PERFORMANCE OF RAPESEED (*Brassica campestris*) LINE SAU-C-F_7 TO DIFFERENT ROW SPACING AND IRRIGATION LEVEL

BY

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This is to certify that the thesis entitled ***"Performance of rapeseed (Brassica campestris) line SAU-C-F_7 to different row spacing and irrigation level"*** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, 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 Mirza Hasanuzzaman, Roll No. 00127, Registration No. 23849/00127 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.

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DEDICATED

TO

MY BELOVED PARENTS

DECLARATION

I do hereby declare that this thesis entitled "***Performance of rapeseed (Brassica campestris) line SAU-C-F$_7$ to different row spacing and irrigation level***" has been written and composed by myself with my own investigated research data.

I further declare that this thesis has not been submitted anywhere in any form for any academic degree.

December 2005 **(Mirza Hasanuzzaman)**

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ABBREVIATIONS AND UNITS

Abbreviation

AEZ	Agro Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
C.V.	Coefficient of Variation
CPE	Cumulative Pan Evaporation
cv.	Cultivar
DAE	Days after emergence
DAS	Days after sowing
DM	Dry matter
E	East
et al.	*et alibi* (and others)
etc.	*et cetra* (and so on)
FAO	Food and Agricultural Organization
Fig.	Figure
HI	Harvest index
HYV	High yielding variety
i.e.	id est (that is)
IW	Irrigation water
LSD	Least significant difference
MJ	Mega Joule
N	North
NNC	National Nutritional Council
NSB	National Seed Board
PAR	Photosynthetically active radiation
PD	Population density
SAU	Sher-e-Bangla Agricultural University
TDM	Total dry matter
viz.	Videlicet (namely)
WAS	Weeks after sowing

Unit

%	Percentage
^0C	Degree Celsius
cm	Centimeter
g	Gram
ha	Hectare
kcal	Kilocalorie
kg	Kilogram
m	Meter
q	Quintal
t	Ton

ABSTRACT

An experiment was conducted at the Agronomic field of Sher-e-Bangla Agricultural University, Dhaka-1207 on silty clay loam soil during the period from October, 2004 to January, 2005 to find out the optimum row spacing and irrigation level for the rapeseed line SAU-C-F_7. The experiment was carried out with three row spacings (20 cm, 30 cm and 40 cm) and 3 levels of irrigation (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS). The experiment was laid out in split-plot design with four replications.

Row spacing and irrigation level significantly influenced the growth, development and yield of the rapeseed line.

Among the row spacings, the widest spacing (40 cm) influenced plant to have maximum above ground fresh weight, dry matter and its partition, number of siliquae, number of seeds siliqua^{-1}, number of seeds, number of branches, 1000-seed weight, seed yield and also seed yield ha^{-1}. But, the maximum plant height and number of plant m^{-2} was found with closer row spacing (20 cm). Maximum seed yield plant^{-1} at 40 cm row spacing was 29.34% and 1.3% higher than 20 cm row spacing (S_1) and 30 cm row spacing (S_2), respectively.

Two irrigation – one at 30 DAS (pre-flowering stage) and another at 60 DAS (siliquae developmental stage) increased economic yield with higher values of harvest index as the yield attributes like branches plant^{-1}, siliquae plant^{-1}, seeds siliqua^{-1}, seeds plant^{-1}, 1000-seed weight. The number of plants m^{-2} was found similar under different irrigation level. The increased seed yield plant^{-1} with two irrigations was 364.6 % and 84.2% higher than no irrigation and one irrigation, respectively.

In most of the cases the wider row spacing coupled with two irrigations were found to be influenced for better growth and yield of plant. The highest seed yield per plant was found with the interaction of two irrigations and 40 cm row spacing. This was achieved due to maximum number of branches plant^{-1}, number of siliquae plant^{-1} and 1000-seed weight. The yield attributes were supported with appreciable production of dry matter and its partition towards different parts.

Number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight had a significant correlation with seed yield plant^{-1} with the r values of 0.95**, 0.97**, 0.67*, 0.96** and 0.94**. They were also positively correlated with each other.

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Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Rapeseed and mustard belong to the family Cruciferae are important oil crops and currently ranked as the world's third important oil crop in terms of production and area. Among the species, *Brassica napus* and *Brassica campestris* are regarded as 'rapeseed' while *Brassica juncea* is regarded as 'mustard'. Worldwide the total annual production of *Brassica* is 44.41 million tons of seed from an area of 27.24 million hectares (FAO, 2004). The rapeseed and mustard growing areas in Bangladesh with production and yield are shown in Appendices I, II, III and IV. Rapeseed and mustard contain 40 - 45% oil and 20 - 25% protein in seed.

Edible oil is a high-energy component of food and meeting the calorie requirements of human nutrition. Each gram of oil supplies 9 kcal energy, whereas 4 kcal energy comes from one gram carbohydrate or protein (Stryer, 1980). The chemical composition of seeds and oilcake of *Brassica* is given in Appendix V. Bangladesh has been facing acute shortage of edible oil for the last several decades (BBS, 2004). According to the National Nutrition Council (NNC) of Bangladesh, the recommended dietary allowance (RDA) is estimated to be 11 g oil capita^{-1} day^{-1} for a diet with 2700 kcal (NNC, 1984). On the basis of RDA, Bangladesh requires 0.29 million tons of oil to meet the demand of her people (FAO, 1998). One-third of the total requirement of oil is meeting by local production of rapeseed and mustard (BBS, 2004).

At present about 0.297 million hectares of land is under rapeseed and mustard cultivation in Bangladesh with a production of 0.211 million tons (BCA, 2004). The average seed yield of rapeseed and mustard is 0.71 t ha^{-1} in this country (BBS, 2004), which is far below the level as compared to that of the advanced countries like Belgium (4.7 t ha^{-1}), Denmark (3.6 t ha^{-1}), France (3.54 t ha^{-1}), Netherlands (3.47 t ha^{-1}), U. K. (2.89 t ha^{-1}), Germany (2.80 t ha^{-1}), Japan (2.16 t ha^{-1}) and Poland (1.86 t ha^{-1}) according to the statistics of FAO (2001). The major reasons for such poor yield of rapeseed and mustard in Bangladesh may be attributed to lack of improved varieties and poor management practices in the framers' field.

Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have released a number of new high yielding varieties (HYV) of these crops for farmer's cultivation. The yield of HYV cultivars ranges from 1.4 to 2.1 t ha^{-1} (BARI, 2002a). However, the yields in farmer's fields are still low compared to their potentialities due to lack of proper management practices. Therefore, there is a scope to increase the yield level of HYVs with proper management practices like spacing, irrigation, seed rate, fertilizer application etc.

Establishment of optimum plant population by maintaining proper row spacing is one of the important factors to secure a good yield in any crop. Population density can be adjusted by maintaining row spacing and distance from plant to plant. Optimum spacing ensures proper growth, development and yield of the plant through efficient utilization of solar energy, nutrients and water. Moreover, determination of optimum spacing for different mustard varieties can help the engineers to make a design for the seed drill to facilitate mechanical cultivation of the crop. Singh and Kumar (1990) found maximum seed yield at 30 cm × 15 cm spacing (22.22 plants m^{-2}) in *Brassica campestris*. Bhan *et al.* (1995) recorded higher seed yield of two varieties of both *Brassica juncea* and *Brassica campestris* with 44 plants m^{-2}.

Plant architecture is one of the phenological attributes of a crop that influences light interception through the crop canopy (Squire, 1990). Row spacing indirectly may also influence plant architecture. Plant architecture and row spacing combinedly affect light interception and its conversion efficiency (g MJ^{-1}). Moreover, row spacing may also need to be adjusted to facilitate mechanical weeding and other intercultural operations for better crop management and thus providing congenial production environment for better growth and higher yield of crop (Alam, 2004).

In Bangladesh both rapeseed and mustard are mostly grown on the residual soil moisture in rabi season (Kaul and Das, 1986). But irrigation is a vital factor for proper growth and development of these crops in dry season (Roy and Tripathi, 1985). The crop essentially requires water ranging from 60 to 169 mm throughout its life cycle (Rahman, 1989; Sarkar *et al.*, 1989). In fact, *Brassica* is an irrigated crop since its yield is greatly increased by the presence of adequate soil moisture at different growth stages (Andrews, 1972; Singh and Yusuf, 1979; Singh and

Srivastava, 1986; Prasad and Eshanullah, 1988). Irrigation has been found to increase 1000-seed weight, number of siliquae plant^{-1}, number of seeds plant^{-1} and seed yield, (Sharma and Kumar, 1989a) and harvest index (Shrivastava *et al.*, 1988) of this crop. Mondal *et al.* (1988) reported that one irrigation at flowering and another at siliquae development stages gave the highest yield (2.56 t ha^{-1}) Irrigation has also an effect in increasing the fertilizer uptake (Reddy and Sinha, 1987) thus increased biomass, which ultimately increases the yield. In recent years in Bangladesh some promising varieties have been released which are being grown as irrigated crops. The promising rapeseed line SAU-C-F_7 from Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh used in this experiment is under observations with agronomic managements like different spacing and irrigation level before being released by National Seed Board (NSB).

Taking the above mentioned points in view, the present study was undertaken with the following objectives:

a) to find out the suitable row spacing for the cultivation of the rapeseed line SAU-C-F_7.

b) to find out the optimum number of irrigation for getting higher yield of that line.

c) to study the combining effect of row spacing and irrigation level on the growth and yield of the line.

Chapter 2
Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

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

2.1 Effect of row spacing

Many authors demonstrated the yield response of rapeseed and mustard to different levels of plant densities which differ with genotypes and growing conditions.

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

The yield performance of rapeseed in tropical and temperate countries with the closer spacing (200 to 300 plants m^{-2}) was found to be higher in rapeseed (Kondra, 1975; Clark and Simpson, 1978).

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

2.1.1 Plant height

Scarisbrick *el al.* (1982) stated a negative relationship between plant heights with higher plant density. McGregor (1987) observed that when rapeseed was grown with 5 kg seed ha^{-1} or with wider row spacing, plant height increased. Wankhede *et al.* (1970) reported that different levels of population density (PD) did not have any effect on the height of individual plant.

Uddin *et al.* (1992) observed that seed rate did not have any significant effect on the yield parameters but plant height decreased as the seed rate was increased or spacing decreases.

Chauhan *et al.* (1993) reported no significant effect of row spacing on the plant height of toria. They evaluated three row spacings viz. 20, 30 and 40 cm. The maximum plant height was found at 20 cm row spacing which was similar to the plant height found at 30 cm row spacing and lowest at 40 cm row spacing. It showed that plant height decrease with the increase of row spacing.

Sharma and Thakur (1993) reported positive relationship between plant height and increasing row spacing of rapeseed. During 1988-1989 among three row spacings of 30, 37.5 and 45 cm for the sowing of rapeseed, they found the tallest plant with 45 cm row spacing which was higher than 37.5 cm and 30 cm row spacing. But the effect was not statistically influencing.

Oad *et al.* (2001) conducted a field experiment in Pakistan to determine the effect of row spacing on growth and yield of rapeseed (*B. napus*).The homogeneous seeds of rape cv. P-53 were sown at 3 row spacing (30, 45 and 60cm). They observed that plant height was affected significantly by row spacing and among them 60 cm row spacing produced the tallest plant.

Meitei *et al.* (2001) conducted a two year experiment to determine the effects of spacing (66.6 cm × 66.6 cm, 50 cm × 50 cm, 50 cm × 40 cm. 40 cm × 40 cm, 50 cm × 25 cm, 40 cm × 25 cm and 25 cm × 25 cm) on the yield and yield components of *Brassica juncea*. They observed 66.6 cm row spacing resulted with the tallest plants. But, Butter and Aulakh (1999) reported that row spacing had no significant effect on plant height.

Johnson and Hanson (2003) conducted a study to determine the interactions for commonly used spacing with canola (*Brassica napus*) performance using contemporary open-pollinated, hybrid and transgenic cultivars. They observed that row spacing and cultivar interaction were only significant for plant height. Shorter plants for the *Brassica rapa* cultivars was found when grown at the narrower row spacing, but *B. napus* cultivars had similar plant height at both row spacings and the hybrid *B. napus* cultivar yielded greater than the open-pollinated cultivars. Seed yield and oil content, the primary characters determining crop value, were not affected by row spacing.

The final plant height reflects the growth behavior of a crop. Besides genetic characteristics and environmental factors also play vital role in determining the height of the plants (Sana *et al.*, 2003).

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

2.1.2 Above ground dry weight of plants

In rapeseed and mustard more than 90% of the total dry matter (TDM) was accumulated during the reproductive period and one third of TDM was partitioned into seed yield (Chauhan and Bhargava, 1984). Scarisbrick *et al.* (1982) obtained a TDM yield of 1100 g m^{-2} or less at a population density of 160 plants per m^2.

Khader and Bhargava (1985) investigated the dry matter accumulation, yield and yield components of *Brassica juncea* and *Brassica campestris* in relation to population density (15, 22 and 44 plants m^{-2}) under irrigated and unirrigated conditions. In both the species they noticed that only 10-15% of the DM accumulated before flowering and 85-90% of the DM accumulated after flowering. At maturity it was noticed that stems and siliquae accumulated 43-51 and 48-57% of DM, respectively. They noticed that at preflowering stage 82-85% of the DM was in leaves and only 10-12% in stems. In post flowering stage 41-55% in stem, 32-43% in siliquae and only 7-8% in leaves. Dry matter of leaves, stems and siliquae increased significantly with increased population density (PD) and irrigation. They also concluded that total dry matter (TDM) can be increased by irrigation and increasing PD up to 44 plants m^{-2} to attain higher seed yield.

Chauhan *et al.* (1993) reported that total dry matter (TDM) of mustard differed significantly with row spacing where dry matter increased with the increase of row spacing. It might be due to more branching and siliquae in wider space. Maximum dry weight per plant was found from 40 cm row spacing while the lowest dry matter per plant was found with 20 cm row spacing. However, 30 cm row spacing gave moderate dry matter production.

2.1.3 Number of branches per plant

Number of branches per plant is the result of genetic make up of the crop and environmental conditions, which plays a remarkable role towards the final seed yield of the crop (Sana *et al.*, 2003).

Wankhede *et al.* (1970) investigated that different levels of population density (PD) did not have any significant effect on the number of branches plant^{-1}. Khader and Bhargava (1985) conducted an experiment with two varieties of *Brassica juncea* and *Brassica campestris* and found maximum number of branches plant^{-1} at the population density of 44 plants m^{-2}.

Kumar and Gangwar (1984) planted *B. campestris* var. Toria at 20, 30 and 40 cm apart rows and observed that number of primary and secondary branches plant^{-1} were increased at 40 cm which gave over all poor growth of the plant.

Gangwar and Kumar (1986) reported highest number of branches plant^{-1} at 6.6 plants m^{-2} in *Brassica campestris* var. Toria.

Gupta (1988) conducted a field experiment to determine the effects of spacing (60 cm × 5 cm, 50 cm × 5 cm, 50 cm × 10 cm, 40 cm × 10 cm, 40 cm × 15 cm and 25 cm × 15 cm) on rapeseed and he reported that wider spacing (40 cm) increased the number of branches plant^{-1}.

Tomar (1989) conducted a study on *B. campestris* var. Toria and found that when population density (PD) was maintained at 22.2 plants m^{-2} that increased the number of primary and secondary branches $plant^{-1}$. McGregor (1987) observed that the number of branches $plant^{-1}$ increased when seed rate of rapeseed was maintained 5 kg ha^{-1}.

Shrief *et al.* (1990) maintained population density of 30, 60 and 90 plants m^{-2} for raising rapeseed and found positive response towards yield improvement. They reported that branch per plant was significantly superior to the plant density of 30 plants m^{-2} compared to those at 60 and 90 plants m^{-2}.

Chauhan *et al.* (1993) found significant differences among the row spacing (20, 30 and 40 cm) in relation to production of branches per plant of rapeseed. Among three row spacings 40 cm row spacing gave highest number of branches per plant while 20 cm row spacing gave minimum number of branches.

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

Oad *et al.* (2001) observed in rapeseed cv. P-53 that branches per plant were affected significantly by row spacings and among them 60 cm row spacing proved to be the best. The rape seed cv. P-53 was sown at 3 row spacing (30, 45 and 60 cm).

2.1.4 Number of siliquae per plant

Wankhede *et al.* (1970) investigated that different levels of population density did not have any significant effect on the siliquae $plant^{-1}$ while a little bit increase was noted with lower population. Mudolkar and Ahlawat (1981) reported that a density level with broadcasting was superior to seed drilling with 2 kg ha^{-1} in 30 cm apart in row in terms of number of siliquae $plant^{-1}$.

Allen and Morgan (1972) found that the seed yield of *Brassica* species were dependent upon siliquae m^{-2}. They also concluded that siliquae m^{-2} or siliquae $plant^{-1}$ at the same population density (PD) seemed to be the determinant factor of seed yield. Yadav *et al.* (1978) suggested that for ensuring high yield in *B. juncea,* the plant type should have more number of siliquae $plant^{-1}$. Tayo and Morgan (1979) also found the positive relations of row spacing with the number of siliquae in rapeseed.

Singh and Singh (1984a) reported that lower density recorded higher number of siliquae $plant^{-1}$ in rapeseed.

Gangwar and Kumar (1986) reported that lower population density (PD) in *B. campestris* var.Toria increased the number of siliquae $plant^{-1}$ but it did not differ significantly at different density levels.

Singh and Singh (1987) observed that higher seed yield was positively correlated with siliquae $plant^{-1}$. Ghosh and Chatterjee (1988) noticed that the higher seed yield of Indian mustard *(Brassica juncea)* was closely related with the number of siliquae m^{-2}. McGregor (1987) observed with rapeseed that the wider spacing increased the number of siliquae $plant^{-1}$.

Shrief *et al.* (1990) showed that number of siliquae in the main raceme was significantly superior in the plant density of 30 plants m^{-2} over 60 and 90 plants m^{-2}.

Chauhan *et al.* (1993) reported that the number of siliquae per plant was significantly affected by row spacing. They found that number of siliquae increased with the increase of row spacing. The maximum number of siliquae per plant was found from 40 cm row spacing and 20 cm row spacing gave lowest number of siliquae. Number of siliquae were found 24% more in 40 cm row spacing than those of 20 cm.

Thakuria and Gogoi (1996) conducted a field experiment to evaluate *Brassica juncea* cv. TM 2, TM 4 and Varuna at 2 row spacings (30 and 45 cm). The effects of cultivars and row spacing on seed yield and yield attributes was insignificant, except siliquae plant^{-1} which increased under 45 cm row spacing.

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

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

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

2.1.5 Number of seeds per siliqua

The number of seeds per siliqua contributes materially towards the final seed yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield attributes of rapeseed and mustard and row spacing is a vital factor in producing optimum number of seeds siliqua^{-1}.

Singh and Singh (1984a) reported that lower density recorded higher seeds siliqua^{-1} than higher population density (PD) level.

Tomar and Namedo (1989) concluded from a study on *Brassica campestris* var. Toria that when population density (PD) was maintained at 22.2 plants m^{-2} increased the number of seeds siliqua^{-1}.

An increasing trend of seeds per siliqua was found from wider row spacing (Singh and Dhillon, 1991). They found maximum number seeds of Toria per siliqua when row spacing was 45 cm than those of 37.5 cm and 30 cm row spacing.

Sharma and Thakur (1993) found no significant effect of row spacing on seeds siliqua^{-1} of rapeseed. But they found higher number of seeds per siliqua with closer row spacing (30 cm). In another experiment 30 cm row spacing gave maximum seeds siliqua^{-1} while 37.5 cm and 45 cm row spacings gave lower number of seeds siliqua^{-1}.

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

Gurjar and Chauhan (1997) found maximum numbers of seed $siliqua^{-1}$ (11.89) in Indian mustard with 30 cm row spacing. But it was less than the number of seed $siliqua^{-1}$ (11.74) produced at 45 cm row spacing.

2.1.6 1000-seed weight

The weight of 1000-seed expressed the magnitude of seed development that is an important yield determinant and plays a decisive role in showing the yield potential of a variety.

Patel *et al.* (1980) conducted an experiment during 1977-1978 with rapeseed and reported about the positive relation between row spacing and 1000-seed weight. They stated that among 30, 45 and 60 cm row spacings 60 cm row spacing gave highest 1000-seed weight than other row spacings, which indicated the lower 1000-seed weight with closer spacing.

Singh and Singh (1987) found no significant effect of row spacing on 1000-seed weight of mustard. But the weight increased with the increase of row spacing and the highest seed weight was found from 60 cm row spacing and 30 cm row spacing gave the lowest weight of 1000-seed.

Singh and Dhillon (1991) also found an increase of 1000-seed weight with the increase of row spacing in lentil. They found maximum weight of 1000-seed with 45 cm row spacing while 37.5 cm and 30 cm row spacings produced lighter seeds.

Sharma (1992) found a significant increasing rate of 1000-seed weight with the increase of row spacing in different mustard varieties. He conducted an experiment with four row spacing viz. 30.0, 33.5, 37.5 and 45.0 cm. Among all row spacings maximum seed weight was found from 45 cm row spacing which was significantly higher from others. Lowest seed weight was found from 33.5 cm row spacing. But, Watt and Singh (1992) reported that seed weight decreases with increasing row spacing from 20 to 30 cm.

Chauhan *et al.* (1993) reported a positive relation between row spacing and 1000-seed weight. They found a significant effect of row spacing (20, 30 and 40 cm) on 1000-seed weight of Toria. Among the row spacings 40 cm row spacing gave highest weight of 1000-seed while 20 cm row spacing gave lowest weight.

Singh and Verma (1993) reported significant difference of 1000-seed weight with different row spacing (40, 50 and 60 cm). They reported that 1000-seed weight increased during 1988-1989 and 1989-1990 with 60 cm row spacing. Lowest test weight was found with 30 cm row spacing. Sharma and Thakur (1993) reported the similar result.

Singh *et al.* (1994) observed heavier seeds of mustard with 30 cm row spacing and smaller from 20 cm row spacing.

2.1.7 Seed Yield

Final seed yield per unit area of rapeseed is the cumulative effect of various yield components like number of siliquae per plant, number of seeds per siliqua, 1000-seed weight etc.

Seed yield increased with increased plant population but this relationship was found parabolic (Downey, 1971). Donald (1963) and Stern (1965) found that at high plant density, growth was greatly reduced as inter plant competition developed earlier and became progressively more severe thus some plants would die. As density increased beyond this point, DM production remained constant and the grain yield gradually declined (Donald and Hamblin, 1976).

Kondra (1975) showed that narrower row spacing (15 cm apart in row) at 3 kg ha^{-1}, recorded the highest seed yield. From other experiments, they concluded that a rate of 6 kg seed ha^{-1} was optimum for maximum seed yield of *Brassica campestris*.

Shastry and Kumar (1981) obtained maximum seed yield of mustard when population was maintained as 14.8 plants m^{-2}. They also noticed that higher population density (PD) enhanced maturity that is on an average, crop took 5 to 10 days less time to reach 50 percent flowering, siliquae formation and completion of siliquae setting and 80 percent maturity.

Mudholkar and Ahlawat (1981) reported that 16.6 plants m^{-2} was superior to drilling with 2 kg ha^{-1} in 30 cm apart in row in terms of dry matter production and number of siliquae per plant but seed yield remained unaffected. On the other hand, maximum seed yield was recorded from 22.2 plants ha^{-1} (Shinde and Borulakar, 1981).

Scarisbrick *et al.* (1982) observed negative relationship among stand establishment, plant height, plant weight and total dry matter (TDM) production with higher plant density levels. Seed yield did not increase when the crop was raised with 4.5 to 18.0 kg seed ha^{-1}. Plant density at 54 plants m^{-2} showed maximum seed yield per unit area in *Brassica napus*. Giri and Gangasaran (1985) recorded significantly higher seed yield in Indian rape with the planting geometry of 30 cm × 15 cm.

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

Gangwar and Kumar (1986) reported that PD at 16.6 plants m^{-2} in *Brassica campestris* var. Toria increased the number of branches plant^{-1}, number of siliquae plant^{-1} and 1000-seed weight which resulted in higher seed yield ha^{-1}, but it did not differ significantly from the yield obtained at the density level of 22.2 plants m^{-2}.

Bhati *et al.* (1987) conducted a study on Indian mustard *(Brassica juncea)* and grown at a plant spacing of 10, 15, 20 and 25 cm with 30 and 45 cm apart row. They found that among the spacing combination 30 cm × 15 cm gave the highest seed yield.

Gupta (1988) recorded maximum seed yield of mustard when population size was maintained at 44.4 plants m^{-2}. On the other hand, he found that wider spacing increased the number of branches and siliquae plant^{-1} and 1000-seed weight but ultimately these could not improve the seed yield per unit area.

Chavan *et al.* (1989) investigated that when mustard was planted maintaining a spacing of 45 cm × 15 cm i.e. 15 plants m^{-2} significantly increased seed yield over the population density (PD) of 30 cm × 15 cm and 22.5 cm × 15 cm i.e. 22 and 30 plants m^{-2}, respectively.

Tomar and Namedo (1989) concluded from a study on *Brassica campestris* var. Toria that when population density (PD) was maintained at 22.2 plants m^{-2}, which increased the number of primary and secondary branches and siliquae plant^{-1}, number of seeds siliqua^{-1} and 1000-seed weight. These significantly increased the seed yield and higher oil content of Toria.

El-Nakhlawy and El-Fawal (1991) found the effect of spacing on the yield of rape. In another experiment rape was grown on sandy soil in rows 20, 30 or 40 cm apart in two subsequent years in 1984-1985 and 1985-1986. They found that, in 1985, highest average seed yield at 40 cm spacing and in 1986 the highest yield at 30 cm spacing indicating significant effect of row spacing.

Chauhan *et al.* (1993) reported that seed yield of mustard was greatly influenced by row spacing (20, 30 and 40 cm). It was found that seed yield of Toria was highest with 30 cm row spacings. It was statistically different with the seed yield found by other row spacing. The lowest seed yield was found from 20 cm row spacing which was identical with 40 cm row spacing.

Khandey *et al.* (1993) reported that densities of 44.4 plants m^{-2} produced maximum seed yield than 33.3 and 66.6 plants m^{-2}.

