) was found from SS-75 and lowest (39.3%) from Rai-5. Under medium management, highest oil content (43.8%) was found from SS-75 and lowest (40.4%) from Rai-5. Under high management, highest oil content (43.8%) was found from SS 75 and lowest (40.8%) from Daulat.

Singh *et al*. (1999) found oil content variation due to different variety and different method. They estimated oil content of different varieties from different species and highest oil content (44.3%) from variety PYS841 (*B. campestries*) and lowest (40.8%) from Kranti (*B. juncea*) by Soxhlet method. But by Bold perculation method, they found highest oil content (44%) in the variety PYS841 (*B. campestries*) and lowest (40%) in PBC221 (*B. carinata*).

Jahan and Zakaria (1997) observed the performance of seven local and three early varieties of rapeseed, mustard and canola. The varieties differed with respect to oil content of seeds. In general, local varieties had higher oil content compared to exotic varieties. The higher oil content of 41.85% was found in Sonali sarisha which was identical to that found in Sampad. The lowest oil content of 30.90% was found in BLN-900.

Ullah *et al.* (1997) reported that among the rapeseed-mustard varieties, Dhali had the highest value of 44.7% for free oil followed by 44.0% of Agrani, 43.7% of BARI Sarisha-8, 43.5% of Safal and 43.1% of BARI Sarisha-7. Dhali also produced the highest seed yield 2000 kg ha^{-1}, accounting to oil yield of 922 kg ha^{-1}. Except the traditional varieties Tori-7 and Rai-5, all other varieties had higher oil content and always produced higher oil yield. Similar results were observed by Robertson *et al.* (1978) while studying with rapeseed and mustard varieties.

Hossain *et al.* (1996) found highest oil content (%) in the variety Sampad followed by BLN-900 and Dhali by Ghani mill.

Rahman (1977) reported that the content of seed oil in oliferous *Brassica* showed distinct variation due to species and varieties. The ranges of variability present in different species were almost different.

According to Georing *et al*. (1965), the variability in oil content varied from 29.70 to 48.80% in most of the commercially important species of *Brassica* taken from World's collection of USDA. But taking the lowest and highest values, the range became 17.40 to 50.30%. This wide range of variation in oil content within and outside the species might be due to the origin and subsequent adaptation and selection of various types in different regions.

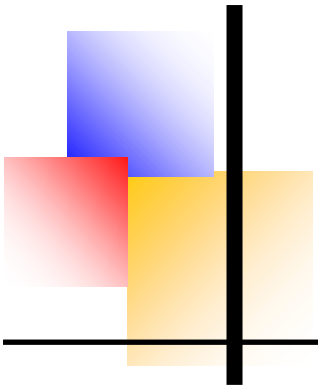
Appelqvist and Ohlson (1972) reported that three species of *Brassica* i.e. *Brassica campeastries, Brassica juncea* and *Brassica napus* are generally cultivated for oil purpose. Among the three species *B. campestries* and *B. juncea* are widely cultivated in Indo-Bangladesh subcontinent; and *B. napus* is mostly grown in European countries and Canada where it gives higher yield than the other two species. Seed coat color of the varieties of *B. napus* is black. Yellow seed coat offers several advantages over the black or even brown coated ones.

Prakash and Chopra (1988) reported that yellow-coated seeds have extra 2-3% oil, better mealing quality with higher energy content due to low crude fibre and absence of discoloring of oil. Although naturally occurring yellow seeded variants are not available in *B. napus* (Prakash and Chopra, 1988), efforts have been taken and still are under way in different countries to produce such lines by gene transfer/ introgression from different closely related species.

2.3 Interaction of sowing 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*.

At Bhubaneshwar, line sowing of yellow sarson after land preparation produced maximum seed yield (870 kg ha^{-1}) with 40 kg N ha^{-1}. Aira 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.



Chapter 3

Materials and Methods

MATERIALS AND METHODS

3.1 Site selection

The research work was carried out at experimental field of Agronomy Department of Sher-e- Bangla Agricultural University, Dhaka during the period from November 2004 to February 2005. The field was located at southeast part of main academic building. The soil of the experimental plot belongs to the Agro ecological zone of the Modhupur Tract (AEZ-28). The details of materials and methods employed during the course of this investigation are presented hereunder.

3.2 Soil

Soil samples from 0-15 cm depths were collected from experimental field. The collected soil sample was mainly sandy to silty and loamy in texture. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physio-chemical properties of the soil are presented in Appendix B.

3.3 Climate

The experimental area is under the subtropical climate. Usually the rainfall was heavy during Kharif season and scanty in Rabi season. The atmospheric temperature increased as the proceeds towards Kharif season. The weather conditions of crop growth period such as monthly rainfall (mm), mean temperature (^{o}c), sunshine hours/day and humidity (%) are presented in Appendix C.

3.4 Planting material

Four released varieties of rapeseed and mustard *(Brassica spp.*) namely BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha 2 were selected for the study. From *Brassica campestris* were BARI Sarisha 15 and SAU Sarisha 2. The *Brassica napus* variety was BARI Sarisha 13. BARI Sarisha 11 was from the *Brassica juncea* group. The seeds of BARI Sarisha-11, BARI Sarisha-13 and BARI Sarisha-15 were collected from the oilseeds Research

centre of BARI, Gazipur and SAU Sarisha 2 were from Genetics & Plant Breeding division, Sher-e-Bangla Agricultural University. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found over 90% for all the varieties.

3.4.1 Brief description of selected varieties

BARI Sarisha-11: This is a composite mustard variety evolved by the BARI. Its grain colour is brownish and round shape. The grain is medium in size.

BARI Sarisha-13: This is a composite rapeseed variety evolved by BARI. Its grain colour is brownish and oval in shape. The grain is large in size.

BARI Sarisha-15: This is a composite rapeseed variety evolved by BARI. Its grain colour is yellow and oval in shape. The grain is small in size.

SAU Sarisha 2: This is a composite rapeseed variety evolved by SAU. Its grain colour is yellow and oval in shape. The grain is small in size.

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubbles and weeds were removed. The first ploughing and the final land preparation were done on October 27 and November 3, 2013, respectively. Whole experimental land was divided into unit plots following the design of experiment. The plots are spaded one day before planting and the basal dose of fertilizers for better incorporation of fertilizers and soil.

3.5.1 Preparation of raised bed

Soils are earthen up by spade from all sides of the raised bed plot and they were placed on the raised bed. For that a good irrigation channel also created. The raised beds were 15 cm higher than that of broadcasting method line sowing method plots.

3.5.2 Preparation of SMI plot

SMI plots were prepared by making ridge and furrow. The fields are prepared according to ridge-and-furrow methods. The plough is run fairly deep while making the furrows. Then, inside the plough furrow, ripened manure and the recommended quantity of fertilizers mixture calculated to each meter-length of the furrow line is added by the workers. This is a kind of precision farming. Then a plank is run lightly along the furrow lines in order to partially cover the fertilizers, but still leaving a line of depression. When this is done, the plough is again run alternatively between the furrow spaces. This is called skip-furrow method. Finally, furrows are cut crosswise across the field at proper distances to form irrigation and drainage channels.

3.5.2.1 Transplanting

20 days old seedlings were uprooted from the polybag with care, without injuring their roots. Then, water was let into the plots from one end, and the seedlings were began to transplanted just like rice seedlings, but only one plant per hill, following the fertilizer line at a distance of 40 cm from plant to plant and 40 cm from ridge to ridge.

3.6 Fertilizer application

The land was fertilized uniformly with following fertilizer dose. One third of the urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining urea was top dressed into two splits at 17 and 27 days after sowing (DAS). Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc oxide and boric acid were used as source of nitrogen, phosphorus, potassium, sulphur, zinc and boron respectively. The rate of N, P_2O_5, K_2O, S, Zn and Boron was 115-82-51-27-7.8-0.05 kg ha^{-1} respectively (BARI, 2002).

3.7 Experimental Materials and Treatment Combinations

3.7.1 Experimental Materials

The experiment was two factorials with four mustard and rapeseed variety and four sowing techniques.

A. Variety:

V_1= BARI Sarisha-11

V_2= BARI Sarisha-13

V_3= BARI Sarisha-15

V_4= SAU Sarisha 2

B. Sowing technique

S_1= Broadcasting

S_2= Line Sowing

S_3= Raised Bed

S_4= System of Mustard Intensification (SMI)

3.7.2 Treatment Combinations

Treatment	Combination of Variety & Sowing technique
T_1	V_1S_1
T_2	V_1S_2
T_3	V_1S_3
T_4	V_1S_4
T_5	V_2S_1
T_6	V_2S_2
T_7	V_2S_3
T_8	V_2S_4
T_9	V_3S_1
T_{10}	V_3S_2
T_{11}	V_3S_3
T_{12}	V_3S_4
T_{13}	V_4S_1
T_{14}	V_4S_2
T_{15}	V_4S_3
T_{16}	V_4S_4

3.7.3 Experimental Design and Layout

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There were 16 treatments (4 Variety × 4 Sowing techniques). The size of unit plot was 3 m x 3 m. The distance between two rows was 30 cm and plant to plant 5 cm in line sowing and raised bed method. The drainage channels were made 15 cm below from the adjacent soil with soil surface.

3.8 Germination test

Germination test was performed before sowing the seeds in the field. Petridishes were used for laboratory test. Three layers of filter paper were placed on petridishes and the filter papers were soft with water. Seeds were distributed at random in four petridishes. Each petridish contained 25 seeds. Data on emergence were collected on percentage basis by using the following formula:

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

3.9 Sowing of seeds in the field

In line sowing and raised bed method, seeds were sown in rows made by hand rake on November 5, 2013. The seeds were placed continuously within the rows at a depth of 2-3 cm from the soil surface. In broadcasting method seeds were broadcasted @6 kg ha^{-1}. In SMI method seeds were grown in polybag. 20 days old seedlings were transplanted in the main plot.

3.10 Intercultural operations

3.10.1 Thinning

Thinning operation was done on November 20, 2013 (15 days after sowing) and November 25, 2013 (20 days after sowing) with maintaining population density.

3.10.2 Irrigation and weeding

Two irrigations were given during the life cycle. The first irrigation was given at 20 DAS (days after sowing) on November 20, 2013 and the second was done at 40 DAS on 15 December, 2013. In total, three irrigations were applied at intervals of every 20 days at pre-flowering, at full bloom, and at pod-formation stages. The crop field was weeded twice, first weeding was done at 16 DAS on November 21, 2013 and second weeding was done at 26 DAS on December 01, 2013. Demarcation boundaries and drainage channels were also kept weed free.

3.10.3 Plant protection

At middle stage of growth, Aphids attacked the crop. To control this pest, Sumithion 50 EC@ 20 ml liter^{-10} water was sprayed twice on December 20, 2013 (45 DAS) and January 5, 2014 (61 DAS).

3.11 Sampling and data collection

The first sampling was done at 30 DAS and it was continued at an interval of fifteen days, viz. 45 DAS, 60 DAS and 75 DAS and at harvest. Three plants were selected and marked at each plot. The height of plants was measured with a scale placed on the ground level to top of the leaves. Number of branches, number of siliquae plant^{-1}, siliqua length, number of seeds siliqua^{-1}, weight of 1000 seeds, sterility percentage were recorded separately. Each time 3 plants were selected from each plot for measuring dry matter weight. Selected plants of each plot were uprooted carefully by a khurpi and washed in running tape water to remove the soil. Then the plants were dried under sun for one day. Then these were transferred into electric oven. After 15 days the dries plants were weighed on an electric balance.

3.12 Harvest and post-harvest operations

Harvesting was done at different times with maturity. First harvesting was done on January 31, 2014 (88 DAS) and last harvesting was done at 3 March, 2014 (118 DAS) The harvest area (1 m^2) was maintained by leaving the border rows from which the grain weight, straw weight and 1000 seed weight were collected after proper drying. The harvest index was later calculated from the data.

3.13 Recording of data

The data on crop characters were recorded at harvest. The yield and yield contributing characters were recorded from the selected plants and from harvest area in each plot.

3.14 Procedure of recording data

3.14.1 Plant height (cm)

The height of pre-selected ten plants from each plot were measured with a meter scale from the ground level to the top of the plants at 30, 45, 60, 75 DAS and at harvest and the mean height was expressed in cm.

3.14.2 Number of branches plant^{-1}

The primary and secondary number of branches were collected from each sample plant and the mean data was recorded.

3.14.3 Number of leaves plant^{-1}

Number of leaves were calculated from each sample plant and the mean data was recorded. W_2-W_1

3.14.4 Crop growth rate (g plant^{-1} day^{-1})

Crop growth rate was calculated by using the following standard formula (Radford, 1967 and Hunt, 1978) as shown below:

$$CGR = \{(W_2 - W_1) \div (T_2 - T_1)\} \text{ g plant}^{-1} \text{ day}^{-1}$$

Where, W_1= Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

3.14.5 Relative growth rate (g g^{-1} day^{-1})

Relative growth rate was calculated by using the following formula (Radford, 1967) as shown below:

$$RGR = \{(LnW_2 - LnW_1) \div (T_2 - T_1)\} \text{ g g}^{-1} \text{ day}^{-1}$$

Where, W_1 = Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

Ln = Natural logarithm

3.14.6 Number of siliquae plant^{-1}

Number of total siliquae of ten plants from each unit plot was noted and the mean number was expressed as per plant basis.

3.14.7 Length of siliqua (cm)

The length of 10 siliquae from each sample was collected randomly and the mean number was expressed as per siliqua basis (cm).

3.14.8 Number of seeds siliqua^{-1}

Number of total seeds of ten randomly sampled siliquae from each plot was noted and the mean number was expressed as per siliqua basis.

3.14.9 Weight of 1000 seeds (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using an electric balance of 0.001 g sensitivity and the mean weight were expressed in gram.

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

Dry weight of seed from harvested area of each plot was taken and then converted to ton hectare^{-1}.

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

Dry weight of stover from harvested area of each plot was taken and then converted to ton hectare^{-1}.

3.14.12 Shell yield (t ha^{-1})

Dry weight of siliqua shell from harvested area of each plot was taken and then converted to ton hectare^{-1}.

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

Biological yield was calculated by summing up the total seed yield, straw yield and sliqua shell yield.

3.14.14 Harvest index

The harvest index was calculated on the ratio of grain yield to biological yield and expressed into percentage. It was calculated by using the following formula:

$$Harvest\ Index\ (\%) = \frac{Grain\ Yield}{Biological\ Yield} \times 100$$

3.14.15 Yield day^{-1}

Yield day^{-1} was calculated by dividing total yield (ton×1000=kg) by total growing period (days).

3.14.16 Oil content of seed

The oil content of seeds was determined by "Soxhlet" method in percentage. This was done in Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701.

Estimation of oils/fats

Reagents & Equipments

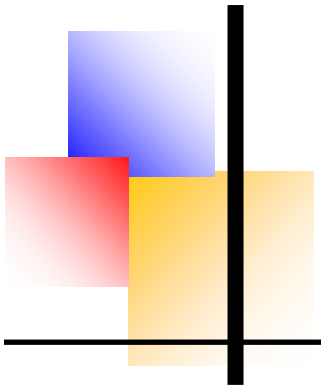
1. Anhydrous ethyl ether
2. Soxhlet, flask and condenser
3. Hot plate

Procedure

Dried mustard flour sample was weighed out into an extraction thimble. Weight of thimble and sample were recorded in laboratory book. The thimble was placed into the soxhlet. 50-100 ml ethyl ether was added to the soxhtet flask then it was connected to holder and condenser. Soxhlet flask was placed on hot plate and distilled at low temperature for 16-20 hours. After extraction it was turned off and allowed to cool. When distillation was ceased, the extraction thimble was removed and allowed to air dry for 30-40 minutes the thimble was weighed out. The loss of weight was cured fat.

3.15 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the CROPSTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by 5% level of significance (Gomez and Gomez, 1984).



Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. To strength in discussion, information in the form of table and figures are added. The whole chapter has been has been categorized and presented under the following headings.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of variety

The plant height (cm) of mustard and rapeseed were significantly influenced by different varieties throughout the growing period (Appendix V and Figure 1). At 30 DAS, SAU Sarisha 2 scored the highest plant height (33.64 cm) which was statistically similar with BARI Sarisha-11 (32 cm) and BARI Sarisha-15 (30.58 cm). The lowest plant height (25.72 cm) was observed at BARI Sarisha-13. On 45 DAS, highest plant height (96.28 cm) was recorded at BARI Sarisha-11which was statistically similar (93.17 cm) with SAU Sarisha 2 and the lowest plant height (69.94 cm) was observed at BARI Sarisha-13. In case of 60 DAS, highest plant height (123.38 cm) was recorded at BARI Sarisha-11 and the lowest plant height (93.23 cm) was observed at BARI Sarisha-13. At 75 DAS and at harvest the highest plant height (133.03 and 132.88 cm) was recorded at BARI Sarisha-11 and the lowest plant height (100.47 and 100.43 cm) was observed at BARI Sarisha-13 which was statistically similar (103.55 and 103.39 cm) with BARI Sarisha-15. Ali and Rahman (1988) and Mondal *et al*. (1992) also found significant variation in plant height of different varieties of rapes and mustard.

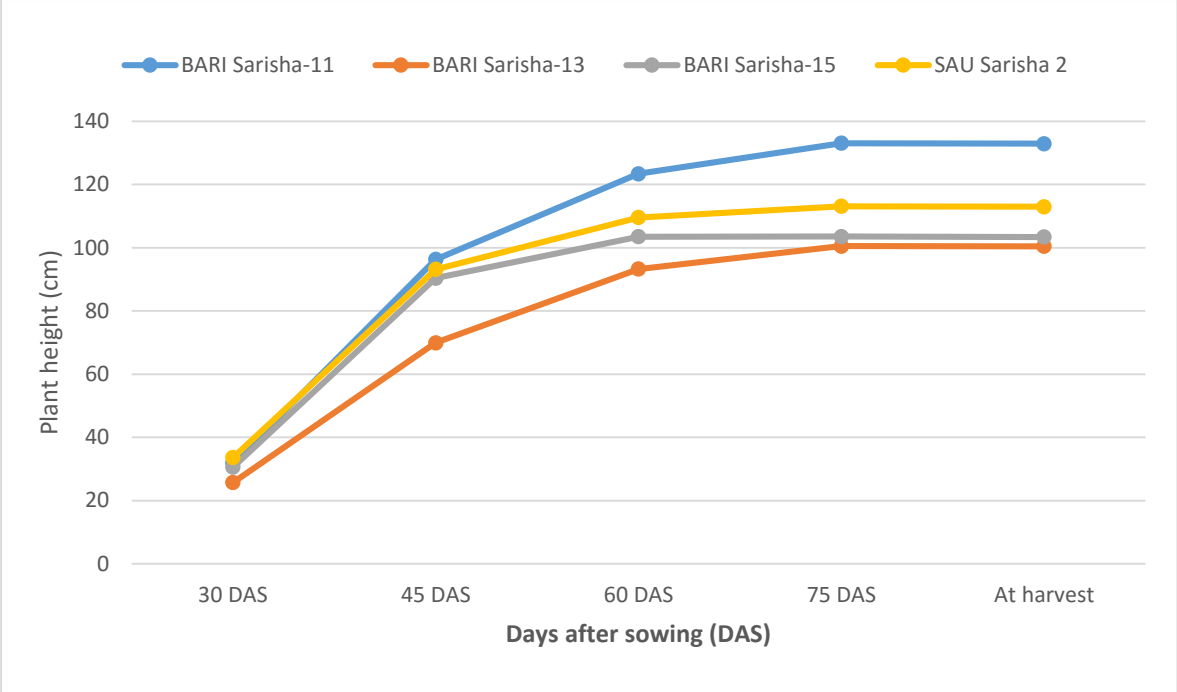


Figure 1. Effect of variety on plant height of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 4.43, 3.57. 8.77, 8.36 and 8.32 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.1.2 Effect of sowing techniques

The plant height (cm) of mustard and rapeseed was significantly varied by different sowing techniques at 30, 45 and 75 DAS but not significantly affected at 60 DAS (Appendix V and Figure 2). At 30 DAS, raised bed scored the highest plant height (34.86 cm) which was statistically similar with broadcasting (33.33 cm) and line sowing **(**30.5 cm). The lowest plant height (18.25 cm) was recorded at system of mustard intensification (SMI). On 45 DAS, highest plant height (99.64 cm) was recorded at raised bed and the lowest plant height (66 cm) was recorded at SMI. In case of 60 DAS, highest plant height (113.49 cm) was recorded at raised bed which was statistically similar with broadcasting technique (109.55 cm) and lowest plant height (103.24 cm) was observed at SMI which was statistically similar with broadcasting (109.55 cm) and line sowing (103.36 cm). At 75 DAS and at harvest the highest plant height (120.88 and 121.31 cm) was recorded at SMI which was statistically similar (115.86 and 115.53 cm) with raised bed technique. On the other hand, the lowest plant height

(105.11 and 104.87 cm) was observed at line sowing which was statistically similar (108.31 and 107.97 cm) with broadcasting. Khan *et al.* (2000) and Sarkees (2013) also found significant variation in plant height of of rapes and mustard at different sowing techniques.

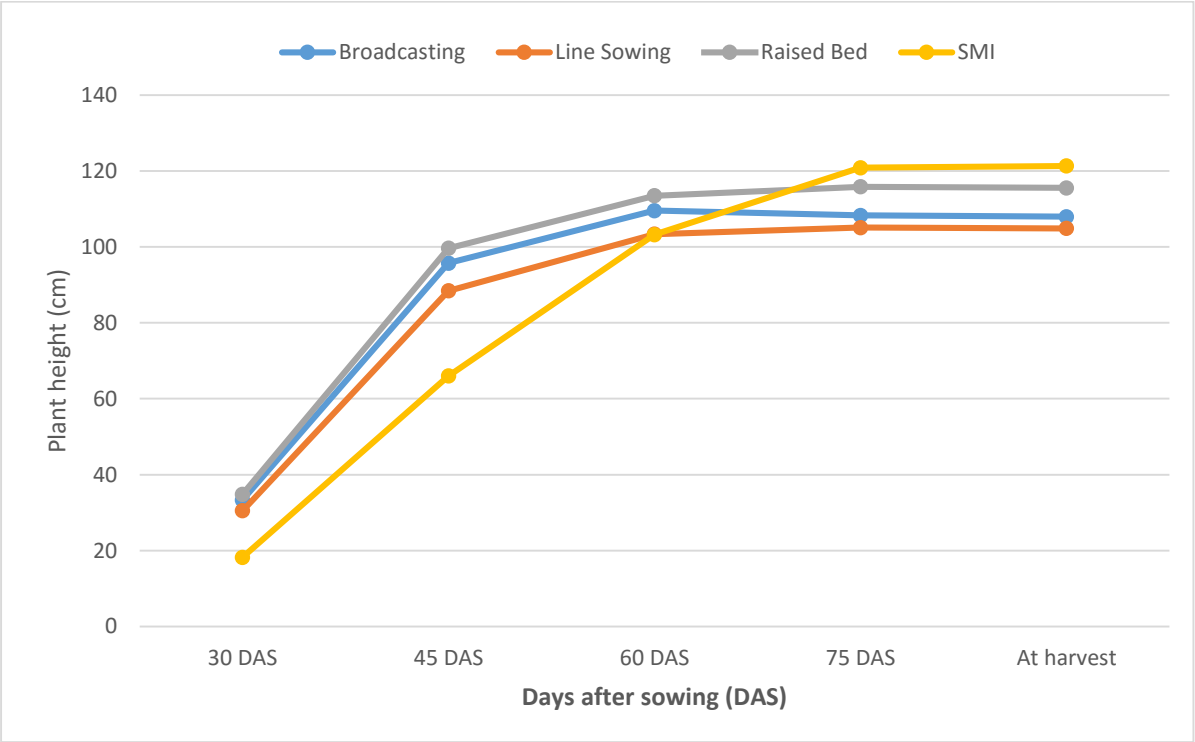


Figure 2. Effect of sowing techniques on plant height of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 4.43, 3.57. 8.77, 8.36 and 8.32 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.1.3. Interaction effect of variety and sowing technique

Plant height (cm) was not significantly affected by the interaction of variety and sowing techniques at 30, 60 and 75 DAS and at harvest but significantly affected at 45 DAS which is shown in Table 1. At 30 DAS, highest plant height (42.11 cm) was recorded from the combination of BARI Sarisha-11 and broadcasting technique (V_1S_1) which was statistically similar with V_1S_3, V_2S_1, V_3S_1, V_3S_3, V_4S_1, V_4S_2 and V_4S_3. On the other hand, the lowest plant height (16.89 cm) was obtained from the combination of BARI Sarisha-11 and SMI technique (V_1S_4) which was statistically similar with V_2S_2, V_2S_4 and V_4S_4. Combination of BARI Sarisha-11 and raised bed technique (V_1S_3) scored the highest plant height (113

cm) at 45 DAS which was statistically similar with V_1S_1. The lowest plant height (46.33 cm) was recorded at the combination of BARI Sarisha-13 and SMI technique (V_2S_4). At 60 DAS, highest plant height (136.26) was obtained from the combination of BARI Sarisha-11 and raised bed technique (V_1S_3) which was statistically similar with V_1S_1 (126.08 cm) and V_1S_2 (120.17 cm). On the other hand, lowest plant height (80.58 cm) was observed from the combination of BARI Sarisha-13 and line sowing technique (V_2S_2) which was statistically similar (95.08 cm) with the combination of BARI Sarisha-13 and SMI technique (V_2S_4). At 75 DAS and at harvest highest plant height (144.11 and 143.58 cm) were obtained from the combination of BARI Sarisha-11 and raised bed technique (V_1S_3) which were similar (141.67 and 142.1 cm) with V_1S_4. On the other hand lowest plant height (87.56 and 87.31 cm) was observed at the combination of BARI Sarisha-13 and line sowing technique (V_2S_2) which were statistically similar to V_2S_1, V_2S_3, V_3S_1, V_3S_2 and V_3S_3.

