EFFECT OF VARIETY AND ROW SPACING ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF RAPESEED

A THESIS

By

Md. Imam Husain

Registration No. 07-02592

Session: January-June, 07

Submitted to the Department of Agronomy

Sher-e-Bangla Agricultural University, Dhaka,

In partial fulfilment of the requirements

For the degree of

MASTER OF SCIENCE (M.S)

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 07

Approved by

Prof. Dr. Md. Hazrat Ali
Dean, Agriculture faculty
Supervisor

Prof. Md. Sadrul Anam Sardar
Co-supervisor

Prof. ~~Dr.~~ Md. Jafar Ullah
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e -Bangla Nagar, Dhaka-1207.

CERTIFICATE

This is to certify that the research work entitled, "**EFFECT OF VARIETY AND ROW SPACING ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF RAPESEED**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY,** embodies the result of a piece of bonafide research work successfully carried out by MD. IMAM HUSAIN bearing Registration No. **07-02592** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 26/6/08
Place: Dhaka, Bangladesh

Prof. Dr. Md. Hazrat Ali
Dept. of Agronomy
Sher-e-Bangla Agricultural University.

Dedicated to My Beloved Parents

&

All of the Freedom Fighters in Bangladesh

ACKNOWLEDGEMENTS

All praises are devoted to Almighty Allah, who is the supreme authority of this universe, and who enabled me to complete the research work and submit the thesis for the degree of Master of Science (M.S) in Agronomy.

I would like to acknowledge the untiring inspiration, encouragement and invaluable guidance provided by my respected teacher and supervisor Professor Dr. Hazrat Ali, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. His constructive criticism, continuous supervision and valuable suggestions were helpful in completing the research and writing up the manuscript.

I would like to express my heartiest appreciation, ever indebtedness and deep sense of gratitude to my co-supervisor Professor Sadrul Anam Sardar, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his sincere advice, constant supervision, valuable suggestions and factual comments in upgrading the quality of the research work and in preparing the manuscript.

I would like to express my heartiest appreciation, ever indebtedness and deep sense of gratitude to Professor Dr. Md. Jafar Ullah, Head, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his kind permission to allow the departmental and laboratory facilities.

I express my thanks to all other staff members of the farm of Sher-e-Bangla Agricultural University, Dhaka for their help in conducting the experiment.
I feel proud to express my unreserved gratitude to Lona, Mony, Shuvo, Tanu, Babu, Joyonto, Hasan, Riaz Khan, Shamima Apu for their heartfelt cooperation during research period and writing up the manuscript.

The Author

ABSTRACT

An experiment was carried out at the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2007 to February 2008 to study the effect of row spacing on the yield and yield contributing characters of rapeseed. Four high yielding varieties of rapeseed (viz. Improved Tori 7, SAU Sharisa 1, BARI Sharisa 9, BARI Sharisa 13) and three row spacings (viz. 15, 30 and 45 cm) were included as experimental treatments. The experiment was laid out in a two factor randomized completely block design with three replications. The spacing between plants in a row was maintained at 5 cm distance. Result showed that BARI Sharisa 9 produced the highest yield of 1.54 t ha^{-1}. The lowest seed yield (0.96 t ha^{-1}) was obtained from the variety BARI Sharisa 13. Improved Tori 7 and SAU Sharisa 1 produced 1.34 and 1.10 t ha^{-1} seed yield respectively. The 30 cm row spacing gave the highest seed yield of 1.44 t ha^{-1} followed by 45 cm row spacing (1.23 t ha^{-1}). The maximum seed yield of rapeseed could be obtained by using BARI Sharisa 9 sown 30 cm apart keeping 5 cm plant to plant distance.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS

AEZ	:	Agro-ecological Zone
BARI	:	Bangladesh Agricultural Research Institute
BBS	:	Bangladesh Bureau of Statistics
cm	:	Centimeter
Contd.	:	Continued
CV	:	Co-efficient of Variation
et al.	:	and others
FAO	:	Food and Agricultural Organization
FPPM	:	Fifty Percent Pod Maturity
g	:	Gram
ha	:	Hectare
HI	:	Harvest Index
i.e.	:	That is
kg	:	Kilogram
LSD	:	Least Significant Difference
MP	:	Murate of Potash
N	:	Nitrogen
No.	:	Number
RCBD	:	Randomized Complete Design
t ha^{-1}	:	Ton per Hectare
TSP	:	Triple Super Phosphate
UNDP	:	United Nations Development Programme
viz	:	namely
%	:	Percentage
°C	:	Degree Celsius

Chapter 1
INTRODUCTION

INTRODUCTION

Rapeseed has been grown for thousands of years as lamp fuel, cooking oil and as forage. During World War II, rapeseed acreage increased dramatically because it was used as a lubricant for steamships. In course of time, Rapeseed has become a promising oil seed crop in the world (Weber *et al.*, 1991). It belongs to the genus *Brassica* under the family *Cruciferae.* There are three edible oil producing species namely *Brassica napus, Brassica campestris and Brassica juncea.* According to the report of FAO (2006), the annual production of rapeseed in the world was 46.5 million ton seeds from an area of 30.3 million hectares. It occupies the third position in terms of production and area after soybean and cotton.

Bangladesh is facing a huge deficit of edible oil. According to the National Nutrition Council (NCC) of Bangladesh, the recommended dietary allowance (RDA) is estimated to be 6 g oil per capita per day for a diet with 2700 kcal. On this RDA basis, Bangladesh requires 0.29 million tons, equivalent to 0.8 million tons of oil seeds for nourishing her people. (NCC, 1984)

In Bangladesh rapeseed is the most widely grown oil seed crop. Out of the total cropped area of 13.53 million ha oil crops occupy only 0.561 million ha which is about 4.2% of the total cropped area. Rapeseed and mustard occupies 60% of the oil cropped area (Wahhab *et al.*, 2002).

Rapeseed- mustard oil has only 6 % saturated fat, which is lower than any other vegetable oil. It is also composed of 58% mono saturated fat, a desirable trait to consumers. Rapeseed meal is a safe protein source in animal feed having 32-38 % protein (Myers, 1995). So the prospects for rapeseed appear to be good. In Bangladesh context, it is popular edible oil in rural area and is considered important for improving the taste of a number of food items. It also serves as an important raw material for industrial use such as soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Oil cakes and meals can also be used as animal feeds and as manures.

The yield of rapeseed in Bangladesh has been increased obviously with the introduction of high yielding varieties. However their yields in farmer's fields are still low compared to their potentialities. Moreover, the yields of these high yielding cultivars are far behind compared to that of other rapeseed growing countries of the world. The cause of lower yield of rapeseed in Bangladesh is mainly due to poor management practices and use of non-recommended local varieties. Therefore, there is a scope to increase the yield by using HYV and adopting proper management practices such as spacing, seed rate, fertilizer application and other intercultural operations. Proper agronomic manipulation could elevate the yield of rapeseed nearer to the level of varietal potentiality. Plant architecture differs among varieties. Therefore, there is a need of optimizing the row spacing in order to facilitate mechanical weeding and other intercultural operations for better crop management and thus providing congenial crop environment for better growth and higher yield.

Establishment of an optimum plant population by maintaining proper row spacing is one of the important factors to secure a good yield in any crop. Population density can be adjusted by maintaining row spacing while in the rows, by keeping a constant distance from plant to plant. Optimum spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, spaces and water. It is well established that the crop environment with regard to light intensity and concentration of carbon dioxide play a vital role in photosynthesis of the plant thus increase dry matter accumulation and vegetative growth of the plant. Hence plant density per unit area influences the crop yield considerably.

Moreover, determination of optimum spacing for different rapeseed varieties could help engineers to design the seed drill to facilitate mechanical cultivation of the crop. However, the present information regarding row spacing effect of yield of available cultivars of rapeseed and mustard is not enough in Bangladesh as new varieties are coming from research organizations every year for cultivation at farmer's fields.

Therefore, the present experiment was undertaken to study the effect of row spacing on the yield and yield components of some BARI and one SAU developed rapeseed and mustard varieties together with the following objectives:

1) To study the effect of varieties on yield and yield contributing characters of rapeseed.
2) To study the effect of different row spacing on yield and yield contributing characters of rapeseed.
3) To observe which variety at what row spacing gives highest yield.

Chapter 2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

In Bangladesh rapeseed crop complex comprises three ecotypes of *Brassica campestris* L. viz. Yellow sarson, Brown sarson and Toria which are collectively called as Sarson or rapeseed and the other spp, *Brassica juncea* commonly known as Mustard, Indian Mustard, Brown Mustard, Rai and Raya. Summer or winter *Brasasica* spp are *Brassica campestris* and *Brassica juncea* which are commonly cultivated in Europe, Canada and Australia, while leafy forms of *Brassica campestris* and *Brassica juncea* pre dominate in Japan and China. Rapeseed and mustard are the principle edible oil producing crops in Bangladesh.

Among crop species the rapeseed and mustard complex is probably the one group of crop plants that has received the least attention from the physiologist and agronomist. As a result comprehensive information is not yet available on the manipulation of growth as well as yield of these crops in Bangladesh. Although some modern varieties have been developed, still there is a large yield gap between theoretical potential yields (Yield at research level) and field yield (Yield at farmer's field). This is largely due to management constraints. It warrants maximum research thrust for achieving quantum jumps in the yield levels of the crops.

Various authors found that the yield response to different levels of plant densities appeared to differ with genotypes and growing conditions. The yield performance of rapeseed and mustard in tropical and temperate countries, for instance, the closer spacing accommodating 200 to 300 plants per m^2 was found to yield higher in summer rapeseed, *B. napus* (Kondra, 1975; Clark and Simpson, 1978)

Elias *et al.* (1982) found that in different places of Bangladesh farmers generally practiced broadcast method of seeding and used variable seed rate (5 kg to 20 $kgha^{-1}$), irrespective of both traditional and improved varieties of rapeseed and mustard. In line sowing only row to row distance are maintained without looking into plants per row. Over population within the row or plants per unit area create heavy competition causing either reduction of growth or death of plant, which reduce per plant yield and yield per unit area.

Downey (1971) reported that optimum spacing or population density (PD) per unit area plays an important role towards increased yield. Grain yield can be increased by raising plant population, but this relationship is parabolic.

Mustard is an important oil yielding crop in Bangladesh which could contribute to a large extent in the national economy. But, the research works done on this crop with respect to agronomic practices are not sufficient. Only limited studies have so far been conducted on the response of mustard to agronomic management practices particularly row spacing. A number of such studies have, however, been carried out in other parts of the world. Some of the studies relevant to the present line of work have been reviewed.

2.1 Plant height

Plant height of rapeseed and mustard differs among the varieties depending on their genetic makeup. There are three species of oliferous *Brassica viz.*, *Brassica campestris*, *Brassica juncea* and *Brassica napus* each of which differs from one another with respect to plant development, growth and yield. Varieties have different plant types and therefore plant height in particular differs widely.

Johnson *et al.* (2003) conducted a study to determine the optimum row spacing of canola using contemporary open pollinated, hybrid and transgenic cultivars. They observed that variety and row spacing interaction was only significant for plant height. Short plant of the *Brassica napus* cultivars was found when grown at the narrower row spacing but *Brassica napus* cultivars had similar plant height at both row spacing and the hybrid *Brassica napus* cultivar yielded greater than the open pollinated cultivars.

Oad *et al*. (2001) conducted a field experiment in Pakistan to determine the effect of row spacing on growth and yield of rapeseed (*Brassica napus*). The homogeneous seeds of rape cv. P 33 were sown at 3 row spacing (30, 45, 60 cm). They observed that plant height was affected significantly by row spacing and among them 60 cm row spacing produced the tallest plant.

Meitei *et al*. (2001) conducted a two year experiment to determine the effects of spacing (66.6 cm × 66.6 cm, 50 cm × 50 cm, 50 cm × 40 cm, 40 cm ×40cm, 50 cm × 25 cm, 40 cm × 25 cm and 25 cm × 25 cm) on the yield and yield components of *Brassica juncea* var. Rugosa cultivars (Hanggam Amubi, Hanggam Angoubi and Hanggam Anganbi). They observed that Hanggam Angoubi gave the highest plant height (52.25 and 48.29 cm) and 66.6 cm row spacing resulted in the tallest plants (55.00 and 48.38 cm)

Butter *et al*. (1999) conducted a study on Indian mustard cv. RLM 619 and maintained 3 row spacings (15, 22.5 and 30 cm). They observed that row spacing had no significant effect on plant height.

Ahmed *et al*. (1999) stated that the tallest plant (102.56 cm) was recorded in the variety Daulat. No significant difference was observed in plant height of BARI Sharisa 6 and Nap 8509.

Jahan and Zakaria (1997) reported that BARI Sharisa 6 was the tallest plant (142.5 cm) which was at par with Sonali (139.5 cm) and Jatarai (138.6 cm). The shortest plant was observed in Tori 7 which was significantly shorter than other varieties. The exotic varieties were of intermediate type.

Hussain *et al.* (1996) observed that the highest plant height was with Narendra (175 cm) which was identical with AGA 95-21 (166 cm) and Hyola 50 (165 cm).

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

Ali *et al.* (1986) and Bhuiyan (1989) observed significant variation in plant height due to different varieties of mustard and rape. According to Bhargava and Tomar (1982) the ideotype should combine the major yield attributes of varieties having plant height ranges between 1 - 1.25 m.

Rahman *et al.* (1982) observed the performances of different *Brassica* germplasms including M 127 and M 257 and M 284 and concluded that there were no significant differences among the lines considering the characters of plant height.

Scarisbric *et al.* (1982) reported a negative relationship between plant heights with higher plant density.

Wankhede *et al.* (1970) reported that population density did not have any effect on the height of individual plant.