Sharma (1993) conduct a field experiment on sandy loam soil with four mustard *(B. juncea)* cultivars sown in rows 22.5, 30.0, 37.5 and 45.0 cm apart. Irrespective of cultivars, 37.5 cm row spacing gave the maximum seed yield.

Bhan *et al.* (1995) observed that when mustard was grown at variable population density (PD), the higher density (20 cm × 10 cm) i.e. 50 plants m^{-2} produced higher seed yield ha^{-1} than others.

Kalaria *et al.* (1997) conducted an experiment with mustard (*Brassica juncea*) for comparing 2 row spacings (30 or 45 cm), 3 sowing patterns (uniform sowing, 3 rows followed by 1 missed row and 2 rows followed by 1 missed row). They observed that seed yield was higher for the narrow spacing along with uniform sowing.

Shahidulla *et al.* (1997) conducted a field experiment during 1994-1995 to observe the effect of row spacing and plant spacing on mustard (*Brassica campestris*). The treatments were with three row spacing (20, 30 and 40 cm) and four plant spacings (10, 15, 20 and 30 cm). They reported that 30 cm row spacing gave the highest seed yield with 15 cm plant spacing. Surya *et al.* (1998) reported similar result in rapeseed.

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

Sahoo *et al.* (2000) conducted a field experiment on Indian mustard cv. Chikaballpur local in kharif season and found greater seed yield at closer spacing (30cm × 15cm). Chowdhury *et al.* (1999) reported similar result in mustard.

Walkowski (2001) conducted an experiment of rapeseed with different seed rates (80, 120, 160 and 200 seeds m^{-2}) and sowing dates (early sowing and two weeks delayed). He reported highest yield with early sowing along with a variation of seed rate i.e. 120-160 seeds m^{-2}.

Oad *et al.* (2001) conducted a field experiment in Pakistan to determine the effect of row spacing on growth, yield and oil content of rape *(Brassica napus)*.

The homogeneous seeds of rape cv. P-53 were sown with 3 row spacings (30, 45 and 60 cm). They observed that days to maturity, plant height and branches, siliquae and seed weight per plant, seed index, seed yield and oil contents were affected significantly by row spacing and among all 60 cm row spacing proved to be the best.

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

Behera *et al.* (2002) conducted a field experiment to study the effect of plant population on the yield of mustard *(Brassica juncea)* and found the maximum seed yield at the intermediate population level of 14.8 plants m^{-2}.

Bilgili *et al.* (2003) observed a significant response between all yield contributing characters and seed yield in *Brassica rapa* L. Seed yield was similar at all seeding rates. However, row spacing was associated with seed yield. The highest seed yield was obtained for the 35 cm row spacing.

2.1.8 Stover yield

Singh and Singh (1984a) observed the highest harvest index and stover yield with population density (PD) of 33.3 plants m^{-2}. Chauhan *et al.* (1985) found a positive correlation between HI and seed yield of Toria.

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

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

2.1.9 Biological yield

Singh *et al.* (2003) reported that Indian mustard gave the highest total biomass production at 45 cm row spacing over 30 and 60 cm row spacings. However, there was a scarcity of information regarding the biological yield due to spacing variation in rapeseed or mustard cultivation.

2.1.10 Harvest index

The physiological efficiency and yielding ability of a crop plant are reflected with its harvest index value. The higher the value more will be the seed yield per unit of dry matter.

Scarisbrick *et al.* (1982) used variable seed rate for raising rapeseed and noticed that seed yield did not increase when the seed rate was raised from 4.5 to 18.0 kg ha^{-1} whereas 54 plants m^{-2} gave higher HI value.

Shrief *et al.* (1990) reported higher seed yield of rapeseed along with higher harvest index where density was maintained as 30 plants m^{-2}.

Singh and Verma (1993) reported that harvest index was not significantly influenced by row spacing difference. They found more harvest index of mustard from 20 cm row spacing than that of 30 cm row spacing.

Plant density at different levels increased the harvest index of rapeseed (Ali *et al.*, 1996). Populations of 70 and 100 plants m^{-2} did not show significant difference in harvest index but 40 plants m^{-2} gave higher harvest index and higher seed yield.

The above findings revealed that the yield of different rapeseed and mustard varieties differed among themselves due to their genetic makeup as expressed by the difference in their plant height, number of branches per plant, siliquae per plant, siliquae length, number of seed per plant and 1000-seed weight which were being optimized with proper row spacing maintenance.

2.2 Effect of irrigation level

In strict sense *Brassica* is an irrigated crop (Andrews, 1972). Performance of *Brassica* is greatly affected by irrigation. Seed yield of *Brassica* are greatly affected by water stress during flower initiation and siliquae filling stage (Richard and Thurling, 1978).

Singh *et al.* (2002) tested four *Brassica spp.* (*Brassica carinata, Brassica napus, Brassica juncea and Brassica campestris*) under 2 moisture regimes, i.e. normal irrigation (3 irrigations at branching, bolting and siliquae filling stages) and limited irrigation (one irrigation at branching stage). Results revealed that growth, development and yield of all *Brassica spp.* were adversely affected under limited water conditions. This clearly indicates that yield expression of *Brassica spp.* differs under varying soil water regimes.

2.2.1 Plant height

Saran and Giri (1988) reported that plant height of rapeseed was found to be highest when one irrigation at 30 DAS was applied. But two irrigations applied at 30 and 60 DAS produced more plant height than under rainfed condition. There was a significant relationship between irrigation levels and plant height.

Siag *et al.* (1993) found a relationship between irrigation levels and plant height of Toria. In an experiment plant height was increased with the increasing levels of irrigation. Plant height was greater with 2 irrigations at branching and siliquae development stage and it was the highest compared to one irrigation at branching stage and without irrigation.

2.2.2 Above ground dry weight of plants

One irrigation at flowering stage was enough to increase the yield of dry matter in *Brassica campestris* (Maini *et al.*, 1965). Singh *et al.* (1972) noticed that one irrigation at flowering stage of rapeseed was better than two irrigations – one at flowering and one at fruiting stage. Dalal *et al.* (1963) suggested for one irrigation at the blooming stage in brown sarson (*Brassica campestris* var. Sarson).

Saran and Giri (1988) found that dry matter in plant of mustard was significantly increased with the increasing levels of irrigation. But the differences were not significant. Highest dry matter accumulation was found with two irrigations. In some of the cases, at the time of harvest dry matter was found to be the highest with one irrigation.

Patel *et al.* (1991) found a significant difference in case of dry matter accumulation in mustard with the application of irrigation. One irrigation produced more dry matter, which was significantly higher than that was produced without irrigation.

Tomer *et al.* (1992) found increasing dry matter production in mustard plant with increasing number of irrigation. They conducted an experiment with no irrigation, one irrigation at pre-flowering and two irrigation (one at pre-flowering and one at fruiting). Significant increase in dry matter was found with irrigation. The maximum dry mater production was found to be highest with two irrigations while one irrigation and control (no irrigation) produced lower dry matter per plant, respectively.

Gill and Narag (1993) observed distinct differences in dry matter production after 70 DAS in case of mustard, when differential irrigation schedules were maintained. Three irrigations (one at 28 DAS and 2 at 80 mm cumulative pan evaporation, CPE) produced maximum dry matter, being significantly more than that produced by one and two irrigations at all the growth stages.

Paul and Begum (1993) showed that total dry weight of different irrigation treatments at successive stage of growth of rapeseed was significant except the first harvest (38 DAS). The plant receiving continuous irrigation throughout the growing period had the highest dry weight while rainfed plant had the lowest total dry weight. Among the remaining treatments, irrigation at 50% flowering stage proved to be the most important single irrigation treatment. Two irrigations also increased dry matter production.

A field experiment was conducted by Mahal *et al.* (1995) during the Rabi seasons of 1987 and 1988 at Ludhiana, India. Toria was irrigated at 50, 60 or 70% depletion of available soil moisture. The dry matter of leaves, stems and siliquae of mustard increased with irrigation at lower depletion levels.

Raut *et al.* (1999) studied the effects of irrigation (at pre-flowering and siliqua-setting stages, preflowering + 50% flowering + siliqua setting stages, pre-flowering + 50% flowering + seed-filling stages, and pre-flowering +50% flowering + siliqua-setting + seed filling stages) on the dry matter production and yield of Indian mustard cv. Pusa Bold. Irrigation once at pre-flowering+50% flowering + siliqua-setting + seed-filling stages gave the highest dry matter production at 30 and 60 days after sowing (DAS). Irrigation at pre-flowering +50% flowering + seed-filling stages gave the highest dry matter production at 90 DAS and at harvest as well as the highest grain yield.

On the contrary, Giri (2001) reported that dry matter per plant of rapeseed was not significantly increased with irrigation treatments. He conducted two experiments to find out the effect of irrigation on growth and yield of mustard. In 1995-1996 total dry matter production was higher with two irrigations at flowering and siliquae development stage than the dry matter produced irrigation with one irrigation at flowering stage. But in 1996-1997, one irrigation produced higher dry matter production than two irrigation. Those dry matter productions were not significantly different.

2.2.3 Number of branches per plant

Clarke and Simpson (1978) observed in an analysis of yield components of rape under field conditions that irrigation scarcely affected the number of branches.

Joarder *et al.* (1979) working with mustard cv. Rai 7, Laha 101 and Rai 5 cultivated under irrigated or rainfed condition observed that irrigation increased the number of primary and secondary branches per plant.

Saran and Giri (1988) reported for the maximum numbers of branches per plant of mustard with one irrigation at 30 DAS than two irrigations at 30 and 90 DAS followed by no irrigation. Highest branches per plant were found with one irrigation whereas two irrigations and rainfed condition produced less number of branches per plant.

Prasad and Ehsanullah (1988) reported that number of primary branches of mustard were significantly increased with irrigation levels. They found maximum number of primary branches per plant with two irrigations at 30 and 60 DAS which was followed by one irrigation at 30 DAS and without irrigation, respectively.

Rathore and Patel (1989) found the number of branches plant^{-1} of mustard increased with increase in irrigation frequency.

Patel *et al.* (1991) found that irrigation produced higher number of branches of mustard plant than unirrigated condition. In another experiment one irrigation produced significantly higher number of branches per plant compared to unirrigated control.

Tomer *et al.* (1992) concluded that branches per plant of rapeseed were significantly increased with irrigation. Branches per plant were highest with two irrigation compared to one irrigation or without irrigation (control). They reported that branches per plant were highest when two irrigations were applied at pre-flowering and fruiting stage. When one irrigation was applied at preflowering stage it produced lower branches per plant. The least number of branches was produced at control treatment.

Singh *et al.* (1994) conducted a field trial with *Brassica juncea* irrigated at 50% flowering, at 50% flowering + 50% siliquae development, or given no post-sowing irrigations. They found the maximum branching with increased irrigation level.

Giri (2001) showed that branches per plant increased with the increasing irrigation levels in mustard plant. He observed that when one irrigation was applied it produced more branches per plant compared to that of two irrigations. The difference was not significant.

2.2.4 Number of siliquae per plant

Clarke and Simpson (1978) observed in an analysis of yield components of rape under field conditions for two years at Saskatoon, Canada that irrigation increased number of siliquae $plant^{-1}$.

Sharma and Kumar (1989b) found in another experiment with mustard that the number of siliquae $plant^{-1}$ increased with increasing irrigation frequency, while irrigation was applied with zero and one level at the rosette or at siliquae formation stage.

Giri (2001) found that in case of two irrigation 277 siliquae were found in mustard at flowering and siliquae formation stage followed by 324 siliquae per plant with one irrigation at flowering stage. But the difference was not significant.

2.2.5 Number of seeds per siliqua

Generally, seeds per siliqua increases with the application of irrigation in case of mustard. Clarke and Simpson (1978) also found the increasing number of seeds per siliqua with irrigation than rainfed condition.

Joarder *et al.* (1979) conducted an experiment with mustard cv. Rai 7, Laha 101 and Rai 5 cultivated under irrigated or rainfed condition observed that irrigation increased the number of seeds $siliqua^{-1}$, and therefore, increased yield $plant^{-1}$ and yield ha^{-1} by 65 and 59% compared to the rainfed treatments, respectively.

Prasad and Ehsanullah (1988) found an increasing trend of seeds $siliqua^{-1}$ in mustard with irrigation levels. The maximum numbers of seeds per siliqua were found when irrigation was applied at 30 and 60 DAS. It was followed by irrigation at 30 DAS and without irrigation which produced lower seeds siliqua^{-1} in 1984-85.

In an experiment in 1985-1986, Saran and Giri (1988) found that maximum siliquae per plant were produced with two irrigations at 30 DAS and 90 DAS which was identical with the number of siliquae produced without irrigation (control). One irrigation at 30 DAS produced lower numbers of siliquae than unirrigated control and two irrigations.

Sharma and Kumar (1989a) conducted an experiment on *Brassica juncea* cv. Krishna with two irrigation levels. They observed that number of seed siliqua^{-1} was higher, when irrigation was applied at irrigation depth and cumulative pan evaporation ratio of 0.6. Number of seed siliqua^{-1} was lower with irrigation to a ratio of 0.4 or without irrigation.

Tomer *et al.* (1992) conducted an experiment to observe the effect of irrigation on the growth and yield of mustard (*Brassica juncea*). They tested three irrigation treatments viz. no irrigation, one irrigation (at pre-flowering stage) and two irrigation (one at pre-flowering and one at fruiting stage). Maximum number of siliquae were found per plant when two irrigations were applied. One irrigation and without irrigation produced lower siliquae per plant.

Patel *et al.* (1991) reported that one irrigation produced higher siliquae per plant while minimum was produced per plant without irrigation.

Tomer *et al.* (1992) reported that seeds per siliquae were also significantly increased with irrigation. Maximum numbers of seeds per siliqua were found when two irrigations were applied (one at pre-flowering stage and one at fruiting stage). A siliqua produced 12.36 seeds on an average when two irrigations were applied while one irrigation and without irrigation produced 10.81 and 8.02 seeds siliqua^{-1}, respectively.

Siag *et al.* (1993) found that two irrigations given either at branching and siliquae development or at branching and flowering stages of rapeseed recorded a significant increase in siliquae plant^{-1}. The highest number of siliquae (261) was found with two irrigations at branching and siliquae development stages. These results are in agreement with those of Raja (1987).

2.2.6 1000-seed weight

Thousand seed weight was significantly increased by irrigation. Clarke and Simpson (1978) reported that under field conditions irrigation scarcely affected 1000-seed weight of mustard. The seed yield was positively correlated with 1000-seed weight.

On the contrary, thousand seed weight did not significantly differ with irrigation (Saran and Giri, 1988). One irrigation applied at 30 DAS on rapeseed produced similar 1000-seed weight that found from two irrigations at 30 DAS and 90 DAS. Lowest weight of 1000-seed was found without irrigation but the difference was not significant.

Prasad and Ehsanullah (1988) reported that irrigation significantly increased the 1000-seed weight of rapeseed. They found maximum weight of 1000-seed from the application of two irrigations at 30 and 60 DAS. The lowest weight of 1000-seed was found in rainfed condition (without irrigation) which was lower than the application of one irrigation at 30 DAS.

Sarker and Hassan (1988) also reported increased 1000-seed weight with increasing levels of irrigation applied on rapeseed. Sharma and Kumar (1989a) observed that 1000-seed weight was higher, when irrigation was applied at irrigation depth and cumulative pan evaporation ratio of 0.6. Thousand seed weight was lower with irrigation to a ratio of 0.4 or without irrigation.

Tomer *et al.* (1992) reported that maximum weight of 1000-seed was found when one irrigation was applied during pre-flowering stage and another one during fruiting stage of mustard. Least weight of 1000-seed was found without irrigation.

2.2.7 Seed yield

Different scientists observed that yield of rapeseed and mustard crop increased with iirrigation levels due to the improvement of yield components like number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1} and 1000-seed weight.

Singh and Yusuf (1979) reported that seed yield of brown sarson (*Brassica campestris* var. Dichotoma) was curvilinearly related to irrigation levels reaching a maximum yield, and yield response to nitrogen was greater with irrigation than without irrigation.

Singh (1983) found in an experiment with mustard (*Brassica Juncea*) grown with a pre-sowing irrigation in the Rajastan arid zone of India that irrigation at the pre-flowering stage increased the yield of mustard. But the irrigation given at siliquae formation stage did not further increase seed yield.

Roy and Tripathi (1985) recorded that the growth characters and yield of *Brassica juncea* were significantly increased with irrigation at IW:CPE (Irrigation water depth: cumulative pan evaporation ratio) of 0.6 compared to irrigation at IW:CPE ratio of 0.4. They found yield as positively associated with number of branches and siliquae plant^{-1}, number of seeds siliqua^{-1} and 1000-seed weight.

Singh and Srivastava (1986) observed a significant increase of seed yield of mustard (*Brassica juncea*) with irrigation. They found the seed yields of *Brassica juncea* with 1 irrigation at (a) the flower bud stage and 2 irrigations at (a) and the siliquae formation stage were 430 and 610 kg ha^{-1}, respectively, compared with 330 kg without irrigation. Yield was highest (960 kg) with 2 irrigations and 80 kg N.

Gangasaran and Giri (1986) reported that *Brassica juncea* seed yields and oil contents were increased by applying 1 irrigation and were similar at densities of 100 000 and 170 000 plants ha^{-1}.

Reddy and Sinha (1987) observed in an experiment with *Brassica juncea* in Rabi seasons of 1983-1985 that irrigation at IW andCPE ratio of 0.6 and 0.3 (three and one irrigation respectively) gave maximum seed yield compared to that of rainfed crops.

Hoque *et al.* (1987) observed that yield increase was highly significant for two irrigations applied on rapeseed, one at the early vegetative stage and the other at the initial siliquae formation stage.

Katole and Sharma (1988) conducted a field experiment on clay loam soils with rapeseed to study the effect of irrigation schedule and found that yield was highest with two irrigations one at branching and other at siliquae development stage.

Prasad and Eshanullah (1988) pointed out in an experiment in 1983-1985 with *Brassica juncea* that two irrigations with six cm irrigation at irrigation water depth and cumulative pan evaporation ratio of 0.8 or at 30 and 60 day after sowing gave maximum seed yield compared to one irrigation and without irrigation. Seed yield was minimum with no irrigation treatment.

Saran and Giri (1888) observed that *Brassica juncea* grown under rainfed conditions or with 1-2 irrigations gave similar seed yields of 0.8-1.5 t ha^{-1} in 1984-85 and 1.40-1.50 t in 1985-86. The yields were markedly higher with increasing irrigation levels.

Sarker and Hassan (1988) made an experiment with *Brassia juncea* at two locations in Bangladesh. They irrigated the crop at one to six levels commencing 20-25 day after sowing and obtained maximum seed yield at BINA farm with three levels of irrigation and that at RARS Ishurdi farm with five levels of irrigation.

Sharma and Giri (1988) reported that *Brassica juncea* grown with 0-80 kg N ha^{-1} under rainfed conditions or with one-two irrigations gave similar seed yield during two consecutive growing seasons.

Sharma and Kumar (1988) studied an irrigated mustard (*Brassica juncea*) with 60 cm irrigation at irrigation water depth and cumulative pan evaporation ratio of 0.4 or 0.6 (one and two irrigations respectively) and reported that seed yield were higher in 1984-1985 and 1985-1986 compared with respective yield under rainfed conditions.

Mondal *et al.* (1988) conducted a field trials in the Rabi (winter) seasons of 1980-1982, *Brassica juncea* cv. T-59 was sown in the 1st week of November and given 14 irrigation treatments (1-4 irrigations at preflowering, flowering, early siliqua or late siliqua developmental stages). The yield obtained is maximum with 1 irrigation at flowering, intermediate with 2 irrigations at flowering and late siliqua stages and minimum with 3 irrigations supplied at preflowering, early and late siliqua stages.

Hasan *et al.* (1988) conducted a field experiment in at 2 locations in Bangladesh, mustard (*Brassica juncea*) was given no irrigation, 1 irrigation at 25 days after sowing (I_1), or I_1 together with later irrigation when IW:CPE (irrigation water depth and cumulative potential evaporation ratio) reached at 0.2, 0.4, 0.6 or 1.0. Highest seed yield resulted from irrigation at I_1 and 2 irrigations when IW:CPE was 0.4 at 1 location, whereas at the other location the highest seed yield resulted from irrigation at I_1 and 4 irrigations when IW:CPE was 1.0.

Sharma and Kumar (1989b) observed *Brassica juncea* cv. Krishna was unirrigated or given 1 irrigation at the rosette stage with or without 1 irrigation at siliqua formation. Average seed yield was higher with irrigation and lower for unirrigated treatment.

Rathore and Patel (1989) reported that mustard (*Brassica juncea*) gave highest seed yield with 3 irrigations at branching, 50% flowering and seed filling, followed by 2 irrigations at branching and 50% flowering, and one irrigation at late branching.

Parihar and Tripathi (1989) gave irrigation to mustard (*Brassica juncea*) with six cm irrigation and found that average yield were varied for irrigation depth and cumulative pan evaporation ratios of 0.4, 0.6 and 0.8, respectively.

Lal *et al.* (1989) irrigated mustard cv. Varuna with one to three levels at different growth stages in one of their experiment. They found that application of one level of irrigation at flowering stage gave the highest seed yield. Addition of irrigation did not improve seed yield. Seed yield was lowest under rainfed condition.

Sarkar *et al.* (1989) reported that mustard irrigated at flowering stage produced the highest seed yield and this was followed by the plants irrigated at vegetative and siliqua filling stages.

Siag and Verma (1990) concluded that mustard (*Brassica juncea*) yield increased with irrigation frequencies at different growth stages.

Tomer and Singh (1990) studied the effects of 0, 1 or 2 irrigations on the yield of *Brassica juncea* cv. Varuna. They found that increasing irrigation levels increased seed and oil yield. In another experiment on mustard, Sharma and Kumar (1990) observed that one or two levels of irrigation produced the maximum seed yield in 1984-1985 and 1985-1986. Yields were obtained lower without irrigation in those years.

Rarihsr (1990) found in an experiment with mustard that the seed yield and yield components were greater while irrigation was applied at irrigation depth and cumulative pan evaporation ratio of 0.6.

Sharma (1991) conducted two experiments on mustard (*Brassica juncea*) cv. Varuna in the Rabi seasons of 1986-1987 on clay loam soil at Mandsaur, Madhya Pradesh of India and found that 1 irrigation at 15 or 30 days after sowing or 2 irrigations at 15 + 30 or 30 + 60 days after sowing, i.e. increasing irrigation frequency elevated seed yield over no irrigation.

Ghatak *et al.* (1992) reported that mustard is irrigated at flowering (Ifl), irrigated at branching (Ibr) + Ifl, or Ibr + Ifl + irrigation at seed development (Isd), i.e. with increased level of irrigation produced greater seed yield compared to the control (rainfed).

Tomer *et al.* (1992) conducted an experiment to find out the effect of irrigation levels on the growth and yield of mustard (*Brassica juncea*). They worked with three irrigation treatments viz. no irrigation, one irrigation (at pre-flowering stage) and two irrigation (one at pre-flowering and another at fruiting stage). They concluded both levels of irrigation significantly increased the seed yield over no irrigation. Application of 2 irrigations (at pre-flowering and fruiting stage) outyielded 1 irrigation (pre-flowering stage).

Tiwari and Chaplot (1993) conducted a field experiment on the effect of irrigation levels on mustard (*Brassica juncea* cv. Varuna) which was irrigated at vegetative, flowering, siliqua development or seed filling stage corresponding 3, 6, 9, or 12 weeks after sowing (WAS) or at various combinations of these dates. Seed yield increased with increase in irrigation frequency. The highest mean seed yield was obtained from irrigating the crop at 3, 6 and 9 WAS.

Sharma and Singh (1993) conducted an experiment with *Brassica juncea* cv. Pusa Bold which was not irrigated, irrigated at the rosette stage (28-30 days after sowing (DAS), siliqua formation stage (55 DAS) or rosette + siliqua formation stages. One irrigation at the rosette stage gave appreciable yield compared with one irrigation at siliqua formation stage and unirrigated treatments.

Gill and Narang (1993) observed in an experiment with Gobhi sarson that all growth parameters and seed yield significantly increased, while irrigation was applied at 20 days after sowing under cumulative pan evaporation of 80 mm.

Padman *et al.* (1994) in a field experiment during the winter seasons of 1987-1989 at Udaipur, Rajasthan, India observed that seed yield of *Brassica juncea* increased with increasing levels of irrigation.

Mahal *et al.* (1995) reported that maximum seed yield were recorded with 2 irrigations (at 3-4 weeks and at 9-10 weeks after sowing) in consecutive two years experimnnt.

Samadder *et al.* (1997) studied the *Brassica juncea* cv. Bhagirathi with non irrigated condition and irrigation at flowering or at flowering + seed formation stages and found that seed yield was highest with 2 irrigations.

Singh *et al.* (1997) reported that the stages most sensitive to water stress were the seedling stage followed by the flowering stage. Decrease in seed yield varied from 22.13 to 36.57% when irrigation was withheld at seedling and flowering stages, 17.98 to 32.43% when withheld at seedling and seed development stages, and 1.59 to 3.45% when withheld at the seed development stage compared with irrigation applied at all these stages. However, early water stress from flowering to seed development stages decreased the yield by 4.83 to 15.46% compared with irrigation at all 3 stages.

Raut *et al.* (1999) conducted a field experiment in Akola, Maharashtra, India, during the Rabi season of 1996-97 to study the effects of irrigation (at pre-flowering and siliqua-setting stages, pre-flowering+50% flowering+siliqua-setting stages, pre-flowering+50% flowering+seed-filling stages, and pre-flowering+50% flowering+siliqua-setting+seed-filling stages) yield of Indian mustard cv. Pusa Bold. Irrigation at pre-flowering+50% flowering+seed-filling stages gave the highest grain yield (15.99 q ha^{-1}).

2.2.8 Stover yield

Saran and Giri (1988) reported that irrigation significantly increased the total biomass yield of mustard in the year 1984-1985. The maximum yield of biomass was produced with two irrigations applied at 30 DAS and 90 DAS and intermediate yield with one irrigation at 30 DAS. The lowest biomass yield was obtained when no irrigation was applied.

Stover yield was found to be higher with the application of irrigation in mustard (Patel *et al.*, 1991). Maximum straw yield was found with one irrigation compared to unirrigated control.

