SEED YIELD AND OIL QUALITY OF RAPESEED AS INFLUENCED BY DATE OF PLANTING

BY

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This is to certify that the thesis entitled, "Seed yield and oil quality of rapeseed as influenced by date of planting" 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 *bona fide* research work carried out by Mohammad Sarfuddin Bhuiyan Registration No. 23928/00174 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 26.06.06
Place: Dhaka, Bangladesh

(Dr. Md. Rafiqul Islam Mondal)
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DEDICATED TO MY

Beloved Parents

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LIST OF ABBREVIATIONS OF SYMBOLS AND TERMS

Full Word	Abbreviation
And others (at elli)	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Coefficient of Variation	CV
Degree Celsius (Centigrade)	^{0}C
Etcetera	etc.
Example	e.g.
Gram	g
Hectare	ha
Hour	hr
Hydrogen ion conc.	p^{H}
Kilogram	kg
Least Significant Difference	LSD
Meter	m
Micron	µ
Milliequivalent	meq
Muriate of potash	MP
Namely	viz.
Percent	%
Square meter	m^2
Ton	t
Triple Super Phosphate	TSP

SEED YIELD AND OIL QUALITY OF RAPESEED AS INFLUENCED BY DATE OF PLANTING

ABSTRACT

An experiment was conducted at the Agriculture Research Station, Bangladesh Agricultural Research Institute, Burirhat, Rangpur during rabi season of 2004-05 to find out optimum planting time for the newly selected genotype BCYS-03. There were five planting dates viz. October 20, October 30, November 10, November 20 and November 30. Significant variations due to different planting dates were observed in days to maturity, plant height, number of primary branches plant^{-1}, seed yield plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1}, 1000-seed weight, seed yield ha^{-1}, biological yield ha^{-1}and dry weight plant^{-1}. Results showed that the highest seed yield (1.86 t ha^{-1}) was obtained from the second planting (October 30) and it was significantly different from the yields of all other dates of planting. Yield contributing characters were also found higher in the plants of second planting. The seed yield (1.47 t ha^{-1}) of last planting was also satisfactory because of the prolong winter season prevails in the northern part of the country. Variations in respect of oil content in seed and fatty acid composition of oil were also obtained from different planting dates. Seeds obtained from the early plantings contained higher oil percentage in seed and lower concentration of erucic acid in oil. Variations of oleic, linoleic and linolenic acids in oil also observed due to different planting dates.

CHAPTER 1

Introduction

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CHAPTER 1
INTRODUCTION

Rapeseed and Mustard commonly known as mustard in Bangladesh belongs to the family *Cruciferae*. Botanically three species, *Brassica campestris* L., *Brassica napus* L., and *Brassica juncea* (L.) Czern & Coss are cultivated for edible oil (Appleqvist, 1972). In Bangladesh, *Brassica campestris* L. covers about more than 60% area of mustard cultivation and the rest area is covered by *Brassica juncea*. For the last few years attempts have been made to introduce *Brassica napus* L. in Bangladesh because this species gives more yields per unit area of land. Very limited area is covered by this species in Bangladesh (Akbar, 1987; Wahiduzzaman, 1987; Wahhab *et al.*, 2000).

Rapeseed and mustard occupied almost 75% land whereas the other oilseeds in rest of the land. In Bangladesh about 3 lakh ha of land is under mustard cultivation which produces 2.2 lakhs metric ton of seeds. The average per hectare yield of mustard in this country is 739 kg/ha which is alarmingly very poor compared to that of advanced countries like Germany, France, U.K, Canada and Poland producing 6667 kg/ha, 3507 kg/ha, 3264 kg/ha, 3076 kg/ha respectively. The world average yield of mustard is 1575 kg/ha (FAO, 2003). The internal production of edible oil can meet up only one-third of the annual requirement (Mondal and Wahhab, 2001). It needs to import oil and oilseeds to meet up the deficit every year spending huge foreign exchange.

The low yield of mustard and rapeseed in Bangladesh is mainly due to late sowing, lack of improved seeds of new varieties, insufficient uses of fertilizers, lack of irrigation and other management practices. Farmers usually grow rapeseed and mustard after harvesting of transplanted aman rice and as a result, the late sowing is very common. The farmers are not so careful about the use of appropriate rate of fertilizers. They are not also well aware about the updated management practices developed by the research institutions. The total production of rapeseed and mustard can be increased either by increasing the acreage or by increasing per unit yield. In the first case, horizontal increase of production is impossible as the land occupied under different rabi crops during the growing period of rapeseed and mustard, and also due to increased population density. Using new high yielding varieties with an improved package of management practices may increase the productivity of rapeseed/mustard. So, from the practical point of view, attention should be paid to increase per unit yield through the application of improved production technology including the choice of cultivar, land preparation, timely sowing, seed rate, fertilizer dose, water management, plant protection measures etc.

The seed yield and maturity of mustard plants are greatly influenced by environmental conditions regardless of genotypes. Therefore, whenever a new genotype/variety is developed or introduced in a region, an appropriate package of production practices must be developed. A suitable planting date is very important for good agronomic performance of any crop. Planting date has significant effect on seed yield and yield components of rapeseed/mustard (Singh *et al.*, 1972; Uddin *et al.*, 1986; Saran and Giri, 1987; Rahman *et al.*, 1988; Mondal *et al.*, 1992; Mondal and Islam, 1993 and Mondal *et al.*, 1999). Seed yield of mustard declined gradually by 11.7, 21.5, 43.4 and 62.9%, respectively, for each week delay after 1 November sowing (Rahman *et al.*, 1993).

Rapeseed and mustard are thermosensitive as well as photosensitive crops (Ghosh and Chatterjee, 1988). Mustard grows best in between the temperatures of 12^0C and 25^0C. The optimum temperature for maximum growth and development of mustard just in between maximum temperature 20^0C and minimum temperature 5^0C (Wahhab, *et al.*, 2002). Bangladesh weather allows very short sowing period for rapeseed/mustard, because the winter in Bangladesh is not very long, it starts from the end of October and temperature starts rising from the month of February. So, mustard harvesting should be completed by middle of February, otherwise the crop faces high temperature; and yield becomes low. In the northern part of the country the climatic conditions are quite different, where winter comes early and goes late. So, the duration of winter season is longer here than the other parts. Sowing at proper time allows sufficient growth and development of a crop to obtain satisfactory yield. Different sowing dates provide variable environmental conditions within the same location for growth and development of crop yield stability (Pandey *et al.*, 1981).

BCYS-03 is a newly selected *Brassica campestris* L. genotype with white flowers, yellow seed coat colour with shorter duration. Therefore, the present study was undertaken to find out optimum planting time for the genotype for higher seed yield and to study the effect of sowing time on yield components, seed yield and the quality of oil in the northern part of Bangladesh.

In view of the information on the problems mentioned above, a field study containing the different sowing dates were undertaken with the following objectives:

i) to study the effect of date of planting on yield and yield contributing parameters of mustard as well as quality of oil.

ii) to determine optimum planting time for the selected genotype.

CHAPTER 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

2.1 Botany of rapeseed

2.1.1 Species relationships

Rapeseed is not the product of single species. There are three basic species of *Brassica* with haploid chromosome numbers of 8, 9 and 10. Hybridization has played the most important role in species formation. The cytogenetical relationships between the four species viz. *Brassica carinata, B. juncea, B.campestris* and their closest allies' *B. nigra* (Black mustard) and *Brassica oleracea* (the cabbages and kales) have been shown in fig. 2.1.

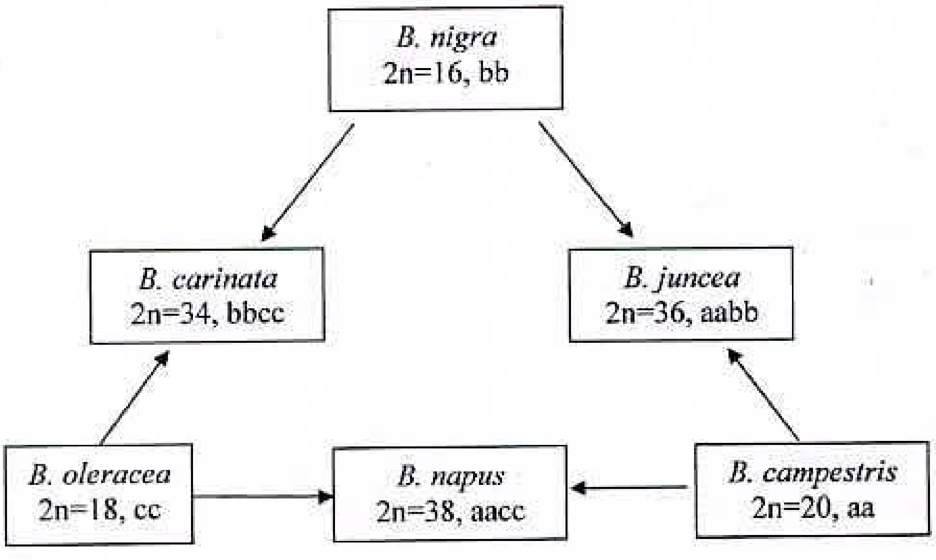


Fig. 2.1 Cytogenetical relationships of *Brassica* species based on chromosome numbers and genome formulae (U, 1935).

The cytogenetical relationships were established by the Japanese Scientist U (1935) and showed that *B. nigra* (2n=16, bb), *B. oleracea* (2n=18, cc) and *B. campestris* (2n=20, aa) are the primary species, and that *B. carinata* (2n=34, bbcc), *B. juncea* (2n=36, aabb) and *B. napus* (2n=38, aacc) are amphidiploids resulting from paired crossings between the primary species (Morinaga, 1934 and Yarnell, 1954). In Bangladesh, two species, *B. campestris* and *B. juncea*, are widely cultivated (Kaul and Das, 1986).

2.1.2 General description

Rapeseed (*Brassica* spp.) is an annual herb with lateral branching. The plant has a richly branched taproot, usually horizontal. The plant height in Toria type ranges from 30 to 125 cm whereas in *B. juncea* and *B. napus* the same ranges from 70 to 175 cm. After emergence of seedling, the first true leaves form a rosette. The leaves are alternate, simple and much dissected with wavy margins. The tips of the leaves are obtuse, with leaf base encircling the stem. Leaves are dark green, glaucous, lyrate, pinnatified and stalked on the lower. There is no stipule. The floral leaves are petiolate as in *B. juncea* and sessile as in *B. campestris* and *B. napus*. The floral leaves are full clasping the stem as in *B. campestris* and half clasping as in case of *B. napus*. The inflorescence is an elongated raceme, born terminally on the main stem and branches, usually carrying bright yellow flowers, although colour varies from orange to creamy white. The flower is pedicillate, ebracteate, actinomorphic, hermaphrodite, complete, regular, hypogynous and tetramerous. Calyx is composed of 4 free imbricate sepals. Corolla cruciform and stamens are six, tetradinamous (4+2) with two short at the outer whorl and four long at the inner whorl. *B. campestris* flowers are both cross and self pollinated with some possible exceptions while those of *B. napus* are self-pollinated. *B. juncea* is also self-pollinated. The fruit is long narrow pod or siliqua, 5-10 cm in length, consisting of two carpels separated by a false septum which shatters when mature. Pod or siliqua with wide range of characteristics have been reported. These include 3 or 4 carpels, thick walls and non-shattering types. Different types of siliqua may occur on the same plant (Sabnis and Pathak, 1935; Quddus and Rahman, 1980). The siliqua or pod contains 15-40 small round seeds usually 1.75-2.0 mm in diameter. Seed colour varies from light dark brown to black. Recently yellow seeded cultivars have been developed.

Rapeseed is grown both under short-day condition during winter season in Bangladesh; and under long- day condition during summer in the countries of temperate regions of Europe and Canada. In temperate countries, it has both spring and winter forms. The winter form needs over wintering for flowering while the spring form can flower directly during summer. Both the winter and summer type varieties of rapeseed grown under long-day condition of temperate regions are not suitable for cultivation in Bangladesh condition. (Akbar, 1987; Wahiduzzaman, 1987)

Man has very little control over the environment but agronomic research has indicated that it is possible to a certain extent to overcome some of the environmental limitations of crop production by influencing the elements of microenvironment and manipulation of cultural techniques to suit particular environmental condition. The cultural techniques cover the choice of crop variety, sowing time, method of its establishment, seed rate, fertilization, water management, crop protection etc. Variations in mustard and rapeseed yield may be due to any or all of those factors which might vary from time to time and from region to region.

The evidence showed that the yield and production of mustard and rapeseed are highly correlated to its cultural practices like planting date, seed rate and so on. These practices cost very negligible and in some cases nothing, but adds greatly to the harvest by counter-balancing the effect of environmental adversities.

Several scientists, both at home and abroad, have carried out studies on the effect of those cultural practices on mustard and rapeseed. But till today, enough work has not been done in Bangladesh regarding location specific production package for any crop which is highly desirable. Different studies indicated that sowing time has an immense effect on the yield and yield contributing characters of mustard and rapeseed. Some of those, which are pertinent to present study, are cited below.

2.2 Effect of sowing date on rapeseed/mustard plant characters

Different sowing dates created different environmental conditions for crop growth and development within the same area. This in turn affects the different crop characters.

2.2.1 Days to flowering

Flowering is a varietal character of any plant. But it can be affected due to various environmental factors and some agricultural management practices. Among the agricultural management, date of sowing influences a lot on the flowering and yield of rapeseed and mustard. Scientists of home and abroad put some valuable information about flowering influenced by date of sowing. Some of them are given below.

Hang and Gilliland (1984) reported that, days to flower varied from year to year depending upon temperature.

Mondal and Islam (1993) found that maximum days to flower (38 days) were required by the 15 October sown plant which was followed by 1, 15 November, and 1 December sowing. Delaying in seeding reduced the number of days to flower. In case of very early sowing, plant faced little warm temperature during vegetative stage and the growth was slow that is why maturity periods were longer, and later sowing plants completed vegetative growth earlier than the plant of early sowing.

Mondal *et al.* (1999) stated that, seeding date significantly influenced days to flowering. Delayed sowing reduced days to flowering.

Robertson *et al.* (2004) found that, sowing date is an important determinant of yield in canola. Three cultivars were studied: an early and late flowering canola and an advanced breeding line of Indian mustard. For all 3 genotypes, a delay in sowing shortened the time to 50% flowering. For sowings at Tamworth in Australia beyond 15 May, 1 day delay in sowing delayed flowering by 0.42, 0.42 and 0.37 days in Indian mustard, Monty and Oscar, respectively.

2.2.2 Days to maturity

Among the varietal characteristics of any plant, days to maturity are the most influential character. It is the yield attributive character of rapeseed. But it also can be affected due to various environmental factors and some agricultural management practices. Yield and yield loss of rapeseed and mustard are influenced a lot by the days to maturity. Scientists of Bangladesh and all over the world showed the relationships of days to maturity with sowing dates and its influence on seed yield.

Later sowing generally produces early maturity in *B. campestris* and delays maturity in *B. napus* (Depauw, 1977, Kondra, 1977). Saran and Giri (1987) also observed a significant role of temperature during the periods from sowing to flowering and flowering to maturity. Mondal *et al.* (1992) observed that, there was a trend of reduction in days to maturity with delayed plantings. In the first planting, it took 89 days to mature (average of four varieties) and in the last planting, this was 83 days.

Bajpai *et al.* (1981) mentioned that, the flowering to maturity period was reduced due to harmful high temperatures occurring during the seed filling stages. Robertson *et al.* (2004) found that, delay in maturity was 0.58, 0.56 and 0.54 days per day delay in sowing date. In India, Ghosh and Chatterjee (1988) reported that the thermal effect was significant during the vegetative as well as reproductive stages. During delay planting the temperature falls gradually and the maturity days are delayed by 1-4 days.

Mondal and Islam (1993) found that maximum days to maturity (115 days) were required by the 15 October sown plant which was followed by 1, 15 November, and 1 December sowing. Delaying in seeding reduced the number of days to maturity. In case of early sowing, plant faced little warm temperature during vegetative stage and the growth were slow that is why maturity periods were longer than that of later sowing plants completed vegetative growth. Hang and Gilliand (1984) reported that days to maturity varied from year to year depending upon temperature.

