INFLUENCE OF IRRIGATION AND NITROGEN ON THE YIELD OF RAPESEED (*Brassica napus*)

By

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Dedicated to

My

Beloved Parents &

Brothers

CERTIFICATE

This is to certify that the thesis entitled "**Influence of irrigation and nitrogen on the yield of rapeseed** (*Brassica napus*)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by Mohammad Abdul Latif, Registration No. 25289/00394 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 during the course of this investigation has duly been acknowledged.

Dated: June 25. 2006
Dhaka, Bangladesh

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(Prof. Dr. Md. Hazrat Ali)
Supervisor

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√ABSTRACT

An experiment was conducted at the agronomy field laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October, 2005 to February, 2006 to examine the influence of irrigation and nitrogen on the yield of rapeseed (*Brassica napus*). There were four different levels of irrigation viz. no irrigation, one irrigation at 30 DAS, two irrigations at 30 and 50 DAS and three irrigations at 30,50 and 65 DAS and four levels of nitrogen viz. 0, 40, 80 and 120 kg N ha^{-1}. The experiment was laid out in split plot design with 3 replications assigning irrigation in the main plots and levels of nitrogen in the sub-plots.

Irrigation and nitrogen significantly influenced the growth, development, yield and yield attributers of rapeseed. Plant height, dry matter, branches plant^{-1}, length of main inflorescence, number of siliquae in the main inflorescence, siliquae plant^{-1}, siliqua length, seeds siliqua^{-1}, weight of 1000 seeds, seed yield, stover yield, harvest index and oil content were significantly influenced by both irrigation and nitrogen.

Among the irrigation treatments, three irrigations- one at 30 DAS (pre-flowering stage), second at 50 DAS (siliquae formation stage) and another at 65 DAS (siliquae development stage) resulted the greater growth parameters like plant height, dry matter weight and the yield components like branches plant^{-1}, length of main inflorescence, number of siliquae in the main inflorescence, siliquae plant^{-1}, siliqua length, seeds siliqua^{-1}, 1000 seed weight, seed yield, stover yield and harvest index. However, irrigation levels influenced the oil content. Three irrigations at 30, 50 and 65 DAS showed the best performance in all respect. The highest seed yield (1455.96 kg ha^{-1}) was obtained at three irrigations while control treatment gave the lowest yield (348.05 kg ha^{-1}). The results revealed that nitrogen at the rate of 120 kg ha^{-1} showed the best results in all respect except oil content. The highest seed yield (1347.72 kg ha^{-1}) was obtained at 120 kg N ha^{-1} while control treatment produced the lowest yield (408.5 kg ha^{-1}).

The interaction effect of irrigation and nitrogen revealed that three irrigations one at 30 DAS (pre-flowering stage), second at 50 DAS (siliqua formation stage) and another at 65 DAS (siliqua development stage) in combination with 120 kg N ha^{-1} showed the best performance in most of the cases whereas, the combination effect of control treatments showed the least performance.

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ACRONYMS

AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
FAO	=	Food and Agricultural Organization
DAE	=	Days After Emergence
LAI	=	Leaf Area Index
WAS	=	Weeks After Sowing
LAD	=	Leaf Area Diameter
N	=	Nitrogen
S	=	Sulphur
P_2O_5	=	Phosphorus Penta Oxide
K_2O	=	Potassium Oxide
DAS	=	Days After Sowing
SAU	=	Sher-e- Bangla Agricultural University
HI	=	Harvest Index
%	=	Percent
G	=	Gram (s)
kg	=	Kilogram (s)
TDM	=	Total Dry Matter
cv.	=	Cultivar (s)
T/ha	=	Tones per hectare
CV(%)	=	Coefficient of Variation
hr	=	Hour(s)
ppm	=	Parts per million
P, K, B	=	Phosphorus, Potassium, Boron
CPE	=	Cumulative Pan Evaporation
IW	=	Irrigation Water Depth
CEC	=	Cation Exchange Capacity
mm	=	Millimeter
^0C	=	Degree Celsius
M^2	=	Meter squares
NS	=	Non significant
pH	=	Hydrogen ion conc.
cm	=	Centi-meter
LYV	=	Low yielding varieties
HYV	=	High yielding varieties
No.	=	Number
LSD	=	Least significant difference
RDA	=	Recommended Dietary Allowance
var.	=	Variety
et al.	=	And others
etc	=	Etcetera

Chapter 1
Introduction

Chapter 1

INTRODUCTION

Rapeseed and mustard belongs to the family Cruciferae are important oil crops and currently ranked as the worlds 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). Rapeseed and mustard contain 40-45% oil and 20-25% protein in seed.

Oilseed crops play a vital role in human nutrition. It is not only a rich source of energy (about 9 Kcal/g) but also rich in soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6g of oil for a diet with 2700 Kcal. On RDA basis, the edible oil need for 150 millions people per annum is 0.33 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984).

In Bangladesh, sources of edible oil are rapeseed-mustard, sesame, groundnut, soybean, niger, linseed, sunflower and safflower. But rapeseed-mustard is one of the important oilseed crops of the world after soybean and palm (FAO, 2004). Rapeseed-mustard is the principal oilseed crop of Bangladesh. In Bangladesh, it covers an area of 0.28 million hectares with a production of 0.21 million tons (BBS, 2005). Rapeseed oil is widely used as cooking oil and as medicinal ingredient and supplies fat in our daily diet. Rapeseed oil cake is used as feed for cattle and fish and as manure for crops. The average yield of rapeseed in Bangladesh is very low (0.77 t/ha) that is less than 50% of the world average (FAO, 2004).

Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% of total cropped area in Bangladesh (BBS, 2002). The annual oil seed production was about 0.41 million tons of which the share of rapeseed-mustard was 0.21 million tons, which comes about 52 % of the total edible oil seed production (BBS, 2005). It is top of the list in respect of area and production compared to other oilseed crops grown in Bangladesh.

Bangladesh is running with acute shortage of about 70% edible oil. Annually producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons and to meet the demand, the country has to import oil and oilseeds to the tune of about US $ 160 million per annum (Wahhab *et al.*, 2002).

Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have released quite a number of new high yielding varieties (HYV) of these crops. The yield of HYV cultivars ranges between 1.4 and 2.1 t/ ha (BARI, 2002). 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, fertilizer application and seed rate.

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 the crops in dry season (Roy and Tripathy, 1985). The crop essentially requires water ranging from 60-169 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 for different growth stages (Prasad and Eshanullah, 1988). Irrigation has been found to increase 1000 seed weight, number of siliquae plant^{-1}, number of seed plant^{-1} and seed yield and harvest index (Shrivastava *et al.,* 1988) of this crop. Mondal *et al.* (1988) reported that one irritation at flowering and pod development stage gave the highest yield (2. 56 t/ha). Irrigation has also an effect in increasing the fertilizer uptake (Reddy and Sinha, 1987) thus increased biomass, which ultimately increase the yield. In recent year, some promising varieties have been released in Bangladesh which are being grown as irrigated crops.

The yield of rapeseed can be augmented with the use of high yielding varieties and appropriate agronomic inputs. Fertilizer is the depending source of nutrient that can be used to boost up growth and yield of mustard (Sinha *et al.*, 2003; Shukla *et al.*, 2002a; Meena *et al.*, 2002 and Zhao *et al.*, 1997). High yielding varieties of rapeseed are very responsive to fertilizers especially nitrogen and sulphur (Patel *et al.*, 2004; Sharawat *et al.*, 2002; Ali and Rahman, 1986). Application of 100 kg N and 30 kg S/ha promoted most of the growth parameters and yield attributes of mustard (Islam *et al.*,2004).

Rapeseed is highly sensitive to nitrogen and this element has tremendous influence on plant height, dry matter accumulation and all the yield attributes at 120 kg N ha^{-1} (Tripathi and Tripathi, 2003; Singh *et al.*, 2002; Shukla *et al.*, 2002b; Saikia *et al.*, 2002 and Srinivas and Raju, 1997). Excessive use of this element may produce too much of vegetative growth and thus fruit production may be impaired (Sheppard and Bates, 1980). An efficient method and time of application is very much important for proper utilization of nitrogen by plants (Ibrahim *et al.*, 1989). Proper fertilization is an essential need to maximize rapeseed production in Bangladesh soil. The high yielding varieties of rapeseed introduced into intensive cropping system and need through investigation on the requirement of irrigation and N for their growth and development to obtain maximum yield. In view of the limited information on the problems mentioned above point in mind, the present piece of work was undertaken with the following objectives:

1. Determine the proper number of irrigation for getting higher yield of rapeseed
2. Find out the optimum dose of nitrogen for getting higher yield of rapeseed
3. Examine the interaction effect of irrigation and nitrogen on the growth, yield attributes and yield of rapeseed.

Chapter 2
Review of literature

Chapter 2

REVIEW OF LITERATURE

Rapeseed-mustard is an important oil crop in Bangladesh, which can contribute largely in the national economy. But the research works done on this crop with respect to agronomic practices are inadequate. The proper fertilizer management accelerates its growth and influenced its yield as well as oil content. Therefore, available findings of the direct effect of irrigation and nitrogen fertilizer and combination effect relevant to the present study have also been briefly reviewed under the following heads:

2.1 Effect of irrigation

Seed yield of *Brassica* is 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 irrigation condition. This clearly indicates that yield expression of *Brassica spp.* differs under varying soil water environment.

2.1.1 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 120.5 cm with 2 irrigations at branching and siliquae development stage and it was the highest compared to 113.0 cm and 108.7 cm with one irrigation at branching stage and without irrigation respectively.

Saran and Giri (1988) reported that plant height was found to be highest when one irrigation at 30 DAS was applied. But two irrigations applied at 30 and 90 DAS produced more plant height than under rainfed condition. There was a significant relationship between irrigation levels and plant height.

2.1.2 Dry matter accumulation

Giri (2001) reported that dry matter per plant was not significantly increased with irrigation treatments. He conducted two experiments to find out the effect of irrigation on growth and yield of mustard. Dry matter production was 107.1 g plant^{-1} with two irrigations at flowering and siliquae development stage, which was higher than the dry matter produced with one irrigation at flowering stage but one irrigation, produced higher dry matter than two irrigation.

Raut *et al.* (1999) studied the effects of irrigation (at pre-flowering and siliquae- setting stages, pre-flowering + 50% flowering + siliquae setting stages, pre-flowering + 50% flowering + seed – filling stages, and pre-flowering + 50% flowering + siliquae-setting + seed filling stages) on the dry matter production and yield of Indian mustard cv. Pusa Bold. Irrigations once at pre-flowering + 50% flowering + siliquae-setting + seed- filling stages gave the highest dry matter production at 30 (1.2 g pre-flowering + 50% flowering + seed filling stages gave the highest dry matter production at 90 DAS (74.0 g per plant) and at harvest (112.25 g per plant) as well as the highest grain yield (15.99 q ha^{-1}).

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

Gill and Narang (1993) observed distinct differences in dry matter production after 70 DAS in case of mustard, when differential irrigation schedule were maintained. Three irrigations (one at 28 DAS and 2 at 80 mm 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 matter weight of different irrigation treatment 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.

Tomer *et al.* (1992) found increased dry matter production in mustard 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 up to two irrigation. The maximum dry matter production was found to be 102.37 g with two irrigations while one irrigation and control (no irrigation) produced 90.61 g and 67.75 g dry matter per plant respectively.

Patel *et al.* (1991) found a significant difference in case of dry matter accumulation in mustard with application of irrigation. One irrigation produced more dry matter (53.2 g plant^{-1}) which was significantly higher than that was produced without irrigation (47.0 g plant^{-1}).

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

2.1.3 Number of branches plant^{-1}

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.

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 40.29 when two irrigations were applied at pre-flowering and fruiting stage. When one irrigation was applied at pre-flowering stage it produced 33.00 branches per plant. The least number of branches (26.56) was produced at control treatment.

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

Rathore and Patel (1989) found the number of branches plant^{-1} of mustard increased with increased in irrigation frequency. Prasad and Ehsanullah (1988) reported that number of primary branches of mustard was significantly increased with irrigation levels. They found maximum number of primary branches (5.7) per plant with two irrigations at 30 and 60 DAS which was followed by 4.3 and 4.1 with one irrigation at 30 DAS and without irrigation respectively. No significant difference was found among the irrigation treatments on primary branches plant $^{-1}$, because of high rainfall.

Saran and Giri (1988) reported the maximum number of branches per plant of mustard with one irrigation at 30 DAS than two irrigations at 30 and 90 DAS followed by no irrigation. Seven (7.0) branches per plant were found with one irrigation whereas, two irrigations and rainfed condition produced 6.4 and 5.4 branches per plant.

2.1.4 Number of siliquae plant^{-1}

✓ 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.

✓ 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.

2.1.5 Length of siliquae

Singh and Saran (1992) observed in an experiment with *Brassica campestris* during the winter seasons of 1987-1989 that irrigation at IW and CPE ratio of 0.4 and 0.2 (two and one irrigation, respectively) gave average siliquae length of 6.1 and 6.2 cm, respectively compared to 5.5 cm from the control treatment. Final plant height, leaf-area index (60 DAS) and dry matter ha^{-1} changed favorably with an increasing in irrigation regime up to 0.4 IW : CPE ratio, whereas, siliquae length significantly increased only up to 0.2 IW : CPE ratio.

2.1.6 Number of seeds $siliqua^{-1}$

Patel *et al.* (2004) reported that one irrigation produced 465 siliquae per plant while 327 siliquae were produced per plant without irrigation. Siag *et al.* (1993) found that when two irrigations were given either at branching and siliquae development or at branching and flowering stages recorded a significant increase in siliqua $plant^{-1}$. The highest number of siliquae (261) was found with two irrigations at branching and siliquae development stages.

Tomer *et al.* (1992) conducted an experiment to observed 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 stage and one at fruiting stage). Maximum number of siliquae (523.16) was found per plant when two irrigations were applied. One irrigation and without irrigation produced 422.83 and 332.45 siliquae per plant respectively.

Tomer *et al.* (1992) reported that seeds per silquae were also significantly increased with irrigation. Maximum number 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.

Sharma and Kumar (1989a) conducted an experiment with *Brassica juncea* cv. Krishna and irrigated the crop with two levels. They observed that number of seed siliqua^{-1} was highest, 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.

Prasad and Ehsanullah (1988) found an increasing trend of seeds siliqua^{-1} in mustard with irrigation levels. The maximum number of seeds (12.0) 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 10.8 and 10.0 seeds siliqua^{-1}.

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 number of siliquae than unirrigated control and two irrigations.

2.1.7 Weight of 1000 seeds

Tomer *et al.* (1993) reported that maximum weight of 1000 seed was found when one irrigation was applied during pre-flowering stage and another one during fruiting stage. Least weight of 1000 seed was found without irrigation.

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

Thousand seed weight did not significantly differ with irrigation (Saran and Giri, 1988). One irrigation applied at 30 DAS produced 1000 seed weight of 5.2 g, which was same to the 1000 seed weight 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. They found maximum weight of 1000 seed (4.6 g) from the application of two irrigations at 30 and 60 DAS. The lowest weight of 1000 seed (4.0 g) was found in rainfed condition (without irrigation) which was lower than the application of one irrigation at 30 DAS that produced 4.2 g.

2.1.8 Seed yield

Different scientists observed that yield of rapeseed and mustard crop increased with irrigation levels due to 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 *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 applied at seedling and flowering stages, 17.98 to 32.43% when irrigation was applied at seedling and seed development stages, and 1.59 to 3.45% when irrigation was applied 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.