2.2.9 Biological yield

Bhargava (1991) demonstrated that biological yield, harvest index and siliqua productions per plant were positively correlated with higher seed yield of rapeseed and mustard but number of seed per siliqua was negatively correlated. Correlation studies between biological yield and seed yield was significant and suggested that higher seed yield can be obtained from vigorous genotypes that give greater biomass. However, information is very scarce regarding to the effect of irrigation on biological yield of rapeseed.

2.2.10 Harvest index

Shrivastava *et al.* (1988) observed in an experiment with mustard (*Brassica juncea*) cv. Varuna that two irrigations at pre-flowering and seed development stages gave higher harvest index. They also observed that irrigation at pre-flowering stage gave higher harvest index value than those of irrigation at seed development stage or without irrigation. However, information is very scarce regarding to the effect of irrigation on harvest index of rapeseed.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

A field experiment with different row spacing and irrigation level was conducted in the Rabi season (October, 2004 to January, 2005) to evaluate the new rapeseed line SAU-C-F_7 in respect of growth and yield performances.

3.1 Experimental site

The research was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from October 2004 to January 2005. The experimental field is located at $90^0 33'$ E longitude and $23^0 77'$ N latitude at a height of 9 meter above the sea level (BCA, 2004). The land was medium high and well drained.

3.2 Climate

The annual precipitation and potential evapotranspiration of the site were 2152 mm and 1297 mm, respectively. The average maximum and minimum temperature was 30.34^0C and 21.21^0C, respectively with mean temperature of 25.17^0C.

Temperature during the cropping period ranged between 12.2^0C to 31.2^0C. The humidity varied from 73.52% to 81.2%. The day length ranged between 10.5-11.0 hours only and there was no rainfall during the experimentation. The weekly average rainfall, air temperature and relative humidity of the site during the experimental work have been shown in Appendices VI, VII and VIII.

3.3 Soil

The soil of the experimental site belongs to the agro-ecological region of 'Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The top soil is silty clay loam in texture. Organic matter content was very low (0.82%) and soil pH varied from 5.47 - 5.63.

3.4 Experimental materials

The experiment was done with a new line of rapeseed (*Brassica campestris*) named SAU-C-F_7 which was developed by Dr. Md. Shaheedur Rashid Bhuiyan, Professor of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207. The line is now under final evaluation before being released.

3.5 Experimental treatments

There were two factors in this experiment, viz. row spacing and irrigation level. The Factors were studied under different levels. The row spacings were denoted as 20 cm (S_1), 30 cm (S_2) and 40 cm (S_3). Irrigation levels were no irrigation (I_0), one irrigation at 30 DAS (I_1) and two irrigations at 30 and 60 DAS (I_2).

3.6 Experimental layout and design

The experiment was laid out in a two factor Split Plot design with four replications. Irrigation was given in main plot and row spacing was in sub-plots. Each replication was divided into 3 equal main plots randomly. Further each main plot was also divided into 3 sub plots. Thus the total plot number was 36. The size of each plot was 4 m × 3 m (12 m^2). The distance between two adjacent unit plots was 0.5 m and distance between two replications and between two main plots was 1.5 m.

3.7 Crop Husbandry

3.7.1 Land Preparation

The experimental field was ploughed with power tiller drawn rotovator. Subsequent cross ploughing was done followed by laddering to make the land level. All weeds, stubles and residues were removed from the field.

3.7.2 Fertilization

The experimental plots were fertilized with a recommended dose of 300, 180, 100, 180, 5 and 10 kg ha^{-1} of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP), Gypsum, Zinc Oxide (ZnO) and Boric Acid, respectively. During final land preparation one half of the urea and total amount of other fertilizers were applied and incorporated into soil. Rest of the urea was top dressed on 23 November, 2004 during first weeding at 28 days after sowing (DAS).

3.7.3 Sowing of seeds

Seeds of SAU-C-F_7 line were sown on 26^{th} October, 2004 maintaining row spacing in each plot as per experimental treatments. Sowing was done continuously in rows at a seed rate of 7.5 kg ha^{-1} (BARI 2002b).

3.7.4 Weeding and thinning

The experimental plots were found to be infested with different kinds of weeds, viz. Bathua (*Chenopodium album* L.), Bermuda Grass (*Cynodon dactylon*), Nut sedge (*Cyperus rotundus* L.), Biskatali (*Polygonum hydropiper* L.) etc. Weeding was done two times manually with 'nirani'. Thinning was done in all the unit plots with care to maintaining a constant plant population in each row following different spacing treatments. Finally plants were kept at 5 cm distance in rows.

3.7.5 Irrigation

First irrigation was given at 26 November 2004 (30 DAS) in the plots according to treatments. The second irrigation was given at 26 December 2004 (60 DAS) in the plots as required by the treatments. Irrigation was done by check basin method. Control plots were maintained with no irrigation.

3.7.6 Pest and disease management

The crop was sprayed with Malathion 60 EC to prevent infestation of mustard aphids at siliqua formation stage. Dithane M-45 was also applied immediately after irrigation to prevent soft rot of plants.

3.7 Harvesting and Processing

At maturity when 80% of the siliquae turned straw yellowish in colour, the experimental crop was harvested. The sub-plots under the main plots without irrigation was harvested on 24 January, 2005 (96 DAS), the sub-plots under the main plots with one irrigation was harvested on 25 January 2005 (97 DAS), and the sub-plots under the main plots with two irrigation was harvested on 28 February 2005 (100 DAS). Harvesting was done in the morning to avoid shattering. Four linear meter were harvested from the centre of each plot at ground level with the help of a sickle and the yield was converted to kg per hectare. The harvested plants from each plot were bundled separately, tagged and brought to a clean cemented threshing floor. The crop was sun dried by spreading them over the floor and seeds were separated from the siliqua by beating the bundles with bamboo sticks.

The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were also dried in the sun. Seed and stover yield were recorded. The biological yield was calculated as the sum of the seed yield and stover yield.

3.8 Data Collection

Ten plants were taken out randomly from each plot leaving the border plants as destructive sampling. This sampling was done to record the following data at an interval of 15 days starting from 30 DAS (just before first irrigation).

i) Plant height (cm)

ii) Above ground fresh weight per plant (g)

iii) Dry weight of leaf per plant (g)

iv) Dry weight of stem per plant (g)

v) Dry weight of siliqua per plant (g)

vi) Above ground total dry weight per plant (g)

vii) Number of branches per plant

viii) Number of siliqua per plant

ix) Number of seeds per siliqua

x) Number of seeds per plant

xi) 1000-seed weight (g)

xii) Seed yield per plant (g)

xiii) Seed yield per hectare (kg)

xiv) Stover yield per hectare (kg)

xv) Biological yield (kg)

xvi) Harvest index (%)

3.8.1 Plant height

The height of ten plants was measured from ground level (stem base) to the tip of the plant. Mean plant height was calculated and expressed in cm.

3.8.2 Above ground fresh weight per plant

To measure the fresh weight of plant, ten plants were selected randomly and data were recorded. Mean weight was calculated and expressed as gram per plant.

3.8. 3 Dry weight of leaf per plant

The separated leaves of the plants were dried in an electric oven at 70^0 C for 48 hours and the dry weight was measured with a digital balance for different growth stage. Leaf dry weight of ten plants was then calculated for the weight of single plant and shown as gram per plant for each harvest.

3.8.4 Dry weight of stem per plant

Dry weight of stem was measured and calculated and expressed in gram per plant for each harvest.

3.8.5 Dry weight of siliqua per plant

Dry weight of siliqua was measured and calculated and shown as gram per plant for each harvest.

3.8.6 Above ground total dry weight per plant

It was the sum of dry weight of leaves, stems, siliqua including seeds) per plant.

3.8.7 Number of branches per plant

The number of branches of ten randomly sampled plants at harvest were counted and recorded. Average value of ten plants was recorded as number of branches per plant.

3.8.8 Numbers of siliqua per plant

Number of siliqua was counted from ten plants and divided by ten which indicated the number of siliqua per plant.

3.8.10 Number of seeds per siliqua

The number of seeds per siliqua was counted by splitting twenty siliqua which were sampled randomly from sampled plants and then mean value was determined.

3.8.11 Number of seeds per plant

Number of seeds per plant was calculated by multiplying the number of siliqua per plant and number of seed per siliqua.

3.8.12 1000-seed weight

From the seed stock of each plot, 1000-seed were randomly counted. Then the weight was taken by a digital balance. The 1000-seed weight was recorded in gram.

3.8.13 Seed yield per plant

The separated seeds of ten plants were collected, cleaned, dried and weighed properly. The average seed yield per plant was then calculated.

3.8.14 Seed yield per hectare

After threshing, cleaning and drying, total seed yield from the harvested area (1 m^2) were recorded and was converted to kg ha^{-1}.

3.8.15 Stover yield per hectare

After the separation of seeds from plant of harvested area, the straw and shell per plot was dried separately and the weight was recorded. These were then converted into stover yield (kg ha^{-1}).

3.8.16 Biological yield per hectare

It is the summation of seed yield and stover yield per hectare.

3.8.17 Harvest index

Harvest Index was calculated by the following formula of Donald (1963).

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.9 Statistical analysis

The data were analyzed following Analysis of Variance (ANOVA) technique and mean differences were adjusted by the t-test (Gomez and Gomez,

1984) using the statistical computer programme ALPHA and MSTAT-C v.1.2. Means were compared by using LSD test at 5% level of significance. The correlation analysis was done by SPSS v. 13.1 Software. Regression was measured and plotted with the Microsoft Excel 2003 Software.

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to study the performance of rapeseed line SAU-C-F_7 as influenced by different row spacing and level of irrigation. The results of the present investigation have been presented, discussed and compared as far as possible with the results of other researchers.

4. 1 Plant height

Effect of row spacing

In the initial stage up to 30 DAS the growth of the line was very slow and then the crop remained in rosette form. Stem elongation started with the initiation of reproductive phase of development. The rapid increase of plant height was observed from 30 DAS to 75 DAS. After 75 DAS the growth of plant height became very slow. In the initial stage the plant canopy was very small and competition was mainly negligible. When the canopy began to increase the competition was started for aerial space. Row spacing caused significant variation in plant height of rapeseed line SAU-C-F_7 (Table 4.1). The closest row spacing (20 cm) ultimately produced significantly tallest plant than S_2 (30 cm) and S_3 (40 cm) in almost all the growth stages. The plant tended to be taller for getting the light in closed place. Sharma and Thakur (1993) reported that the highest plant height was observed from the closest row spacing of 20 cm. The closest row spacing caused the plants to compete more nutrient, water and light required for their growth and development. This competition for space might have elongated the densely populated plants (Willey and Heath, 1969). Increasing population density increased plant height in rapeseed was also reported by Singh and Dhillon (1991), Misra and Rana (1992) and Chauhan *et al.* (1993). The positive effect of increasing population density on plant height has been reported also in other crops like soybean (Sharma *et al.*, 1992 and Prasad *et al.*, 1993), sesame (Roshid, 1998) and rice (Talukder, 1998).

Table 4.1 Plant height (cm) of rapeseed line SAU-C-F_7 at different age as affected by row spacing

Row spacing	Days after sowing (DAS)				
	30	45	60	75	90
S_1	13.69	46.40	85.04	91.27	91.80
S_2	13.45	46.08	81.14	88.64	89.12
S_3	13.21	43.67	78.85	87.36	87.38
LSD 0.05	**NS**	**2.69**	**5.43**	**NS**	**2.96**
CV (%)	**8.63**	**7.12**	**7.76**	**5.53**	**4.21**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

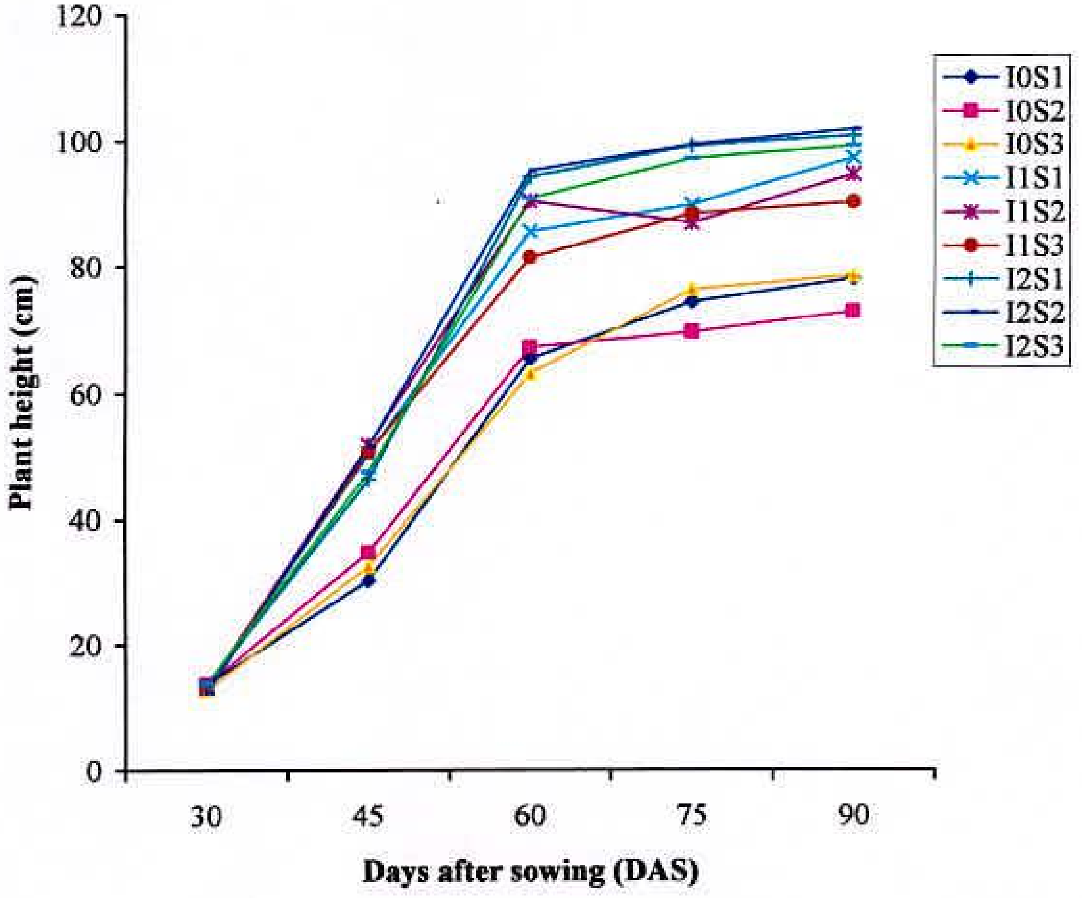
Effect of irrigation level

Significant variation was found among the irrigation levels for plant height of rapeseed line SAU-C-F_7 which started from 45 DAS and onwards (Table 4.2). At 45 DAS, I_1 (one irrigation) produced significantly tallest plant which was followed by I2 (two irrigations, one at 30 DAS and another at 60 DAS). The treatment I_2 showed significantly tallest plant from 45 to 90 DAS and it was followed by I_1 (45 to 75 DAS). The lowest plant height was found for the control treatment (no irrigation) throughout the life cycle. No significant difference was found between the treatment I_1 and I_2 as the soil moisture availability for the plant was sufficient before second time irrigation at 60 DAS. Similar result was reported by Bihari *et al.* (1992). Sarker (1994) found tallest plant with one irrigation while the smallest plant was found without irrigation. This finding was at per with the result of Saran and Giri (1988). Paul and Begum (1993) also found that one irrigation at bud initiation stage gave maximum plant height at harvest in mustard plant. Siag *et al.* (1993) reported maximum plant height when irrigation was applied during branching and siliquae development stage.

Table 4.2 Plant height (cm) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level

Irrigation level	Days after sowing (DAS)				
	30	45	60	75	90
I_0	13.10	32.60	65.32	73.53	75.02
I_1	13.29	51.02	89.10	95.12	96.06
I_2	13.96	48.52	90.63	98.62	99.32
LSD 0.05	**NS**	**3.72**	**7.69**	**4.51**	**3.60**
CV (%)	**8.63**	**7.12**	**7.76**	**5.53**	**4.21**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS



I_0 = No irrigation S_1 = 20 cm row spacing
I_1 = One irrigation at 30 DAS S_2 = 30 cm row spacing
I_2 = Two irrigations at 30 and 60 DAS S_3 = 40 cm row spacing

Fig. 4.1 Plant height of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing

Interaction effect of irrigation level and row spacing

The interaction effect of irrigation and row spacing had a great effect on the plant height of new rapeseed line in this study (Fig. 4.1). Significant differences of plant height were found in every stages of growth except at the early stage (up to 30 DAS). This was due to the slow growth rate and also for the reason of no irrigation was applied before 30 DAS. Maximum plant height was observed in the treatment I_2S_2 (two irrigation and 30 cm row spacing) in all the stages of life cycle. The lowest plant height was found with of all the row spacings (20 cm, 30 cm and 40 cm) with no irrigation treatment (control). The plant response in terms of height to the combined treatment was found higher in the middle of growth stage (from 45 DAS to 60 DAS) because of better growth. The maximum plant height (100.84 cm) at harvest was obtained from the treatment I_2S_2 which was statistically identical with I_2S_3 and I_2S_1. Siag *et al.* (1993) also found this result which indicated that 30 cm row spacing with 2 irrigations at branching and flowering stage would give tallest plants.

4.2 Above ground fresh weight per plant

Effect of row spacing

The fresh weight production in rapeseed over time was influenced by row spacing (Table 4.3). Significant fresh weight was found in different row spacing in all the growth stages. The wider row space (S_3) produced significantly highest fresh weight at 30, 60, 75 and 90 DAS. The treatment S_2 showed significantly highest weight at 45 DAS and at per with S_3 at 60 DAS. The closest row spacing produced the lowest fresh weight with time. The highest fresh weight at wider space might be due to the availability of light and air that helped the plants to have the largest canopy. Sharma and Thakur (1993) reported the highest number of branches with wider spacing which provided more fresh weight than closer spacing. The lowest fresh weight with time and might be due to leaf senescence, leaf dropping and siliquae shattering and so on.

Table 4.3 Above ground fresh weight per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by row spacing during 2004-2005 Rabi season

Row spacing	Days after sowing (DAS)				
	30	45	60	75	90
S_1	2.65	16.16	31.53	39.59	24.95
S_2	2.66	21.68	42.45	42.03	26.48
S_3	2.78	18.02	42.73	48.98	29.97
LSD 0.05	**0.22**	**1.55**	**3.27**	**3.23**	**1.19**
CV (%)	**9.52**	**9.76**	**9.81**	**8.66**	**5.13**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Effect of irrigation level

Numbers of irrigation produced significant variation in fresh weight of rapeseed line SAU-C-F_7. Treatment I_2 was found to produce the highest fresh weight and unirrigated control (I_0) plots produced the lowest weight in all the growth stages (Table 4.4). At 45 DAS no significant variation was found between I_1 and I_2. At 60 DAS to 90 DAS the treatment I_2 produced the highest fresh weight which was significantly different from I_1 and I_0. It might be due to the second irrigation (I_2) at siliqua development stage, which increased the weight of the reproductive parts. At harvesting stage (90 DAS) fresh weight was found to be reduced which might be due to leaf senescence, siliquae shattering etc. Gill and Narag (1993) found similar results with two irrigations.

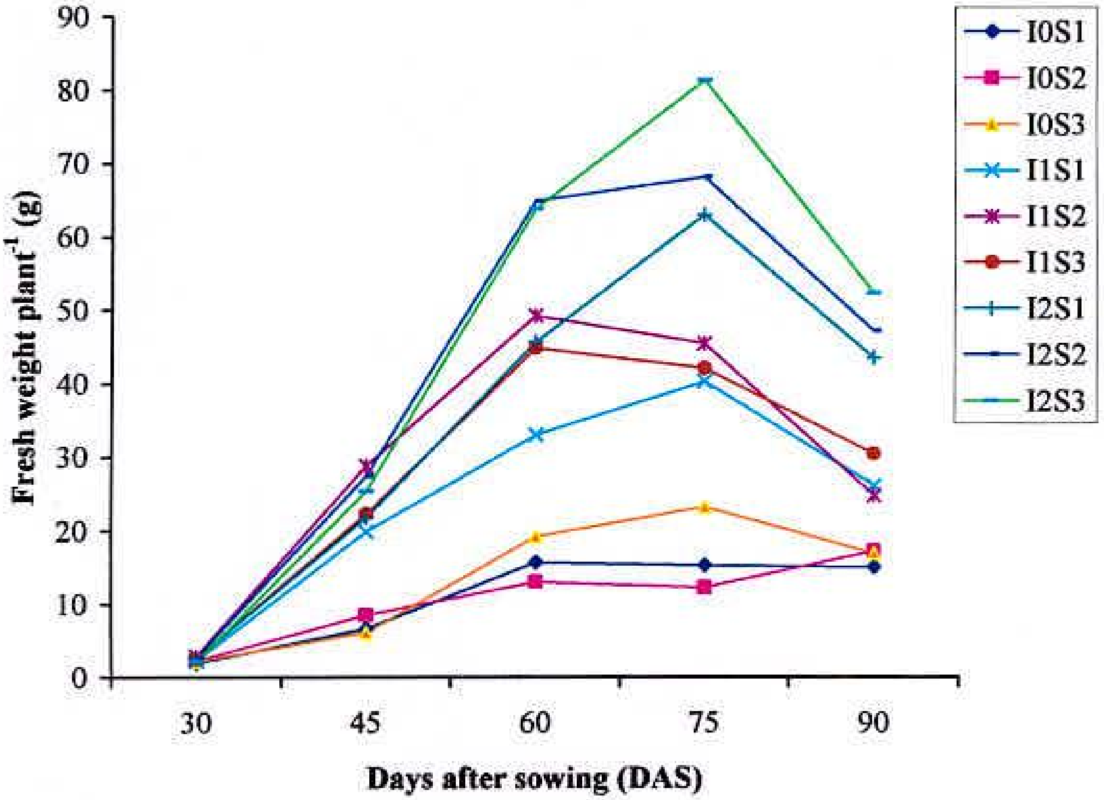
Table 4.4 Above ground fresh weight per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	Days after sowing (DAS)				
	30	45	60	75	90
I_0	2.15	7.15	16.04	16.99	26.41
I_1	2.29	23.76	42.46	42.70	27.24
I_2	2.35	24.95	58.21	70.90	47.75
LSD 0.05	**0.30**	**1.68**	**3.37**	**4.49**	**1.40**
CV (%)	**9.52**	**9.76**	**9.81**	**8.66**	**5.13**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

Interaction effect of irrigation level and row spacing

Significant effect of interaction between row spacing and irrigation was observed (Fig. 4.2). At 30 DAS the highest (3.60 g) fresh weight was found from one irrigation (I_1) with widest row spacing (S_3). The closest spacing without any irrigation produced the lowest fresh weight at 30 DAS. At 45 DAS the maximum fresh weight was found from the interaction between I_1 and S_2 and the lowest fresh weight was found from closest spacing (S_1) with no irrigation. At 60, 75 and 90 DAS the highest fresh weight was produced from the treatment I_2S_3



I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Fig. 4.2 Above ground fresh weight per plant of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing

4.3 Above ground total dry weight per plant

Effect of row spacing

Row spacing significantly influenced the total dry matter production in the rapeseed line SAU-C-F_7. Significant variation was found at all the growth stages except 30 DAS (Table 4.5). Accumulation of dry matter was very slow at 30 DAS and found no significant differences of production with space variations. Significant difference was found from 45 to 90 DAS for dry matter production with different row spacings. Among the row spacings, the treatment S_2 (30 cm row spacing) produced the highest dry weight plant^{-1} at 45 DAS and 60 DAS which was statistically identical to S_3 and the total dry matter accumulation was lowest in the treatment S_1. In case of 75 DAS and 90 DAS the row spacing S_3 facilitated the plants to have more air and light, which helped accumulation of the highest dry matter and it was significantly different from S_1 and S_2. In this stage, S_1 produced the minimum dry matter. The production of maximum dry matter of wider spaced plant also might be accounted for the luxuriant growth of plant as well as higher number of primary branches plant^{-1}. Alam (2004) concluded that photosynthetically active radiation (PAR) interception is maximum at wider row spacing which resulted more dry matter in different organ. This result corroborated with the result found by Chauhan *et al.* (1993) who reported maximum dry matter production per plant from 40 cm row spacing. This result is also supported by the findings reported by of Singh and Singh (1984b) who found that the dry matter of Indian rape was increased with the increase of plant spacing as it facilitates the maximum spaces for plant.

Table 4.5 Above ground total dry weight per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by row spacing during 2004-2005 Rabi season

Row spacing	Days after sowing (DAS)				
	30	45	60	75	90
S_1	0.38	1.54	6.55	7.77	8.47
S_2	0.43	2.06	8.10	9.72	9.95
S_3	0.39	2.05	7.89	10.43	11.67
LSD 0.05	**NS**	**0.02**	**0.29**	**0.33**	**0.25**
CV (%)	**8.36**	**1.36**	**4.57**	**3.94**	**3.01**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Effect of irrigation level

Significant variation was found in total dry matter per plant with different levels of irrigation at all growth stages except early growth stage (30 DAS). Distinct differences were observed in dry matter production after 30 DAS when irrigations were initiated (Table 4.6). These differences further increased at the successive stages. The total dry matter production was increased with each increment of irrigation levels. At 45 DAS the treatment I_1 produced the maximum dry matter which was significantly different from I_2 and I_0. At 60 DAS, 75 DAS and 90 DAS the highest dry matter accumulation was found from the treatment I_2. I_1 produced the second highest dry matter where this accumulation was least in I_0 treatment. The lowest dry matter in plant was due to internal moisture deficit that made the plants to have lower height and failed to increase growth parameters due to lower net assimilation rate. This adversely affected dry matter accumulation in plants. Wright *et al.* (1988) expressed the similar observation. The I_2 treatment produced highest number of branches which might have contributed in the accumulation of highest dry matter at those three stages. It might be due to attain a maximum plant height and stem thickness with this treatment. Treatment I_0 failed to improve dry matter production after 75 DAS and it might be due to maximum leaf senescence, leaf dropping and so on which were resultant of water shortage. Siddqui (1999) reported that regardless of population density, accumulation of TDM in rapeseed increased progressively over time attaining a peak at 80 DAE to attain the physiological maturity of the crop. The rate of increase in TDM, however, varied depending on growth stage. TDM increased at a slow rate upto 30 DAE. A very sharp rise in TDM production occurred from 30 to 60 DAS and thereafter the rate of increase was comparatively low. Total dry matter showed a declining tendency after 80 DAS. This was mainly due to leaf senescence and leaf abscission. Paul and Begum (1993) stated that dry matter production was highest with one irrigation at bud initiation stage. One irrigation at 30 DAS produced higher dry matter than that of two irrigation because there was no moisture deficiency in the soil. Saran and Giri (1988) also noticed increasing trend of dry matter accumulation in mustard plant with increasing irrigation levels. Tomer *et al.* (1992) noticed that dry matter per plant was highest with two irrigations – one at pre-flowering stage and another at fruiting stage. Giri (2001) found more dry matter weight per plant in mustard with two irrigations than with one irrigation.