Islam *et al.* (1994) stated that delayed sowing curtailed the period of crop duration in all varieties. In all sowings, varieties Tori-7 and TS-72 matured much earlier (75-78 days) than the other (90-107days). It appears that rise of temperature from January onwards might have greatly influenced the post flowering developments, particularly for late sown crops resulting in the shorter maturity periods.

Mondal *et al.* (1999) observed that, seeding date significantly influenced days to maturity; and delayed sowing reduced days to maturity. The longer period for maturity was taken by the first planting. The maturity period became gradually shorter with the delayed sowing as 100, 99, 97, 97, 92 days with five seeding date as 1 October, 16 October, 1 November, 16 November and 1 December respectively.

2.2.3 Plant height

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

Mondal (1986) conducted an experiment on sowing date on seven sites of New York State with Canola varieties and found that early sowing (05 May) for both the varieties in each case produced tallest plants than in late sowing (20 June) decreased plant height but planting too early (20 April) decreased plant height. In India, Maini *et al.* (1964) found that too early (September 28) and too late (October 29) planting reduced the height of toria.

Saran and Giri (1987) reported that plant height decreased gradually (151 to 140 cm) with delaying the sowing by one month (15 October-15 November). Mohammed *et al.* (1987) observed similar results at Aligarh (India). A number of authors also reported that the seeding mustard in October produced the highest plant height (Kandil, 1983; Ansari *et al.*, 1990). Majumder and Sandhu (1964) reported that sowing in October was superior with respect to growth characteristics in sarson. Angrej *et al.* (2002) found that, early sowing was recorded higher value for the different plant height.

Kolsarici and Er (1988) in Turkey found that plant height was not significantly influenced by sowing date. BARI (1992) also reported that sowing date had no influence on plant height.

Mondal and Islam (1993) found that the longest plants were found in the plots of November 1 sowing which was followed by November 15, and October 15 sowing. The shortest plant height was found in the plots of December 1 sowing. In case of late sowing in December 1, plants faced higher temperature during later stages of growth, so the plants were shorter than the other sowing dates. Islam *et al.* (1994) observed a significant lower plant height in the crops sown on 2 December, which resulted in 24% shorter plants compared to that of sowing on 2 November. Shahidullah *et al.* (1997) reported that plant height was the highest in the second sowing date (6 November) among the three sowing dates on 27 October, 6 November and 16 November.

2.2.4 Number of primary branches plant^{-1}

Maini *et al.* (1964) found that the number of primary branches was reduced with each delay in sowing from mid-September to late October. Late sowing in oilseed rape suppressed the number of branches plant^{-1} (Ali *et al.*, 1985). Shahidullah *et al.* (1997) reported that number of branches/plant were higher with the first two sowing dates (27 October and 6 November) among the three sowing dates on 27 October, 6 November and 16 November.

Uddin *et al.* (1986) reported that sowing date had no significant effect on number of primary and secondary branches/plant.

Bukhtiar *et al.* (1992) found that early sown crop produced more primary branches than that of late planted crop in the end of October and mid November. Islam *et al.* (1994) stated that delayed sowing significantly reduced branches plant^{-1} except that the differences were statistically similar between sowing of 04 and 18 November over the varieties. The maximum (4.55) number of branches per plant produced on 20 October and minimum (3.31) on 2 December.

Generally, development of primary branches depends on planting space and vegetative growth of the whole plant. Although the number of primary branches plant^{-1} has a very low direct effect on seed yield but it has an indirect positive effect via pods plant^{-1} (Rahman *et al.*, 1993). Majumder and Sandhu (1964) found that the number of primary branches /plant had a significant positive correlation with number of pods /plant and seed yield. Number of primary branches /plant was influenced by different sowing dates (Chatterjee *et al.*, 1985; Mondal *et al.*, 1992; Uddin *et al.*, 1987).

Angrej *et al.* (2002) found that, the highest numbers of primary and secondary branches per plant were obtained when the crop was sown between 10 and 30 October.

Shivani *et al.* (2002) experimented on the sowing dates from 25 September to 5 November; and recorded significantly higher number of branches on 25 September and 5 October than that on 15 October, 25 October and 4 November. Number of branches decreased progressively with delay in planting.

2.2.5 Number of siliqua plant^{-1}

Scott *et al.* (1973) observed that late sowing produced plants with minimum number of pods plant^{-1}. It occurred due to rapid inflorescence initiation, insect and disease pest infestation and frost damage. On the other hand, several scientists observed that early sowing produced too many pods plant^{-1} (Patel *et al.*, 1980; Mendham *et al.*, 1981, Chauhan and Bhargava, 1984; Uddin *et al.*, 1987 and Chay and Thurling, 1989).

The number of siliqua plant^{-1} is an important yield contributing character of oilseed rape. Several studies suggest that a higher number of siliqua plant^{-1} has the greatest effects on seed yield on rape and mustard (Mendham and Scott, 1975; Thurling, 1974; Rahman *et al.*, 1988). Mendham *et al.* (1981) strongly pointed out that delayed sowing always reduced the number of pods plant^{-1}. Shivani *et al.* (2002) experimented sowing on 25 September and 5 October recorded significantly higher number of siliqua per plant. Number of siliqua per plant was significantly influenced by sowing date.

According to Saran and Giri (1987) pods plant^{-1} decreased gradually from early (15 October) to late (25 October; 5 November and 15 November) sowings. Ghosh and Chatterjee (1988) also reported that fifteen days to one-month delay in sowing produced 24 to 57% reduced pods m^{-2}.

Mondal *et al.* (1992) reported that number of siliqua plant^{-1} decreased in late planting. Buttar and Aulakh (1999) found pods plant^{-1} were higher in 25 October (1st date) sowing. This was due to the fact that under earlier sown crop, the temperature and other climatological parameters played a major role for growth and yield attributes. Brar *et al.* (1998) stated that early sown crop produced higher number of siliqua plant^{-1} compared to late sown crop. Sowing on 30 October and 15 November were apart with each other but further delay in sowing caused significant reduction in number of siliqua plant^{-1}.

Mondal and Islam (1993) found that the highest number of siliqua plant^{-1} was in the plants of 1 November sowing and the lowest number of siliqua plant^{-1} was in the plants of 1 December sowing.

Shahidullah *et al.* (1997) reported that number of siliqua/plant was decreased with delay in sowing among the three sowing dates on 27 October, 6 November and 16 November. Uddin *et al.* (1986) also reported that numbers of siliqua/plant were gradually reduced with delay in sowing among the four sowing dates on 25 October, 4 November, 14 November and 24 November.

Mondal *et al.* (1999) stated that, the highest number of siliqua/plant was found in the plants of third planting (1 November). The number of siliqua was less in the last two plantings and first planting.

2.2.6 Number of seed siliqua^{-1}

Number of seeds per siliqua contributes directly to the total seed yield. Seeds siliqua^{-1} in mustard is directly affected by sowing date (Beech and Norman, 1964; Ghosh and Chatterjee, 1988). Ghosh and Chatterjee (1988) reported that one-month delay in sowing decreased seeds pod^{-1} by 23%. Saran and Giri (1987) also observed that delayed sowing decreased seeds pod^{-1} and 1000-seed weight in several other trials (Scott *et al.*, 1973; Beech and Norman, 1964; Uddin *et al.*, 1987; Ansari *et al.*, 1990; Kalra *et al.*, 1985).

Shahidullah *et al.* (1997) reported that number of seeds/siliqua was decreased with delay in sowing among the three sowing dates on 27 October, 6 November and 16 November. Mondal *et al.* (1999) stated that, the highest number of seeds/siliqua was found in the plants of third planting (1 November). Majumder and Sandhu (1964) found more seeds pod^{-1} in October 25.

Shivani *et al.* (2002) experimented and found that sowing on 25 September and 5 October recorded significantly higher number of seeds per siliqua than that on 15 October, 25 October and 4 November. Number of seeds per siliqua decreased progressively with delay in planting. Number of seeds per siliqua was significantly influenced by sowing date.

There are, however, some opinions that sowing date has no significant effect on number of seeds pod^{-1} (Degenhardt and Kondra, 1981; Kandil, 1983; Brar *et al.*, 1998).

2.2.7 Seed yield plant^{-1}

Kalra (1983) conducted an experiment on Indian mustard to observe the effect of date of sowing on seed yield and its component traits. They sown the crop on three dates (25 September, 10 October and 25 October). It was observed that the late sown mustard crop produced a higher yield population which in term reduce weight of seeds plant^{-1} and ultimately reduced the yield.

Uddin *et al.* (1986) reported that seed yield/plant of three mustard varieties was generally decreased from 7.02 to 0.36 g, 6.52 to 0.015 g and 4.14 to 0.64 g with delay in sowing among the four sowing dates on 25 October, 4 November, 14 November and 24 November but there was little difference in seed yield between the two earliest sowing dates.

Bukhtiar *et al.* (1992) found that higher seed yield per plant was obtained from the crops sown on end of September, whereas the lowest seed yield per plant was obtained from the mid November planted crop.

2.2.8 Thousand seed weight

Seed weight is an important yield contributing character of rapeseed. It is mainly controlled by genetic factor. But it may also be influenced by many factors like nutrition, management practices and planting time. A number of studies revealed that planting date has significant effect on seed weight.

Majumder and Sandhu (1964) found highest 1000-seed weight in 1 October sowing. Delayed sowing decreased the seed weight (Lutman and Dixon, 1987). Similar findings were reported by many scientists (Scott *et al.*, 1973; Beech and Norman, 1964; Uddin *et al.*, 1986; Ansari *et al.*, 1990; Kalra *et al.*, 1985). Delayed sowing in oilseed rape severely reduces 1000-seed weight (Mendham *et al.*, 1981; Scarisbrick *et al.*, 1981). Mondal *et al.* (1999) stated that, 1000 seed weight reduced with the delayed planting time.

Hossain *et al.* (1984) found no significant influence of sowing dates on individual seed weight in terms of 1000-seed weight.

Ghosh and Chatterjee (1988) reported that one month later planting produced 32% reduction in seed weight. Saran and Giri (1987) observed that sowing in 25 October gave 11% higher 1000-seed weight than that of 15 November sowing. Shivani *et al.* (2002) experimented and found that, 1000-seed weight was significantly influenced by sowing date. Sowing on 25 September and 5 October recorded significantly higher 1000-seed weight than that of 15 October, 25 October and 4 November sowing. 1000-seed weight decreased progressively with delay in planting.

2.2.9 Seed yield ha^{-1}

Time of sowing is very important for cultivation of rape and mustard in that, it has a direct effect on seed yield. This view was supported by many researchers all over the world. In general, early plantings of rapeseed give higher seed yield than that of late sowing. Individual genotypes also differ in seed yield from one planting date to another. The optimum sowing time of individual genotype differs from place to place depending on environment and edaphic conditions.

In India, several studies on date of planting on mustard and rapeseed indicates that a suitable sowing time for higher seed yield is specified for a particular area. Best time in Punjab is the last week of September (Maini *et al.*, 1964); In West Bengal and in

Haryana, it was last week of October (Sen and Sur, 1964; Vacchani, 1952; Bishnoi and Singh, 1979; Ghosh and Chatterjee, 1988).

Singh (1988), and Saran and Giri (1987) reported that delay in sowing by two and four weeks produced 27% and 57% lower yields respectively compared to normal planting time.

Jain *et al.* (1989) found with four *Brassica juncea* cultivars were sown on 19 October, 29 October, 8 November and 18 November in field trials at Gwalior, where seed yields of each cultivar decreased with delayed sowing.

Joshi *et al.* (1989) reported that in India sowing too early and too late resulted in seed yield reduction due to natural hazards like insect pest and disease infestations. Early sowing reduced seed yield than in late sowing (mid July-mid August) since the former had a risk of rotting.

Rahman *et al.* (1989) studied with four sowing dates (25 October and 4, 14 and 24 November) to see the effects on yield of rapeseed. Sowing in October and early November gave the highest yields while later sowing gave the lowest yields. In field trials on 30 October, 10 November and 20 November gave the average seed yields of 0.84, 0.69 and 0.60 tha^{-1}, respectively.

Three varieties of mustard were evaluated for productivity under 4 sowing dates during Rabi seasons of 1984-85 and 1985-86 in Madhya Pradesh, India. Sowing on 8 October resulted higher seed yield as compared to late sowing (Bhagat and Singh, 1989).

Uddin *et al.* (1987) suggested 18 and 28 October sowings were better over 7 November sowing for higher yield; and higher yield was attributed by pods plant^{-1} and seed pod^{-1}. They also observed that the seed yield decreased gradually with the delay in sowing in all varieties.

Mondal *et al.* (1992) reported that the highest seed yield ha^{-1} (1.45 t) was obtained from second planting (October 16) and was significantly different from the last planting (November 16). Shah *et al.* (1985) also obtained the highest seed yield of mustard from middle of October sowing in Jessore areas.

Jadhav and Singh (1993) found that, seed yield was higher in crops sown in October than in November. Bali *et al.* (1992) found that, in a field experiment in 1986-88 at Shalimar, Jammu and Kashmir, mean seed yields of *B. juncea* cv. Kos 1 and EC 132142 sown on 25 September, 15 October or 4 November were 1.44, 1.27 and 0.51 t/ha, respectively.

Mondal and Islam (1993) found that the highest seed yield plant^{-1} and seed yield ha^{-1} were obtained from the October 15 sowing which were almost similar to 1 November. Seed yield decreased with delayed sowing.

Choudhary and Thakuria (1994) found that, in a field experiment during the winter season of 1991/92 at Karimganj, Assam, seed yields of *B. juncea* cv. TM 2 and TM 4 and *B. campestris* var. toria cv. TWC 3 and M 27 were significantly decreased by delaying sowing after 15 Nov.

Yadav *et al.* (1994) stated that, *B. juncea* cv. Vaibhav, Vardan, Rohini and Varuna seed yields were decreased by delaying sowing after 15 Oct. in 1987/88 and 5 Oct. in 1988/89. Yadav *et al.* (1996) reported that, early sowing in October resulted significantly higher seed yield compared to the later sowings.

Dudhade *et al.* (1996) reported that in a field experiment conducted at Rahuri, Maharashtra during the winter seasons of 1991/92 and 1992/93, with *B. juncea* cv. Seeta, Pusa Bold and Pusa Barani were sown on 1, 15 or 30 October, or 15 or 30 November. Seed yield was the highest in Seeta and with the earliest sowing date.

Sarmah (1996) stated that, sowing on 25 October or 9 November resulted in substantial increases in seed yield as compared to delayed sowing on 24 November and 9 December. Delayed sowing on 24 November and 9 December resulted in a 24.8 and 51.6% yield reduction in comparison with sowing on 25 October.

Shahidullah *et al.* (1997) reported that the seed yield were higher with the first two sowing dates(27 October and 6 November) among the three sowing dates on 27

October, 6 November and 16 November. Nair (1998) stated that mean seed yield in the both years among the varieties decreased with later sowing.

Yadav *et al.* (1997) stated that, mean seed yield was 2.10, 2.00 and 1.75 tha^{-1} when sown on 17 October, 27 October and 6 November respectively. Water use efficiency was recorded highest from the sowing on 27 October.

Brar *et al.* (1998) stated that crops sown on October 30 recorded the highest seed yield (16.5 q ha^{-1}) than 30 November and 15 December sowings. Chakraborty *et al.* (1991) reported that early sowing (16 October) produced 24% higher seed yield than that of later sowing (2 November). Ghosh and Chatterjee (1988) stated similar results in their experiments with sowing dates.

BARI (1999) stated that different sowing dates significantly influenced the yield of mustard. Significantly highest grain yield was obtained from 19 November sowing. Yield reduction was 31 to 72% when mustard was sown in December, and 28% in 29 October sowing. BARI (2001) reported that at Joydebpur location seed yield and other yield contributing characters were significantly varied among the dates of plantings.

Buttar and Aulakh (1999) observed that the seed yield of Indian mustard was obtained significantly higher when the crop was sown on 25 October than the crops sown on 15 November and 5 September. Shastry and Kumar (1981) and Narang and Singh (1987) also made similar observations.