2.2 Branches plant^{-1}

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

Oad *et al*. (2001) conducted a field experiment in Pakistan to determine the effect of row spacing on growth and yield of rapeseed (*B. napus*). The homogeneous seeds of rape cv. P 33 were sown at 3 row spacing (30, 45 and 60 cm). They observed that branches plant^{-1} was affected significantly by row spacing and among them 60 cm row spacing proved to be the best.

BARI (2000) found that the number of primary branches plant^{-1} was higher (4.2) in the variety SS 75 and lower (2:1) in the variety BARI Sharisa 8 under poor management. Under medium management, the higher number of primary branches/plant was found in BARI Sharisa 6 (5.5) and lower in BARI Sharisa 8. Under management, the highest number of primary branches/plant was with BARI Sharisa 6 (5.9) and lower (3.0) with Nap-248.

Butter *et al*. (1999) conducted a study on Indian mustard cv. RLM 619 and maintained 3 row spacings (15, 22.5 and 30 cm). They found that row spacing had no significant effect on number of secondary branches plant^{-1}.

Jahan and Zakaria (1997) found that the local varieties Tori and Sampad produced the highest number of primary branches plant^{-1} (4.07) which was at par with BLN-900. The minimum primary branches plant^{-1} (2.90) was found in Jatarai which was identical to those found in Hyola-40 and BARI Sharisa 8.

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

2.3 Pods plant^{-1}

Pods plant^{-1} is also an important determinant of the seed yield of rapeseed and mustard. Row spacing has a remarkable effect in producing more number of fertile pods plant^{-1}. Wider spacing facilitate favorable environment for producing more pods than closer spacing.

Bilgili *et al.* (2003) observed a significant response between yield contributing characters and seed yield of *B. rapa* L. The number of pods main stem^{-1} was affected by row spacing but not by the seeding rate. In contrast, the number of pods plant^{-1} clearly increased with increasing row spacing but decreased with increasing seeding rate.

Butter *et al.* (1999) conducted a study on Indian mustard cv. RLM 619 and maintaining 3 row spacings (15, 22.5 and 30 cm). Result showed that row spacing had significant effect on number of pods plant^{-1} and increased with widening row spacing.

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

2.4 Number of seeds pod^{-1}

Number of seeds pod^{-1} is also an important yield contributing attribute of rapeseed and mustard. Different variety produces different number of seeds pod^{-1}.

Jahan and Zakaria (1997) found that BARI Sharisa 6 produced the highest number of seeds pod^{-1} (26.13) which was at par with Sonali (23.5) and Jatarai (22.8). The lowest number of seeds pod^{-1} (26.13) was at per with Sonali (23.5) and Jatarai (22.8). The lowest number of seeds pod^{-1} (18.0) was found in Tori-7 which at per with that of Sampad (20.0), Hyola 401 (20.3), BARI Sharisa 7 (20.5), AGA-95-21 (20.7) and BARI Sharisa 8 (21.6).

Hussain *et al*. (1996) stated that there were significant differences among the varieties with respect to number of seeds pod^{-1}. The maximum number of seeds pod^{-1} was produced in the hybrid BLN-900(29.5) and the minimum number was recorded in Tori 7 as well as Semu 249/84

Mondal *et al*. (1992) found the highest number of seeds pod^{-1} (27.6) in SS 75 which was significantly different from all other varieties. The lowest number of seeds pod^{-1} (13.8) was found in J-5004.

2.5 Pod length

The pod length varies due to differences in genotypes. Masud *et al*. (1999) found significant genetic variation in pod length among seven genotypes of *B.campestris* and a cultivar of *B.napus*. Similar result for pod length was observed by Lebowiz (1989) and Olsson (1990).

Hussain *et al*. (1996) stated that the varieties differed significantly in respect of pod length. The longer pod (7.75 cm) was found in the hybrid BLN-900 which was identical to Hyola 101. Sampad, BARI Sharisa 6 and Hyola 51.The shortest pod length (4.62 cm) was found in the hybrid Semu 249/84 which was identical to those of Semu-DNK-89/218, AGH 7 and Tori 7. The longest pod (8.07 cm) was found in BLN 900 and Hyola 401 (Jahan and Zakaria, 1997).

Regression analysis revealed that pod weight significantly influenced seed yield where as pod length and pod diameter had a marginal effect (Gangasarn *et al.* 1981). They further noticed that pod length and pod number served as the most reliable index of selection for yield improvement in brown sarson (*B. campestris* var.sarson).

2.6 1000- Seed weight

It is also an important character which reflects the seed size. It varies from genotype to genotype and it is influenced by some production factors. A good number of research works have been conducted on this character.

Singh *et al.* (2002) reported that 1000-seed weight ranged between 2.36 and 4.20 g in F_1 and 2.46, 4.30 g in F_2 population. Significant genetic variations were observed among a large number of strains of *B.campestris, B.napus* and *B. juncea*. Sing (1986), Chowdhury *et al.*(1987), Jain *et al.* (1988), Yin (1989), Yadav *et al.* (1993), Kudla (1993), Kumar and Singh (1994) and Hussain *et al.*(1998)

BARI (2001) concluded that there was significant variation in 1000-seed weight of rapeseed and mustard in different variety and the highest weight of 1000-seed was observed in variety Jamalpur 1 and the lowest in BARI Sharisa 10.

Mondal and Wahab (2001) described that weight of 1000-seeds varied from variety to variety and species to species. They found 1000-seed weight 2.50-2.65 g in case of improved Tori 7(*B. campestris*) and 1.50-7.80 g in case of Rai 5(*B. juncea*).

Karim *et al.* (2000) stated that varieties showed significant variation in the weight of thousand seeds. They found higher weight of 1000-seed in J 3023(3.43 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 influenced by different varieties. They found Hyola 401 had the highest 1000-seed weight (3.4 g) and the lowest 1000-seed weight was recorded in Tori 7 (2.1g).

Jahan and Zakaria (1997) carried out an experiment to find out the performance of different varieties of rapeseed and mustard. They found variation in 1000-seed weight and the highest seed weight in the variety BLN 900(3.37 g) and the lowest in Tori 7 (2.27 g).

2.7 Seed Yield

It is an important polygenic character which is highly influenced by other characters and production factors. A good number of reports revealed that there were variability's among different genotypes of rapeseed and mustard. In an experiment, Kumar *et al.* (2000) studied different induced quantitative characters in 23 and 13 mutants of Indian mustard cultivars Varuna and BR 40, respectively and found high coefficient of variation in yield plant^{-1}, pods plant $^{-1}$ and branches plant^{-1}. Significant variability was also observed by Alam *et al.* (1986), Kumar *et al.* (1996), Choudhury *et al.* (1999) and Pant and Singh (2001).

Goyal *et al.* (2006) recorded the highest seed yield of variety Varuna (6.13 g per plant) followed by Kranti (6.10 g per plant). The highest seed yield was recorded in 6th November sowing as compared to delayed sowings. Vardan found to be a good yielder in all temperature regimes as compared to other varieties.

Mottalebipour and Bahrani (2006) observed that increasing plant density increased plant height and decreased pods per plant and 1000-seed weight, but it had no significant effect on branches plant^{-1}, seeds pod^{-1}, seed yield and oil yield. Increasing row spacing significantly increased the values of almost all yield attributes.

Parminder and Sidhu (2006) reported that the oil and protein content significantly decreased as sowing was delayed from 15 October to 15 December in both years. The highest oil content (35.3%) was recorded for the crop sown in 15 October. The increase in the N level decreased the oil content, but increased the protein content and protein yield. A row spacing of 60 cm recorded a higher protein content and lower oil content than a row spacing of 45 or 30 cm.

Mahar *et al.* (2004) conducted an experiment in Pakistan to determine the effect of row spacing (30, 45 and 60 cm) on the growth and development of Indian mustard cultivars of Early Raya and P-269. Data were recorded for plant height, number of branches plant^{-1}, number of days to flower formation, number of days to pod formation, number of days to grain formation, number of days to maturity, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, seed weight plant^{-1}, seed index, 1000-seed weight, biological yield plot^{-1}, seed yield plot^{-1} and calculated seed yield ha^{-1}.

Faraji (2004) observed that a decrease in row spacing resulted in the increase in number of pods plant^{1}, number of grain pod^{-1} and grain yield. Row spacing at 12 cm produced the highest grain yield (4626 kg ha^{-1}), while spacing at 36 cm produced the lowest (3093 kg ha^{-1}). The interaction between year and spacing showed a significant effect on lodging at 1% level. Lodging occurred only during the second year and incidence increased with increasing spacing. Sowing rates at 6, 8 and 10 seeds ha^{-1} resulted in grain yields of 4061, 3698 and 3622 kg ha^{-1} respectively. The 12 cm row spacing and the sowing rate of 6 seeds/ha resulted in the highest grain yield of 5044 kg ha^{-1}.

Bilgili *et al.* (2003) observed a significant response between all yield contributing characters and seed yield of *B. rapa* L. Seed yield was similar at all seeding rates, averaging 1151 kg ha^{-1}. However, row spacing was associated with seed yield. The highest seed yield (14090 kg/ha) was obtained for the 35 cm row spacing and 200 seed m^{-2} seeding rate.

Ozer (2003) observed that the increase in spacing between rows resulted in the increase in plant height, number of branches and pods $plant^{-1}$ and number of seeds pod^{-1}. Thus, the greatest average plant height (114.32 cm), number of branches (5.11) and pods (204.5) $plant^{-1}$, and number of seeds pod^{-1} (25.15) were obtained with a spacing of 45 cm between rows. In contrast, the lowest number of days to flowering (57.58) and maturity (126.08), and the highest seed yield (1195 kg ha^{-1}) were obtained with a spacing of 15 cm between rows. The effect of spacing within rows was significant only on the number of days to flowering, which was lowest (58.46) with a spacing of 5 cm. The results suggest that less spacing, which results in greater crop density, produces higher seed yield in rape

Heidari *et al.* (2003) reported that the effect of row spacing was significant on plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight, and was highly significant on grain yield. The grain yield was also highly variable among the cultivars. A row spacing of 15 cm was optimum.

Shivani and Kumar (2002) stated that seed yield was significantly influenced by different row spacing. Significantly higher seed yield ha^{-1} was recorded with 30 and 45 cm row spacing than 60 cm row spacing. A row spacing of 45 cm was found suitable for crops sown on 25 September and 5 October, while 30 cm was optimum for Indian mustard sown beyond 5 October. Oil content was significantly influenced by sowing date but remained unaffected due to variation in row spacing.

Behera *et al.* (2002) conducted a field experiment to study the effect of plant population and sulfur levels on yield of mustard (*B. juncea*) and found interaction effects of variety and plant population significant on pooled seed yield and recorded the maximum seed yield at the intermediate population level.

Chaniyara *et al.* (2002) conducted a field experiment to determine the effect of intra row spacing on the yield of Indian mustard cv. Gujarat Mustard-1 maintaining inter row spacing treatments of 45, 60, 75 and 90 cm, while intra row spacing were 15, 20 and 25 cm and they found seed yield, gross and net returns were the highest at 45 and 15, inter and intra row spacing respectively.

Chaniyara *et al.* (2002) examined the effect of intra and inter row spacing on the yield of Indian mustard cv. Gujarat Mustard 1. Inter row spacing treatments were 45, 60, 75 and 90 cm, while intra row spacing were 15, 20 and 25 cm. Grain yield, and gross and net returns were highest at 45 and 15, inter and intra row spacing's respectively.

Oad *et al.* (2001) conducted a field experiment in Pakistan to determine the effect of row spacing on growth, yield and oil content of rape (*B. napus*). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing (30, 45 and 60 cm). They observed that days to maturity, Plant height and branches, pods and seed weight per plant seed index, seed yield and oil content were affected significantly by row spacing and among all 60 cm row spacing proved to be the best.

Oad *et al.* (2001) evaluated the effect of row spacing on growth, yield and oil content of rape (*Brassica napus* [*B. napus* var. oleifera]). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing i.e. 30, 45 and 60 cm. Days to maturity, plant height, branches, pods and seed weight plant^{-1}, seed index, seed yield and oil content were affected significantly by row spacing. Among all, 60 cm row spacing proved to be the best and is recommended for maximum seed and oil production.

In Poland, Walkowski (2001) conducted a experiment with different seed rates (80, 120, 160 and 200 seed m^{-2}) and sowing date (early sowing and two weeks delayed) and the highest yields were obtained under the combination of 160-200 seed m^{-2} and early sowing time 120-160 seed m^{-2} respectively.

Meitei *et al.* (2001) examined the effects of spacing (66.66 x 66.6, 50 x 50, 50 x 40, 40 x 40, 50 x 25, 40 x 25 and 25 x 25 cm) on the yield and yield components of *B. juncea* var. rugosa cultivars. Hanggam Angoubi recorded the greatest plant height (52.25 and 48.29 cm), number of leaves per plant (9.90 and 9.42) and fresh weight of leaves per plant (452.98 and 445.87 g) in 1996/97 and 1997/98, as well as the highest average yield (403.80 q ha^{-1}).

Sahoo *et al.* (2000) conducted a field experiment on Indian mustard in Kharif season result showed that mustard cv. Chikaballpur Local had significantly higher seed yield (836.44 kg ha^{-1}) than cv. RH-30 (397.63 kg

ha^{-1}). Similarly, seed yield was also higher at closer (30cm × 15 cm, 669.52 kg ha^{-1}).

Singh and Chandra (2000) observed that crop yield in an advanced variety trial in Rajasthan, India, during the rabi season of 1997-98. RH-819 gave the highest yield (17.85 q/ha), while the lowest (12.61 q ha^{-1}) was given by Varuna. The yields of Kranti and RN 393 were 16.19 and 16.61 q ha^{-1}, respectively.