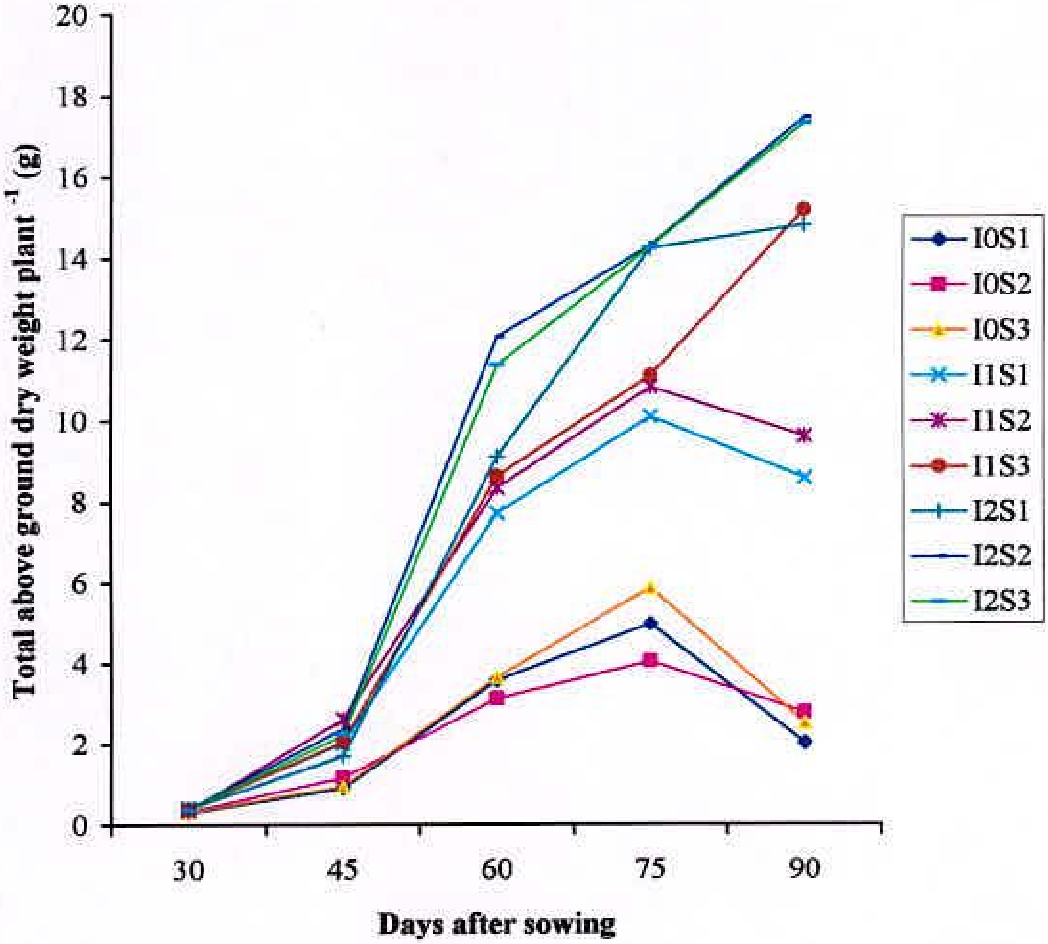
Table 4.6 Above ground total dry weight per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	Days after sowing (DAS)				
	30	45	60	75	90
I_0	0.32	1.01	3.45	4.96	2.43
I_1	0.39	2.24	8.47	10.67	11.13
I_2	0.39	2.11	10.59	14.28	16.53
LSD 0.05	**NS**	**0.031**	**0.48**	**0.347**	**0.29**
CV (%)	**8.36**	**1.36**	**4.57**	**3.94**	**3.01**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigation at 30 and 60 DAS

Interaction effect of irrigation levels and row spacing

The effect of interaction between irrigation levels and row spacing on dry matter production was significan at different stages except 30 DAS (Fig. 4.3). At 45 DAS the treatment I_1S_2 produced the highest dry matter (2.62 g) and the lowest dry matter (0.90 g) was found from the treatment I_0S_1. The treatment I_2S_2 produced the highest dry matter at 60, 75 and 90 DAS (12.06, 14.30 and 17.46 g, respectively) and next highest by the treatment I_2S_3 and I_2S_1. The lowest dry matter was found from the treatment I_0S_2 at 60 and 75 DAS and I_0S_1 at 90 DAS. Saran and Giri (1988) also found maximum dry matter from the interaction of wider row spacing (50 cm) and 2 irrigations at 30 and 90 DAS. Tomer *et al.* (1992) found maximum dry matter plant^{-1} with 2 irrigations at flowering and fruiting stages when 40 cm row spacing was maintained. Gill and Narag (1993) and Giri (2001) also observed similar trend of dry matter in mustard and rapeseed plants.



I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Fig. 4.3 Above ground total dry weight per plant of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing

4.4 Dry matter partitioning

Accumulation of dry matter and its partitioning into different plant components is an important consideration in achieving desirable economic yield from the crop plants. The economic yield is greatly determined by the production of total dry matter and its partitioning by the reproductive organ (Singh and Yadav, 1989). Irrigation and row spacing exerted significant effect on dry matter accumulation and its partitioning into the components of rapeseed at all stages of crop growth.

Effect of row spacing

Spacing is an important criterion for dry matter accumulation as it facilitates light interception for photosynthesis. Dry matter accumulation in leaves was affected by different spacing (Table 4.7). At 30 DAS there was no significant effect was found on leaf dry matter weight as they were not affected by population density. At 45 and 60 45 DAS the highest dry matter in leaves was found at widest row spacing S_3 (40 cm). It was followed by S_2 (30 cm) at 45 DAS where the S_1 produced the lowest leaf dry matter. At S_3 spacing the plants could absorb required nutrients and intercept more light than S_2 and S_1. But at 75 DAS the leaf dry matter accumulation was lesser than 60 DAS and no significant differences were found among the treatments as leaf senescence occurred. At 90 DAS the plants remained in the field without any leaf. The decrease in leaf dry weight during seed development stage might be attributed to remobilization of stored assimilates from the vegetative parts to the reproductive ones. Siddiqui (1999) reported that irrespective of population density, the leaf dry weight continued to increase up to

50 DAE and then declined and ceased completely at 90 DAE due to senescence and abscission. He also noted that the contribution of leaf to the total dry matter was dominant up to 40 DAE i.e. flower initiation. Similar report was presented by Lodhi *et al.* (1979) in mustard plants.

Table 4.7 Dry weight of leaves per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by row spacing during 2004-2005 Rabi season

Row spacing	Days after sowing (DAS)			
	30	**45**	**60**	**75**
S_1	0.38	1.54	1.21	0.73
S_2	0.43	2.06	1.25	0.66
S_3	0.39	2.05	1.41	0.73
LSD 0.05	**NS**	**0.02**	**0.05**	**NS**
CV (%)	**8.36**	**1.36**	**5.00**	**11.67**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Figure 4.4 revealed that 100% total dry matter was partitioned in leaves at 30 and 45 DAS with 20, 30 and 40 cm row spacing. Thereafter 18%, 17% and 17% of total dry matter was accumulated in leaves with different spacing treatments. Only 8%, 7% and 7% dry matter was partitioned in leaves at 75 DAS. At 90 DAS there was no dry matter accumulation in leaves with any row spacing as leaves were senescenced at this stage.

The decrease in leaf dry weights during seed development stage might be attributed to remobilization of stored assimilates from the vegetative organs to the reproductive ones. From 75 DAS onwards, the major portion of TDM was accumulated in reproductive organs i.e. siliqua. Thus the contribution of siliquae dry weight to TDM weight increased to a great extent.

The dry matter accumulation in stem started from 60 DAS. Significant difference was found for all growth stages (Table 4.8). The wider spaced (S_3) plant produced significantly maximum stem dry weight at 60, 75 and 90 DAS. The second highest weight was measured with S_2 treatment. Closer spacing (S_1) had significantly lowest stem dry weight at all the said growth stage.

The S_3 (40 cm) produced the highest stem dry matter because the plants could get necessary light, nutrients, space compared to the plants of other closer spacings (20 and 30 cm). Scarisbrick *et al.* (1982) and Khader and Bhargava (1985) reported higher stem dry matter weight of *Brassica campestris* and *Brassica juncea* with wider plant density than closer one.

Table 4.8 Dry weight of stem per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by row spacing during 2004-2005 Rabi season

Row spacing	**Days after sowing (DAS)**		
	60	**75**	**90**
S_1	3.03	3.28	3.31
S_2	3.55	3.92	3.99
S_3	3.71	4.93	5.27
LSD 0.05	**0.20**	**0.26**	**0.21**
CV (%)	**6.87**	**7.80**	**6.03**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Figure 4.4 revealed that accumulation of dry matter in stem was started at 60 DAS. At 60 DAS 47%, 46% and 45% dry matter was observed to accumulate in stem with closer to wide spaced plant. At 75 DAS 36%, 40% and 44% dry matter was partitioned in stem. At 90 DAS 39%, 40% and 45% dry matter was observed to accumulate with closer to wide spaced plant.

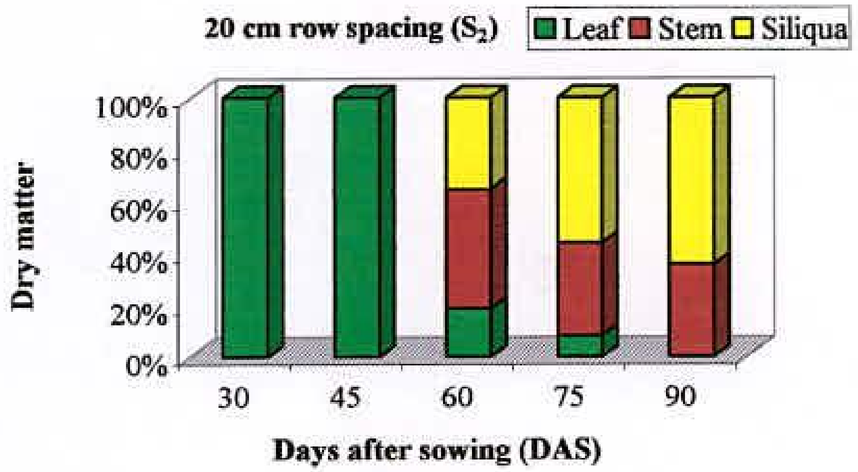
Significant dry matter accumulation in reproductive organs (siliqua) observed at 60 DAS and accumulation continued till 90 DAS (Table 4.9). After 60 DAS i.e. during seed development period, leaf dry weight tended to decrease while siliqua dry weight started to increase. Wider spacing (40 cm) influenced plant to produce significantly highest siliquae dry weight at 60, 75 and 90 DAS. The next higher production found with S_2 treatment at the said growth stages. S_1 treatment gave the lowest siliquae dry matter. At 90 DAS maximum dry matter weight in siliquae was found. Similar results were obtained in rapeseed by Lodhi *et al.* (1979). At S_3 (40 cm spacing) the plant could get adequate nutrient and space to produce highest number of siliquae with highest dry matter. At S_1 spacing (20 cm) the shortage of space and higher competition for nutrient reduced the dry matter accumulation in siliquae. Oad *et al.* (2001) observed the more competition with closer row spacing in rapeseed.

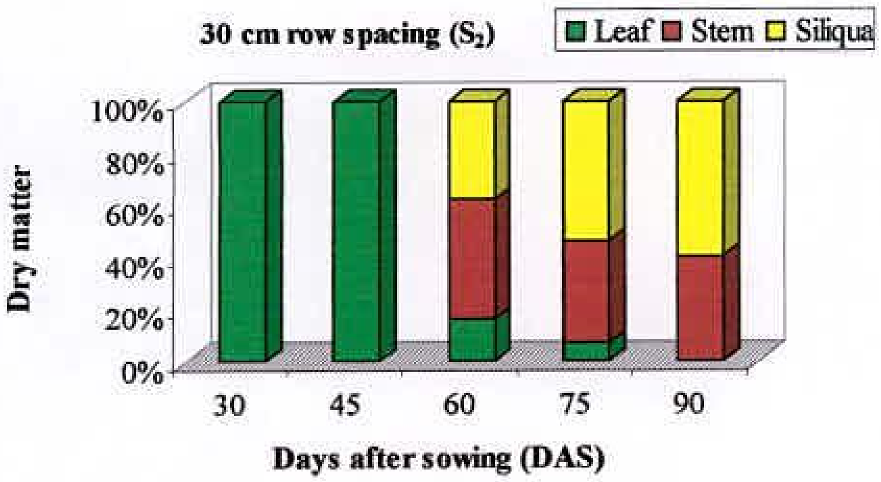
Table 4.9 Dry weight of siliquae per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by row spacing during 2004-2005 Rabi season

Row spacing	Days after sowing (DAS)		
	60	75	90
S_1	2.31	5.13	5.16
S_2	2.97	5.34	5.95
S_3	3.08	5.55	6.40
LSD 0.05	**0.19**	**0.20**	**0.18**
CV (%)	**8.02**	**4.44**	**3.64**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

From Figure 4.4, it was observed that accumulation of dry matter in siliquae was started at 60 DAS. At 60 DAS 35%, 38% and 38% dry matter was observed to accumulate in siliquae with closer to wide spaced plant. At 75 DAS 56%, 53% and 49% dry matter was partitioned in siliquae. At 90 DAS 61%, 60% and 55% dry matter was observed to accumulate with closer to wide spaced plant.





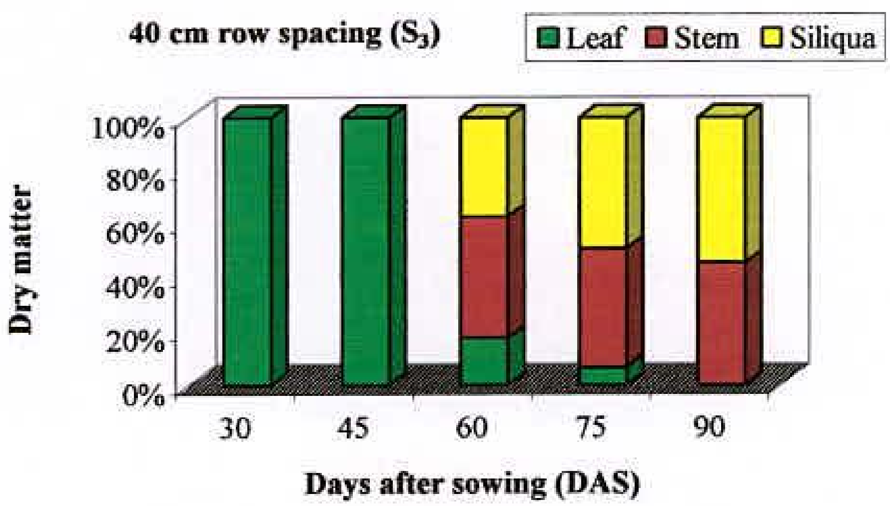


Fig. 4.4 Dry matter accumulation in different parts of rapeseed line SAU-C-F_7 at different ages as affected by row spacing

Effect of irrigation level

Irrigation showed significant difference in leaf dry matter production at different growth stages (Table 4.10). At 30 DAS there were no significant differences in leaf dry weight among the treatments. The treatment I_2 produced the highest leaf and stem dry matter both at 60 and 75 DAS and lowest dry matter was produced under control condition (no irrigation). The dry matter of leaf at 75 DAS was much lower than the dry matter at 60 DAS and it might be due to the leaf defoliation. The defoliation rate was higher at one irrigation (I_1) than 2 irrigations probably the second irrigation supplied sufficient moisture which helped in retaining more leaves for a longer period and thus increase seed yield. Major (1977) observed similar result while working with rapeseed.

Table 4.10 Dry weight of leaves per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	Days after sowing (DAS)			
	30	45	60	75
I_0	0.32	1.01	0.53	0.40
I_1	0.39	2.24	1.36	0.48
I_2	0.39	2.10	1.99	1.25
LSD 0.05	**NS**	**0.03**	**0.11**	**0.01**
CV (%)	**8.36**	**1.36**	**5.00**	**11.67**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

Figure 4.5 revealed that 100% total dry matter was partitioned in leaves at 30 and 45 DAS with no irrigation (I_0), one irrigation (I_1) and two irrigation (I_2). Thereafter 15%, 16% and 19% of total dry matter was accumulated in leaves with different irrigation treatments. Only 8%, 4% and 9% dry matter was partitioned in leaves at 75 DAS. At 90 DAS there was no dry matter accumulation in leaves with any irrigation level as leaves were senescenced at this stage.

An increasing trend was found in stem dry matter weight production at different growth stages with increase in the number of irrigation (Table 4.11). A significant variation was found among the different irrigation levels where I_2 produced the highest dry matter at all the stages and the next highest weight were produced by I_1. The lowest dry matter weight was accumulated with no irrigation which indicated that irrigation was needed for dry matter weight production in rapeseed. Two irrigations facilitated to have maximum stem thickness and branching rendering more dry matter accumulation in this organ. Ahmad *et al.* (2002) found increasing dry matter weight with increase level of irrigation in *Sophora secundiflora*.

From Figure 4.5, it was observed that accumulation of dry matter in stem was started at 60 DAS. At 60 DAS 46%, 47% and 44% dry matter was observed to accumulate in stem with increasing irrigation levels. At 75 DAS 37%, 38% and 41% dry matter was partitioned in stem. At 90 DAS 39%, 45% and 37% dry matter was observed to accumulate in stem with no I_0, I_1 and I_2.

Table 4.11 **Dry weight of stem per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level, during 2004-2005 Rabi season**

Irrigation level	**Days After Sowing (DAS)**		
	60	**75**	**90**
I_0	1.58	1.83	1.86
I_1	4.02	4.07	5.40
I_2	4.69	5.83	6.08
LSD 0.05	**0.18**	**0.29**	**0.13**
CV (%)	**6.87**	**7.80**	**6.03**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

A significant difference was found in case of dry matter accumulation in siliquae at different times with different irrigation levels (Table 4.12). At every stage, maximum dry weight of siliquae was found with two irrigations at 30 and 60 DAS (I_2) while zero irrigation treatment (I_0) produced the lowest dry weight of siliqua. At advanced stages slower increasing trend was found at I_0 and I_1 which might be from the deficiency of soil moisture at these stages. Kaul and Das (1986) and Paul and Begum (1993) reported similar result. At I_2 there was no deficiency of soil moisture at the advance stages, as a result dry matter accumulation was higher than those of other irrigation levels.

Table 4.12 Dry weight of siliquae per plant (g) of rapeseed line SAU-C-F_7 at different age as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	Days after sowing (DAS)		
	60	75	90
I_0	1.34	2.72	2.85
I_1	3.11	6.12	6.72
I_2	3.91	7.18	10.40
LSD 0.05	**0.31**	**0.17**	**0.25**
CV (%)	**8.02**	**4.44**	**3.64**

Figures in a column having a common letter do not differ significantly at 0.05 level.

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

From Figure 4.5, it was observed that accumulation of dry matter in siliquae was started at 60 DAS. At 60 DAS 39%, 37% and 37% dry matter was observed to accumulate in stem with increasing irrigation levels. At 75 DAS 55%, 58% and 50% dry matter was partitioned in siliquae. At 90 DAS 61%, 55% and 63% dry matter was observed to accumulate in siliquae with no I_0, I_1 and I_2.

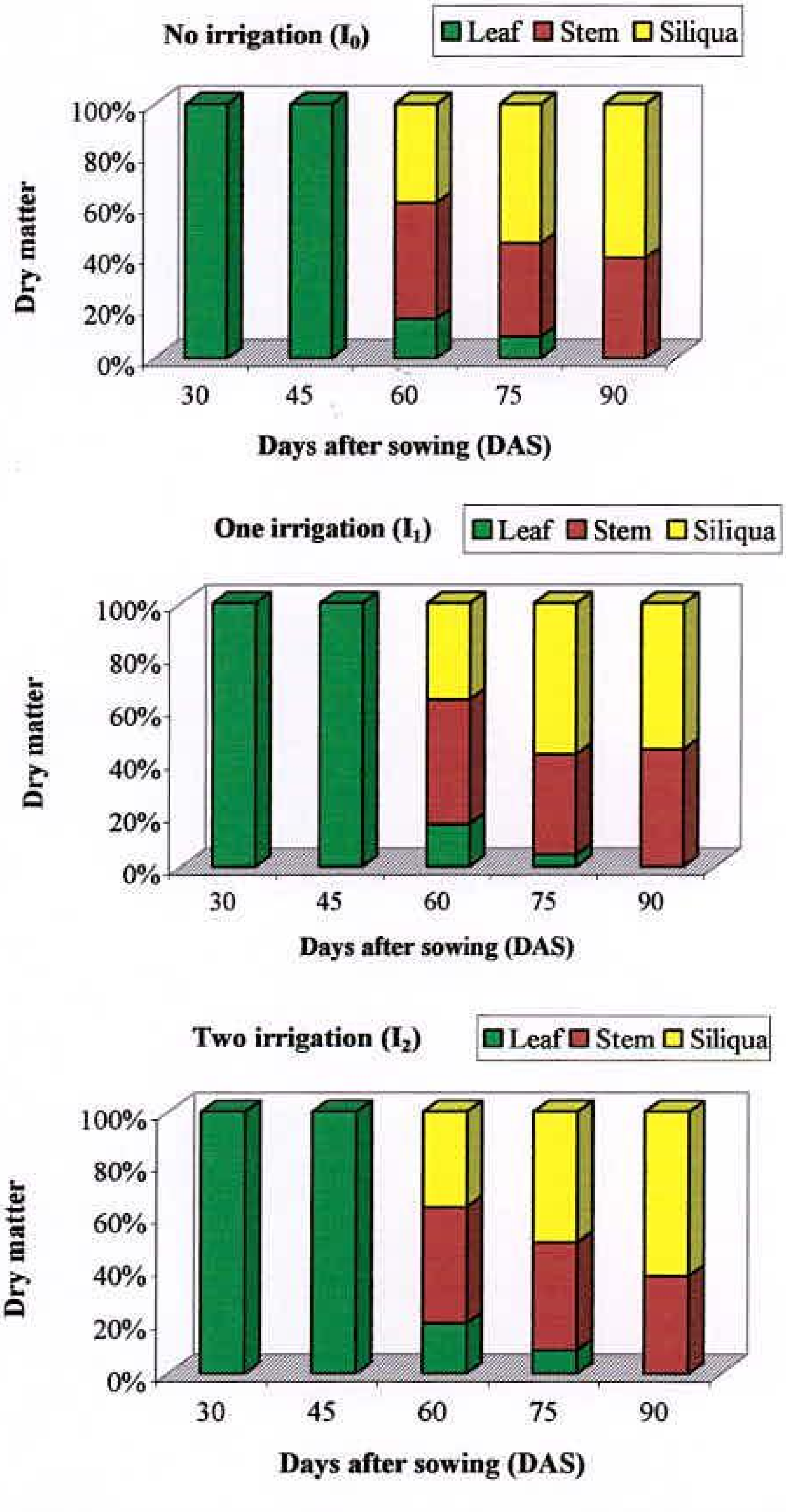
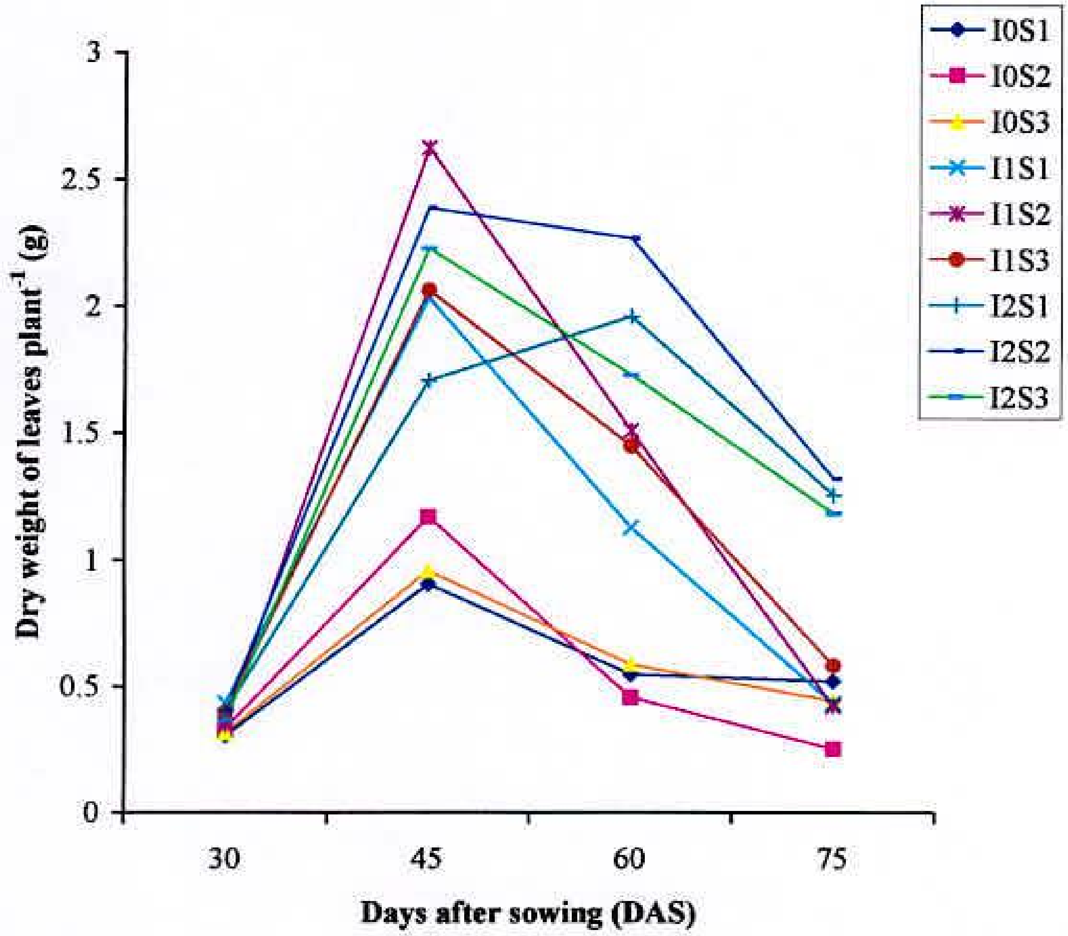