Mondal *et al.* (1999) reported that, the highest seed yield ha^{-1} (1.39 t) was obtained from the third planting (1 November) compared to the first and last four planting dates. Different sowing times significantly influenced the yield of mustard (BARI, 1999).

Prasad and Singh (1999) determined that, altering the sowing date resulted in significant differences in the infestation of *L. erysimi*, with the infestation intensity depending on weather condition and crop period. Earlier planting dates (25 September) resulted in less crop damage compared to later planting dates (10 and 25 October).

Panwar *et al.* (2000) reported that yield of *Brassica* spp. decreased when sown on 5 November (mean 1.17 ton ha^{-1}) compared to 5 and 20 October (1.70 and 1.77 t ha^{-1} respectively). Berea (1999) reported that seed yield was influenced by sowing date. The highest yield was given by sowing on 13 August or 5 September.

Angrej *et al.* (2002) found that the highest yield was obtained when the crop was sown in between 10 and 30 October. Yield reductions of 26.4 and 40.2% were obtained when sowing was delayed up to 20 November and 10 December.

Razzaque *et al.* (2002) mentioned that the crop sown on 15 November recorded the highest seed yield (1164.4 kg/ha) but it did not differ significantly from that of 23 November sowing (1001.9 kg/ha). Lower yield was obtained from 7 December (612 kg/ha) sowing which was statistically identical to 30 November sowing (700.6 kg/ha) and it was due to high temperature at reproductive stage.

Shivani *et al.* (2002) experimented sowing on 25 September, 5 October recorded and significantly higher seed yield than that of 15 October, 25 October and 4 November sowing. Seed yield decreased progressively with delay in planting.

Kumar and Singh (2003) found that, there was a significant decrease in seed yield with the advancement of sowing date. The maximum seed yield (1735 kg/ha) was obtained from 20-25 October-sown crop.

Sihag *et al.* (2003) found that among the sowing dates 15 October, 30 October, 14 November and 29 November, the highest dry matter accumulation at 90 days of crop growth (31.07 g per plant) and at harvest (42.40 g per plant) was obtained in 15 October-sown crops. The highest seed (21.50 q/ha) was obtained in 15 October-sown crops. The highest biological yield (65.23 q/ha) was obtained from 15 October-sown crop.

Srivastava and Balkrishna (2003) stated that, optimum sowing dates for mustard were in between October 31 to November 20 for achieving maximum yield. The latter was positively correlated with total dry matter production. Late sowing of mustard retarded yield by adversely altering reproductive growth.

Panda *et al.* (2004) mentioned that, the crop sown on 16 October recorded a higher seed yield (1945 kg/ha) than the crops sown on 31 October (1556 kg/ha) and 15 November (872 kg/ha). Delayed sowing beyond 16 October significantly reduced growth, yield attributes and seed yields.

Robertson *et al.* (2004) found that, the decline of grain yield with delay in sowing date could be largely explained by the decline in biomass production. Patel *et al.* (2004) showed that, Indian mustard seeds were sown on 8, 18 and 28 November, and 8 and 18 December in a field experiment conducted in India during winter of 1995-98. The yield and yield components of Indian mustard decreased with delay in sowing. The highest seed yield (1409 kg/ha) was recorded from 8 November sowing.

Si and Walton (2004) explained that, cultivars differed in their capacities to produce seed yield. The ranking of cultivars for seed yield to a lesser extent remained constant across sowing dates and locations. Seed yield decreased with delayed sowing. On an average, seed yield decreased by 309 kg/ha for every 2 weeks delay in sowing.

2.2.10 Dry plant weight (Stover yield)

Sowing time directly influenced plants dry plant weight (Stover yield). Lutman and Dixon (1987) pointed out that sowing of oilseed rape beyond mid September produced significantly less vigorous plants and ultimately produced less crop dry weight compared to early sown crops.

Chakraborty *et al.* (1991) stated that delayed sowing significantly reduced stover yield. October sown crops produced higher dry matter compared to November sown crops. Ghosh and Chaterjee (1988) obtained higher dry matter accumulation from an October sown crop compared to a crop sowing in November.

Islam *et al.* (1994) stated that stover yield was significantly influenced by sowing date. Higher stover yield was observed in 20 October sowing that gradually decreased in 02 December sowing. BARI (2001) reported that sowing time have significant effect on stover yield. In sowing date 16 November stover yield (3991 kg ha^{-1}) was higher than that 30 December sowing (2417.56 kg ha^{-1}). Brar *et al.* (1998) also stated that straw yield decreased significantly with the each delay in sowing.

2.2.11 Biological yield

Majumder and Sandhu (1964) reported that the highest dry matter production was obtained from 1 October sowing compared to each 16 October and 4 November plantings. In their another study, higher dry matter production was obtained from planting on 29 September compared to planting on 4 September and 24 October (Maini *et al.*, 1964). Ghosh and Chatterjee (1988) made similar observations.

The dry weight of rape plants in the autumn and winter was severely reduced by delay in drilling (Lutman and Dixon, 1987). Thurling (1974) reported significant correlation between yield and total dry weight of total plant in both *B. campestris* and *B. napus*. High temperature at vegetative stage was conducive to high dry matter production (Degenhardt and Kondra, 1981). Dry matter accumulation/ plant in the late sown crop was less at all stages of crop growth as reported by Saran and Giri (1987).

Islam and Razzaque (1999) stated that the biological yield reduced in general with delaying the day of sowing. Higher biological yield was obtained from the first and second date of sowing. The last date of sowing (1 December) reduced biological yield.

Sihag *et al.* (2003) a field experiment was conducted in Bikaner, Rajasthan, India, during the 1998/99 rabi season to determine the effect of sowing date (15 October, 30 October, 14 November and 29 November) of Indian mustard. The highest biological yield (65.23 q/ha) was obtained from 15 October-sown crops.

2.2.12 Oil content in seed

There is much variability in oil content within different species and different genotypes of rapeseed. But many studies suggest that environmental factors, especially temperature have a direct effect on total oil content of seed.

Saran and Giri (1987) reported that late sown crops had less oil in the seed than the earlier sown crops. Similar results were found by Majumder and Sandhu (1964), Bishnoi and Singh (1979), Vashi *et al.* (1986). BARI (2001) conducted experiments with six genotypes of mustard to see the effect of time of seeding on oil content, and found that all six genotypes gave significantly higher oil content in seeds of sown on 16 November sown crop than that of on 3 December.

Jain *et al.* (1989) found with four *Brassica juncea* cultivars were sown on 19 October, 29 October, 8 November and 18 November in field trials at Gwalior, which produced corresponding oil content in seeds were 41.9, 38.8, 32.6 and 30.8%.

Three varieties of mustard were evaluated for productivity under 4 sowing dates during Rabi season of 1984-85 and 1985-86 in Madhya Pradesh, India. Sowing on 8 October resulted higher oil content as compared with late sowing (Bhagat and Singh, 1989).

Roy *et al.* (1993) found that, in a field experiment during the winter seasons of 1989-91 in Bangladesh, *B. campestris* cv. TS 72 sown on 20 October, 9 November, 30 November, 20 December produced mean seed yields of 0.96, 1.17, 0.73 and 0.24 t/ha respectively.

The seed oil content and fatty acid composition of high- and low-erucic acid rapeseed were studied under three different controlled- temperature regimes: low, 12/17^{0}C; medium, 17/22^{0}C and high, 22-27^{0}C. Under low temperatures, seeds of high erucic acid rape had higher erucic and lower oleic acid levels, while seeds of low erucic, high oleic acid rape had a lower level of oleic acid and higher level of linoleic acid. The reverse was found at high temperatures. Oil content decreased significantly with an increase in temperature (Yaniv *et al.* 1994).

BARI (2000) reported that 13 varieties/ genotypes of mustard were sown in 11 November, 22 November, 2 December to see the oil content as affected by sowing time. It was observed that Rai-5 gave higher oil content in seed at early sowing. Daulat, Jun 2592, BARI Sarisha-10 and Dhali gave higher oil content at late sowing.

BARI (2001) reported that six genotypes of rapeseed/mustard sown on two different dates to study the effect of time of sowing on oil content. It revealed that six genotypes gave significantly higher oil content in seed sown on 16 November compared to that of December sown.

2.2.13 Fatty acid composition of oil

Si and Walton (2004) explained that, cultivars differed in their capacities to produce oil. The ranking of cultivars for oil concentration, and seed yield to a lesser extent, remained constant across sowing dates and locations. Oil concentration decreased with delayed sowing. On an average, oil concentration was reduced by 1.1 percentages. The magnitude of reduction in oil concentration from delayed sowing was far greater in a low rainfall site than in the high rainfall site.

2.2.14 Oil yield

Hossain *et al.* (1996) found that the highest oil yield (401 kg/ha) recorded in Tori-7 which was in the 1st date of sowing crop and the lowest oil yield (173 kg/ha) was recorded in Tori-7 which was in the 4th date of sowing crop by Ghani mill. In NMR method, the highest oil yield (601 kg/ha) was found in Dhali (1st date of sowing crop) and the lowest oil yield (217 kg/ha) in Tori-7 (4th date of sowing crop).

Sihag *et al.* (2003) reported that, among the sowing dates, 15 October, 30 October, 14 November and 29 November; the highest oil yields (839.17 kg/ha) was obtained from 15 October-sown crops.

Yadav *et al.* (1996) stated that, early sowing (October) resulted in significantly higher oil and protein yield and N uptake by the seed compared with later sowing. Jadhav and Singh (1993) also found that, seed oil concentration was decreased by sowing in November compared to October sowing.

CHAPTER 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

3.1 Site & Soil

The research work was conducted at the Agricultural Research Station, Burirhat, Rangpur during the period from October 2004 through February 2005. This station is one of the important research stations of Bangladesh Agricultural Research Institute, in the northern parts of the country. The station is located at 12 kilometres north from Rangpur town by the side of Rangpur-Gangachara road. Geographical location of this station is 25.45^0N latitude and 89.15^0E longitude. It is about 32.2m above the sea level. The land was medium high belonging to the Tista Meander Floodplain, AEZ-3 (UNDP and FAO, 1988). The soil type was loamy in texture having pH value ranges from 4.5 to 5.5. The physical and chemical compositions of the soil as obtained from soil analysis are shown in Appendix II. The organic matter and K content of the soil is low but status of CEC and P is medium (BARC, 1997).

3.2 Climate

The experimental field was situated under the sub-tropical climate. Annual rainfall is about 2169 mm. Monthly average minimum temperature is 15^0C and the average maximum temperature 31^0C. But sometimes in the month of January, the minimum temperature goes down to 7^0C. The rainfall is heavy in kharif season (April to September). Rabi season starts with low temperature and plenty of sun shine and temperature increases as the season proceeds towards summer. But in Rangpur area winter comes early and goes late. So cool period is long. Weather reports in respect of rainfall, temperature and humidity during the study period have been presented in Appendix VI, VII and VIII.

3.3 Plant material

Seeds of the selected genotype BCYS-03 were collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Before sowing, seeds were tested for germination in the laboratory and the percentage of germination was found over 90%. The important characteristics of the genotype are mentioned below.

3.3.1 Characteristics of BCYS-03:

The genotype BCYS-03 is under *Brassica campestris* L. species of the family Cruciferae. It is 1 to 1.15 m in height. Leaves are without petiole and base of the leaf clasped the stem fully. It has 6 to 7 primary branches and there are some secondary branches also. The genotype can be grown as an early crop. The first flower comes at 28 to 30 days after sowing. Flowering is completed within 10 to 15 days after first flower. Newly opened flowers always lie above the buds. It has some special characteristics viz. it takes short period of time to mature (77- 80 days), seed coat colour is yellow and flower colour is white. Siliqua is two chambered with 18 to 24 seeds per siliqua. The siliqua number per plant is 66 to 85. Yield potential of this genotype is 1.4 to 1.9 ton per hectare. Oil content of seeds ranges from 42 to 44%.

3.4 Treatments

There were five planting dates for the experiment as follows:

i. T_1 = October 20

ii. T_2 = October 30

iii. T_3 = November 10

iv. T_4 = November 20

v. T_5 = November 30

3.5 Experimental design and layout

The experimental design was Randomised Complete Block Design (RCBD) with four replications. It consisted of 20 (twenty) plots (5 sowing dates X 4 replications). Total experimental area was 240 sq. m, divided into four blocks, each representing a replication. The treatments were allocated in the field randomly. The size of the each unit plot was 4m X 3m (0.0012 hectare). Each unit plot and block was separated by a border of 1.0 m and 1.5 m, respectively.

3.6 Land preparation

The experimental land was first opened in the end of September 2004 with a bullock drawn country plough. The land was made ready for sowing with subsequent four ploughings and cross ploughing with the help of a power tiller followed by laddering. All the weeds, stubbles were removed and the land was prepared properly. The layout of the experiment was accomplished according to the design of the experiment one day before sowing.

3.7 Fertilizer application

The fertilizer dose used for the experiment was 120, 35, 90, 27, 3 and 0.8 kg ha^{-1} of N, P, K, S, Zn and B in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate, and boric acid respectively (BARC, 1997). Half of the urea and whole amount of all other fertilizers were applied in the unit plots at the time of final land preparation prior to sowing. The remaining half of the urea was applied as topdressing in one instalment one day after first irrigation just before initiation of bud i.e. 22 days after emergence of seedlings.

3.8 Sowing of seeds

Seeds were sown as per experimental specification with the help of hand at 30 cm apart line made by a tine. The seed rate was 8 kg ha^{-1}. Pre sowing irrigation was given prior to last sowing for the confirmation of proper germination of seeds. About 90% seedlings emerged after 4 days of sowing.

3.9 Weeding and thinning

Two weeding cum thinning were done at 10 and 18 days after emergence of seedlings for each planting dates keeping 60 plants per square metre.

3.10 Application of pesticides

The crop was grown with proper care and management from sowing until harvest. Malathion 60 EC was applied at the rate of 2 ml/L water to control aphid (*Lipaphis erysimi*) at the flowering stage for the last two dates of sowing. Spraying was done in the afternoon to save the life of pollinating insects. Some plants were infested with leaf blight (*Alternaria spp.)* and it was controlled effectively by spraying with Rovral (0.2%) at 10 days intervals starting from 45 DAS.

3.11 Irrigation

Irrigation was applied twice at 20 and 45 days of sowing in order to maintain adequate moisture in the field.

3.12 Harvesting and threshing

The crop was harvested when about 80% siliqua of mustard became straw colour. The plants were cut by sickle at the ground level. Harvesting area was determined excluding 50 cm border from each side of a unit plot. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading on the threshing floor for 4 days. The seeds were separated from the pods by beating with bamboo sticks. Seeds were cleaned and dried in the sun upto 9% moisture content. The weights of the dried straws were also taken for each sample.

3.13 Sampling and data collection

Ten randomly selected sample plants were collected separately from each plot for data collection. The plants were numbered first and were harvested by uprooting the plants. From each plot, the weight of seeds and straw were taken; and the biological yield was also calculated from these data.

Data were collected on the following parameters from sowing to harvesting of the crop.

1. Days to emergence
2. Days to 1st flowering
3. Days to flowering (50%)
4. Days to maturity
5. Plant height (cm)
6. Number of primary branches $plant^{-1}$
7. Number of siliqua $plant^{-1}$
8. Number of seeds $siliqua^{-1}$
9. Weight of seeds $plant^{-1}$
10. Thousand seed weight
11. Dry weight $plant^{-1}$ (Stover yield)
12. Seed yield ha^{-1}
13. Biological yield
14. Oil content in seed
15. Fatty acid composition of oil
16. Oil yield (t ha^{-1})

3.14 Procedures for data collection from sowing to after harvest

3.14.1 Days to emergence

When the seedlings were emerged above ground level.

3.14.2 Days to 1st flowering

When first flower was in blooming condition.

3.14.3 Days to flowering (50%)

When 50% of the flowers of the plot were in blooming condition.

3.14.4 Days to maturity

When 80% plants were straw colour, plants were harvested and counted the days from emergence to maturity.

3.14.5 Plant height (cm)

The heights of the plants were measured from the ground level to the tip of the plant.