Table 1. Interaction effect of variety and sowing technique on plant height (cm) at 30, 45, 60, 75 DAS and at harvest

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	42.11 a	107.33 ab	126.08 ab	123.34 b	123.02 b
V_1S_2	31.56 b-e	101.00 b-d	120.17 a-c	123.00 b	122.82 b
V_1S_3	37.45 a-c	113.00 a	136.26 a	144.11 a	143.58 a
V_1S_4	16.89 g	63.78 g	111.02 b-e	141.67 a	142.10 a
V_2S_1	34.11 a-d	82.22 e	98.83 de	96.56 de	96.25 cd
V_2S_2	23.22 e-g	65.11f g	80.58 f	87.56 e	87.31 d
V_2S_3	27.55 d-f	86.11 e	98.42 de	99.45 de	99.21 cd
V_2S_4	18.00 g	46.33 h	95.08 ef	118.33 bc	118.97 b
V_3S_1	36.33 a-d	96.89 d	102.81 c-e	102.33 c-e	102.10 cd
V_3S_2	29.66 c-f	87.55 e	99.81 de	99.22 de	98.80 cd
V_3S_3	35.22 a-d	94.89 d	100.7 de	100.22 de	99.98 cd
V_3S_4	21.11 f	82.22 e	110.68 b-e	112.40 b-d	112.69 bc
V_4S_1	40.78 a	96.44 d	110.49 b-e	111.00 b-d	110.50 bc
V_4S_2	37.55 a-c	100-00 cd	112.87 b-d	110.67 b-d	110.55 bc
V_4S_3	39.22 ab	104.55 bc	118.57 bc	119.66 b	119.35 b
V_4S_4	17.00 g	71.67 f	96.18 d-f	111.11 b-d	111.47 bc
$LSD_{(0.05)}$	8.87	7.13	17.54	16.72	16.64
CV (%)	17.4	4.9	9.8	8.9	8.9

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.2 Leaf Number

4.1.2.1 Effect of variety

Leaf number was not significantly affected by variety at 30 DAS but significantly affected at 45, 60 and 75 DAS and at harvest (Appendix V and Figure 3). At 30 DAS, maximum leaf number (7.36) was recorded at SAU Sarisha 2 and minimum leaf number (6.47) was observed both at BARI Sarisha-13 and BARI Sarisha-15. All the treatments showed statistically similar result.

On 45 DAS maximum leaf number (61.75) was recorded at SAU Sarisha 2 and minimum leaf number (24.53) was observed at BARI Sarisha-13. At 60 DAS, maximum leaf number (96.36) was observed at BARI Sarisha-15 and minimum leaf number (61.42) was observed at BARI Sarisha-13. In case of 75 DAS, maximum leaf number (94.11) was recorded at SAU Sarisha 2. On the other hand, BARI Sarisha-13 scored the minimum leaf number (57.44). At harvest, maximum leaf number (43.92) was recorded at BARI Sarisha-11 and minimum leaf number (16.42) was observed at BARI Sarisha-13.

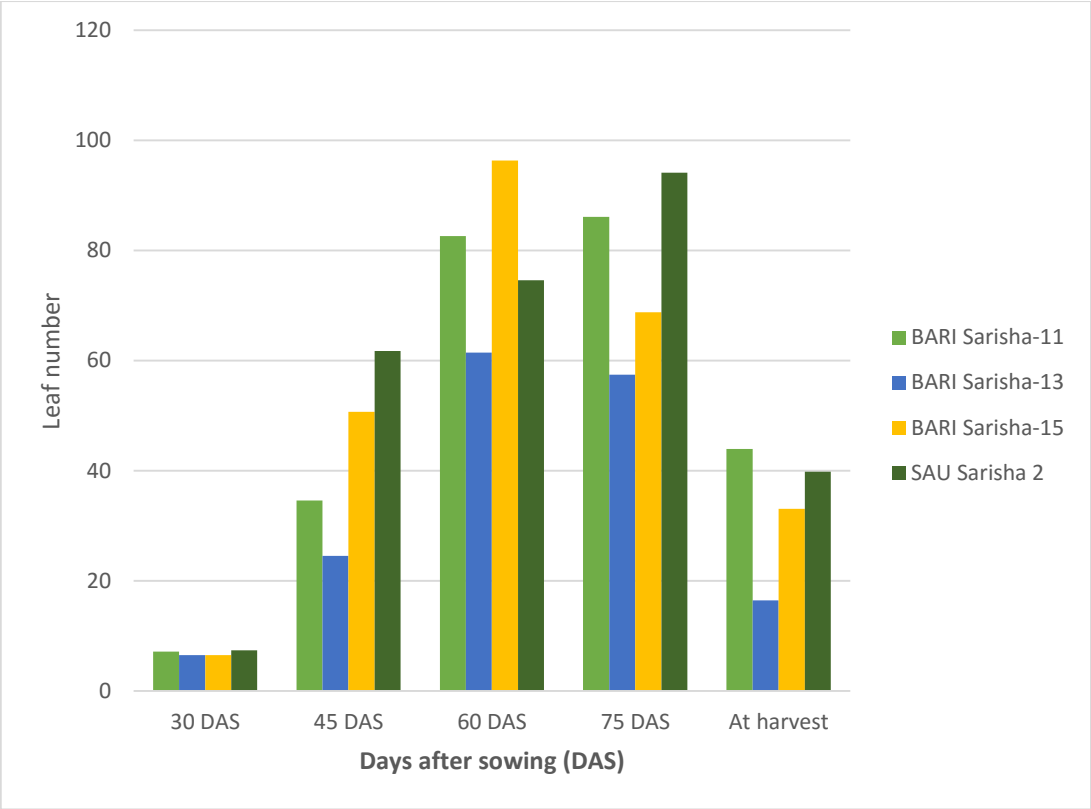


Figure 3. Effect of variety on leaf number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.9, 1.92, 3.38, 4.57 and 2.48 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.2.2 Effect of sowing technique

Leaf number was not significantly affected by sowing techniques at 30 DAS but significantly affected at 45, 60 and 75 DAS and at harvest (Appendix V and Figure 4). At 30 DAS, maximum leaf number (7.06) was recorded in line sowing and minimum leaf number (6.64) was observed in broadcasting technique. All the treatments showed statistically similar result. On 45 DAS, maximum leaf number (59.25) was recorded in SMI technique and minimum leaf number (31.06) was observed in broadcasting technique. At 60 DAS, maximum leaf number (142.17) was observed at SMI technique and minimum leaf number (51) was observed in broadcasting technique. In case of 75 DAS, maximum leaf number (201.81) was recorded at SMI technique. On the other hand, line sowing scored the minimum leaf number (30) which was statistically similar (31.22) with broadcasting technique. At harvest, maximum leaf number (78.58) was recorded at SMI technique and minimum leaf number (14) was observed at broadcasting technique.

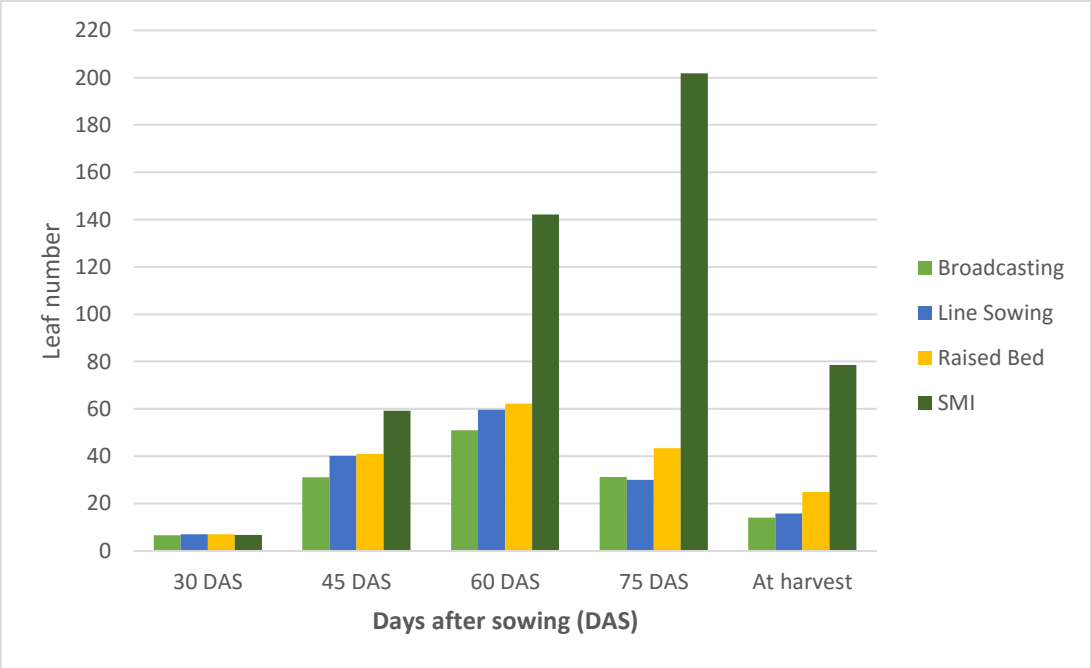


Figure 4. Effect of sowing technique on leaf number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.9, 1.92, 3.38, 4.57 and 2.48 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.2.3. Interaction effect of variety and sowing technique

Leaf number was not significantly affected by the interaction of variety and sowing technique at 30 DAS but significantly affected at 45, 60 and 75 DAS and at harvest which is shown in Table 2. At 30 DAS, maximum leaf number (8) was recorded at the combination of BARI Sarisha-11 and line sowing technique (V_1S_2) which was statistically similar with V_1S_1, V_1S_3, V_1S_4, V_2S_2, V_2S_3, V_2S_4, V_3S_1, V_3S_2, V_3S_3, V_3S_4, V_4S_1, V_4S_2, V_4S_3 and V_4S_4. Minimum leaf number (6) was observed at the combination of BARI Sarisha-13 and broadcasting technique (V_2S_1) which was statistically similar with V_1S_1, V_1S_3, V_1S_4, V_2S_2, V_2S_3, V_2S_4, V_3S_1, V_3S_2, V_3S_3, V_3S_4, V_4S_1, V_4S_2, V_4S_3 and V_4S_4. On 45 DAS, maximum leaf number (73.33) was recorded at the combination of SAU Sarisha 2 and line sowing (V_4S_2) which was statistically similar (72.56) with V_3S_4. In case of 60 DAS, maximum leaf number (167.67) was recorded at the combination of BARI Sarisha-15 and SMI technique (V_3S_4). At 75 DAS, maximum leaf number (268.89) was recorded at the combination of SAU Sarisha 2 and SMI technique (V_4S_4). At harvest, maximum leaf number (112.67) was observed at the combination of BARI Sarisha-11 and SMI technique (V_1S_4). At 45, 60 and 75 DAS and at harvest minimum leaf number (10.78, 26.44, 8.11 and 3) was observed at the combination of BARI Sarisha-13 and line sowing (V_2S_1).

Table 2. Interaction effect of variety and sowing technique on leaf number at 30, 45, 60, 75 DAS and at harvest

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	6.78 ab	31.67 f	73.44 f	59.22 d	21.67 gh
V_1S_2	8.00 a	25.56 g	61.89 g	33.33 f-h	18.00 hi
V_1S_3	7.11 ab	28.33 fg	62.78 g	43.89 e	23.33 fg
V_1S_4	6.56 ab	52.67 cd	132.33 c	208.00 b	112.67 a
V_2S_1	6.00 b	10.78 i	26.44 k	8.11 j	3.00 k
V_2S_2	6.33 ab	18.67 h	48.00 i	23.44 i	8.00 j
V_2S_3	6.67 ab	24.56 g	54.00 hi	30.22 g-i	13.67 i
V_2S_4	6.89 ab	44.11 e	117.22 d	168.00 c	41.00 d
V_3S_1	6.22 ab	30.56 f	63.11 g	25.44 hi	13.33 i
V_3S_2	6.33 ab	43.22 e	71.33 f	28.11 g-i	17.67 hi
V_3S_3	6.33 ab	56.33 c	83.33 e	59.11 d	35.00 e
V_3S_4	7.00 ab	72.56 a	167.67 a	162.33 c	66.33 c
V_4S_1	7.56 ab	51.22 d	41.00 j	32.11 f-i	18.00 hi
V_4S_2	7.56 ab	73.33 a	57.33 gh	35.11 e-g	19.67 gh
V_4S_3	7.67 ab	54.78 cd	48.56 i	40.33 ef	27.33 f
V_4S_4	6.67 ab	67.67 b	151.44 b	268.89 a	94.33 b
$LSD_{(0.05)}$	1.79	3.85	6.77	9.14	4.95
CV (%)	15.7	5.4	5.2	7.2	8.9

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.3 Dry Matter Accumulation

4.1.3.1 Effect of variety

Dry matter (g) production was significantly affected by variety throughout the lifecycle (Appendix V and Figure 5). At 30 DAS, maximum weight (1.07 g) was gained at BARI Sarisha-11 and minimum dry matter weight (0.63 g) was recorded at BARI Sarisha-13 which was statistically similar (0.7 g) with BARI Sarisha-15. On 45 DAS, maximum dry matter accumulation (11.44 g) was recorded at BARI Sarisha-11 and minimum dry matter accumulation (6.69 g)

was observed at BARI Sarisha-13. At 60 DAS, maximum dry matter weight (21.3 g) was gained at BARI Sarisha-11 and minimum dry matter weight (13.33 g) was recorded at BARI Sarisha-15 which was statistically similar (13.69 g) with SAU Sarisha 2. At 75 DAS, maximum dry matter weight (25.87 g) was gained at BARI Sarisha-11 and minimum dry matter weight (17.91 g) was recorded at BARI Sarisha-15 which was statistically similar (19.19 g) with BARI Sarisha-13.

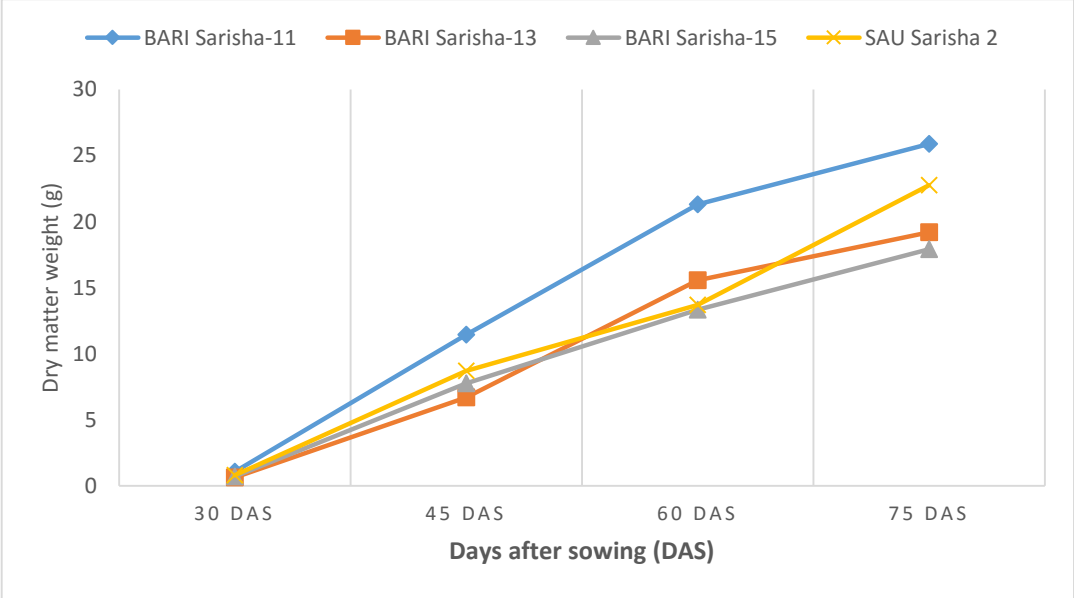


Figure 5. Effect of variety on dry matter accumulation of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.12, 0.32, 0.81 and 2.76 at 30, 45, 60 and 75 DAS respectively)

4.1.3.2 Effect of sowing technique

Dry matter (g) production was significantly affected by sowing technique throughout the lifecycle (Appendix V and Figure 6). At 30 DAS, maximum weight (1.2 g) was gained at raised bed technique and minimum dry matter weight (0.51 g) was recorded at SMI technique which was statistically similar (0.62 g) with broadcasting technique. On 45, 60 and 75 DAS, maximum dry matter accumulation (14.85, 28.68 and 36.44 g) was recorded at SMI technique and minimum dry matter accumulation (5.54, 12.02 and 16.93 g) was observed at line sowing.

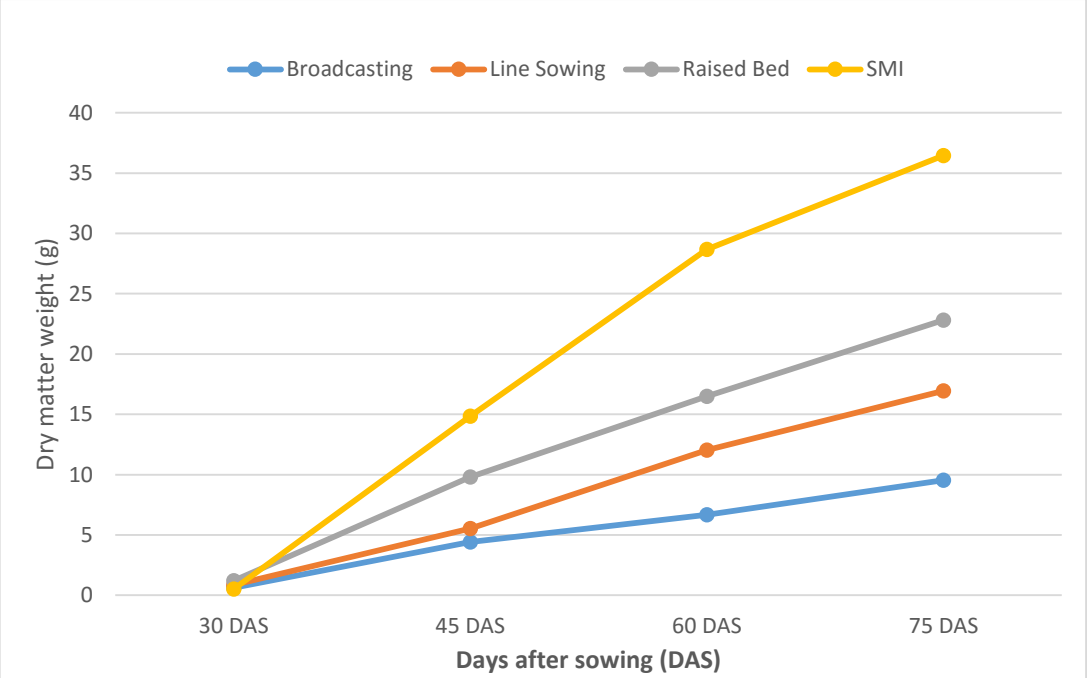


Figure 6. Effect of sowing technique on dry matter accumulation of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.12, 0.32, 0.81 and 2.76 at 30, 45, 60 and 75 DAS respectively)

4.1.3.3. Interaction effect of variety and sowing technique

Dry matter accumulation (g) was significantly affected by the interaction of variety and sowing technique at 30, 45 and 60 DAS but not significant at 75 DAS which is shown in Table 3. At 30 DAS, maximum dry matter (1.7 g) accumulation was recorded at the combination of BARI Sarisha-11 and raised bed technique (V_1S_3) and minimum dry matter (0.45 g) accumulation was observed at the combination of BARI Sarisha-15 and SMI technique (V_3S_4) which was statistically similar with V_1S_1, V_1S_4, V_2S_1, V_2S_2, V_2S_4, V_3S_1, V_3S_2 and V_4S_4. On 45 DAS, maximum dry matter (19.2 g) production was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and minimum dry matter (3.43) production was recorded at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar (3.93 g) with V_4S_1. At 60 DAS, maximum dry matter (35.12 g) production was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and

minimum dry matter (6.21 g) production was recorded at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_3S_1 and V_4S_1. At 75 DAS, maximum dry matter (39.93 g) production was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) which was statistically similar with V_2S_4 and V_4S_4. On the other hand, minimum dry matter (7.68 g) production was recorded at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_3S_1, V_3S_2 and V_4S_1.

Table 3. Interaction effect of variety and sowing technique on dry matter accumulation (g) at 30, 45, 60 and 75 DAS

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
V_1S_1	0.61 e-g	5.25 hi	6.96 kl	11.53 gh
V_1S_2	1.41 b	6.11 g	20.12 e	24.01 de
V_1S_3	1.70 a	15.18 c	23.00 d	28.02 cd
V_1S_4	0.57 fg	19.20 a	35.12 a	39.93 a
V_2S_1	0.58 fg	3.43 j	6.42 l	7.68 h
V_2S_2	0.61 e-g	5.83 gh	10.47 hi	13.94 fg
V_2S_3	0.83 de	6.27 g	16.39 f	20.61 e
V_2S_4	0.48 g	11.24 e	28.91 b	34.52 ab
V_3S_1	0.48 g	5.05 i	6.81 l	8.56 gh
V_3S_2	0.63 e-g	5.23 hi	8.47 jk	11.18 gh
V_3S_3	1.24 bc	7.78 f	12.06 h	18.56 ef
V_3S_4	0.45 g	12.99 d	25.96 c	33.34 bc
V_4S_1	0.81 d-f	3.93 j	6.52 l	10.45 gh
V_4S_2	0.83 de	4.98 i	9.02 ij	18.57 ef
V_4S_3	1.05 cd	9.94 e	14.5 g	24.02 de
V_4S_4	0.54 g	15.98 b	24.72 c	37.98 ab
$LSD_{(0.05)}$	0.24	0.64	1.62	5.51
CV (%)	18.3	4.4	6.1	15.4

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.4 Crop Growth Rate (CGR)

4.1.4.1 Effect of variety

Crop growth rate (CGR) is a measure of the increase in size, mass or number of crops over a period of time. The increase can be plotted as a logarithmic or exponential curve in many cases. CGR was significantly affected by variety throughout the life cycle (Appendix V and Figure 7). At 30-45 DAS, highest CGR (0.691 g plant^{-1} day^{-1}) was recorded at BARI Sarisha-11 and lowest CGR (0.405 g plant^{-1} day^{-1}) was recorded at BARI Sarisha-13. On 45-60 DAS, highest CGR (0.658 g plant^{-1} day^{-1}) was recorded at BARI Sarisha-11 and lowest CGR (0.332 g plant^{-1} day^{-1}) was observed at SAU Sarisha 2 which was statistically similar (0.371 g plant^{-1} day^{-1}) with BARI Sarisha-15. At 60-75 DAS, highest CGR (0.604 g plant^{-1} day^{-1}) was recorded at SAU Sarisha 2 and lowest CGR (0.243 g plant^{-1} day^{-1}) was observed at BARI Sarisha-13 which was statistically similar with BARI Sarisha-11 (0.305 g plant^{-1} day^{-1}) and BARI Sarisha-15 (0.306 g plant^{-1} day^{-1}).