Fig. 4.5 Dry matter accumulation in different parts of rapeseed line SAU-C-F_7 at different ages as affected by irrigation level

4.3.2.3 Interaction effect of irrigation level and row spacing

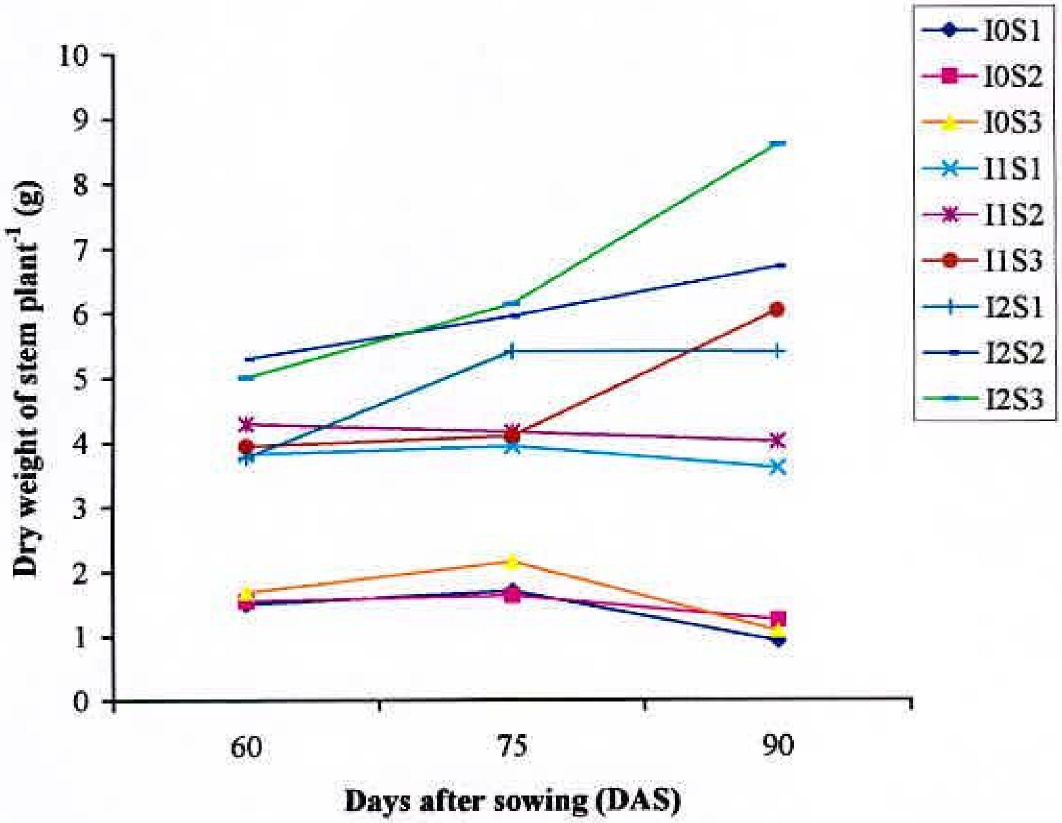
Interaction between irrigation and spacing produced significant variation in dry matter accumulation in leaves, stem and siliquae. In case of dry matter accumulation in leaves, the treatment I_2S_2 showed the highest at 60 and 75 DAS (Fig. 4.6). At both the stages the treatment I_0S_2 produced the lowest dry matter in leaves. In stem the treatment I_2S_3 produced the highest dry matter in all the stages except 60 DAS. In case of 60 DAS the leaf canopy was lower and the spacing S_2 (30 cm) was sufficient for canopy growth and that is why I_2S_2 produced highest dry matter in leaf per plant at this stage (2.27 g). At 75 DAS the highest dry matter was produced with I_2S_2 and it was followed by I_2S_1. In case of stem dry weight, both at 60 and 75 DAS I_2S_2 produced the highest dry matter. At 90 DAS, the highest dry matter was produced in I_1S_3 (Fig. 4.7). The lowest dry matter was produced in I_0S_1 treatment which was followed by I_0S_2 and I_0S_3.

Like dry matter production in leaves and in stem, significant interaction effect was found for dry matter accumulation in siliquae per plant (Fig. 4.8). The treatment I_2S_3 produced the highest dry matter in siliquae which was followed by I_2S_2 for all the growth stages (60 DAS, 75 DAS and 90 DAS). In this treatment two irrigations one at 30 DAS and other at 60 DAS provided favourable soil moisture and S_3 (40 cm) provided the maximum space for plant growth and development for the reproductive organs which might be the causes of accumulating highest dry matter from the treatment I_2S_3.



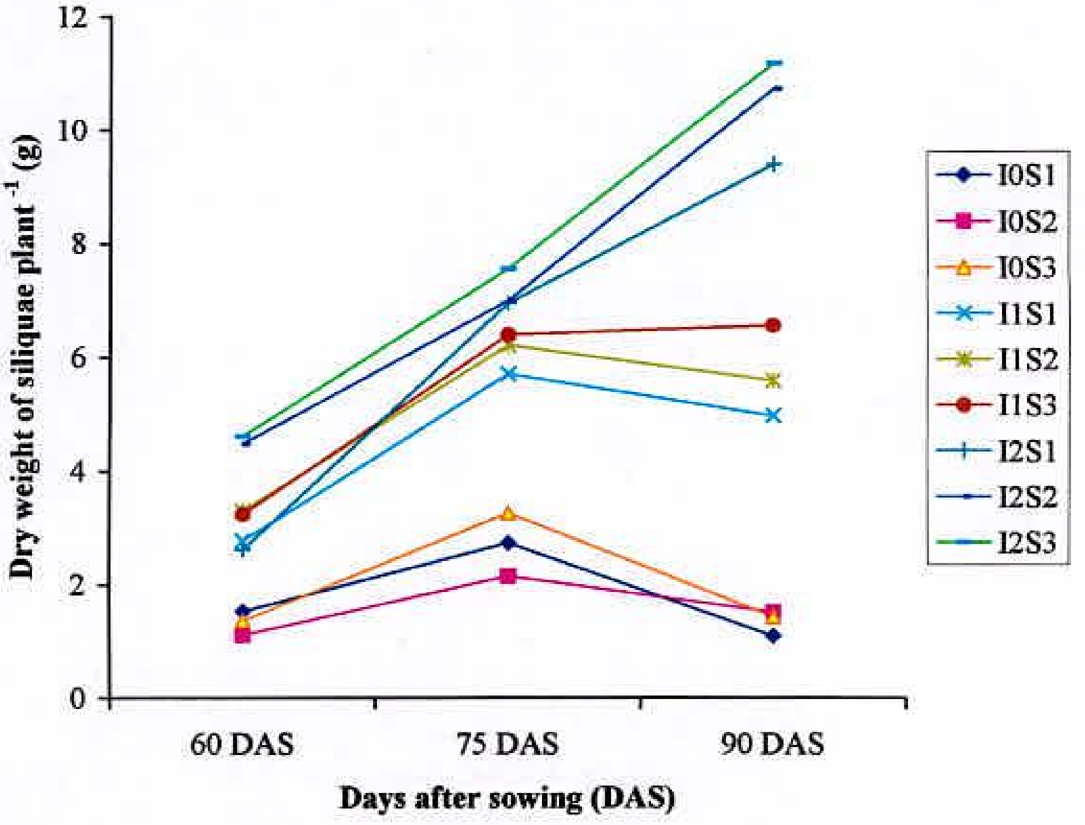
I_0 = No irrigation	S_1 = 20 cm row spacing
I_1 = One irrigation at 30 DAS	S_2 = 30 cm row spacing
I_2 = Two irrigations at 30 and 60 DAS	S_3 = 40 cm row spacing

Fig. 4.6 Dry weight of leaves of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing



I_0 = No irrigation	S_1 = 20 cm row spacing
I_1 = One irrigation at 30 DAS	S_2 = 30 cm row spacing
I_2 = Two irrigations at 30 and 60 DAS	S_3 = 40 cm row spacing

Fig. 4.7 Dry weight of stem of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing



I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS
S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Fig. 4.8 Dry weight of siliquae of rapeseed line SAU-C-F_7 at different ages as affected by the combined effect of irrigation level and row spacing

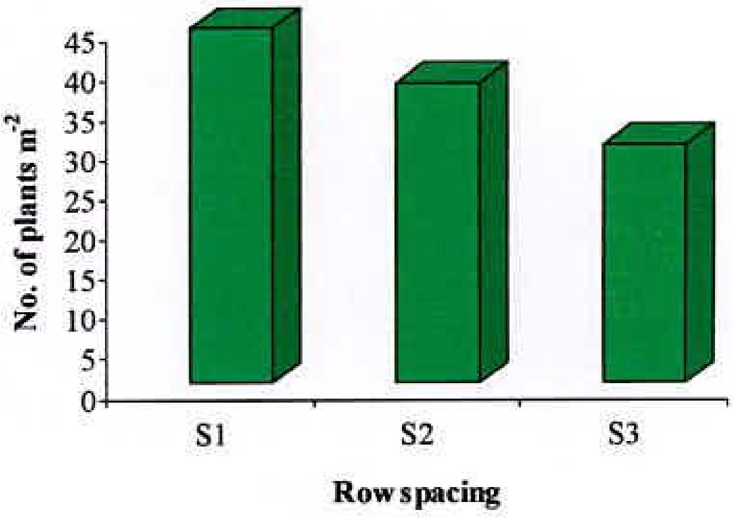
4.5 Number of plants per m^2 at harvest

Effect of row spacing

Row spacing greatly influenced the number of plants per meter square. Significant differences were found in case of plants per meter square under different row spacings. In the study, plants per meter square was decreased with the increase of row spacing (Fig 4.9). The highest number of plants per meter square (44.75) was found with 20 cm row spacing while 40 cm row spacing gave the lowest of number of plants per meter square (30.17). The decrease of plant per meter square with the increase of row spacing was due to the less number of rows in a unit area.

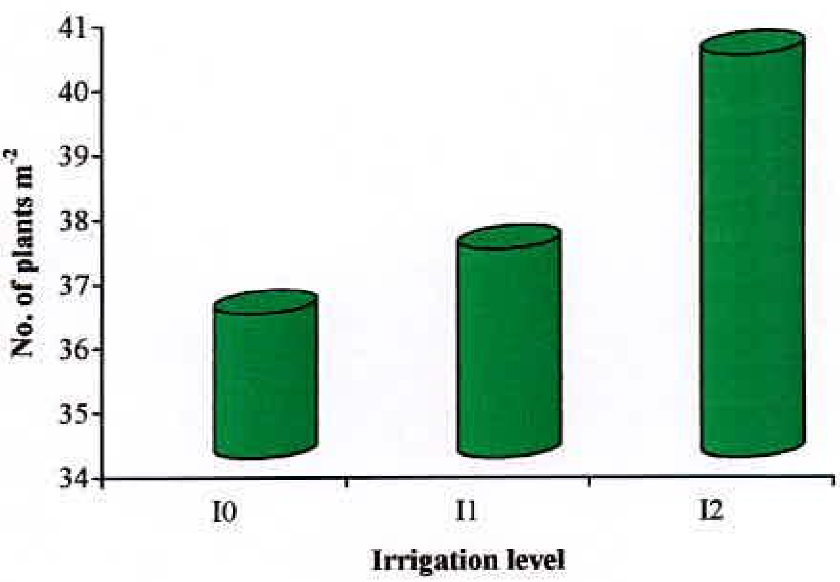
Effect of irrigation level

The number of plant per meter square was not significantly increased by irrigation in the study. There were little differences among the number of plants per meter square (Fig. 4.10). Initially, seeds were given light irrigation for proper germination and establishment. Therefore, plant establishment was almost same in every plot. The highest number of plants per meter square (40.25) was found with two irrigations at 30 DAS and 60 DAS while the lowest number of plants (36.25) were found without irrigation in case of rapeseed line SAU-C-F_7 (Fig. 4.10). The small differences were due to the mortality of some plants without irrigation. This result confirms the findings of Sarker *et al.* (2001) who noticed more number of populations per m^2 in rapeseed was more with increased irrigation levels but the differences were not statistically different.



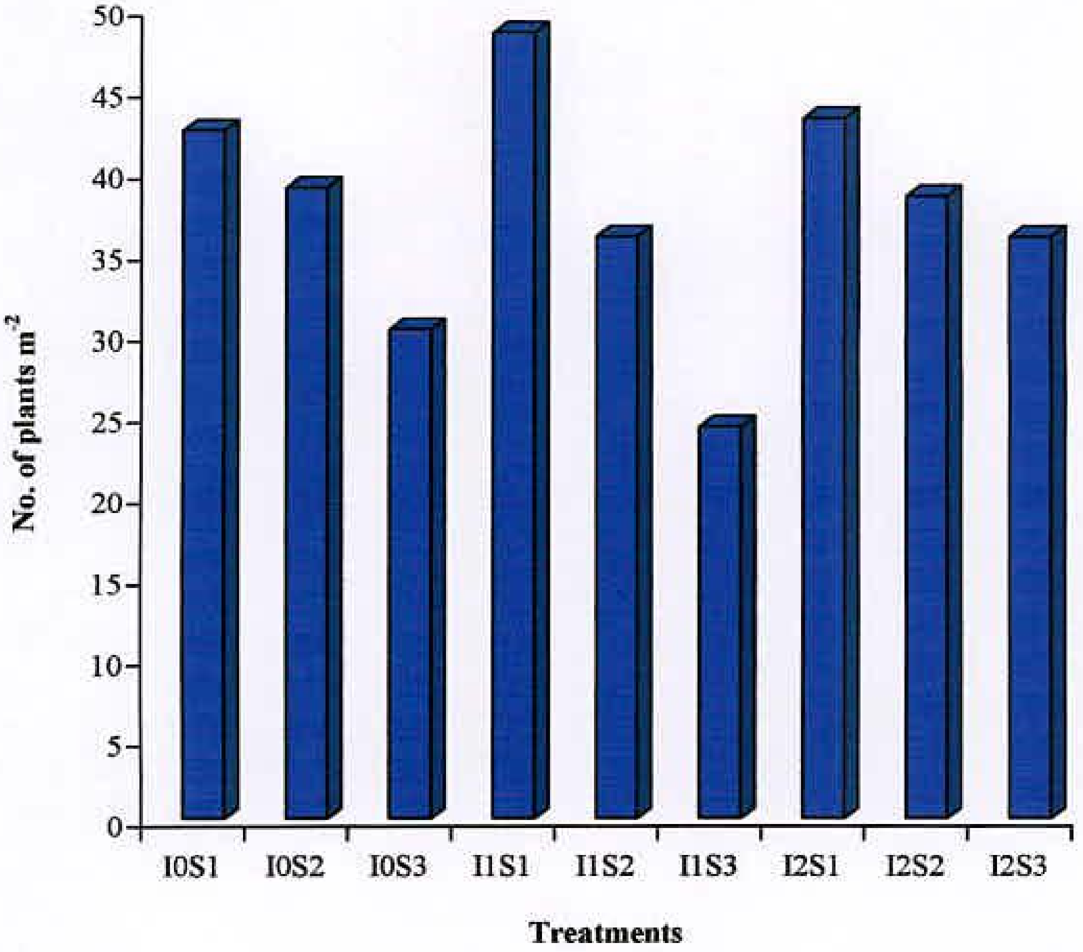
S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Fig. 4.9 Number of plants m^{-2} of rapeseed line SAU-C-F_7 at harvest as affected by row spacing



I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

Fig. 4.10 Number of plants m^{-2} of rapeseed line SAU-C-F_7 at harvest as affected by irrigation level



I_0 = No irrigation S_1 = 20 cm row spacing
I_1 = One irrigation at 30 DAS S_2 = 30 cm row spacing
I_2 = Two irrigations at 30 and 60 DAS S_3 = 40 cm row spacing

Fig. 4.11 Number of plants m^{-2} of rapeseed line SAU-C-F$_7$ at harvest as affected by the combined effect of irrigation level and row spacing

Interaction effect of irrigation level and row spacing

Significant variation in the number of plants per meter square was found among irrigation and row spacing combinations (Fig. 4.11). In this study, significantly highest number of plants per meter square (48.50) was found from the interaction of one irrigation and 20 cm row spacing (I_1S_1). The second highest population was observed with I_2S_1 (43.25) which were identical with I_0S_1 (42.50). The lowest number of plants per meter square (24.25) was found from the interaction of one irrigation and 40 cm row spacing (I_1S_3). These results indicated that spacing had more contribution than irrigation in their interaction effect in relation to the number of plants per meter square in the rapeseed line SAU-C-F_7.

4.6 Yield attributes

4.6.1 Number of branches per plant

Number of branches per plant is the result of genetic make up of the crop and environmental conditions, which plays a remarkable role towards the final seed yield of the crop (Sana *et al.*, 2003). Number of branches per plant is an important factor which affects the yield per plant and in this study it indicated that the number of branches per plant varied significantly with different row spacing and level of irrigation.

Effect of row spacing

Number of branches per plant was significantly influenced by row spacing (Table 4.13). Closer row spacing significantly decreased the number of branches per plant. The significantly highest number of branches per plant (7.83) was found in the widest row spacing of 40 cm and the lowest (6.38) from the closer row spacing of 20 cm. Wider spacing increased the number of branches per plant by 22.7% over control. Intermediate spacing increased 13.0% branch. Chauhan *et al.* (1993) found similar results. Lower density increased the number of branches which might be due to less inter plant competition for light, nutrients, space and environmental resources (Alam, 2004). In rapeseed reduced number of branches per plant due to increasing population density has been reported by Giri and Gangasaran (1985), Ali *et al.* (1990), Singh and Dhillon (1991) and Singh and Verma (1993). Kumar and Ganwar (1984) obtained maximum number of primary and secondary branches plant^{-1} in *Brassica campestris* at 30 and 40 cm apart in row, which eventually significantly increased the seed yield. When the crop was planted at 20 cm apart rows the number of branches plant^{-1} was reduced resulting in less seed yield ha^{-1}. Ganwar and Kumar (1986) and Tomar (1989) reported that when *Brassica campestris* var. Toria was growing and maintaining 16.6 and 22.2 plants m^{-2} (50 cm and 45 cm row spacing), it increased the number of primary and secondary branches plant^{-1} and those profuse branches was desirable for higher seed yield of rapeseed and mustard (*Brassica campestris* and *Brassica juncea*). Shrief *et al.* (1990) reported that lower plant density increased the number of branches plant^{-1}. Oad *et al.* (2002) found maximum branches per plant in safflower when row spacing was maintained as 45 cm and it was significantly different from the number of branches found from 35 cm and 25 cm row spacing.

Effect of irrigation level

From the study it was found that irrigation has great influence on the number of branches per plant in rapeseed line SAU-C-F_7 (Table 4.14). Number of irrigation significantly increased the number of branches per plant. The maximum numbers of branches (9.45) were found from a plant subjected to two irrigations, one at 30 DAS and other at 60 DAS. The lowest numbers of branches (4.49) were found from control treatment. The maximum increases in branches was observed as 110.5% compared to unirrigated control when two irrigation was applied at 30 and 60 DAS. Branch number was also increased with the application of one irrigations at 30 DAS over control. But the rate was lower (62.36%) than two irrigations. Clarke (1978) and Clarke and Simpson (1978) found that irrigation scarcely affected number of branches plant^{-1}. Joarder *et al.* (1979) also observed that irrigation increased primary and secondary branches plant^{-1}. Tomer *et al.* (1992) noticed significant increase in the number of branches per plant up to two irrigations. Rahman (1994) also reported that two irrigations gave the highest number of branches plant^{-1} and the lowest number of branches per plant was found in case of without irrigation. Probably irrigation water supported plant to initiate more branches.

Interaction effect of irrigation levels and row spacing

In the rapeseed line SAU-C-F_7 the number of branches per plant were significantly increased by the interaction effect of irrigation level and row spacing (Table 4.15). The effect of irrigation interacts better with row spacing when sufficient moisture was supplied. In the study the maximum number of branches per plant (9.57) was found from the interaction between two irrigations at 30 and 60 DAS (I_2) and 40 cm row spacing (S_3). It was followed by all the combinations of row spacing with two irrigations (I_2S_1, I_2S_2 and I_2S_3). The least number of branches (4.25) were found from the interaction between I_0 (without irrigation) and closer row spacing of 30 cm (S_1). Wider spacings combined with no irrigation could improve the situation. It revealed that a rapeseed plant with sufficient moisture with sufficient space only produced higher number of branches per plant. The current study with wider row spacing (40 cm) and two irrigations gave 107% more branches than that of wider spacing combined with no irrigation. This finding was in agreement with the result found by Tomer *et al.* (1992) who obtained maximum number of branches per plant with 40 cm row spacing and 2 irrigations at preflowering and fruiting stage. Irrigated plant was stimulated to produce maximum branches when it had favourable environment due to wider row spacing.

4.6.2 Number of siliquae per plant

Number of siliquae per plant is the result of genetic make up of the crop and environmental conditions (Sana *et al.*, 2003). It is an important yield contributing character which has a great effect on final yield.

Effect of row spacing

Significant difference was found in number of siliquae per plant at different row spacing. The number of total siliquae per plant gradually declined with the increase in number of plants per unit area due to closer spacing. This result confirmed the findings of Ali *et al.* (1990), Singh and Dhillon (1991), Misra and Rana (1992), Chauhan *et al.* (1993) and Roy *et al.* (1993).

Table 4.13 Yield attributes and yield of rapeseed line SAU-C-F$_7$ as affected by row spacing during 2004-2005 Rabi season

Row spacing	No. of branches plant^{-1}	No. of siliquae plant^{-1}	No. of seeds siliqua^{-1}	No. of seeds plant^{-1}	1000-seed weight (g)
S_1	6.38	73.28	18.01	1467.10	2.82
S_2	7.21	74.63	20.25	1515.40	2.88
S_3	7.83	79.47	20.30	1611.20	2.94
LSD 0.05	**0.43**	**5.00**	**0.96**	**102.90**	**0.06**
CV (%)	**8.06**	**7.70**	**5.73**	**7.84**	**2.54**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Increase in population by closer row spacing exerted a detrimental effect in siliqua fertility in rapeseed (Siddiqui, 1999). Table 4.13 showed that number of siliquae per plant decrease with the increase of population per unit area. The highest number of siliquae per plant (79.47) was recorded at wider spacing of 40 cm (S_3) and the lowest (73.28) at closest spacing (20 cm) which was a difference of 8.5%. Number of siliquae plant^{-1} directly correlates with dry matter production by the plants (Mumier-Jolain *et al.*, 1998). Singh and Singh (1984a) and Gupta (1988) obtained higher number of siliquae plant^{-1} at lower plant density. The treatment S_1 produced the lowest number of siliquae per plant, because mutual shading reduced the light interception. As a result, photosynthesis was affected and siliqua formation was hampered. The wider spacing (S_3) produced more number of siliquae plant^{-1} than closer row spacing because of the fact that wider spacing facilitates maximum utilization of solar energy by providing sufficient space to intercept light as well as other environmental resources which helped photosynthesis and ultimately produced more dry matter that eventually partitioned towards sink (siliqua). This result was corroborated with the results found by Alam (2004).

Effect of Irrigation level

Number of siliquae is an important factor for increasing yield, which is adversely affected by the soil moisture. So irrigation plays an important role in increasing the yield and yield attributes. In the present study, number of irrigation showed significant variation in producing siliquae plant^{-1} (Table 4.14). Among the treatment I_2 produced the highest number of siliquae (120.3) which was statistically different from I_1 (76.14) and I_0 (30.99) and the differences were 288.2% and 145.7%, respectively over control. The treatment I_2 (two irrigations at 30 DAS and 60 DAS) showed around 4 times higher number of siliquae per plant over the control (no irrigation). The treatment I_0 which received no irrigation throughout the life cycle thus produced the lowest number of siliquae. In case of I_2 the second irrigation at siliqua formation stage helped in producing more number of siliquae. But in case of treatment I_1 only one irrigation was applied at flowering stage and at later stage (siliqua formation) insufficient soil moisture reduced the number of siliquae per plant. Second irrigation also reduced the dropping of siliquae. The results obtained from the study were partially supported by Clarke and Simpson (1978), Joarder *et al.* (1979), Sarker and Hassan (1988), Sharma and

Kumar (1989a) and Dobariya and Mehta (1995) who reported that irrigation increased siliquae plant^{-1}. Tomer *et al.* (1992) concluded that number of siliquae per plant was significantly increased up to two irrigations at pre-flowering and fruiting stage.

Table 4.14 Yield attributes of rapeseed line SAU-C-F_7 as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	No. of branches plant^{-1}	No. of siliquae plant^{-1}	No. of seeds siliqua^{-1}	No. of seeds plant^{-1}	1000-seed weight (g)
I_0	4.49	30.99	17.51	543.60	2.71
I_1	7.29	76.14	19.69	1482.30	2.86
I_2	9.45	120.30	21.37	2567.50	3.07
LSD 0.05	**0.38**	**8.81**	**0.96**	**173.20**	**0.09**
CV (%)	8.06	7.70	5.73	7.84	2.54

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

Interaction effect of irrigation level and row spacing

Favourable moisture regimes influenced plant to produce more biomass, which eventually portioned to siliquae. Significant difference was found due to the interaction of irrigation and row spacing (Table 4.15). Two irrigation, at 40 cm row spacing (I_2S_3) produced the highest number of siliquae per plant (131.40) which about 392.1% greater than that of I_0S_2, which confirmed the results of Tomer *et al.* (1992). The lowest number of siliquae (26.70) was found from the treatment I_0S_1. Even wider space with no irrigation could not improve the siliquae number. At I_2S_3 second irrigation provided sufficient soil moisture and S_3 provided more space and light which helped in producing more siliquae. Andrews (1972) reported the positive effect of irrigation water towards siliqua formation.