3.14.6 Number of primary branches plant^{-1}

The Number of primary branches plant^{-1} was counted for all ten sample plants and mean value was taken.

3.14.7 Number of siliqua plant^{-1}

Siliqua were counted from each of 10 sample plants and mean value was found out.

3.14.8 Number of seeds siliqua^{-1}

Number of seeds siliqua^{-1} of ten randomly selected siliqua were counted by splitting each siliqua with care.

3.14.9 Weight of seeds plant^{-1}

The seeds weight plant^{-1} was determined by measuring with electrical balance.

3.14.10 Thousand seed weight

The weights of thousand seeds were taken three times from the seed yield of each plot and average value was found out.

3.14.11 Dry weight plant^{-1} (stover yield plant^{-1})

The weight of the plants containing grain was taken. By subtracting the grain weight from the total weight, the stover weights were calculated.

3.14.12 Seed yield ha^{-1}

By threshing the plants of the harvested area of each plot and the mean weights were taken and converted to t ha^{-1}.

3.14.13 Biological yield

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

Biological yield = Grain Yield + Stover yield

3.14.14 Determination of oil content of seeds

Oil content of seed samples were determined following the methods given by Cocks and Van Rede (1966) and Mehlenbacher (1960).

Principle:

The principle of this method lies in mixing the sample with a solvent, petroleum ether (B.P. 40 to 60^0C), which was then removed by distillation and the residue was dried and weighed. The extraction procedure was carried out in the Soxhlet apparatus.

Reagent:

A) Petroleum ether (B.P. 40 to 60^0C)

Procedure:

About 10 grams of clean seeds from each lot was placed in a small screw cap glass vial. All these samples were dried in an oven for 3 hours at 130^0C. After that all caps were closed tightly and the samples were stored in the desiccators.

The dry sample (5 to 10 g) was weighed accurately and crushed into a powder form by a grinder. Then the crushed sample was transferred to an extraction thimble. The thimble was then placed in a Soxhlet apparatus and extracted with petroleum ether for about 16 hours. The ether extract was then transferred into a weighed conical flask. The flask containing the original ether extract was washed 4 to 5 times with small quantities of ether and the washings were also transferred to the conical flask. The ether in the conical flask was then removed by evaporation in an oven and then desiccated, and weighed.

Calculation:

Percentage of oil content = $(W^1 \times 100)/W$

Where,

W^1 = Weight of the ether extract

W = Weight of the sample

3.14.15 Determination of fatty acid composition of oil

The collected seed samples were analyzed for fatty acid composition by the gas liquid chromatography method as described by Jellum and Worthington (1966).

Preparation of Fatty Acid Methyl Esters:

A. Reagents:

i) Heptadecanoic acid standard prepared by adding 10 mg of heptadecanoic acid to 0.5 ml petroleum ether to make a 20 mg/ml solution.

ii) 3% sulphuric acid: prepared by adding 3 ml of concentrated sulphuric acid to 97 ml absolute methanol.

B. Procedure:

About 0.5 g of oven dried seed sample was crushed in a smaller mortar by a pestle, and 0.1 gm of this crushed seed sample was put in a 25 ml culture tube with screw cap. Then 2 ml chloroform and 1ml absolute methanol were added to the tube and gently mixed by swirling the tube. The mixture was left overnight for extraction lipids. The next day, 50 µl of heptadecanoic acid standard (20 mg/ml) and 5 ml of 3% sulphuric acid in absolute methanol were added. After shaking, the tube was incubated in an oven at 67^0C for 5 hours. After that 2 ml of petroleum ether was added and the tube was shaken to permit the fatty acid methyl esters to enter into the (petroleum ether) layer. Distilled water was added very carefully and slowly into the tube to raise the petroleum ether layer, which was removed with a Pasteur pipette and transferred into a small screw cap vial. The petroleum ether extract containing the methylated fatty acids of the vial was evaporated with a stream of nitrogen until only about 0.1ml sample remained in the vial. The cap was screwed up tightly. The required numbers of samples were prepared by this procedure and were stored in a deep freezer at -18^0C until analyzed.

Gas Chromatography:

Gas chromatography for fatty acid composition was done according to the chromatographical estimation method of McNair and Bonelli (1968)

A. GLC conditions:

A column of stainless steel 1.8 metre long and 4 mm internal diameter was used. The packing material was 15% Diethylene Glycol Succinate (DEGC) on a chromosorb W solid support. The column was conditioned at 210^0C overnight in a vernian Aerograph 1800 gas chromatography equipped with flame ionization detectors. Column, detector and injector temperatures were maintained at 197^0, 230^0 and 230^0 C respectively. Nitrogen gas was used as a carrier gas; and hydrogen and compressed air were used for flame ionization. Gas flow rates were maintained at 40, 30, and 300 ml/minutes respectively. A linear recorder was used by maintaining a speed of 2.5 cm per 10 minutes for recording peaks of different fatty acids on the graph paper.

B. Injection of samples:

A 2μl sample was injected into the GLC by a small syringe. Peaks for each sample were recorded on the graph paper of the recorder.

C. Identification of Fatty Acids:

Comparing their retention times to those obtained from known standards, which were chromatographed under identical conditions, identified peaks representing different fatty acids.

D. Calculation of Fatty Acids Concentration:

The area of each peak was recorded in the graph paper. Dividing peak areas of individual fatty acid by the area of total fatty acids and multiplying 100 calculated the percentages of different fatty acids.

3.14.16 Oil yield

Oil yield (t ha^{-1}) was determined by multiplying seed yield (t ha^{-1}) and oil content (%) in seed.

3.15 Analysis of data

The Collected data under the present study were statistically analyzed using MSTAT-C statistical programme. The level of significance and analysis of variance along with the Least Significant Difference (LSD) Test were done following Gomez and Gomez (1984).

CHAPTER 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from the study to see the effects of date of sowing on seed yield and yield attributes of rapeseed. Treatment effects on yield, yield attributes and quality parameters are presented in Table-1, 2, 3; Figure 1, 2, 3, and 4. Analysis of variance of different parameters is given in Appendix III.

4.1 Days to emergence

Days to emergence of the genotype was more or less similar to the different dates of sowing. Only the plants of first sowing (October 20) needed four days to emergence. But all other sowing dates needed five days to emergence (Table 1). It may be due to comparatively high temperature during first sowing.

4.2 Days to 1st flowering

The plants of first sowing needed the highest number of days to first flowering. It needed 29 days to produce first flower in the plants. Plants of last planting (November 30) needed the lowest number of days (25) to give first flower. The third and fourth planting (November 10 and November 20) both took 26 days to first flower while the second planting took twenty seven days to flower first (Table 1).

Table 1 Plant characteristics of rapeseed genotype BCYS-03 as influenced by different dates of planting during rabi season 2004- 05

Treatment	Days to emergence	Days to first flowering	Days to flowering (50%)	Days to maturity	Plant height (cm)	No. of primary branches/plant
T_1	4	29	34	80	100	6.85
T_2	5	27	31	79	105	6.72
T_3	5	26	31	79	115	6.22
T_4	5	26	31	77	104	6.25
T_5	5	25	29	77	100	6.20
CV (%)	-	-	-	1.18	2.76	6.16
LSD 0.05	-	-	-	2.97	6.27	0.17

N. B. Days to emergence, Days to first flowering and Days to flowering (50%) were not statistically analyzed.

4.3 Days to flowering (50%)

The first sowing needed the highest number of days to 50 % flowering. It took 34 days to produce 50 % plants to flower. Plants of second (October 30), third (November10) and fourth planting (November 20) needed 31 days and the last planting took 29 days to give 50 % plants to flower (Table 1).

4.4 Days to maturity

Days to maturity was significantly influenced by five different planting dates. The longest period to mature (80 days) was required by the plants of first sowing and it was statistically similar to second and third plantings. The shortest period (77 days) to mature was required by the fourth and fifth plantings (Table 1). Early plantings required longer period to mature and delayed sowing reduces time to mature. Delayed sowing faced comparatively higher temperature at reproductive stage, which affect directly to the maturity period. In fact, from the end of January, temperature started rising which might have been forced the plant to mature early. Incase of early sowing, plants faced little warm temperature during vegetative stage and the growth was slow, that is why maturity period was longer than that of later sowing plants which completed vegetative growth very quick and matured early.

Hang and Gilliand (1984) also reported that days to maturity varied from year to year depending upon the temperature. The present results are in well agreement with Depauw (1977), Kondra (1977) and Mondal *et al.* (1999) who reported that the maturity period became gradually shorter with the delayed sowing which was completely supported by Bajpai *et al.* (1981), Islam *et al.* (1994) and Robertson *et al.* (2004).

4.5 Plant height

The highest plant height, 115 cm was recorded from the plants of third planting (10 November) and it was significantly different from the all other planting dates. Plants of early planting dates (20, 30 October) and late plantings (20, 30 November) were shorter than the plants of 10 November planting. Mustard plants required lower temperature from planting time to harvesting. In this experiment, during first two planting dates during germination and vegetative stage the crop faced little high temperature. Similarly plants of later two plantings (20, 30 November) were faced little high temperature during the reproductive stage. But after germination, plants of third planting received optimum temperature from sowing to harvesting, so the growth was optimum and the plants were little longer than the plants of other plantings (Table 1).

The results corroborate with the reports of Mondal (1986) and Maini *et al.* (1964) who stated that too early and too late planting reduced the height of mustard plant. Mondal and Islam (1993) supported the above result and said that sowing in the early November gave the highest plant height than in October and December. Shahidullah *et al.* (1997) also reported similar findings.

Majumder and Sandhu (1964), Saran and Giri (1987), Mohammed *et al.* (1987) partially supported the results of the present study and reported that early sowing was recorded higher values of plant height. Kandil (1983), Ansari *et al.* (1990) and Angrej *et al.* (2002) also found similar results.

But this result was in contradiction with the findings of Kolsarici and Er (1988) and BARI (1992) who reported that change of sowing date did not significantly influence the plant height.

4.6 Number of primary branches plant^{-1}

Among the five planting dates the highest number of primary branches plant^{-1} (6.85) was found from the plants of first planting (October 20). But it was statistically similar with the plants of second planting (October 30) and fourth planting (November 20). The lowest number of primary branches plant^{-1} was recorded from the plants of fifth planting, which was 6.20. The plants of earlier planting got a long period of winter, which was very effective for their vegetative growth. The plants of later planting gradually got short period of cold as a result they could not give higher number of branches (Table 1).

The results are in well agreement with the results of Maini *et al.* (1964) who observed a marked effect on branches by variation in sowing dates and obtained the reduced number of primary branches plant^{-1} varied from 6.89 to 8.35 in toria genotype with delay in sowing. Similar results were also obtained by Bukhtiar *et al.* (1992), Islam *et al.* (1994) and Ali *et al.* (1985). Angrej *et al.* (2002) also supported and reported that primary and secondary branches plant^{-1} were obtained when the crop was sown in between 10 to 30 October.

On the contrary, Uddin *et al.* (1986) reported that sowing date had no significant effect on number of primary branches plant $^{-1}$.

4.7 Number of siliqua plant^{-1}

From the analysis of variance table (Appendix III) it is revealed that numbers of siliqua per plant was significantly influenced by five different planting dates. The highest number of siliqua plant^{-1} (85) was obtained from the plants of second sowing (October 30), which was statistically similar to the first, third and fourth plantings. Though these were statistically similar, it was observed a trend of reduction of siliqua plant^{-1}. From October 30 sowing a progressive reduction was found in siliqua number with each deferment in sowing. As a result the lowest siliqua plant^{-1} was found from the plants of the fifth and final sowing (November 30) which was 66 siliqua plant^{-1}. The crop sown on October 20 also produced a reduced number of siliqua than that of October 30 sown crops. This was due to the fact that the early sown crop, the temperature and other climatological parameters played a major role for the growth and yield attributes of mustard plants.

This finding was in conformity with the findings of Mondal *et al.* (1999) who stated that the plants of third planting (November 10) produced the highest number of siliqua plant^{-1} and reduced in the late sowings. Shahidullah *et al.* (1997) also showed that the reducing trend continued through 27 October, 6 November and 16 November. The findings also corroborate the reports of Scott *et al.* (1973), Uddin *et al.* (1986), Brar *et al.* (1998), who also reported that number of siliqua plant^{-1} decreased when the crop was not sown in optimum time.

Table 2 Seed yield and yield contributing characteristics of rapeseed genotype BCYS-03 as influenced by different dates of planting during rabi season 2004- 05

Treatment	Siliqua plant^{-1} (No.)	Seeds siliqua^{-1} (No.)	1000-seed weight (g)	Seed yield plant^{-1} (g)	Dry plant weight/ plant	Seed yield (t ha^{-1})	Biological yield (t ha^{-1})
T_1	84	21.25	3.68	3.69	6.42	1.59	6.06
T_2	85	24.00	3.80	3.78	6.20	1.86	5.98
T_3	77	22.75	3.68	3.66	5.35	1.56	5.40
T_4	77	21.75	3.28	3.44	4.90	1.52	5.04
T_5	66	18.75	3.24	3.41	4.75	1.47	4.80
CV (%)	11.09	7.48	6.44	6.17	16.32	5.41	8.13
LSD 0.05	18.69	3.51	0.08	0.34	1.48	0.19	0.25

4.8 Number of seeds siliqua^{-1}

Analysis of variance (Appendix III) showed that the number of seeds siliqua^{-1} was highly significant due to sowing date. The highest number of seeds siliqua^{-1} was produced in the plants of October 30 sowing and was statistically similar with those of October 20, November 10 and November 20 sowings. The lowest seed number siliqua^{-1} was found in the plants of November 30 sowing which was significantly different from all other sowing dates (Table 2). These results are in well agreement with the results of Mondal *et al.* (1999) and Majumder and Sandhu (1964) who demonstrated that sowing date markedly influenced the number of seeds siliqua^{-1} and it was the highest in the crop sown between the date 25 October and November 1. Shahidullah *et al.* (1997) also showed that sowing on October 27 produced the highest seed siliqua^{-1} among the sowing dates October 27, November 6 and November 16. In contradiction to this result, Kandil (1983), Brar *et al.* (1998) found no significant variation in seed number siliqua^{-1} through sowing the crop in different dates. However, the variation between the present study and that of Kandil (1983) and Brar *et al.* (1998) could be due to the variation in the environment and native fertility level of the soil.

4.9 Weight of seeds plant^{-1}

The observed data on weight of seeds plant^{-1} with respect to sowing date has been presented in Table 2 and the analysis of variance in Appendix III. The results showed that the effect of sowing date on weight of seeds plant^{-1} was significant in 5% level of probability.

The results presented in Table 2, showed that the highest weight of seeds plant^{-1} was in second sowing which was 3.78 g per plant statistically different from other dates of sowing. The lowest weight of seeds plant^{-1} (3.41 g plant^{-1}) was produced from the plants of November 30 sowing.

The results of this experiment are in conformity with that of Uddin *et al.* (1986). They observed that delayed sowing after the month of October reduced the seed yield plant^{-1} but there was little difference in seed yield between the two earliest sowing dates. Kalra *et al.* (1983) and Bukhtiar *et al.* (1992) also recorded that delaying in planting time reduced the seed yield plant^{-1}.

4.10 Thousand seed weight

A significant difference was noticed in weight of 1000-seed with the variation of sowing dates. From Table 2, it was observed that the highest 1000-seed weight was recorded in October 30 sowing which was statistically similar to those of October 20 and November 10 sowings. The November 30 sowing was recorded the lowest weight of 1000-seed indicating reduced test weight with each successive delay in sowing after October 30.

The above results could be completely supported by Saran and Giri (1987) who stated that sowing date exerted a significant effect on 1000-seed weight and sowing in October 25 gave 11% higher 1000-seed weight than that of November 15 sowing. Seed yield in terms of 1000-seed reduced successively in the sowing after the month of

October was also supported by Majumder and Sandhu (1964), Uddin *et al.* (1986), Kalra *et al.* (1985). Mendham *et al.* (1981), Scarisbrick *et al.* (1981) and Mondal *et al.* (1999) further stated that 1000-seed weight reduced with the delayed planting time. However, Hossain *et al.* (1984) found no significant influence of sowing dates on individual seed weight (in terms of 1000-seed weight).