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 (1.49 t ha^{-1}) with 2 irrigations.

Mahal *et al.* (1995) reported that maximum seed yield (1.96 t ha^{-1} in 1987 and 1.66 t ha^{-1} in 1988) was recorded with 2 irrigations (at 3-4 weeks and at 9-10 weeks after sowing). 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, siliquae development or seed filling stage corresponding 3, 6, 9, or 12 weeks after sowing (WAS) or at various combinations of these dates. Seed yields increased with increase in irrigation frequency. The highest mean seed yield of 1.09 t ha^{-1} 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) , siliquae formation stage (55 DAS) or rosette siliquae formation stages. One irrigation at the rosette stage gave significantly higher yields compared with one irrigation at siliquae 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.

Tomer *et al.* (1993) 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) out yielded 1 irrigation (pre-flowering stage).

Sharma (1991) conducted an experiment in the rabi seasons of 1986-1987 on clay loam soil at Mandsaur, Madhya Pradesh of India and found that no irrigation, 1 irrigation at 15 or 30 days after sowing or 2 irrigations at 15 + 30 or 30 + 60 days after sowing gave mustard (*Brassica juncea*) cv. Varuna seed yields of 0.92, 1.05, 1.11, 1.28 and 1.47 t ha^{-1}, respectively, in 1986-1987 and 1.24, 1.46, 1.59 and 1.96 t ha^{-1} in 1987-1988.

✓Siag and Verma (1990) concluded that mustard (*Brassica juncea*) given 1 irrigation at the vegetative, flowering or siliquae development stage, or 2 or 3 irrigations, gave average seed yields of 1.67, 1.78, 1.90, 1.95-1.98 and 2.14 t ha^{-1} respectively.

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 yields. In another experiment on mustard, Sharma and Kumar (1990) observed that one or two levels of irrigation produced the seed yields of 1.11 and 1.37 t ha^{-1}, respectively in 1984-1985. The corresponding values were 1.26 and 1.38 t ha^{-1}

in 1985-1986. Yields were obtained 0.95 and 0.71 t ha^{-1} without irrigation those years respectively.

Rarihsr (1990) found in an experiment with mustard that the seed yield and yield components were greater while irrigation was applied at irrigation depth cumulative pan evaporation ratio of 0.6. Tomer and Singh (1990) found that irrigating *Brassica juncea* cv. Varuna at flowering or flowering and fruiting stages or not irrigating, produced seed yields of 1.18, 1.45 and 0.83 t ha^{-1} respectively.

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 siliquae formation. Average seed yield ranged from 0.77 t ha^{-1} without irrigation to 1.37 t ha^{-1} with irrigation.

Rathore and Patel (1989) reported that mustard (*Brassica juncea*) gave highest yields with 3 irrigations at branching, 50% flowering and seed filling, followed by 2 irrigations at branching and 50% flowering , and irrigation at late branching. Parihar and Tripathi (1989) gave irrigation to mustard (*Brassica juncea*) with six cm irrigation and found that average yields were 0.69, 1.00 and 1.05 t ha^{-1} in irrigation depth and cumulative pan 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 irrigation at flowering stage gave the highest seed yields. They further observed that irrigation with one to three levels gave seed yields of 1.11-1.36 t ha^{-1} where seed yield 0.97 t ha^{-1} were obtained under rainfed conditions.

Sharma and Kumar (1989b) found in another experiment with mustard that seed yield increased with increasing irrigation frequency, while irrigation was applied with zero and one level at the siliquae formation stage.

Lal *et al.* (1989) reported that mustard (*Brassica juncea* cv. Varuna) gave seed yields of 1.11-1.36 t ha^{-1} with 1-3 irrigations applied at different growth stages, compared with 0.97 t ha^{-1} under rainfed conditions. Applying one irrigation at the flowering stage gave the highest yields.

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

Katole and Sharma (1988) conducted a field experiment on clay loam soils to study the effect of irrigation schedule and found that yield was highest with two irrigations one at branching one 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 DAS gave seed yields of 1.81-1.83 t ha^{-1} compared to 1.18-1.49 t ha^{-1} with one irrigation and 0.99-1.05 t ha^{-1} without irrigation. Results obtained by Mondal *et al*. (1988) from a field experiment with *Brassica juncea* cv. T-59 irrigated with 4 levels revealed that the maximum yields with one irrigation at flowering and siliquae development stages were 2.56 and 2.46 t ha^{-1} and with three irrigations supplied at pre-flowering, early and late siliquae stages were 2.06 and 2.10 t ha^{-1} respectively.

Sarker and Hassan (1988) made an experiment with *Brassica juncea* at two locations in Bangladesh. They irrigated the crop at one to six levels commencing 20-25 DAS and observed the highest seed yield of 1.29 t ha^{-1} with three levels of irrigation and 1.18 t ha^{-1} with five irrigations.

Sharma and Giri (1988) reported that *Brassica juncea* grown with 0-80 kg N ha^{-1} under irrigated conditions and one-two irrigations gave similar seed yields of 0.8-1.5 t ha^{-1} in 1984-1985 and 1.40-1.50 t ha^{-1} in 1985-1986. Sharma and Kumar (1988) irrigated mustard (*Brassica juncea*) with 60 cm water depth and cumulative pan evaporation ratio of 0.4 or 0.6 (one and two irrigations respectively) and reported the seed yields of 1.31 and 1.46 t ha^{-1} in 1984-1985 and 1.03 and 1.23 t ha^{-1} in 1985-

1986 respectively compared with respective yields of 0.82 and 0.71 t ha^{-1} under rainfed conditions.

Mondal *et al.* (1988) conducted a field trials in the rabi (winter) seasons on *Brassica juncea* cv. T-59 was sown in the 1st week of November and given 1-4 irrigation treatments (1-4 irrigations at pre-flowering, flowering, early siliquae or late siliquae developmental stages). Maximum yields with 1 irrigation at flowering were 1.81 and 1.85 t ha^{-1} with 2 irrigations at flowering and late siliquae stages were 2.56 and 2.46 t ha^{-1}, and with 3 irrigations supplied at pre-flowering, early and late siliquae stages were 2.06 and 2.10 t ha^{-1}.

Hasan *et al.* (1988) conducted a field experiments in 1986-1987 at 2 locations in Bangladesh, mustard (*Brassica juncea*) was given no irrigation, 1 irrigation 20-25 DAS (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 of 1.29 t ha^{-1} 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 of 1.18 t ha^{-1} resulted from irrigation at I_1 and 4 irrigations when IW : CPE was 1.0.

Reddy and Sinha (1987) observed in an experiment with *Brassica juncea* in rabi seasons of 1983-1985 that irrigation at IW and CPE ratio of 0.6 and 0.3 (three and one irrigation, respectively) gave average seed yields of 1.79 and 1.64 t ha^{-1} respectively compared to 1.5 t ha^{-1} from the rainfed crops. Haque *et al.* (1987) observed that yield increase was highly significant for two irrigations, one at the early vegetative stage and the other at the initial siliquae formation stage.

Roy and Tripathi (1985) reported 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. Yield was positively associated with number of branches and siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$ and 1000 seed weight.

Roy and Tripathi (1985) found that, in multiple correlation analysis , yield was positively associated with number of branches and siliquae plant^{-1} , number of seeds siliqua^{-1} and 1000-seed weight and the yield was greatly influenced by 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 from 0.62 to 1.17 t ha^{-1}. But the irrigation given at siliquae formation stage did not further increase seed yields.

2.1.9 Stover yield

Stover yield was found to be higher with the application of irrigation in mustard (Patel *et al.*, 1991). Maximum straw yield (17.0 q ha^{-1}) was found with one irrigation compared to unirrigated control which produced only 12.8 q ha^{-1}.

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 (54.0 q ha^{-1}) was produced with two irrigations applied at 30 DAS and 90 DAS. One irrigation at 30 DAS produced 52.5 q ha^{-1} biomass which was significantly lower than the highest yield. The lowest biomass yield (44.1 q ha^{-1}) was found when no irrigation was applied.

2.1.10 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 than that was given by irrigation at seed development stage or without irrigation. However, information is very scarce regarding to the effect of irrigation on harvest index of rapeseed.

2.1.11 Oil content

Singh and Saran (1992) observed in an experiment with *Brassica campestris* during the winter seasons of 1987-1989 that irrigation at IW and CPE ratio of 0.4 and 0.2 (two and one irrigation, respectively) gave average oil content of 43.2 and 43.0 %

respectively compared to 43.3 % from the control treatment. They observed that there was no significant effect of irrigation levels on oil content.

2.2 Effect of nitrogen

2.2.1 Plant height

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N ha^{-1} under irrigated or non-irrigated condition in a field experiment. They observed that plant height increased with increasing rate of nitrogen and were higher under irrigated than non-irrigated condition. Singh *et al.* (2002) also reported that plant height increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

BARI (1999) conducted trial in two different regions of Bangladesh, at Joydebpur and Ishwardi to justify the effect of N on yield of mustard. The experiment kept 3 levels of nitrogen 0, 120, 160 kg ha^{-1} and plant height was found 87.78, 113.94, 106.46 cm, respectively at Joydebpur and 90.79, 118.46, 113.69 cm at Ishwardi. The highest plant height was found in both the locations at 120 kg N ha^{-1}.

Brar *et al.* (1998) observed that each successive increase in nitrogen doses from 100 to 200 kg N ha^{-1}, there was significant increase in plant height. This might be due to the fact that nitrogen plays vital role in both cell division and cell enlargement. Islam and Mondal (1997) showed that application of nitrogen at the rate of 0,100,200,300 kg ha^{-1}, the maximum plant height was found 93.6 cm at 300 kg N ha^{-1}.

Ali and Ullah (1995) reported that with the application of different doses of nitrogen and maximum plant height was obtain from at 120 kg N ha^{-1}. Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased plant height.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation, observed that plant height increased progressively with the increasing levels of nitrogen but was not significantly different with the application of different levels of nitrogen. Nitrogen at the rate of 120 kg ha^{-1} gave the highest plant height. Mondal and Gaffar (1983) observed highest plant height of the variety 'Sampad' by the use of 140 kg N ha^{-1}, which was identical with 105 kg N ha^{-1}.

2.2.2 Dry matter accumulation

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N ha^{-1} under irrigated or non-irrigated condition. They observed increased dry matter accumulation with increasing rate of nitrogen application.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They found highest total dry matter at the application of 120 kg N ha^{-1}. Saikia *et al.* (2002) estimated that the total dry matter significantly responsed with the increasing levels of nitrogen (0, 30, 90, 120 and 150 kg ha^{-1}).

Singh *et al.* (2002) also concluded that dry matter accumulation $plant^{-1}$ increased significantly with each successive increase in nitrogen level up to 120 kg ha^{-1}. Brar *et al.* (1998) carried out a field trial and observed that application of 100, 150 and 200 kg N ha^{-1} dry matter accumulation increased significantly up to 200 kg N ha^{-1}.

Patil *et al.*(1997) worked on Brassica *campestris* with 0, 40, 80 and 120 kg N ha^{-1} and observed the changes in dry matter accumulation in various plant parts. They reported that the application of nitrogen up to 120 kg ha^{-1} had an effect on the increase in leaves, stems and siliquae during the entire period of crop growth. They also reported the beneficial effect of nitrogen on dry matter accumulation for each successive increase in nitrogen dose. Vyas *et al.* (1995) observed the effect of nitrogen on the dry matter production of Indian mustard. They reported that an increase in N rate increased the DM production.

Patra *et al.* (1994) conducted field trial on mustard (*Brassica juncea*) cv. Sarama. The crop was given 20 or 40 kg N ha^{-1}. They found maximum dry matter accumulation after 90 days in mustard with 40 kg N ha^{-1}. Sharma and Kumar (1989b) showed that an application of 120 kg N ha^{-1} increased photosynthetic surface area owing to greater accumulation of photosynthates and production of more dry matter in Indian mustard.

2.2.3 Number of branches $plant^{-1}$

Number of branches per plant influences the yield of rapeseed-mustard and it gradually increased with the increase in nitrogen fertilizers. Singh *et al.* (2003) reported the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg ha^{-1}) and basis of N application (row and even application) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg ha^{-1} produced higher number of branches per plant compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1} did not increase the number of branches per plant.

Tripathi and Tripathi (2003) performed an experiment to investigate the effect of N levels (80, 120, 160 and 200 kg ha^{-1}) on the branches number of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that the number of primary branches per plant increased up to 200 kg N ha^{-1}.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They found that the highest number of branches per plant was obtained with the application of 120 kg N ha^{-1}. Singh *et al.* (2002) reported that primary and secondary branches per plant increased significantly with each successive increase in nitrogen up to 120 kg ha^{-1}.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted the highest number of branches (24.4) per plant. Mondal *et al.* (1996) grew four rapeseed genotypes with five levels of nitrogen and observed that number of primary branches per plant increased progressively with the increasing nitrogen doses and the highest number of primary branches per plant was obtained from the highest level of nitrogen (250 kg N ha^{-1}).

Tarafder and Mondal (1990) reported from an experiment conducting for determining the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sarisha) and found that the number of branches per plant increased with the increasing levels of nitrogen. The combination of nitrogen and sulphur fertilizers significantly increased the number of primary branches per plant. Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation and observed that nitrogen at the rate of 120 kg ha^{-1} gave highest number of primary branches per plant (5.03).

Patel *et al.*(1980) observed the highest number of branches $plant^{-1}$ at 50 kg N ha^{-1} among the four levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}). Primary and secondary branches per plant significantly increased with the increase in nitrogen levels from 0 to 100 kg N ha^{-1} and the highest number of primary and secondary branches per plant was observed with the highest level of nitrogen.

2.2.4 Number of siliquae $plant^{-1}$

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}). He observed that adequate N fertilization is important in increasing siliquae number per plant and observed highest siliquae number per plant of summer oilseed rape at the rate of 160 kg N ha^{-1}.

Singh *et al.* (2003) reported from an experiment conducting for determining the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg ha^{-1}) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg ha^{-1} produced higher number of siliquae per plant (48.03), siliquae weight (2.09) compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1} did not increase the number of siliquae significantly.

Sharma and Jain (2002) studied with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted in the highest number of siliquae per plant (260.9). Singh *et al.* (2002) also reported that siliquae per plant increased significantly with each successive increase in nitrogen up to 120 kg ha^{-1}.

Shukla *et al.* (2002b) performed an experiment to observe the integrated nutrient management for Indian mustard (*Brassica juncea*). They found that maximum number of siliquae per plant was obtained with the application of 120 kg N ha^{-1}. Abadi *et al.* (2001) indicated that N had significant effect to increase the number of silique per plant of rapeseed.

BARI (1999) investigated in a field trial application with 0, 80, 120, 140 N kg ha^{-1} and siliquae per plant were found 22.7, 42.0, 45.6, and 48.0 respectively.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased the number of siliquae per plant. Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation and observed that N at the rate of 120 kg ha^{-1} significantly increased the number of siliquae per plant.

2.2.5 Length of siliquae

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N and P increased the length of siliqua. However, the significant increase in length of siliqua was recorded up to 120 kg N ha^{-1} with 60 kg P ha^{-1}.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They observed maximum siliquae length with the application of 120 kg N ha^{-1}. Singh *et al.* (2002) also reported that growth characters length of siliqua increased significantly with the successive increase in nitrogen up to 120 kg ha^{-1}.