Table 4.15 Yield attributes of rapeseed line SAU-C-F_7 as affected by the combined effect of irrigation level and row spacing during 2004-2005 Rabi season

Irrigation level × Row spacing	No. of branches plant^{-1}	No. of siliquae plant^{-1}	No. of seeds siliqua^{-1}	No. of seeds plant^{-1}	1000-seed weight (g)
I_0S_1	4.25	26.70	19.26	525.10	2.66
I_0S_2	4.60	27.05	16.06	429.20	2.76
I_0S_3	4.62	39.22	17.20	676.60	2.72
I_1S_1	6.45	61.41	20.70	1270.30	2.83
I_1S_2	7.70	79.95	22.25	1775.60	2.88
I_1S_3	7.72	87.05	16.11	1402.50	2.89
I_2S_1	9.42	112.10	20.95	2628.40	2.98
I_2S_2	9.35	117.30	22.44	2321.30	3.01
I_2S_3	9.57	131.40	20.72	2751.40	3.21
LSD 0.05	**0.84**	**8.67**	**1.66**	**178.20**	**0.10**
CV (%)	**8.06**	**7.70**	**5.73**	**7.84**	**2.54**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

6.3 Number of seeds per siliqua

Number of seeds per siliqua is also an important factor which contributes towards seed yield. Row spacings as well as irrigation levels had a significant effect on the number of seeds siliqua^{-1} in this study.

Effect of row spacing

Number of seeds per siliqua varied significantly with the variation in row spacing. It evident that the number of seeds per siliqua significantly decreases with the increase of population density for closer row spacing (Table 4.13). On an average, the highest number of seeds per siliqua (20.30) was recorded from the widest row spacing of 40 cm which was statistically identical with the seeds per siliqua found from 30 cm row spacing. The lowest number of seeds per siliqua (18.01) was found from the closest row spacing of 20 cm. Decrease in row spacing increase population density which decreases the number of seeds per siliqua because increasing population density exerted a detrimental effect on siliqua formation in rapeseed (Siddiqui, 1999) . Singh and Singh (1984a) reported that the number of seeds siliqua^{-1} increased as the plant density decreased. Because, at higher densities inter-plant competition was also highest which eventually caused reduction in number of seeds per siliqua. Reduction in number of seeds per siliqua in rapeseed and mustard with increasing population density was reported by Singh and Singh (1984b), Singh and Dhillon (1991), Misra and Rana (1992) and Sharma (1992).

Effect of irrigation level

Number seeds per siliqua were significantly affected by irrigation levels in this experiment. The number of seeds per siliqua was increased with the increase of irrigation number (Table 4.14). The significantly highest number of seeds (21.37) was found with two irrigations at 30 DAS and 60 DAS while the lowest number of seed per siliqua (17.51) was found from the control treatment. Seed per siliqua increased with increasing levels of irrigation due to the supply of adequate soil moisture which helped to be the siliquae longer and have more number of seeds. The second irrigation at 60 helped in the formation of seeds in siliqua. Tomer *et al.* (1992) found a significant increase of seeds $siliqua^{-1}$ with two irrigations-one at pre-flowering stage and another at fruiting stage. A number of researchers (Clarke and Simpson, 1978; Prasad and Eshanullah (1988), Sarker and Hassan, 1988; Sharma and Kumar, 1989b and Dobariya and Mehta (1995) also observed that irrigation increased number of seed $siliqua^{-1}$.

Interaction effect of irrigation level and row spacing

Irrigation as well as row spacing interact each other to produce seeds per siliqua in rapeseed line SAU-C-F_7. Significant variations in the number of seeds per siliqua were found with the different interaction of irrigation and row spacing in the study (Table 4.15). The highest number of seeds per siliqua (22.44) was found when two irrigations were applied with 30 cm row spacing (I_2S_2) which was followed by I_1S_2 (22.25) and I_2S_1 (20.95). The lowest number of seeds per siliqua (16.06) were found from the treatment I_0S_2 which was statistically identical with I_0S_3 and I_1S_3. It revealed that irrigation had contributed more in the formation of seed in the siliqua of wider spaced plant. The increasing demand of moisture for siliqua setting was only fulfilled in the plots provided by two irrigations.

4.6.4 Number of seeds per plant

The number of seeds per plant contributes materially towards the final seed yield in rapeseed and it was affected by irrigation levels and row spacing in this study.

Effect of row spacing

Row spacing also affected the number of seeds per plant significantly in the study (Table 4.13). Row spacing of 40 cm provided the highest number of seed per plant (1611.2) which was also identical with the results at 30 cm spacing. The number of seeds was found to be lowest (1467.1) with 20 cm spacing which was identical with the result of 30 cm spacing. The closer the row spacing lower was the number of seeds per plant. It might be due to less number of siliquae per plant as well as less number seeds per siliqua as higher population density subjected to maximum competition, which affected the siliquae fertility. The similar conclusion was drawn by Siddiqui (1999).

Effect of irrigation level

Number of seeds per plant was greatly increased with the increase of irrigation levels in rapeseed line SAU-C-F_7. Because irrigation significantly increased the number of siliquae per plant and seeds per siliqua as well (Table 4.14). The highest number of seeds per plant (2567.5) was found from two irrigation at 30 DAS and 60 DAS because irrigation created favourable conditions to develop siliquae and seeds. The lowest number of seeds per plant (543.6) was found with unirrigated control. The treatment I_2 produced around 3 times and 4 times more seeds than I_1 and I_0, respectively. The reason for the maximum number of seeds plant^{-1} with two irrigations might be due to adequate soil moisture at flowering and seed filling stage. Two irrigations increased the number of siliquae per plant as well as seeds per siliqua which are in consonance with those of Saran and Giri (1988). Angadi *et al.* (1999) reported that in semi-arid regions, the rooting characteristics of canola (*Brassica napus*) require adequate subsoil moisture to sustain the crop during flowering and seed filling to get more seeds per plant.

Interaction effect of irrigation level and row spacing

In the study, the interaction of irrigation levels and row spacing has also a great influence on the number of seeds per plant. Any interaction of row spacing with two irrigations one at 30 DAS and other at 60 DAS provided more number of seeds per plant than others (Table 4.15). The highest number of seeds (2751.4) were found with the interaction of two irrigations and 40 cm row spacing (I_2S_3) which was statistically identical with the number of seeds per plant found from the interaction of two irrigations and 20 cm row spacing (I_2S_1). The lowest number of seed (429.2) was found from non irrigated condition at 30 cm row spacing (I_0S_2). This result corroborated with the finding of Saran and Giri (1988).

4.6.5 1000-seed weight

The weight of seed is related with the magnitude of seed development because it is an important yield determinant factor and plays a decisive role in expressions yield potential of a variety (Sana *et al.*, 2003). It is evident from the study that 1000-seed weights of rapeseed line SAU-C-F_7 greatly affect the yield.

Effect of row spacing

Thousand seed weight of rapeseed line SAU-C-F_7 was significantly influenced by row spacing (Table 4.13). Sparsely populated crop produced heavier seeds than densely populated one. The highest 1000-seed weight of 2.94 g was recorded from the widest row spacing of 40 cm but it was statistically identical with the seed weight measured from 30 cm row spacing. The lowest 1000-seed weight (2.82 g) was obtained from the closest row spacing of 20 cm. In general, higher was the population density lower was the 1000-seed weight which confirmed the findings of Singh and Dhillon (1991), Singh and Verma (1993), Singh *et al.* (1996). At wider row spacing 1000-seed weight was higher because inter-plant competition was less and the plants got more space and growth resources for better seed development which resulted in heavier seeds (Siddiqui, 1999). At closer row spacing the situation was just reverse. Reduction in 1000-seed weight due to increased population density was been reported by Miah *et al.* (1987), Gupta (1988), in mustard; Misra and Rana (1992) and Chauhan *et al.* (1993) in rapeseed; Prasad *et al.* (1993) in soybean; Kenjale *et al.* (1995) in French bean; and Reddy and Giri (1989) in groundnut.

Effect of irrigation level

From Table 4.14, it can be seen that the irrigation levels had significant effect on 1000-seed weight. Two irrigations at 30 DAS and 60 DAS produced the highest 1000-seed weight of 3.07 g which was significantly superior to 2.86 g produced by one irrigation applied at 30 DAS. The lowest 1000-seed weight (2.71 g) was produced by plants without irrigation (control). More seed weight was gained with more irrigation. Rahman (1994) found a significant effect of irrigation on 1000-seed weight. The results obtained in the study were supported by Sarkar and Hassan (1988), Sharma and Kumar (1990) and Sarker *et al.* (2000) who reported that increasing frequency of irrigation increased 1000-seed weight.

Interaction effect of irrigation levels and row spacing

In this study, interaction effect of irrigation and row spacing was found significant in relation to 1000-seed weight of rapeseed line SAU-C-F_7 (Table 4.15). The highest weight of 1000 seed (3.21 g) was found from the combination of two irrigation one at 30 DAS and other at 60 DAS with 40 cm row spacing (I_2S_3). Tomer *et al.* (1992) also found maximum weight of 1000 seed (3.93 g) with 2 irrigations at preflowering and fruiting stages at 40 cm row spacing. The lightest seed was found from the treatment combination of no irrigation and 20 cm row spacing (I_0S_1). However, the combination of the all the row spacings with no irrigation treatment were found statistically identical.

4.7 Seed yield per plant

Effect of row spacing

Row spacing is an important factor, which facilitates the use of plant nutrition, air and space to promote the seed yield of rapeseed (Thurling, 1974; Tomer *et al.*, 1992; Shahidullah *et al.*, 1997 and Roshid, 1998). In the present study, significant variation was found in seed yield per plant at different row spacings (Table 4.16). Among the treatments S_3 (40 cm row spacing) produced the highest seed yield per plant (4.76 g) which was statistically identical to S_2 (30 cm row spacing) where as S_1 produced the lowest seed yield per plant (3.68 g). Seed yield plant^{-1} with 40 cm row spacing was 29.34% and 1.28% higher than 20 cm row spacing (S_1) and 30 cm row spacing (S_2), respectively. As the treatment S_3 provided the maximum space, the rate of photosynthesis was higher and the partitioning of photosynthate was effectively translocated to the reproductive part. The reduction in seed yield per plant might be due to cumulative effect of less number of siliquae, smaller seed size, less number of seed per siliqua at for closer row spacing at S_1 (20 cm row spacing). This results corroborated with the result of Siddiqui (1999).

Effect of irrigation level

Seed yield per plant is a complex character which depends on the different yield contributing characters such as number of branches, number of siliquae per plant, number of seed per siliqua, 1000-seed weight etc. In this study seed yield per plant was significantly influenced by different irrigation treatments (Table 4.17) which ultimately affected those characters mentioned above. The treatment I_2 (two irrigation- one at 30 DAS and other at 60 DAS) produced the highest seed yield per plant (7.48 g) which was statistically different from I_1 (one irrigation at 30 DAS) (4.06 g) and the least seed yield was found at I_0 (no irrigation) (1.61 g). The increased seed yield plant^{-1} with two irrigations (I_2) was 364.59 % and 84.97% higher than one irrigation (I_1) and without irrigation (I_0). The treatment I_2 produced the highest number of branches, siliquae per plant, seed per siliqua, 1000-seed weight which ultimately increased the yield per plant. The second irrigation which was applied 60 DAS tremendously increased the number of siliquae which might be the major causes for increasing the yield. The treatment I_1 where only one irrigation was applied at branching stage increased the number of branches but during the siliqua formation stage the insufficient soil moisture hampered the siliqua production. The lowest yield was found from control treatment (no irrigation) because in this case growth and reproduction was hampered due to soil moisture deficit throughout the life cycle, which aggravated leaf senescence. These results corroborate the findings of Giri (2001) in case of rapeseed. Seed yield is greatly affected by water stress during flower initiation and siliqua filling stage. Two irrigations, one after 30 DAS and another at 60 DAS (siliqua filling stage) were most economic to increase the seed yield (Richard and Thurling, 1978). Irrigation greatly helps in retaining leaves which produces assimilates for a longer period and thus increase seed yield (Major, 1977). In *Brassica napus* removal of leaves at the commencement of flowering adversely affects yield, but defoliation after flowering has no significant effect (Frayman *et al.*, 1973; Clarke, 1978). The increased seed weight may be due to the availability of more photosynthate to the lesser number of seeds produced under such circumstances of irrigation (Kaul and Das, 1986). Rahman (1994) reported that the highest seed weight plant^{-1} was produced by two irrigations which were statistically superior to that produced by one irrigation.

Interaction effect of irrigation levels and row spacing

Significant interaction between irrigation and row spacing was found for the production of seed yield per plant in rapeseed line SAU-C-F_7 (Table 4.18).

Among the treatments I_2S_3 (two irrigation at 30 DAs and 60 DAS and 40 cm row spacing) produced the highest seed yield per plant (8.25 g) and it was followed by I_2S_2 (7.99 g). The treatment I_2S_1 produced the next highest yield which may be due to the shortage of soil moisture throughout the life cycle of plant. The least seed yield was confirmed with I_0S_2 (1.22 g). Treatment I_2S_3 outyielded I_0S_2 by 576.23%. Giri (2001) also found the maximum seed yield plant^{-1} with 2 irrigations at flowering and pod developing stages with wider row spacing (50 cm).

Table 4.16 Yield and harvest index of rapeseed line SAU-C-F_7 as affected by row spacing during 2004-2005 Rabi season

Row spacing	Seed yield plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
S_1	3.68	1502.20	2767.40	4585.10	32.17
S_2	4.70	1793.50	2933.20	6162.20	36.20
S_3	4.76	1652.30	2558.60	5218.30	33.58
LSD 0.05	**0.42**	**196.80**	**75.86**	**211.30**	**2.20**
CV (%)	**11.30**	**13.91**	**3.21**	**5.60**	**8.04**

S_1 = 20 cm row spacing
S_2 = 30 cm row spacing
S_3 = 40 cm row spacing

Table 4.17 Yield and harvest index of rapeseed line SAU-C-F_7 as affected by irrigation level during 2004-2005 Rabi season

Irrigation level	Seed yield plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
I_0	1.61	592.00	1232.10	1824.10	32.67
I_1	4.06	1439.40	3247.50	5218.40	27.20
I_2	7.48	2915.10	3778.30	6162.30	47.08
LSD 0.05	**0.744**	**356**	**58.26**	**332.2**	**5.596**
CV (%)	**11.30**	**13.91**	**3.21**	**5.60**	**8.04**

I_0 = No irrigation
I_1 = One irrigation at 30 DAS
I_2 = Two irrigations at 30 and 60 DAS

Table 4.18 Yield and harvest index of rapeseed line SAU-C-F_7 as affected by the combined effect of irrigation level and row spacing during 2004-2005 Rabi season

Irrigation levels × Row spacing	Seed yield plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
I_0S_1	1.56	664.70	1313.10	1978.40	33.31
I_0S_2	1.22	631.40	1451.20	1931.30	24.73
I_0S_3	2.06	479.90	932.90	1564.20	39.97
I_1S_1	3.31	1607.20	3131.70	5730.10	28.00
I_1S_2	4.82	1729.10	3363.60	5447.10	31.71
I_1S_3	4.04	981.90	3494.50	4476.40	21.90
I_2S_1	6.19	2683.10	2718.30	6047.10	46.74
I_2S_2	7.99	3169.40	4123.40	6300.40	50.29
I_2S_3	8.25	2891.20	3247.20	6138.10	44.21
LSD 0.05	0.73	340.80	131.40	366.10	4.25
CV (%)	11.30	13.91	3.21	5.60	8.04

I_0 = No irrigation S_1 = 20 cm row spacing
I_1 = One irrigation at 30 DAS S_2 = 30 cm row spacing
I_2 = Two irrigations at 30 and 60 DAS S_3 = 40 cm row spacing

4.8 Seed yield per hectare

Effect of row spacing

Row spacing has significant effect on plant population per unit area, number of siliquae per plant, number of seeds per siliqua and individual seed weight and the improved seed yield per hectare. Table 4.16 showed the significant variation in seed yield per hectare at different row spacing ranging from 1502.20 to 1793.50 kg. The treatment S_2 produced the significantly highest seed yield (1793.50 kg ha^{-1}) which was followed by S_3 (1652.3 kg ha^{-1}). The maximum seed yield ha^{-1} with 30 cm row spacing was 19.39% and 8.54% higher than the yield obtained from 20 cm and 40 cm row spacing, respectively. This indicated that the number of plant population must be optimum to achieve the highest seed yield. In case of excessive plant population inter and intra-plant competition reduces the seed yield. On the contrary, the lower number of plant per unit area reduced the seed yield due to insufficient plant population. So, S_1 treatment provided maximum number of plant population which decreased the seed yield due to mutual shading and less photosynthesis. It indicated that among the row spacings S_2 provided optimum number of plant as well as the highest yield. The treatment S_1 produced the lowest yield (1502.2 kg ha^{-1}). Too large population causes inter and intra plant competition, reduce the overall efficiency of crop (Siddiqui, 1999). BARI (1989) reported maximum seed yield ha^{-1} with 30 cm row spacing. Patel *et al.* (1980) and Singh and Singh (1987) found maximum seed yield with 45 cm row spacing. These results supported the agreement with those of Scarisbrick *et al.* (1982), Hamid and Hashem (1987) and Islam (1992) who reported that the highest seed yield per hectare of rapeseed could be achieved with population densities ranging from 50 to 60 plants m^{-2}. Singh and Dhillon (1991), Sharma and Thakur (1993), Singh and Verma (1993) and Gurjar and Chauhan (1997) found maximum seed yield per hectare with 30 cm row spacing. Alam (2004) observed that intermediate plant density assisted to produce substantially higher seed yield. This was mainly due to the fact that an optimum plant density facilitated maximum utilization of solar radiation and nutrients which enhanced total dry matter production and development of other yield components. Closer row spacing causes competition for light, space, nutrients and environments and therefore, could not produce branches $plant^{-1}$, siliquae $plant^{-1}$, seeds $siliqua^{-1}$, 1000-seed weight and ultimately seed yield per unit area. Khader and Bhargava (1985) and Gupta (1988) recorded maximum seed yield of *Brassica juncea* and *Brassica campestris* with plant density of 44 plants m^{-2} (40 cm row spacing). Singh and Singh (1984a) obtained higher seed yield of *Brassica campestris* var. Toria with plant density level at 33.3 plants m^{-2} (45 cm row spacing).

Effect of irrigation level

Irrigation significantly increased the seed yield per hectare in rapeseed line SAU-C-F_7. In this study seed yield per hectare increased with increase of irrigation levels (Table 4.17). Maximum seed yield per hectare (2915.10 kg) was found from two irrigations (One at 30 DAS and another at 60 DAS) which were 206.65% and 102.52% higher than the yield obtained from the control treatment (I_0) and one irrigation (I_1). The lowest seed yield ha^{-1} was found from unirrigated control (592.00 kg ha^{-1}). In control condition high mortality of seedlings resulting from shortage of soil moisture drastically reduced the yield. Samui *et al.* (1986) and

Malavia *et al.* (1988) reported similar results in mustard. Under no irrigation treatment internal moisture deficit led to lower plant height, failed to increase in growth parameters and reduced the net assimilate rate, which adversely affected yield components and thus yield was reduced. The treatment I_2 (one at 30 DAS and another at 60 DAS) significantly increased the seed yield due to favourable growth condition with maximum production of dry matter especially at siliqua formation stage the second irrigation helped increasing the siliquae number. Similar result was also found by Singh *et al.* (1972) and Ali (1973) who noticed that the seed yield increased when the crop was irrigated twice – once at flowering stage, and the other at fruit forming stage rather than one – at flowering stage. The results obtained from the study are in agreement with those obtained by Joarder *et al.* (1979) who reported that irrigation increased seed yield of mustard. Sarma and Kumar (1989a) observed that seed yield was increased with increasing frequency of irrigation. Singh and Srivastava (1986) revealed that yield was the highest with two irrigations. Rahman (1994) reported that the highest seed yield was produced by two irrigations. The significantly lowest yield was produced by no irrigation and this was statistically inferior to one irrigation. Under non-irrigated condition internal moisture deficit led to lower plant height, failed to increase the growth parameters, which adversely affected the yield components, viz. dry matter accumulation, siliquae plant^{-1}, seeds siliqua^{-1} and 1000-seed weight (Tomer *et al.*, 1992). These result corroborated with the results of Khan and Agarwal (1985), Samui *et al.* (1986), Malavia *et al.* (1988), Rana *et al.* (1991) and Gill and Narag (1993). Water stress during flowering causes severe yield loss. Johnston *et al.* (2002) reported that heat stress during flowering of a canola (*Brassica napus*) crop can permanently stop flowering, resulting in limited seed set after accumulation of large amounts of dry matter.

Interaction effect of irrigation level and row spacing

Interaction between irrigation and row spacing plays an important role for promoting the yield. Table 4.18 showed significant variation in interaction effect between irrigation and row spacing. Among the treatments I_2S_2 produced the highest seed yield (3169.40 kg ha^{-1}) which was 560.42% higher than the lowest yield (479.90 kg ha^{-1}) by I_0S_3. It was followed by I_2S_3 (2891.20 kg ha^{-1}). The lowest seed yield was obtained from I_0S_3. This result confirmed the findings of Siag *et al.* (1993) who obtained maximum yield with two irrigations at branching and flowering stages with 30 cm row spacing. Gill and Narag (1993) also found similar result with 45 cm row spacing. At I_2S_2 two irrigations at 30 DAS and 60 DAS along with 30 cm row spacing provided optimum soil moisture for adequate number of plant population which helped producing higher yield than the other treatments. The treatment I_0S_3 produced the lowest yield which might be referred to soil moisture deficit and inadequate plant population.

4.9 Stover yield per hectare

Effect of row spacing

Stover yield of rapeseed is greatly affected by row spacing as it was determined by plant population per unit area. Table 4.16 showed significant variation in stover yield among the row spacings. Among 3 row spacings (20, 30 and 40 cm), 30 cm row spacing produced the significantly highest stover yield

(2933.20 kg ha^{-1}) which was 5.99.65% and 14.64% higher than the stover yield obtained from 20 cm row spacing (S_1) and 40 cm row spacing (S_3). Patel *et al.* (1980) and Chauhan *et al.* (1993) found maximum stover yield with 30 cm row spacing. The 30 cm row spacing maintained adequate number of plants with higher biomass yield. At S_1 (20 cm row spacing) though the plant population was higher, lower was the plant growth which was found due to inter-plant competition that reduced the stover yield. At 40 cm row spacing though the plant growth was more vigorous but lower plant population reduced the stover yield per unit area due to poor growth performance.

Effect of irrigation level

The number of irrigation increases the plant height, number of branches, number of leaves, length of the inflorescence which ultimately increases the stover yield. In this study, significant variation was found in stover yield at different irrigation levels (Table 4.17). The treatment I_2 produced the highest stover yield (3778.40 kg ha^{-1}) which was statistically different from I_1 and I_0. It was 206.65% and 16.34% higher than the yield found from I_0 (no irrigation) and I_1 (one irrigation at 30 DAS), respectively. In the previous discussion it was shown that the I_2 treatment produced the tallest plant height, number of branches per plant and number of siliquae per plant, which cumulated the increased stover yield. The treatment I_0 (no irrigation) produced the lowest stover yield (1232.10 kg ha^{-1}). Patel *et al.* (1991), Sarker *et al.* (2000), and Sarker *et al.* (2001) found increased stover yield with increase number of irrigation. Sarker (1994) reported that two irrigations gave the highest stover yield plant^{-1} while the lowest yield was found from zero irrigation. This was in conformity with the findings of Saran and Giri (1988).

Interaction effect of irrigation level and row spacing

The number of irrigation along with different row spacing showed significant variation in producing stover yield. Table 4.18 showed that the treatment I_2S_2 produced the significantly highest stover yield (4123.40 kg ha^{-1}) whereas the treatment I_0S_3 produced the lowest stover yield (932.90 kg ha^{-1}).

4.10 Biological yield per hectare

Biological yield is the summation of seed yield and stover yield which was greatly influenced by different row spacing and irrigation level.

Effect of row spacing

The row spacing is an important factor for biological yield per unit area because number of plant population significantly influences the total biomass per unit area. In this experiment, Table 4.16 showed that the row spacing had significant effect on biological yield. The highest biomass (6162.20 kg ha^{-1}) was produced at S_2 (20 cm row spacing) which was significantly different from biomass produced at S_3 (40 cm row spacing). The second highest biological yield (5218.30 kg ha^{-1}) was found at S_3 (40 cm row spacing) which was statistically identical with S_1 (20 cm row spacing) which produced lowest biological yield (4585.10 kg ha^{-1}). At S_2 adequate number of plants increased the biological yield. On the contrary, S_1 provided the highest number of plant population but the mutual shading reduced the photosynthesis leading to production of minimum biomass, which measured in lower biological yield. The lowest biological yield in S_3 was due to inadequate plant population.

Effect of irrigation level

Different irrigation levels produced significantly variation in biological yield of rapeseed line SAU-C-F_7. Among the three irrigation levels I_2 produced the highest biological yield (6162.3 kg ha^{-1}). The control treatment produced the lowest biological yield (1824.10 kg ha^{-1}) which may be referred to water stress. Table 4.17 showed that I_2 increased not only seed yield but also hay yield. Reproductive development as well as vegetative growth promote the biological yield. Different experiments showed significant variation in biological yield at different irrigation levels. So, stover yield is equally important to seed yield for biological yield. Biological yield increases with the increase in irrigation levels (Saran and Giri, 1988). Maximum plant survival was also a reason to give highest biological yield per hectare (Subhanullah *et al.*, 1997) because they produced more seed and stover with two irrigations.

Interaction effect of irrigation level and row spacing

Table 4.18 showed that the combined effect of irrigation and row spacing influenced the biological yield (kg ha^{-1}) in the present study. The treatment I_2S_2 produced the highest biological yield and it was followed by I_2S_3 and I_2S_1. The lowest biomass was found from the treatment I_0S_3 and significantly different from the other.

4.11 Harvest index

Harvest index is the ratio of economic yield and biological yield and it was also influenced by row spacings and different irrigation levels.