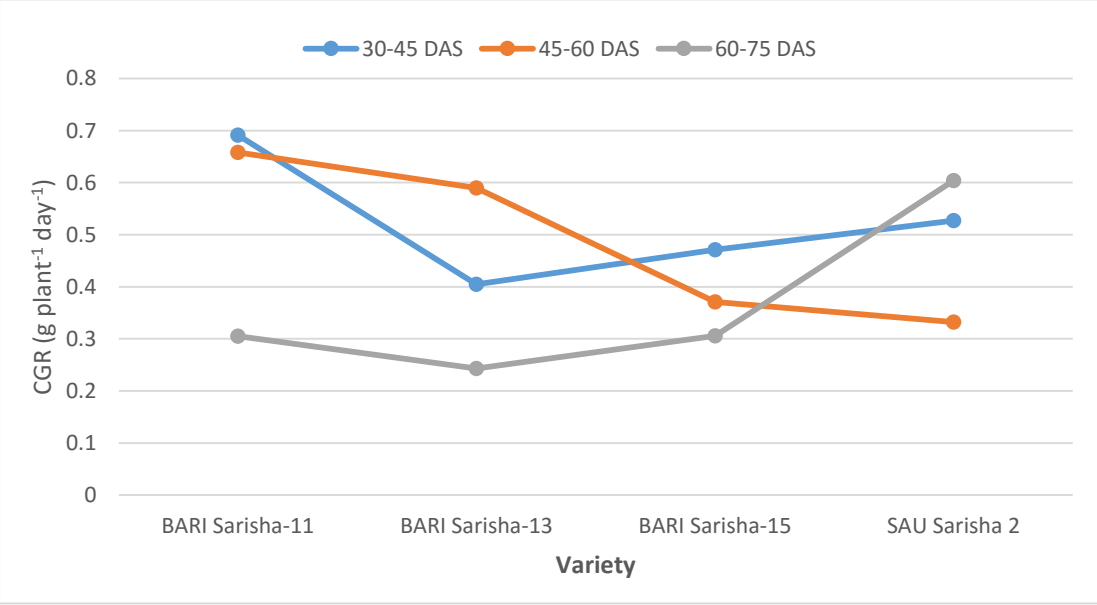


Figure 7. Effect of variety on CGR of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.021, 0.054 and 0.167 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.4.2 Effect of sowing technique

CGR was significantly affected by sowing technique throughout the life cycle (Appendix V and Figure 8). At 30-45 DAS, highest CGR (0.956 g plant^{-1} day^{-1}) was recorded at SMI technique and lowest CGR (0.253 g plant^{-1} day^{-1}) was recorded at broadcast sowing technique. On 45-60 DAS, highest CGR (0.658 g plant^{-1} day^{-1}) was recorded at SMI technique and lowest CGR (0.151 g plant^{-1} day^{-1}) was observed at broadcast sowing technique. At 60-75 DAS, highest CGR (0.518 g plant^{-1} day^{-1}) was recorded at SMI technique and lowest CGR (0.192 g plant^{-1} day^{-1}) was observed at broadcast sowing technique which was statistically similar (0.327 g plant^{-1} day^{-1}) with line sowing technique.

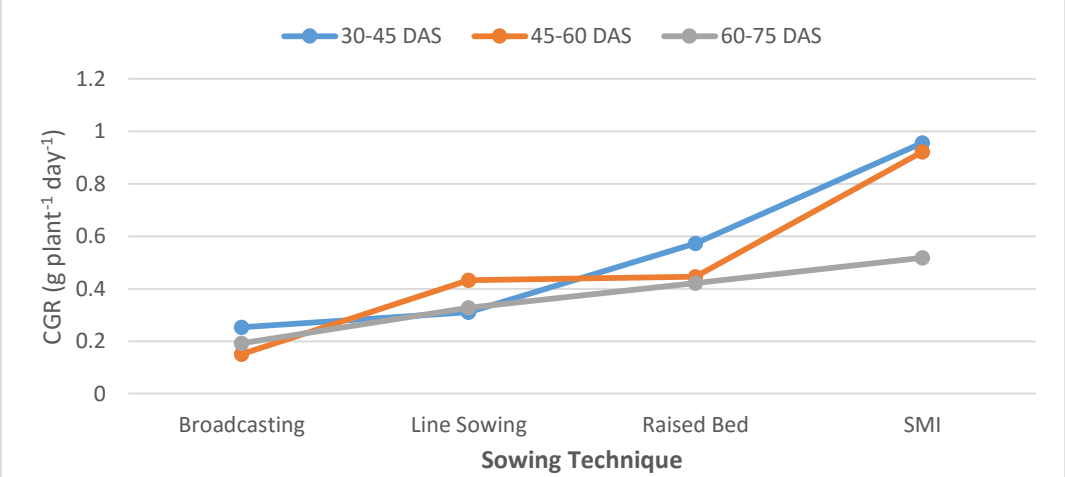


Figure 8: Effect of sowing technique on CGR of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.021, 0.054 and 0.167 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.4.3. Interaction effect of variety and sowing technique

CGR was significantly affected by the interaction of variety and sowing technique at 30-45 and 45-60 DAS but not significant at 60-75 DAS which is shown in Table 4. At 30-45 DAS, highest CGR (1.242 g plant^{-1} day^{-1}) was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and lowest CGR (0.19 g plant^{-1} day^{-1}) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar (0.208 g plant^{-1} day^{-1}) with V_4S_1. At 45-60 DAS, highest CGR (1.178 g plant^{-1} day^{-1}) was recorded at the combination of BARI Sarisha-13 and SMI technique

(V_2S_4). Lowest CGR (0.114 g plant^{-1} day^{-1}) was observed at the combination of BARI Sarisha-11 and broadcast sowing technique (V_1S_1) which was statistically similar with V_2S_1, V_3S_1, V_3S_2 and V_4S_1. At 60-75, highest CGR (0.884 g plant^{-1} day^{-1}) was recorded at the combination of SAU Sarisha 2 and SMI technique (V_4S_4) which was statistically similar with V_4S_2 and V_4S_3. Lowest CGR (0.084 g plant^{-1} day^{-1}) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_1S_2, V_1S_3, V_1S_4, V_2S_2, V_2S_3, V_2S_4, V_3S_1 and V_3S_2.

Table 4. Interaction effect of variety and sowing technique on crop growth rate (g plant^{-1} day^{-1}) at 30-45, 45-60 and 60-75 DAS

Treatments	30-45 DAS	45-60 DAS	60-75 DAS
V_1S_1	0.309 ij	0.114 i	0.305 b-e
V_1S_2	0.314 ij	0.934 c	0.259 c-e
V_1S_3	0.898 c	0.522 e	0.334 b-e
V_1S_4	1.242 a	1.061 b	0.321 b-e
V_2S_1	0.190 k	0.199 g-i	0.084 e
V_2S_2	0.348 hi	0.309 f	0.232 c-e
V_2S_3	0.362 h	0.675 d	0.282 c-e
V_2S_4	0.717 e	1.178 ah	0.374 b-e
V_3S_1	0.305 j	0.117 i	0.117 de
V_3S_2	0.306 ij	0.216 f-i	0.181 c-e
V_3S_3	0.436 g	0.286 fg	0.433 b-d
V_3S_4	0.836 d	0.865 c	0.492 bc
V_4S_1	0.208 k	0.173 hi	0.262 c-e
V_4S_2	0.276 j	0.270 f-h	0.637 ab
V_4S_3	0.593 f	0.304 fg	0.635 ab
V_4S_4	1.030 b	0.582 de	0.884 a
$LSD_{(0.05)}$	0.042	0.107	0.334
CV (%)	4.8	13.2	55

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.5 Relative Growth Rate (RGR)

4.1.5.1 Effect of variety

Relative growth rate (g g^{-1} day^{-1}) is the increase of materials per unit of plant materials per unit of time. RGR was not significantly affected by variety at 30-45 DAS but significant at 45-60 and 60-75 DAS (Appendix V and Figure 9). At 30-45 DAS, highest RGR (0.161 g $plant^{-1}$ day^{-1}) was recorded at BARI Sarisha-15 and lowest RGR (0.15 g g^{-1} $day^{-1}$was recorded at SAU Sarisha 2. All the treatments showed statistically similar result. On 45-60 DAS, highest RGR (0.052 g g^{-1} day^{-1}) was recorded at BARI Sarisha-13 and lowest RGR (0.032 g g^{-1} day^{-1}) was observed both at BARI Sarisha-15 and SAU Sarisha 2. At 60-75 DAS, highest RGR (0.035 g g^{-1} day^{-1}) was recorded at SAU Sarisha-2. On the other hand, lowest RGR (0.014 g g^{-1} day^{-1}) was observed at BARI Sarisha-13 which was statistically similar with BARI Sarisha-11 (0.016 g g^{-1} day^{-1}) and BARI Sarisha-15 (0.019 g g^{-1} day^{-1}).

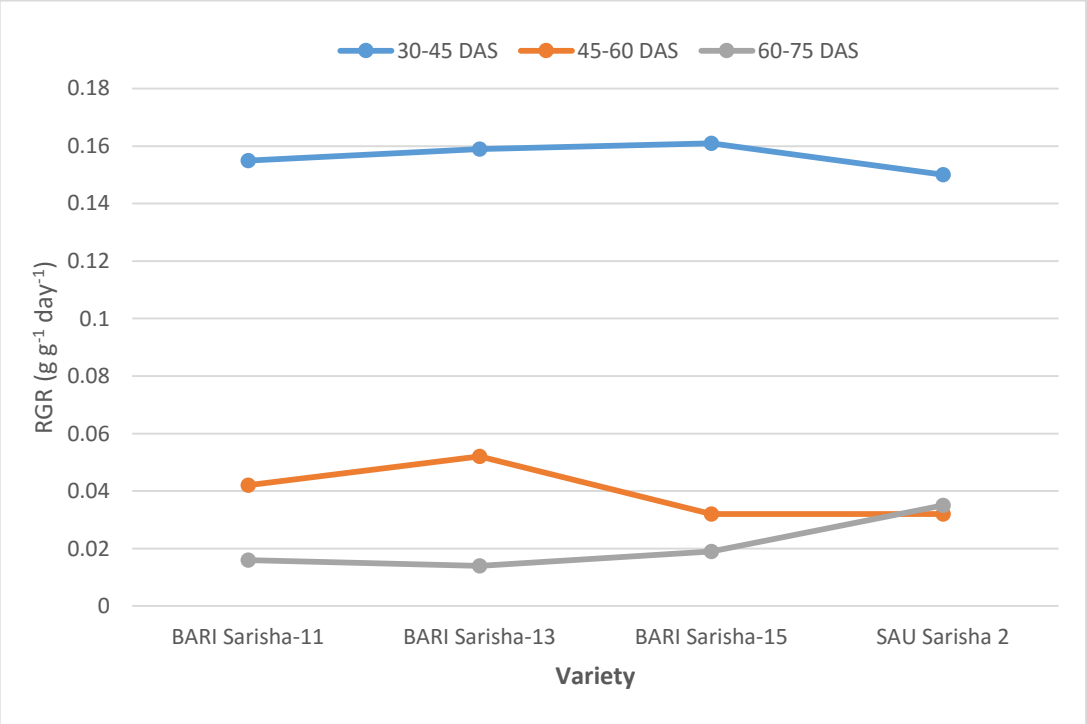


Figure 9. Effect of variety on RGR of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.016, 0.005 and 0.01 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.5.2 Effect of sowing techniques

RGR was significantly affected by sowing technique at 30-45 and 45-60 DAS but not significant at 60-75 DAS (Appendix V and Figure 8). At 30-45 DAS, highest RGR (0.224 g g^{-1} day^{-1}) was recorded both at SMI technique and lowest RGR (0.132 g g^{-1} day^{-1}) was recorded both at broadcast and line sowing technique which was statistically similar (0.138 g g^{-1} day^{-1}) with raised bed technique. On 45-60 DAS, highest RGR (0.048 g g^{-1} day^{-1}) was recorded at line sowing which was statistically similar (0.045 g g^{-1} day^{-1}) with SMI technique. On the other hand, lowest RGR (0.029 g g^{-1} day^{-1}) was observed at broadcast sowing. At 60-75 DAS, highest RGR (0.024 g g^{-1} day^{-1}) was recorded at line sowing and lowest RGR (0.016 g g^{-1} day^{-1}) was observed at SMI technique. All the treatments showed statistically same result.

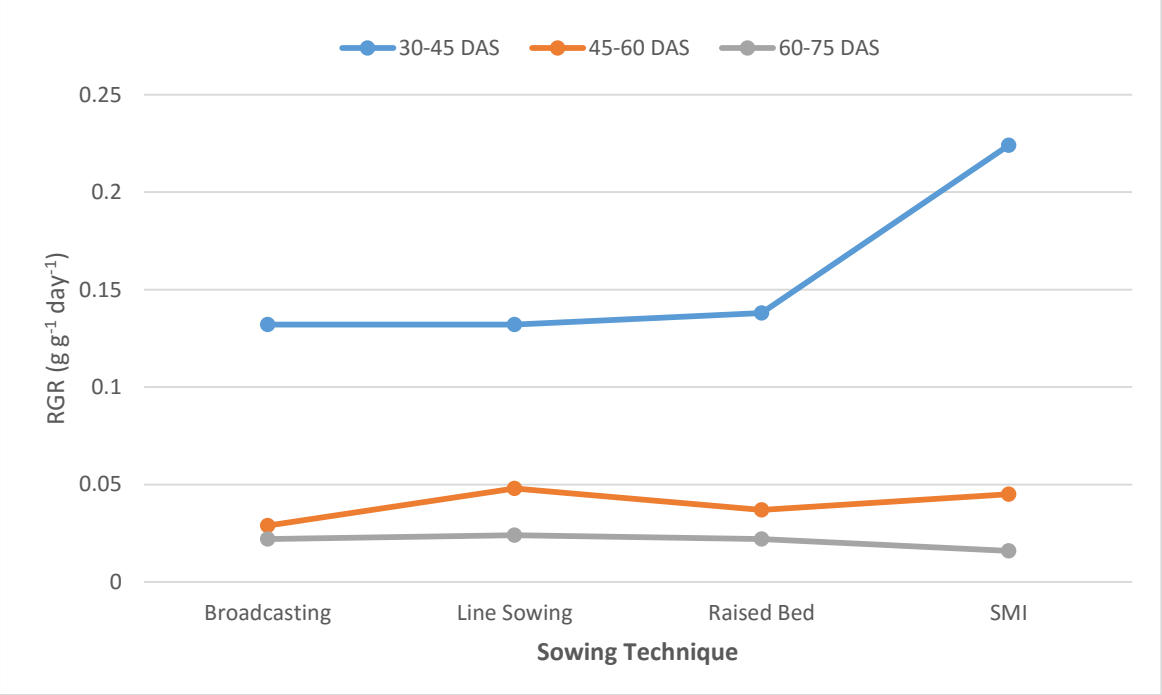


Figure 10. Effect of sowing technique on RGR of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.016, 0.005 and 0.01 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.5.3. Interaction effect of variety and sowing technique

RGR was significantly affected at 30-45 and 45-60 DAS but not significant at 60-75 DAS by the interaction of variety and sowing technique which is shown in Table 5. At 30-45 DAS, highest RGR (0.234 g g^{-1} day^{-1}) was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) which was statistically similar with V_2S_4, V_3S_4 and V_4S_4. Lowest RGR (0.098 g g^{-1} day^{-1}) was observed at the combination of BARI Sarisha-11 and line sowing (V_1S_2) which was statistically similar with V_2S_1, V_3S_3, V_4S_1 and V_4S_2. At 45-60 DAS, highest RGR (0.079 g g^{-1} day^{-1}) was recorded at the combination of BARI Sarisha-11 and line sowing (V_1S_2). Lowest RGR (0.019 g g^{-1} day^{-1}) was observed at the combination of BARI Sarisha-11 and broadcast sowing technique (V_1S_1) which was statistically similar with V_1S_3, V_3S_1, V_3S_3, V_4S_3 and V_4S_4. At 60-75 DAS, highest RGR (0.084 g g^{-1} day^{-1}) was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and lowest RGR (0.012 g g^{-1} day^{-1}) was observed at the combination of BARI Sarisha-11 & broadcast technique (V_1S_4), at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) and at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_1S_3, V_2S_2, V_2S_3, V_3S_1, V_3S_2, V_3S_3, V_3S_4, V_4S_1 and V_4S_4.

Table 5. Interaction effect of variety and sowing technique on relative growth rate (g g^{-1} day^{-1}) at 30-45, 45-60 and 60-75 DAS

Treatments	30-45 DAS	45-60 DAS	60-75 DAS
V_1S_1	0.144 b-d	0.019 g	0.029 b-d
V_1S_2	0.098 f	0.079 a	0.012 d
V_1S_3	0.146 b-d	0.028 fg	0.013 cd
V_1S_4	0.234 a	0.040 cd	0.084 a
V_2S_1	0.121 d-f	0.042 cd	0.012 d
V_2S_2	0.170 b	0.039 c-e	0.019 cd
V_2S_3	0.135 c-e	0.064 b	0.015 cd
V_2S_4	0.210 a	0.063 b	0.012 d
V_3S_1	0.158 bc	0.020 g	0.015 cd
V_3S_2	0.140 b-d	0.033 d-f	0.018 cd
V_3S_3	0.123 d-f	0.029 e-g	0.027 b-d
V_3S_4	0.225 a	0.046 c	0.017 cd
V_4S_1	0.106 ef	0.034 d-f	0.032 b-d
V_4S_2	0.119 d-f	0.039 c-e	0.046 b
V_4S_3	0.150 b-d	0.025 fg	0.033 bc
V_4S_4	0.226 a	0.029 e-g	0.029 b-d
$LSD_{(0.05)}$	0.032	0.01	0.02
CV (%)	12.4	14.5	56.3

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.6 Number of primary branches

4.1.6.1 Effect of variety

Number of primary branches were significantly affected by variety throughout the life cycle (Appendix V and Figure 11). At 30 DAS, maximum number of primary branches (3.25) were recorded at SAU Sariha 2 which was statistically similar with BARI Sarisha-11 (2.92) and BARI Sarisha-15 (3). On the other hand, minimum number of primary branches (1.42) were recorded at BARI Sarisha-13. On 45 DAS, maximum number of primary branches (8.25) were

recorded at BARI Sarisha-15 which was statistically similar (7.67) with SAU sarisha 2. On the other hand, minimum number of primary branches (4.67) were recorded at BARI Sarisha-13 which was statistically similar (5.17) with BARI Sarisha-11. In case of 60 DAS, maximum number of primary branches (8.39) were recorded both at BARI Sarisha-15 and SAU Sarisha 2. On the other hand minimum number of primary branches (6.31) were recorded at BARI Sarisha-13 which was statistically similar (6.61) with BARI Sarisha-11. At 75 DAS and at harvest, maximum number of primary branches (9.14) were recorded at BARI Sarisha-15 which was statistically similar (8.75) with SAU Sarisha 2. On the other hand minimum number of primary branches (6.5) were recorded at BARI Sarisha-13 which was statistically similar (6.86) with BARI Sarisha-11. Hossain *et al.* (1996) and Jahan and Zakaria (1997) also found that the rapeseed and mustard varieties were statistically different with respect to the number of branches plant^{-1}.

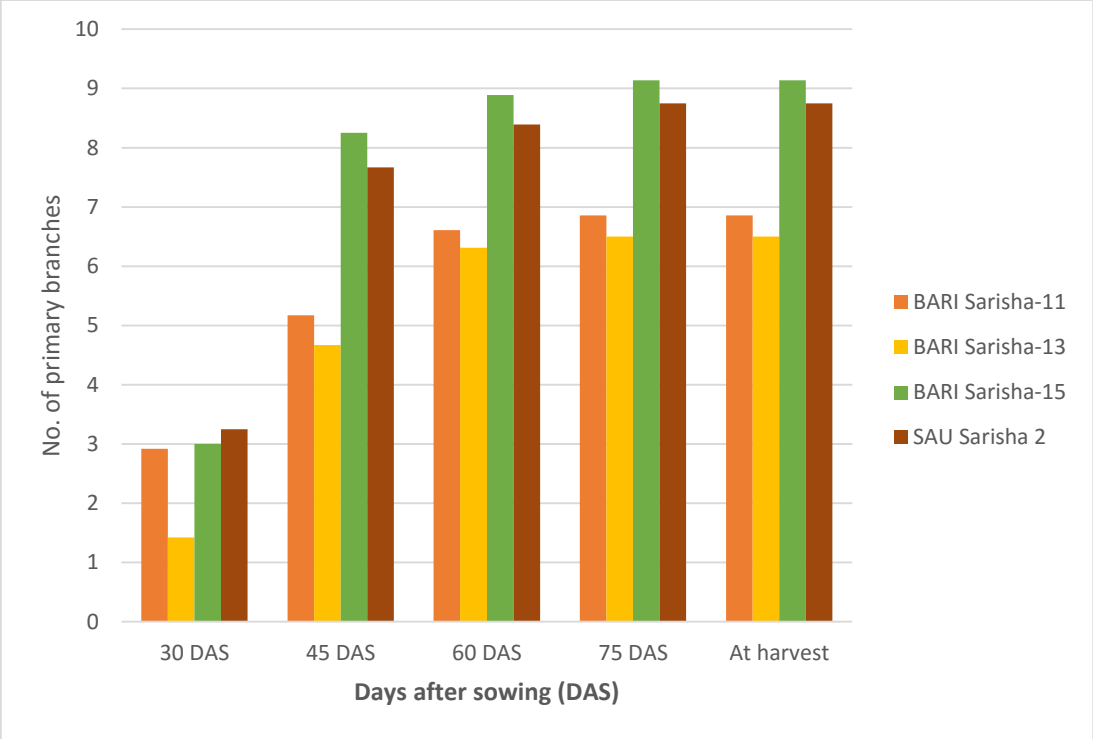


Figure 11. Effect of variety on primary branch number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.68, 0.88, 0.76, 0.91 and 0.91 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.6.2 Effect of sowing technique

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 (Appendix V and Figure 12). At 30 DAS, maximum number of primary branches (3.17) were recorded at raised bed technique which was statistically similar (2.58) with line sowing and SMI technique. On the other hand, minimum number of primary branches (2.25) were recorded at broadcast sowing technique which was statistically similar with line sowing and SMI technique. On 45 DAS, maximum number of primary branches (7.58) were recorded at SMI technique which was statistically similar (6.75) with raised bed technique. On 60 and 75 DAS, maximum number of primary branches (10.7 and 11.14) were recorded at SMI technique and minimum number of primary branches (5.58 and 5.92) were recorded at broadcast sowing technique. At harvest, maximum number of primary branches (11.14) were recorded at SMI technique and minimum number of primary branches (5.92) were recorded at broadcast sowing technique which was statistically similar (6.67) with line sowing. Hossain *et al.* (2013) also reported that sowing method had significant effect on the production of total branches plant^{-1}.