Khan *et al*. (1999) conducted an experiment on rape cv. Shiralee grown in rows 15, 30 and 45 cm apart or was sown in broadcast. They observed that row spacing of 15 cm and broadcasting produced the highest and the lowest seed yield respectively.

Sharma *et al*. (1999) conducted a field experiment with mustard (*B. juncea*) cv. RH 30 and Varuna were grown at 2 row spacing (20 cm and 30 cm) and they found no significant variation by spacing.

Thakur (1999) reported that yield attributes, as well as seed yield, significantly increased with increasing rates of nitrogen up to 60 kg ha^{-1} at the 30 cm spacing, whereas at 20 cm spacing the yield increased up to 75 kg N ha^{-1}. Spacing had no significant effect on plant height, number of seeds $silique^{-1}$, 1000-seed weight and seed yield. However, the number of primary and secondary branches $plant^{-1}$, and siliques $plant^{-1}$ were higher in the 30 cm spacing compared to the 20 cm spacing. Significant interaction effects between N and spacing were observed, resulting in increased seed yield.

Buttar and Aulakh (1999) stated that plant height, number of pods and secondary branches per plant, and seed yield were highest with the early sowing (25 October). Nitrogen and row spacing had no significant effect on plant height and number of secondary branches plant^{-1}. However, number of pods plant^{-1} increased with increasing rates of N and widening row spacing. Seed yield was highest with 15 cm row spacing in both 1996-97 (1466 kg ha^{-1}) and 1997-98 (1156 kg ha^{-1}).

Khan and Muendel (1999) observed that row spacing of 15 cm and broadcasting produced the highest and lowest seed yields and lowest and highest infestations by oats (Avena sativa) respectively. In weed free plots, seed yield was highest with the 30 cm row spacing

Reddy and Reddy (1998) stated that Kranti had the greatest plant height, GM 1 the highest number of pods plant^{-1} and TM 2 the highest seed yield.

Surya *et al*. (1998) performed a field experiment in the rabi (winter) season of 1996/97 in Hisar, where *Brassica juncea* cv.Varuna,RH-30 and Laxmi were sown 5 or at spacing of 30×15 cm or 40×30 cm .Yield and yield components were not affected by spacing , Laxmi gave the highest yield , followed by RH 30 than Varuna.

Jahan and Zakaria (1997) stated that yield variation was present in different varieties. They found the highest yield in the exotic variety BLN-400(2013 kg ha^{-1}) and the lowest seed yield was in AGA 21 (819 kg ha^{-1})

Kalaria *et al*. (1997) conducted a field experiment with mustard (*B. juncea*) to comparing 2 row spacing (30 or 45 cm), three patterns (uniform sowing, three rows followed by one missed row and two rows followed by one missed row). They observed that yields were higher for the narrow spacing and uniform sowing.

Shahidullah *et al.* (1997) observed that Mustard (*Brassica campestris* cv. Sonali was grown at Dhaka in 1994/95 at 20, 30 or 40 cm row spacing and

10, 15, 20 or 25 cm plant spacing. The highest yield was given by 30 x 15 cm spacing.

Kalaria *et al.* (1997) reported that yields were higher for the narrow spacing, uniform sows and the fluchloralin + hand weeding treatments.

Suraj *et al.* (1995) conducted a study on Indian mustard (*B. juncea*) and maintained 5 row spacing of 10, 15, 20, 25 and 30 cm and row orientation of N-S or E-W. Seed yields were the highest at 15 cm spacing, while row orientation did not affect seed yield significantly.

Sharma (1993) conducted a field experiment on sandy loam soil with four mustard (*B. juncea*) cultivars sown in rows 22.5, 30, 37.5 and 45 cm apart and found mean seed yield of 1.44, 1.83 and 1.64 t ha^{-1} respectively. Cv. Puabold, Kranti, varuna and Krishna produced mean seed yields of 1.71, 1.88, 1.69 and 1.47 t/ha respectively.

Khandey *et al.* (1993) described *B. juncea* cv. Kosland and found that densities of 33.3, 44.4 or 66.6 plants m^{-2} produced seed yield of 0.31, 0.87 and 0.82 t/ha, respectively.

Mondal *et al.* (1990) from a field experiment found that mustard crops grown at 28, 34 or 40 plants m^{-2} gave yields of 1.27, 1.45 and 1.25 t ha^{-1} respectively.

Singh and Singh (1984a) observed that when population density (PD) of 33.3 plants/m^2 were maintained, it gave higher HI, increased seed and stover yields of *B. campestris* var. Toria. Similarly, Chauhan *et al.* (1985) found a positive correlation between HI and higher seed yield of Toria.

Bengtsson and Ohlssen (1973) conducted 41 experiments in Sweden on winter rape using the seed rates of 2, 4 and 6 kg ha^{-1} and found the seed rate 6 kg/ha gave the highest yield as compared with the rates of 2 or 4 kg ha^{-1}.

Delhay (1972) used several levels of seed rate ranging from 1.5-12 kg ha^{-1} of rapeseed (*B. napus*) and reported that 6 kg ha^{-1} was the optimum seed rate for higher seed yield. The winter rapeseed sown at the 8 kg ha^{-1} produced significantly higher yield than did the rate of 4 kg ha^{-1} (Larsen and Nordestgard, 1972) and also reported that row spacing had no influence on oil content of winter rapeseed.

2.8 Stover yield

Singh *et al.* (2003) reported that in Indian mustard gave the highest seed yield and total biomass produced maintaining 45 cm row spacing than 30 and 60 cm row spacing.

BARI (2000) reported that in case of poor management ISD local gave the highest stover yield (3779 kg ha^{-1}) and the lowest stover yield (1295 kg ha^{-1}) was found from NAP 248. In case of medium management highest weight (6223.3 kg ha^{-1}) was same variety and the lowest (3702.3 kg ha^{-1}) from PT 303 under high management conditions. The stover yield, 6400 kg $ha^{-1}$was obtained from the variety Rai 505 and the lowest stover yield, 4413.3 kg ha^{-1} was obtained from Tori 7.

Singh and Singh (1984a) observed that when population density (PD) of 33.3 plant m^{-2} was maintained, it gave higher HI, increased seed and stover yields of *Brassica campestris* var. Toria. Similarly, Chauhan *et al.* (1985) found a positive correlation between HI and higher seed yield of Toria.

2.9 Total Dry Matter

Bhargava (1991) summarized that biological yield, harvest index and pod production per plant were positively correlated with higher seed yield of rapeseed and mustard where as seed number per pod or seed was not. Correlation studies between biological yield and seed yield was significant and suggested that higher seed yield can be obtained from vigorous genotype that vive greater biomass.

Khader and Bhagava (1985) investigated the dry matter accumulation, yield and yield components of *B. juncea* and *B. campestris* in relation to population density (1522 and 44 plants m^{-2}) under irrigated and unirrigated condition. In both the species they noticed only 10-15% of the DM accumulated before flowering and 85-90% of the DM accumulated after flowering. At maturity it was noticed that stems and pods accumulated 43-51 and 48-57% DM, respectively. They noticed that preflowering stage 82-85% of the DM was in leaves and only 10-12% in stems. In post flowering stage more than 41-55% in stem, 32-43% in pod and only 7-8% in pod and only 7-8% in leaves. Dry matter production by leaves, steams and pods increased significantly with increased Pd and irrigation. They concluded that total dry matter can be increased by irrigation and increasing PD up to 44 plants m^{-2} to attain higher seed yield.

In Britain, Scarisbric *et al*. (1982) obtained a TDM yield of 1100 g/m^2 or less at a PD of 160 plants m^{-2} where as in India, Bhargava and Tomar (1982) obtained a maximum DM yield of 1162 g m^{-2} at harvest of yellow sarson (*B. campestris*).

2.10 Harvest Index

Islam *et al.* (1994) showed that varieties had significant effect on harvest index (%) of rapeseed and mustard. They found the highest harvest index the variety TS 72 which was identical to Daulat and the lowest in Sonali Sharisa (21.90%) followed by Sambal (26.7%).

Scarisbrick *et al.* (1982) used variable seed rate for raising rapeseed and noticed that seed yield did not increase when the seed rate was raised from 4.5-18.0 kg ha^{-1}. Population density at 54 plants m^{-2} gave higher HI value in *Brassica spp* HI is strongly influenced by environment (Thurling, 1974). He also reported that higher HI was positively correlated to higher seed yield of *B. campestris* than *B. napus*. However, TDM and HI were ranged from 10-23% in both the spp.

The above reviews revealed that the yield of different rapeseed and mustard varieties differed among themselves due to their genetic makeup as expressed by the difference in their pod height, number of branches $plant^{-1}$, pods $plant^{-1}$, pod length, number of seeds $plant^{-1}$ and 1000-seed weight. These yield contributing characters are also influenced by the row spacing and ultimately the yield of these varieties varies with variable row spacing. In the present experiment an attempt has been made to see the effect of different varieties of rapeseed and mustard on yield and yield components as influenced by row spacing.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Experimental site and soil

The experiment was carried out at the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2007 to February 2008. The experimental site was located under the Agro-ecological zone 28 (Madhupur Tract) having the red brown terrace soils and acid basin clay. The soils are acidic in reaction with low status of organic matter, low moisture holding capacity and low fertility level. Soils are mainly phosphate fixing and low in K, S and Ca (Appendix -II).

3.2 Climate

The crop was grown in winter season when the day length (sunshine period) reduced to 10.5-11.0 hours and there was unexpected rainfall at beginning of the experiment and also at the time of harvesting. Temperature during the cropping period ranged between 14^0c and 30^0c with generally 61-71% humidity in the air. The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are enclosed in Appendix-I.

3.3 Experimental treatments, design and layout

Date of Sowing: 05 November 2007

Per Plot Size: 3m x 2.5m

Total Plot Size: 461.25m^2

Three spacing (S):

1) 15 cm
2) 30 cm
3) 45 cm

Four Varieties (V):

1) Improved Tori 7 (V_1)

2) SAU Sharisa 1 (V_2)

3) BARI Sharisa 9 (V_3)

4) BARI Sharisa 13 (V_4)

Replication(R) three: R_1, R_2, R_3

Experimental Design: Two Factor Randomized Complete Block Design

3.4 Experimental material

Four recommended high yielding varieties of rapeseed and mustard viz. Improved Tori 7, SAU Sharisa 1, BARI Sharisa 9, BARI Sharisa 13 were used as the test crop. The SAU Sharisa 1 variety was developed by Prof. Dr. Shahidur Rashid Bhuyan, Dept. of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University and the rest three varieties were developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gajipur.

Short descriptions of the varieties used in the trial are as follows:

Improved Tori 7

Improved Tori 7 (*Brassica campestris*) is a mutant and short stature improved cultivar of mustard. The plant is bushy with branches and attains about 60-70 cm in height. The crop matures within 70-75 days. Seeds are blackish brown containing 40-42% oil. Seed yield varies from 0.9-1.1 t ha^{-1} (BARI.2000).

SAU Sharisa 1

The height of the variety SAU Sharisa 1 is 80-90 cm. Leaf sessile and the base of the leaves surrounded the stem. Comparatively more branches are produced from the base of the steam. The no. of primary branches is 5-8.

The number of pods plant^{-1} is 150. Pods are two chambered. Field duration of this variety is about 75-80 days and yield of this variety varies from 1.55-1.75 t ha^{-1}.

BARI Sharisa 9

BARI Sharisa-9 is under the genus (*Brassica campestris* L.). It is a short duration variety like the traditional variety Tori 7. It can be sown early like Tori 7. Seeds are purple in color. Plant height is about 80-85 cm. Field duration of this variety is about 80-85 days and yield of this variety varies from 1.25-1.45 t ha^{-1}.

BARI Sharisa 13

Leaves are rough, hairy and with prominent leaf stalk, steam and roots of the plant and strong. This variety is drought and moderately saline resistant. There are 75-100 siliqua in each plant and siliqua is two chambered. Yield potential of this variety is 2.0-2.5 t ha^{-1} under good management condition.

3.5 Husbandry

3.5.1 Land preparation

The experimental field was opened with a tractor drawn disc plough. Subsequently cross ploughing was done four times with a country plough followed by laddering to make the land even. All weeds, stubbles and residues were eliminated from the field.

3.5.2 Fertilization

The experimental plots were fertilized with a general dose of 90, 70, 50, 30 and 5 kg ha^{-1} of n, P_2O_5, K_2O, S and Zn from the source of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP), gypsum, Zinc Oxide, respectively (BARC, 1997). During final land preparation of 12 December 2003 one half of the urea and total amount of all other fertilizers were applied and incorporated into soil and the rest of the urea were top dressed on 8 December 2007.

3.5.3 Sowing of seeds

Seeds of the different varieties as per treatment were collected from Bangladesh Agricultural Research Institute (BARI) and Sher-e-Bangla Agricultural University (SAU). The seeds were sown on 05 November 2003 maintaining row spacing as per experimental specification. Sowing was done manually by hand continuously in rows and finally plants were kept at 5 cm distance in rows by thinning.

3.5.4 Weeding and thinning

The experimental plots were found to be infested with weeds of different kind's viz., Nut sedge (*Cyperus rotundus L.*). Biskatali (*Ploygonum hydropiper L.*), Bermuda grass (*Cynodon dactylon*), Bathua (*Chenopodium album L.*), Clammy ground cherry (*Phsalis heterophyla*) etc and weeding was done three times (15, 25 and 40 DAS) with 'niri'. Thinning was done in all the unit plots with care to maintain a constant plant population in each row.