4.11 Dry plant weight (stover yield)

A wide range of variation in stover yield was observed with different dates of sowing (Table 2). The highest dry weight or stover yield was found from the plants of first sowing i.e., the sowing of October 20 yielded the most vigorous plant weight which was 6.42 g $plant^{-1}$. The second highest dry weight per plant was obtained from the plants of second sowing (October 30) which was 6.20 g $plant^{-1}$ followed by the sowing date of November 10, November 20 and November 30 which produced 5.35, 4.90 and 4.75 g $plant^{-1}$ stover weight respectively. The result was supported by the results of Islam *et al.* (1994) and BARI (2001).

4.12 Seed yield ha^{-1}

Analysis of variance in Appendix III, showed that seed yield difference was highly significant in rapeseed in response to variation in sowing date. The results obtained in the present study exhibited that the highest seed yield was produced by October 30 sowing and it was significantly different from those of all other sowing dates (Table 2). This higher yield (1.86 t ha^{-1}) might be attributed to higher number of siliqua in individual plants, number of seeds per siliqua and 1000-seed weight. Sowing on October

20 yielded the second highest yield which is 1.59 t ha^{-1}. The lowest seed yield was obtained from November 30. The first sowing (October 20) gave 14.51% less yield than that of October 30 sowing. However the magnitude of yield variation was much greater between the yield of October 30 and November 30 sowings than any other sowing date. Reduced number of siliqua appeared to be the main cause of the lower yield (Fig. 4).

This happened due to optimum temperature and moisture received by the plants from October 20 to November 10 and stressed conditions of both these factors were apparent from November 20 onwards. This might be due to the fact that early sown crop completed its vegetative phase in favourable climatic condition and started flower initiation while in late sown crops seed filling period was less due to increase in temperature at that stage. So, the longer reproductive period resulted in better yield of early crop, while in delay sowing there was drastic reduction in yield due to shorter reproductive period. Short growth period and adverse temperature might have affected the yield in late sown crop. The higher seed yield in early sown crop was owing to favourable yield attributing parameters. But gradual decrease in the yield with delay in sowing might be due to the relatively low temperature at vegetative stage but high temperature during reproductive phase that could have adversely affected the plant growth and development.

The higher yield ha^{-1} was supported by higher number of siliqua $plant^{-1}$ as reported by Mondal *et al.* (1992) and Ali *et al.* (1985). The findings in present study about seed yield was fully supported by Brar *et al.* (1998), Buttar and Aulakh (1999), Mondal *et al.* (1999).

4.13 Biological yield

Analysis of variance in Appendix III showed that biological yield difference was highly significant in rapeseed in response to variation in sowing date. The results obtained in the present study exhibited that the highest biological yield was produced by October 20 sowing and it was significantly different from those of all other sowing dates (Table 2). The highest biological yield 6.06 t ha^{-} was found from the plants of 20 October sowing. The lowest biological yield was obtained from November 30 which is 4.80 t ha^{-}. However the magnitude of biological yield variation was much greater between the yield of October 20 and November 30 sowings than any other sowing date.

Degenhardt and Kondra, (1981) made almost a similar conclusion and supported the present findings.

4.14 Oil content in seed

Oil content was highest (43.47%) in October 20 sowing which was similar to the plants of October 30 sowing (43.10%). The lowest oil content (42.40%) was found from November 30 sowing (Table 3). It may be due to rainfall at first 2 weeks enhanced oil content of seed (Appendix VI). This result agrees with BARI (2000) which reported that delay sowing reduced oil content.

From Fig. 1, it is evident from the regression curve that the response of oil content to different planting dates follows equation.

$Y = -0.0267x + 51.222$

4.15 Fatty acid composition of oil

Fatty acid composition of oil differed from date to date of sowing. Incase of oleic acid the percentage of 12.62, 14.37, 17.15, 15.42 and 14.96 were found from the seeds of first, second, third, fourth and fifth sowing dates respectively (Table 3).

Incase of linooleic acid the percentage of 16.45, 17.37, 16.18, 13.52 and 13.72 were found from the seeds of first, second, third, fourth and fifth sowing dates respectively (Table 3).

Table 3 Oil content and fatty acid composition of rapeseed genotype BCYS-03 as influenced by different dates of planting during rabi season 2004- 05

Treatment	Oil content (%)	Oil yield ($t\ ha^{-1}$)	Fatty acids (%)			
			Oleic acid ($C_{18:1}$)	Linoleic acid ($C_{18:2}$)	Linolenic acid ($C_{18:3}$)	Erucic acid ($C_{22:1}$)
T_1	43.47	0.69	12.62	16.45	12.69	44.22
T_2	43.10	0.80	14.37	17.37	10.52	48.59
T_3	42.67	0.66	17.15	16.18	8.54	47.79
T_4	42.50	0.64	15.42	13.52	7.13	51.94
T_5	42.40	0.62	14.96	13.72	7.31	51.59

N.B. These three parameters like Oil content (%), Oil yield ($t\ ha^{-1}$) and Fatty acids (%) were not statistically analyzed.

Incase of linolenic acid the percentage of 12.69, 10.52, 8.54, 7.13 and 7.31 were found from the seeds of first, second, third, fourth and fifth sowing dates respectively (Table 3).

Incase of erucic acid the percentage of 44.22, 48.59, 47.79, 51.94 and 51.59 were found from the seeds of first, second, third, fourth and fifth sowing dates respectively (Table 3).

4.16 Oil yield (t ha^{-1})

The highest oil yield ha^{-1} (0.80 t) was obtained from the crops of second planting (October 30). The second highest oil yield was found from the plants of October 20 sowings which was 0.69 t ha^{-1}. The oil yield gradually reduced with the later sowings after the second sowing. The third (November 10), fourth (November 20) and fifth (November 30) sowings resulted the yield of 0.66, 0.64 and 0.62 t ha^{-1} oil respectively. The yield contributing characters such as siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and thousand seed weight were recorded the highest in the plants of October 30 sowing and thus they helped to get highest oil yield ha^{-1} in this date of sowing (Table 3).

Yadav *et al.* (1996) and Jadhav and Singh (1993) supported above findings and made the conclusion that sowing in October produced higher oil than sowing in November.

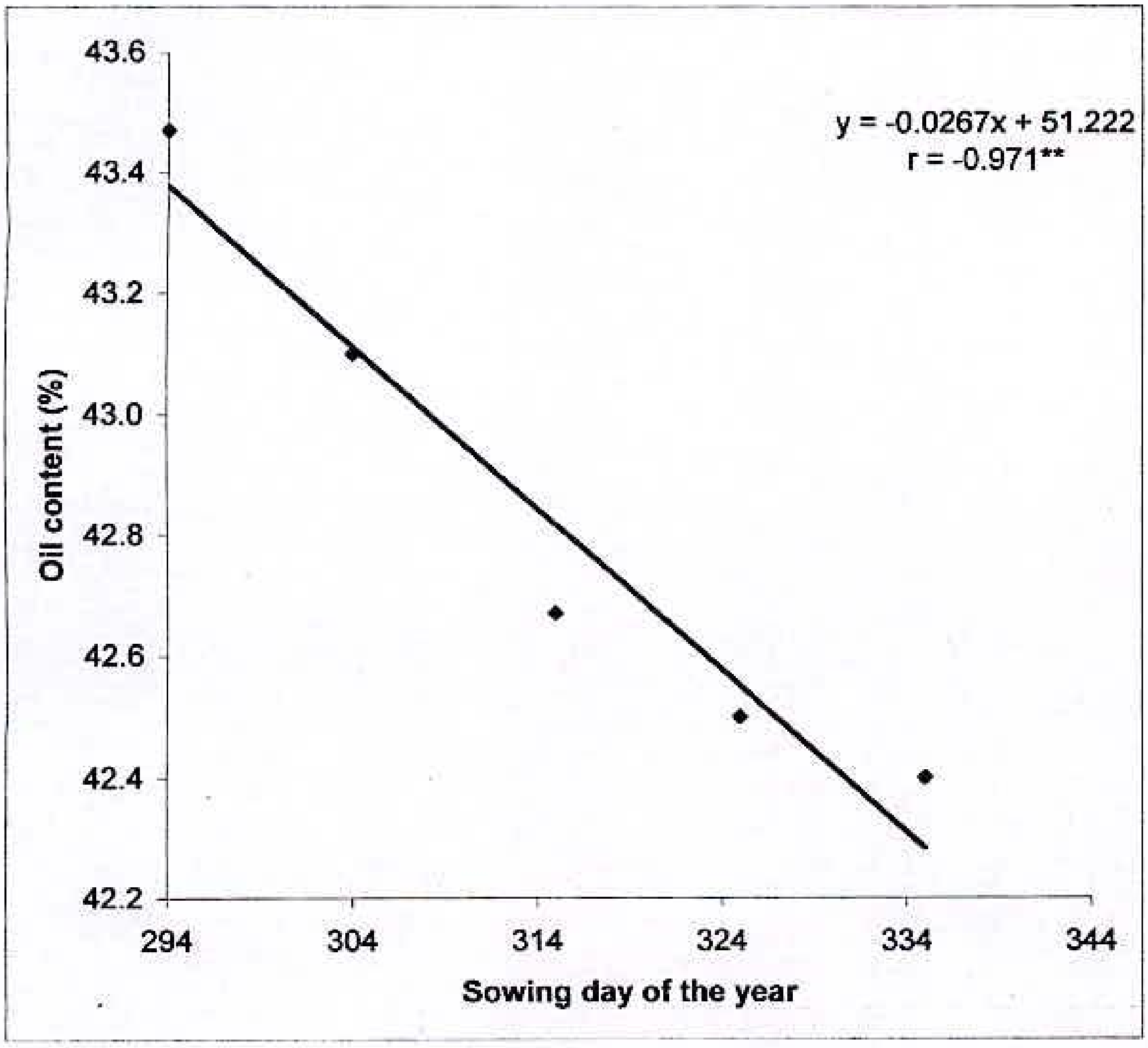


Fig. 1 Relationship between sowing day of the year and oil content (%) of mustard

4.17 Correlation and regression studies

Statistical relationship between total number of siliqua plant^{-1}, number of seeds siliqua^{-1}, 1000-seed weight and seed yield of different sowing date have been presented in Figures (2 through 4) and Appendix IX.

4.17.1 Number of siliqua plant^{-1} and seed yield

The relationship between total number of siliqua plant^{-1} and seed yield has been found out. The correlation coefficient (r=0.744) was found non significant.
The line of regression of Y (yield) on X (siliqua plant^{-1}) having equation Y= 0.0149x +0.4404 is shown in Fig. 2. The positive slope indicates that total number of siliqua plant^{-1} and seed yield is directly related.

4.17.2 Number of seed siliqua^{-1} and seed yield

The relationship between total number of seeds siliqua $^{-1}$ and seed yield has been calculated out and found positively correlated. The correlation coefficient (r= 0.790) was non significant. The regression line with Y (yield) on X (seeds siliqua^{-1}) can be shown as Y=0.0614 +0.2668 (Fig. 3)

4.17.3 Thousand seed weight and seed yield

The correlation study between 1000-seed weight and seed yield has been calculated out and found positively correlated. The correlation coefficient (r= 0.770) was non significant. The regression line with Y (yield) on X (seeds siliqua^{-1}) can be shown as Y= 0.0555x-0.0107 (Fig. 4).

This result agreed with Bhargava and Tomar (1982) and Khader and Bhargava (1984) who reported that in *Brassica spp.* yield unit^{-1} area was determined largely by three major components (i) number of siliqua plant^{-1} (ii) seed number siliqua^{-1} and (iii) 1000-seed weight and they are positively correlated.

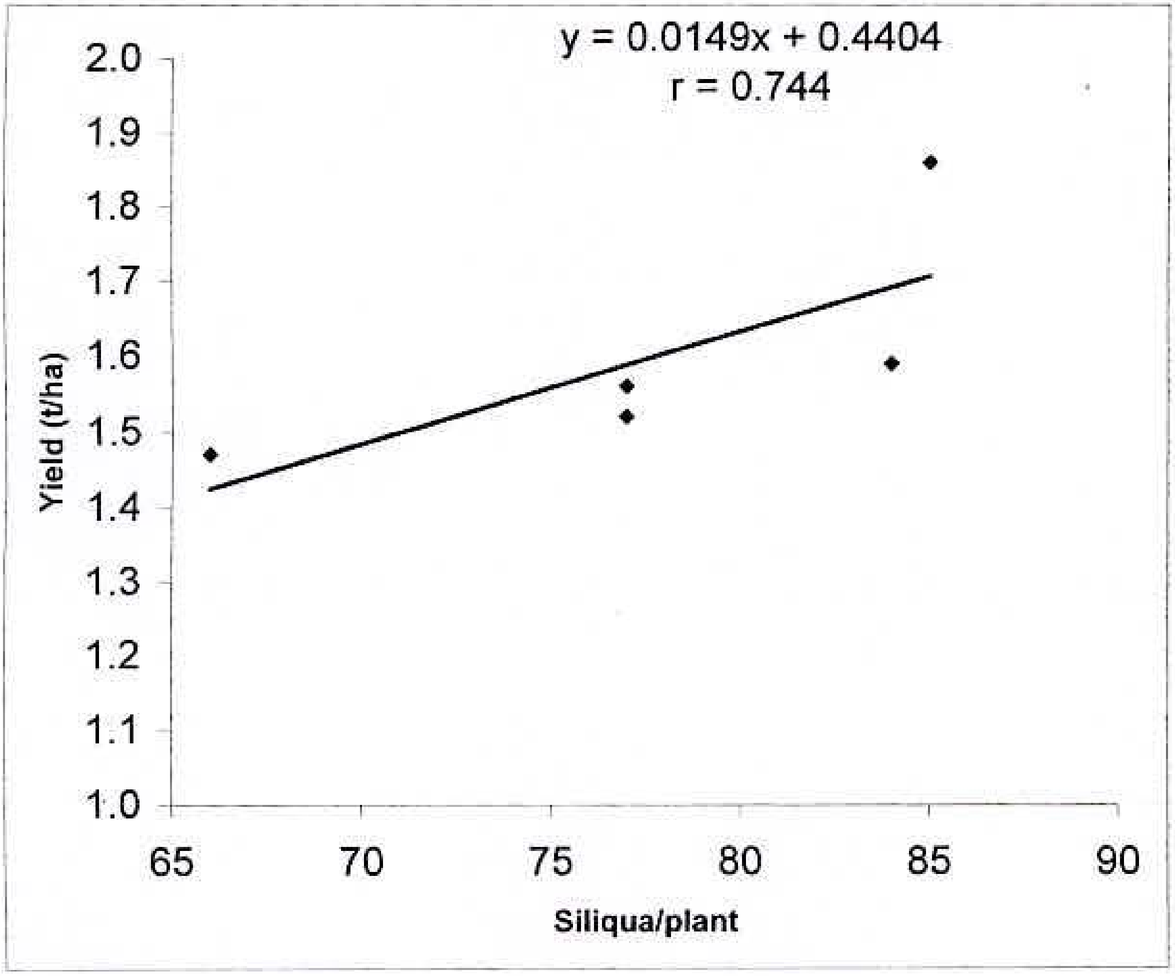


Fig. 2 Relationship between siliqua plant^{-1} and yield (t ha^{-1}) at different date of sowing of mustard