Effect of row spacing

Different row spacing affected the plant population which ultimately affected the reproduction and growth of rapeseed line SAU-C-F_7. In this study row spacing had significant effect on harvest index (Table 4.16). The treatment S_2 produced the highest harvest index (36.02%) which was significantly greater than S_3 (33.58%) and S_1 (32.17%). This results corroborated the result of Shrief *et al.* (1990). According to Singh *et al.* (1996), maximum harvest index was found with 30 cm row spacing. Ali *et al.* (1996) reported the highest harvest index at plant density of 40 plants m^{-2}. Singh and Singh (1984a) reported that at higher plant density levels of 33.3 plants m^{-2} resulted with higher harvest index and consequently higher grain yield in *Brassica campestris*. Roshid (1998) observed that harvest index declined as the population densities exceeded 40 plants m^{-2} in sesame.

Effect of irrigation level

It was observed from the Table 4.17 that different irrigation levels had significant effect on harvest index. Among the three irrigation levels two irrigations gave the highest harvest index (47.08%) and it was significantly different from the other treatments. The lowest value of harvest index (27.20%) was obtained from the treatment I_1 (one irrigation at 30 DAS). Two irrigations, one at 30 DAS and other at 60 DAS produced higher seed yield which increased the harvest index. At I_0 treatment the plant suffered from severe water stress condition and they reproduced poor seed. One irrigation at pre-flowering stage increased the vegetative growth but at reproductive phase due to shortage of soil moisture the seed yield was seriously hampered and that is why it produced the lowest harvest index. Shrivastava *et al.* (1988) also found that two irrigations at pre-flowering and seed development stages produced higher harvest index. Similar results were obtained by Sarker (1994) who observed that two irrigations gave the higher harvest index and this was statistically superior to one irrigation. He found the lowest harvest index was given by no irrigation which was statistically inferior to two irrigations but statistically identical with one irrigation. It is evident from the result that increasing irrigation levels significantly increased harvest index. The cause of increase in harvest index may be due to the higher seed yield compared to biological yield as obtained by increasing levels of irrigation.

Interaction effect of irrigation level and row spacing

Interaction between irrigation and row spacing may be important determining factor for harvest index. Table 4.18 showed the significant interaction between irrigation and row spacing on harvest index where the treatment I_2S_2 produced the highest harvest index (50.29%) which was followed by I_2S_1 (46.74%). The treatment I_1S_3 produced the lowest harvest index (21.90%). In the treatment I_2S_2, two irrigations one at 30 DAS and other at 60 DAS influenced the economic yield with optimized plant population. In the treatment I_2S_3 though two irrigations were applied the wider plant spacing facilitated vegetative growth rather than reproductive development. As a result, the harvest index was smaller than I_2S_2.

4.12 Correlation and regression analysis

Table 4.19 revealed that number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight and seed yield plant^{-1} were positively correlated with each other. The intercorrelations were also significant except the relation of number of branches plant^{-1} and number of siliquae plant^{-1} each with the number of seeds siliqua^{-1}. Number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight had a significant correlation with seed yield plant^{-1} with the r values of 0.95, 0.97, 0.67, 0.96 and 0.94. All of them except number of seed siliqua^{-1} were highly significant. Number of seed siliqua^{-1} was significantly correlated with seed yield plant^{-1} at 5% level. The coefficients of determination also showed a positive linear and significant relation of number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight with seed yield plant^{-1} with R^2=0.91**, R^2=0,95**, R^2=0.46*, R^2=0.92**, R^2=0.88**, respectively (Fig. 4.12, 4.13, 3.14, 4.15 and 4.16). The slope for number of siliquae plant^{-1} and seed yield plant^{-1} indicated that an increment of 1 siliquae plant^{-1} increases 0.06 g seed yield plant^{-1} (Fig. 4.13).

The seed yield variations of rapeseed could be attributed to the number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight following different row spacing and irrigation levels in rapeseed plant. The above relations suggested ensuring the maximum yield it should be improved the yield attributes.

Table 4.19 Correlation between seed yield and yield attributes of rapeseed line SAU-C-F_7 as affected by the combination effect of irrigation level and row spacing

Parameters	No. of branches plant^{-1}	No. of siliquae plant^{-1}	No. of seeds siliqua^{-1}	No. of seeds plant^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)
No. of branches plant^{-1}	1.00	0.98 **	0.61 NS	0.97 **	0.92 **	0.95 **
No. of siliquae plant^{-1}		1.00	0.58 NS	0.97 **	0.95 **	0.97 **
No. of seeds siliqua^{-1}			1.00	0.68 *	0.50 NS	0.67 *
No. of seeds plant^{-1}				1.00	0.93 **	0.96 **
1000-seed weight (g)					1.00	0.94 **
Seed yield plant^{-1} (g)						1.00

** significant at the 0.01 level.
* significant at the 0.05 level.
NS = non-significant

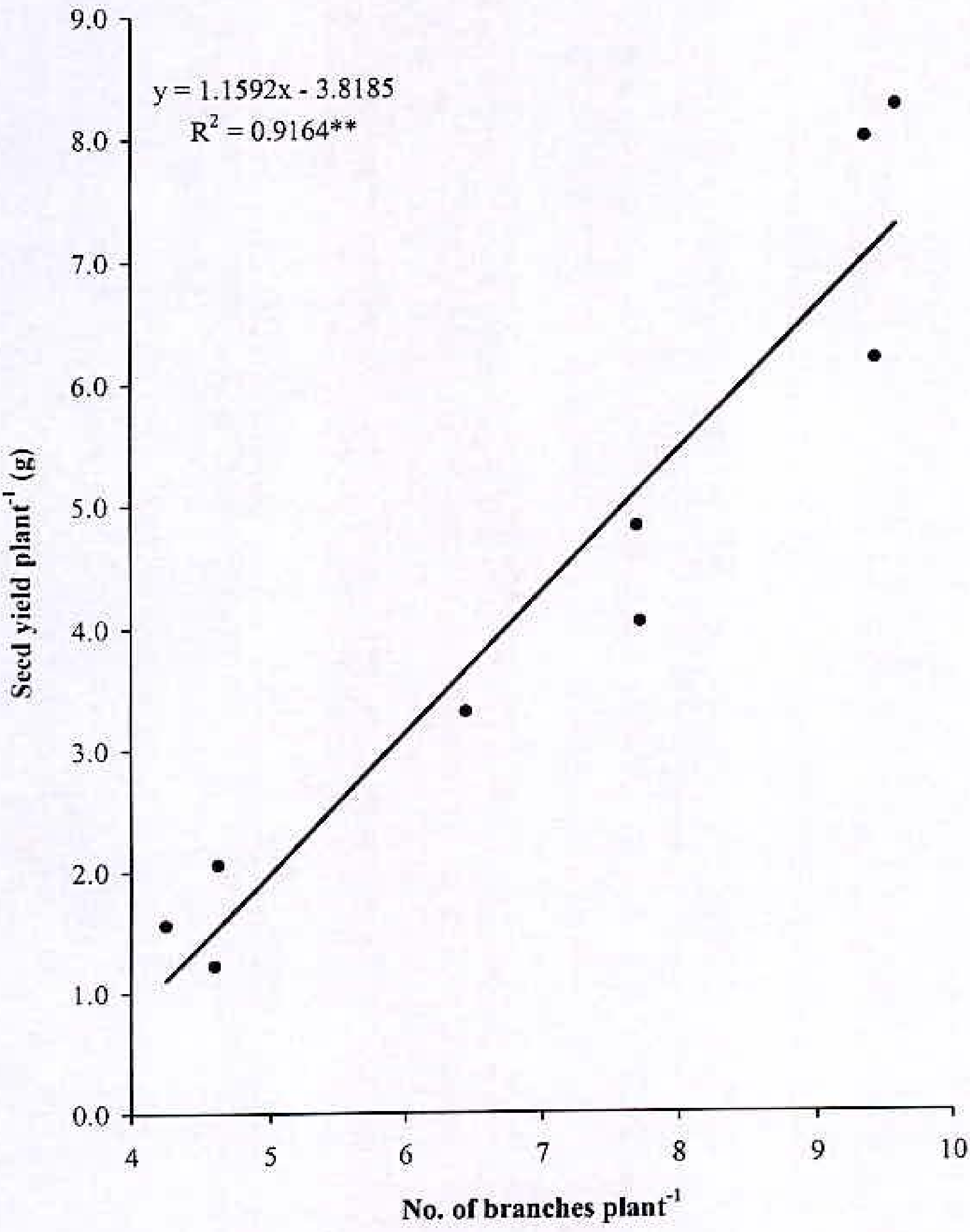


Fig. 4.12 Relationship between number of branches plant^{-1} and seed yield plant^{-1} of rapeseed line SAU-C-F_7

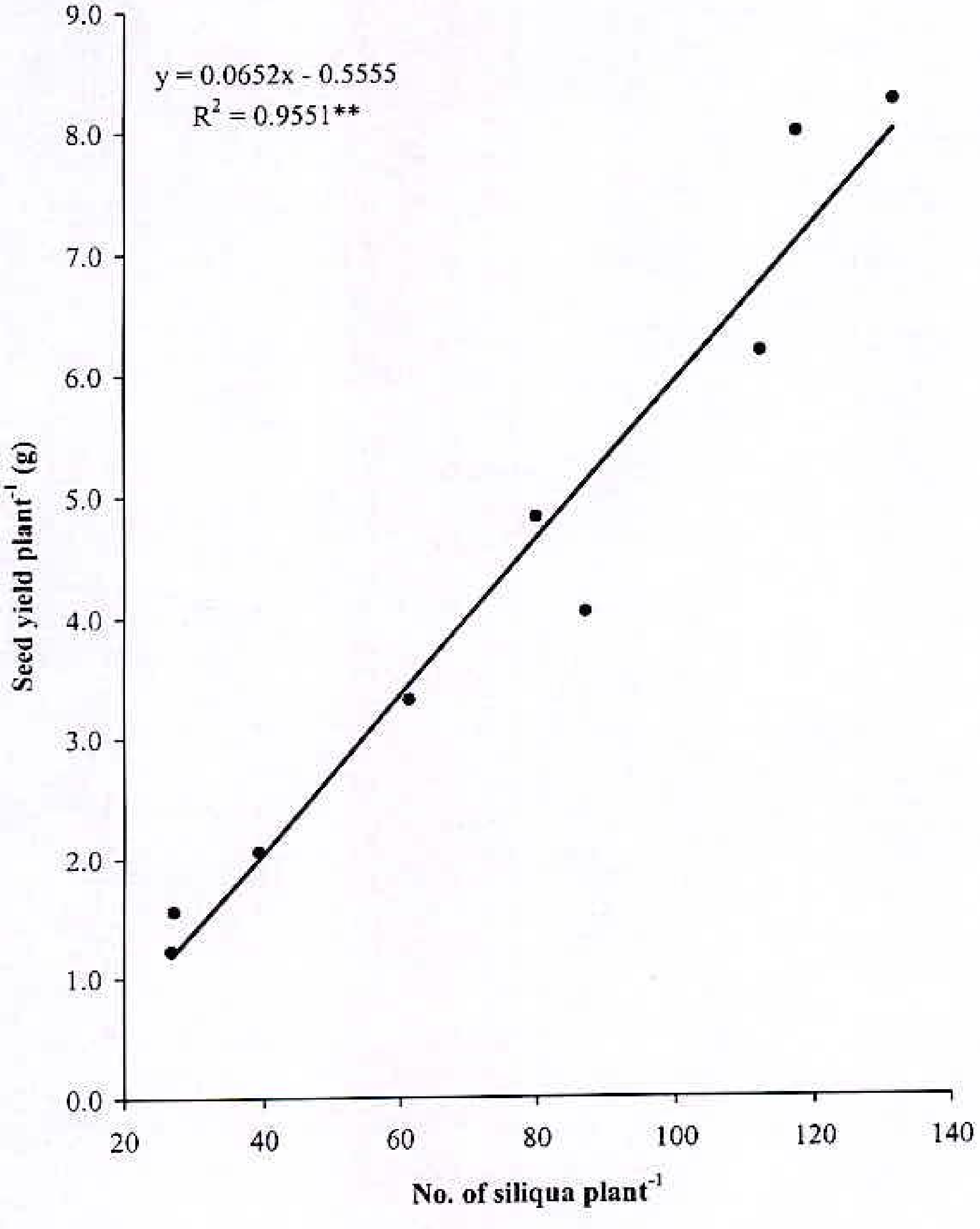


Fig. 4.13 Relationship between number of siliquae plant^{-1} and seed yield plant^{-1} of rapeseed line SAU-C-F_7

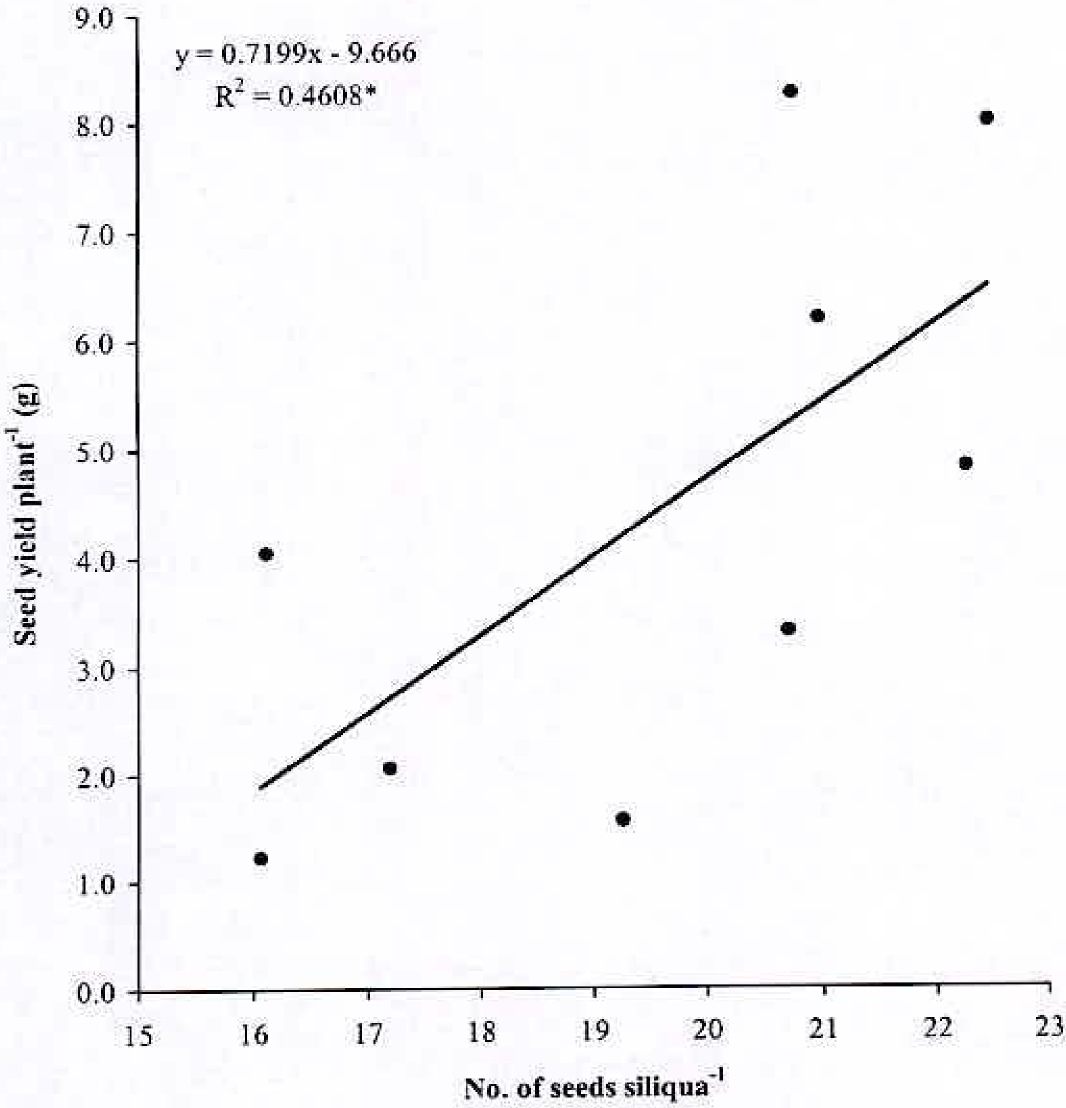


Fig. 4.14 Relationship between number of seeds siliqua^{-1} and seed yield plant^{-1} of rapeseed line SAU-C-F_7

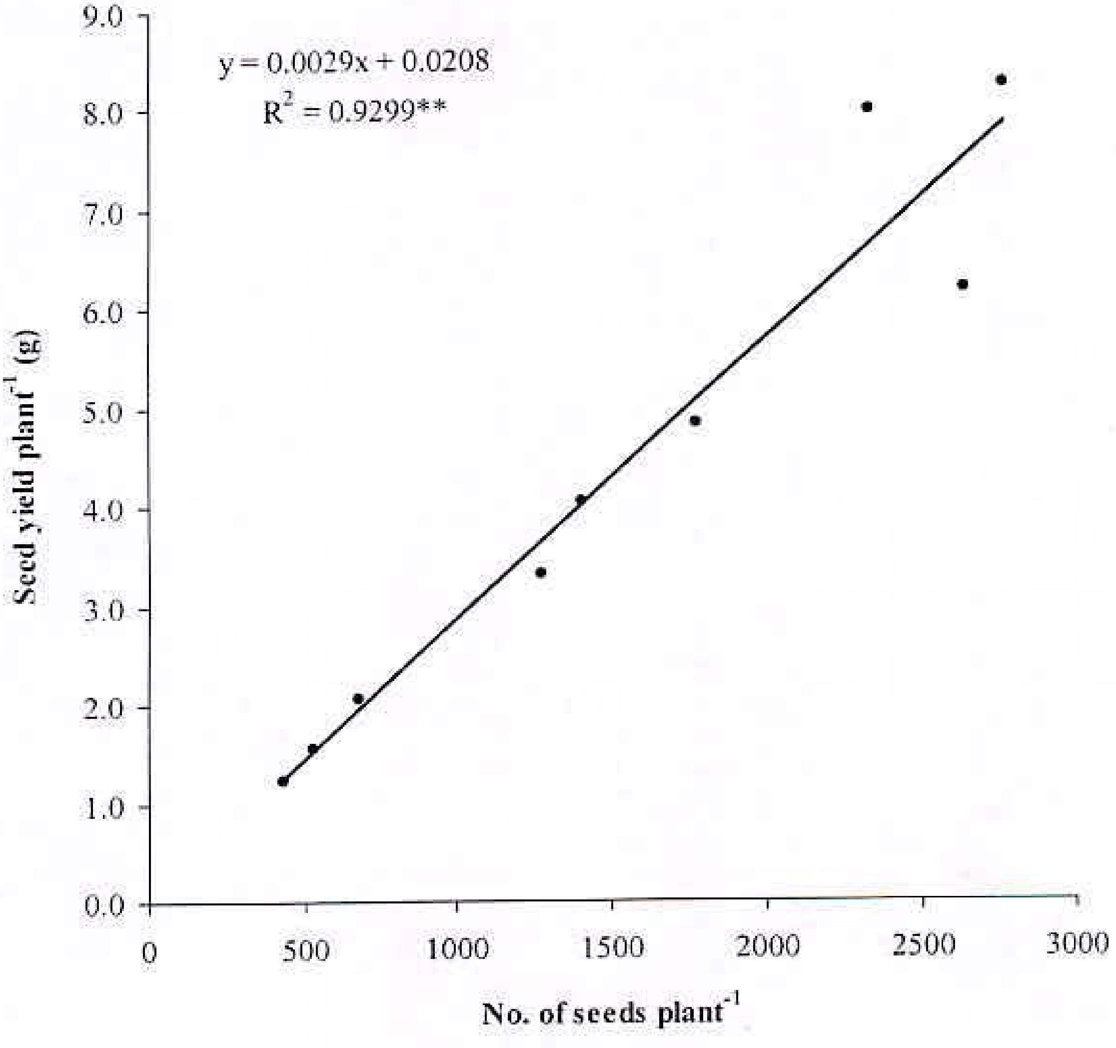


Fig. 4.15 Relationship between number of seeds plant^{-1} and seed yield plant^{-1} of rapeseed line SAU-C-F_7

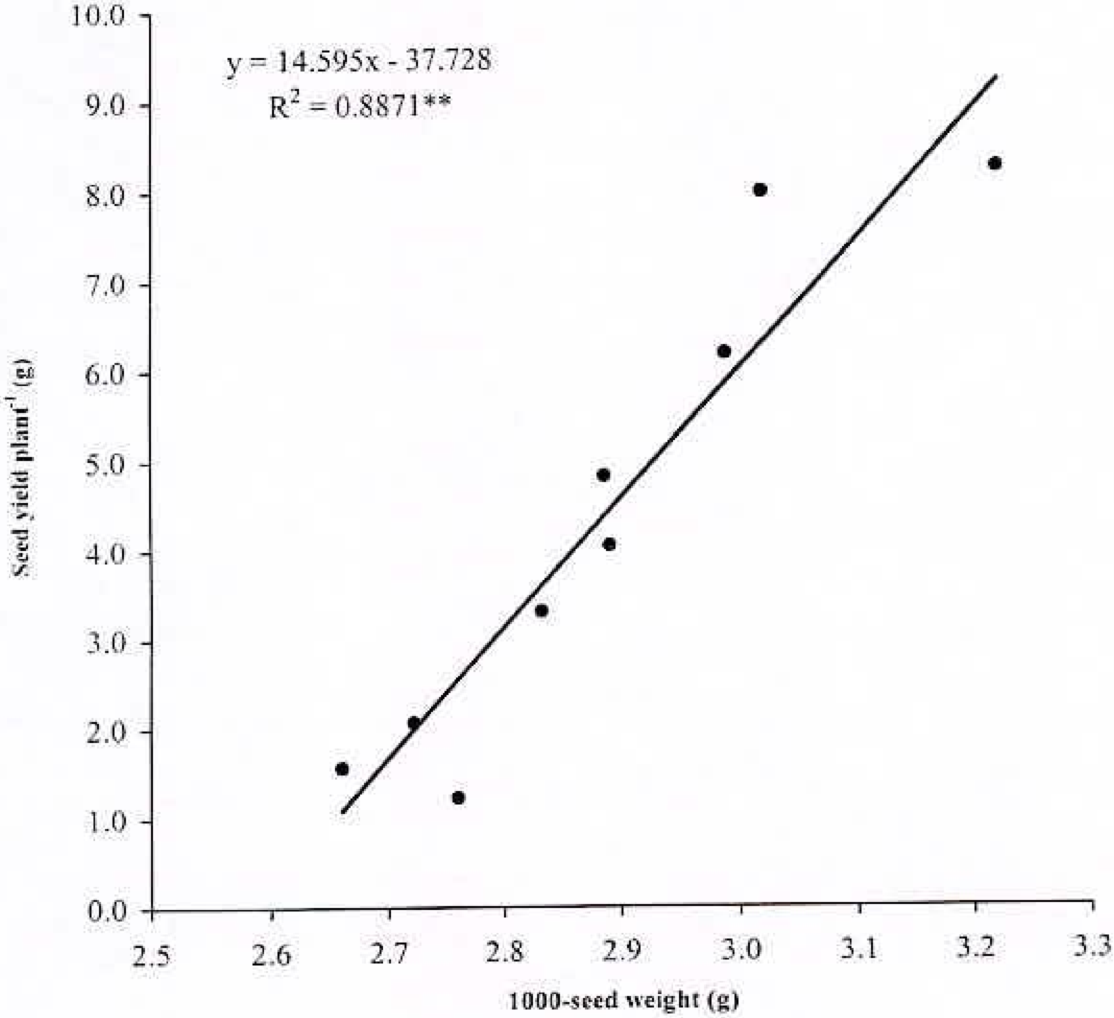


Fig. 4.16 **Relationship between 1000-seed weight and seed yield plant^{-1} of rapeseed line SAU-C-F_7**

Chapter 5

Conclusion

CHAPTER 5

CONCLUSION

The study was carried out to find out the suitable row spacing and irrigation level for optimum yield of the rapeseed line SAU-C-F_7. The results are summarized below.

The rapid increase in plant height was observed from 30 DAS to 75 DAS. The closest row spacing (20 cm) produced the tallest plant than 30 cm and 40 cm row spacing because the plants competed for light and air while the plants with wider spaces got sufficient light. Significant variation was found in plant height for the irrigation levels. The maximum plant height was found from two irrigations. Likewise, the plant height was found to be significant in this line due to the interaction effect of irrigation and row spacing. Maximum plant height was found from the treatment combination of two irrigation and 30 cm row spacing in all stages of the life cycle.

Fresh weight was greatly influenced by row spacing. The closest row spacing produced the lowest fresh weight of plant and the wider row spacing produced the highest fresh weight at 60, 75 and 90 DAS. At 60 DAS and 75 DAS two irrigations produced the highest fresh weight which was significantly different from one irrigation and zero irrigation. The widest row spacing (40 cm) along with two irrigations produced the highest fresh weight at 45 DAS and 60 DAS. After 60 DAS two irrigations with 40 cm row spacing gave the highest fresh weight.

Total dry matter varied at all the growth stages with different row spacing. The widest row spacing (40 cm) produced the highest dry matter at all growth stages. It also played an important role in dry matter partitioning. Significant variation was found in total dry matter plant^{-1} among the different levels of irrigation except 30 DAS. Second irrigation at siliqua developing stage was found to be most effective. Dry matter partitioning was also influenced by irrigation and consequently two irrigations gave the best result.

In case of interaction effect, the treatment combination of two irrigation and 30 cm row spacing produced the highest dry matter which seemed to be most effective treatment for this line. This treatment also influenced partitioning of dry matter components.

Plants m^{-2} was decreased with the increase of row spacing. The highest number of plants m^{-2} (44.75) was found with 20 cm row spacing while 40 cm row spacing gave the lowest number of plants m^{-2} (30.17). The highest number of plants m^{-2} (40.25) was also found with two irrigations at 30 DAS and 60 DAS while the lowest number of plants (36.25) was found from control treatment. Interaction of one irrigation and 20 cm row spacing gave the highest number of plants m^{-2} (48.50).