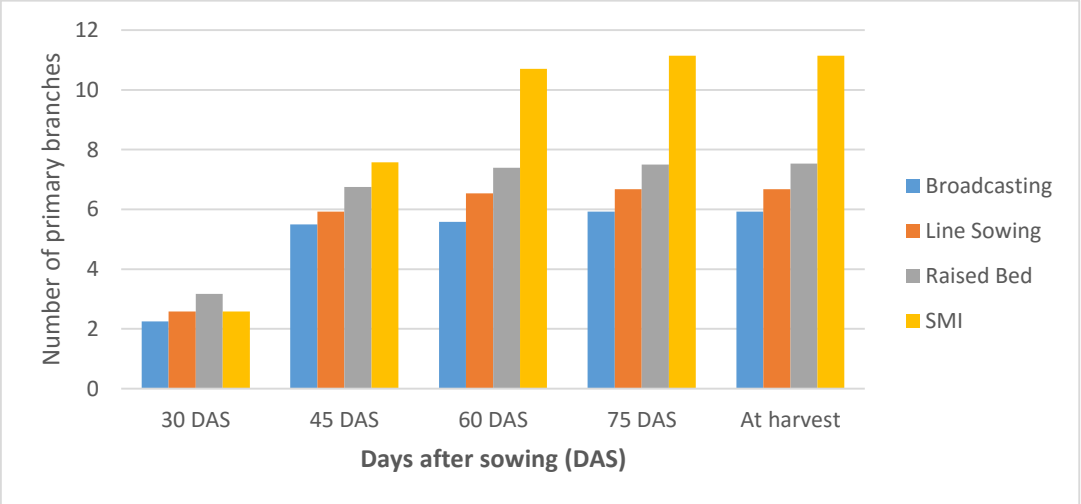


Figure 12. Effect of sowing technique on primary branch number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.68, 0.88, 0.76, 0.91 and 0.91 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.6.3. Interaction effect of variety and sowing technique

Number of primary branches was not significantly affected by the interaction of variety and sowing technique at 30 and 45 DAS and at harvest; but significant at 60 and 75 DAS which is shown in Table 6. At 30 DAS, maximum number of primary branches (4) were recorded at the combination of SAU Sarisha 2 and raised bed technique (V_4S_3) which were statistically similar with V_1S_2, V_1S_3, V_1S_4, V_3S_2, V_3S_3, V_3S_4, V_4S_2 and V_4S_4. On the other hand, minimum number of primary branches (1) were observed at the combination of BARI Sarisha-13 and line sowing (V_2S_2) which was statistically similar with V_1S_1, V_2S_1, V_2S_3, V_2S_4 and V_3S_1. On 45 DAS, maximum number of primary branches (9.33) was recorded at the combination of BARI Sarisha-15 and SMI technique (V_3S_4) which was statistically similar with V_3S_1, V_3S_2, V_3S_3, V_4S_3 and V_4S_4. On the other hand minimum number of primary branches (3.67) was observed both at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1), BARI Sarisha-13 and line sowing technique (V_2S_2) which was statistically similar with V_1S_1, V_1S_2 and V_1S_3. In case of 60 DAS, maximum number of primary branches (11.67) was recorded at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) which were statistically similar with V_3S_4 and V_4S_4. On the other hand, minimum number of primary branches (3.45) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1 and V_2S_2. In case of 75 DAS, maximum number of primary branches (12.67) was recorded at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) which were statistically similar with V_3S_4 and V_4S_4. On the other hand, minimum number of primary branches (4.44) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_1S_2, V_2S_2 and V_2S_3. At harvest, maximum number of primary branches (11.67) were recorded at the combination of BARI Sarisha-15 and SMI technique (V_2S_4) which were statistically similar with V_2S_4 and V_4S_4. On the other hand, minimum number of primary branches (4.33) was observed at the combination of BARI Sarisha-13

and broadcast sowing technique (V_2S_1) which was statistically similar with V_1S_1, V_1S_2, V_2S_2 and V_2S_3.

Table 6. Interaction effect of variety and sowing technique on number of primary branches at 30, 45, 60, 75 DAS and at harvest

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	2.33 b-e	4.33 hi	4.89 hi	5.11 hi	5.00 hi
V_1S_2	2.67 a-d	4.67 g-i	5.78 f-h	5.67 g-i	5.78 f-i
V_1S_3	3.33 ab	5.00 f-i	6.11 f-h	6.33 f-h	6.33 f-h
V_1S_4	3.33 ab	6.67 c-f	9.67 b-d	10.33 bc	10.33 ab
V_2S_1	1.67 c-e	3.67 i	3.45 i	4.44 i	4.33 i
V_2S_2	1.00 e	3.67 i	4.67 hi	4.56 i	4.67 hi
V_2S_3	1.67 c-e	5.67 e-h	5.44 gh	5.67 g-i	5.67 g-i
V_2S_4	1.33 de	5.67 e-h	11.67 a	12.67 a	11.33 a
V_3S_1	2.33 b-e	7.67 a-d	6.89 fg	6.89 e-g	7.22 d-g
V_3S_2	3.33 ab	8.00 a-d	8.44 de	8.33 de	8.67 b-e
V_3S_3	3.67 ab	8.00 a-d	9.22 cd	9.00 cd	9.00 b-d
V_3S_4	2.67 a-d	9.33 a	11.00 ab	11.67 ab	11.67 a
V_4S_1	2.67 a-d	6.33 d-g	7.11 ef	7.22 ef	7.11 e-g
V_4S_2	3.33 ab	7.33 b-e	7.22 ef	8.11 de	7.56 c-f
V_4S_3	4.00 a	8.33 a-c	8.78 d	9.00 cd	9.11 bc
V_4S_4	3.00 a-c	8.67 ab	10.45 a-c	11.22 ab	11.22 a
$LSD_{(0.05)}$	1.36	1.75	1.52	1.45	1.83
CV (%)	30.8	16.3	12.1	11.0	14.0

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.7 Number of secondary branches

4.1.7.1 Effect of variety

Number of secondary branches was significantly affected by variety throughout the life cycle (Appendix V and Figure 13). At 45 DAS, maximum number of secondary branches (7.56) was recorded at BARI Sarisha-11 and minimum number of secondary branches (1.17) were observed at BARI Sarisha-15. On

60 and 75 DAS and at harvest, maximum number of secondary branches (23.06, 25.92 and 28.11) was recorded at BARI Sarisha-11 and minimum number of secondary branches (12.89, 16.56 and 17.72) was observed at BARI Sarisha-13.

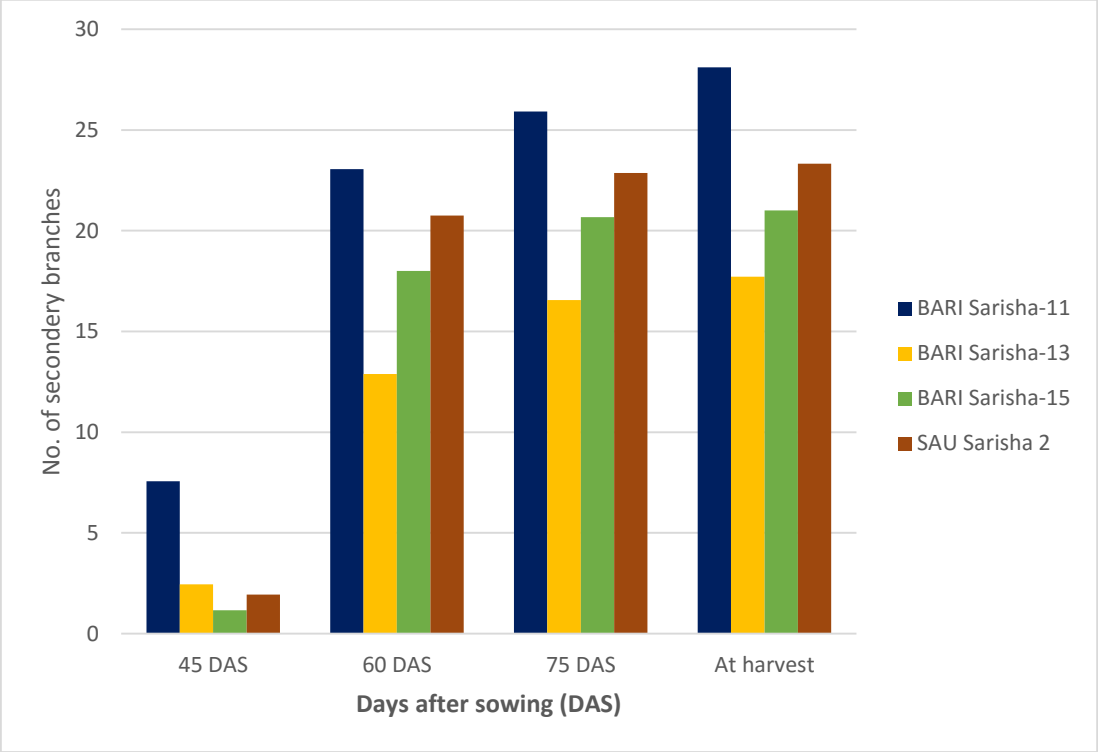


Figure 13. Effect of variety on secondary branch number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.52, 2.26, 1.97and 2.49 at 45, 60 and 75 DAS and at harvest respectively)

4.1.7.2 Effect of sowing technique

Number of secondary branches was significantly affected by sowing technique throughout the life cycle (Appendix V and Figure 14). At 45 DAS, maximum number of primary branches (6.39) was recorded at SMI technique and minimum number of secondary branches (1.22) was observed at broadcasting technique which was statistically similar (1.67) with line sowing. At 60 and 75 DAS and at harvest, maximum number of secondary branches (41.11, 47.31 and 51.08) was recorded at SMI technique and minimum number of secondary branches (8.5, 8.78 and 8.72) was observed at broadcast sowing technique.

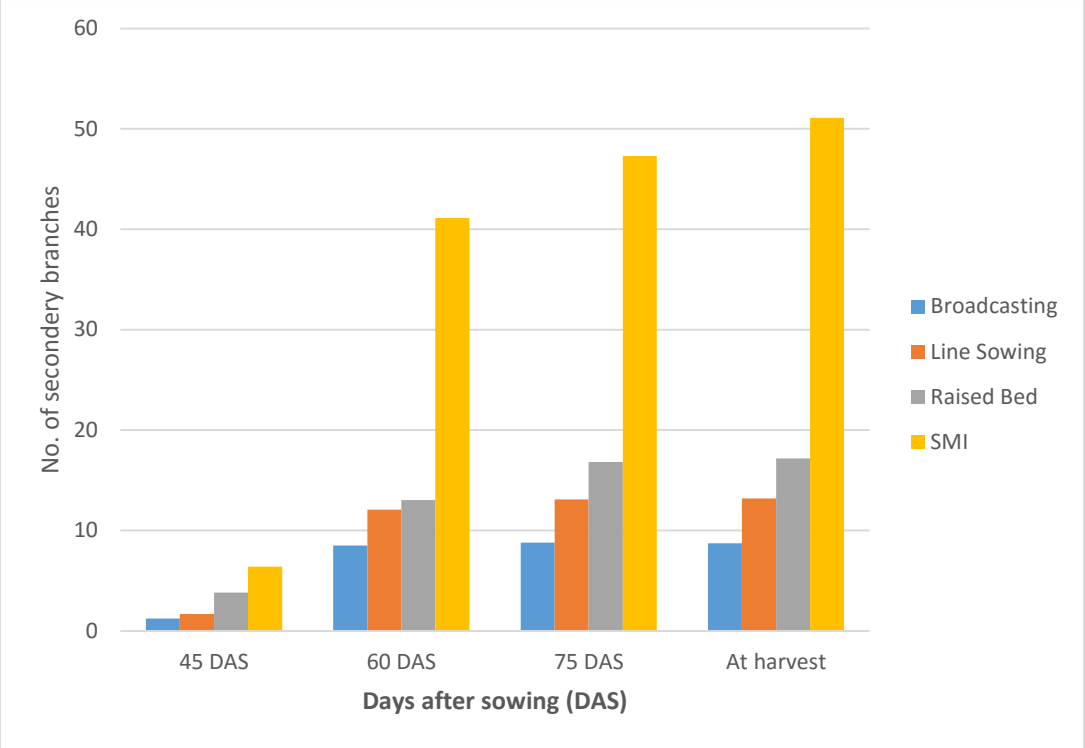


Figure 14: Effect of sowing technique on secondary branch number of mustard and rapeseed plant at different DAS ($LSD_{0.05}$= 0.52, 2.26, 1.97and 2.49 at 45, 60 and 75 DAS and at harvest respectively)

4.1.7.3. Interaction effect of variety and sowing technique

Number of secondary branches was significantly affected by the interaction of variety and sowing technique throughout the lifecycle which is shown in Table 7. At 45 DAS, maximum number of secondary branches (13.89) was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and minimum number of secondary branches (0) was observed both at the combination of BARI Sarisha-15 & line sowing (V_3S_2) and BARI Sarisha-15 and raised bed technique (V_3S_3) which was statistically similar with V_2S_1, V_3S_1, V_4S_1 and V_4S_2. At 60 and 75 DAS and at harvest maximum number of secondary branches (52, 62 and 70.33) was recorded at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and minimum number of secondary branches (2.33, 2.78 and 2.56) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1).

Table 7. Interaction effect of variety and sowing technique on secondary branches at 60, 75 DAS and at harvest

Treatments	45 DAS	60 DAS	75 DAS	At harvest
V_1S_1	2.89 de	11.89 e-h	12.00 e-g	12.00 e-g
V_1S_2	4.45 c	13.78 e-g	14.00 ef	14.11 d-g
V_1S_3	9.00 b	14.56 ef	15.67 de	16.00 de
V_1S_4	13.89 a	52.00 a	62.00 a	70.33 a
V_2S_1	0.56 h	2.33 i	2.78 h	2.56 h
V_2S_2	1.67 fg	8.78 h	10.67 fg	11.00 fg
V_2S_3	2.67 d-f	9.55 gh	15.00 de	16.00 de
V_2S_4	4.89 c	30.89 d	37.78 c	41.33 c
V_3S_1	0.44 h	10.11 f-h	10.33 fg	10.33 fg
V_3S_2	0 h	13.33 e-g	15.00 de	15.00 d-f
V_3S_3	0 h	12.56 e-h	18.00 d	18.00 d
V_3S_4	4.22 c	36.00 c	39.33 c	40.67 c
V_4S_1	1.00 gh	9.67 gh	10.00 g	10.00 g
V_4S_2	0.56 h	12.33 e-h	12.67 e-g	12.67 e-g
V_4S_3	3.67 d	15.45 e	18.67 d	18.67 d
V_4S_4	2.55 ef	45.56 b	50.11 b	50.00 b
$LSD_{(0.05)}$	1.05	4.52	3.94	4.98
CV (%)	19.2	14.5	11	13.2

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.1.8 Growth duration

4.1.8.1 Effect of variety

Growth duration (Day) was significantly affected by different varieties of mustard and rapeseed plant (Appendix V and Figure 15). Highest growth duration (112.5 day) was recorded at BARI Sarisha-11 and lowest growth duration (93.5 day) was observed at SAU Sarisha-2.

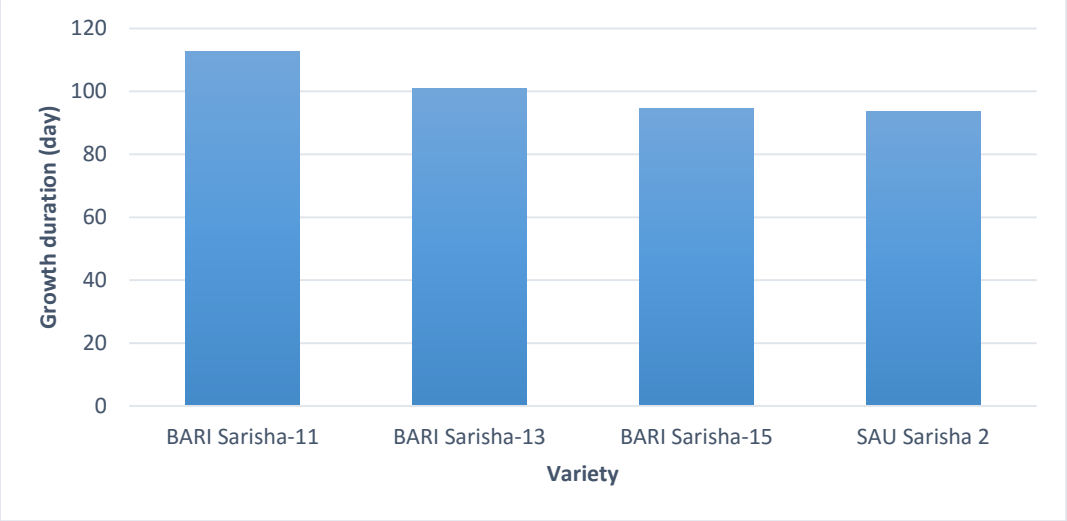


Figure 15. Effect of variety on growth duration of mustard and rapeseed plant

4.1.8.2 Effect of sowing technique

Growth duration of mustard and rapeseed plant was significantly affected by different sowing techniques (Appendix V and Figure 16). Highest growth duration (106.5 day) was recorded at SMI technique and lowest growth duration (95.5 day) was observed at broadcast sowing technique.

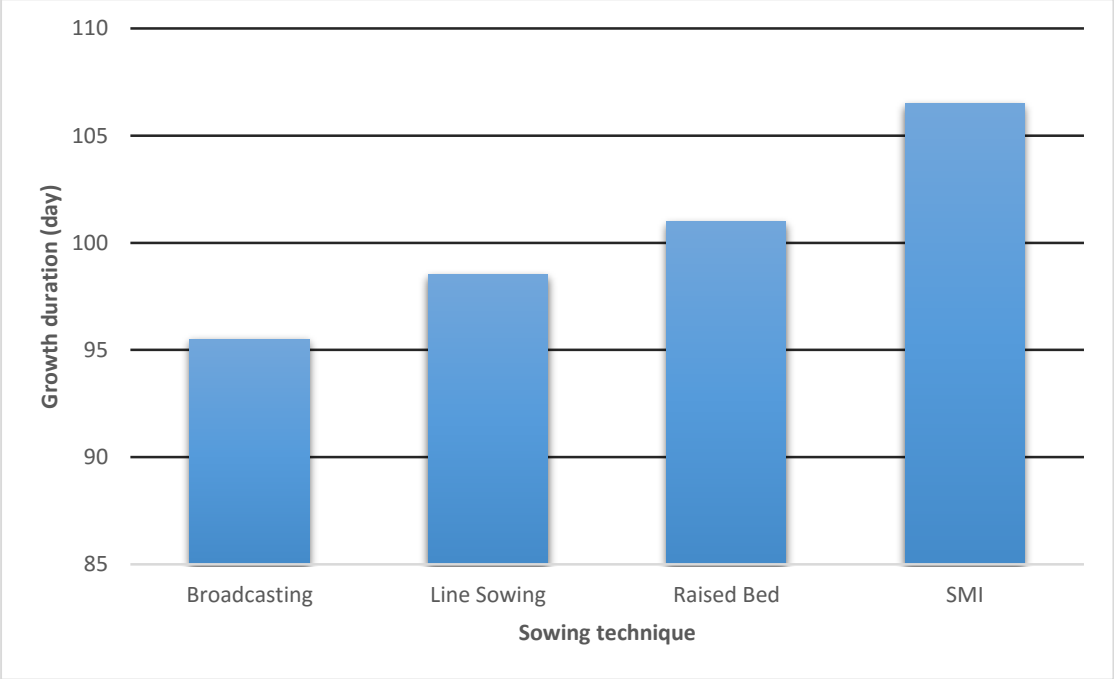


Figure 16. Effect of sowing technique on growth duration of mustard and rapeseed plant

4.1.8.3 Interaction effect of variety and sowing technique

Growth duration of mustard and rapeseed plant was significantly affected by the interaction of variety and sowing technique which is shown at Table 10. Highest growth duration (118 day) was obtained at the combination of BARI Sarisha-11 and SMI technique (V_1S_4). On the other hand, lowest growth duration (88 day) of mustard and rapeseed plant was found at the combination of SAU Sarisha 2 and broadcast sowing technique (V_4S_1).

4.2 Yield contributing characters

4.2.1 Number of siliquae plant^{-1}

4.2.1.1 Effect of variety

Number of siliquae plant^{-1} was significantly affected by variety (Appendix V and Figure 17). Maximum number of siliquae plant^{-1} (460.22) was recorded at BARI Sarisha-11 and minimum number of siliquae plant^{-1} (178.03) was observed at BARI Sarisha-15. Hossain *et al.* (1996) and Jahan and Zakaria (1997) also stated that there was marked statistical variation in number of siliquae plant^{-1}.

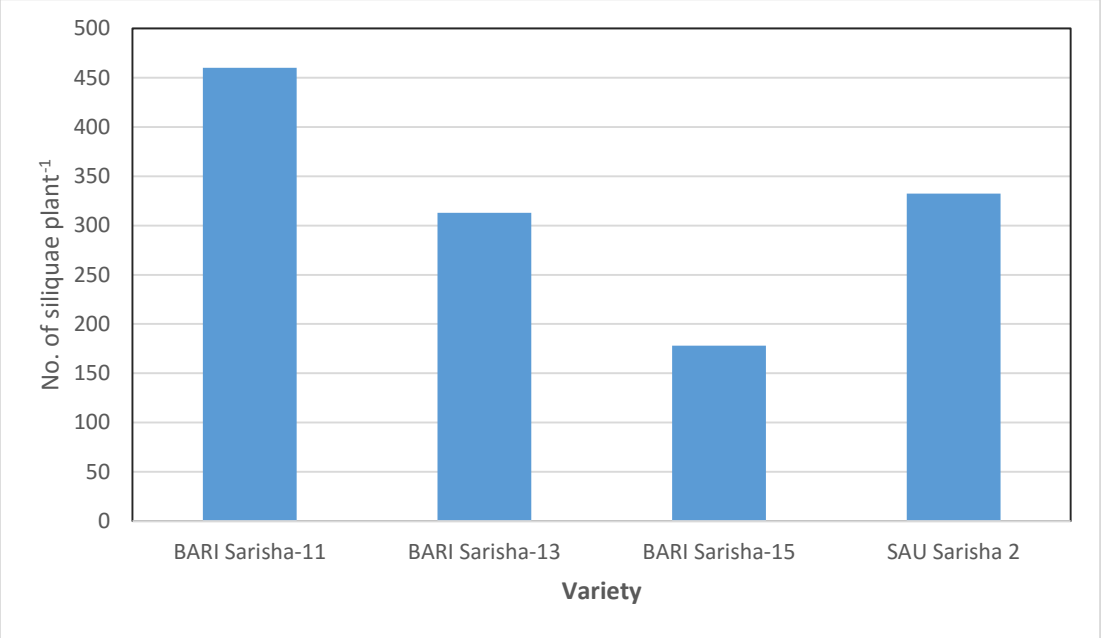


Figure 17. Effect of variety on number of siliquae plant^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 26.12)

4.2.1.1 Effect of sowing technique

Number of siliquae plant^{-1} was significantly affected by sowing technique (Appendix V and Figure 18). Maximum number of siliquae per plant (790.83) was recorded at SMI technique and minimum number of siliquae plant^{-1} (118.75) was observed at broadcast sowing technique. Hossain *et al.* (2013) also stated that there was marked statistical variation in number of siliquae plant^{-1} at different sowing technique.