3.5.5 Irrigation

One irrigation was given on 03 December 2007 (28 DAS) in order to maintain adequate moisture in the field.

3.6 Harvesting and processing

3.6.1 Harvesting

At maturity (when about 80% of the pod turned chocolate brown to black in color), the experimental crop was harvested plot- wise from the last week of

January to last week of February 2008. Harvesting was done on 18 January (75 DAS) for Improved Tori 7, on 5 February for BARI Sharisa 9. Harvesting was done in the morning to avoid shattering. An area of 1 m^2 (1m × 1m) was harvested from the centre of each plot at ground level with the help of a sickle. Prior to harvesting, ten plants were sampled randomly from within the harvest area and uprooted for data recording. The harvested crop from each plot was bundled separately, tagged and brought to a clean cemented threshing floor. The crop was sun dried for four consecutive days by spreading them over the floor and was separated from the straw by beating the bundles with bamboo sticks.

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to about 9% level. The Stover was well dried in the sun. Seed yield and Stover yield were determined. The moisture of the seed was recorded by a constant oven drying method keeping the oven at 103^0c for 17 hours (ISTA, 1999).

3.7 Data recording

1) Plant height
2) Number of branches $plant^{-1}$
3) Number of pods $plant^{-1}$
4) Length of pod (cm)
5) Number of seeds pod^{-1}
6) 1000-seed weight (g)
7) Total dry matter (g $plant^{-1}$)
8) Seed yield
9) Stover yield
10) Biological yield
11) Harvest index (%)

Data on individual plant character of serial number (1-4 & 7) was recorded randomly from selected plants of each plot and those of 1000-seed weight, seed yield, stover yield, biological yield and harvest index was recorded from the whole plant at harvest.

3.7.1 Plant height

The height of ten randomly selected plants was measured from the ground level to the tip of the top most pod and mean plant height was recorded in cm.

3.7.2 Number of branches plant^{-1}

The number of branches of the ten-sample plant were counted and recorded.

3.7.3 Number of pods plant^{-1}

The sum of the total pods plant^{-1} was regarded as the number of pods plant^{-1}.

3.7.4 Number of pods branch^{-1}

Number of pods on the main stem and also on different branches was recorded.

3.7.5 Pod dry matter

Total pod dry matters of ten randomly selected sampled plants were recorded at fifty percent pod maturity (FPPM), 5 days after FPPM, 10 days after FPPM and 15 days after FPPM by constant oven drying method keeping in the oven at 103^0 for 17 hours and converted to g m^{-2}.

3.7.6 Length of pod

Length of ten randomly selected pods from test plants were measured and average length per pod was recorded in cm.

3.7.7 Number of seeds pod^{-1}

The number of seeds was counted by splitting five pods taken at same part of each plant.

3.7.8 Weight of 1000-seed

From the seed stock of each plot 1000-seed were collected randomly and weight was taken by an electric balance. The 1000-seed weight was recorded in gram (g).

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

After threshing, cleaning and drying the total seed from the harvested area (1 m^2) including the ten sampled plants were recorded as seed yield which was converted to t ha^{-1}.

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

After the separation of seeds from plants, the straw per plot was dried separately and recorded the weight. These weights were converted into straw yield (t ha^{-1}).

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

The summation of grain yield and straw yield per plot gave the biological yield.

3.7.12 Harvest index (HI)

Harvest Index was calculated by dividing the economic (seed) yield from the test plot by the total biological yield (Seed + Stover) from the same area and multiplying by 100.

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

3.8 Data analysis

The data collected on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The differences between pairs of means were compared by Duncan's multiple range test (DMRT) as stated by Gomez and Gomez (1984)

3.7.12 Harvest index (HI)

Harvest Index was calculated by dividing the economic (seed) yield from the test plot by the total biological yield (Seed + Stover) from the same area and multiplying by 100.

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

3.8 Data analysis

The data collected on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The differences between pairs of means were compared by Duncan's multiple range test (DMRT) as stated by Gomez and Gomez (1984)

Chapter 4
RESULTS AND DISCUSSION

RESULT AND DISCUSSION

The experiment was aimed at studying the performance of four rapeseed-mustard varieties as influenced by row spacing. The result of the present investigation have been presented and discussed in this chapter.

4.1 Plant height

4.1.1 Effect of variety

Plant height varied significantly among the varieties (Table 1). The plant height was the highest for Improved Tori 7(97.85 cm) while the lowest from SAU Sharisa 1(81.33 cm) (Table 1). Improved Tori 7 was followed by variety BARI Sharisa 9 (94.09 cm) and BARI Sharisa 13 (87.48 cm) in that height.

Varieties had different plant types and therefore, plant height in particular differed widely. Ali *et al.* (1990) and Bhuiyan (1989) observed significant variation in plant height in different varieties of mustard and rape. Jahan and Zakaria (1997) observed that BARI Sharisa 6 was the tallest plant (142.5 cm) which was at per with Sonali (139.5 cm) and Jatarai (138.6 cm). The shortest plant was observed in Tori 7 (90.97 cm). Mondal *et al* (1992) observed the highest plant height (134.4 cm) in the variety J-5004, which was identical with SS-75 and Improved Tori 7 and significantly taller than TS-72. Ahmed *et al.* (1999) observed the tallest plant (120.56 cm) in the variety Daulat.

The result indicated that Improved Tori 7 and BARI Sharisa 9 were of tall type and others were intermediate and short stature in plant height. So the significant difference in plant height may be associated with the varietal characteristics or genetic make up of the varieties of rapeseed.

4.1.2 Effect of row spacing

Row spacing had a significant effect on plant height of rapeseed and mustard. The tallest plant (98.47 cm) (Table 2) was noted with the 45 cm row spacing. While the shortest plant (82.20 cm) plant was found with 15 cm row spacing. The increased plant population increased competition for nutrients, space and light that might have resulted in the stunted growth.

The result revealed that the plant height decreased as the row spacing decreased. The plant height of 30 cm row spacing was 89.88 cm which was also higher than 15 cm row spacing. This was mainly due to over population pressure.

Suraj *et al.* (1975) obtained maximum plant height of mustard when a population size was maintained at 50 plants m^{-2}. Miah *et al.* (1987) reported that when rapeseed was grown with higher seed rate, it increased plant height. On the other hand, Gupta (1988) recorded significant taller plant height of mustard with wider spacing.

4.1.3 Interaction effects of variety and row spacing

There was a significant interaction between variety and row spacing (Table 3). However there were differences when row spacing increased. The highest plant height (109.20 cm) was found from the treatment combination of variety BARI Sharisa 9 with 45 cm row spacing (Table 3). The lowest (74.33) was found from the SAU Sharisa 1 with 15 cm row spacing.

4.2 Number of branches plant^{-1}

4.2.1 Effect of variety

There was a significant variation in number of branches plant^{-1} among the varieties (Table 1). The variety BARI Sharisa 9 produced the highest number of branches plant^{-1} (5.36) and the lowest number of branches plant^{-1} (3.92) was produced by the variety BARI Sharisa 13. The number of branches plant^{-1} was 5.264 for the variety of Improved Tori 7 and 3.95 for the variety of SAU Sharisa 1 which was statistically identical to BARI Sharisa 13.

Jahan and Zakaria (1997) observed 4.07 primary branches plant^{-1} in the local Tori-7 and Sampad which were at per BLN-900. The minimum primary branches plant^{-1} (2.90) was produced by Jataria. Khaleque (1989) observed 3.9 and 3.1 branches plant^{-1} in TS-72 and Sonali Sharisa, respectively.

4.2.2 Effect of row spacing

Row spacing significantly influenced the number of branches plant^{-1} (Table 2). Increase of row spacing increased the number of branches plant^{-1} significantly. Row spacing 30 cm produced the highest number of branches plant^{-1} (5.717). The closer row spacing (15 cm) produced the lowest number of (3.33) branches plant^{-1}. The other row spacing of 45 cm produced 4.83 branches plant^{-1} which was statistically different to each other (Table 2). Wider row spacing produced higher number of primary branches plant^{-1} which might be due to less interplant competition for light, space nutrients and environmental resources.

Kumar and Gangwar (1984) obtained maximum number of primary and secondary branches plant^{-1} when *B. campestris* was grown at 30 and 40 cm apart in row, increased seed yield significantly. When the crop was planted at 20 cm apart rows the number of branches/plant was reduced consequently that resulted less seed yield/ha.

Gangwar and Kumar (1986) and Tomar (1989) reported that when *B. campestris* var. Toria was grown maintaining 16.6 and 22.2 plants m^{-2}, the number of primary and secondary branches $plant^{-1}$ were increased and that produced higher seed yield ha^{-1}. Bhargava (1991) also reported that profuse branching was desirable for higher seed yield of rapeseed and mustard (*B. campestris* and *B. juncea*). Shrief *et al.* (1990) stated that plant density increased the number of branches $plant^{-1}$ but higher plant density increased the seed yield by 7.27 %.

4.2.3 Interaction effects variety and row spacing

Number of branches $plant^{-1}$ was significantly influenced by the interaction effect of variety and row spacing (Table 3). The maximum number of (6.80) produced by the interaction effects of SAU Sharisa 1 with 30 cm row spacing which was identical with BARI Sharisa 9 with 15 cm row spacing. The lowest number of branches $plant^{-1}$ was produced by the interaction effects of SAU Sharisa 1 with 15 cm row spacing.

4.3 Number of Pods $plant^{-1}$

4.3.1 Effect of variety

There was a significant difference in number of pods $plant^{-1}$ among the varieties (Table 1). The highest number of pods $plant^{-1}$ (131.5) was produced by the variety BARI Sharisa 9 and the second highest produced by the variety Improved Tori 7(125.5). The rest two varieties SAU Sharisa 1 and BARI Sharisa 13 produced 109.3 and 97.02 pods $plant^{-1}$ respectively.

These values were statistically smaller than those of BARI Sharisa 9 and Improved Tori 7.

Mondal *et al.* (1992) observed the maximum number of pods plant^{-1} (136) in the variety J 5004 which was identical with the variety Tori 7 and the lowest number of pods plant^{-1} (45.9) was found in the variety SS-75.

4.3.2 Effect of row spacing

The number of pods plant^{-1} differed significantly due to variation of row spacing. As the row spacing increased the number of pods plant^{-1} also increased significantly (Table 2). The highest number of pods plant^{-1} (139.8) was found from the row spacing of 45 cm and the lowest (77.56) in 15 cm row spacing. In 30 cm row spacing it was 130.1. Wider row spacing produced more number of pods plant^{-1} than closer row spacing mainly because of the fact that wider spacing facilitated maximum utilization of solar energy as well as other environmental resources which helped more dry matter production. Number of pods plant^{-1} directly correlates with the dry matter production by the plants (Mumier *et al.*, 1998). Singh and Singh (1984) and Gupta (1988) obtained higher number of pods plant^{-1} at lower plant density but higher seed yield of *B. campestris* and *B. juncea* were recorded at 33.3 and 44.4 plants m^{-2} increased the number of pods plant^{-1}, which promoted higher seed yield ha^{-1}. On the other hand, Miah *et al.* (1987) observed that when rapeseed was grown maintaining 5 kg ha^{-1}, increased the number of pods plant^{-1} which promoted higher seed yield ha^{-1}.

4.3.3 Interaction effects

There was significant difference in number of pods plant^{-1} due to variety and row spacing interaction (Table 3). Results showed that with increasing row spacing in all the varieties, the number of pods plant^{-1} increased.

Apparently the highest number of pods plant^{-1} was found from the treatment combination of variety BARI Sharisa 13(154.80) and 30 cm row spacing and the lowest number of pods plant^{-1} was found from the treatment combination of the variety Improved Tori 7 and 15 cm row spacing (Table 3)

4.4 Pod dry matter at different harvesting stages

4.4.1 Effect of variety

There was a significant variation in pod dry matter due to varieties of rapeseed and mustard at different ripening stages (Table 4). The result showed that at all stages, the variety BARI Sharisa 9 produced the highest pod dry matter of 217.10, 233.20, 244.10, 253.80 g m^{-2}, respectively at fifty percent pod maturity (FPPM), 5 days after FPPM, 10 days after FPPM and 15 days after FPPM (Table 4). Pods dry matter increased gradually and reached the maximum value at 10 days after FPPM. After the pods dry matter decreased in all the varieties. BARI Sharisa 13 produced statistically the lowest pod dry matter in all ripening stages. Improved Tori 7 prduced 208.20, 208.00, 215.60, 219.60 g m^{-2} and SAU Sharisa 1 produced 186.10, 197.30, 204.50, 204.00 g m^{-2}pod dry matter respectively (50%, 5, 10, 15 days after FPPM). FPPM might have been caused due to shattering losses of seeds. Therefore, the shattering loss was the highest in variety SAU Sharisa 1and the lowest in variety Improved Tori 7. The present result indicates that delayed harvesting could reduce seed yield due to shattering of pods to a substantial level.

4.4.2 Effect of row spacing

Row spacing significantly increased the pod dry matter at all ripening stages (Table 5). In general, 30 cm row spacing produced the highest pod dry matter at fifty percent pod maturity (FPPM), 5 days after FPPM, 10 days after FPPM and 15 days after FPPM and those were 210.90, 220.50, 229.80, 237.80 g m^{-2} respectively (Table 5). The lowest pod dry matter was produced by the row spacing of 45 cm pods at all stages.