Singh and Saran (1992) set an experiment with *Brassica campestris* var. Toria and applied different doses (0, 40 and 80 kg N ha^{-1}) of nitrogen. They found that nitrogen application significantly increased the siliqua length up to 80 kg N ha^{-1}. Effect of nitrogen was noticed only up to 40 kg ha^{-1} on yield attributes, such as primary branches $plant^{-1}$, siluquae $plant^{-1}$, siliqua length. Favorable effect of N on these yield attributes can be explained that application of N resulted in higher leaf-area index and dry matter accumulation and its translocation to reproductive parts.

2.2.6 Number of seeds $siliqua^{-1}$

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted in the highest number seeds per siliqua (15.3).

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N and P increased the number of seeds per siliqua. However, the significant increase in length of siliquae was recorded up to 120 kg N ha^{-1} with 60 kg P ha^{-1}. Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They obtained maximum number of seeds per siliqua when nitrogen was applied at 120 kg ha^{-1}.

Generally, the number of seeds per siliqua increased with increasing levels of N. Hossain and Gaffer (1997) observed that number of siliquae per plant, number of seeds per siliqua and 1000 seed weight varied significantly with mustard varieties and the highest number of siliquae per plant and 1000 seed weight and grain yield were obtained with 250 kg N ha^{-1}.

Tomar *et al.* (1997) worked with Indian mustard with 3 levels of nitrogen (60, 120 and 180 kg ha^{-1}) and showed that yield attributes (siliquae per plant, seeds per siliqua and 1000 seed weight) increased significantly with every increase in N up to

180 kg ha^{-1}. Due to enhanced growth attributes that diverted the photosynthates to reproductive organs for the formation of large sized, more number of seeds of higher seed weight that ultimately increased the yield ha^{-1}.

Tarafder and Mondal (1990) reported from an experiment conducting for determining the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sharisa) and found that the combine effect of nitrogen and sulphur fertilizers increased the number of seeds per siliqua.

2.2.7 Weight of 1000 seeds

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}). He observed that adequate N fertilization is important in increasing 1000 seed weight in summer oilseed rape and suggested that the rate of 160 kg N ha^{-1} will be adequate for the crop to meet its N requirements. 1000 seed weight differs with nitrogen levels that enhanced yield.

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N and P increased 1000 seed weight. However, the significant increase in 1000 seed weight was recorded up to 120 kg N ha^{-1} with 60 kg P ha^{-1}. Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted in 1000 seed weight (3.55 g).

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They obtained maximum 1000 seed weight with the application of 120 kg N ha^{-1}.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased 1000 seed weight. Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation and observed that 1000 seed weight increased progressively with the successive increase of N rate up to 120 kg ha^{-1}.

2.2.8 Seed yield

Sinsinwar *et al.* (2004) observed the increased seed yield of Indian mustard with each increment of N fertilizer up to 60 kg ha^{-1}, beyond this the increase was marginal. On an average, the increase in seed yield compared to the control was 33.3 and 83.8% with 30 and 60 kg N ha^{-1} respectively.

Singh (2004) conducted a field experiment using blue green algae (BGA) and *Azolla* in integration with graded levels of N fertilizer in rice followed by rapeseed. *Azolla* were found better in seed yield with regard to the effect on subsequent crop of rapeseed and the highest yield was recorded with higher dose of N (80 kg N ha^{-1}) in integration with *Azolla*.

Singh *et al.* (2003) reported from an experiment conducting for determining the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg ha^{-1}) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg ha^{-1} produced higher seed yield (2.55 q ha^{-1}) compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1}, did not increase the yield significantly.

Tripathi and Tripathi (2003) performed an experiment to inspect the effect of N levels (80, 120, 160 and 200 kg ha^{-1}) on the yield of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that seed yield increased with increasing N levels up to 160 kg N ha^{-1}. Singh and Prasad (2003) reported that 120 kg N ha^{-1} gave the highest seed yield (20.24 q ha^{-1}). But the highest cost benefit ratio (0.85) was obtained with 180 kg N ha^{-1}.

Kumar and Singh (2003) reported significant increase in seed yield (1617 kg ha^{-1}) with nitrogen at 150 kg ha^{-1}. Addition of 50 kg N ha^{-1} resulted in producing 8.62 kg of seed per kg of N applied. The maximum yield (24.51 q ha^{-1}) was obtained from 20-25 October sown crops with 40 cm row spacing and supplied with 150 kg N ha^{-1}.

Khan *et al.* (2003) studied the interactive effect of nitrogen (0, 40, 60 and 80 kg ha^{-1}) and plant growth regulators (cycocel and ethrel both at 200 or 400 ppm) on the photosynthetic biomass production and partitioning in response of seed yield of indian mustard cv. Alankar and found that 80 kg N ha^{-1} and ethrel at 200 ppm increased the seed yield.

Ozer (2003) studied the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}) on two cultivars of rapeseed. He observed that adequate N fertilization is important in yield formation in summer oilseed rape and suggested that the rate of 160 kg N ha^{-1} will be about adequate for the crop to meet its N requirements.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted in the highest seed yield (1649.22 kg ha^{-1}). The highest values of seed yield and yield attributes were recorded for *S. canabina* – Indian mustard receiving 80 kg N ha^{-1}. Shukla *et al.* (2002a) also conducted an experiment to investigate the effect of S (0 or 40 kg ha^{-1}) and N (60, 90 or 120 kg ha^{-1}) on the yield and yield attributes of rape cultivars. Sulphur did not significantly affect the seed yield and yield attributes. But N at 120 kg ha^{-1} produced higher seed yield than N at 60 and 90 kg ha^{-1}.

Singh (2002) conducted a study with variety Varuna of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N and P increased the seed yield. However, the significant increase in seed yield was recorded up to 120 kg N ha^{-1} with 60 kg P ha^{-1}. The maximum seed yields (12.98 and 13.83 q ha^{-1}) were obtained with the application of nitrogen at 120 kg ha^{-1}.

Shukla *et al.* (2002b) investigated the integrated nutrient management for Indian mustard (*B. juncea*). They observed maximum seed yield per hectare with the application of 120 kg N ha^{-1}.

Ghosh *et al.* (2001) conducted an experiment to study the response of 3 levels of K (0, 12.5 and 25 kg ha^{-1}), 3 levels of N (0, 40 and 80 kg ha^{-1}) and biofertilizers (*Azotibacter, Azospirillum*) under irrigated condition. Interaction between K and biofertilizer and between biofertilizer and N were found significant in increasing the yield of rapeseed. They observed that maximum yield of rapeseed was obtained followed by the yield obtained with 80 kg N ha^{-1} along with 12.5 kg K ha^{-1}.

Sidlauskas (2000) found that the yield of rapeseed was increased with the increasing rate of nitrogen levels up to 120 kg ha^{-1}. Further increase of nitrogen level did not affect the seed yield.

BARI (1999) investigated with 4 levels of nitrogen (0, 80,120,140 kg ha^{-1}) on different varieties of mustard and yields were found 493.3, 833.3, 940.0, 993.7 kg ha^{-1} respectively. Zekaite (1999) also reported that, the seed yield of rapeseed (0.88 t ha^{-1}) was obtained at a nitrogen fertilization of 90 kg ha^{-1}. Fertilization of nitrogen at 120 kg ha^{-1} significantly increased the seed yield.

Patel (1998) conducted an experiment to study the response of mustard (*Brassica juncea*) cv. Varuna to 3 levels of irrigation and 4 levels of nitrogen (0, 20, 40 and 80 kg ha^{-1}). He obtained seed yield averaged 0.43, 0.73, 0.95 and 1.21 t ha^{-1} with 0, 20, 40 and 60 kg N ha^{-1}, respectively. Singh *et al.* (1998) reported that seed and oil yields as well oil component values were increased with increasing nitrogen rates (0, 40, and 80 kg N ha^{-1}).

Shukla and Kumar (1997) reported that six varieties of Indian mustard were grown to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content. They found that N application at 120 kg ha^{-1} significantly influenced the seed yield. Gurjar and Chauhan (1997) observed that Pusa Bold and Kranti were grown in winter seasons at 5 N + P levels and at row spacing of 30 cm or 45 cm. They found that seed yield did not differ between cultivars, was greater at 30 cm spacing (1.68 vs. 1.12 t ha^{-1}) and increased up to 75 kg N + 50 kg P_2O_5 ha^{-1}.

Islam and Mondal (1997) in a field trial showed that application of four levels of nitrogen 0, 100, 200, 300 kg ha^{-1} yielded 0.69, 1.29, 1.45, 1.21 t ha^{-1} seeds, respectively. They observed increased seed yield up to 200 kg N ha^{-1}. Hossain and Gaffer (1997) conducted a trial with 5 level of nitrogen at 0,100,150,200,250, kg ha^{-1} on rapeseed and maximum yield was found 1.73 t ha^{-1} with 250 kg N ha^{-1}.

Thakuria and Gogoi (1996) conducted an experiment on *Brassica juncea* cv, TM 2, TM 4 and Varuna to evaluate the effect of 2 row spacings with 4 levels of nitrogen fertilizer (0, 40, 80 and 120 kg N ha^{-1}). Seed yield and yield components significantly increased with increasing N application up to 80 kg ha^{-1}. Tuteja *et al.* (1996) investigated the effect of nitrogen at 60, 90 and 120 kg ha^{-1} on the yield of *Brassica juncea* cv. Varuna. Seed yield was highest (1.12 t ha^{-1}) with 120 kg N ha^{-1}.

Mondal *et al.* (1996) reported that the highest seed yield of rapeseed (1.40 t ha^{-1}) was obtained from fertilizer levels of 150:90:100:30:4:1 kg ha^{-1} of N, P_2O5, K_2O, S, Zn and B with 6 tones of cow dung. This level of fertilizer was the most profitable among the 5 levels of fertilizers. Arthamwar *et al.* (1996) conducted an experiment with mustard variety (Pusa Bold and T-59) having both the 3 levels of N (0, 50 and 100 kg ha^{-1}) and P_2O_5 (0, 40 and 80 kg ha^{-1}). Result showed that highest seed yield obtained with N at of 100 kg ha^{-1} (1.20 t ha^{-1}) and 80 kg P_2O_5 ha^{-1} (1.25 t ha^{-1}).

Dobariya and Mehta (1995) also reported that increasing nitrogen rate from 25 to 75 kg ha^{-1} increased seed yield from 2.07-2.41 t ha^{-1}. Letu *et al.* (1994) also reported that application of 3 levels of N at 0, 120, 160 kg ha^{-1} produced the seed yield of 1.3, 1.4 and 1.5 t ha^{-1}, respectively.

Tarafder and Mondal (1990) set an experiment to evaluate the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sarisha) and found that seed yield increased with increasing levels of nitrogen or both nitrogen and sulphur. The results suggested that the nitrogen at the rate of 120 kg ha^{-1} did produce the economic seed yield in mustard in the grey terrace soil of Joydebpur.

Perniona *et al.* (1989) studied the effect of nitrogen (50, 100 and 150 kg ha^{-1}) on winter rape and found that average seed yield increased with the increased rate of nitrogen at 150 kg ha^{-1}. Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased the seed yield. This dose gave seed yields of 1.20 t ha^{-1} compared to 0.89 t ha^{-1} without nitrogen. A further increase in yield with 90 kg ha^{-1} was not significant.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation and observed that different levels of nitrogen did not significantly differed the seed yield. Nitrogen at the rate of 120 kg ha^{-1} gave seed yield of 830 kg ha^{-1}.

Mondal and Gaffer (1983) conducted experiment with Sampad variety of mustard having 5 levels of N (0, 35, 70, 105 and 140 kg ha^{-1}) and four levels of P_2O_5 (0, 35, 70 and 105 kg ha^{-1}). The highest seed yield (1280.95 kg ha^{-1}) was obtained from N treatment of 140 kg ha^{-1} which was found identical with that of 105 kg ha^{-1}.

2.2.9 Stover yield

Prasad *et al.* (2003) reported the effect of N, S and Zn fertilizers on the nutrient uptake, quality and yield of Indian mustard cv. Vaibhav. The treatments consisted of 60 kg N ha^{-1} singly or in combination with 30 kg P, 20 kg S, 5 kg Zn; 30 kg P + 20 kg S; 30 kg P + 5 kg Zn; 20 kg S + 5 kg Zn; or 30 kg P + 20 kg S + 5 kg Zn/ha. N, P, S and Zn were applied through urea, diammonium phosphate, gypsum and zinc oxide respectively. The application of 60 kg N + 30 kg P + 20 kg S + 5 kg Zn and 60 kg N + 30 kg P + 20 kg S ha^{-1} gave the highest stover yield (33.08 q ha^{-1}). Singh and Prasad (2003) also mentioned that 120 kg N ha^{-1} gave the highest stover yield (12.22 q ha^{-1}).

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that the application of 60 kg N ha^{-1} registered significantly higher stover yield of mustard over control. Singh *et al.* (2002) also reported that stover yield increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

2.2.10 Harvest index

Cheema *et al.* (2001) reported that increased fertilizer application up to 90 kg N ha^{-1} increased the harvest index. Kachroo and Kumar (1999) got higher harvest index at higher N rates.

Shukla and Kumar (1997) grew six varieties of Indian mustard to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content. They found that N application at the rate of 120 kg ha^{-1} significantly influenced harvest index.

Ali *et al.* (1996) observed that harvest index invariably increased owing to increased rate of N application. Ali and Ullah (1995) obtained the maximum harvest index in rapeseed with 120 kg N ha^{-1}.

Srivastava *et al.* (1988) got higher harvest index in mustard with 90 kg N ha^{-1} applied at the pre-flowering stage. Patel *et al.* (1980) reported that highest seed yield was achieved at the rate of 50 kg N ha^{-1} due to the formation of higher harvest index in rapeseed.

Harvest index or the capacity to convert biomass into harvestable organs has been recognized as an important selection criterion for many crops (Donald, 1963). Thus the increase in yield of cereals during past decades has been associated with the improvement of harvest index. Nitrogen fertilizer influences the harvest index.

2.2.11 Oil content

Patel *et al.* (2004) conducted experiment to investigate the effect of irrigation schedule, spacing (30 and 40 cm) and N rates (50, 75 and 100 kg ha^{-1}) on the growth, yield and quality of Indian mustard cv. GM-2. They reported that oil contents decreased with increasing nitrogen levels. Saha *et al.* (2003) also reported the highest oil content at 30 kg N ha^{-1}. Singh *et al.* (2004) conducted an experiment to study the response of Indian mustard cv. T-59 to nitrogen and sulfur rates. Different levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) application did not differed the oil content in mustard

Prasad *et al.* (2003) reported the effects of N, S and Zn fertilizers on nutrient uptake, quality and yield of Indian mustard (cv. Vaibhav).The application of 60 kg N ha^{-1} gave the highest oil content (39.98 %). Singh and Meena (2003) conducted a field experiment to determine the effect of N fertilizers (20, 40, 60, 80 and 100 kg N ha^{-1}) on the oil and protein yield of Indian mustard cv. Varuna. Pooled analysis of data showed that 40 kg N ha^{-1} gave the highest oil content (39.61%). The most profitable rate of N was found at 80 kg ha^{-1}.