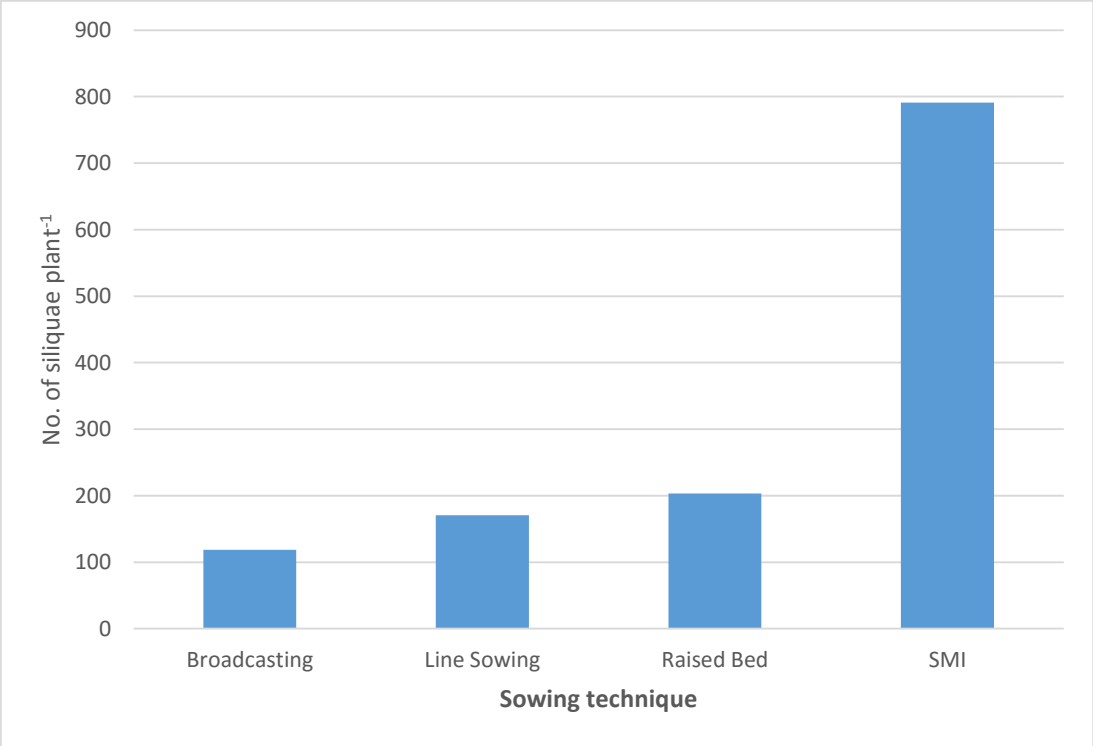


Figure 18. Effect of sowing technique on number of siliquae plant^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 26.12)

4.2.1.3. Interaction effect of variety and sowing technique

Number of siliquae plant^{-1} was significantly affected by the interaction of variety and sowing technique which is shown at Table 8. Combination of BARI Sarisha-11 and SMI technique (V_1S_4) scored the maximum number of siliquae plant^{-1} (1179.67) and minimum number of siliquae plant^{-1} (79.33) was recorded at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1) which was statistically similar with V_3S_1, V_3S_2 and V_3S_3.

4.2.2 Sterility

4.2.2.1 Number of sterile siliquae plant^{-1}

4.2.2.1.1 Effect of variety

Number of sterile siliquae plant^{-1} was not significantly affected by variety (Appendix V and Figure 19). Maximum number of sterile siliquae plant^{-1} (1.42) was recorded at SAU Sarisha 2 which was statistically similar (0.92) with BARI Sarisha-15. On the other hand, minimum number of sterile siliquae plant^{-1} (0.25) was observed both at BARI Sarisha-11 and BARI Sarisha-13 which was statistically similar with BARI Sarisha-15.

4.2.2.1.2 Effect of sowing technique

Number of sterile siliquae plant^{-1} was not significantly affected by sowing technique (Appendix V and Figure 20). Maximum number of sterile siliquae plant^{-1} (1.25) was recorded at raised bed technique which was statistically similar with line sowing (1.08) and broadcast sowing technique (0.5). On the other hand minimum number of sterile siliquae plant^{-1} (0) was observed at SMI technique which was statistically similar with broadcasting technique.

4.2.2.1.3 Interaction effect of variety and sowing technique

Number of sterile siliquae plant^{-1} was not significantly affected by the interaction of variety and sowing technique which is shown at Table 8. Combination of SAU Sarisha 2 & line sowing (V_4S_2) and SAU Sarisha 2 & raised bed technique (V_4S_3) scored the maximum number of sterile siliquae plant^{-1} (2.33) which was statistically similar with V_1S_3, V_2S_2, V_3S_1, V_3S_2, V_3S_3 and V_4S_1. On the other hand, minimum number of sterile siliquae plant^{-1} (0) was recorded at V_1S_1, V_1S_2, V_1S_4, V_2S_1, V_2S_3, V_2S_4, V_3S_4 and V_4S_4 which was statistically similar with V_1S_3, V_2S_2, V_3S_1, V_3S_2, V_3S_3 and V_4S_1.

4.2.2.2 Sterility percentage

4.2.2.2.1 Effect of variety

Sterility percentage of siliqua was not significantly affected by variety (Appendix V and Figure 19). Highest sterility percentage (0.92%) was recorded at BARI Sarisha-15 which was statistically similar (0.65%) with SAU Sarisha 2. On the other hand, lowest sterility percentage (0.08%) was observed at BARI Sarisha-11 which was statistically similar with BARI Sarisha-13 (0.17%) and SAU Sarisha 2 (0.65%).

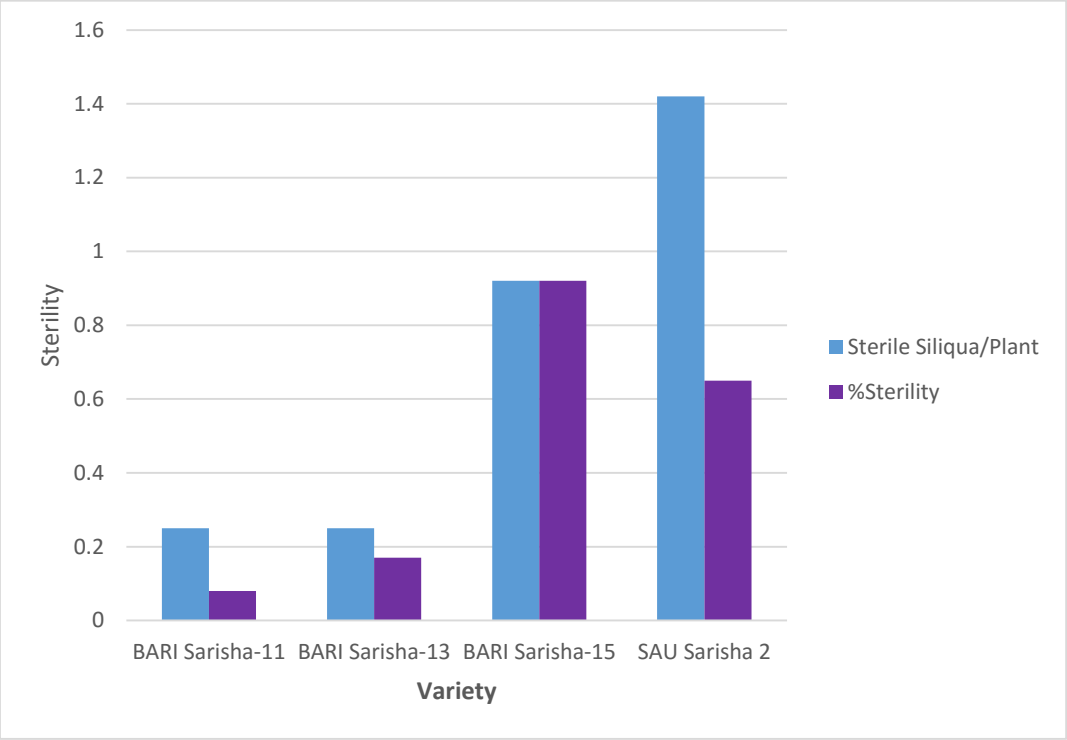


Figure 19. Effect of variety on sterility of siliqua of mustard and rapeseed plant ($LSD_{0.05}$= 1.05 and 0.71)

4.2.2.2.2 Effect of sowing technique

Sterility percentage of siliqua was significantly affected by sowing technique (Appendix V and Figure 20). Highest sterility percentage (0.77%) was recorded at raised bed technique which was statistically similar with broadcasting (0.38%) and line sowing technique (0.66%). On the other hand lowest sterility percentage (0) was observed at SMI technique which was statistically similar (3.51%) with broadcasting and line sowing technique.

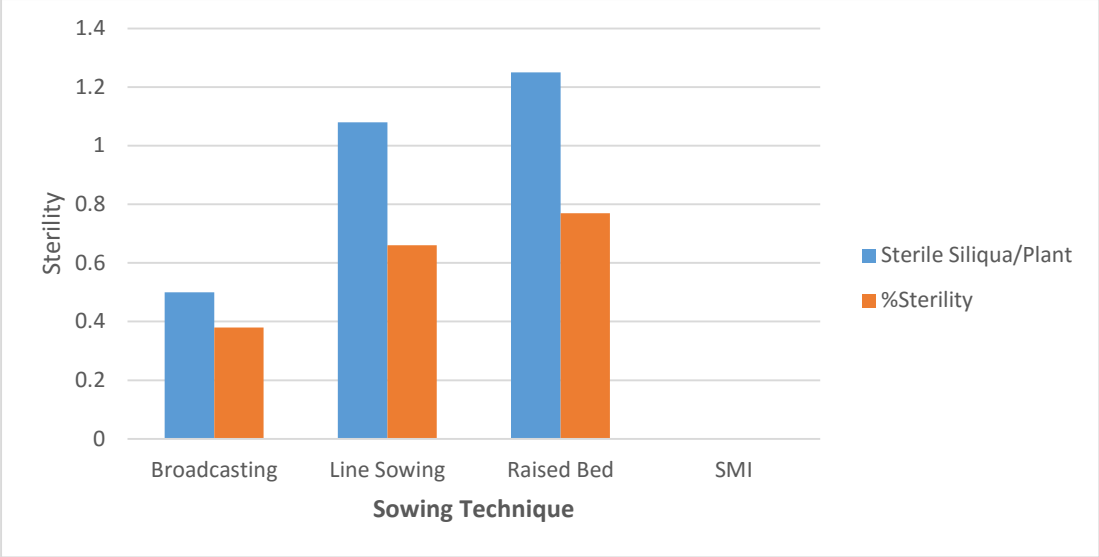


Figure 20. Effect of sowing technique on sterility of siliqua of mustard and rapeseed plant ($LSD_{0.05}$= 1.05 and 0.71)

4.2.2.2.3 Interaction effect of variety and sowing technique

Sterility percentage of siliqua of mustard and rapeseed plant was not significantly affected by the interaction of variety and sowing technique which is shown at Table 8. Highest sterility percentage (1.85%) was recorded at the combination of BARI Sarisha-15 and raised bed technique (V_3S_3) which was statistically similar with V_2S_2, V_3S_1, V_3S_2, V_3S_3, V_4S_1, V_4S_2 and V_4S_3. Lowest sterility percentage (0%) was recorded at V_1S_1, V_1S_2, V_1S_4, V_2S_1, V_2S_3, V_2S_4, V_3S_4 and V_4S_4 which was statistically similar with V_1S_3, V_2S_2, V_3S_1, V_3S_2, V_3S_3, V_4S_1 and V_4S_3.

4.2.3 Siliqua Length

4.2.3.1 Effect of variety

Siliqua length (cm) of mustard and rapeseed plant was significantly affected by variety (Appendix V and Figure 21). Biggest siliqua length (8.24 cm) was recorded at BARI Sarisha-13 and smallest siliqua length (4.21 cm) was observed at BARI Sarisha-11. BARI (1999) and Hossain et *al.* (1996) also reported that rapeseed and mustard varieties showed significant variations in respect of siliquae length.

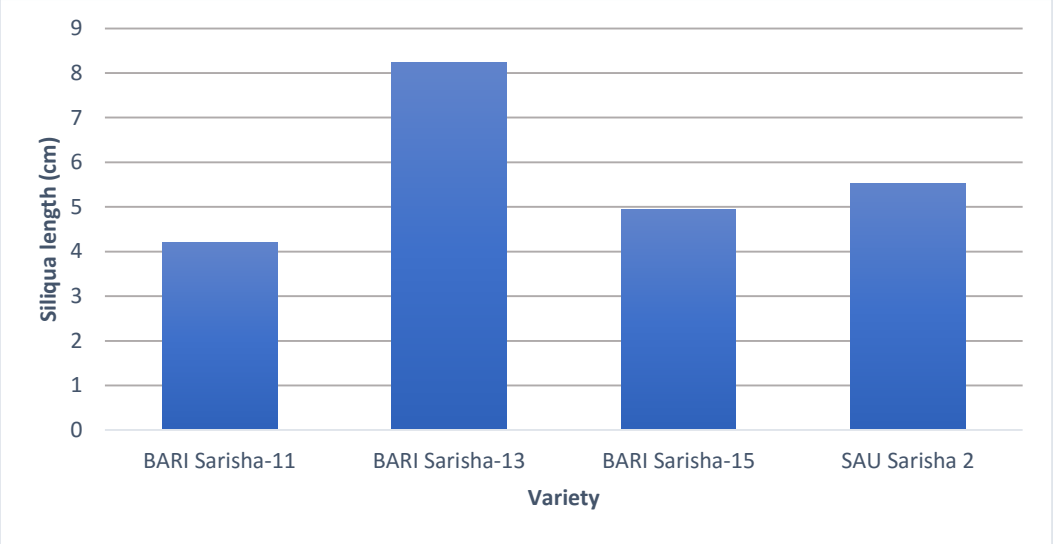


Figure 21. Effect of variety on siliqua length (cm) of mustard and rapeseed plant ($LSD_{0.05}$= 0.34)

4.2.3.2 Effect of sowing technique

Siliqua length of mustard and rapeseed plant was significantly affected by sowing technique (Appendix V and Figure 22). Biggest siliqua length (6.13 cm) was recorded at SMI technique. On the other hand, smallest siliqua length (5.57 cm) was observed at line sowing which was statistically similar with broadcast sowing (5.63 cm) and raised bed technique (5.6 cm). Hossain *et al.* (2013) found opposite result.

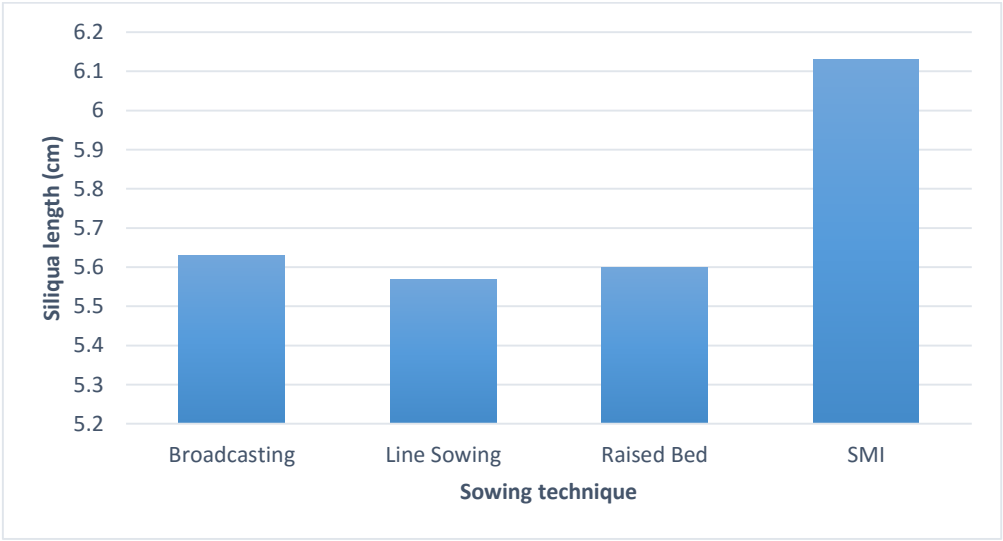


Figure 22: Effect of sowing technique on siliqua length (cm) of mustard and rapeseed plant ($LSD_{0.05}$= 0.34)

4.2.3.3 Interaction effect of variety and sowing technique

Siliqua length was not significantly affected by the interaction of variety and sowing technique which is shown at Table 8. Biggest siliqua length (8.99 cm) was recorded at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) and smallest siliqua length (3.92 cm) was observed at the combination of BARI Sarisha-11 and broadcast sowing technique (V_1S_1) which was statistically similar with V_1S_2, V_1S_3 and V_1S_4.

4.2.4 Number of seeds siliqua^{-1}

4.2.4.1 Effect of variety

Number of seeds siliqua^{-1} of mustard and rapeseed plant was significantly affected by variety (Appendix V and Figure 23). Maximum number of seeds siliqua^{-1} (24) was recorded at BARI Sarisha-13 and minimum number of seeds siliqua^{-1} (10.75) was observed at BARI Sarisha-11. Mondal *et al.* (1992) and Hossain *et al.* (1996) also reported that there was significant difference among the varieties with respect to number of seeds siliqua^{-1}.

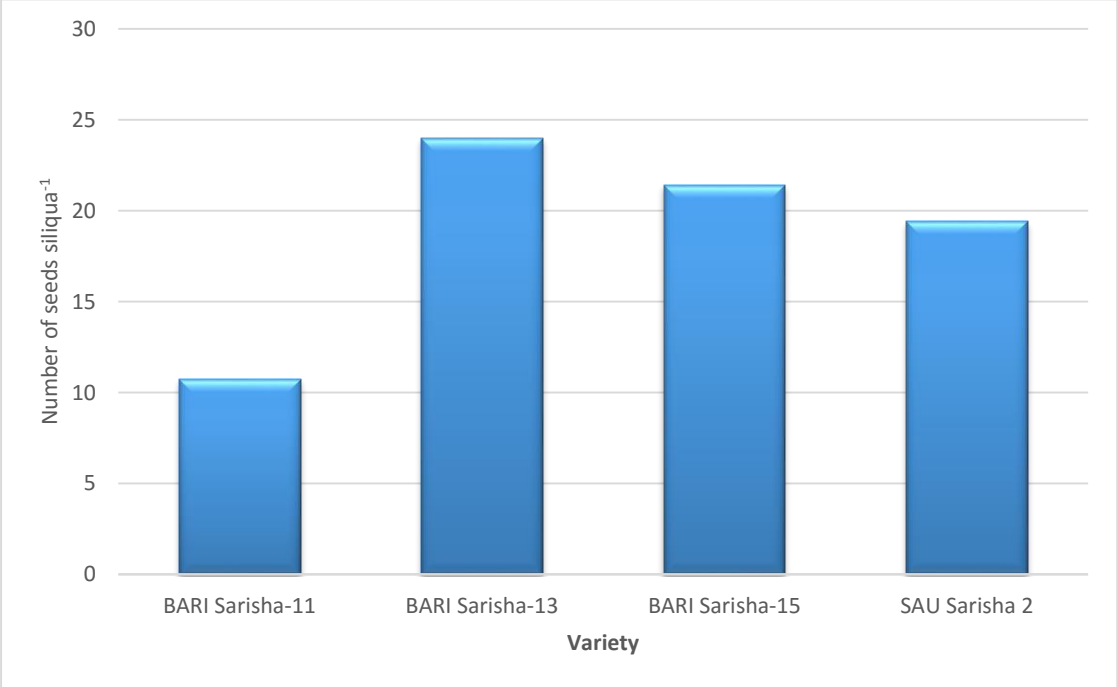


Figure 23. Effect of variety on number of seeds siliqua^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 1.55)

4.2.4.1 Effect of sowing technique

Number of seeds siliqua^{-1} of mustard and rapeseed plant was significantly affected by sowing technique (Appendix V and Figure 24). Maximum number of seeds siliqua^{-1} (23.08) was recorded at SMI technique and minimum number of seeds siliqua^{-1} (15.75) was observed at broadcast sowing technique.

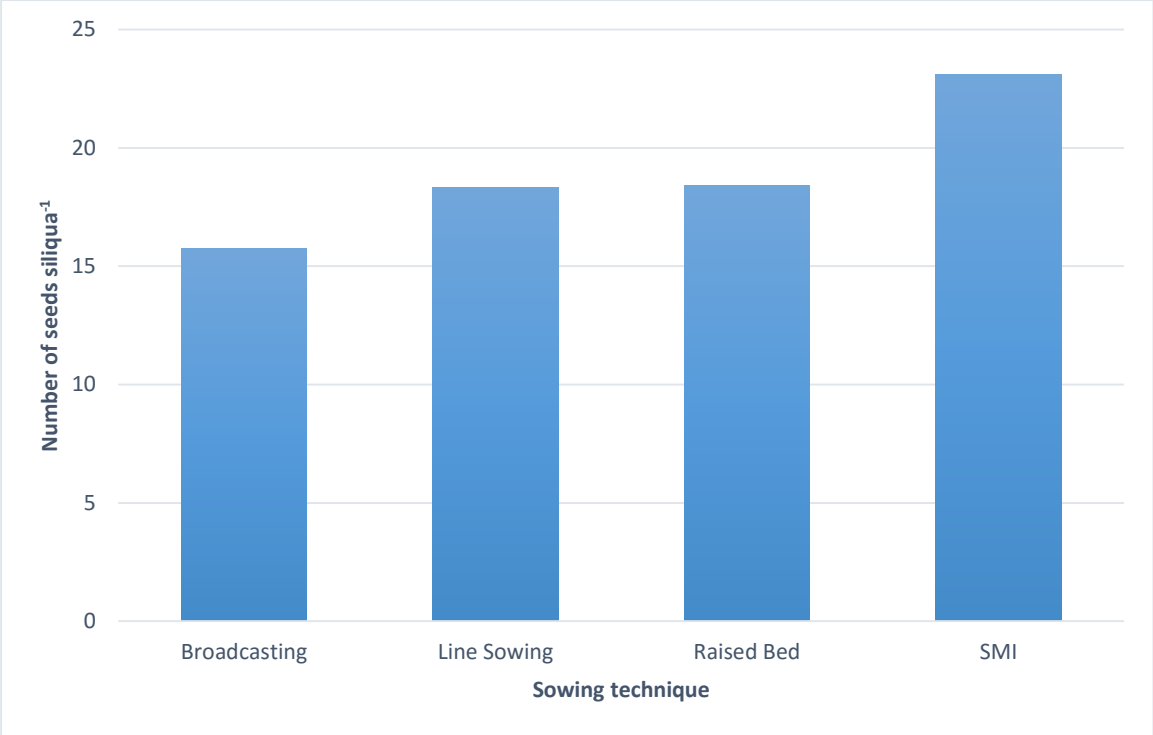


Figure 24. Effect of sowing technique on number of seeds siliqua^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 1.55)

4.2.4.3 Interaction effect of variety and sowing technique

Number of seeds siliqua^{-1} was significantly affected by the interaction of variety and sowing technique which is shown at Table 8. Maximum number of seeds siliqua^{-1} (30.33) was recorded at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) and minimum number of seeds siliqua^{-1} (9.67) was observed at the combination of BARI Sarisha-11 and broadcast sowing technique (V_1S_1) which was statistically similar with V_1S_2, V_1S_3, V_1S_4 and V_4S_1.

Table 8. Interaction effect of variety and sowing technique on no. of siliquae plant^{-1}, sterile siliquae plant^{-1}, %sterility, siliqua length and no. of seeds siliqua^{-1}

Treatments	No. of siliquae plant^{-1}	No. of sterile siliqua plant^{-1}	Sterility (%)	Siliqua length (cm)	No. of seeds siliqua^{-1}
V_1S_1	137.11 ij	0 b	0 b	3.92 f	9.67 f
V_1S_2	228.22 fg	0 b	0 b	4.26 ef	11.00 f
V_1S_3	295.89 e	1.00 ab	0.33 b	4.30 ef	11.00 f
V_1S_4	1179.67 a	0 b	0 b	4.38 ef	11.33 f
V_2S_1	79.33 k	0 b	0 b	8.26 b	21.33 c-e
V_2S_2	146.33 ij	1.00 ab	0.68 ab	7.73 b	21.67 c-e
V_2S_3	163.11 hi	0 b	0 b	7.97 b	22.67 cd
V_2S_4	862.33 b	0 b	0 b	8.99 a	30.33 a
V_3S_1	96.66 jk	1.00 ab	0.97 ab	4.87 de	19.67 de
V_3S_2	104.22 jk	1.00 ab	0.86 ab	4.88 de	21.67 c-e
V_3S_3	96.22 jk	1.67 ab	1.85 a	4.78 de	20.33 de
V_3S_4	415 d	0 b	0 b	5.25 cd	24.00 bc
V_4S_1	161.89 hi	1.00 ab	0.57 ab	5.47 cd	12.33 f
V_4S_2	203.22 gh	2.33 a	1.11 a	5.40 cd	19.00 e
V_4S_3	257.78 ef	2.33 a	0.90 ab	5.36 cd	19.67 de
V_4S_4	706.33 c	0 b	0 b	5.89 c	26.67 b
5% LSD	52.25	2.1	1.42	0.69	3.1
CV (%)	9.8	178	187.8	7.2	9.8

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.2.5 Shell yield

4.2.5.1 Effect of variety

Shell yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different variety (Appendix V and Figure 25). Highest shell yield (2.62 t ha^{-1}) was obtained at BARI Sarisha-13 and lowest shell yield (1.01 t ha^{-1}) was found at BARI Sarisha-15. Sultana *et al.* (2005) and Akhter (2005) also found the same result.