4.4.3 Interaction effects of variety and row spacing

The effect of interaction between variety and row spacing on pod dry matter was found significant at 50% pod maturity stage and at 10 days after FPPM but not at 5 days after FPPM and 15 days after FPPM (Table 6). At 50% pod maturity (FPPM), 5 days after FPPM, 10 days after FPPM and 15 days after FPPM the highest pod dry matter was obtained in BARI Sharisa 9 and 30 cm row spacing (234.70, 250.00, 261.00, 270.40 g m^{-2} respectively) and the lowest pod dry matter was obtained at 50% pod maturity (FPPM), 5 days after FPPM, 10 days after FPPM 15 days after FPPM with BARI Sharisa 13 and 45 cm row spacing (160.10, 174.40, 180.30, 190.40 g m^{-2}) (Table 6).

4.5 Length of pods

4.5.1 Effects of variety

There was a significant difference among the varieties in producing pod length (Table 1). The highest pod length (5.27 cm) was found from the variety BARI Sharisa 9 but this was statistically identical to that of the variety BARI Sharisa 13 (5.24 cm). Improved Tori 7 and SAU Sharisa 1 produced same pod length (4.50 cm). The above results indicate that there exists substantial variation for pod length among the varieties. So the significant difference in pods length may be associated with the varietal characteristics or genetic make up of the varieties of rapeseed and mustard. Similar variation in this character was also reported by Lebowitz (1989), Olsson (1990) and Masood *et al.* (1999) in several genotypes of rapeseed and mustard. Jahan and Zakaria (1997) observed the longest pod (8.07 cm) in BLN-900 and shortest pod length (4.83 cm) in Hyola-401.

4.5.2 Effects of row spacing

There was a significant variation in respect of pod length due to row spacings. Result showed that increased row spacing significantly increased the length of each pod (Table 2). The maximum length of pod (5.50 cm) was obtained from the row spacing of 45 cm. The lowest pod length (4.07 cm) was observed from closest row spacing (15 cm) and 30 cm row spacing produced 5.07 cm pod length. Wider row spacing, however, increased the pod length, which might be due to less competition for light, nutrients, space and environments. Singh and Singh (1984) and Shrief *et al.* (1990) reported that lower plant density increased the pod length.

4.5.3 Interaction effects of variety and row spacing

There was significant variation in producing pod length by the interaction effect of variety and row spacing (Table 3). The highest length of pod (5.86 cm) was produced by the variety BARI Sharisa 13 and row spacing of 45 cm. The lowest pod length (3.63 cm) was produced by the variety Improved Tori 7 with 30 cm row spacing whish is statistically identical to 15 cm row spacing.

4.6 Number of seeds pod^{-1}

4.6.1 Effect of variety

There was a significant variation in number of seeds pod^{-1} among the varieties. The number of seeds pod^{-1} (25.17) produced by the variety BARI Sharisa 9 was the highest. The minimum number of seeds pod^{-1} (12.58) was produced by the variety BARI Sharisa 13. SAU Sharisa 1 and Improved Tori 7 produced 14.36 and 15.13 respectively. The significant difference in number of seeds pod^{-1} may be associated with the varietal characteristics or genetic make up of the varieties of rapeseed. Das *et al.* (1999) reported that MM 7 (Mutant) produced the highest number of seeds pod^{-1} (29.2) followed by MM 20 (Mutant) and BINA Sharisa 4 (27.8) at Dinajpur.

4.6.2 Effect of row spacing

Row spacing had a significant effect on number of seeds pod^{-1} (Table 2). The highest number of seeds pod^{-1} (18.46) was observed by row spacing of 45 cm and the lowest number of seeds pod^{-1} (14.20) was found in 15 cm row spacing (Table 2).The result revealed that the number of seeds pod^{-1} decreased as the row spacing decreased. Mondal *et al.* (1992) observed the highest seeds pod^{-1} (27.6) in SS-75 and the lowest number of seeds pod^{-1} in J-5004.

Singh and Singh (1984) reported that the number of seeds pod^{-1} increased as the plant density decreased. Tomar (1989) obtained maximum number of seeds pod^{-1} at 22 plants m^{-2}. Jahan and Zakaria (1997) observed the highest number of seeds pod^{-1} (26.13) in BARI Sharisa 6 which was at par with Sonali (23.5) and Jatarai (22.8) and the lowest number of seeds pod^{-1} (18.0) was in Tori 7.

4.6.3 Interaction effects of variety and row spacing

There was a significant interaction effect of the variety and row spacing in producing the number of seeds pod^{-1} (Table 3). The highest number of seeds pod^{-1} (28.78) was produced by the treatment combination variety BARI Sharisa 13 and 30 cm row spacing.

4.7 1000-Seed Weight

4.7.1 Effect of variety

The seed weight in terms of 1000-seed varied significantly among the varieties. The variety BARI Sharisa 9 and Improved Tori 7 produced heavier 1000-seed weight (3.18 g and 3.22 g) which were identical to each other and were heavier compared to 2.71 g and 2.56 g produced by SAU Sharisa 1 and BARI Sharisa 13.

Similar to the result of this study significant variation for this character was also found by Singh (1986), Kudla (1993), Yadav *et al*. (1993), Kumar and Singh (1994) and Hussain *et al*. (1998) in a large number of strains of *B. campestris*, *B. napus* and *B. juncea*. Mondal *et al* (2001) observed that 1000-seed weight ranged 2.5-2.65 g in Improved Tori 7 (*B. campestris*) and 1.5-7.8 g in Rai-5 (*B. juncea*).

4.7.2 Effect of row spacing

Effect of row spacing did not show any significant affect on 1000- seed weight of rapeseed and mustard. Numerically the highest 1000-seed weight (2.98 g) was observed in 45 cm row spacing and the lowest 1000-seed weight (2.84 g) was observed in 15 cm row spacing. Singh and Singh (1984) and Gupta (1998) recorded higher 1000-seed weight at lower plant density, but higher seed yield of *B. campestris* and *B. juncea* obtained with plant density of 33.3 and 44.4 plants m^{-2} due to optimum plant population. Miah *et al*. (1987) and Tomar (1989) obtained higher 1000-seed weight, when rapeseed was grown with 5 kg ha^{-1} seed rate and 22 plants m^{-2} respectively.

4.7.3 Interaction effects of variety and row spacing

There was no significant difference in 1000-seed weight due to the interaction effect of variety and row spacing (Table 3)

4.8 Seed yield

4.8.1 Effect of variety

The seed yield of rapeseed and mustard significantly differed among the varieties (Table 1). BARI Sharisa 9 produced the highest yield of 1.54 t ha^{-1}. The lowest seed yield (0.96 t ha^{-1}) was obtained from the variety BARI Sharisa 13. Improved Tori 7 and SAU Sharisa 1 produced 1.34 and 1.10 t ha^{-1} seed yield respectively. BINA (2001) reported that the higher seed yield was positively correlated with plant height, number of branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight. Gosh and Chatterjee (1988) noticed that the higher seed yield of Indian mustard (*B. juncea*) was closely related with the number of pods m^{-2}. Rahman (2002) observed higher seed yield in BARI Sharisa 7, BARI Sharisa 8 and BARI Sharisa 11 (2.00-2.50 t ha^{-1}) and the lowest yield in variety Tori 7 (0.95-1.10 t ha^{-1})

4.8.2 Effect of row spacing

Row spacing had a significant effect on seed yield of rapeseed and mustard (Table 2). Increasing row spacing up to 30 cm increased the seed yield per unit area significantly and thereafter, it sharply declined (Table 2). The 30 cm row spacing gave the highest seed yield of 1.44 t ha^{-1} followed by 45 cm row spacing giving seed yield of 1.23 t ha^{-1}. On the other hand 15 cm row spacing gave the lowest seed yield 1.04 t ha^{-1}. It may be concluded that intermediate plant density assisted to produce substantially higher seed yield. This is mainly due to the fact that an optimum plant density facilitated maximum utilization of solar radiation and nutrients which enhanced TDM production and development other yield components. In closer row spacing against all the varieties there were competition for light, space, nutrients and environments and therefore could not produce no primary branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight ultimately seed yield per unit area.

Khader and Bhargava (1985) and Gupta (1988) recorded maximum seed yield of *B. juncea* and B.campestris with plant density at 44 plant m^{-2}. Singh and Singh (1984) obtained higher seed yield of *B. campestris* var. toria, with plant density level at 33.3 plants m^{-2}. Contrary to that, Patli and De (1978), Shinde and Borulaker (1981), Shastry and Kumar (1981), Giri and Gangasaran (1985), Tomar (1989), Singh and Kumar (1990) and Ali *et al*. (1990) obtained maximum seed yield of Brassica spp. with plant density at 22 plants m^{-2}. On the other hand Kumar and Gangwar (1985) reported higher seed yield of *B. campestris*, when plant density was maintained 16.6 plants m^{-2}. Morrision *et al*. (1990) obtained higher seed yield of summer rape when the crop was grown with 1.5 kg seed ha^{-1} in 15 cm apart in row.

4.8.3 Interaction effects of variety and row spacing

There was significant variation in seed yield due to the interaction effect of variety and row spacing (Table 3). The highest seed yield was 1.93 t ha^{-1} obtained from the treatment combination of the variety BARI Sharisa 9 and 30 cm row spacing and lowest seed yield was 0.87 t ha^{-1} obtained from the treatment combination of variety Improved Tori 7 and 15 cm row spacing (Table 3). The next highest seed yield 1.49 t ha^{-1} obtained from the combination of BARI Sharisa 13 with 30 cm row spacing and this yield was identical to 1.48 t ha^{-1} obtained from SAU Sharisa 1 with 30 cm spacing.

4.9 Stover yield

4.9.1 Effect of variety

The Stover yield of 5.66 t ha^{-1} produced by the variety BARI Sharisa 9 was the highest and the lowest Stover yield of 4.69 t ha^{-1} was obtained from the variety BARI Sharisa 13. Improved Tori 7 and SAU Sharisa 1 produced 5.36 and 4.86 t ha^{-1} stover yield respectively.

4.9.2 Effect of row spacing

Stover yield increased significantly with the row spacing (Table 1). The highest Stover yield was 5.79 t ha^{-1} was produced by the closest row spacing (15 cm row spacing) and the lowest Stover yield was 4.39 t ha^{-1} was produced by the widest row spacing (45 cm) (Table 2). It might be due to accommodation of more number of plants/m^2 in closer row spacing.

4.9.3 Interaction effects of variety and row spacing

There was no significant effect of interaction between variety and row spacing in respect of stover yield (Table 3). The stover yield numerically decreased with the increasing of row spacing in case of all the varieties. The highest stover yield was found from the closer row spacing and lowest was found from the wider row spacing.

4.10 Biological Yield

4.10.1 Effect of variety

There was a significant difference among the varieties in Biological yield (Table 1). The highest biological yield (7.20 t ha^{-1}) was produced by the variety BARI Sharisa 9. The lowest biological yield (5.66 t ha^{-1}) produced by the variety BARI Sharisa 13. Improved Tori 7 and SAU Sharisa 1 produced biological yield 6.70 and 6.08 t ha^{-1} respectively.

4.10.2 Effect of row spacing

There was a significant variation in respect to biological yield due to row spacing (Table 2). The highest biological yield (6.93 t ha^{-1}) was produced by the closer row spacing (15 cm). The lowest biological yield (5.62 t ha^{-1})

produced by 45 cm row spacing (Table 2). Obviously the biological yield in mustard increased with decreasing row spacing as shown in this study. Whereas, Clark and Simpson (1978) reported the yield of 19.20 - 32.00 t ha^{-1} with and without irrigation, respectively at plant density level of 300 plants m^{-2} under Canadian conditions. In Britain, Scarisbrick *et al.* (1982) obtained a biological yield of 11.00 t ha^{-1} at a plant density of 160 plants, whereas, In India, Bhargava and Tomar (1982) obtained maximum biological yield of 11.62 t ha^{-1} at harvest of *B. campestris*.

4.10.3 Interaction effects of variety and row spacing

There was significant variation in interaction effect between variety and row spacing (Table 3). Increasing row spacing of all the varieties increased the biological yield (Table 3).

4.11 Harvest index

4.11.1 Effect of variety

There was significant difference in harvest index (HI) values among the varieties. Statistically the highest harvest index value of 21.33% was observed by the variety BARI Sharisa 9 and the lowest HI values of 17.24% in the variety BARI Sharisa 13. Mehrota *et al* (1976) recorded harvest index values ranging from 25 to 40 % in *B. juncea* and that for *B. campestris* from 27 to 42 %.

4.11.2 Effect of row spacing

Row spacing significantly affected the harvest index (Table 3). The highest harvest index value of 21.82% was obtained from the row spacing of 45 cm which was statistically superior from that of 30 and 15 cm row spacing. The lowest HI value of 14.94% was found from the row spacing of 15 cm (Table 2). Scarisbrick *et al.* (1982) reported that plant density at 54 plants

m^{-2} performed higher harvest index, consequently, which executed higher seed yield of *B. napus*. Singh and Singh (1984) reported that plant density level of 33.3 plants m^{-2} resulted higher harvest index, consequently higher grain yield of *Brassica campestris.* Shrief *et al.* (1990) also reported higher seed yield and higher HI of rapeseed with 30 plants m^{-2}.

4.11.3 Interaction effects of variety and row spacing

There was significant difference in harvest Index due to the interaction effect of variety and row spacing (Table 3). The highest harvest index (24.98%) was found in the treatment combination of variety BARI Sharisa 9 at 30 cm row spacing. The lowest harvest index (13.71%) was found in the variety Improved Tori 7 at 30 cm row spacing.