Meena and Sumeriya (2003) carried out a study to evaluate the effect of nitrogen (0, 30, 60 and 90 kg ha^{-1}) on oil content of mustard *Brassica juncea.* Application of 60 kg N ha^{-1} gave the maximum oil (37.04%) content, compared to no nitrogen application. Abadi *et al.* (2001) also indicated that N had a significant effect on oil content of rapeseed and mustard.

Shukla and Kumar (1997) investigated six varieties of Indian mustard (Krishna, Varuna, Vardan, Kranti, Rohini and Pusa Bold) to assess the effect of nitrogen fertilization on seed yield and oil content. A decreasing trend of oil content was observed with the increase in N fertilization. Dubey *et al.* (1994) carried out an experiment on *B. juncea* cv. Varuna and was given 0, 30, 60 or 90 kg N ha^{-1} under irrigated condition. Seed oil content decreased by N application.

2.3 Interaction effect of irrigation and nitrogen on the growth, yield and yield attributes of rapeseed

2.3.1 Plant height

Tomar *et al.* (2001) conducted an experiment to studied on three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that the plant height significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

Abadi *et al.* (2001) reported that the plant height increased significantly with successive increase in two levels of irrigation (at 30 and 60 DAS) with the application of 120 kg N ha^{-1}.

Singh *et al.* (1998) conducted an experiment during winter (rabi) season of 1994-1995 and 1995-1996 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and irrigation levels on growth, yield and yield attributes. Application of 120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S ha^{-1} with two irrigation (at 30 and 60 DAS) significantly increased the plant height.

Singh *et al.* (1997) conducted an experiment with four levels of irrigation (30, 45, 60 and 75 DAS) and five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) on Indian mustard. They observed that three irrigations (at 30, 45 and 60 DAS) along with 120 kg N ha^{-1} significantly increased the plant height.

2.3.2 Dry matter accumulation

Tomar *et al.* (2001) conducted an experiment to studied on three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that the dry matter production increased significantly with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

Abadi *et al.* (2001) reported that the dry matter production increased significantly with successive increase in irrigation levels (at 30 and 60 DAS) with the application of 120 kg N ha^{-1}.

Mondal *et al.* (2000) conducted an experiment and studied the response of mustard (*Brassica juncea*) cv. Varuna to three levels of irrigation (at 30, 60, 75 DAS) and four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}). The maximum dry matter obtained by the application 2 levels of irrigation (at 30 and 60 DAS) along with 80 kg N ha^{-1}.

2.3.3 Number of siliquae plant^{-1}

Tomar *et al.* (2001) conducted an experiment to studied on three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that the number of siliquae plant^{-1} significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

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2.3.4 Number of seeds siliquae^{-1}

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that two irrigation (at 30 and 50 DAS) with the application of 120 kg N ha^{-1} registered significantly higher seeds per siliquae.

Tomar *et al.* (2001) conducted an experiment to studied on three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that the number of seeds per siliquae significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

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2.3.5 Weight of 1000 seeds

Tomar *et al.* (2001) investigated the effect of three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels of P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that the weight of 1000 seed significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

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2.3.6 Seed yield

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that two irrigation (at 30 and 50 DAS) along with the application of 120 kg N ha^{-1} registered significantly higher seed yield.

Tomar *et al.* (2001) carried out an experiment with three irrigations (at 30, 45 and 60 DAS), four levels of nitrogen (at 0, 60, 90 and 120 kg N ha^{-1}) and five levels P (0, 15, 30, 45 and 60 kg P ha^{-1}) on growth and yield of mustard. They observed that seed yield significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

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Singh *et al.* (1997) conducted an experiment with four levels of irrigation (30, 45, 60 and 75 DAS) and five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) on Indian mustard. They observed that three irrigations (at 30, 45 and 60 DAS) along with 120 kg N ha^{-1} significantly increased seed yield.

Chapter 3
Materials and Methods

Chapter 3

MATERIALS AND METHODS

The experiment was undertaken to examine the influence of irrigation and nitrogen on the yield of rapeseed (*Brassica napus*).

3.1 Location

The research was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from October 2005 to February 2006.

3.2 Site selection

The experimental field was located at $90^0 22'$ E longitude and $23^0 41'$ N latitude at an altitude of 8.6 meters above the sea level. The land was in Agro-ecological zone of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The soil was sandy loam in texture having pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.3 Climate

Cold temperature and minimum rainfall is the main feature of the *Rabi* season. Monthly total rainfall, average sunshine hour and temperature during the study period (October to February) are shown in Appendix II.

3.4 Variety

BARI Sharisha-8 (*Brassica napus*) was used in the experiment as the test crop. Its leaves are deep green, smooth and hairless and look like leaves of cauliflower. Leaves are without petiole and base of the leaf clasped half of the stem. Open flower lies below the bud. In each plant there are 60 to 70 siliquae. Siliqua is long, two chambered and each siliqua contains 25-30 seeds. Seeds are big and 1000 seed weight is 3.5 g. Seeds are blackish in colour. Plant height is 0.8 to 1.0 m. There are 4-5 primary branches per plant. Flowers are yellow in colour. First flower is seen after 25-30 days of sowing. Duration of flowering stage is longer than the other varieties. It takes 95-100 days to mature. Per hectare yield ranges from 2100 to 2400 kg/ha. The seed was collected from the Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701. Before sowing, germination test was carried out in the laboratory and percentage of germination was over 95.

3.5 Lay out of the experiment

The experiment was laid out in a split plot design with three replications. Irrigation treatments were applied in main plot and nitrogen treatments in sub plot. There were 4 irrigation treatments and 4 nitrogen fertilizer treatments for rapeseed. In the experiment, there were 3 replications and the total numbers of plots were 16×3=48. The size of each unit plot was 2.7m×4m=10.8 m^2. The replications were separated from one another by 1 m. The distance between plots was 1 m.

3.6 Irrigation treatments under investigation

There were 4 irrigation treatments in the experiment. The treatments were

I_0 = No irrigation

I_1 = One irrigation at 30 DAS

I_2 = Two irrigation at 30 and 50 DAS; and

I_3 = Three irrigation at 30, 50 and 65 DAS.

Irrigations were given as per treatments. First irrigation was given at 14 December 2005 (30 DAS) in the plots according to treatments. The second irrigation was given at 03 January 2006 (50 DAS) in the plots as required by the treatments. The third or final irrigation was given at 18 January 2006 (65 DAS) in the plots as required by the treatments. Irrigation was done by check basin method. After first irrigation at joe condition all the plots were spaded uniformly and carefully to conserve the moisture.

3.7 Fertilizer treatments

There were 4 Nitrogen fertilizer treatments in the experiment. The standard rate of P_2O_5 @ 86 kg ha^{-1}, K_2O @ 60 kg ha^{-1}, Sulphur @ 32 kg ha^{-1}, zinc oxide @ 5 kg ha^{-1} and Boric acid @ 10 kg ha^{-1} were applied to all the plots (BARI, 2001). There were four levels of N:

N_0 = Control

N_1 = 40 kg N ha^{-1}

N_2 = 80 kg N ha^{-1} and

N_3 = 120 kg N ha^{-1}

3.8 Details of the field operations

The particulars of cultural operations carried out during the experimentation are presented below.

3.8.1 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought into desirable fine tilth and leveled by four of ploughing operations and repeated laddering. The land was fallow, so the weeds of fallow land were cleaned properly. The final ploughing and land preparation was done on November 12, 2005.

3.8.2 Application of fertilizer

The amounts of fertilizer in the forms of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid required per plot were calculated from fertilizer doses. During final land preparation one - half of urea and total amount of all other fertilizers were applied and incorporated into soil. Rest of the urea as per treatment was top dressed after 30 days of sowing (DAS).

3.8.3 Sowing and seed rate

Seeds were sown continuously in 30 cm apart in rows at the rate of 9 kg ha^{-1} on good tilth soil condition to conserve moisture, which ensured satisfactory germination of seeds. After sowing; the seeds were covered with the soil and slightly pressed by hand. Plant populations were kept constant through maintaining plant-to-plant distance 5 cm in rows.

3.8.4 Thinning and weeding

The optimum plant population was maintained by thinning 15 DAS. At final thinning plant spacing within rows was maintained 5 cm plant to plant distance in rows. Thinning was done in the entire plots with special care as to maintain a constant plant population in the entire plot. One weeding with khurpi was given 25 days after sowing.

3.8.5 Pest and disease management

The crop was sprayed with Malathion 57 EC @ 2 ml per litre of water, at siliquae formation stage to control aphids.

3.8.6 Harvesting and threshing

The crop was harvested when 80% of the siliquae in terminal raceme turned golden yellow in colour. The crop maturity varied with fertilizer and irrigation treatments. Samples were collected from different places of each plot leaving undisturbed one meter square in the centre. After collecting sample plants, harvesting was started on February 20 and completed on February 25, 2006. The harvested crops were tied into bundles, tagged and carried to the clean cemented threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.8.7 Drying and weighing

The seeds thus collected were dried to 6-8 % moisture contents. The stovers were also dried in the sun. Dried seeds and stovers of each plot was weighed and subsequently converted into kg ha^{-1}.

3.9 Collection of experimental data

For the convenient of collecting data, ten plants per plot were randomly selected and tagged for recording various yield contributing characters and yield. But for estimation of total dry matter, five plants were selected per plot for each time (30, 45, 60, 75 DAS and at harvest) at different growth stages of plant.

3.9.1 Plant height (cm)

At different stages of crop growth for all treatments the height of five randomly selected plants were measured from the base to the tip of the plant and mean plant height was determined. The plant height was measured at 30, 45, 60, 75 DAS and at harvest.

3.9.2 Dry matter (g/plant)

Dry matter at 30, 45, 60, 75 days after sowing and at harvest was observed and average was recorded.

3.9.3 Number of primary branches plant^{-1}

The primary branches were counted from the ten tagged plants in each plot at harvest and average was taken.

3.9.4 Number of secondary branches plant^{-1}

The ten tagged plants in each plot were also used for counting the number of secondary branches at harvest. The secondary branches which borne at least one siliqua, were termed productive secondary branches and these were counted at harvest and expressed on per plant basis.

3.9.5 Length of main inflorescence (cm)

The ten tagged plants in each plot were also used for measure the length of main inflorescence. The main axis length represents the section of plant from point of initiation of first siliqua of most branches is termed as main inflorescence. These lengths were measured at harvest and expressed on main inflorescence basis.

3.9.6 Number of siliquae in the main inflorescence

Number of siliquae for each main inflorescence of ten tagged plants was counted at harvest.

3.9.7 Number of siliquae plant^{-1}

The number of siliquae from ten tagged plants were counted after the harvest and expressed on per plant basis.

3.9.8 Length of siliqua (cm)

Length of ten siliquae was randomly collected from the ten tagged plants and average length per siliqua was calculated.

3.9.9 Number of seeds siliqua^{-1}

At the time of counting the number of siliquae, all the siliquae of ten plants were thoroughly mixed and twenty siliquae were taken from this lot for counting the seeds and was made average to find out the number of seeds per siliqua.

3.9.10 Weight of 1000 seeds (g)

A composite sample was taken from the yield of ten tagged plants. 1000 seeds of each plot were counted and weighed with a fine electric digital balance. The 1000 seed weight was recorded in g.

3.9.11 Seed yield (kg ha^{-1})

1m × 1m = 1m^2 areas were selected in middle points of each plot for recording seed yield per hectare. The total produce from the net area of each plot was cleaned, weighted, and computed the seed yield in kg ha^{-1}.

3.9.12 Stover yield (kg ha^{-1})

Before threshing, the total biological yield from the net area was recorded. Later, the stover per net area of each plot was obtained by deducting the seed yield per plot from the biological yield (seed+stover) per plot and used to compute the stover yield in kg ha^{-1}.

3.9.13 Harvest index (%)

Harvest index was calculated by dividing the economic (seed) yield from the net plot by the total biological yield (seed+stover) from the same area (Donald, 1963) and multiplying by 100:

$$\text{Harvest index} = \frac{\text{Seed yield (t/ha)}}{\text{Biological yield (t/ha)}} \times 100 .$$

3.9.14 Oil content (%)

The oil content of seed was determined by Soxhlet method (Hughes, 1965) in percentage (%). This was done in Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701.

3.10 Soil sampling

Three composite soil samples were collected within 15 cm depth of soil profile, taking one from each block at first ploughing. Each composite sample was a mixture of 10 samples obtained from ten different spots in each block. Collected samples were air dried and ground to pass a 10-mesh sieve and stored in polythene bags for laboratory analysis. Soil analysis was done at Soil Resources Development Institute (SRDI).

3.11 Data analysis

The collected data were complied and analyzed by split plot design to find out the statistical significance of experimental results. The collected data were analyzed by MSTAT software (Russell, 1986). The means for all recorded data were calculated and the analyses of variance for all characters were performed. The mean differences were evaluated by least significant difference (LSD) test.

Chapter 4
Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. Experimental results pertaining to the effects of different treatments viz. irrigation and nitrogen levels on the yield of rapeseed during 2005-2006 are presented here. The yield and yield components included plant height (cm), total dry matter per plant, number of primary branches per plant, number of secondary branches per plant, length of main inflorescence, number of siliquae in main inflorescence, number of siliquae per plant, siliqua length, number of seeds per siliqua, 1000 seed weight, seed yield ha^{-1}, stover yield ha^{-1} and harvest index have been presented in different tables and figures. Chemical composition of some *Brassica* oilseeds have been presented in appendix III. The analyses of variance in respect of all the characters under study have been presented in Appendix IV-VI. The detailed experimental findings have been explained and discussed below with supporting references wherever possible.

4.1 Plant height (cm)

4.1.1 Effect of irrigation

Significant variation was found among the irrigations (Table 1) for plant height of rapeseed. The highest plant height at harvest was found from the treatment I_3 (three irrigations), which was significantly different from the other treatments. The lowest plant height was found from the control treatment (no irrigation) throughout the life cycle. No significant difference was found between the treatment I_2 and I_3 because the third irrigation was applied after 65 DAS. It might be due to the soil moisture availability for the plant was sufficient before third time irrigation at 65 DAS. Similar result was reported by Bihari *et al.* (1992). Sarker (1994) found tallest plant with one irrigation while the smallest plant was found in without irrigation. This finding was at par 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 1. Plant height (cm) of rapeseed at different days after sowing (DAS) as affected by different irrigation levels

Irrigation levels	DAS				
	30	45	60	75	At harvest
I_0	10.41	47.14	62.51	73.73	73.76
I_1	11.05	50.28	72.95	84.36	85.36
I_2	11.10	54.72	77.66	99.07	100.29
I_3	11.27	56.12	79.88	103.10	104.46
LSD (at 5%)	**NS**	**1.85**	**2.41**	**1.54**	**2.46**

4.1.2 Effect of nitrogen

Each successive increase of nitrogen increased the plant height significantly. It was observed from Table 2 that plant height varies due to variation of nitrogen at different growth stages. Application of 120 kg N ha^{-1} produced the tallest plant height and the shortest plant height was produced due to control treatment. This might be due to the fact that nitrogen plays vital role in both cell division and cell enlargement. These findings are in agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003), Singh *et al.* (2002). Tarafder and Mondal (1990) who obtained tallest plant height of mustard with the application of N at 120 kg ha^{-1}. Patel (1998), Shamsuddin *et al.* (1987), Gurjar and Chauhan (1997), Thakuria and Gogoi (1996) revealed taller plant height at 140 kg N ha^{-1} which was identical with that of 105 kg N ha^{-1}. Maximum plant height was recorded at 100 kg N ha^{-1} reported by Patel *et al.* (2004).