4.2.5.2 Effect of sowing technique

Shell yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing techniques (Appendix V and Figure 26). Highest shell yield (2.44 t ha^{-1}) was obtained at SMI techniques and lowest shell yield (1.38 t ha^{-1}) was found at broadcast sowing techniques. Hossain *et al.* (2013) was also found significant influence was found on shell yield due to sowing method.

4.2.5.3 Interaction effect of variety and sowing technique

Shell yield (t ha^{-1}) was significantly affected by the interaction of variety and sowing technique which is shown at Table 9. Highest shell yield (3.91 t ha^{-1}) was obtained at the combination of BARI Sarisha-13 and SMI technique (V_2S_4) and lowest shell yield (0.63 t ha^{-1}) was found at the combination of BARI Sarisha-15 and broadcast sowing technique (V_3S_1) which was statistically similar with V_3S_2.

4.2.6 Stover yield

4.2.6.1 Effect of variety

Stover yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different variety (Appendix V and Figure 25). Highest stover yield (6.95 t ha^{-1}) was obtained at BARI Sarisha-13 and lowest stover yield (3.77 t ha^{-1}) was found at BARI Sarisha-15.

4.2.6.2 Effect of sowing technique

Stover yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing techniques (Appendix V and Figure 26). Highest stover yield (6.62 t ha^{-1}) was obtained at SMI technique and lowest stover yield (3.72 t ha^{-1}) was found at broadcast sowing technique.

4.2.6.3 Interaction effect of variety and sowing technique

Stover yield (t ha^{-1}) was significantly affected by the interaction of variety and sowing technique which is shown at Table 9. Highest stover yield (8.76 t ha^{-1}) was obtained at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) which was statistically similar with V_1S_3. On the other hand, lowest stover yield

(2.8 t ha^{-1}) was found at the combination of BARI Sarisha-15 and broadcast sowing technique (V_3S_1).

4.2.7 Grain yield

4.2.7.1 Effect of variety

Grain yield (t ha^{-1}) of rapeseed plant was significantly affected by different variety (Appendix V and Figure 25). Highest grain yield (3.74 t ha^{-1}) was obtained at BARI Sarisha-11 and lowest grain yield (2.54 t ha^{-1}) was found at BARI Sarisha-15. Mendham *et al.* (1990) and Rahman (2002) also showed that seed yield was dissimilar due to varietal differences.

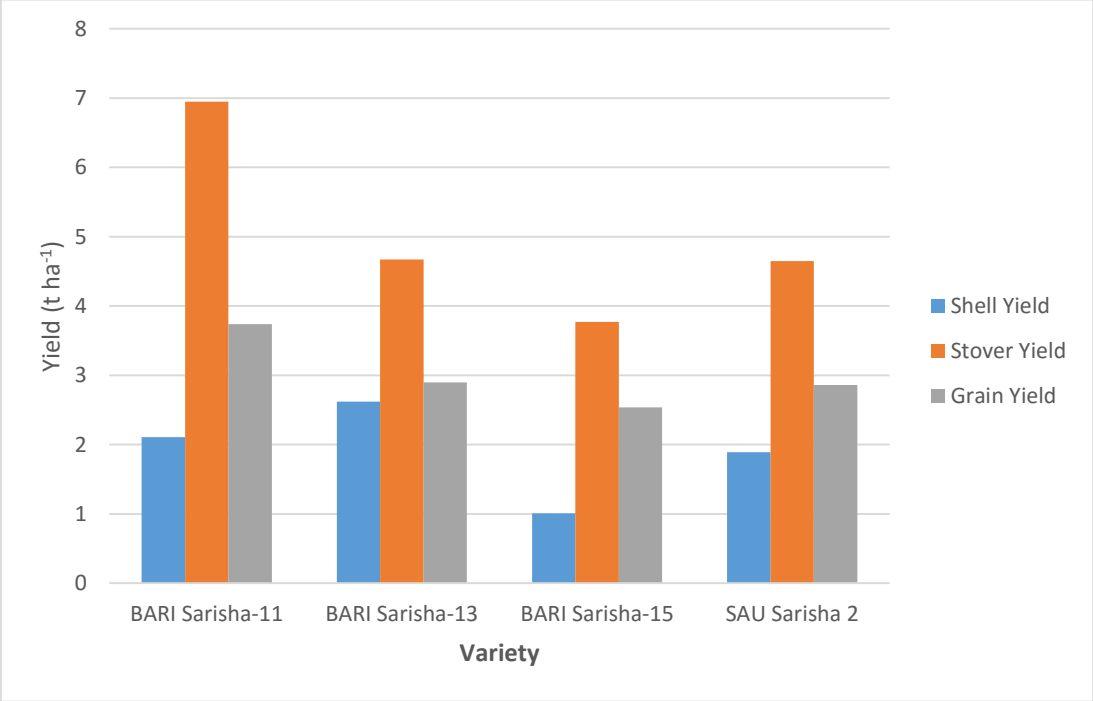


Figure 25. Effect of variety on shell, stover and grain yield of mustard and rapeseed plant ($LSD_{0.05}$= 0.12, 0.18 and 0.12 respectively)

4.2.7.2 Effect of sowing techniques

Grain yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing techniques (Appendix V and Figure 26). Highest grain yield (3.8 t ha^{-1}) was obtained at SMI technique and lowest grain yield (2.11 t ha^{-1}) was found at broadcast sowing technique. Hossain *et al.* (2013) and Sarkees (2013) also reported that sowing method had significant influence on seed yield.

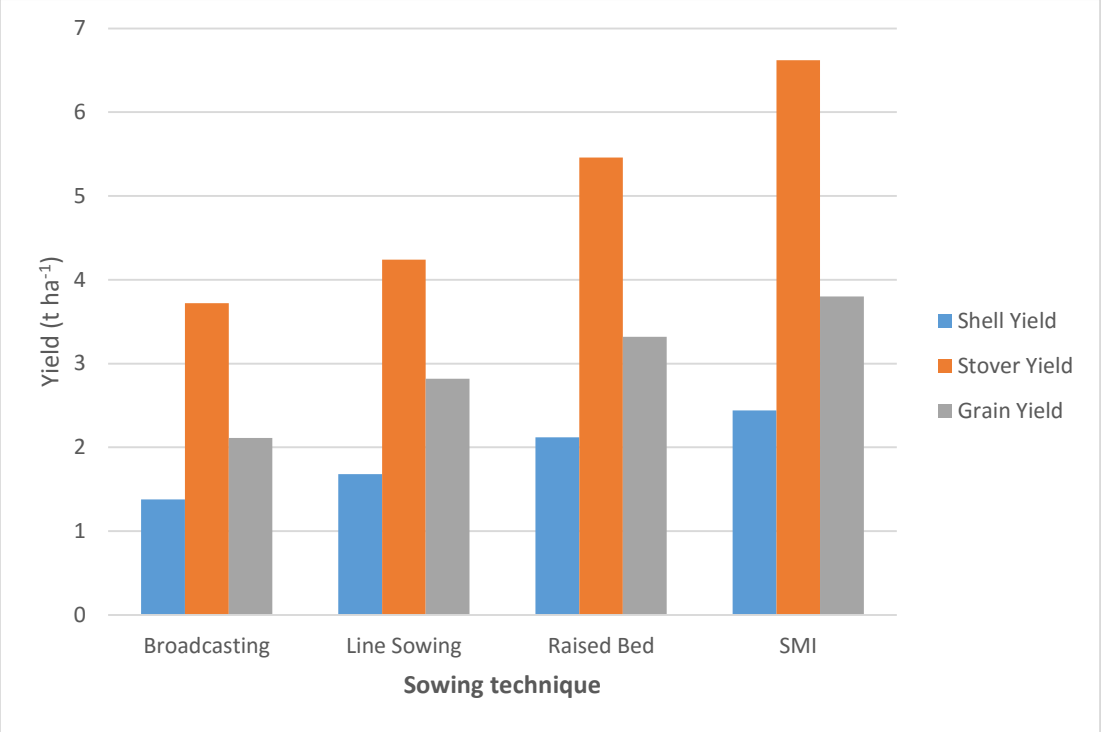


Figure 26. Effect of sowing technique on shell, stover and grain yield of mustard and rapeseed plant ($LSD_{0.05}$= 0.12, 0.18 and 0.12 respectively)

4.2.7.3 Interaction effect of variety and sowing technique

Grain yield (t ha^{-1}) was not significantly affected by the interaction of variety and sowing technique which is shown at Table 9. Highest grain yield (4.75 t ha^{-1}) was obtained at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) and lowest grain yield (1.47 t ha^{-1}) was found at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1). Khan and Agarwal (1985) also found the same result.

4.2.8 Biological yield

4.2.8.1 Effect of variety

Biological yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different variety (Appendix V and Figure 27). Highest biological yield (12.8 t ha^{-1}) was obtained at BARI Sarisha-11 and lowest biological yield (7.32 t ha^{-1}) was found at BARI Sarisha-15.

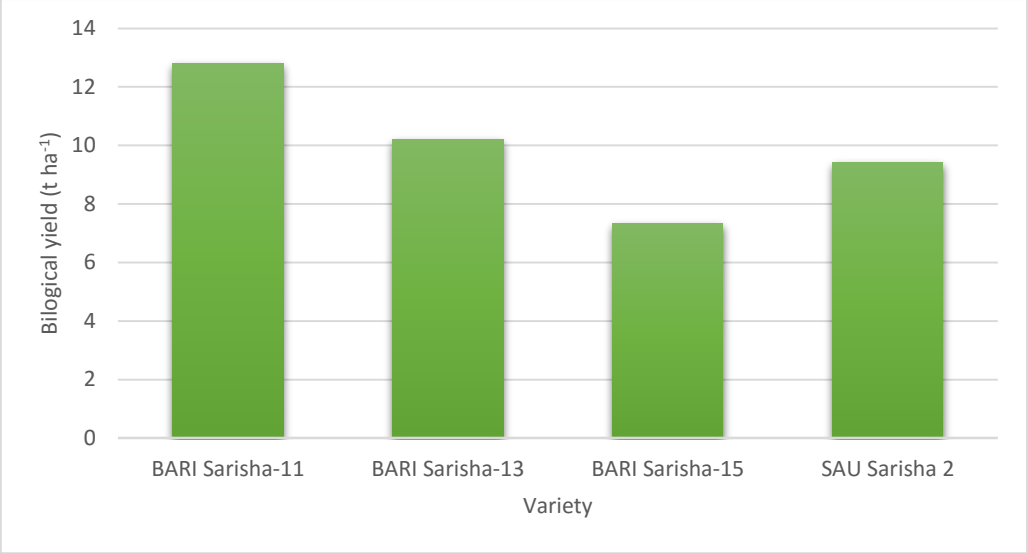


Figure 27. Effect of variety on biological yield of mustard and rapeseed plant ($LSD_{0.05}$= 0.26)

4.2.8.2 Effect of sowing technique

Biological yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing technique (Appendix V and Figure 28). Highest biological yield (12.86 t ha^{-1}) was obtained at SMI technique and lowest biological yield (7.21 t ha^{-1}) was found at broadcast sowing technique. Khan *et al.* (2000) also studied the result of biological yield as affected by different sowing methods. He also found the same result.

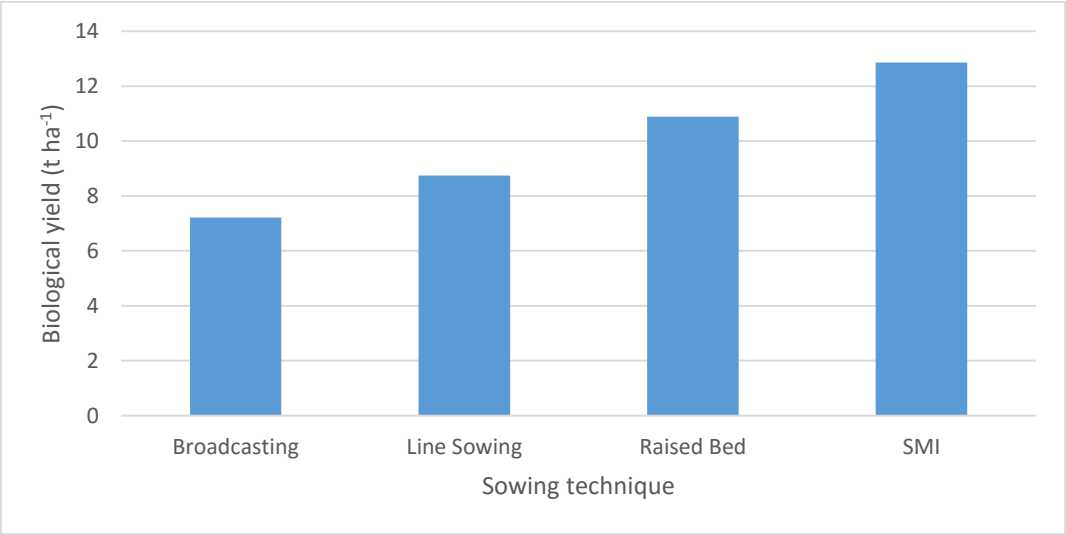


Figure 28: Effect of sowing technique on biological yield of mustard and rapeseed plant ($LSD_{0.05}$= 0.26)

4.2.8.3 Interaction effect of variety and sowing technique

Biological yield (t ha^{-1}) was significantly affected by the interaction of variety and sowing technique which is shown at Table 9. Highest biological yield (16.06 t ha^{-1}) was obtained at the combination of BARI Sarisha-11 and SMI technique (V_1S_4). On the other hand, lowest biological yield (5.28 t ha^{-1}) was found at the combination of BARI Sarisha-15 and broadcast sowing technique (V_3S_1).

4.2.9 Harvest Index

4.2.9.1 Effect of variety

Harvest Index (%) of mustard and rapeseed plant was significantly affected by different variety (Appendix V and Figure 29). Highest harvest index (34.84%) was observed at BARI Sarisha-15 and lowest harvest index (28.04%) was obtained at BARI Sarisha-13. Islam *et al.* (1994) also reported that varieties had significant effect on harvest index (%) of mustard.

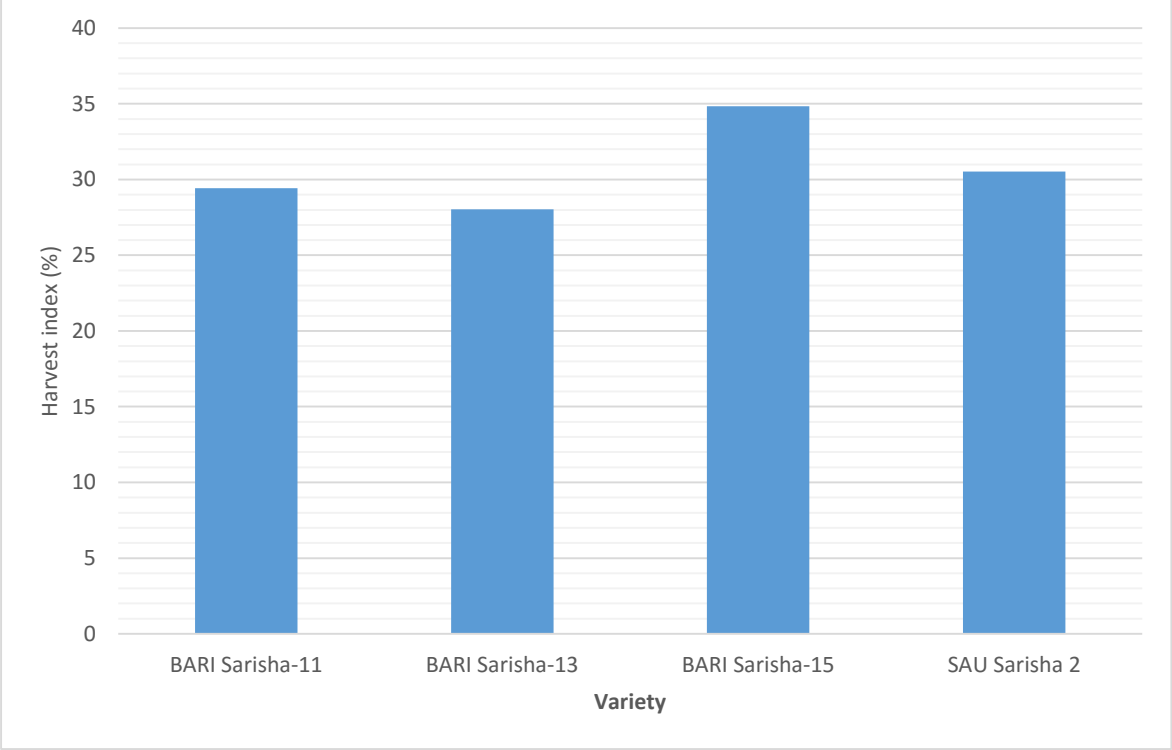


Figure 29. Effect of variety on harvest index of mustard and rapeseed plant ($LSD_{0.05}$= 0.94)

4.2.9.1 Effect of sowing technique

Harvest Index of rapeseed plant was significantly affected by different sowing techniques (Appendix V and Figure 30). Highest harvest index (32.45%) was observed at line sowing and lowest harvest index (29.43%) was obtained at broadcast sowing which was statistically similar (29.83%) with SMI technique.

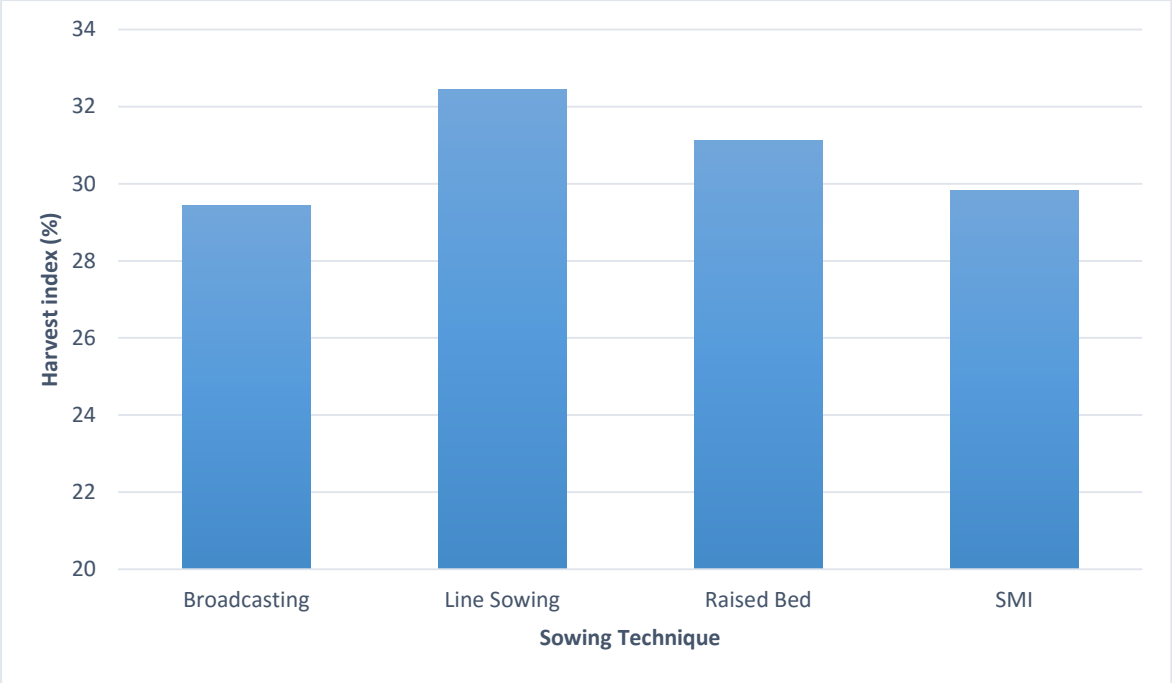


Figure 30. Effect of sowing technique on harvest index of mustard and rapeseed plant ($LSD_{0.05}$= 0.94)

4.2.9.3 Interaction effect of variety and sowing technique

Harvest Index was significantly affected by the interaction of variety and sowing technique which was shown at Table 9. Highest harvest index (36.45%) was obtained at the combination of BARI Sarisha-15 and line sowing (V_3S_2) which was statistically similar with V_3S_1 and V_3S_3. Lowest harvest index (22.12%) was found at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1).

Table 9. Interaction effect of variety and sowing technique on yield and Harvest Index of rapeseed plant

Treatments	Shell yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
V_1S_1	1.50 hi	4.98 d	2.70 gh	9.18 f	29.44 hi
V_1S_2	1.97 ef	5.53 c	3.51 c	11.01 d	31.88 d-f
V_1S_3	2.42 bc	8.53 a	4.00 b	14.95 b	26.78 j
V_1S_4	2.55 b	8.76 a	4.75 a	16.06 a	29.56 hi
V_2S_1	1.72 gh	3.48 f	1.47 k	6.67 h	22.12 k
V_2S_2	2.24 cd	3.89 e	2.84 fg	8.96 f	31.65 d-g
V_2S_3	2.61 b	4.67 d	3.18 de	10.46 e	30.39 f-h
V_2S_4	3.91 a	6.66 b	4.11 b	14.68 b	27.99 ij
V_3S_1	0.63 k	2.80 g	1.85 j	5.28 i	35.03 ab
V_3S_2	0.71 k	3.65 ef	2.50 hi	6.86 h	36.45 a
V_3S_3	1.45 ij	3.87 e	2.81 fg	8.13 g	34.59 a-c
V_3S_4	1.23 j	4.76 d	2.99 ef	8.98 f	33.29 b-d
V_4S_1	1.69 gh	3.62 ef	2.40 i	7.71 g	31.13 e-h
V_4S_2	1.80 fg	3.90 e	2.42 i	8.12 g	29.8 g-i
V_4S_3	1.98 ef	4.75 d	3.28 cd	10.01 e	32.73 c-e
V_4S_4	2.07 de	6.32 b	3.34 cd	11.74 c	28.46 ij
$LSD_{(0.05)}$	0.23	0.36	0.24	0.53	1.88
CV (%)	7.4	4.4	4.9	3.2	3.7

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI

4.2.10 Thousand Seed Weight

4.2.10.1 Effect of variety

Thousand seed weight (g) was significantly affected by different variety (Appendix V and Figure 31). Highest weight of thousand seeds (3.94 g) were obtained at BARI Sarisha-13 which was statistically similar (3.89 g) with BARI Sarisha-11. Lowest weight of thousand seeds (3.31 g) were recorded at BARI Sarisha-15 which was statistically similar (3.37 g) with SAU Sarisha 2. Mondal and Wahab (2001) also found that weight of 1000 seeds of rapeseed and mustard varied from variety to variety and species to species.