Table: 1. Effect of variety on the yield and yield attributes of rapeseed-mustard

Treatment (Variety)	Plant height (cm)	Number of Branches Plant^{-1}	Number of Pods Plant^{-1}	Length of pod (cm)	Number of Seeds pod^{-1}	1000 Seed wt (g)	Seed Yield (t ha^{-1})	Stover Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (%)
Improved Tori 7	97.85a	5.26b	125.5b	4.50b	15.13b	3.222 a	1.34 b	5.36b	6.70 b	20.43b
SAU Sharisa 1	81.33d	3.96c	109.3c	4.50b	14.36 c	2.717b	1.10c	4.86c	6.08c	18.40c
BARI Sharisa 9	94.09b	5.36 a	131.5a	5.27a	25.17a	3.183a	1.54a	5.66a	7.20 a	21.33a
BARI Sharisa 13	87.48c	3.93c	97.02d	5.24a	12.58 d	2.567b	0.96d	4.69d	5.66 d	17.24d
$S\bar{x}$	0.2576	0.02789	0.2915	0.05676	0.07149	0.05676	0.2300	5.621	0.3861	0.08433
F test	**	**	**	**	**	**	**	**	**	**
% CV	0.86	1.83	0.75	3.48	1.50	5.78	0.56	3.28	0.18	1.30

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Table: 2. Effect of row spacing on the yield and yield attributes of rapeseed-mustard

Treatment (spacing) (cm)	Plant height (cm)	Number of Branch Plant^{-1}	Number of Pods Plant^{-1}	Length of pod (cm)	Number of Seeds pod^{-1}	1000 Seed wt (g)	Seed Yield (t ha^{-1})	Stover Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (HI)
15	82.20c	3.33c	77.56c	4.07c	14.20c	2.838	1.04c	5.79 a	6.93 a	14.94 c
30	89.88b	5.72a	130.1b	5.07b	17.47b	2.950	1.44a	5.24 b	6.68 b	21.32 b
45	98.47a	4.83b	139.8a	5.50a	18.46a	2.979	1.23b	4.39 c	5.62 c	21.78 a
S$\bar{x}$	0.2230	0.02415	0.2525	0.04916	0.06191	0.04916	0.1992	4.868	1.333	0.07303
F test	**	**	**	**	**	NS	**	**	**	**
% CV	0.86	1.83	0.75	3.48	1.50	5.78	0.56	3.28	0.18	1.30

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Table: 3. Interaction effect of variety and row spacing on the yield and yield attributes of rapeseed-mustard

Variety	Spacing (cm)	Plant height (cm)	Number of Branch Plant^{-1}	Number of Pods Plant^{-1}	Length of pod (cm)	Number of Seeds pod^{-1}	1000 Seed wt (g)	Seed Yield (t ha^{-1})	Stover Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index (HI)
Improved Tori 7	15	90.08 ef	3.40 g	69.45 j	3.83 gh	12.50	3.18 a	1.17 f	9.19	7.37 c	15.99 g
	30	74.87 h	3.03 h	82.27 i	3.63 h	11.28	2.68 b	0.92 i	5.46	6.71 e	13.71 h
	45	89.53 f	3.93 f	89.96 h	4.68 e	21.55	2.92 ab	1.21 e	6.24	7.45 b	15.82 g
SAU Sharisa 1	15	74.33h	2.97 h	68.55 j	4.15 fg	11.47	2.57 b	0.87 j	5.29	6.17 g	14.24 h
	30	94.23 d	6.80 a	143.00 c	4.76 e	16.48	3.23 a	1.48 b	5.50	6.97 d	21.38 d
	45	85.48 g	4.82 d	120.00 e	4.50 ef	15.65	2.71 b	1.25 d	4.88	6.14 h	20.28 e
BARI Sharisa-9	15	101.10 b	6.75 a	149.80 b	5.30 cd	25.17	3.33 a	1.09 h	5.79	7.72 a	24.98 a
	30	98.10 c	4.50 e	107.80 g	5.72 ab	12.57	2.56 b	1.93a	4.78	5.89 i	18.65 f
	45	109.20a	5.59 b	151.20 b	4.92 de	16.40	3.25 a	1.38 c	4.39	5.76 j	23.93 b
BARI Sharisa 13	15	84.17 g	4.02 f	138.4 d	5.38 bc	16.15	2.76 b	1.14 g	4.24	5.39 k	21.19 d
	30	91.67 e	5.40 c	154.80 a	5.83 a	28.78	3.30 a	1.49 b	4.94	6.43 f	23.18 c
	45	89.47 f	4.32 e	114.70 f	5.86 a	13.70	2.60 b	0.92 i	3.99	4.92 l	18.82 f
Sx		0.4461	0.4830	0.5050	0.09832	0.09832	0.1238	0.3983	9.736	0.6688	0.1461
F test		**	**	**	**	NS	**	**	NS	**	**
% CV		0.86	1.83	0.75	3.48	5.78	1.50	0.56	3.28	0.18	1.30

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Table: 4. Effect of variety on the pod dry matter (g m^{-2}) of rapeseed-mustard at different stage of harvest

Variety	Pod dry matter (g m^{-2}) Stages of harvest				% shattering loss
	50 % Pod Maturity (FPPM) (g m^{-2})	5 days after FPPM	10 Days after FPPM	15 Days after FPPM	
Improved Tori 7	208.20 b	208.00 b	215.60 b	219.60 b	0.92
SAU Sharisa 1	186.10 c	197.30 c	204.50 c	204.00 c	7.9
BARI Sharisa 9	217.10 a	233.20 a	244.10 a	253.80 a	9.6
BARI Sharisa 13	175.80 d	184.80 d	192.90 d	201.50 c	5.6
S$\bar{x}$	0.4742	0.5033	0.6705	5.573	-
F test	**	**	**	**	-
% CV	0.72	0.73	0.94	7.61	-

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Table: 5. Effect of row spacing on the pod dry matter (g m^{-2}) of rapeseed-mustard at different stage of harvest

Spacing (cm)	Pod dry matter (g m^{-2}) Stages of harvest				% shattering loss
	50 % Pod Maturity (FPPM)	5 days after FPPM	10 Days after FPPM	15 Days after FPPM	
15	196.70 b	204.80 b	212.80 b	211.80 b	4.10
30	210.90 a	220.50 a	229.80 a	237.80 a	5.3
45	182.80 c	192.20 c	200.30 c	209.60 b	5.6
$S\bar{x}$	0.4107	0.4359	0.5807	4.826	
F test	**	**	**	**	
% CV	0.72	0.73	0.94	7.61	

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Table: 6. Interaction effect of variety and row spacing on the pod dry matter (g m^{-2}) of rapeseed-mustard at different stage of harvest

Treatments		Pod dry matter (g m^{-2})				% shattering loss
		Stages of harvest				
Variety	Spacing (cm)	50 % Pod Maturity (FPPM)	5 days after FPPM	10 Days after FPPM	15 Days after FPPM	
Improved Tori 7	15	211.30 c	214.30 d	218.50 e	219.50 bc	1.33
	30	184.20 g	189.10 h	198.10 h	173.00 d	0.67
	45	216.50 b	235.00 b	244.70 b	260.30 ab	0.73
SAU Sharisa 1	15	174.80 h	180.90 j	189.90 i	194.50 cd	2.33
	30	218.90 b	224.50 c	237.20 c	242.30 ab	3.9
	45	197.60 de	208.50 e	212.50 f	218.80 bc	6.73
BARI Sharisa 9	15	192.40 f	199.00 f	208.40 f	219.70 bc	0.88
	30	234.70a	250.00a	261.00a	270.40a	2.69
	45	194.40 ef	185.20 i	191.10 i	197.10 cd	2.58
BARI Sharisa 13	15	176.50 h	194.50 g	202.90 g	220.30 bc	1.04
	30	200.20 d	214.60 d	226.70 d	230.60 abc	3.78
	45	160.10 i	174.40 k	180.30 j	190.40 cd	6.38
$S\bar{x}$		0.8214	0.8718	1.161	9.653	-
F test		**	**	**	*	-
% CV		0.72	0.73	0.94	7.61	-

In a column figure with same letter or without letters do not differ significantly whereas dissimilar letter differ significantly (as per MDRT) at 5% level of probability. *Significant at 5% level of probability. ** Significant at 1% level of probability. NS not significantly different at $p<0.05$

Chapter 5
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The experiment was carried out at the research Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2007 to February 2008 to study the effect of row spacing on the yield and yield contributing characters of rapeseed. Four high yielding variety of rapeseed (viz. Improved Tori 7, SAU Sharisa 1, BARI Sharisa 9, BARI Sharisa 13) and three row spacings (viz. 15 cm, 30cm and 45 cm) were included as experimental treatments. The experimental site was located under the Agro-ecological zone 28 (Madhupur Tract) having the red brown trace soils and acid basin clay. The soils were strongly acidic in reaction with low status of organic matter, low moisture holding capacity and low fertility level. Soils were mainly phosphate fixing and low in K, S and Ca. The experiment was laid out in a two factor randomized completely block design with three replications. The spacing between plants in a row was maintained at five cm distance. The unit plot size 3m x 2.5m. The land preparation, fertilization, irrigation, drainage, pest management and other intercultural operations, harvesting, post harvest operations and data collection were done carefully.

Result showed that plant height, number of branches plant^{-1}, number of pods plant^{-1}, seeds pod^{-1}; 1000-seed weight (g) harvest index differed significantly among the four varieties of rapeseed. The plant height was the highest for Improved Tori 7(97.85 cm) while the lowest plant height was obtained from SAU Sharisa 1(81.33 cm). The variety BARI Sharisa-9 produced the highest number of branches plant^{-1} (5.36) and the lowest number of branches plant^{-1} (3.92) produced by the variety BARI Sharisa 13. The number of branches plant^{-1} was 5.264 for the variety of Improved Tori 7 and 3.95 for the variety of SAU Sharisa 1 which was statistically identical to BARI Sharisa 13. The highest number of pods plant^{-1} (131.5) was produced by the variety BARI Sharisa 13 which was statistically identical to the variety Improved Tori 7(125.5). The number of seeds pod^{-1} (25.17) produced by the variety BARI Sharisa 9 was the highest. The minimum number of seeds pod^{-1} (12.58) was produced by the variety BARI Sharisa 13. SAU Sharisa 1 and Improved Tori 7 produced 14.36 and 15.13 respectively. The lowest 1000-seed weights (2.72 g) were produced by SAU Sharisa 1. BARI Sharisa 9 produced the highest yield of 1.54 t ha^{-1}. The lowest seed yield (0.96 t ha^{-1}) was obtained from the variety BARI Sharisa 13. Improved Tori 7 and SAU Sharisa 1 produced 1.34 and 1.10 t ha^{-1} seed yield respectively. The Stover yield of 5.66 t ha^{-1} produced by the variety BARI Sharisa 9 was the highest and the lowest Stover yield of 4.69 t ha^{-1} was obtained from the variety BARI Sharisa 13.

Row spacing had a significant effect of plant height, number of branches plant^{-1}, number of pods plant^{-1}, seeds pod^{-1}; 1000-seed weight (g), Seed yield, Stover yield. The tallest plant (98.47 cm) (Table 2) was noted with 45 cm row spacing. While the shortest plant (82.20 cm) plant was found with 15 cm row spacing. Row spacing 45 cm produced the highest number of branches plant^{-1} (5.717). The closest row spacing (15 cm) produced the lowest number of (3.93) branches plant^{-1}. The highest number of pods plant^{-1} (139.8) was found from the row spacing of 45 cm and the lowest (77.56) in 15 cm row spacing. In 30 cm row spacing it was 130.1. The maximum length of pod (5.50 cm) was obtained from the row spacing of 45 cm. The lowest pod length (4.07 cm) was observed from closest row spacing (15 cm) and 30 cm row spacing produced 5.07 cm pod length. The highest number of seeds pod^{-1} (18.46) was observed by row spacing of 45 cm and the lowest number of seeds pod^{-1} (14.20) was found in 15 cm row spacing. The highest 1000 seed weight (2.98 g) was found in 45 cm row spacing which was statistically identical to those of 15 and 30 cm row spacing (2.84 g and 2.95 g). The 30 cm row spacing gave the highest seed yield of 1.44 t ha^{-1} followed by 15 cm row spacing giving seed yield of 1.04 t ha^{-1}. The highest Stover yield was 5.79 was produced by the closer row spacing (15 cm row spacing) and the lowest Stover yield was 4.39 t ha^{-1} was produced by the wider row spacing.

The present study concludes that the variety BARI Sharisa 9 could give the highest seed yield than any other variety tested. It was also concluded that 30 cm × 5 cm spacing could give highest seed over any other spacing tested. The higher yield of BARI Sharisa 9 is attributing to the production of higher number of branches plant^{-1}, number of pods plant^{-1}, seeds pod^{-1}. Therefore, higher seed yield of rapeseed could be obtained by using BARI Sharisa 9 sowing at 30 cm × 5 cm spacing under the Agro climatic condition of Dhaka (AEZ 28)

REFERENCES

REFERENCES

Alam, M.S., Das, M.K. and Khair, B.M.A. (1986). Genetic variation and correlation and path analysis in B. *juncea*. *Bangladesh J. Agric*. 12 (3): 149-154.

Ahmed, F., Karim, M.R. and Jahan, M.A. (1999). Effect of different management practices on the productivity and profitability of mustard under late sown condition. *Bangladesh J. Agril. Res*. 211(3): 425-430.

Ali, M.H. and Rahman, A.M.M.D. and Ullah, M.J. (1990). Effect of plant population and nitrogen on yield and oil content of rapeseed (*Brassica campestris*) *Indian J. Agric. Sci.* 60 (9): 627-630.

Ali, M.H. and Rahman, M.A. (1986). Response of nitrogen in TS-72 (kalayania) cultivar of *Brassica campestris*. *Bangladesh J. Agric.* 11 (3): 83-86.

BARI. (2000). Annual Report. Oilseed Research Centre. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur.

BARI. (2000). KRISHI PROJUKTI HATBOI (Handbook of Agro-technology). 2nd edition. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. Pp. 113-118.