Table 2. Plant height (cm) of rapeseed at different days after sowing (DAS) as affected by different nitrogen levels

Nitrogen levels	DAS				
	30	45	60	75	At harvest
N_0	10.10	44.33	62.97	82.43	82.69
N_1	10.39	49.86	69.82	86.06	86.96
N_2	11.36	54.96	77.59	93.78	94.92
N_3	11.99	59.11	82.63	98.00	99.30
LSD (at 5 %)	NS	1.70	1.33	1.33	1.41

4.1.3 Interaction effect of irrigation and nitrogen

The interaction effect of irrigation and nitrogen had remarkable effect on the plant height of rapeseed (Figure 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 before 30 DAS. It was found from Figure 1 that the interaction of three levels of irrigations with 120 kg N ha^{-1} gave the tallest plant height viz. 12.53 cm, 65.09 cm, 89.05 cm, 113.60 cm and 114.77 cm at 30, 45, 60, 75 DAS and at harvest, respectively. Maximum plant height was observed in the treatment $I_3 N_3$ (three irrigation and 120 kg N ha^{-1}). The lowest plant height was found from the treatment I_0N_0 (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 75 DAS) because of better growth. The maximum plant height at harvest (114.77 cm) was obtained from the treatment I_3N_3, which was statistically similar with I_2N_3 and I_3N_2. Singh *et al.* (1998), Tomar *et al.* (2001) and Abadi *et al.* (2001) obtained significantly taller plant height when two irrigations were applied in combination with 120 kg N ha^{-1}. Singh *et al.* (1997) obtained significant taller plant height by applying three levels of irrigations and N rates up to 120 kg ha^{-1}.

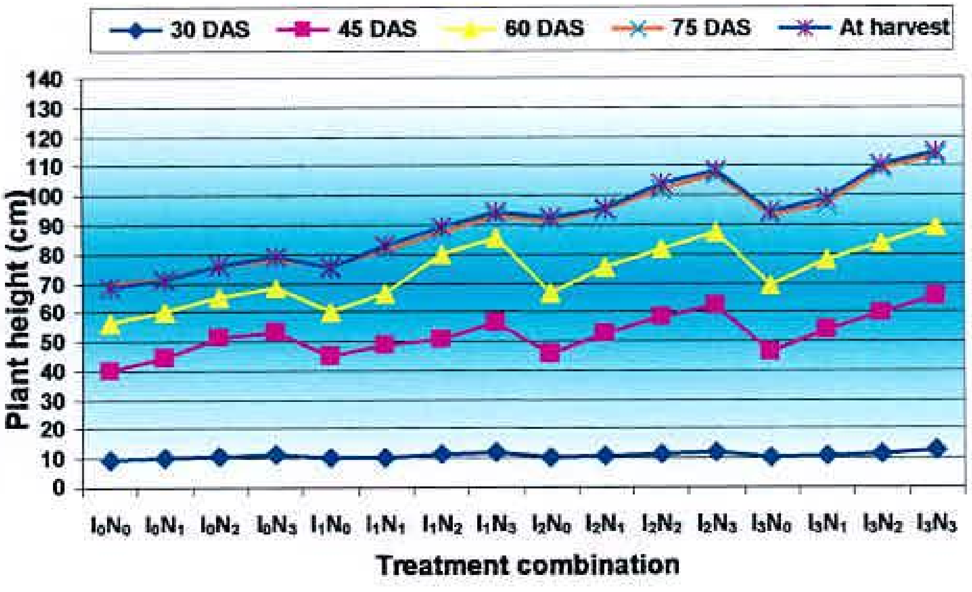

Figure 1. Plant height of rapeseed at different days after sowing (DAS) as affected by interaction effect of irrigation and nitrogen (LSD 0.05 = NS, 3.39, 2.67, 2.66, 2.82 at 30, 45, 60, 75 DAS and at harvest)

4.2 Total dry matter (g/plant)

4.2.1 Effect of irrigation

Significant variation was found in total dry matter per plant with the time among the different levels of irrigation except early growth stages. Distinct differences were observed in dry matter production after 30 DAS when irrigations were initiated (Table 3). These differences further increased at the successive stages. Wright *et al.* (1988) expressed the similar observation. The total dry matter production was increased with each increment of irrigation levels. At 45 DAS the treatment I_3 (30, 50 and 65 DAS) produced the maximum dry matter which was statistically similar with I_1 (30 DAS) and I_2 (30 and 50 DAS). At 60, 75 and 90 DAS the highest dry matter accumulation was found from the treatment I_3 (30,50 and 65 DAS) followed by I_2 and I_1. The I_3 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 maximum plant height and stem thickness in this treatment. The lowest dry matter was found from the control treatments. Siddqui (1999) reported that regardless of population density, cumulation 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 up to 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. 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. 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 that adversely affected dry matter accumulation in plants. Tomer *et al.* (1992), Saran and Giri (1988) also noticed increasing trend of dry matter accumulation in mustard plant with increasing irrigation levels. Giri (2001) found more dry matter weight per plant in mustard with two irrigations than with one irrigation.

Table 3. Dry matter weight (g/plant) of rapeseed at different days after sowing (DAS) as affected by different irrigation levels

Irrigation levels	DAS				
	30	45	60	75	At harvest
I_0	0.43	1.46	3.85	6.89	7.22
I_1	0.57	2.38	5.60	9.88	10.41
I_2	0.60	2.39	7.78	14.36	15.43
I_3	0.61	2.49	8.02	16.37	17.74
LSD (at 5 %)	**NS**	**0.20**	**0.23**	**0.56**	**0.65**

4.2.2 Effect of nitrogen

The dry matter per plant at 30, 45, 60, 75 DAS and at harvest was higher due to nitrogen application. Each level of nitrogen significantly increased dry matter over preceding level (Table 4). Nitrogen at 120 kg ha^{-1} produced the highest dry matter per plant (0.75 g, 2.97 g, 8.73 g, 15.95 g and 17.03 g at 30, 45, 60, 75 DAS and at harvest) than 40 and 80 kg N application ha^{-1} and also control. The yield of a crop depends on the dry matter production and amount of dry matter partitioning into its harvestable organ. The increase in the number of branches per plant may be ascribed to the functional role of nitrogen in the plant body. The chief functions of N are cell multiplication, cell elongation and tissue differentiation. With adequate supply of N the plants grew taller, produced more functional leaves with higher chlorophyll content. Thus photosynthesizing area might have increased resulting in greater production of dry matter per plant. So, at any given time the dry matter accumulation is a physiological index, which is closely related to the photosynthetic activity of leaves. These findings confirm the observations of Kumar and Gangwar (1985), Tomar and Mishra (1991) and Upasani and Sharma (1986). Bharati and Prasad (2003),Vyas *et al.* (1995), Singh *et al.* (2002), Shukla *et al.* (2002b), Murtaza and Paul (1989), Mondal and Gaffer (1983) also obtained highest result at the rate of 120 kg N ha^{-1} on dry matter production.

Table 4. Dry matter weight (g/plant) of rapeseed at different days after sowing (DAS) as affected by different nitrogen levels

Nitrogen levels	DAS				
	30	45	60	75	At harvest
N_0	0.37	1.33	2.89	7.31	7.83
N_1	0.48	1.93	5.95	10.40	11.17
N_2	0.62	2.49	7.68	13.83	14.76
N_3	0.75	2.97	8.73	15.95	17.03
LSD (at 5 %)	**0.01**	**0.10**	**0.20**	**0.36**	**0.43**

4.2.3 Interaction effect of irrigation and nitrogen

It was revealed from Figure 2 that the combined effect of three levels of irrigation (30,50 and 65 DAS) with 120 kg N ha^{-1} gave the significant weight of dry matter per plant at all growth stages (0.81, 3.49, 10.99, 20.77, 22.29 g per plant at 30, 45, 60, 75 DAS and at harvest respectively). Control treatment of irrigation and nitrogen gave the lowest dry matter production (0.26, 0.83, 1.86, 3.43 and 3.48 g per plant at 30, 45, 60, 75 DAS and at harvest). The result is in confirmation with that of Tomar *et al.* (2001), Abadi *et al.* (2001) who observed two irrigations and N at the rate of 120 kg ha^{-1} increased the dry matter production per plant. Mondal *et al.* (2000) obtained significantly higher dry matter production by applying two levels of irrigations with 80 kg N ha^{-1}.

4.3 Number of primary branches $plant^{-1}$

4.3.1 Effect of irrigation

From the study it was found that irrigation had great influence on the number of primary branches per plant in rapeseed (Figure 3). Number of irrigation significantly increased the number of primary branches per plant. The maximum numbers of primary branches (3.66) were found from a plant subjected to three irrigations (30, 50, and 65 DAS). The lowest numbers of primary branches were found from control treatment. Tomer *et al.* (1992) noticed significant increase in the number of primary branches per plant up to two irrigations. Rahman (1994) also reported that two irrigations gave the highest primary branches per plant and the lowest number of primary branches per plant was found in case of without irrigation. Probably irrigation water supported the plant to initiate more branches.

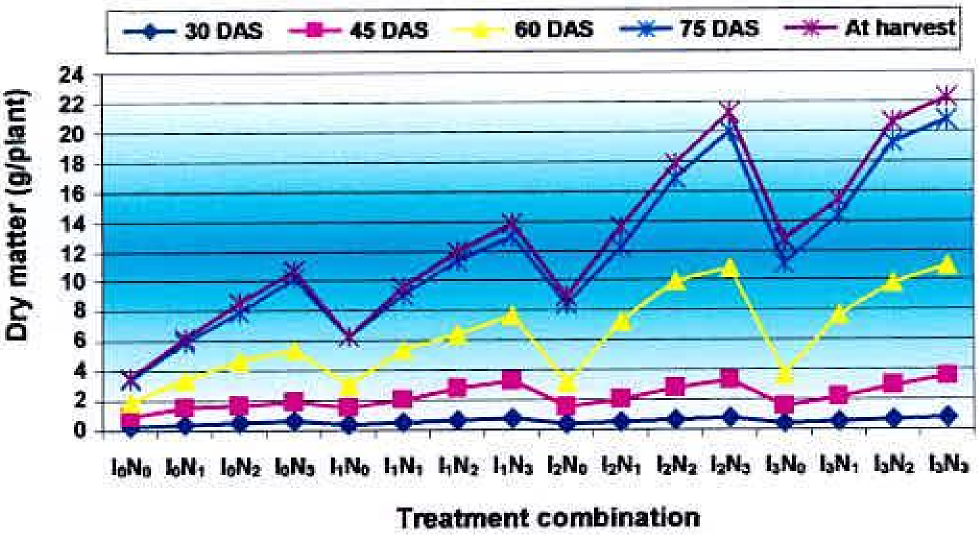

Figure 2. Total dry matter per plant of rapeseed at different days after sowing (DAS) as affected by interaction effect of irrigation and nitrogen (LSD 0.05 = NS, 0.17, 0.40, 0.71, 0.86 at 30, 45, 60, 75 DAS and at harvest)

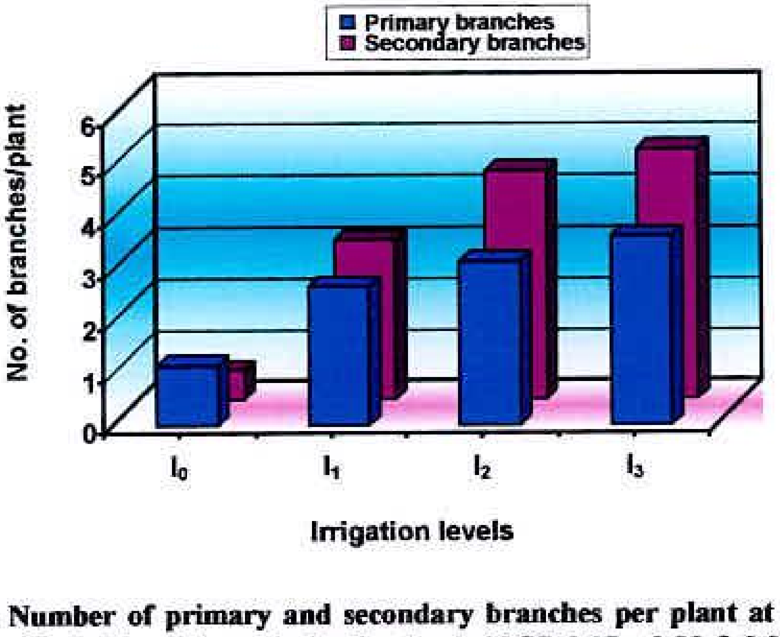

Figure 3. Number of primary and secondary branches per plant at harvest as affected by different irrigation levels (LSD 0.05 = 0.23 & 0.25 at primary and secondary branches per plant)

4.3.2 Effect of nitrogen

Nitrogen fertilizer had significant effect on primary branches per plant. The levels of nitrogen (80 and 120 kg ha^{-1}) produced higher number of primary branches over control (Figure 4). Increasing rates of nitrogen increased the number of primary branches per plant and successive treatment differences were also significant. So number of branches per plant influences the yield of rapeseed and it gradually increased with the increase in nitrogen fertilizers. This findings were supported by Tripathi and Tripathi (2003), Ozer (2003), Singh *et al.* (2003), Sharma and Jain (2002), Singh *et al.* (2002), Shukla *et al.* (2002b), Patel (1998), Tarafder and Mondal (1990), Shamsuddin *et al.* (1987), Mondal and Gaffer (1983) who obtained significant higher number of primary branches per plant by applying nitrogen up to 120 kg ha^{-1}.

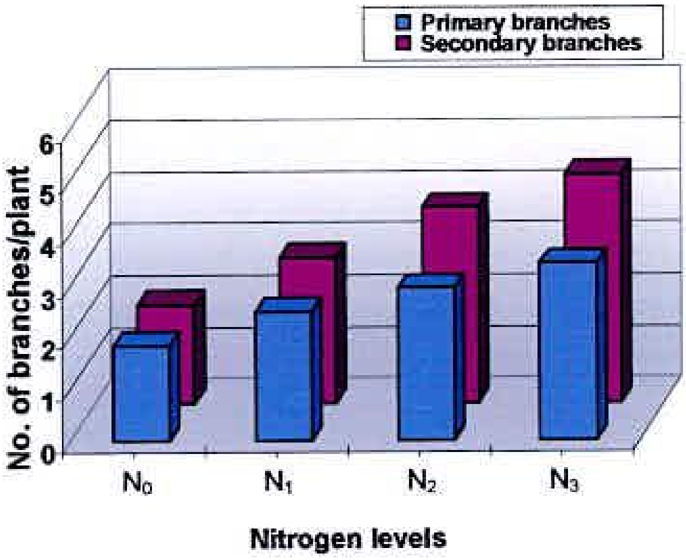

Figure 4. Number of primary and secondary branches per plant at harvest as affected by different nitrogen (LSD 0.05 = 0.13 & 0.16 at primary and secondary branches per plant)

4.3.3 Interaction effect of irrigation and nitrogen

It was observed that combined effect of irrigation and nitrogen had showed significant difference to produce primary branches per plant. The effect of irrigation interacts better with nitrogen when sufficient moisture was supplied. In the study the maximum number of primary branches per plant (4.78) was found from the interaction between three irrigations (30, 50 and 65 DAS) with 120 kg N ha^{-1}. The least number of primary branches (0.72) were found from the interaction of control treatment (Figure 5).