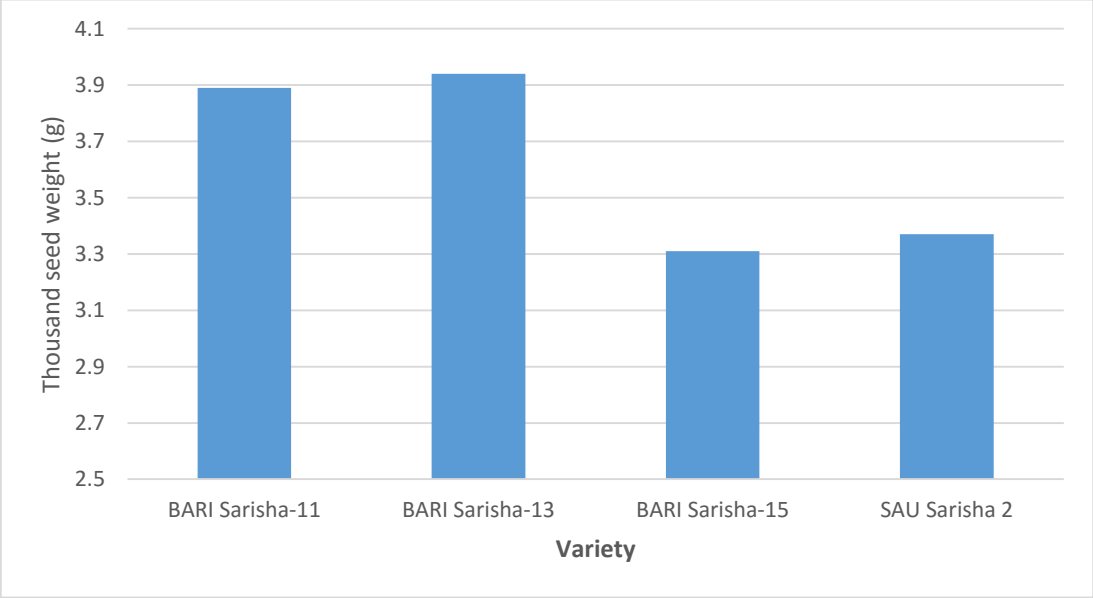


Figure 31. Effect of variety on thousand seed weight of mustard and rapeseed plant ($LSD_{0.05}$= 0.23)

4.2.10.1 Effect of sowing technique

Thousand seed weight (g) was not significantly affected by different sowing techniques (Appendix V and Figure 32). Highest weight of thousand seeds (3.8 g) were obtained at raised bed technique and lowest weight of thousand seeds (3.52 g) were recorded at broadcast sowing technique which was statistically similar with line sowing (3.64 g) and SMI technique (3.55 g). Sarkees (2013) also found similar result but Hossain *et al.* (2013) found opposite result.

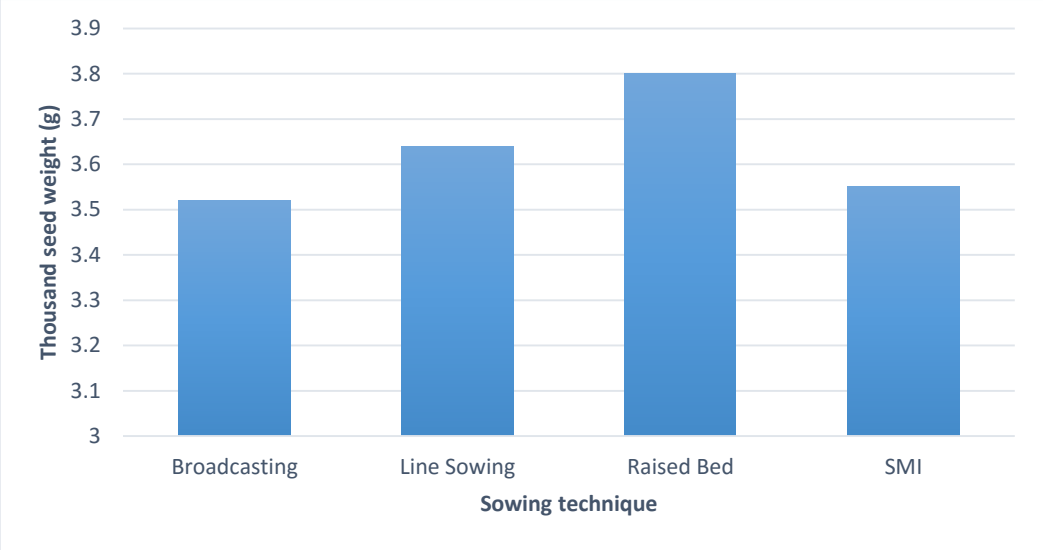


Figure 32. Effect of sowing technique on thousand seed weight of mustard and rapeseed plant ($LSD_{0.05}$= 0.23)

4.2.10.3 Interaction effect of variety and sowing technique

Thousand seed weight (g) of mustard and rapeseed plant was not significantly affected by the interaction of variety and sowing technique which is shown at Table 10. Highest weight of thousand seed (4.26 g) was obtained at the combination of BARI Sarisha-11 and raised bed tecnique (V_1S_3) which was statistically similar with V_1S_2, V_2S_1, V_2S_2, V_2S_3 and V_2S_4. Lowest weight of thousand seed (3.01 g) of mustard and rapeseed plant was found at the combination of SAU Sarisha 2 and SMI technique (V_4S_4) which was statistically similar with V_3S_4 and V_4S_1.

4.2.11 Oil Percentage

4.2.11.1 Effect of variety

Oil percentage of mustard and rapeseed plants seed was significantly affected by variety (Appendix V and Figure 33). Highest oil percentage (40.66%) was obtained at BARI Sarisha-15 and lowest oil percentage (39.17%) was recorded at BARI Sarisha-11. Jahan and Zakaria (1997) and Hossain *et al.* (1996) also found oil content variation due to different variety.

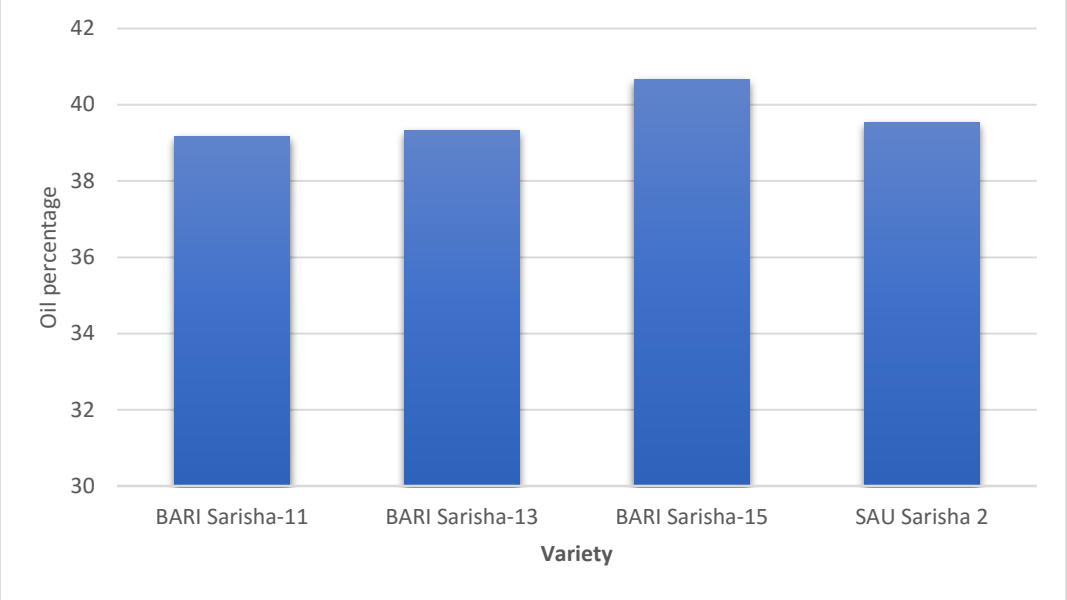


Figure 33. Effect of variety on oil percentage of mustard and rapeseed plant ($LSD_{0.05}$= 0.052)

4.2.11.2 Effect of sowing technique

Oil percentage of mustard and rapeseed plants seed was significantly affected by different sowing technique (Appendix V and Figure 34). Highest oil percentage (40.01%) was obtained at line sowing and lowest oil percentage (39.24%) was recorded at raised bed technique.

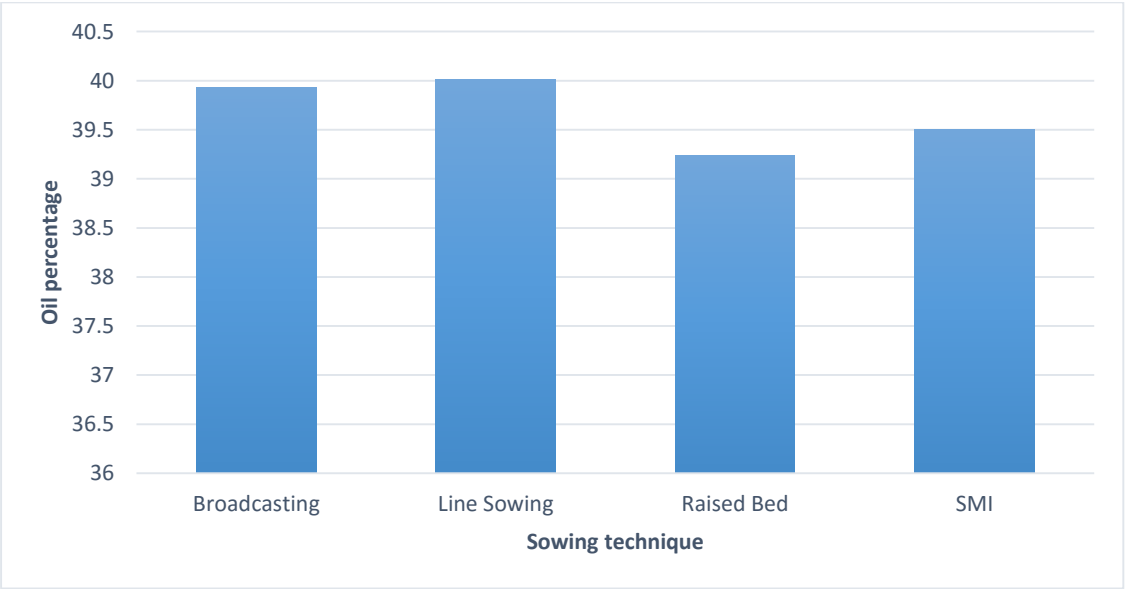


Figure 34. Effect of sowing technique on oil percentage of mustard and rapeseed plant ($LSD_{0.05}$= 0.052)

4.2.11.3 Interaction effect of variety and sowing technique

Oil percentage of mustard and rapeseed plants seed was significantly affected by the interaction of variety and sowing technique which is shown at Table 10. Highest oil percentage (41.73%) was obtained at the combination of BARI Sarisha-15 and line sowing (V_3S_2). On the other hand, lowest oil percentage (38.11%) of mustard and rapeseed plant was found at the combination of BARI Sarisha-11 and SMI technique (V_1S_4). Singh *et al*. (1999) also found oil content variation due to different variety and different method.

4.2.12 Yield day^{-1}

4.2.12.1 Effect of variety

Yield day^{-1} (kg) was significantly affected by different variety of mustard and rapeseed plant (Appendix V and Figure 35). Highest yield day^{-1} (33.08 kg) was recorded at BARI Sarisha-11 and lowest yield day^{-1} (26.75 kg) was observed at BARI Sarisha-15.

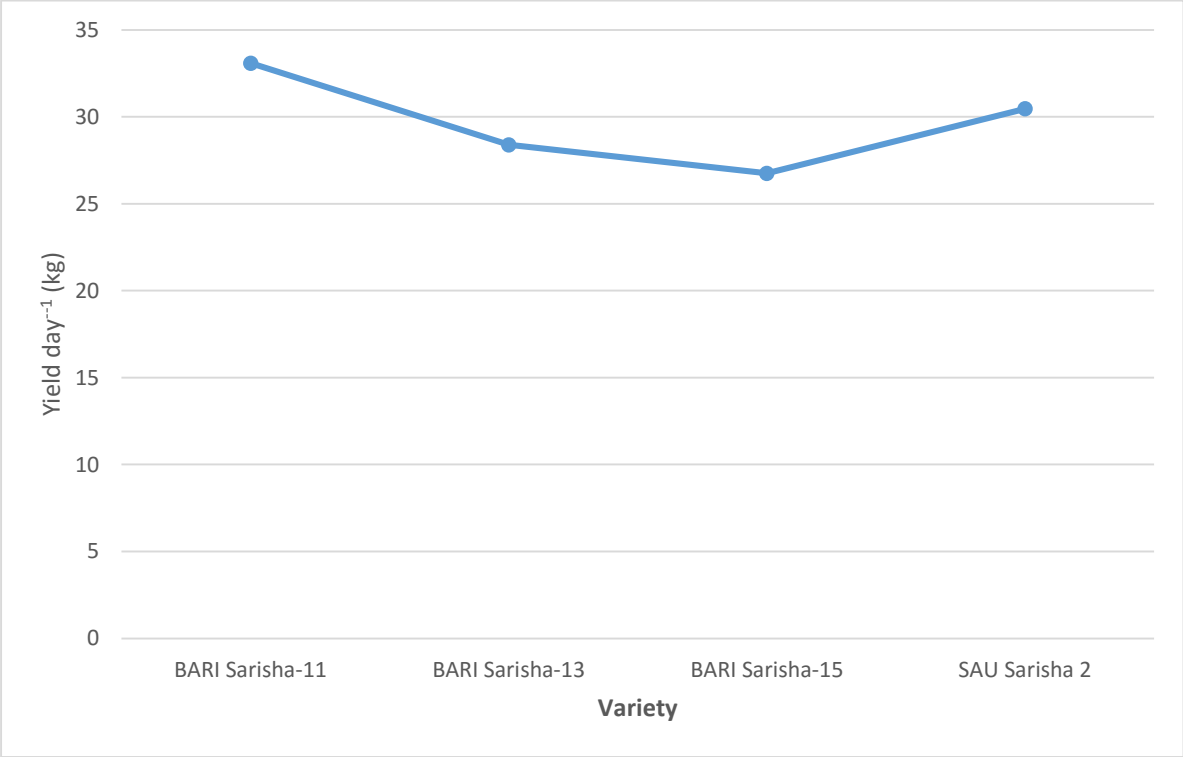


Figure 35. Effect of variety on yield day^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 1.15)

4.2.13.2 Effect of sowing technique

Yield day^{-1} (kg) of mustard and rapeseed plant was significantly affected by different sowing technique (Appendix V and Figure 36). Highest yield day^{-1} (35.41 kg) was recorded at SMI technique and lowest yield day^{-1} (22.05 kg) was observed at broadcast sowing technique.

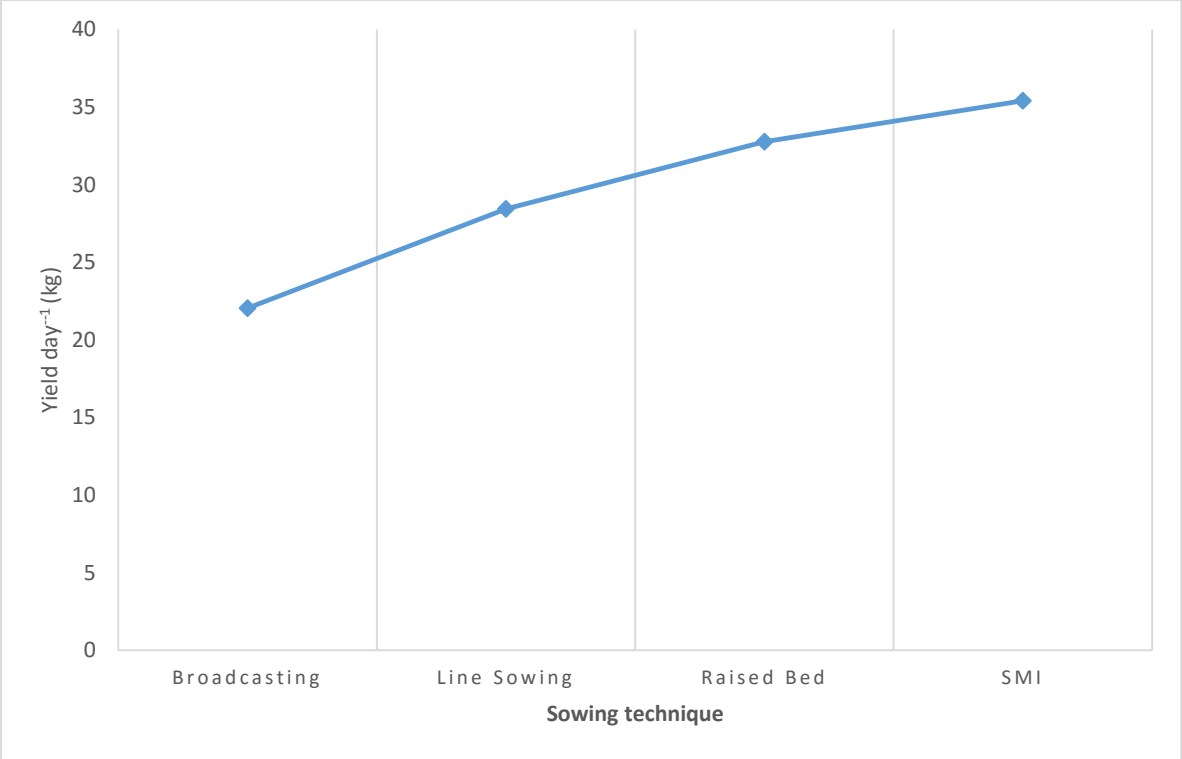


Figure 36: Effect of sowing technique on yield day^{-1} of mustard and rapeseed plant ($LSD_{0.05}$= 1.15)

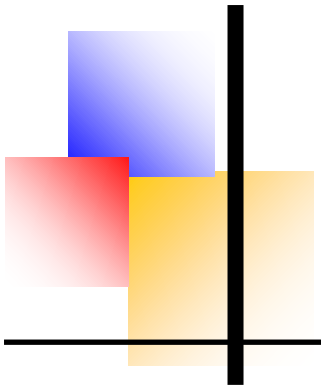
4.2.12.3 Interaction effect of variety and sowing technique

Yield day^{-1} (kg) of mustard and rapeseed plant was significantly affected by the interaction of variety and sowing technique which is shown at Table 10. Highest yield day^{-1} (40.25 kg) was obtained at the combination of BARI Sarisha-11 and SMI technique (V_1S_4) which was statistically similar (38.38 kg) with V_2S_4. On the other hand, lowest yield day^{-1} (15.35 kg) of mustard and rapeseed plant was found at the combination of BARI Sarisha-13 and broadcast sowing technique (V_2S_1).

Table 10. Interaction effect of variety and sowing technique on thousand seed weight, oil percentage, growth duration and yield day^{-1} of mustard and rapeseed plant

Treatments	Thousand seed weight (g)	Oil percentage	Growth duration (day)	Yield day^{-1} (kg)
V_1S_1	3.72 b-f	39.65 ef	108 d	25.03 g
V_1S_2	3.83 a-e	40.14 c	111 c	31.59 cd
V_1S_3	4.26 a	38.77 k	113 b	35.43 b
V_1S_4	3.75 b-e	38.11 l	118 a	40.25 a
V_2S_1	3.83 a-e	39.01 i	96 j	15.35 i
V_2S_2	3.97 a-c	39.25 h	99 i	28.65 ef
V_2S_3	3.91 a-d	39.62 f	102 f	31.18 cd
V_2S_4	4.06 ab	39.35 h	107 e	38.38 a
V_3S_1	3.19 gh	41.08 b	90 n	20.56 h
V_3S_2	3.12 h	41.73 a	92 m	27.21 fg
V_3S_3	3.55 c-h	38.83 jk	95 k	29.61 de
V_3S_4	3.39 e-i	41.01 b	101 g	29.6 de
V_4S_1	3.32 f-i	39.98 d	88 o	27.27 fg
V_4S_2	3.65 c-g	38.91 ij	92 m	26.30 g
V_4S_3	3.49 d-h	39.75 e	94 l	34.86 b
V_4S_4	3.01 i	39.51 g	100 h	33.40 bc
$LSD_{(0.050}$	0.46	0.1	0	2.3
CV (%)	7.6	0.2	0	4.6

V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2, S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI



Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

The present work was done at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from Robi, 2013-14 to to investigate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques.

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 3 m x 3 m and total number of plot was 48. There were 16 treatments (4 Variety x 4 Sowing technique). The variety treatments were V_1= BARI Sarisha-11, V_2= BARI Sarisha-13, V_3= BARI Sarisha-15, V_4= SAU Sarisha 2. Sowing technique treatments were S_1= Broadcasting, S_2= Line Sowing, S_3= Raised Bed, S_4= SMI.

The data on crop growth parameters like plant height, Number of leaves plant^{-1}, dry matter, CGR, RGR, Number of primary branches and secondary branches plant^{-1} and growth duration were recorded at different growth stages. Yield parameters like number of siliquae plant^{-1}, sterile siliquae plant^{-1}, %sterility, siliqua length, seeds siliqua^{-1}, 1000-grains weight, stover yield, shell yield, grain yield and yield day^{-1} were recorded after harvest. The oil content of seeds was determined by "Soxhlet" method in percentage. This was done in Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701. Data were analyzed using the CROPSTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by 5% level of significance (Gomez and Gomez, 1984).

Results showed that, At 30 DAS, SAU Sarisha 2 scored the highest plant height (33.64 cm) and the lowest plant height (25.72 cm) was observed at BARI Sarisha-13. BARI Sarisha-11 showed the tallest plant height (96.28, 123.38. 133.03 and 132.88 cm) at 45, 60, 75 DAS and at harvest. On the other hand, BARI Sarisha-13 showed the shortest plant height (69.94, 93.23, 100.47 and 100.43 cm) at 45, 60, 75 DAS and at harvest. At 30 DAS, highest leaf number (7.36) was observed at SAU Sarisha 2 and lowest leaf number (6.47) was

observed both at BARI Sarisha-13 and BARI Sarisha-15. At 45, 60 and 75 DAS and at harvest, highest leaf number (61.75, 96.36, 94.11 and 43.92) was observed at SAU Sarisha 2, BARI Sarisha-15, SAU Sarisha 2, and BARI Sarisha-11 respectively. On the other hand, lowest leaf number (24.53, 61.42, 57.44 and 16.42) was observed at BARI Sarisha-13. BARI Sarisha-11 scored the maximum dry matter production (1.07, 11.44, 21.3 and 25.87 g) throughout the life cycle (30, 45, 60 and 75 DAS). At 30 and 45 DAS, minimum dry matter accumulation (0.63 and 6.69) was recorded at BARI Sarisha-13. At 60 and 75 DAS, minimum dry matter accumulation (13.33 and 17.91 g) was recorded at BARI Sarisha-15. At 30-45, 45-60 and 60-75 DAS, highest CGR (0.691, 0.658 and 0.604 g plant^{-1} day^{-1}) was found at V_1, V_1 and V_4 respectively and lowest CGR (0.405, 0.332 and 0.243 g plant^{-1} day^{-1}) was found at V_2, V_4 and V_2 respectively. At 30-45, 45-60 and 60-75 DAS, highest RGR (0.161, 0.052 and 0.035 g g^{-1} day^{-1}) was found at V_3, V_2 and V_4, respectively. At 30-45 DAS, lowest RGR (0.15 g g^{-1} day^{-1}) was found at V_4. At 45-60 DAS, lowest RGR (0.032 g g^{-1} day^{-1}) was found both at V_3 and V_4. At 60-75 DAS, lowest RGR (0.014 g g^{1} day^{-1}) was found at V_2. At 30 and 45 DAS, maximum number of primary branches (3.25 and 8.25) was achieved by V_4 and V_3 respectively. At 60 DAS, maximum number of primary branches (8.39) was recorded both at V_3 and V_4. At 75 DAS and at harvest, maxmum number of primary branches (9.14) was found at V_3. V_2 scored minimum number of primary branches (1.42, 4.67, 6.31, 6.5 and 6.5) throughout the lifecycle. At 45, 60 and 75 DAS and at harvest, maximum number of secondary branches (7.56, 23.06, 25.92 and 28.11) was achieved at V_1. At 45 DAS minimum number of secondary branches were observed at V_3. At 60 and 75 DAS and at harvest, minimum number of secondary branches (12.89, 16.56 and 17.72) were achieved by V_2. Maximum growth duration (112.5 day) was recorded at V_1 and minimum growth duration (93.5 day) was recorded at V_4.