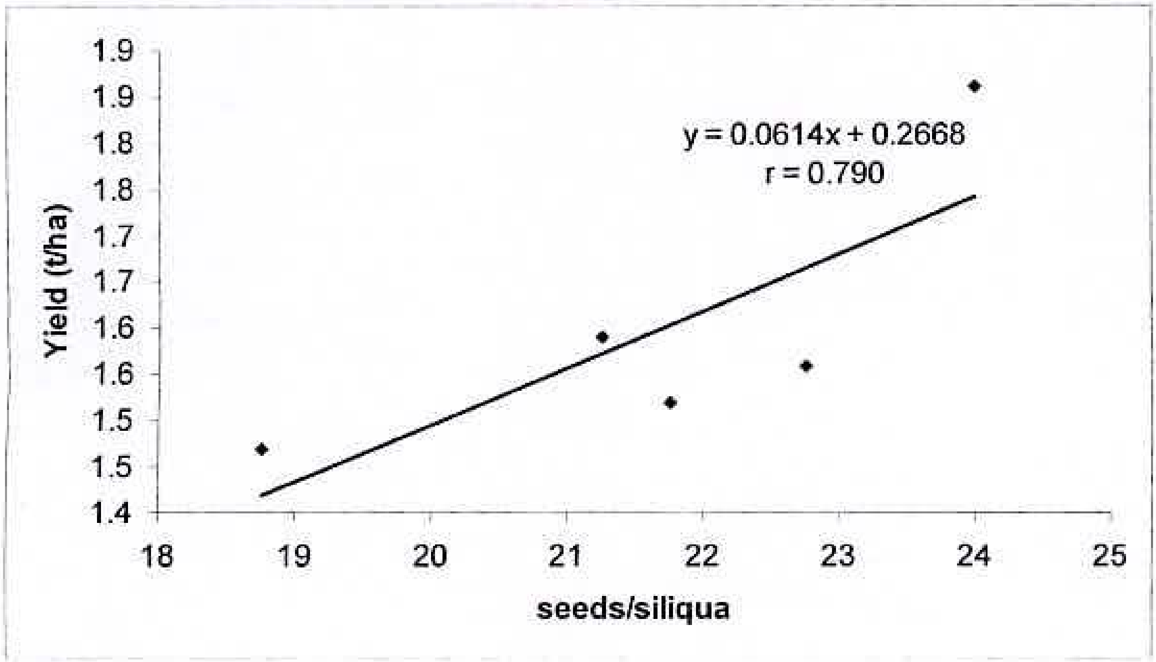


Fig. 3 Relationship between seeds siliqua^{-1} and yield (t ha^{-1}) at different date of sowing of mustard

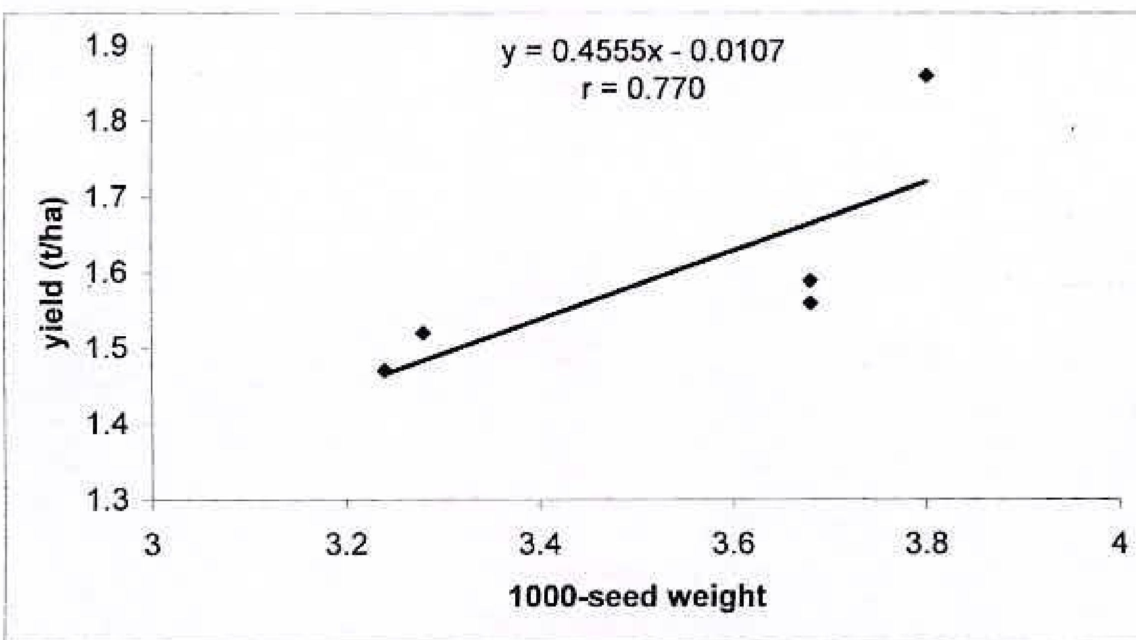


Fig. 4 Relationship between 1000-seed weight (g) and yield (t ha^{-1}) at different date of sowing of mustard

CHAPTER 5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was carried out at the field of Agriculture Research Station, BARI, Burirhat, Rangpur from October 2004 to February 2005 to find out the effect of sowing time on seed yield, yield components, oil content and oil quality of mustard. The experimental treatments were consisted of five sowing dates viz. October 20, October 30, November 10, November 20 and November 30 and the genotype was BCYS-03. The experiment was laid out in a Randomized Complete Block Design (RCBD) following the principles of randomization with four replications. The unit plot size was 4.0 m x 3.0 m and the plot to plot distance was 1 m.

Data were made on days to emergence, days to 1st flowering, days to flowering (50%), days to maturity, plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, seed yield plant^{-1}, thousand seed weight, dry weight plant^{-1}, seed yield ha^{-1} , biological yield, oil content , fatty acid composition of oil and oil yield ha^{-1}. Ten plants were randomly selected from each unit plot for taking data on plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}. Weight of seeds plant^{-1} was taken from ten plants and then converted to weight of seed plant^{-1}. An area of 2 m^2 from each plot was harvested for seed yield, stover yield, biological yield and then converted into t ha^{-1}. Thousand seed weight (g) was measured from sample seed. Oil content and fatty acid composition of oil were also determined of the seeds from each plot.

The findings showed that sowing time influenced days to emergence, days to 1st flowering, days to flowering (50%), days to maturity, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, seed yield plant^{-1}, thousand seed weight, dry weight plant^{-1}, seed yield, biological yield, oil content , fatty acid composition of oil and oil yield. Maximum days to flowering was found from the plants of first sowing (October 20) and minimum in last sowing (November 30). Maximum days to maturity was found from the plants of first sowing (October 20) and minimum in last sowing (November 30). The highest plant height was found in November 10 planting and the lowest in November 30. The highest primary branches plant^{-1}were found in October 20 sowing and the lowest in November 30. The highest siliqua plant^{-1}, seeds siliqua^{-1}, seed yield plant^{-1}, and thousand seed weight was found in October 30 sowing and the lowest in November 30. The highest dry weight plant^{-1} was found in October 20 sowing and the lowest in November 30. The highest seed yield, 1.86 t ha^{-1} and biological yield, 6.06 t ha^{-1} were found in October 30 and October 20 sowing and the lowest seed yield, 1.47 t ha^{-1} and biological yield, 4.80 t ha^{-1} in November 30 respec tively. The highest oil content was found from the plants of first sowing (October 20) and the lowest in last sowing (November 30). The highest oil yield (0.80 t ha^{-1}) was found in October 30 sowing and the lowest in November 30 sowing.

Late sown crops resulted in early maturity and inferior to other characters than early sown crops. During the growing season the temperature decreased progressively up to second week of February and that probably caused the late sown crops to mature earlier and lower yield contributing characters.

Finally based on the experiment the following findings were obtained-

i) Seed yield and yield contributing characters were significantly influenced by different planting dates.

ii) Oil content of seed and fatty acid composition of oil were also influenced by planting dates.

iii) The highest seed yield (1.86 t ha^{-1}) was obtained from October 30 planting and though delayed sowing reduced yield gradually but a reasonable yield (1.47 t ha^{-1}) was also obtained from November 30 planting.

From the above findings it may be concluded that mustard genotype BCYS-03 may be sown from end of October to November 30 in the northern parts of the country

However, to arrive a definite conclusion and recommendation more research work on wider range of sowing date of the genotype BCYS-03 should be tested over different Agro-ecological zones.

References

REFERENCES

Akbar, M. A. (1987). Resynthesis of *Brassica napus* for earlyness and day length insensitivity. Ph.D. Dissertation, Dept. Plant Breeding, Swedish Univ. Agril. Sci. Uppsala, Sweden. ISBN 91-576-2919-8.

Ali, N., Shah, S. A. H. and Rashid, A. (1985). Effect of sowing dates on seed yield and yield components of Prorbi Raya. *Pakistan J. Agric. Res.* **6**:97-100.

Angrej, S., Dhingra, K. K., Jagroop, S., Singh, M. P., Singh, J. and Singh, A. (2002). Effect of sowing time and plant density on growth, yield and quality of Ethiopian mustard (*Brassica carinata* A.Br.). *J. Res. Punjab Agril. Uni.* **39**(4): 471-475.

Ansari, A. H., Qayyum, S. M., Mirza, A. A. and N. A. Choudhury. (1990). Effect of different sowing dates on the growth and yield of three varieties of mustard. *Pakistan J. Agric. Res.***11** (4): 234-348.

Appleqvist, L. A. (1972). Chemical constituents of rapeseed. [Appleqvist, L. A. and R. Ohlson (Ed.)] Elsevier Publishing Co., Amsterdam, London, New York. pp. 123-173.

Bajpai, M. R., Singh, G. D. and Chippa. B. R. (1981). Effect of sowing time and irrigation levels on the growth and yield of mustard. *Indian J. Agric.* **15**(3): 197-200.

Bali, A. S., Singh, T., Shah, M. H. Singh, K. N. and Nehvi, F. A. (1992). Response of Indian mustard (*Brassica juncea*) to sowing date and fertilizer application. *Indian J. Agric. Sci.* **62**(10):690-691.

BARC. (1997). Fertilizer Recommendation Guide. 1997. Bangladesh Agril. Res. Council, Farmgate, New Airport Road, Dhaka. p.15.

BARI. (Bangladesh Agricultural Research Institute) (1992). Annual Report (1992-93). Bangladesh Agril. Res. Inst. Joydebpur, pp. 231-298.

BARI. (Bangladesh Agricultural Research Institute) (1999). Annual Report (1998-99). Bangladesh Agril. Res. Inst. Joydebpur, pp.126-131.

BARI. (Bangladesh Agricultural Research Institute). (2000). Annual Report (1999-2000). Oilseed Research Centre. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur pp 115-119.

BARI. (Bangladesh Agricultural Research Institute). (2001). Annual Report (2000-2001. Oilseed Research Centre. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. pp. 231-237.

BBS (Bangladesh Bureau of Statistics). (2001). Statistcal Yearbook of Bangladesh, Statistics Division, Ministry of Planning, Govt. Peoples Repub. Bangladesh. pp 101-125.

Beech, D. F. and Norman, M. J. T. (1964). The effect of time of planting and nitrogen fertilizer on yield attributes of *Brassica* oilseed crops in the Ord River Valley, *Aust J. Exptl. Agric. and Ani. Hus.* **4**: 207-214.

Berea, N. (1999). Influence of sowing time on some winter oilseed rape genotype in The Moldavian Forest Steppe. II. Productivity aspects. Problem de Agrofitotechnic-Teoretica si Aplicata.**21**:1-2, 47-62.

Bhagat, D. V. and Singh, S. (1989). Effect of sowing dates and varieties on seed quality, yield and aphid infestation of mustard. Bharatiya Krishi Anushandhana Patrika. 4:4, 179-183.

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

Bishnoi, K. C. and Singh, K. (1979). Oil yield and quality parameters of three raya varieties as affected by sowing time and nitrogen levels. *Indian J. Agron.* **24**:255-263.

Brar, Z. S., Bal, D. S. and John, A. S. (1998). Influence of sowing dates, nitrogen and planting geometry on the performance of Gobhi Sarson (*Brassica napus* spp. *olefera* var. *annua*). *Indian J. Agron.* **43**(1): 133-137.

Bukhtiar, B. A., Atta, M. and Habib, G. (1992). Effect of sowing dates on seed yield of rapeseed and mustard under rainfed conditions. *J. Agric. Res.* **3 (4)**: 463-469.

Buttar, 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. Agron.* **44**(4): 813-815.

Chakraborty, P. K., Majumder, A. and Chatterjee, B. N. (1991). Physiological process in Indian mustard (*B. juncea*) and yellow sarson (*B. napus* var.*glauca*) and their organic appraisal in mild and short winter prevailing in Gangetic plain of Eastern India. *Indian J. Agric. Sci.* **61**(11): 851-861.

Chaterjee, B. N., Ghosh, R. K. and Chakraborty. (1985). Response of mustard to sulphur and micronutrient. *Indian J. Agron.* **30**(1): 75-80.

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

Chay, P. and Thurling, N. (1989). Variation in pod length in spring rape (*Brassica napus*) and its effect on seed yield and yield components. *J. Agric. Sci.*, Camb. **113**:139-147.

Choudhary, J. K. and Thakuria, R. K. (1994). Response of Indian mustard (*Brassica juncea*) and toria (*Brassica campestris* subsp. *oleifera* var. *toria*) to sowing date under rainfed condition. *Indian J. Agron.* **39**(4):687-688.

Cocks, L. V. and Van Rede, C. (1966). Laboratory hand book for oil and fat analysis. Academic Press, London and New York pp. 20-130.

Degenhardt, D. F. and Kondra, Z. P. (1981). The influence of seeding date and seeding rate on seed yield and growth characters of five genotypes of *Brassica napus*. *Can. J. Plant Sci.* **61**:185-190.

Depauw, R. M. (1977). Agric. Can. Res. Sta. Beaverlodge. Alta. Rep. No. **22**:31-33.

Dudhade, D. D., Gare, B. N., Khade, K. K. and Ramshe, D. G. (1996). Effect of sowing date on growth, yield attributes and yield of Indian mustard (***Brassica juncea***). *Indian J. Agron.* **41**(3):445-447.

FAO. (2003). Production Year Book. Food and Agricultural Organization of The United Nations. Rome 00100. Italy. (57):122.

FAO. (2004). FAOSTAT database of Agriculture (Crops). http://www.fao.org.

Ghosh, R. K. and Chaterjee, B. N. (1988). Effect of dates of sowing on oil content and fatty acid profiles of Indian mustard. *Indian J. Oilseed Res.* **5**(2):144-149.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. A Wiley Int. Sci. Publ. John Wiley and Sons. New York, Brisbane, Singapore pp. 139-240.

Hang, A. N. and Gilliland, G. G. (1984). Planting date effects on yield and quality of oilseed *Brassica* spp. Washington State Univ., Agric. Res. Centre. Res. Bul. 944:1-12.

Hossain, M. F., Zakaria, A. K. M. and Jahan, M. H. (1996). Technical Report on Variety Screening Adaptive Research Oilseeds. Rural Development Acacemy, Bogra, Bangladesh. pp.6-34.

Hossain, M. A., Arabinda, S. and Abedin, M. J. (1984). Effect of seed rate and time of sowing on the yield of mustard under rainfed condition. *Bangladesh J. Agril. Res.* **9**:54-57.

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

Islam, N. and Razzaque, A. S. M. A. (1999). Accomodating mustard in the transplant aman rice mustard cropping pattern. 1. Selection of mustard varieties to late sowing. BAU Res. Prog. 10:58.

Jadhav, S. N. and Singh, N. P. (1993). Effect of sowing date, insect pest-control measures and irrigation on oil content, seed and oil yields in mustard (*Brassica juncea*). *Indian J. Agron.* **38**(1):139-141.

Jain, V. K., Chauhan, Y. S. Khandekar, M. P. and Jain, P. C. (1989). Effect of sowing dates and genotypes on yield and yield attributing traits in Indian mustard. *Madras Agril. J.* **76**(5):241-246.

Jellum, M. D. and Worthington, R. E. (1966). A rapid method of fatty acid analysis of oil from individual corn (*Zea mays* L.) Kernels. *Crop Sci.* **6**:251-254.

Joshi, M. L., Ahuja, B. D. and Mathur, B. N. (1989). Loss in seed yield by insect pests and their occurrence on different dates of sowing in Indian mustard. (*B. juncea* sub sp. *Juncea*) *Indian J. Agric. Sci.* **59**(3):166-168.

Kalra, A. A. (1983). Effect of sowing date on yield, aphid infestation on seed yield and its component traits in Indian mustard (*Brassica juncea* L.). *Agric. Sci. Digest.* **3**(3/4): 177-178.