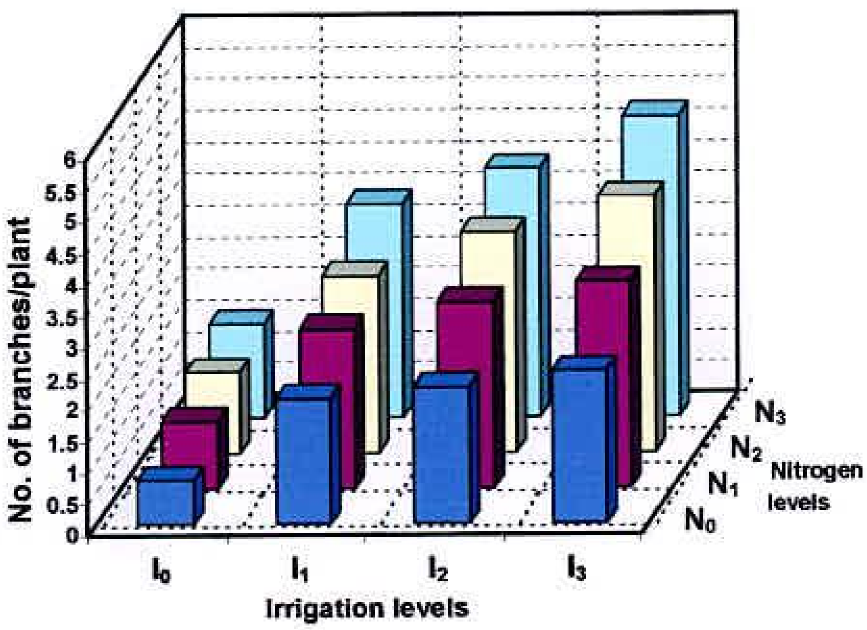

Figure 5. Interaction effect of irrigation and nitrogen on the production of primary branches per plant (LSD 0.05 = 0.27)

4.4 Number of secondary branches plant^{-1}

4.4.1 Effect of irrigation

From the study, it was found that irrigation had great influence on the number of secondary branches per plant in rapeseed (Figure 3). Number of irrigation significantly increased the number of secondary branches per plant. The maximum numbers of secondary branches (4.87) were found from a plant subjected to three irrigations (30, 50 and 65 DAS). The lowest numbers of secondary branches (0.57) were found from control treatment. Tomer *et al.* (1992) noticed significant increase in the number of secondary branches per plant up to two irrigations. Rahman (1994) also reported that two irrigations gave the highest secondary branches per plant and the lowest number of secondary branches per plant was found in case of without irrigation. Probably irrigation water supported plant to initiate more branches.

4.4.2 Effect of nitrogen

Nitrogen application favored to produce number of secondary branches per plant (Figure 4). However, the significant increase was noted at the level of 120 kg N ha^{-1} compared to 40, 80 kg N ha^{-1} and control. Singh *et al.* (2003) and Singh *et al.* (2002) obtained increased number of the secondary branches per plant with nitrogen at 120 kg ha^{-1}. Ali and Ullah (1995) observed the similar trend of branches per plant with the increase in nitrogen levels. Number of branches per plant was highly responsive to nitrogen reported by Prakash and Verma (1997) and Ali and Rahman (1986). But Sharma and Jain (2002) reported higher secondary branches per plant at the rate of 80 kg N ha^{-1}.

4.4.3 Interaction effect of irrigation and nitrogen

The treatment combination of irrigation and nitrogen had significant effect on secondary branches per plant (Figure 6). In the present work, it might be concluded that three irrigations (30, 50 and 65 DAS) and 120 kg N ha^{-1} produced maximum number of secondary branches per plant (6.74) and the lowest number of secondary branches per plant (0.00) were produced from the control treatment.

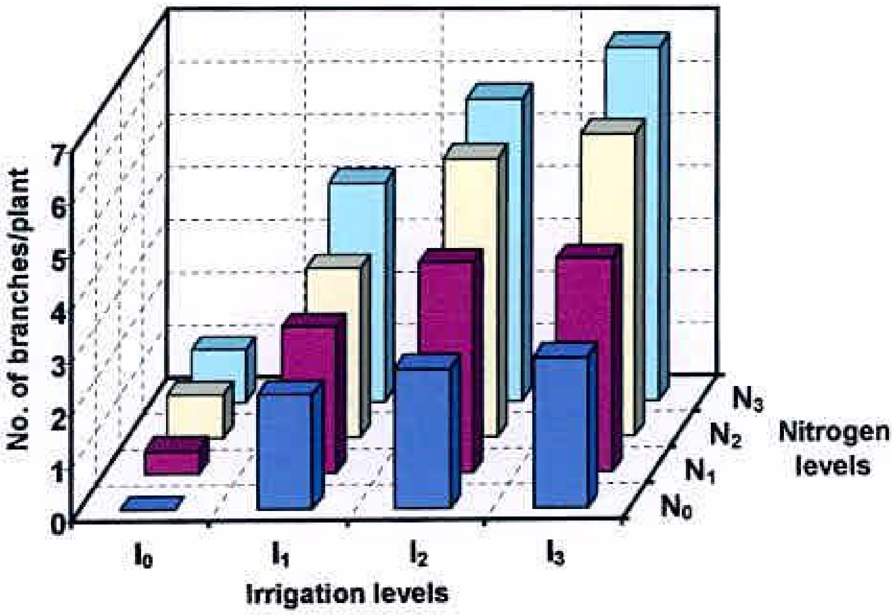

Figure 6. Interaction effect of irrigation and nitrogen on the production of secondary branches per plant (LSD 0.05 = 0.32)

4.5 Length of main inflorescence

4.5.1 Effect of irrigation

From the study, it was found that irrigation had significant effect on the length of main inflorescence (Table 5). The length of main inflorescence significantly increased with the increasing level of irrigations up to three irrigations. Three irrigation levels (30, 50 and 65 DAS) produced highest length of main inflorescence (66.74 cm) and lowest was found (42.39 cm) from the control treatment. Probably favorable moisture regimes influenced the plants to produce more length of main inflorescence.

Table 5. Effect of irrigation on different parameters of rapeseed

Irrigation levels	Length of main inflorescece (cm)	No. of siliquae in the main inflorescence	No. of siliquae per plant	Siliqua length (cm)	No. of seeds per siliqua	Weight of 1000 seeds (g)
I_0	42.39	26.27	35.31	6.38	21.86	3.03
I_1	58.52	41.70	79.45	7.27	23.32	3.17
I_2	63.70	52.12	108.82	7.62	25.83	3.26
I_3	66.74	58.01	136.24	7.65	27.20	3.36
LSD (at 5%)	**1.55**	**3.37**	**3.96**	**0.20**	**1.15**	**0.15**

4.5.2 Effect of nitrogen

Nitrogen fertilizer had significant effect on the length of main inflorescence. The rate of 80 and 120 kg N ha^{-1} showed significant effect on length of main inflorescence (63.35 and 65.11 cm respectively) and control gave the lowest one (50.30 cm) (Table 6). However, the differences between 80 and 120 kg N ha^{-1} were not found significant. The main functions of N are cell multiplication, cell elongation and tissue differentiation. With adequate supply of N the plants grew taller, produced more functional leaves with higher chlorophyll content.

Table 6. Effect of nitrogen on different parameters of rapeseed

Nitrogen levels	Length of main inflorescence (cm)	No. of siliquae in the main inflorescence	No. of siliquae per plant	Siliqua length (cm)	No. of seeds per siliqua	Weight of 1000 seeds (g)
N_0	50.30	36.53	61.39	6.56	20.86	3.00
N_1	55.59	41.03	77.74	7.07	24.02	3.16
N_2	63.35	47.62	103.22	7.55	25.90	3.25
N_3	65.11	52.91	117.46	7.73	27.44	3.41
LSD (at 5%)	**2.58**	**2.19**	**2.31**	**0.18**	**0.85**	**0.096**

4.5.3 Interaction effect of irrigation and nitrogen

It was seen that the treatment combination of three irrigations and the rate of 120 kg N ha^{-1} produced the highest length (75.87 cm) of main inflorescence (Table 7) and it was also similar with the effect of two irrigations and 120 kg N ha^{-1}. The combination of Io and N_0 gave the lowest length (35.57 cm) of main inflorescence.

Table 7. Interaction effect of irrigation and nitrogen on different parameters of rapeseed

Interaction (Irrigation X Nitrogen)	Length of main inflorescence (cm)	No. of siliquae in the main inflorescence	No. of siliquae per plant	Siliqua length (cm)	No. of seeds per siliqua	Weight of 1000 seeds (g)
I_0N_0	35.57	19.98	22.73	5.35	17.00	2.67
I_0N_1	41.60	23.92	34.67	6.30	21.36	3.07
I_0N_2	45.80	28.11	37.60	6.82	23.98	3.14
I_0N_3	46.60	33.07	46.23	7.05	25.10	3.26
I_1N_0	52.67	35.99	65.10	6.70	20.18	3.06
I_1N_1	55.67	38.70	71.77	7.12	22.49	3.13
I_1N_2	59.63	43.19	82.83	7.52	24.55	3.20
I_1N_3	66.10	48.93	98.10	7.73	26.07	3.31
I_2N_0	55.27	40.76	74.63	7.13	22.18	3.13
I_2N_1	61.10	47.57	92.33	7.39	26.00	3.20
I_2N_2	66.57	57.10	129.13	7.91	27.01	3.29
I_2N_3	71.87	63.03	139.17	8.06	28.15	3.43
I_3N_0	57.70	49.42	83.10	7.06	24.10	3.15
I_3N_1	64.00	53.95	112.20	7.49	26.23	3.26
I_3N_2	69.40	62.07	163.33	7.95	28.05	3.38
I_3N_3	75.87	66.61	186.33	8.09	30.43	3.65
LSD (at 5%)	**5.17**	**4.39**	**4.62**	**0.36**	**1.70**	**0.19**

4.6 Number of siliquae in the main inflorescence

4.6.1 Effect of irrigation

Number of siliquae is an important factor for increasing yield, which is adversely affected by the soil moisture. Number of siliquae in the main inflorescence was increased with the increasing levels of irrigations. In the present study, number of irrigation showed significant variation in producing siliquae in the main inflorescence (Table 5). Among the treatment I_3 (30, 50 and 65 DAS) produced the highest number of siliquae (58.01) in the main inflorescence which was statistically different from other treatments. The treatment Io (control) which was received no irrigation throughout the life cycle thus produced the lowest number of siliquae (26.27). In case of the second irrigation at siliquae formation stage helped in producing more number of siliquae in the main inflorescence. But in case of treatment I_1 when only one irrigation was applied at flowering stage and at later stage (siliquae formation) insufficient soil moisture reduced the number of siliquae in the main inflorescence. Third irrigation also reduced the abortion of siliquae. Tomer *et al.* (1992) concluded that number of siliquae in the main inflorescence was significantly increased up to two irrigations at pre-flowering and fruiting stage.

4.6.2 Effect of nitrogen

Application of N at 120 kg ha^{-1} significantly increased the number of siliquae in the main inflorescence (52.91) over control (36.53) (Table 6). Application of 40 and 80 kg N ha^{-1} resulted to produce 41.03 and 47.62 siliquae, respectively in the main inflorescence. The higher number of siliquae with higher rates of N was might be due to higher LAI, which resulted in a greater number of siliquae being carried by each inflorescence.

4.6.3 Interaction effect of irrigation and nitrogen

From the study, it was also observed that treatment combination of irrigation and nitrogen had significant effect on number of siliquae in the main inflorescence. Three levels of irrigation with 120 kg N ha^{-1} produced maximum number of siliquae in the main inflorescence (66.61) which was statistically similar with treatment combination of I_2N_3 and I_3N_2. Minimum numbers of siliquae in the main inflorescence (19.98) were produced by control treatment (Table 7). The combination of optimum irrigation with adequate supply of N the plants grew taller, ultimately produced more number of siliquae in the main inflorescence.

4.7 Number of siliquae plant^{-1}

4.7.1 Effect of irrigation

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 per plant (Table 5). Among the treatment I_3 (three irrigations at 30, 50 and 65 DAS) produced the highest number of siliquae (136.24) which was statistically different from other treatments. The treatment I_3 (three irrigations at 30, 50 and 65 DAS) showed around 4 times higher number of siliquae per plant over the control (no irrigation). The treatment Io (control) which was received no irrigation throughout the life cycle thus produced the lowest number of siliquae. In case of the second irrigation at siliquae formation stage helped in producing more number of siliquae. But in case of treatment I_1, when only one irrigation was applied at flowering stage and at later stage (siliquae formation) insufficient soil moisture reduced the number of siliquae per plant. Third irrigation also reduced the abortion of siliquae. The results obtained from the study were partially supported by Sarker and Hassan (1988), Sharma and Kumar (1989a) and Dobariya and Metha (1995) who reported that irrigation increased siliquae per plant. Tomer *et al.* (1992) concluded that number of siliquae per plant was significantly increased up to two irrigations at pre-flowering and fruiting stage.

4.7. 2 Effect of nitrogen

Nitrogen fertilizer had significant effect on number of siliquae per plant. The rate of 120 kg N ha^{-1} showed highest number of siliquae per plant (117.46) and control treatment gave the lowest one (61.39) (Table 6). Similar results were also obtained by Shukla *et al.* (2002b), Singh *et al.* (2003), Singh *et al* (2002), Tarafder and Mondal (1990) and Shamsuddin *et al.* (1987). On the other hand, higher number of siliquae per plant obtained at 80 kg N ha^{-1} by Khan *et al.* (2003), Sharma and Jain (2002), Patel (1998). Seed yield increased mainly due to greater number of siliquae per plant and seeds per siliqua. The number of siliquae per plant increased linearly with increasing rates of N. The higher number of siliquae with higher rates of N was might be due to higher LAI, which resulted in a greater number of siliquae being carried by each inflorescence. Greater number of siliquae was associated with higher LAI, which combined with larger LAD, led to higher final seed yield of rapeseed (*Brassica napus*).

4. 7 .3 Interaction effect of irrigation and nitrogen

Irrigation and nitrogen showed significant effect on number of siliquae per plant. The highest number of siliquae per plant (186.33) was produced with the interaction of three levels of irrigation and 120 kg N ha^{-1}. Three levels of irrigations (30, 50 and 65 DAS) with the rate of 120 kg N ha^{-1} showed significant difference to produce the number of siliquae per plant. Lowest number of siliquae per plant (22.73) was given by the combination I_0N_0 (without irrigation and N) (Table 7). Singh *et al.* (1998) Tomar *et al.* (2001) also obtained highest number of siliquae per plant with two irrigations and at 120 kg N ha^{-1}. It might be due to enhanced growth attributes that diverted the photosynthates to reproductive organs for the formation of large sized and more number of siliquae.

4.8 Length of siliqua (cm)

4.8.1 Effect of irrigation

Irrigation had significant effect on the siliquae length. It was observed that three irrigations gave the highest siliquae length (7.65 cm) which was statistically similar of treatment I_2 (two irrigations). The lowest siliquae length (6.38 cm) was found from the control treatment (Table 5).

4.8.2 Effect of nitrogen

Nitrogen had significant effect on the siliquae length. It was observed that 120 kg N ha^{-1} gave highest siliquae length (7.73 cm) and control gave the lowest one (6.56

cm) (Table 6). Singh (2002), Shukla *et al.* (2002b), Singh *et al.* (2002) who reported the highest length of siliquae at the rate of 120 kg N ha^{-1}.