V_1 scored the highest number (460.22) of silquae plant^{-1} and V_3 scored the lowest number (178.03) of siliquae plant^{-1}. Maximum number (1.42) of sterile siliquae plant^{-1} was recorded at V_4 and minimum number (0.25) of sterile silquae plant^{-1} was observed both at V_1 and V_2. Highest sterility percentage (0.92%) was

recorded at V_3 and lowest sterility percentage (0.08%) was observed at V_1. Maximum siliqua length (8.24 cm) was scored at V_2 and minimum siliqua length (4.21 cm) was recorded at V_1. Maximum number of seeds siliqua^{-1} (24) was recorded at V_2 and minimum number of seeds siliqua^{-1} (10.75) was recorded at V_1. V_2 scored the highest shell yield (2.62 t ha^{-1}) and V_3 scored the lowest shell yield (1.01 t ha^{-1}). V_1 scored the highest stover yield (6.95) and V_3 scored the lowest stover yield (3.77 t ha^{-1}). Highest grain yield (3.74 t ha^{-1}) was obtained at V_1 and lowest grain yield (2.54 t ha^{-1}) was obtained at V_3. V_1 scored the highest biological yield (12.8 t ha^{-1}) and V_3 scored the lowest biological yield (7.32 t ha^{-1}). Maximum harvest index (34.84%) was recorded at V_3 and minimum harvest index (28.04%) was recorded at V_2. Maximum weight of 1000-seed (3.94 g) was found at V_2 and minimum weight of 1000-seed (3.31 g) was found at V_3. Maximum oil percentage (40.66%) was gained at V_3 and minimum oil percentage (39.17%) was gained at V_1. Maximum yield day^{-1} (33.08 kg) was recorded at V_1 and minimum yield day^{-1} (26.75 kg) was achieved by V_3.

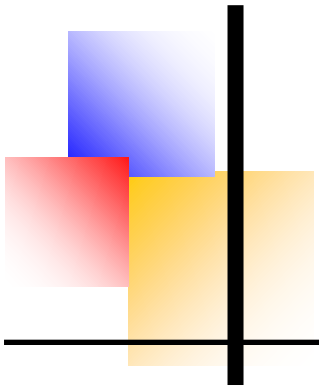
In terms of sowing technique, at 30, 45 and 60 DAS, S_3 showed the tallest plant height (34.86, 99.64 and 113.49 cm) and S_4 showed the shortest plant height (18.25, 66 and 103.24 cm). At 75 DAS and at harvest S_4 showed the tallest plant height (120.88 and 121.31 cm) and S_2 showed the shortest plant height (105.11 and 104.87 cm). At 30, 45, 60 and &75 DAS and at harvest, S_2, S_4, S_4, S_4 and S_4 showed the maximum leaf number (7.06, 59.25, 142.17, 201.81 and 78.58 respectively). On the other hand, S_1, S_1, S_1, S_2 and S_1 showed the minimum leaf number (6.64, 31.06, 51, 30 and 14 respectively). At 30 DAS, maximum dry matter (1.2 g) was produced at S3 and minimum dry matter (0.51 g) was produced at S_4. At 45, 60 and 75 DAS, maximum dry matter (14.85, 28.68 and 36.44 g) was produced at S_4 and minimum dry matter (4.42, 6.68 and 9.55 g) was produced at S_1. On 30-45, 45-60 and 60-75 DAS, highest CGR (0.956, 0.922 and 0.518 g plant^{-1} day^{-1}) was scored at S_4. Lowest CGR (0.253, 0.151 and 0.192 g plant^{-1} day^{-1}) was found at S_1. On 30-45, 45-60 and 60-75 DAS, highest RGR (0.224, 0.048 and 0.024 g g^{-1} day^{-1}) was recorded at S_4, S_2 and S_2. At 30-45 DAS, lowest RGR (0.132 g g^{-1} day^{-1}) was found both at S_1 and S_2. On 45-60 DAS,

lowest RGR (0.029 g g^{-1} day^{-1}) was found at S_1. At 60-75 DAS, lowest RGR (0.022 g g^{-1} day^{-1}) was found both at S_1 and S_3. At 30 DAS, maximum number of primary branches (3.17) were recorded at S_3 and minimum number of primary branches (2.25) were found at S_1. At 45, 60 and 75 DAS and at harvest, maximum number of primary branches (7.58, 10.7, 11.14 and 11.14) were recorded at S_4 and minimum number of primary branches (5.5, 5.58, 5.92 and 5.92) were found at S_1. At 45, 60 and 75 DAS and at harvest, S_4 scored the maximum number of secondary branches (6.39, 41.11, 47.31 and 51.08) and S_1 scored the minimum number of secondary branches (1.22, 8.5, 8.78 and 8.72). Maximum growth duration (106.5 days) was recorded at S_4 and minimum growth duration (95.5 days) was recorded at S_1.

S_4 scored the highest number of silquae $plant^{-1}$ (790.83) and S_1 scored the lowest number of siliquae $plant^{-1}$ (118.75). Maximum number of sterile siliquae $plant^{-1}$ (1.25) was recorded at S_3 and minimum number of sterile silquae $plant^{-1}$ (0) was observed at S_4. Highest sterility percentage (0.77%) was recorded at S_3 and lowest sterility percentage (0) was observed at S_4. Maximum siliqua length (6.13 cm) was scored at S_4 and minimum siliqua length (5.57 cm) was recorded at S_2. Maximum number of seeds $siliqua^{-1}$ (23.08) was recorded at S_4 and minimum number of seeds $siliqua^{-1}$ (15.75) was recorded at S_1. S_4 scored the highest shell yield (2.44 t ha^{-1}) and S_1 scored the lowest shell yield (1.38 t ha^{-1}). S_4 scored the highest stover yield (6.62 t ha^{-1}) and S_1 scored the lowest stover yield (3.72 t ha^{-1}). Highest grain yield (3.8 t ha^{-1}) was obtained at S_4 and lowest grain yield (2.11 t ha^{-1}) was obtained at S_1. S_4 scored the highest biological yield (12.86 t ha^{-1}) and S_1 scored the lowest biological yield (7.21 t ha^{-1}). Maximum harvest index (32.45%) was recorded at S_2 and minimum harvest index (29.43%) was recorded at S_1. Maximum weight of 1000-seed (3.8 g) was found at S_3 and minimum weight of 1000-seed (3.52 g) was found at S_1. Maximum oil percentage (40.01%) was gained at S_2 and minimum oil percentage (39.24%) was gained at S_3. Maximum yield day^{-1} (35.41 kg) was recorded at S_4 and minimum yield day^{-1} (22.05 kg) was achieved by S_1.

In terms of Interaction effect of variety and sowing technique, at 30 and 45 DAS tallest plant height (42.11 and 113 cm) was found at V_1S_1 and V_1S_3 respectively. On the other hand shortest plant height (16.89 and 46.33 cm) was observed at V_1S_4 and V_2S_4 respectively. At 60 and 75 DAS and at harvest V_1S_3 showed the tallest plant height (136.26, 144.11 and 143.58 cm) and V_2S_2 scored the shortest plant height (80.58, 87.56 and 87.31 cm). At 30, 45, 60 and &75 DAS and at harvest, V_1S_2, V_4S_2, V_3S_4, V_4S_4 and V_1S_4 showed the maximum leaf number (8, 73.33, 167.67, 268.89 and 112.67 respectively). On the other hand, V_2S_1 scored the minimum leaf number (6, 10.78, 26.44, 8.11 and 3). At 30 DAS maximum dry matter (1.7 g) was accumulated at V_1S_3 and minimum dry matter (0.45 g) was accumulated at V_3S_4. At 45, 60 and 75 DAS, maximum dry matter (19.2, 35.12 and 39.93 g) was produced at V_1S_4 and minimum dry matter (3.43, 6.42 and 7.68 g) was produced at V_2S_1. On 30-45, 45-60 and 60-75 DAS, highest CGR (1.242, 1.178 and 0.884 g plant^{-1} day^{-1}) was scored at V_1S_4, V_2S_4 and V_4S_4. Lowest CGR (0.19, 0.11 and 0.084 g plant^{-1} day^{-1}) was found at V_2S_1, V_1S_1 and V_2S_1. On 30-45 DAS, highest RGR (0.234 g g^{-1} day^{-1}) was recorded at V_1S_4 and lowest RGR (0.098 g g^{-1} day^{-1}) was found at V_1S_2. On 45-60 DAS, highest RGR (0.079 g g^{-1} day^{-1}) was found at V_1S_2 and lowest RGR (0.019 g g^{-1} day^{-1}) was found at V_1S_2, V_2S_1 and V_2S_4. At 30, 45, 60 and 75 DAS and at harvest, maximum number of primary branches (4, 9.33, 11.67, 12.67 and 11.67) were recorded at V_4S_3, V_3S_4, V_2S_4, V_2S_4 and V_3S_4. At 30 DAS, minimum number of primary branches (1) were found at V_2S_2. At 45 DAS, minimum number of primary branches (3.67) were found both at V_2S_1 and V_2S_2. At 60 and 75 DAS and at harvest, minimum number of primary branches (3.45, 4.44 and 4.33) were found at V_2S_1. At 45, 60 and 75 DAS and at harvest, V_1S_4 scored the maximum number of secondary branches (13.89, 52, 62 and 70.33). At 45 DAS, minimum number of secondary branches (0) were recorded both at V_3S_2 and V_3S_3. At 60 DAS, 75 DAS and at harvest, minimum number of secondary branches (2.33, 2.78 and 2.56) were found at V_2S_1. Maximum growth duration (118 days) was recorded at V_1S_4 and minimum growth duration (88 days) was recorded atV_4 S_1.

V_1S_4 scored the highest number (1179.67) of silquae plant^{-1} and V_2S_1 scored the lowest number (79.33) of siliquae plant^{-1}. Maximum number of sterile siliquae plant^{-1} (2.33) was recorded both at V_4S_2 and V_4S_3. Minimum number of sterile silquae plant^{-1} (0) was observed at V_1S_1, V_1S_2, V_1S_4, V_2S_1, V_2S_3, V_2S_4, V_3S_4 and V_4S_4. Highest sterility percentage (1.85%) was recorded at V_3S_3 and lowest sterility percentage (0) was observed at V_1S_1, V_1S_2, V_1S_4, V_2S_1, V_2S_3, V_2S_4, V_3S_4 and V_4S_4. Maximum siliqua length (8.99 cm) was scored at V_2S_4 and minimum siliqua length (3.92 cm) was recorded at V_1S_1. Maximum number of seeds siliqua^{-1} (30.33) was recorded at V_2S_4 and minimum number of seeds siliqua^{-1} (9.67) was recorded at V_1S_1. V_2S_4 scored the highest shell yield (3.91 t ha^{-1}) and V_3S_1 scored the lowest shell yield (0.63 t ha^{-1}). V_1S_4 scored the highest stover yield (8.76) and V_3S_1 scored the lowest stover yield (2.8 t ha^{-1}). Highest grain yield (4.75 t ha^{-1}) was obtained at V_1S_4 and lowest grain yield (1.47 t ha^{-1}) was obtained at V_2S_1. V_1S_4 scored the highest biological yield (16.06 t ha^{-1}) and V_3S_1 scored the lowest biological yield (5.28 t ha^{-1}). Maximum harvest index (36.45%) was recorded at V_3S_2 and minimum harvest index (22.12%) was recorded at V_2S_1. Maximum weight of 1000-seed (4.26 g) was found at V_1S_3 and minimum weight of 1000-seed (3.01 g) was found at V_4S_4. Maximum oil percentage (41.73%) was gained at V_3S_2 and minimum oil percentage (38.11%) was gained at V_1S_4. Maximum yield day^{-1} (40.25 kg) was recorded at V_1S_4 and minimum yield day^{-1} (15.35 kg) was achieved by V_2S_1.



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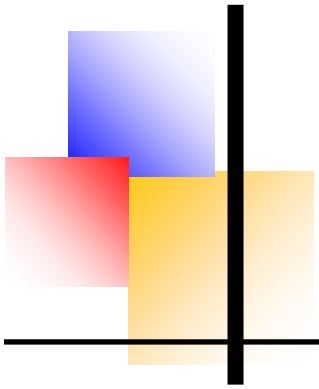


Appendices

APPENDIX–I:

The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth).

Physical composition

Sand : 40%

Silt : 40%

Clay : 20%

Texture : Loamy

Chemical composition

Constituents'	: 0-15 cm depth
pH	: 6.4
Total N (%)	: 0.07
Available P (µ g/g)	: 18.49
Exchangeable K (meq)	: 0.07
Available S (µ g/g)	: 20.82
Available Fe (µ g/g)	: 229
Available Zn (µ g/g)	: 4.48
Available Mg (µ g/g)	: 0.825
Available Na (µ g/g)	: 0.32
Available B (µ g/g)	: 0.94
Organic matter (%)	: 1.4

The soil sample was analyzed by Soil Resources Development Institute (SRDI), 2013

APPENDIX-II

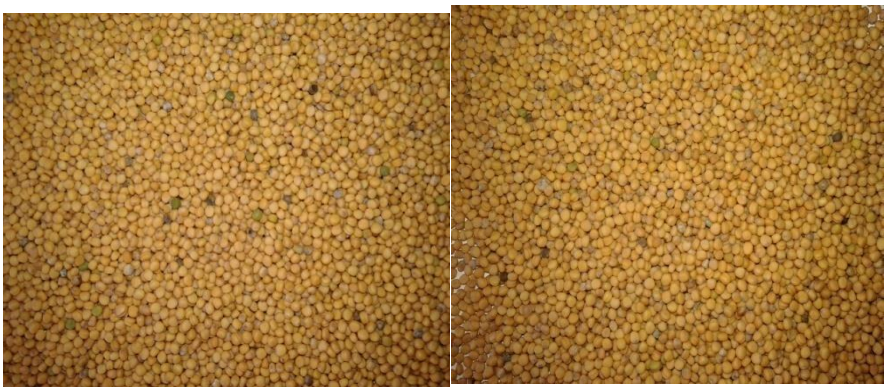
Monthly records of Temperature, Rainfall and Relative humidity of the experiment site during the period from November 2013 to February 2014.

Year	Month	Air temperature (^{O}c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Mean		
2013	November	29.5	18.6	24.0	69.5	0.0
	December	26.9	16.2	21.5	70.6	0.0
2014	January	24.5	13.9	19.2	68.5	4.0
	February	28.9	18.0	23.4	61.0	3.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka- 121

APPENDIX-III: Photographs of experiment

BARI Sarisha-11 BARI Sarisha-13



BARI Sarisha-15 SAU Sarisha 2

Plate 1. Photograph showing variation in seed coat colour, seed size and shape of some selected released varieties of rapeseed and mustard *(Brassica spp.*)

Plate 2. Preparation of soil and polybag for raising seedling of SMI technique

Plate 3. Plot under SMI technique

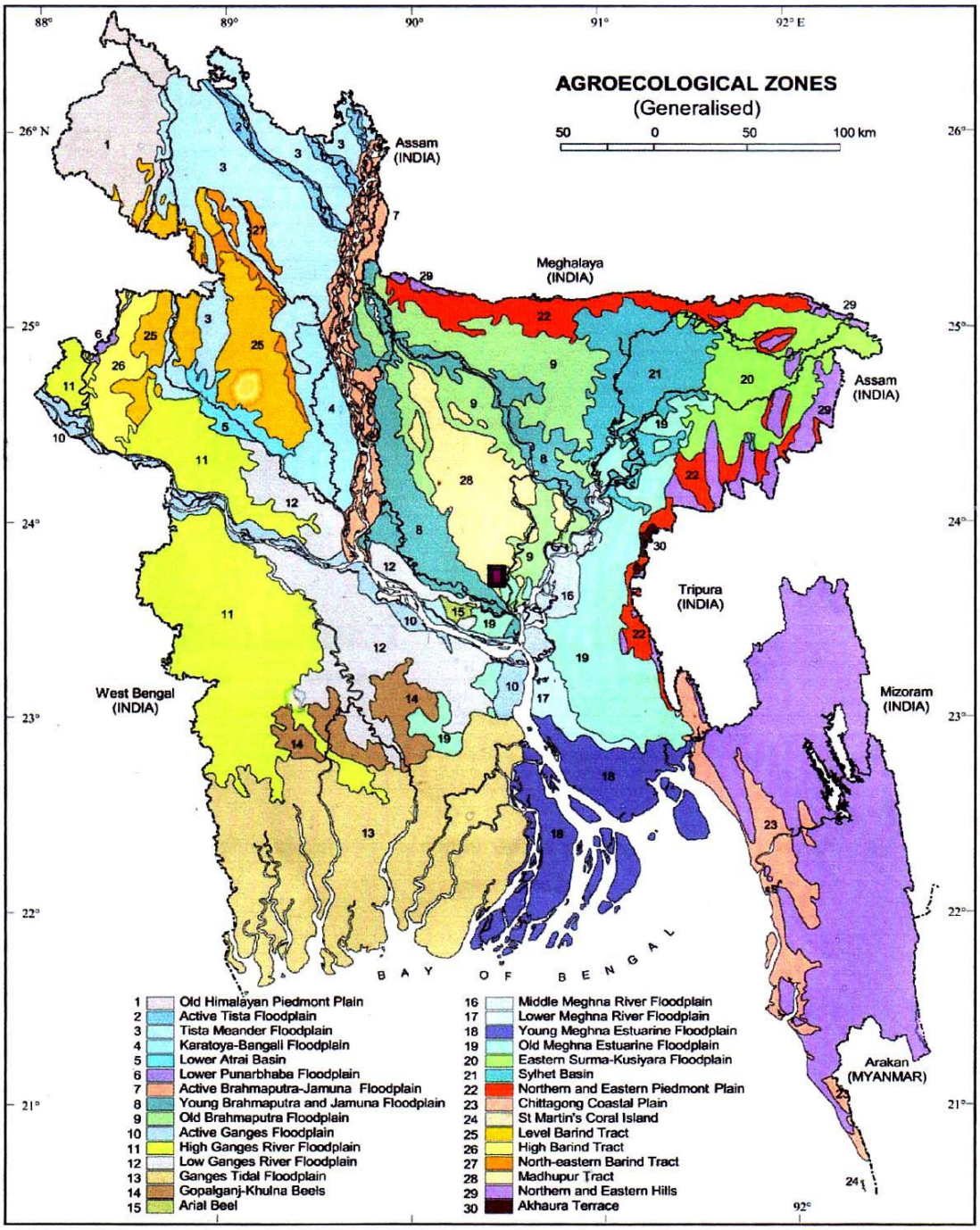
Plate 4. Plot under SMI technique

Plate 5. A view of the experimental plot

Plate 6. Growth of the mustard plant under SMI technique

Plate 7. Performance of BARI Sarisha-11 in raised bed

Appendix IV. Map showing the experimental site under study



APPENDIX-V:

Analysis of variance for yield and other yield attributes

1. Plant height

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**At harvest**
Replication	2	35.67^{ns}	15.33^{ns}	107.48^{ns}	64.31^{ns}	58.08^{ns}
Variety	3	139.73^{*}	1702.95^{*}	1903.9^{*}	2586.59^{*}	2576.3^{*}
Sowing Technique	3	921.79^{*}	2711.65^{*}	301.45^{ns}	614.79^{*}	661.84^{*}
V×S	9	32.58^{ns}	182.61^{*}	200.64^{ns}	148.81^{ns}	148.87^{ns}
Residuals	30	28.29	18.3	110.63	100.52	99.67

* Significant at 5% level
ns- Non significant

2. Leaf number

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**At harvest**
Replication	2	0.78^{ns}	75.8^{*}	244.17^{*}	28.07^{ns}	24.94^{ns}
Variety	3	2.46^{ns}	3291.31^{*}	2571.41^{*}	3302.73^{*}	1761.97^{*}
Sowing Technique	3	0.4^{ns}	1674.13^{*}	21728.1^{*}	84041.2^{*}	11199.4^{*}
V×S	9	0.77^{ns}	229.52^{*}	406.69^{*}	1934.37^{*}	575.74^{*}
Residuals	30	1.16	5.32	16.48	30.07	8.83

* Significant at 5% level
ns- Non significant

3. Dry matter weight

Source of Variation	DF	Means square values at different days after sowing			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.025^{ns}	4.38*	17.06*	9.95^{ns}
Variety	3	0.461*	49.5*	163.11*	155.6*
Sowing Technique	3	1.14*	269.61*	1054.96*	1554.23*
V×S	9	0.144*	11.93*	19.1*	9.23^{ns}
Residuals	30	0.021	0.145	0.941	10.92

* Significant at 5% level
ns- Non significant

4. Crop growth rate (CGR)

Source of Variation	DF	Means square values at different days after sowing		
		30-45 DAS	45-60 DAS	60-75 DAS
Replication	2	0.02*	0.023*	0.09^{ns}
Variety	3	0.18*	0.309*	0.318*
Sowing Technique	3	1.23*	1.23*	0.231*
V×S	9	0.054*	0.115*	0.0381^{ns}
Residuals	30	0.0006	0.004	0.04

* Significant at 5% level
ns- Non significant

5. Relative growth rate (RGR)

Source of Variation	DF	Means square values at different days after sowing		
		30-45 DAS	45-60 DAS	60-75 DAS
Replication	2	0.00088^{ns}	0.00001^{ns}	0.00041^{ns}
Variety	3	0.00027^{ns}	0.00109*	0.00108*
Sowing Technique	3	0.02429*	0.00088*	0.00013*
V×S	9	0.00164*	0.00076*	0.00014*
Residuals	30	0.00038	0.00003	0.00014

* Significant at 5% level
ns- Non significant

6. Number of primary branches

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.396^{ns}	0.75^{ns}	0.839^{ns}	0.258^{ns}	0.75^{ns}
Variety	3	8.3^{*}	38.19^{*}	19.7^{*}	17.38^{*}	21.07^{*}
Sowing Technique	3	1.74^{ns}	10.24^{*}	59.31^{*}	73.51^{*}	64.22^{*}
V×S	9	0.465^{ns}	0.65^{ns}	3.47^{*}	3.48^{*}	1.84^{ns}
Residuals	30	0.663	1.11	0.832	0.756	1.2

* Significant at 5% level
ns- Non significant

7. Number of secondary branches

Source of Variation	DF	Means square values at different days after sowing			
		45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.403^{ns}	6.27^{ns}	4.25^{ns}	14.31^{ns}
Variety	3	100.95^{*}	229.77^{*}	186.03^{*}	229.01^{*}
Sowing Technique	3	67.24^{*}	2730.58^{*}	3681.51^{*}	4487.39^{*}
V×S	9	11.79^{*}	42.85^{*}	87.47^{*}	137.94^{*}
Residuals	30	0.395	7.36	5.59	8.9

* Significant at 5% level
ns- Non significant

8. Siliqua plant^{-1}, Sterile Siliqua plant^{-1}, Sterility percentage, Siliqua length, Seed siliqua^{-1}

Source of Variation	DF	Means square values at different days after sowing				
		Siliqua plant^{-1}	Sterile Siliqua plant^{-1}	Sterility percentage	Siliqua length	Seed siliqua^{-1}
Replication	2	15.21^{ns}	2.15^{ns}	1.23^{ns}	0.079^{ns}	7.27^{ns}
Variety	3	160078*	3.86^{ns}	1.89^{ns}	36.95*	396.13*
Sowing Technique	3	1192650*	3.92^{ns}	1.42^{ns}	0.841*	111.91*
V×S	9	60952.6*	0.954^{ns}	0.475^{ns}	0.161^{ns}	19.37*
Residuals	30	981.797	1.59	0.729	0.17	3.45

* Significant at 5% level
ns- Non significant

9. Stover yield, Straw yield, Grain yield, Biologcal yield, Harvest index

Source of Variation	DF	Means square values at different days after sowing				
		Stover yield	Straw yield	Grain yield	Biologcal yield	Harvest index
Replication	2	0.011^{ns}	0.041^{ns}	0.098*	0.139^{ns}	4.003^{ns}
Variety	3	5.42*	22.21*	3.16*	61.74*	103.63*
Sowing Technique	3	2.63*	20.22*	6.27*	73.37*	22.39*
V×S	9	0.422*	1.26*	0.36*	3.47*	19.78*
Residuals	30	0.02	0.048	0.021	0.099	1.27

* Significant at 5% level
ns- Non significant

10. 1000-seed weight, Oil percentage, Growth duration, Yield day^{-1}

Source of Variation	DF	Means square values at different days after sowing			
		1000-seed weight	Oil percentage	Growth duration	Yield day^{-1}
Replication	2	0.131^{ns}	0.0055^{ns}	0^{ns}	9.1*
Variety	3	1.33*	5.54*	916.75*	89.66*
Sowing Technique	3	0.197^{ns}	1.58*	260.75*	408.4*
V×S	9	0.12^{ns}	2.17*	0.75*	34.56*
Residuals	30	0.076	0.0038	-	1.9

* Significant at 5% level
ns- Non significant