Kalra, U. K., Yadava, T. P. and Bhola, A. L. (1985). Effect of sowing date, nitrogen and row spacing on growth, yield attributes and yield of Indian mustard. Agricultural Science Digest (India) (3-4): 177-178.

Kandil, A. A. (1983). Effect of sowing date on yield, yield components and some agronomic characters of oilseed rape (*Brassica napus* L.). In: 6th Intl. Rapeseed Conf. Paris, France, p.297.

Kaul, A. K. and Das, M. L. (1986). *Oilseeds in Bangladesh*. Bangladesh-Canada Agriculture Sector Team, Ministry of Agriculture, Government of the Peoples' Republic of Bangladesh, Dhaka. pp. 42-62.

Khader, S. S. E. and Bhargava, S. C. (1984). Physiological aspects of yield improvement in *Brassica* species with references to plant density I. Dry matter accumulation and growth attributes. *J. Oilseeds Res.* **1**:37-48.

Kolsarici, O. and Er, C. (1988). Investigation of the most suitable sowing time, variety and plant density in rape cultivar in Amasaya. Doga, Turk Tarim ve Ormancilik Dergici, **12**(2): 161-177. [*Field Crop Abs.* 1989, **42**(20); 137].

Kondra, Z. P. (1977). Effects of planting date on rapeseed. *Can. J. Plant Sci.* **57**:607-609.

Kumar, S. D. and Singh, R. D. (2003). Indian mustard (*Brassica juncea* L.) seed yield as influenced by seeding date, spacing and N levels. *J. Applied Biol.* **13**(1/2): 139-146.

Lutman, P. J. W. and Dixon, F. L. (1987). The effect of drilling date on the growth and yield of oil seed rape (*Brassica napus* L.). *J. Agric. Sci. Camb.* **108**:195-200.

Maini, N. S., Sandhu, I. J. S. and Johal, K. S. (1964). Effect of sowing date, spacing, irrigation and nitrogen levels on the grain yield of toria (*Brassica campestris*). *Indian Oilseed J.* **8**:128-132.

Majumder, D. K. and Sandhu, A. S. (1964). Effect of time of sowing and fertilizers on the growth, development, quality characteristics and chemical composition of rapeseed (*Brassica cmapestris* var. Brown Sarson). *Indian Oilseed J.* **8**:269-276.

McNair, H. M. and Bonelli, E. J. (1968). *Basic Gas Chromatography*. Consolidated pointers, Berkeley, California.

Mehlenbacher, V. C. (1960). *The analysis of fats and oils*. The garad press publisher, Champign, Ilinois.

Mendham, N. J. and Scott, R. K. (1975). The limiting effect of plant size at inflorescence initiation on subsequent growth and yield of oilseed rape (*Brassica napus*) *J. Agric. Camb.* **84**:487-502.

Mendham, N. J., Shipway, P. A. and Scott, R. K. (1981). The effect of delayed sowing and weather on growth, development and yield of winter oilseed rape (*Brassica napus*). *J. Agric. Sci. Camb.* **96**:389-416.

Mohammad, F., Samiullah, M. Afridi, M. R. K. and Khan, N. A. (1987). Morphology of mustard varieties to three sowing dates. I. Growth characteristics. *Bangladesh J. Agric. Res.* **14**(10):66-71.

Mondal, M. R. I. and Islam, M. A. (1993). Effect of seed rate and date on yield and yield components of rapeseed. *Bangladesh J. Agril. Sci.* **20**(1):29-33.

Mondal, M. R. I. and Wahhab, M. A. (2001). Production technology of oil crops. Oilseed Research Center. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. pp. 6-15.

Mondal, M. R. I., Islam, M. A. and Khaleque, M. A. (1992). Effect of variety and planting date on the yield performance of mustard/rapeseed. *Bangladesh J. Agril. Sci.* **19**(2): 181-188.

Mondal, R. I. (1986). Environmental effects on plant growth, morphological characters, yield, oil content and fatty acid composition of canola/ rapeseed (*Brassica napus* L.) M.S. Thesis, Faculty of the Graduate School of Cornell Univ. N. Y. USA. pp. 123.

Mondal, R. I., Biswas, M., Hydar-Ali, M. K. and Akbar, M. A. (1999). Response of rapeseed genotype Dhali to seed rate and seeding date. *Bangladesh J. Agril. Res.* **24**(1):83-90.

Mondal. M. R. I. and Wahhab, M. A. (2001). Production Technology of Oilseeds. Oilseed Res. Centre, Bangladesh Agril. Res. Inst. Joydebpur, Gazipur . pp.6-24.

Morinaga, T. (1934). Interspecific hybridization in *Brassica*. The Cytology of F_1 Hybrid of *B. nigra*. Cytologia, **6**:62-67.

Nair, A. K. (1998). Effect of sowing dates, and nitrogen levels on growth and yield of Ethiopian mustard (*Brassica carinata*) in Sikkim. *J. Andaman Sci. Association.* **14**(2):37-40.

Narang, R. S. and Singh, S. (1987). Studies on sowing dates of Indian mustard for double cropping under irrigated systems. *Indian J. Agron.* **32**(3):208-209.

Panda, B. B., Bandyopadhyay, S. K. and Shivay, Y. S. (2004). Effect of irrigation level, sowing dates and varieties on yield attributes, yield, consumptive water use and water-use efficiency of Indian mustard (*Brassica juncea*). *Indian J. Agril. Sci.* 74(6): 339-342.

Pandey, B. P., Srivastava, S. K. and Lal, R. S. (1981). Genotype x environment interaction in lentil. LENS. **8**:14-17.

Panwar, K. S., Sharma, S. K. and Nanwal, R. K. (2000). Influence of sowing time on the yield of different multard cultivars (*Brassica sp.*) under conserved soil moisture conditions. *Indian J. Agric. Sci.* **70**(6):398-399.

Patel, J. R., Parmnam, M. T. and Patel, J. C. (1980). Effect of different sowing dates, spacing and plant population on yield of mustard. *Indian J. Agron,* **25**:256-257.

Patel, S. R., Awasthi, A. K. and Tomar, R. K. S. (2004). Assessment of yield losses in mustard (*Brassica juncea* L.) due to mustard aphid (*Lipaphis erysimi* Kalt.) under different thermal environments in Eastern Central India. Dept. Agril. Meteorology, Indira Gandhi Agril. Uni., Raipur 492 006 (C.G.), India. *Applied Ecol. Environl. Res.* **2**(1): 1-15.

Pathak, R. K., Sharma, M. K. and Tripathi, R. D. (1973). Quality studies in some cruciferous oilseeds. *Indian J. Agric. Res.* 7(2): 99-103.

Prasad, C. S. and Singh, V. P. (1999). Impact of variety, sowing date and insect-pest control measures on aphid and grain yield of rainfed mustard in lower Kumaon hills of U.P. Pant Univ. Agricl. and Tech. Res. Station, Majhera, Garampani 263 135, Nainital, India. Annals Plant Prot. Sci., 7(2): 222-224.

Quddus, M. A. and Rahman, L. (1980). Notes on multi–valved characters of mustard. *Bangladesh J. Agric.* 5(2):87-95.

Rahman, M. M., Uddin, M. M. and Khan, M. R. (1989). Influence of seeding date on the occurrence of aphids (*Lipaphis pseudobrassicae*) and seed yield of mustard and rapeseed. *Bangladesh J. Sci. Ind. Res.* **24**: 1-4, 116-122.

Rahman, M. M., Salam, M. U., Miah, M. G. and Islam, M. S. (1988). Effect of sowing time on the performance of mustard (SS-75). *Bangladesh J. Agric. Res.* **13 (1)**:47-51.

Rahman, M. M., Hossain, S. M. A., Islam, N., Jalaluddin, M. and Salam, M. U. (1993). Effect of sowing date and boron fertilizer on the yield and oil content of mustard and rapeseed. *Bangladesh Agron. J.* **15**(1&2):73-78.

Razzaque, M. A., Howlader, M. I. A., Rafiquzzaman, S., Ahsanullah, M. and Nizam, M. U. (2002). Effect of sowing time on the performance of mustard varieties in the southern region of Bangladesh. *Bangladesh J. Agril. Res.* **27**(3):479-484.

Robertson, M. J., Holland, J. F. and Bambach, R. (2004). Response of canola and Indian mustard to sowing date in the grain belt of north-eastern Australia. *Aust. J. Exptl. Agri.* **44**(1):43-52.

Roy, S. K., Akteruzzaman, M. and Salahuddin, A. B. M. (1993). Effect of sowing date and seed rate on growth, harvest index and yield of Indian mustard (*Brassica juncea*). *Indian J. Agrl. Sci.* **63**(6):345-350.

Sabnis, T. S. and Pathak, M. G. (1935). A note on the classification of cultivated Indian mustard. *Indian. J. Agric. Sci.* **5**:559-578.

Saran, G. and Giri, G. (1987). Influence of dates of sowing on *Brassica* species under semi-arid rainfed conditions of North-West. *Indian. J. Agric. Sci. Camb.* **108**:561-566.

Sarmah, P. C. (1996). Effect of sowing date and row spacing on rainfed mustard under late sown conditions. *J. Oilseed Res.* **13**(1):10-12.

Scarisbrick, D. H., Daniels, R. W. and Alcock, M. (1981). The effect of sowing date on the yield and yield components of spring oilseed rape. *J. Agric. Sci. Camb.* **97**:189-195.

Scott, R. K., Qgunremi, E. A., Ivind, J. D. and Mendham, N. J. (1973). The effect of sowing date and season on growth and yield of oilseed rape (*Brassica napus*). *J. Agric. Sci. Camb.* **81**:277-285.

Sen, S. and Sur, S. C. (1964). Optimum time of sowing of Tai and Toria in West Bengal. *Indian Oilseed J.* **8**(3):321-326.

Shahidullah, M., Islam, U., Karim, M. A. and Hussain, M. (1997). Effect of sowing dates and varieties on yield and yield attributes of mustard. *Bangladesh J. Sci. Ind. Res.* **32**:4, 515-516

Shastry, A. B. and Kumar, A. (1981). Variation in yield, its attributes and quality of Indian mustard and relation to planting time and levels of plant population. *Indian J. Agil. Sci.* **51**(26-32).

Shah, M.A.R., Yousaff, M.A. and Sardar, N.A. 1985. The effects of different dates of sowing on the yield of three varieties of mustard. Research Report. RARS. Jessore.

Shivani, K., Sanjeev and Kumar, S. (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.

Si, P. and Walton, G. H. (2004). Determinants of oil concentration and seed yield in canola and Indian mustard in the lower rainfall areas of Western Australia. *Aust. J. Agril. Res.* **55**(3): 367-377.

Sihag, J. S., Manohar, S .S. and Chaudhary, T. (2003). Combined effect of sulphur and time of sowing on yield attributes, yield and quality of mustard (*Brassica juncea* L. Czern and Coss). *J. Eco Physiol.* **6**(1/2): 65-68.

Singh, C. (1988). Modern techniques of raising field crops (3rd edition) Oxford and IBH Publishing Co . Ltd. pp.301-213.

Singh, K. B., Bhola, A. L. and Yadava, T. P. (1972). Effect of sowing time and nitrogen application in varieties of Indian mustard (*Brassica juncea*, L. Czern.& Coss) under irrigated condition in Haryana. *Indian J. Agric. Sci.* **42**:601-603.

Srivastava, J. P. and Balkrishna. (2003). Environmental parameters influencing phenological development of mustard in relation to yield. *Indian J. Plant Physiol.* **8**(4):349-353.

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

U, N. (1935). Genome, analysis in *Brassica* with special reference to the experimental formation of *B. napus* and peculiar mode of fertilization. *Jap. J. Bot.* **7**:389-452.

Uddin, M. M., Samad, A., Khan, M. R., Begum, S., Hossain, K. and Khaleda, S. (1987). Variety X sowing date interaction in mustard and rapeseed. *Bangladesh J. Agric. Res.* **12**(2):55-60.

Uddin, M. M., Samad, A., Khan, M. R., Begum, S. and Salam, M. A. (1986). Effect of sowing dates on the yield and some of its components of mustard and rapeseed. *Bangladesh J. Inds.Res.* **21**:159-166.

UNDP (United Nation Development Program) and FAO (Food and Agriculture Organization). (1988). Land Resources Appraisal of Bangladesh for Agricultural Development Report 2. Agro-ecological Regions on Bangladesh. United Nations Development Programme and Food and Agricultural Organization. pp. 212-221

Vacchani, M. V. (1952). The influence of sowing date on the yield of Oleferous *Brassica* crops. *Indian J. Agric . Sci.* **22**(40:397-409).

Vashi, M., Kumar, A. and Rastogi, A. K. (1986). Effect of sowing dates on rapeseed varieties. *Indian. J. Agron.* **31**(10:144).

Wahhab, M. A., Mondal, M. R. I., Akbar, M. A., Alam, M. S., Ahmed, M. U. and Begum, F. (2000). Status of oilseed production in Bangladesh. Oilseed Research Center. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. pp. 9-22.

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

Wahiduzzaman, M. (1987). Potentials for species introgression in *Brassica napus* with special reference to earliness and seed colour. Ph. D. Dissertation. Dept. plant breeding, Swedish Univ. Agril. Sci. Uppsala, Sweden. ISBN, 91-576-2887-4.

Yadav, K. S., Rajput, R. L., Shrivastava, U. K. and Yadav, R. P. (1997). Effect of sowing date and irrigation schedule on productivity of mustard (*Brassica juncea* L.). Advances in Agril. Res. in India. **8**:75-79.

Yadav, R. N., Bhan, S. and Uttam, S. K. (1996). Effect of sowing date, variety and plant population on growth and yield of rainfed Indian mustard (*Brassica juncea*). *Indian J. Agron.* **39**(4):682-684.

Yadav, R. N., Suraj, B., Uttam, S. K. and Bhan, S. (1994). Yield and moisture use efficiency of mustard in relation to sowing date, variety and spacing in rainfed lands of Central Uttar Pradesh. *Indian J. Soil Conservation.* **22**(3):29-32.

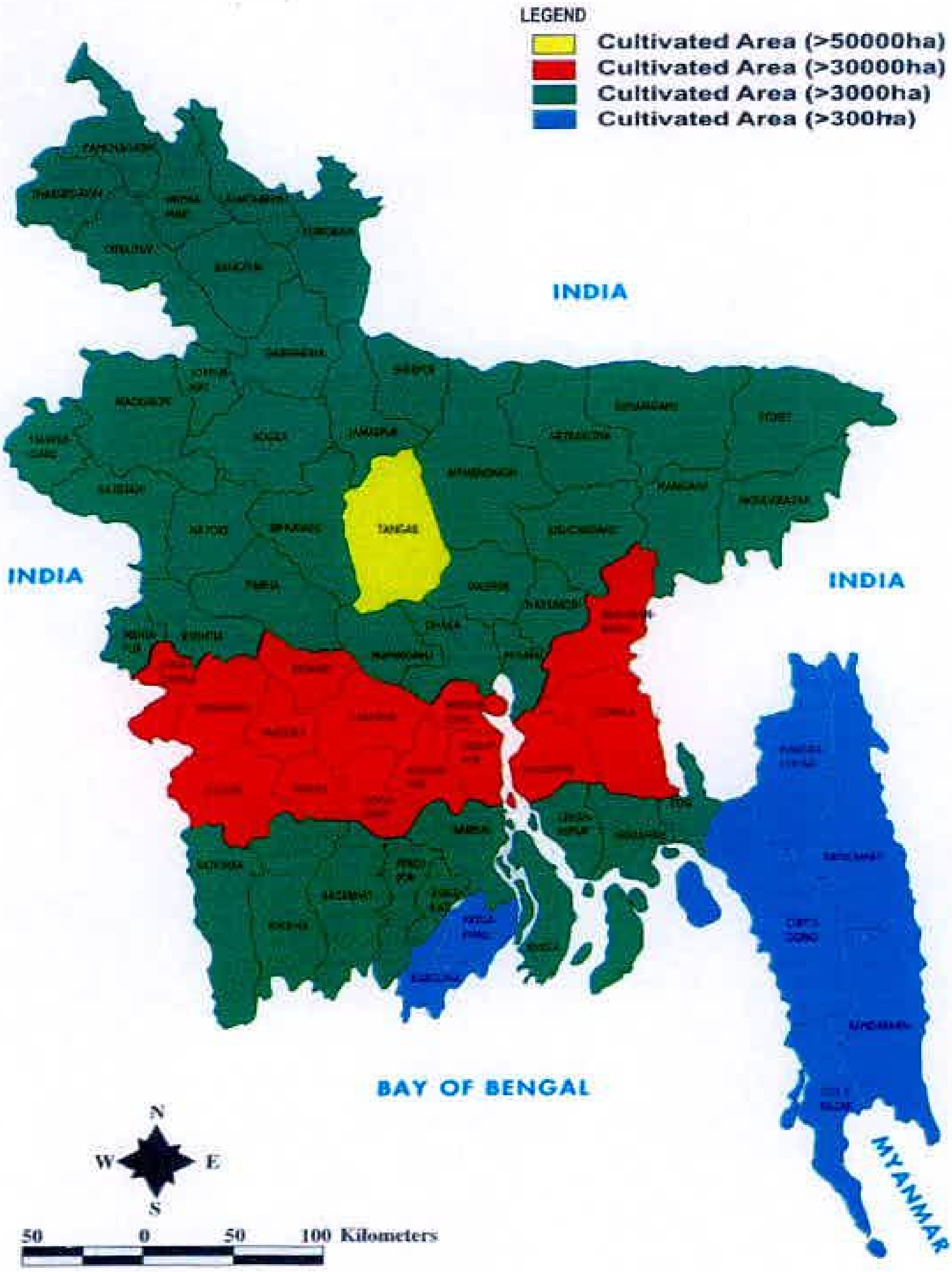
Yaniv, Z., Schafferman, D. and Zur, M. (1994). The effect of temperature on oil quality and yield parameters of high and low-erucic acid Cruciferae seeds (rape and mustard). Industrial Crops Products. **3**(4):247-251.