BARI. (2001). Annual Report. Oilseed Research Centre. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur.

Behera, B., Sharma, H.C. and Panla, P.K. (2002). Effect of plant population and sulphur levels on root growth, seed yield, moisture use efficiency of mustard varieties under rainfed condition. *Indian J. soil conservation*. 3 (2): 161-165.

Bengtsson, A. and Ohlssen, I. (1973). Cultivation techniques for winter oil crops. *Field crop Abs.* 26 (1).

Bhargava, S.C. (1991). Physiology. In: Oilseed *Brassica* in Indian Agriculture. Eds. U.L. Chopra and Shyan Prakas. Har-Anand Publications and Vikas Publish Pvt. Ltd. Pp. 161-197.

Bhargava, S.C. and Tomar, D.P.S. (1982). Physiological basis of yield improvement in rapeseed and mustard. Indo-Swedish Join workshop on rapeseed and mustard. New Delhi, India. Feb. 9-11, 1982. Pp. 33-41.

Bhuiya, M.R. (1989). Techniques of multiplication of pulse and oilseeds. Pulse and oilseeds techniques of Bangladesh. (Ed. Huda, N. and Hussain, M.). BADC. Pp. 98-103.

BINA. (2001). Unnata Krishi Projukti Pariciti. Bangladesh Ins. Nucl. Agric., Mymensingh.

Bilgili, U., Sincik, M., Uzun, A. and Acikgoz, E. (2003). The influence of row spacing and seedling rate on seed yield and yield components of forage turnip (*Brassica rapa* L.). *J. Agron. Crop sci.* 189 (4):250.

Butter, G.S. and Aulakh, C.S. (1999). Effect of sowing date, nitrogen and row spacing on growth, yield attributes and yield of Indian mustard (*Brassica juncea*). *Indian J. Aron.* 44(4):813-815.

Chaniyara, N.J., Solanki, R.M. and Bhalu, V.B. (2002). Effect of inter and intra row spacing on yield of mustard. *Agric. Sci. Dig.* 22(1): 48-50.

Chauhan, Y.S., Behl, R.K. and Kumar, P. (1985). Assosiation of some physiological determinants with seed yield of toria. *J. Oilseeds Res.* 12: 174-182.

Chauhan, Y.S. and Bhargava, S.C. (1984). Physiological analysis of growth and yield variation of rapeseed and mustard. *J. Agric. Sci. Camb.* 103, 249-252d.

Chaudhury, M.A. and Malik, M.A. (1987). Effect of row spacing on the yield of mustard (*Brassica juncea*) under rainfed conditions. *Pakistan J. Sci. Ind. Res.* 30(4):303-304.

Chowdhury, M.A., Miah, A.J., Rahman, L. and Rahman, M. (1999). Correlation and path-coefficient analysis of nine important characters of mustard (*Brassica napus* L. Czern and Cross). *Bangladesh J. Agric.* 129(3):149-154.

Clark, J.M. and Simpson, G.M. (1978). Influence of irrigation and seeding rate on yield and yield components of *Brassica napus* cv. Tower. Can. *J. Plant Sci.* 58:731-737.

Das, M.L., Malek, M.A. and Rahman, A. (1999). Performance of gamma irradiated M5 mutants of rapeseed in different location of Bangladesh. *Bangladesh J. Agric.* 24(1):115-119.

Dellay, R.J. (1972). Results of research on optimum sowing density of winter rapeseed (*Brasssica napus* L.) at Gomblex. *Field Crops Abs.* 259(1):130-131.

Downey, L.A. (1971). Flowering time, climate and genotype. Melbourne, Melbourne University Press. Pp. 193

Elias, S.M., Hussain, M.S. and Bhiyan, S.R. (1982). Agro-economic survey of mustard crop in selected areas of Bangladesh. Agric. Econ. Res. Report. Bangladesh Agril. Res. Ins. (BARI), Joydebpur, Gazipur.

FAO. (2006). Food and Agriculture Organization. Production Yearbook. Rome, Italy. 50: 122

Faraji, A. (2004). Effects of row spacing and seed rate on yield and yield components of rapeseed (Quantum cultivar) in Gonbad. *Seed and Plant.* 20(3): 297-314.

Gangasaran, R., Patil, R. and Prasad, M. (1981). Multiple regression studies on brown sarson. *Indian J. Agron.* 26:220-224.

Gangwar, K.S. and Kumar, A. (1986). Nitrogen fertilization and plant density levels in relation to yield attributes and quality of Toria. J. *Oilseed Res.* 3:151-157.

Ghos, R.K. and Chatterjee, G.N. (1988). Effect of date of sowing on the productivity of Indian mustard (*Brassica juncea* sub. Sp. *Juncea*) in the short and mild winter of the Gangetic plains of West Bengal. *Indian J. Agric. Sci.* 58(8):589-596.

Giri, G. and Gangasaran. (1985). Influence of planting geometry and nitrogen on the performance of Indian range under rained condition. *Indian J. Agron.* 30(4):470-476.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural Research. 2nd edition. A. Wiley-Intersci. Pub., Pp. 130-240.

Goyal, K.S., Das, B., Singh, R., and Mohanty, A.K. (2006). Influence of the thermal environment on phenology, growth and development of mustard varieties. *J. Soils and Crops*. 16(2): 283-290.

Gupta, S.K. (1998). Effect of plant geometry on growth and yield of mustard. *Indian J. Agro.* 33(2):208-209.

Heidari, S., Khademi, K., Nazarian, F. and Ghalavand, A. (2003). Study of row spacing effects on yield and yield components of rapeseed (Brassica napus) cultivars in Khorramabad. *J. Agric. Sci. Islamic Azad Univ.* 9(2): 151-162.

Hussain, M.F., Zakaria, A.K.M. and Jahan, M.H. (1996). Technical report on variety screening. Adaptive research on oilseeds. Rural Development Academy, Bogra, Bangladesh. Pp. 6-34.

Hussain, S., Hazarika, G.N. and Barua, P.K. (1998). Genetic variability, heritability and genetic advance in Indian rapeseed

Islam, N., Chaudhury, M. and Karim, M.R. (1994). Effects of sowing date on growth and development of mustard and rapeseed. Progress Agric. 59:23-29.

ISTA. (1999). International rules for seed testing. Supplement to Seed Science and Technology. 27:1-133.

Jahan, M.H. and Zakaria, A.K.M. (1997). Growth and yield performance of different varieties of rapeseed, mustard and canola in Level Barind Tract. Progress. Agric. 8(1 and 2):144-152.

Jain, A.K., Tiwari, A.S. and Kushwah, V.S. (1988). Genetics of quantitative traits in Indian mustard. *Indian J. Gen. Pl. Breed.* 48(2):117-119.

Johnson, B.L. and Hanson, B.K. (2003). Row spacing interactions on spring canola performance in the Northern Great Plains. *Agron. J.* 95(3):703-708.

Kalaria, P.D., Khistaria, M.K., Khanpara, V.D. and Padmani, D.R. (1997). Effect of spacing, planting pattern and weed control in mustard. *Gujarat Agril. Univ. Res. J.* 22(2):113-115.

Karim, M.R., Islam, F., Ahmed, F. and Islam, M.R. (2000). Performance of some Brassica juncea varieties under on-farm condition at Pabna. *Bangladesh J. Agril. Sci.* 27(1):157-158.

Khader, S.S.E. and Bhargava, S.C. (1985). Physiological aspects of yield improvement of Brassica species with references to plant density II. Dry matter accumulation and growth attributes. *J. Oilseeds Res.* Pp. 218-226.

Khaleque, M.A. (1989). A Guide Book on the production of oilseeds in Bangladesh. Dept. Agric. Ext. Dhaka. Pp. 24-26.

Khan, R.U. and Muendal, H.H. (1999). Effect of row spacing on weed control and seed yield of rapeseed (*Brassica napus*). *Sahrad J. Agril.* 15(1):1-3.

Khandey, B.A., Shah, M.H., Bali, A.S. and Singh, K.N. (1993). Variation in yield and its attributes in Indian mustard (Brassica juncea) in relation to planting time. Fertility and population. *Indian J. Agril. Sci.* 63(3):175-176.

Kondra, Z.P. (1975). Effect of row spacing and seeding rate on rapeseed. *Can. J. Plant Sci.* 55:339-341.

Kudla, M. (1993). Comparative analysis of winter Swede rape genotypes. *Biuletin Instytutu Hodowlo Rosilin.* 190:99-107.

Kumar, A. and Gangwar, K.S. (1984). Growth, development and yield of Indian rape (*Brassica campestris* var. Toria) as influenced by nitrogen fertilization and row spacing's. *Ann. Agric. Res.* 5(1-2):6-13.

Kumar, F., Mustard, B., Hall, A.E. and Madore, M.A. (1996). Response of contrasting vegetable cowpea cultivars to plant density and harvesting of young green pods. II dry matter production and photosynthesis. *Field Crops Research.* 24:11-21.

Kumar, N., Bist, J.K. and Josh, M.C. (2000). Correlation and discriminate function analysis in Indian mustard. Indian *J. Agric. Sci.* 58(1):51-52.

Kumar, V. and Singh, D. (1994). Genetics of yields and its components of Indian mustard (*Brassica juncea* L. Czern and Cross). *Crops Res.* 7(2):243-246.

Larsem, A. and Nordestgard, A. (1972). Row spacing experiments with winter rape (Brassica napus). *Field Crops Abs.* 25(4):807.

Lebowitz, R.J. (1989). Image analysis measurements and repeatedly estimates of pod morphology traits in Brassica campestris L. *Euphytica* 43(1-2):113-116.

Mahar, A.Q., Mahar, A.N., Munir, M., Jumani, M.A. and Chachar, Q.I. (2004). Growth and development response of two mustard varieties to different row spacing. *Indus J. Biol. Sci.* (3): 241-247.

Masood, T., Gilani, M.M. and Khan, F.A. (1999). Path analysis of the major yield and quality characters in Brassica campestris. JAPS, *J. Ani. P. Sci.* 9(1):69-72.

Mehrotra, O.N., Saxena, H.K. and Mosa, M. (1976). Physiological analysis of varietal differences in seed yield of Indian mustard (Brassica juncea L. Czern and Cross). *Indian J. Plant Physiol.* 19:139-146.

Meitei, W.L., Anal, P.M. and Luikham, E. (2001). Performance on broad leaf mustard (Brassica juncea L.) at different spacing. *Indian J. Hill Farming.* 14(2):68-70.

Miah, M.N.H., Karim, M.A., Rahman, M.S., Rahman, A. and Islam, M.A. (1987). Effect of seed rate and method of sowing on the yield and yield components of rapeseed (Brassica campestris). *Bangladesh J. Nucl. Agric.* 3:53-57.

Mondal, M.R.I. and Wahab, M.A. (2001). Production Technology of Oilseeds. Oilseed Res. Cen. Bangladesh Agril. Res. Ins. Joydebpur, Gazipur. Pp. 6-24.

Mondal, S.S., Das, S.K., Pradhan, B.K. and Goswami, S.B. (1990). Effect of potassium on the growth and yield of mustard at varying plant density. *J. Potas. Res.* 6(3):119-123.

Mondol, M.R., Islam, M.A. and Khaleque, M.A. (1992). Effect of variety and planting date on the yield performance of mustard and rapeseed. *Bangladesh J. Agric. Sci.* 19(92):181-188.

Morrison, M.J., Mcvetty, P.B.E. and Scarth, R. (1990). Effect of row spacing and seeding rate on summer rape on southern Manitoba. *Can. J. Plant Sci.* 70:139-149.

Mottalebipour, S. and Bahrani, M.J. Response of two irrigated rapeseed cultivars to plant population. *Crop Res. Hisar*. 32(3): 320-324.

Mumier, J. N.G., Mumier, J.N.M., Ney, B., Roche, R. and Duthion, C. (1998). Seed growth rate in grain legumes. I. Effect of photo assimilates availability on seed growth rate. *J. Exp. Bot.* 49. 1963-1969.

Myers, L.R. (1995). Uses of canola. Canola, Inc., 8910 Purdue Road, Indianapolies, IN 46268.

NNC. (1984). Nutrition Policy and Programme for Bangladesh. National Nutrition Council, Bangladesh. p. 70-79

Oad, F.C., Solangi, B.K., Samo, M.A., Lakho, A.A. and Oad, N.L. (2001). Growth, Yield and Relationship of rapeseed (Brassica napus L.) under different row spacing. *Int. J. Agril. Biol*. 3(4):475-476.

Olsson, G. (1990). Rape yield production components. *Sversk Fortiding*. 59(9):194-197. [Cited from Pl. Br. Abs. 61(5):588(1991)].

Ozer,H.(2003). The effect of plant population densities on growth, yield and yield components of two spring rapeseed cultivars. *Plant Soil and Environ*. 49(9): 422-426.

Pant, S.C. and Singh, P. (2001). Genetic variability in Indian mustard. *Agric. Sci. Dig*. 21(1):28-30.

Parminder, K. and Sidhu, M.S. (2006). Effect of sowing date, nitrogen level and row spacing on oil quality of Ethiopian mustardm. *Environ. Ecol*. 24S (Special 4): 1112-1114

Patil, B.B. and De, R. (1978). Studies on the effect of nitrogen fertilizer, row spacing and use of antitraspirations on rapeseed (Brassica campestris) grown under dry land conditions. *J. Agric. Sci., Camb*. 91:257-264.

Reddy, C.S. and Reddy,P.R. (1998). Performance of mustard varieties on alfisols of Rayalaseema Region of A.P. *J. Oilseeds Res*. 15(2): 379-380.