4. 8 .3 Interaction effect of irrigation and nitrogen

In this study, interaction effect of irrigation and nitrogen showed significant effect on siliquae length. Significant highest siliqua length (8.09 cm) was found from the combination treatment of I_3N_3 (three irrigations with 120 kg N ha^{-1}) which was statistically similar of the combination treatment of I_3N_2, I_2N_3 and I_2N_2, while the shortest siliquae length (5.35 cm) was found from the control treatment (Table 7).

4.9 Number of seeds $siliqua^{-1}$

4.9.1 Effect of irrigation

Numbers of seeds per siliqua were significantly affected by irrigation levels. The number of seeds per siliqua was increased with the increase of irrigation number (Table 5). The significant highest number of seeds per siliqua (27.20) was found with three irrigations at 30, 50 and other at 65 DAS while the lowest number of seeds per siliqua (21.86) was found from the control treatment. Seed per siliqua increased with the increasing levels of irrigation due to the supply of adequate soil moisture which helped to elongate the siliquae length and have more number of seeds. Tomer *et al.* (1993) found a significant increase of seeds per siliqua with two irrigations-one at pre-flowering stage and another at fruiting stage. A number of researchers Prasad and Eshanullah (1988); Sarker and Hassan, (1988); Sharma and Kumar, (1989b) and Dobariya and Metha (1995) also observed that irrigation increased number of seeds per siliqua.

4.9.2 Effect of nitrogen

Nitrogen rates significantly influenced the number of seeds per siliqua. The number of seeds per siliqua was increased with the increase of nitrogen rates (Table 6). The significant highest number of seeds per siliqua (27.44) was found with the rate of 120 kg N ha^{-1} while the lowest number of seeds per siliqua (20.86) were found from the control treatment. Seeds per siliqua increased with the increasing levels of nitrogen up to a certain levels. Some results showed significant effect on number of seed per siliqua that were obtained by Singh (2002), Shukla *et al.* (2002b), Tarafder and Mondal (1990), Mondal and Gaffer (1983) showed significant effect on number of seeds per siliqua nitrogen at rate of nitrogen of 120 kg ha^{-1}. Sharma and Jain (2002) obtained higher number of seeds per siliqua at the rate of 80 kg N ha^{-1}. Patel (1998) also obtained similar response of nitrogen on number of seeds per siliqua. It might be due to the fact that vigorous vegetative growth due to nitrogen resulted in adequate supply of photosynthates for the formation of siliqua.

4.9.3 Interaction effect of irrigation and nitrogen

Irrigation as well as nitrogen interact each other to produce seeds per siliqua in rapeseed. Significant variations in the number of seeds per siliqua were found with the different interaction of irrigation and nitrogen in the study (Table 7). The highest number of seeds per siliqua (30.43) was found when three irrigations were applied with 120 kg N ha^{-1}. The lowest numbers of seeds per siliqua (17.00) were found from the treatment I_0N_0 (control). Singh *et al.* (1998), Tomar *et al.* (2001) and Meena *et al.* (2002) obtained higher number of seed per siliqua when two irrigations were applied in combination with 120 kg N ha^{-1}.

4.10 Weight of 1000 seeds (g)

4.10.1 Effect of irrigation

From the table 5, it can be seen that the irrigation levels had significant effect on 1000-seed weight. Three irrigations at 30, 50 and 65 DAS produced the highest 1000 seed weight of 3.36 g, which was significantly superior to 3.17 g produced by one irrigation applied at 30 DAS. The lowest 1000 seed weight (3.03 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. In his study two irrigations produced the highest 1000 seed weight which was significantly superior to that produced by one irrigation. The lowest 1000 seeds produced without irrigation. The results obtained in the study were supported by Sarkar and Hassan (1988), Sharma and Kumar (1989b) and Sarker *et al*. (2000) who reported that increasing the frequency of irrigation increased 1000 seed weight.

4.10.2 Effect of nitrogen

Table 6, it was reveled that the application of nitrogen at 40, 80 and 120 kg ha^{-1} had significant effect on 1000 seed weight. The 1000 seed weight increased with the increase of nitrogen levels. At the rate of 120 kg N ha^{-1} produced maximum seed weight (3.41 g) and control treatment gave the lowest one (3.00 g). Sharma and Jain (2002) also obtained highest 1000 seed weight at 80 kg N ha^{-1}. But, Ozer (2003), Singh *et al*. (2002), Shukla *et al.* (2002b) and Shamsuddin *et al.* (1987) obtained highest 1000 seed weight N at 120 kg ha^{-1}. It might be due to enhanced growth attributes that diverted the photosynthates to reproductive organs for the formation of large sized, more number of seeds of higher seed weight that ultimately increased the yield per hectare. So seed yield of rapeseed was greatly influenced by 1000 seed weight.

4.10.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen was found significant in relation to 1000 seed weight of rapeseed. (Table 7). The highest weight of 1000 seed (3.65 g) was found from the combination of three irrigations (at 30, 50 and 65 DAS) with 120 kg N ha^{-1} (I_3N_3), it was followed by I_2N_3 (3.43 g). The 1000 seed weight increased with the increasing levels of irrigation and nitrogen reported by Abadi *et al.* (2001) Tomar *et al.* (2001), Singh *et al.* (1998). Mondal *et al.* (2000) obtained significant higher 1000 seed weight by applying two irrigations along with 80 kg N ha^{-1}.

4.11 Seed yield (kg ha^{-1})

4.11.1 Effect of irrigation

Irrigation significantly increased the seed yield per hectare in rapeseed. In this study, seed yield per hectare increased with the increase of irrigation levels (Figure 7) Maximum seed yield per hectare (1455.96 kg ha^{-1}) was found from three irrigations (at 30, 50 and 65 DAS) which was higher than the other treatments. The lowest seed yield ha^{-1} was found from control treatment (348.05 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 assimilation rate, which adversely affected yield components and thus yield was reduced. The treatment I_3 (at 30, 50 and 65 DAS) significantly increased the seed yield due to favorable growth condition with maximum production of dry matter especially at siliquae formation stage. The second irrigation helped increasing the siliquae number. Similar result was also found by Ali *et al.* (1976) 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. Sharma and Kumar (1989a) observed that seed yield was increased with increasing the frequency of irrigation. Rahman (1994) reported that highest seed yield was produced by two irrigations. The lowest yield was produced by Io (without irrigation) and this was statistically inferior to I_1 (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 per plant, seeds per siliqua, and 1000 seed weight (Tomer *et al.*, 1992). These results corroborated with the results of Khan and Agarwal (1985), Samui *et al.* (1986), Malavia *et al.* (1988) and Gill and Narang (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.

4.11.2 Effect of nitrogen

Different rates of nitrogen significantly increased the seed yield per hectare. Nitrogen at 120 kg ha^{-1} significantly increased the seed yield (1347.72 kg ha^{-1}) over 40 kg ha^{-1} (756.77 kg ha^{-1}) and 80 kg N ha^{-1} (1122.58 kg ha^{-1}) and control (408.48 kg ha^{-1}) (Figure 8). Seed yield decreased with the decreasing rates of nitrogen fertilizer application. Higher seed yield (kg ha^{-1}) was also obtained with same nitrogen rate as reported by Singh and Prasad (2003), Singh *et al.* (2003), Shukla *et al.* (2002b), Singh (2002), Shukla *et al.* (2002a), Singh *et al.* (2002), Shukla and Kumar (1997), Tuteja *et al.* (1996), Shamsuddin *et al.* (1987). In some cases the highest seed yields kg ha^{-1} were obtained by Singh (2004), Sharma and Jain (2002), Ghosh *et al.* (2001), Khan *et al.* (2003), Singh *et al.* (1998) and Thakuria and Gogoi (1996) at 80 kg N ha^{-1}.

Increase in the seed yield of rapeseed due to increasing nitrogen levels may be attributed to the favorable improvement in all the yield attributes with N fertilization.

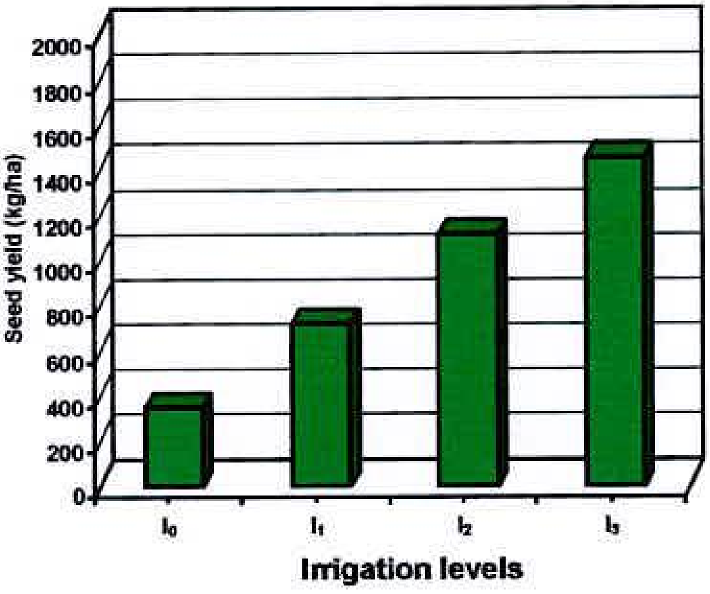

Figure 7. Effect of irrigation on seed yield of rapeseed (LSD 0.05 = 57.76)

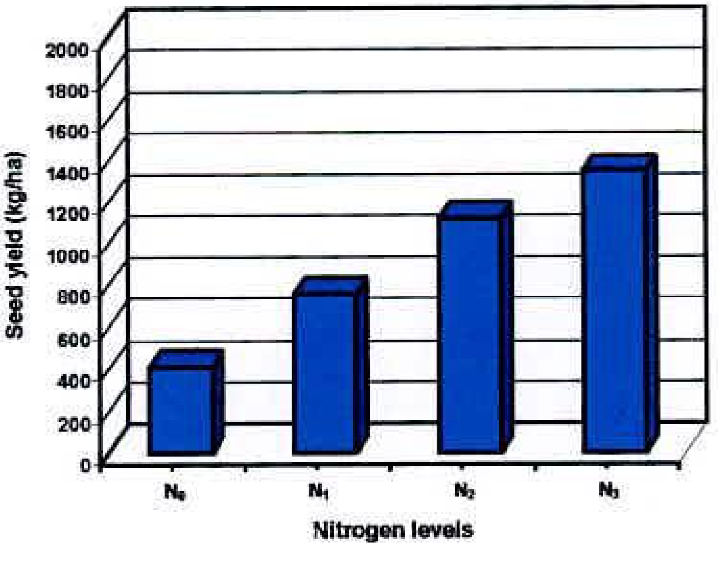

Figure 8. Effect of nitrogen on seed yield of rapeseed (LSD 0.05 = 20.09)

4.11.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen influenced the seed yield per hectare and seed yield was significantly superior (2130 kg ha^{-1}) at three levels of irrigations with 120 kg N ha^{-1}. But control treatment gave the lowest yield (144.83 kg ha^{-1}) (Figure 9) which might be referred to soil moisture deficit and inadequate N application. Meena *et al.* (2002), Tomar *et al.* (2001) and Singh *et al.* (1998) observed higher seed yield with two irrigations at branching and flowering stages in combination with at 120 kg N ha^{-1}. Mondal *et al.* (2000) obtained the highest seed yield of mustard by applying two irrigations in combination with 80 kg N ha^{-1}.

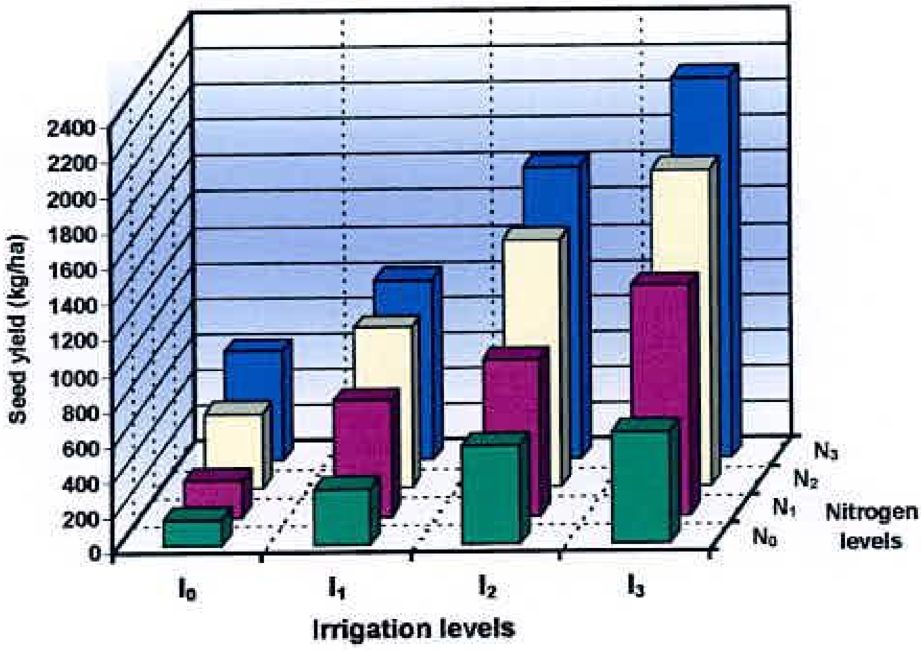

Figure 9. Interaction effect of irrigation and nitrogen on seed yield of rapeseed (LSD 0.05 = 40.17)

4.12 Stover yield (kg ha^{-1})

4.12.1 Effect of irrigation

The number of irrigation when increased the plant height, dry matter, number of branches, length of the main inflorescence, ultimately increased the stover yield. In this study, significant variation was found in stover yield at different irrigation levels (Table 8). The treatment I_3 (irrigations at 30, 50 and 65 DAS) produced the highest stover yield (2916.98 kg ha^{-1}) which was statistically different from I_2, I_1 and I_0. In the previous discussion it was shown that I_3 (irrigations at 30, 50 and 65 DAS) treatment produced the tallest plant height, number of branches per plant and number of siliquae per plant, which cumulatively increased the stover yield. The treatment I_0 (no irrigation) produced the lowest stover yield (852.63 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 per plant while the lowest yield was found from zero irrigation.

Table 8. Effect of irrigation on stover yield, harvest index (%) and oil content (%) of rapeseed

Irrigation levels	Stover yield (kg/ha)	Harvest index (%)	Oil content (%)
I_0	852.63	28.41	40.95
I_1	1622.19	30.30	40.97
I_2	2321.64	31.90	40.99
I_3	2916.98	32.72	40.74
LSD (at 5%)	**112.5**	**0.1915**	**0.0316**

4.12.2 Effect of nitrogen

The nitrogen application favorably influenced the stover yield and the difference among the consecutive levels was significant (Table 9). The application of 120 kg N ha^{-1} gave significantly highest stover yield (2698.53 kg ha^{-1}) over 40 and 80 kg N ha^{-1}(1694.37 and 2349.36 kg ha^{-1} respectively) and also control (971.19 kg ha^{-1}). These findings were in agreement with that of Singh and Prasad (2003), Singh *et al.*

(2002). But, Meena *et al.* (2002) observed higher stover yield of mustard at the nitrogen rate of 60 kg ha^{-1}. It might be due to increasing rate of nitrogen up to 120 kg ha^{-1}, increases the plant height, dry matter, number of branches, length of the main inflorescence and ultimately increased the stover yield.