Yarnell, S. H. (1954). Cytogenetics of the vegetable crops. II Crucifers. Botanical Review, **22**:81-166.

Appendices

APPENDICES

Appendix I. Major rapeseed and mustard growing area (ha) in Bangladesh (1992-1997)



Source: BARI (2002)

Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Locality	: East corner of the field of ARS, Burirhat, Rangpur
Soil type	: Tista Meander Floodplain
Drainage	: Free
Vegetation	: Cropped with rice, wheat pulses and oilseeds

Physical composition:

Particle size constitution	%
Sand	49
Silt	38
Clay	18

Texture : Sandy loam

Chemical composition:

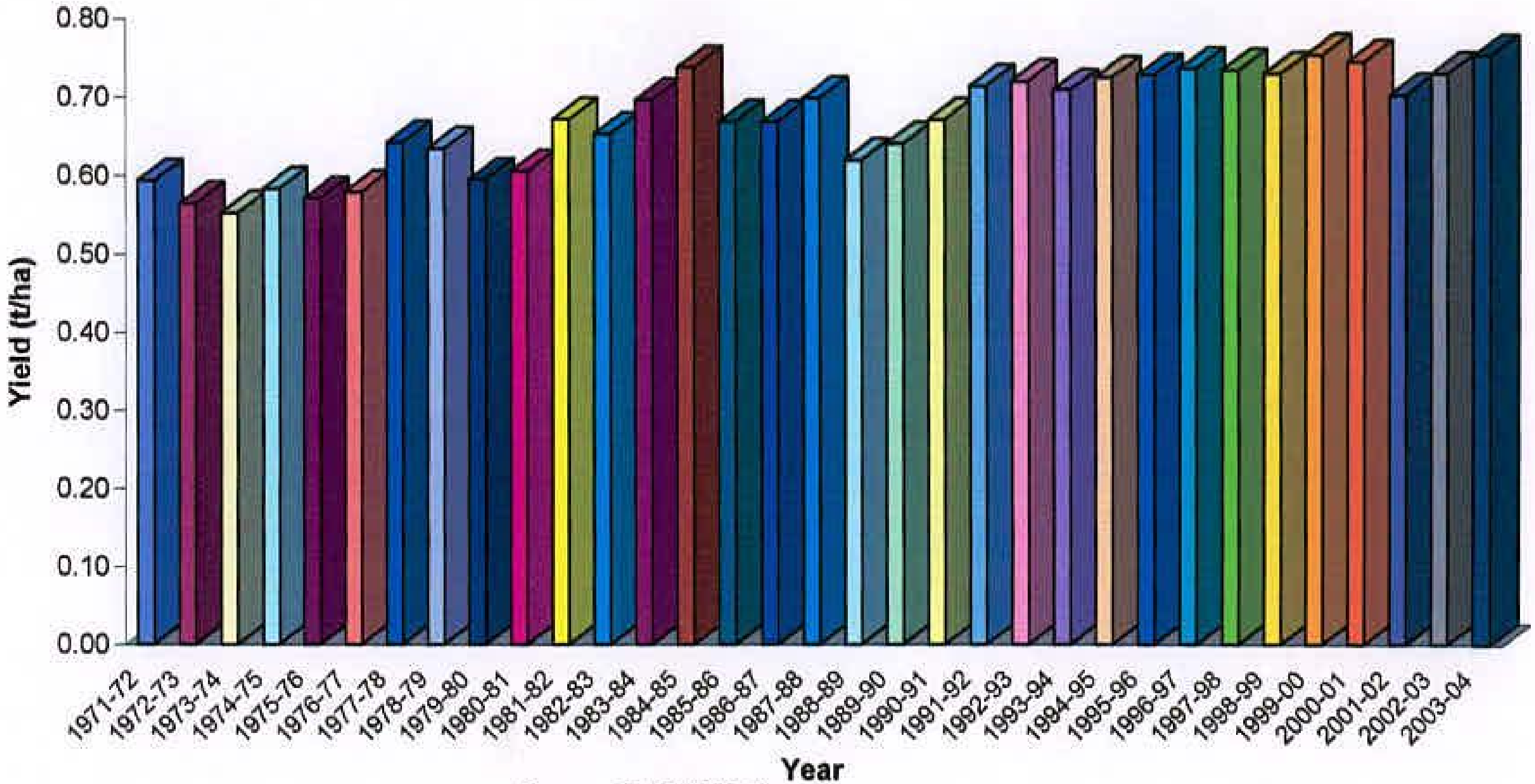
Constituents	**0 -15 cm depth**
pH	4.5-5.5
Total N (%)	0.06
Organic matter (%)	1.20
Available P (meq/g)	12.50
Exchangeable K (meq/100 g)	0.1
Ca (meq/100 g)	1.4
Mg (meq/100 g)	0.6
Available S (meq/g)	8.0
Available Zn (meq/g)	1.2
Available B (meq/g)	0.2

The soil sample was analyzed in the laboratory of Soil Science Division of Bangladesh agricultural Research Institute.

Appendix III **Analysis of variance for yield and other yield attributes**

Source of variation	df	Mean square								
		Days to maturity	Plant height (cm)	Primary branches $plant^{-1}$	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Seeds $plant^{-1}$ (no.)	1000-seed wt.	Seed yield ($t\ ha^{-1}$)	Dry wt./ plant
Replication	3	0.031	7.884	0.381	23.467	1.33	0.085	0.021	0.009	0.805
Sowing time (D)	4	78.40	152.672	0.389	223.875	15.300	0.105	0.263	0.092	2.288
Error	12	0.556	8.416	0.158	74.842	2.633	0.049	0.052	0.008	0.813

Appendix IV Yield of rapeseed and mustard in Bangladesh (1971-2004)



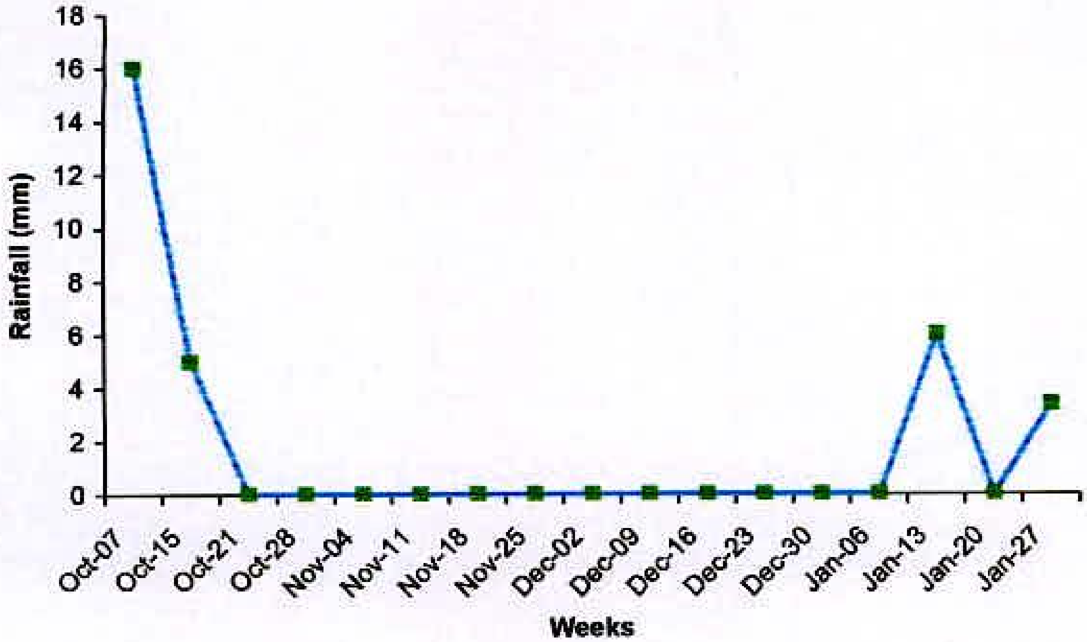
Source: FAO (2004)

Appendix V. Chemical composition of some *Brassica* oilseeds

Species	Seed (%)				Free fatty acid (%)	Cake (%)				
	Moisture	Oil	% Protein	Ash		N	P	K	Ca	Mg
Brassica campestris	6.0	46.38	17.34	3.74	0.28	5.18	0.71	1.45	0.35	0.27
Brassica napus	7.3	39.37	22.99	5.31	1.18	6.07	0.59	1.77	0.40	0.27
Brassica juncea	6.0	44.30	23.60	3.84	4.45	6.78	0.65	1.13	0.48	0.31
Brassica carinata	6.4	39.89	21.67	4.65	0.56	5.76	0.49	0.93	0.82	0.25
Brassica nigra	6.7	28.96	28.77	3.76	0.71	6.48	0.79	1.29	0.60	0.22

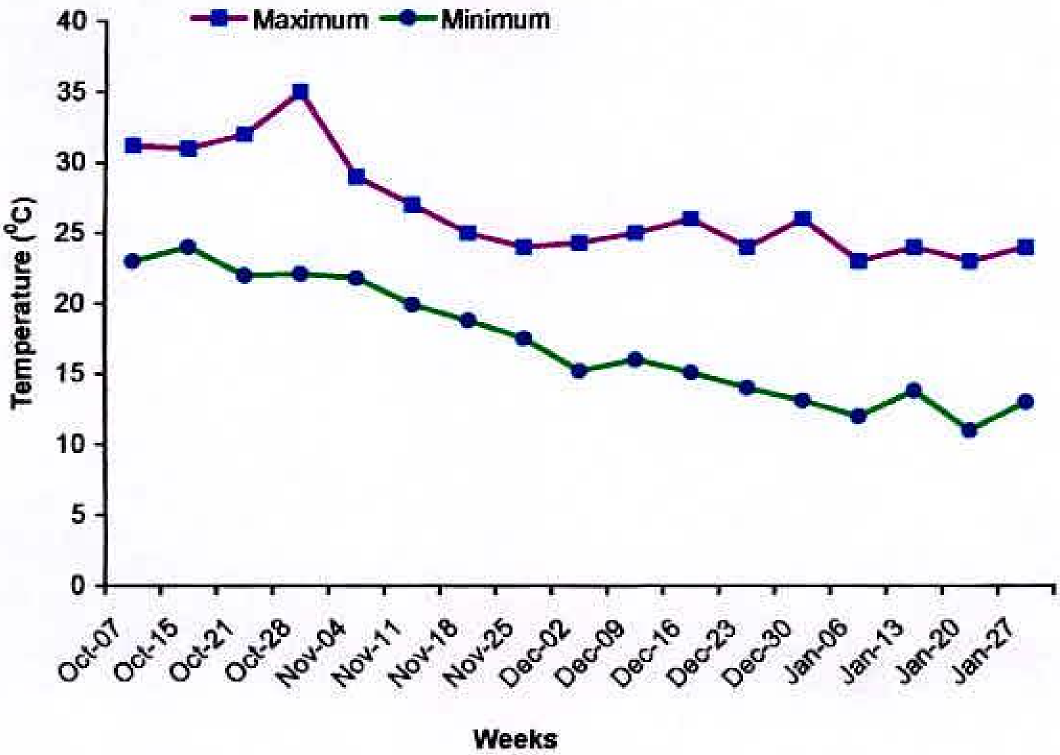
Source: Pathak *et al.* (1973)

Appendix VI. Weekly average total rainfall during the study period (October, 2004 to January, 2005)



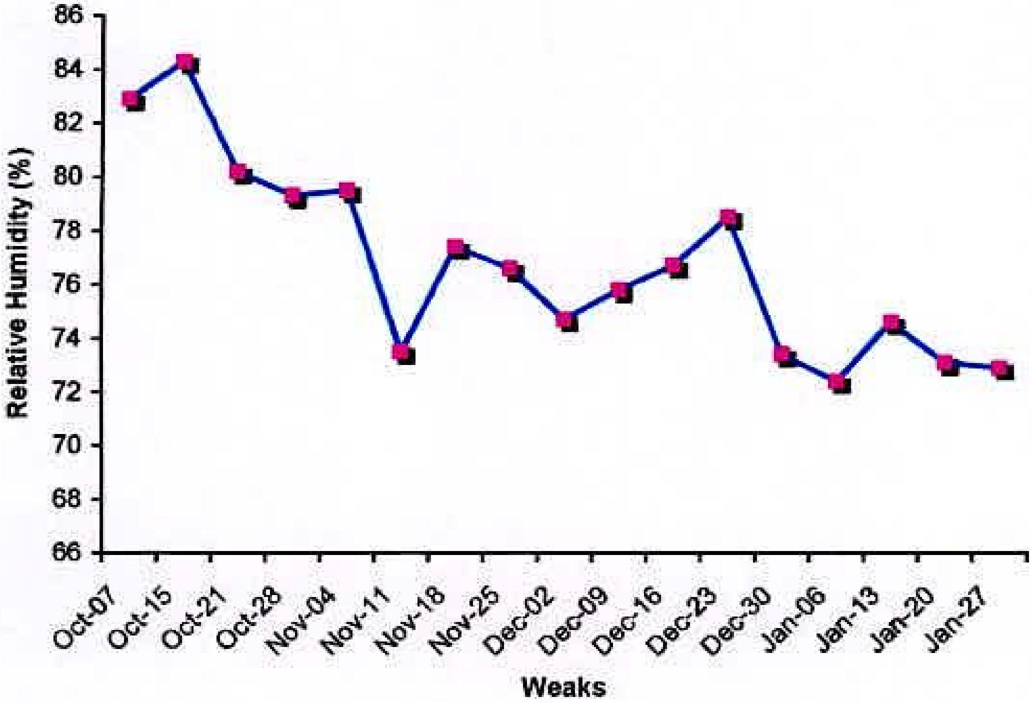
Appendix VII. Weekly average air temperature during the study period

(October, 2004 to January, 2005)



Appendix VIII. Weekly average relative humidity during the study period

(October, 2004 to January, 2005)



Appendix IX. Correlation matrix of different yield contributing characters of rapeseed

	Factor of correlation	Correlation coefficient r value
1.	Total number of siliqua plant^{-1} and seed yield (t ha^{-1}) at different sowing time	0.744^{NS}
2.	Total number of seeds siliqua^{-1} and seed yield (t ha^{-1}) at different sowing time	0.796^{NS}
3.	1000 seed weight (g) and seed yield (t ha^{-1}) at different sowing time	0.770^{NS}