Rahman, M.M. (2002). Status of oil seeds and future prospects in Bangladesh, Paper presented in Review workshop on the Impact of Technology transfer on oil crops, held at BARI on 29 April, 2002.

Rahman, M.M., Salam, M.U., Miah, M.G. and Islam, M.S. (1982). Effect of sowing time on the performance of mustard (SS-75). *Bangladesh J. Agric. Res.* 13(1):47-51.

Russel, D.F. (1986). MSTAT-C Package Programme. Crop and Soil Science Department, Michigan University, USA.

Sahoo, R.K., Khalak, A., Sujith, G.M., Veeranna, H.K. and Krishnamurthy, N. (2000). Growth traits, dry matter accumulation in mustard cultivars as influenced by row spacing and nitrogen levels in Karnataka. Paper presented on species and aromatic plants, Calicut, Kerala, India. 20-23 September, 2000.

Scarisbrick, D.H., Daniels, R.W. and Noor, R. (1982). The effect of varying seed rate on the yield and yield components of oilseed rape (*Brassica napus*). *J. Agric. Sci. Camb.* 99:561-568.

Shahidullah, M., Islam, U., Karim, M.A. and Hussain, M. (1997). Row and plant spacing management in mustard. *Bangladesh J. Sci. Ind. Res.* 32(3):414-417.

Sharma, M.L. (1993). Response of mustard varieties between two spacing's. *Haryana J. Agron.* 9(1):47-49.

Sharma, N.N., Sharma, D. and Paul, S.R. (1999). Effect of nitrogen level and row spacing on growth and yield or rainfed Indian mustard (Brassica juncea) *J. Agril. Sci. Soc. North East India.* 12(2):141-144.

Shastry, A.B. and Kumar, A. (1981). Varieties in yield, its attributes and quality of Indian mustard in relation to planting times and level of plant population. *Indian J. Agric. Sci.* 51d (1):27-32.

Shinde, G.G. and Borulaka, O.N. (1981). Performance of different plant densities. *J. Maharastra Agril. Univ.* 6(3):263-264.

Shivani, and Sanjeev, K. (2002). Response of Indian mustard (Brassica juncea) to sowing date and row spacing in mid-hills of Sikkim under rainfed conditions. *Indian J. Agron.* 47(3): 405-410.

Shrief, S.A., Shavana, R., Ibrahim, A.F. and Geisler, G. (1990). Variation on seedyield and quality characters of four spring oil rapeseed cultivars as influenced by population arrangements and densities. *J. Agron. Crop Sci.* 165(2-3):103-109.

Singh, G.K., Kedar, P. and Prasad, K. (2003). Effect of row spacing and nitrogen doses on nutrient uptake and oil yield in mustard. *Crop Res. Hisar.* 259(3):431-435.

Singh, H. (1986). Genetic variability, heritability and drought Indices analysis in Brassica species. *J. oilseed Res.* 3(2):170-177.

Singh, M., Swarankar, G.B., Prasad, L. and Rai, G. (2002). Genetic variability, heritability and genetic advance for quality traits in Indian mustard (Brassica juncea L. Czern and Cross). *Plant Archives.* 2(1):27-31.

Singh, R.P. and Kumar, A.(1990). Effects of varieties and planting geometry levels on late sown Indian mustard (Brassica juncea). *Indian J. Agric. Sci.* 60(6):392-395.

Singh, T.P. and Singh, H.P. (1984a). Response of Indian rape (Brassica campestris L. var. Toria, Duthe and Full) to planting density, nitrogen and sulphur. *Indian J. Agron.* 29(4):522-527.

Singh, T.P. and Singh, H.P. (1984b). Dry matter accumulation and nutrient uptake in Indian rape as affected by plant density and fertilizer. *Indian J. Agron.* 29(4):539-542.

Singh, G.K. and Kedar, P. (2003). Effect of row spacings, nitrogen levels and basis of N application on yield attributes and yield of mustard variety Basanti. *Crop Res. Hisar*. 25(3): 427-430.

Singh, V and Chandra, A. (2000). Note on evaluation of promising varieties of mustard. *Current Agri.* 24(1/2): 135-136.

Suraj, B., Singh, H.G. and Singh, M. (1975). Note on the effect of variety, spacing and fertility levels on the yield and yield contributing characters of mustard (Brassica juncea L. Czern and Cross). *Indian J. Agric. Res.* 9(4):208-210.

Suraj, Bhan, Uttam, S.K., Awasti, U.D. and Bhan, S. (1995). Effect of plant spacing and direction of sowing on growth and yield of rainfed Indian mustard (Brassica juncea). *Indian J. Agron.* 40(4):636-638.

Surya, K., Singh, D., Rao, V.U.M. and Kant, S. (1998). Effect of sowing date, plant densities and varieties on yield and yield attributes of Indian mustard. Ann. *Agro. Bio. Res.* 3(1):105-107.

Thakur, K.S. (1999). Response of promising varieties of Indian mustard (Brassica juncea) to nitrogen and spacing under mid-hills, rainfed conditions of Himachal Pradesh. *Indian J. Agron.* 44(4): 816-819.

Thurling, N. (1974). Morphological determinants of yield in rapeseed (Brassica campestris and Brassica napus). II yield components. Aust. *J. Agric. Res.* 25:711-721.

Tomar, S.S. and Namedo, K.N. (1989). Response of Indian mustard varieties to row spacing and nitrogen. Indian J. Agron. 34(4):472-473.

Wahab, M.A., Mondal, M.R.I., Akbar, M.A., Alam, M.S., Ahmed, M.U. and Begum, F. (2002). Status of oil crop production in Bangladesh. Oilseed Res. Centre, Bangladesh Agril. Res. Inst., Joydebpur, Gazipur. Pp. 4-62.

Walkowshi, T. (2001). Influence of sowing date and sowing rate on the yields of spring rapeseed varieties; open pollinated variety star and composite hybrid Margo. Rosliny, Olensite. 22(2):409-422.

Wankhede, M.P., I.P.S. and Shlmi, V.M. (1970). Effect of varying levels of irrigation, plant population and fertilizer on yield and quality of Indian rape (*Brasssica campestris* L. var. Toria. Duthie and Full). *Indian J. Agric. Sci.* 40(10):873-877.

Weber, J.A., Myers, L.R. (1991). Canola: A promising oilseed. Canola, Inc., 8910 Purdue Road, Indianapolies, IN 46268.

Yadava, Y.P., Singh, H. and Singh, D. (1993). Gene action for seed yield and its attributes under two environments in Indian mustard. *Crop Res.* 6(1):168-172.

Yin, J.C. (1989). Analysis of ecological, physiological and production characters of high quality rapeseed cultivars. *Agriculture Shanghai.* 5(4):25-31.

APPENDICES

Appendix I: Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2007 to February, 2008.

Month	Relative humidity (%)	Maximum temperature (°C)	Minimum temperature (°C)	Mean	Rainfall (mm)
November	69.5	29.5	18.6	24.0	3.0
December	70.6	26.9	16.2	21.5	00
January	68.5	24.5	13.9	19.2	4.0
February	61.0	28.9	18.0	23.4	3.0

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

Appendix II: Physiochemical properties of the initial soil

Characteristics	Value	Critical value
% sand	26	....
% silt	45	....
% clay	29	....
Textural class	Silty-clay	....
pH	5.6	Acidic
Organic carbon (%)	0.45	....
Organic matter (%)	0.78	....
Total N (%)	0.03	0.12
Available P (ppm)	20.00	27.12
Exchangeable K (me/100 g soil)	0.10	0.12
Available S (ppm)	45	....

Source: Soil Resources Development Institute (SRDI), Dhaka-1207.

Appendix III. Summary of analysis of variance of yield and yield attributes of rapeseed

Source of variation	Degree of freedom	Mean of square									
		Plant height	Branches plant^{-1}	Pods plant^{-1}	Length of pod	Seeds pod^{-1}	1000 seed weight	Seed yield	Stover yield	Biological yield	Harvest Index
Replication	2	5.83	0.049	2.76	0.04	0.07	0.052	4.42	338.56	19.15	28.56
Variety	3	479.45**	5.65**	2207.66**	1.69**	289.69**	0.98**	5897.75**	17837.78**	41591.30**	31.35**
Spacing	2	795.05**	17.41**	13460.60**	6.39**	66.26**	0.07 NS	4624.56**	59892.45**	57352.86**	175.34**
Variety x Spacing	6	49.28**	0.65**	127.25**	0.21**	4.59**	0.03 NS	421.05**	594.18 NS	1263.43**	4.89**
Error	22	0.597	0.007	0.765	0.029	0.064	0.029	0.476	284.369	1.342	0.064

*Significant at 5% level of probability

** Significant at 5% level of probability

NS not significantly different at $p<0.05$

Appendix IV. Summary of analysis of variance of the pod dry matter (gm^{2}) of rapeseed at different stage of harvest

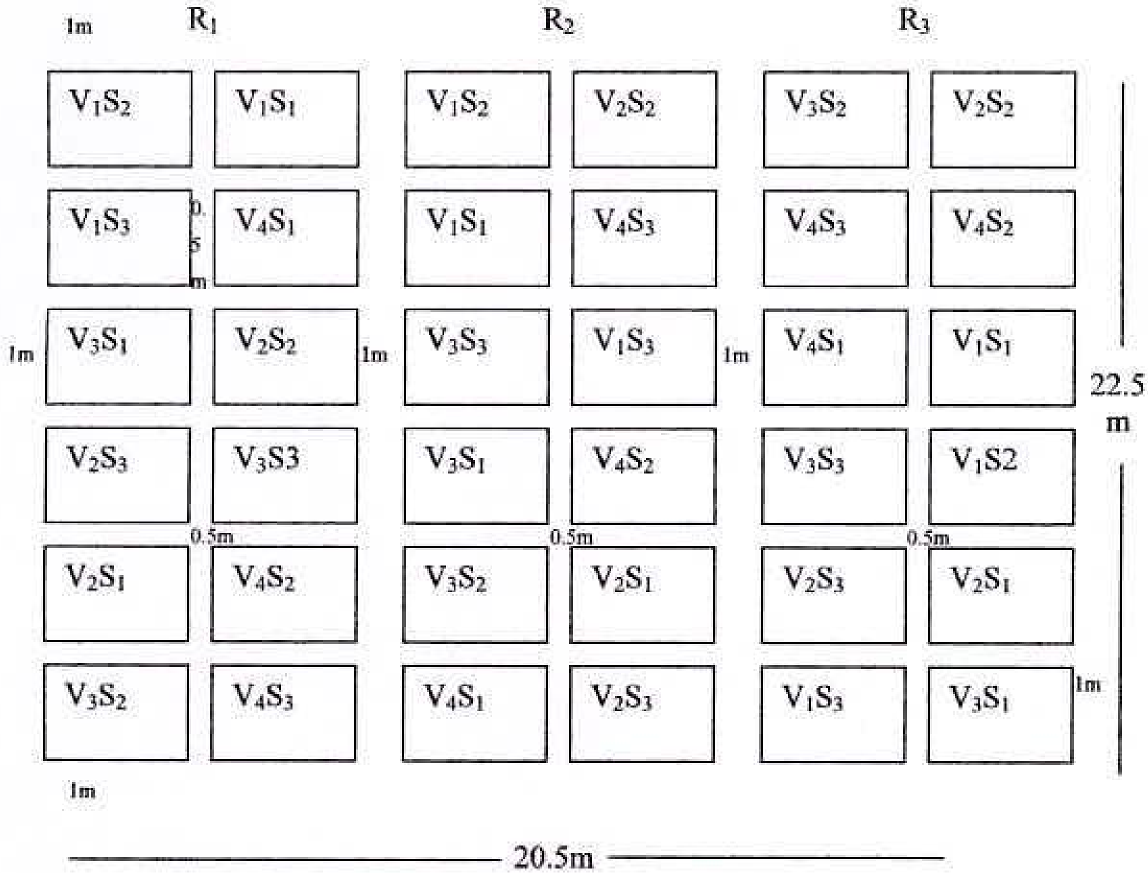
Source of variation	Degree of freedom	Mean of square			
		Stages of harvest			
		50% pod maturity (FPPM)	5 days after FPPM	10 days after FPPM	15 days after FPPM
Replication	2	9.93	9.70	4.39	209.28
Variety	3	3298.04 **	3808.13**	4336.02**	5214.73**
Spacing	2	2373.43**	2416.75**	2635.45**	2951.25**
Variety x Spacing	6	40.55**	189.29**	211.53**	928.52*
Error	22	2.024	2.280	4.046	279.513

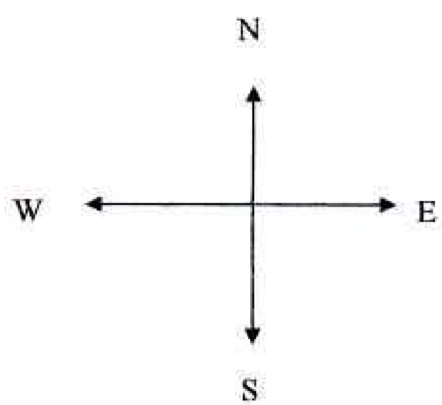
*Significant at 5% level of probability

** Significant at 5% level of probability

NS not significantly different at $p<0.05$

Appendix V: Layout of experimental field





Per Plot Size: 3m x 2.5m
Total Plot Size: 461.25m^2
Three Spacing (S):
1) 15cm (S_1)
2) 30cm (S_2)
3) 45cm (S_3)

Four Varieties (V):
1) IMPROVED TORI 7 (V_1)
2) SAU SARISA 1 (V_2)
3) BARI SARISA 9 (V_3)
4) BARI SARISA 13 (V_4)

Replication(R) three: R_1, R_2, R_3

Experimental Design: Two Factor Randomized Complete Block Design