The highest number of branches plant^{-1} (7.83) was found with the widest row spacing of 40 cm and the lowest (6.38) from the closer row spacing of 20 cm. Maximum number of branches was found from a plant when two irrigations was applied at 30 DAS and 60 DAS. The lowest numbers of branches were found from control plots. The maximum increases of branches were observed to be 110.5% compared to unirrigated control when two irrigations were applied at 30 and DAS. On the other hand, the interaction of two irrigation and 40 cm row spacing produced the maximum branches plant^{-1} (9.57).

The number of siliqua plant^{-1} gradually declined with increase in number of plants per unit area. The widest row spacing (30 cm) produced more number of siliqua plant^{-1} than closer row spacings (20 and 30 cm). Among the irrigation treatments, two irrigation at 30 and 60 DAS produced the highest number of siliqua plant^{-1} which was statistically different from one irrigation and unirrigated control. The treatment one irrigation at 30 DAS affected the siliqua development at later stage which subsequently reduced the number of siliqua plant^{-1}. Two irrigations in combination with 40 cm row spacing produced the highest number of siliqua plant^{-1} (131.40) followed by two irrigations with 30 cm row spacing.

Number of seeds siliqua^{-1} was also significantly affected by row spacing. In case of 30 cm row spacing the highest number of seeds siliqua^{-1} was produced whereas 20 cm row spacing produced the lowest. The second irrigation at 60 DAS of the two irrigation treatment supplied necessary soil moisture which subsequently increased the number of seeds siliqua^{-1}. Treatment combination of two irrigations and 30 cm row spacing found to be superior for producing more seeds siliqua^{-1}.

The single effect of row spacing and irrigation increased the seeds plant^{-1} in the same manner as seeds siliqua^{-1}. But in case of interaction the treatment combination of two irrigations and 40 cm row spacing produced the maximum number of seeds plant^{-1}.

Sparsely populated crop produced heavier seeds than densely populated one and the widest row spacing of 40 cm produced the highest 1000-seed weight and the lowest was produced from 20 cm row spacing. Two irrigations at 30 DAS and 60 DAS produced the highest 1000-seed weight followed by one irrigation at 30 DAS. Interaction effect of irrigation and row spacing was found significant and the height weight of 1000-seed (3.21 g) was found from the combination of two irrigations at 30 DAS and 60 DAS with 40 cm row spacing.

Seed yield plant^{-1} is a complex character which depends on the different yield contributing characters. The treatments 40 cm row spacing produced the highest seed yield plant^{-1} whereas 20 cm row spacing produced the lowest yield plant^{-1}. Seed yield plant^{-1} with 40 cm row spacing was 29.34% and 1.28% higher than 20 cm (S_1) and 30 cm (S_2), respectively. This yield was also significantly influenced by the number of irrigation. Two irrigation produced the highest seed yield plant^{-1} which was statistically different from one irrigation. Lowest yield was found from unirrigated condition. The increased seed yield plant^{-1} with two irrigations (I_2) was 364.59 % and 84.23% higher than one irrigation (I_1) and without irrigation (I_0), respectively. Two irrigations combined with 40 cm row spacing produced the highest seed yield plant^{-1}.

The treatment of 30 cm row spacing optimized the plant population which subsequently increased the seed yield ha^{-1} of the line SAU-C-F_7. The maximum seed yield ha^{-1} with 30 cm row spacing was 19.39% and 8.54% higher than the yield obtained from 20 cm and 40 cm row spacing. Maximum seed yield ha^{-1} was found from two irrigations - one at 30 DAS and another at 60 DAS, which were 206.65% and 102.52% higher than the yield obtained from the control treatment (I_0) and one irrigation (I_1), respectively. In case of interaction effect, two irrigations with 30 cm row spacing produced the highest seed yield (3169.40 kg ha^{-1}) which was followed by two irrigations with 40 cm row spacing (2891.20 kg ha^{-1}).

Among three row spacings the 30 cm row spacing produced the highest stover yield. Two irrigations produced the highest stover yield and the treatment combination of two irrigation with 30 cm row spacing produced the highest stover yield (4123.40 kg ha^{-1}).

The highest biological yield was obtained from treatment 30 cm row spacing and 40 cm row spacing produced the lowest biological yield ha^{-1} in this study. Among irrigation levels, two irrigations at 30 DAS and 60 DAS produced the highest biological yield ha^{-1}. The interaction effect showed that two irrigation coupled with 30 cm row spacing produced the highest biological yield whereas, 30 cm row spacing and no irrigation produced the lowest biological yield.

The treatment 30 cm row spacing had the highest harvest index and two irrigations one at 30 DAS and another at 60 DAS produced the highest harvest index and the combination of two irrigations with 30 cm row spacing was found to be best for harvest index for this line in this study.

From correlation and regression study it was found that there was a significant relationship between the yield attributes and seed yield plant^{-1}. Number of branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, number of seed plant^{-1}, 1000-seed weight had a significant correlation with seed yield plant^{-1} with the r values of 0.95**, 0.97**, 0.67*, 0.96** and 0.94**. All of the yield attributes except number of seed siliqua^{-1} were highly significant. Number of seed siliqua^{-1} was significantly correlated with seed yield plant^{-1} at 5% level.

From the present study it may be concluded that row spacing and irrigation levels influenced the growth, yield and yield components of rapeseed line SAU-C-F_7. Among the irrigation levels two irrigation at 30 DAS and 60 DAS gave the best result. Row spacing of 40 cm provided the best result among the treatments. The interaction effect of two irrigation with 30 cm row spacing were found most effective.

The study will now provide guidelines about row spacing and irrigation scheduling for the line SAU-C-F_7. However, further field trial may be taken in different agroecological zones in relation to the physiological and biological aspects of this line to reestablish the findings obtained in this study.

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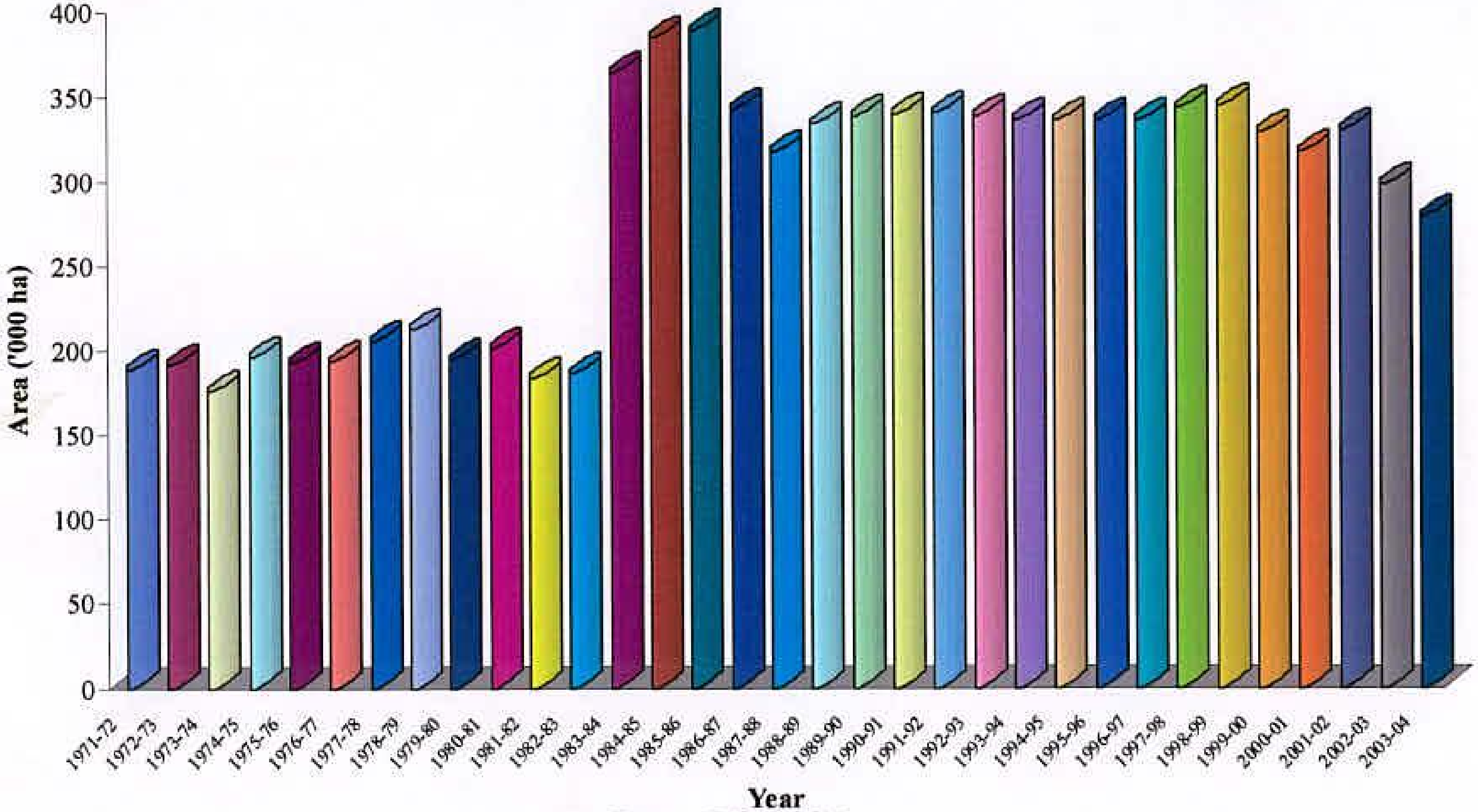
Appendices

APPENDICES

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

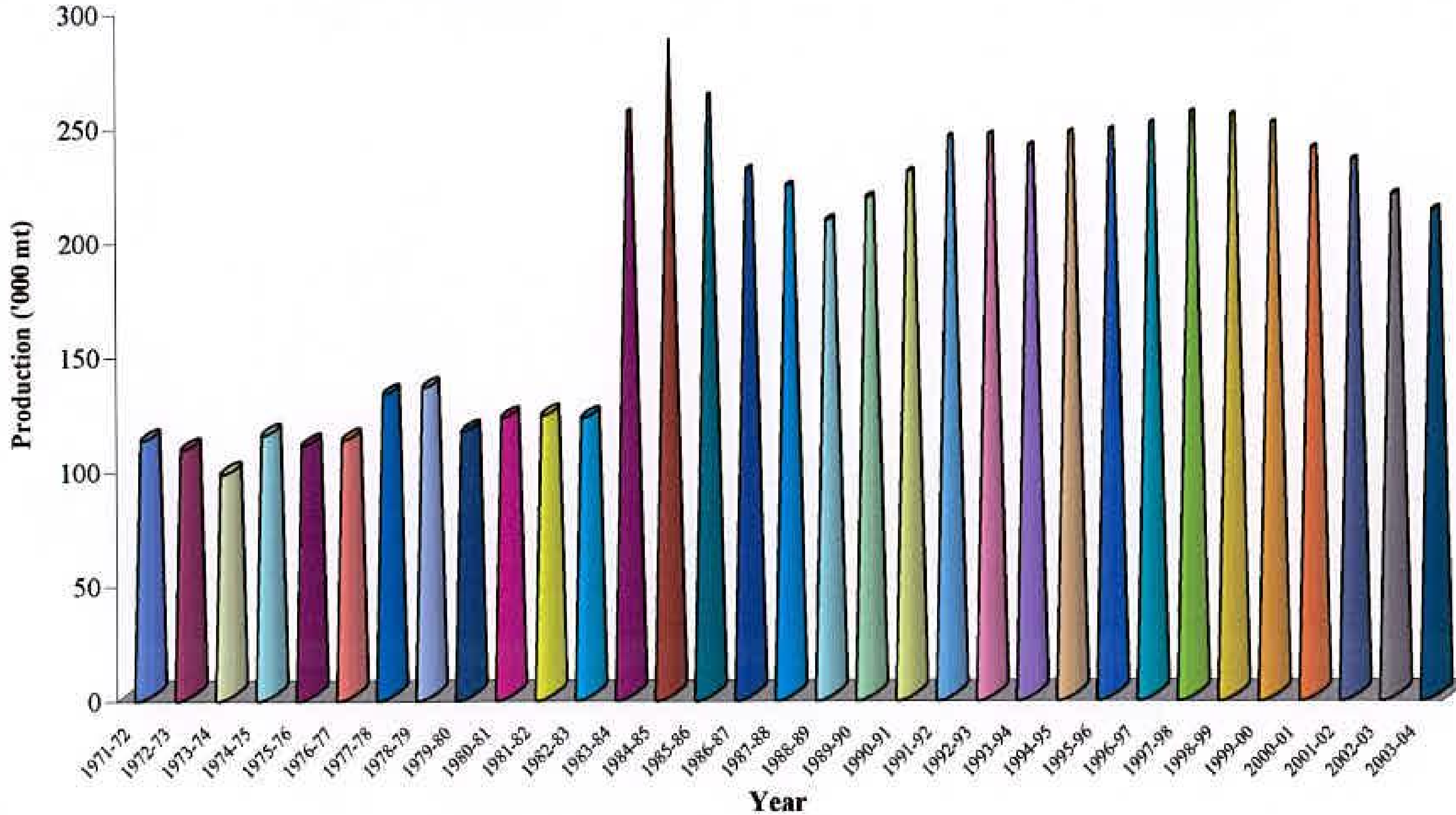
Source: BARI (2002b)

Appendix II. Area under rapeseed and mustard cultivation in Bangladesh (1971-72 to 2003-04)



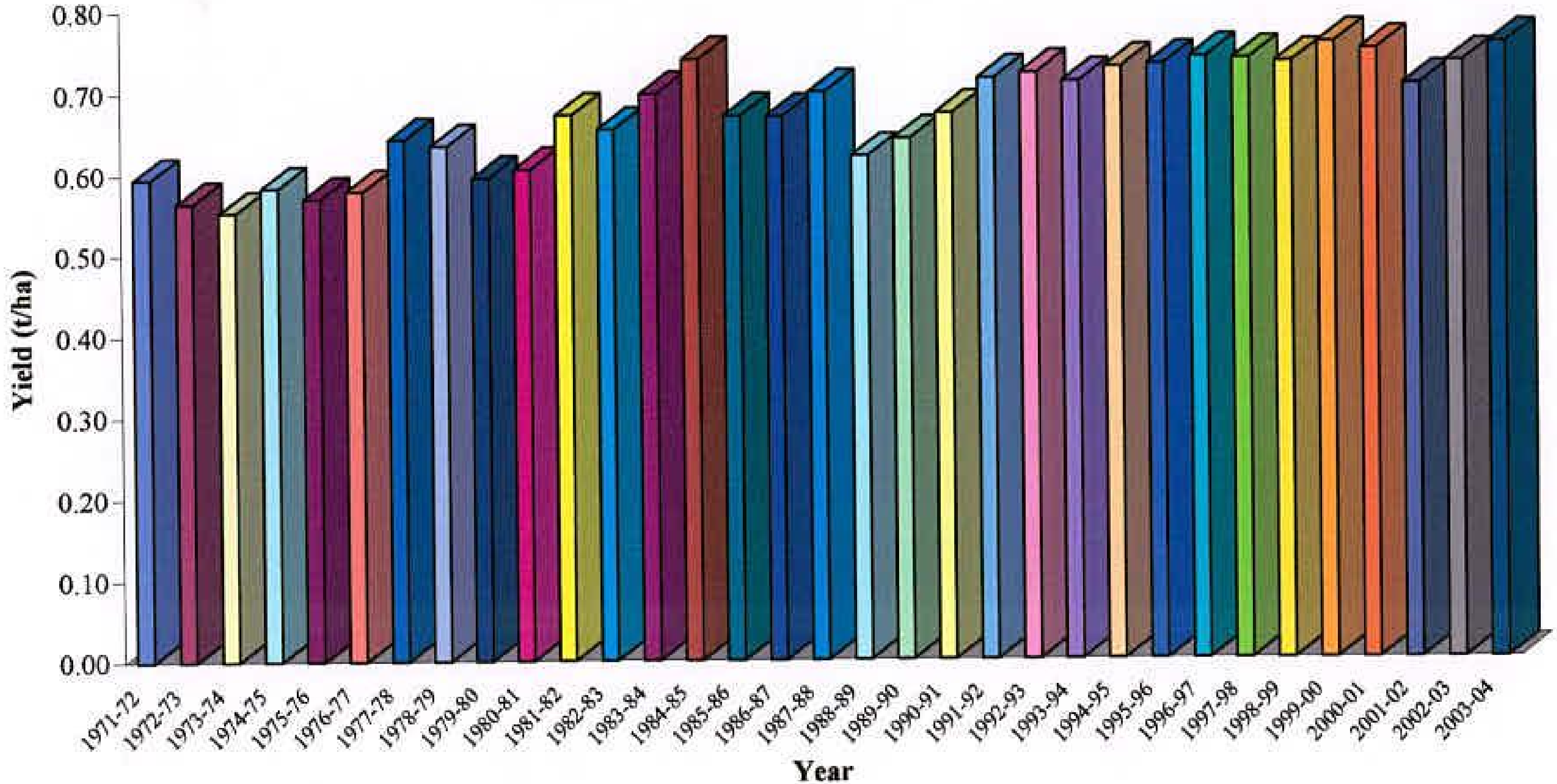
Source: FAO (2004)

Appendix III. Production of rapeseed and mustard in Bangladesh (1971-72 to 2003-04)



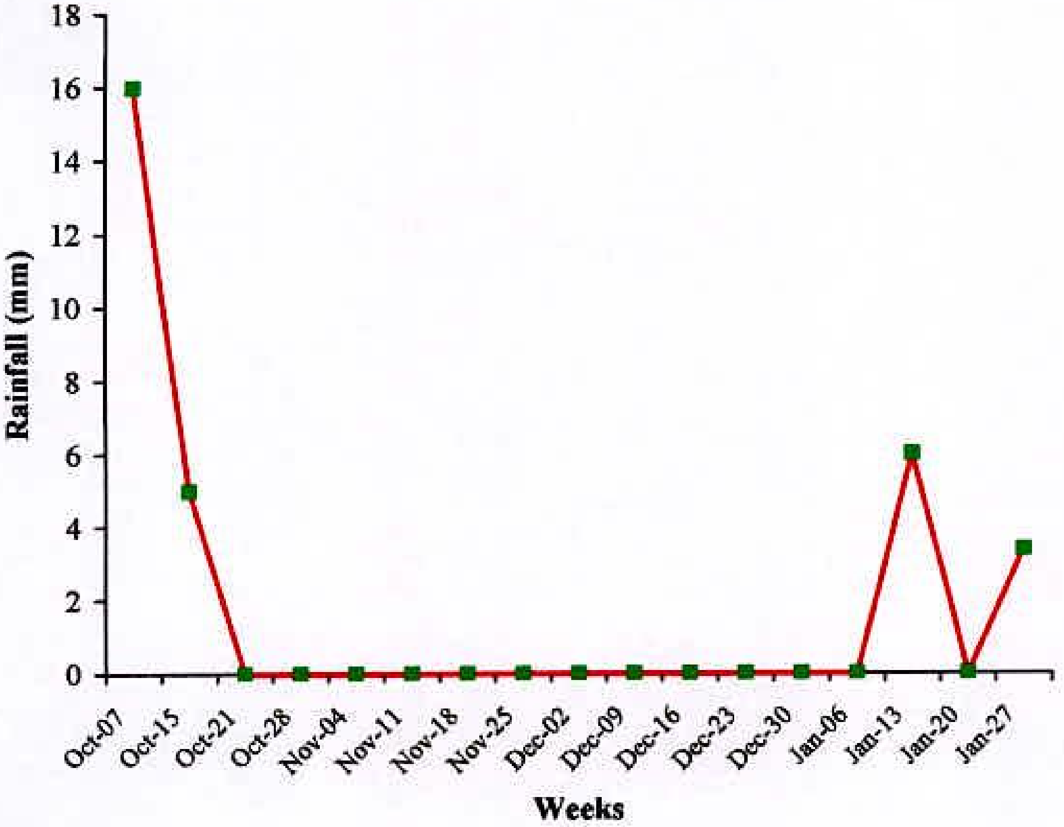
Source: FAO (2004)

Appendix IV. Average yield of rapeseed and mustard in Bangladesh (1971-72 to 2003-04)



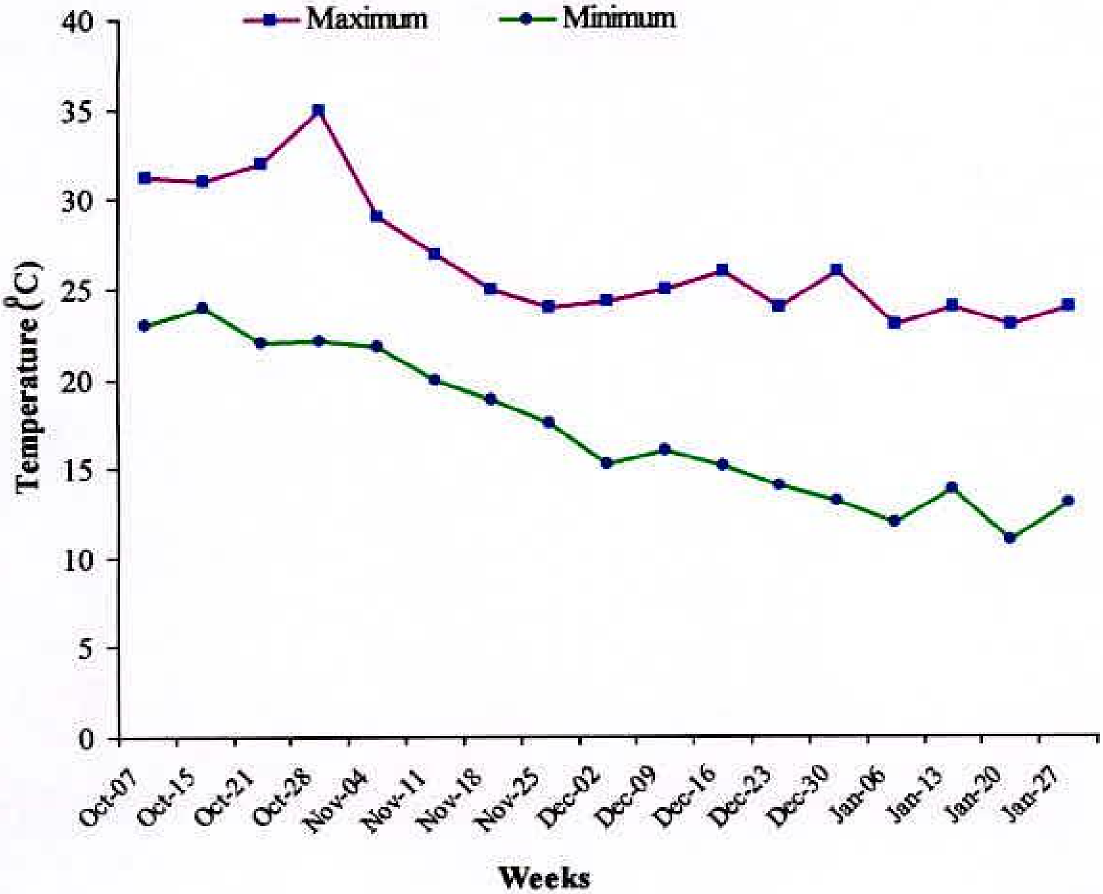
Source: FAO (2004)

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



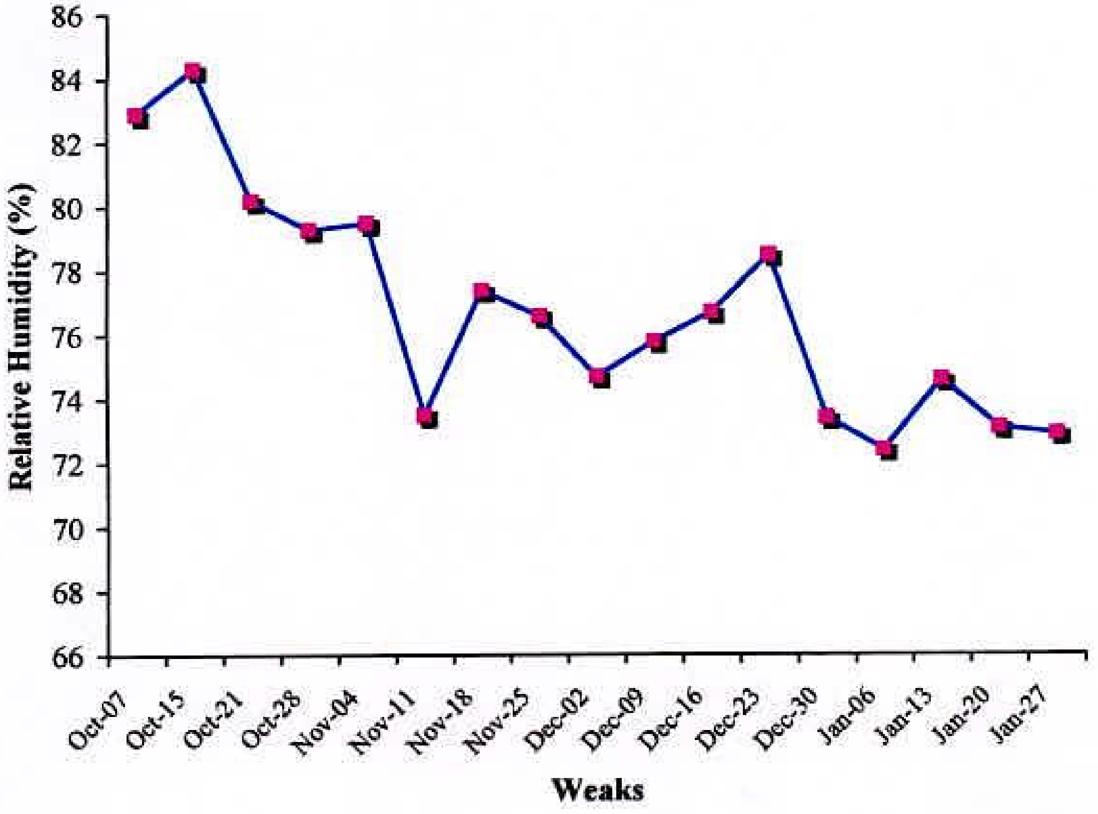
Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka- 1212

Appendix VI. Weekly average air temperature during the study (October to January, 2005)



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

Appendix VII. Weekly average relative humidity during the study (October to January, 2005)



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