Table 9. Effect of nitrogen on stover yield, harvest index (%) and oil content (%) of rapeseed

Nitrogen levels	Stover yield (kg/ha)	Harvest index (%)	Oil content (%)
N_0	971.19	28.89	40.73
N_1	1694.37	30.25	41.19
N_2	2349.36	31.67	40.72
N_3	2698.53	32.52	41.01
LSD (at 5%)	**42.31**	**0.2702**	**0.0377**

4.12.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen had significant effect on stover yield. Stover yield was highest (3995.58 kg ha^{-1}) when three irrigations were applied with 120 kg N ha^{-1}. The three irrigations with the rate of nitrogen at 120 kg ha^{-1} showed the results that was statistically different from other treatments (Table 10). The lowest stover yield (405.67 kg ha^{-1}) was observed by treatment of I_0N_0 (control treatment).

4.13 Harvest index (%)

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

4.13.1 Effect of irrigation

It was observed from the table 8 that different irrigation levels had significant effect on harvest index. Among the four irrigation levels three irrigations at 30, 50 and 65 DAS gave the highest harvest index (32.72%) and it was significantly different from the other treatments. The lowest value of harvest index (28.41%) was obtained from the treatment Io (no irrigation). Three irrigations (at 30, 50 and 65 DAS) produced higher seed yield, which increased the harvest index. At Io treatment, the plant suffered from severe water stress condition and they produced poor seed yield. One irrigation at pre-flowering stage increased the vegetative growth but at reproductive phase due to shortage of soil moisture the seed development was seriously hampered and that is why it produced the lower 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 I_0 (without irrigation) which was statistically inferior to two irrigations but statistically identical with one irrigation. It is evident from the results that increasing irrigation levels significantly increased harvest index. The cause of increase in harvest index might be due to higher seed yield compared to biological yield as obtained by increasing levels of irrigation.

Table 10. Interaction effect of irrigation and nitrogen on stover yield, harvest index (%) and oil content (%) of rapeseed

Interaction (irrigation x nitrogen)	Stover yield (kg ha^{-1})	Harvest index (%)	Oil content (%)
I_0N_0	405.17	26.36	40.80
I_0N_1	527.67	28.14	41.21
I_0N_2	1009.08	29.59	40.89
I_0N_3	1468.62	29.56	40.92
I_1N_0	785.92	28.36	41.05
I_1N_1	1487.42	30.51	41.31
I_1N_2	2007.93	30.92	40.57
I_1N_3	2207.50	31.40	40.93
I_2N_0	1271.92	30.31	40.81
I_2N_1	1981.40	30.64	40.84
I_2N_2	2910.83	32.31	40.91
I_2N_3	3122.42	34.34	41.38
I_3N_0	1421.75	30.51	40.25
I_3N_1	2781.00	31.71	41.40
I_3N_2	3469.58	33.86	40.52
I_3N_3	3995.58	34.77	40.81
LSD (at 5%)	**84.61**	**0.5404**	**0.076**

4.13.2 Effect of nitrogen

From Table 9 it revealed that the different nitrogen levels had significant effect on harvest index. Application of nitrogen at 120 kg ha^{-1} significantly increased the harvest index (32.52%) followed by 40 and 80 kg ha^{-1} (30.25% and 31.67% respectively) and control (28.89%). Highest harvest index observed at 120 kg N ha^{-1}. Similar result was also observed by Shukla and Kumar (1997) at the same nitrogen level.

4.13.3 Interaction effect of irrigation and nitrogen

It was observed that irrigation and nitrogen interaction had significant effect on harvest index. Harvest index was significantly higher when applied three irrigations in combination with 120, 80 and 40 kg N ha^{-1} and produced higher harvest index 34.77%, 33.86% and 31.71% respectively (Table 10). The lowest harvest index (26.36%) was recorded from the treatment combination of I_0N_0.

4.14 Oil content (%)

4.14.1 Effect of irrigation

From Table 8, it was found that irrigation levels had significant effect on oil content of rapeseed. It was observed that two irrigations gave the highest oil content (40.99 %) and three irrigations gave the lowest oil content (40.74 %) of rapeseed. However, one irrigation (40.97 %) and two irrigations (40.99 %) gave statistically similar oil content.

4.14.2 Effect of nitrogen

Nitrogen fertilizer had significant effect on oil content of rapeseed. The rate of 40 kg N ha^{-1} showed the highest oil content (41.19 %) and 80 kg N ha^{-1} (40.72 %) gave the lowest oil content of rapeseed. However, control treatment (40.73 %) and 80 kg N ha^{-1} (40.72 %) gave similar oil content (Table 9).

4.14.3 Interaction effect of irrigation and nitrogen

It was seen that the treatment combination of three irrigations and 40 kg N ha^{-1} gave the highest oil content (41.40 %) of rapeseed (Table 10) which was similar to two irrigations in combination with 120 kg N ha^{-1}. The combination of three irrigations and N_0 (without nitrogen) gave the lowest oil content (40.25 %) of rapeseed.

Chapter 5
Summary and conclusion

Chapter 5

SUMMARY AND CONCLUSION

An experiment entitled "Influence of irrigation and nitrogen on the yield of rapeseed (*Brassica napus*)" was conducted during *Rabi* season (October – February, 2005-2006), at Agronomy field, SAU, Dhaka-1207. The treatment comprised 4 levels of irrigation and 4 levels of nitrogen. The results are summarized below.

The rapid increase in plant height was observed from 30 DAS to 75 DAS. Significant variation was found in plant height among the irrigation levels. The maximum plant height was found from three irrigations. A progressive increase of plant height was observed up to 120 kg N ha^{-1}. Plant heights were significantly influenced by the interaction effect of irrigation and nitrogen on different growth stages and at harvest. Application of three irrigations along with 120 kg N ha^{-1} showed higher plant height, but on the other hand, lower plant height were observed at control combination of treatments. In general, more than 90 percent of the plant height was attained at 60 DAS and the crop reached a maximum height at 75 DAS, there after, height remained more or less constant.

Dry matter accumulation increased significantly at all growth stages. Significant variation was found in total dry matter per plant among the different levels of irrigation except 30 DAS. As the second irrigation (50 DAS) continued soil moisture at siliquae formation stage, and third irrigation (65 DAS) continued at pod developing stage, three irrigation was found to be most effective. At early growth stage maximum dry matter accumulation was observed at higher nitrogen levels but at later stages N at 120 kg ha^{-1} maintained higher dry matter.

In case of interaction effect, the treatment combination of three irrigation along with 120 ka N ha^{-1} produced higher dry matter at different growth stages and at harvest. Three irrigations in combination with 120 kg N ha^{-1} produced maximum dry matter at 75 DAS and at harvest.

The number of primary branches per plant, secondary branches per plant, length of main inflorescence (cm), number of siliquae in the main inflorescence, number of siliquae per plant increased progressively with the increasing level of irrigation. The maximum numbers of primary, secondary branches per plant, length of main inflorescence (cm), number of siliquae in the main inflorescence, number of siliquae per plant were found when three irrigations were applied at 30, 50 and 65 DAS. The lowest results were found from the control treatment. The number of primary branches per plant, secondary branches per plant, length of main inflorescence (cm), number of siliquae in the main inflorescence, number of siliquae per plant increased progressively with the increasing level of Nitrogen. The average numbers of primary, secondary branches per plant, length of main inflorescence (cm), number of siliquae in the main inflorescence, number of siliquae per plant were found at higher rate of 120 kg ha^{-1} nitrogen application.

Interaction of irrigation and N significantly influenced branch number, length of main inflorescence (cm), siliquae number in the main inflorescence and siliquae per plant. Application of three levels of irrigation with 120 kg N/ha gave significantly higher number of primary branches (4.78), secondary branches (6.74), length of main inflorescence (75.87 cm), siliquae number in the main inflorescence (66.61) and siliquae number per plant (186.33).

Irrigations had significant effect on the siliquae length and seeds per siliquae. Among the irrigation treatments, three irrigations at 30, 50 and 65 DAS produced the highest siliquae length (7.65 cm) and seeds per siliquae (27.20) which was statistically different from other irrigation treatments. The highest siliquae length (7.73 cm) and seeds per siliquae (27.44) obtained at 120 kg N ha^{-1}.

Interaction effect of irrigation and N significantly influenced the siliquae length and seeds per siliqua. Application of three levels of irrigation with 120 kg N ha^{-1} gave significantly higher number of siliquae length (8.09 cm) and seeds per siliqua (30.43) and lowest was found from the control treatment.

The 1000 seed weight was little influenced with application of irrigation except irrigation control treatment. But 120 kg N ha^{-1} produced highest 1000 seed weight (3.41 g) and lowest 1000 seed weight (3.00) was obtained at the N control treatment. The highest 1000 seed weight (3.65 g) obtained at the application of three levels of irrigation in combination with 120 kg N ha^{-1}.

Seed yield and stover yield is a complex character, which depends on the different yield contributing characters. The seed and stover yield per hectare was significantly influenced by the number of irrigation and three irrigation produced the highest seed yield (1455.96 kg ha^{-1}) and stover yield (2916.98 kg ha^{-1}) these were statistically different from other irrigations and least seed yield (348.05 kg ha^{-1}) and stover yield (852.63 kg ha^{-1}) was found at unirrigated condition. The seed and stover yield were increased significantly up to 120 kg N ha^{-1}. The highest seed yield (1347.72 kg ha^{-1}) was found at higher rate of 120 kg N ha^{-1}, and lowest seed yield (408.5 kg ha^{-1}) was found at control treatment. The average stover yields were 971.19, 1694.37, 2349.36 and 2698.53 kg ha^{-1} against the treatments of 0, 40, 80 and 120 kg N ha^{-1} respectively.

Seed yield and stover yield were increased significantly by the interaction effect of irrigation and N application. Significant seed yields of 2130.25 kg ha^{-1} and stover yield of 3995.58 kg ha^{-1} were obtained at three levels of irrigations along with 120 kg N ha^{-1}.

Harvest index was influenced by the application of irrigation, higher harvest index (32.72 %) was obtained at three irrigations, and lowest (28.41 %) was found at unirrigated condition. Higher harvest index (32.52 %) was obtained at 120 kg N ha^{-1} and lowest harvest index found at control. All levels of nitrogen significantly differ to increasing the harvest index. Higher HI of 34.77 % was obtained at three levels of irrigation along with 120 kg N ha^{-1}.

Irrigation had a little effect on oil content of rapeseed. Higher oil content (40.99 %) was obtained at two levels of irrigation and lowest oil content (40.74 %) was found at three levels of irrigation. Nitrogen had significant effect on oil content of rapeseed. Higher oil content (41.19 %) was obtained at 40 kg N ha^{-1} and lowest oil content (40.72 % and 40.73 %) was found at 80 kg N ha^{-1} and control treatment respectively. Higher oil content of 41.40 % was obtained at three irrigations along with 40 kg N ha^{-1}.

From the present study, it may be concluded that irrigation and nitrogen influenced the growth, yield and yield components of rapeseed. Among the irrigation levels three irrigations at 30, 50 and 65 DAS gave the best results but oil content was the best result at two levels of irrigation. Among the nitrogen treatments, 120 kg N ha^{-1} gave the best result but the highest oil content was obtained at 40 kg N ha^{-1}. The interaction effects of three irrigations and 120 kg N ha^{-1} were found most effective in respect of seed yield.

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APPENDICES

Appendix I: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth)

A. Physical composition of the soil

Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

B. Chemical composition of the soil

Sl.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner & Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lancster, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner , 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt ,1965
8	Available S (ppm)	16.00	Hunter, 1984
9	PH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Appendix II: Monthly average of temperature, relative humidity, total rainfall and sunshine hour of the experimental site during the period from October 2005 to February 2006

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2005	October	30.6	24.6	27.60	77	326	142.20
	November	29.1	19.8	24.45	70	03	197.63
	December	27.1	15.7	21.4	64	Trace	217.03
2006	January	25.3	18.2	21.75	68	0	165.10
	February	31.3	19.4	25.35	61	0	171.01

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

Appendix III. Chemical composition of some *Brassica* oilseeds

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

Source: Pathak *et al.* (1973)

Appendix IV: Source of variation, degree of freedom and mean square for plant height and dry matter

Source of variation	d. f.	Mean square									
		Plant height					Dry matter				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
R	2	0.175	3.528	6.734	1.461	0.489	0.000	0.077	0.000	0.053	0.086
I	3	1.695^{NS}	203.817***	715.270***	2201.114***	2386.148***	0.087***	2.823***	46.539***	220.842***	272.382***
Error I	6	0.398	1.492	2.525	1.035	2.638	0.000	0.017	0.022	0.139	0.183
N	3	9.122***	490.782***	897.482***	604.602***	678.417***	0.324***	6.026***	78.297***	173.610***	196.307***
I×N	9	0.057^{NS}	9.137**	22.037***	19.785***	13.082***	0.002^{NS}	0.111***	2.688***	4.093***	3.865***
Error II	24	0.039	2.211	1.363	1.354	1.528	0.001	0.006	0.032	0.098	0.141
Total	47										
CV (%)		4.79	3.86	4.59	4.29	4.36	5.35	3.63	5.85	5.64	5.95

Note: Single, double and triple asterisks indicate significant at 5%, 1% and 0.1%levels respectively. NS means non significant, R =Replication, I=Irrigation and N= Nitrogen.

Appendix V: Source of variation, degree of freedom and mean square for yield attributes

Source of variation	d. f.	Mean square							
		No. of primary bracches/plant	No. of secondary bracches/plant	Length of main inflorescence	No. of siliquae in the main inflorescence	Siliquae per plant	Siliquae length (cm)	Seeds per siliqua	1000 seed weight(g)
R	2	0.047	0.130	21.523	0.235	14.063	0.010	0.026	0.003
I	3	13.965***	44.917***	1410.753***	2322.749***	22379.324***	4.198***	69.737***	0.229***
Error I	6	0.024	0.028	5.115	4.965	6.859	0.018	0.578	0.010
N	3	5.304***	14.284***	484.141***	623.812***	7590.223***	3.313***	96.158***	0.355***
I×N	9	0.243***	1.067***	8.629***	13.902**	912.138***	0.083**	1.421*	0.023**
Error II	24	0.014	0.020	1.050	3.702	4.099	0.025	0.553	0.007
Total	47								
CV (%)		4.43	4.39	5.77	4.32	7.25	5.20	4.03	6.57

Note: Single, double and triple asterisks indicate significant at 5%, 1% and 0.1% levels respectively. NS means non significant, R =Replication, I=Irrigation and N= Nitrogen.

Appendix VI: Source of variation, degree of freedom and mean square for yield, harvest index and oil content

Source of variation	d. f.	Mean square			
		Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Oil content (%)
R	2	2515.399	8514.727	0.021	0.006
I	3	2766664.374***	9531860.938***	43.283***	0.154***
Error I	6	1456.226	5528.515	0.016	0.001
N	3	2047171.128***	6965321.076***	30.708***	0.622***
I×N	9	124357.942***	294118.903***	1.109***	0.231***
Error II	24	309.467	1372.730	0.056	0.002
Total	47				
CV (%)		8.94	8.92	2.77	1.11

Note: Single, double and a triple asterisk indicates significant at 5%, 1% and 0.1% levels respectively.
NS means non significant, R =Replication, I=Irrigation and N= Nitrogen.