INFLUENCE OF IRRIGATION AND NITROGEN ON GROWTH AND YIELD OF RAPESEED

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CERTIFICATE

This is to certify that the thesis entitled ***"INFLUENCE OF IRRIGATION AND NITROGEN ON GROWTH AND YIELD OF RAPESEED"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S) IN AGRONOMY****, embodies the results of a piece of bona fide research work carried out by LABONY AKTER Registration. No.* ***08-3066*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: 29.02.2016

Dhaka, Bangladesh

(Prof. Dr. A.K.M.Ruhul Amin)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

And

My DEAR Hubby

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

ABSTRACT

An experiment was conducted at the agronomy research field of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2013 to February 2014 to evalute the influence of irrigation and nitrogen on yield of rapeseed (*Brassica campestries*). There were four different levels of irrigation *viz.*, no irrigation, one irrigation at 25 days after sowing (DAS), two irrigations at 25 and 50 days after sowing (DAS) and three irrigations at 25, 50 and 70 days after sowing (DAS) and four levels of nitrogen *viz.*, 0, 58, 115 kg N ha^{-1} and urea super granule (1.8 gm USG placed at 50 cm distance at 5 cm depth in the row) N ha^{-1}. The experiment was laid out in split plot design with 3 replication. Irrigation and nitrogen significantly influenced the growth, development, yield and yield attributers of rapeseed. Plant height, plant dry matter, branches $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, weight of 1000-seeds, seed yield, stover yield, biological yield and harvest index were significantly influenced by both irrigation and nitrogen. Among the irrigation treatments, three irrigation-one at 25 DAS (pre-flowering stage), second at 50 DAS (siliquae formation stage) and another at 70 (seed maturation stage) resulted the better growth parameters like plant height, dry matter weight and the yield components like branches $plant^{-1}$, siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000 seed weight, seed yield, stover yield, and harvest index. The highest seed yield (1589 kg ha^{-1}) was obtained at three irrigations while control treatment gave the lowest yield (1095 kg ha^{-1}) .The results revealed that, at the rate of 115 kg N ha^{-1} performed the best results in all respect. The highest seed yield (1712 kg ha^{-1}) was obtained at 115 kg N ha^{-1} . The interaction effect of irrigation and nitrogen revealed that three irrigations one at 25 DAS (pre-flowering stage), second at 50 DAS (siliquae formation stage) and another at 70 DAS (seed maturation stage stage) in combination with 115 kg N ha^{-1} gave highest yield (2065 kg ha^{-1}) by producing highest yield contributing characters as well as other yield contributing characters.

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LIST OF ACRONYMS

AEZ	Agro Ecological Zone
Agric	Agriculture
Agril	Agronomy
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BAU	Bangladesh Agricultural University
BADC	Bangladesh Agricultural Development Corporation
C.V.	Coefficient of Variation
cv.	Cultivar
DAS	Days after sowing
Df	Degree of freedom
DMRT	Duncan's Multiple Ranges Test
E	East
et al.	*et alibi* (and others)
etc.	*et cetra* (and so on)
FAO	Food and Agriculture Organization
Fig.	Figure
HI	Harvest index
HYV	High yielding variety
i.e.	(That is)
J.	Journal
Int.	International
Inst.	Institute
LSD	Least significant difference
LAI	Leaf area index
N	North, Nitrogen
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
TSW	Thousand seed weight
TDM	Total dry matter

Res.	Research
Viz	Namely
@	At the rate
%	Percentage
^0C	Degree Celsius
cm	Centimeter
g	Gram
ha	Hectare
kg	Kilogram
m	Meter
t	Ton

Chapter 1
Introduction

INTRODUCTION

Oil seed Brassica species (*B. napus, B. campestris and B. juncea*) ranks the third most important sources of edible vegetable oil in the world after palm and soybean(Adnan *et al.*, 2013; Zhang and Zhou, 2006). Rapeseed and mustard belongs to the family Cruciferae are important oil crops and currently ranks as the world third oil crops in terms of production and area. Among the speices, *Brassica napus* and *Brassica campestris* are regarded as "rapeseed" while *Brassica juncea* is regarded as mustard. It is originated from Asia , but now is cultivating as a main commercial oil crop in Canada, China, Australia, and India. Rapeseed-mustatd is grown more or less all over Bangladesh, but more particularly in the districts of comilla, jessore, Faridpur, Pabna, Rajshahi Dinajpur, Kushtia, Kishhoregonj, Rangpur, Dhaka (BBS, 2012).

The oil is used not only for edible purpose but also used in hair dressing, body massaging and in different types of pickles preparations. The oilcake contains proteins of high biological value and applicable quantities of calcium and phosphorus and is used as a very good animal feed as well as manure for various crops.

Rape oil used in food industry, as an illuminant and lubricant, and for soap manufacture. Residual rapeseed cake, though low in food value, used as livestock feed. Rapeseed oil has potential market in detergent lubrication oils, emulsifying agents, polyamide fibers, and resins, and as a vegetable wax substitute. Rapeseed and mustard are rich source of oil and contains 44% to 46% good quality oil (Rashid, 2013).

In 2012-2013, the edible oil production from major oilseed crops in the world was 497.9 million tons where rapeseed contributes 64.3 million tons. Among the oilseed crops, mustard and rape seed is in the second position after soybean (FAO, 2014).

In the year 2011-12 total oilseed was grown in 972 acres of land where production was 787 thousand M tons, 70.16 % of total oilseed producing land was occupied by rape or mustard seed. The production of rape or mustard in 2011-12 was 262 thousand M tons which was 33.29% of total produced oilseeds (BBS, 2012).

Although a huge amount of oilseed is utilized in Bangladesh, the production is not sufficient to meet the requirement (Razzaque and Karim, 2007). As the population of Bangladesh is increasing and economic prosperity has been growing fast, it is now a challenge for accelerating the production of oils. It is essential to reduce the import dependence of it to insulate the domestic market from the volatility of the world market (Hossain, 2013). About 0.832638 million tons of edible oil produced in Bangladesh which is very low against the requirement (BBS, 2011a). To fulfil the requirement the country imports 0.89970 million tons of *Brassica* oil that costs 371.8457000 million Tk. (BBS, 2011b).

The targeted yield of oil seed in 2015-2020, 2020-2025 and 2025-2030 is 1730, 2141 and 2572 kg ha^{-1} in Bangladesh that is now 1186 kg ha^{-1} only. Meanwhile, about 27 mustard and rapeseed varieties have been released in Bangladesh, among these 16 from Bangladesh Agricultural Research Institute (BARI), five from Bangladesh Institute of Nuclear Agriculture (BINA), two from Bangladesh Agricultural University (BAU) , two from Sher-e-Bangla Agricultural University (SAU) and two from Bangladesh Agricultural Development Corporation (BADC) but most of them are not popular to the farming community because of their long duration, low to moderate yield and susceptibility to severe biotic and abiotic stresses. Therefore, there is a scope to increase the yield level of rapeseed- mustard by using HYV seed and by adopting proper management practices like spacing, irrigation, seed rate, and fertilizer application etc.

In Bangladesh both rapeseed and mustard are mostly grown on the residual soil moisture in Robi season (Kaul and Das ,1986). But irrigation is a vital factor for proper growth and development or 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; Sarker *et al*.,1988). 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 per plant , number of seed per plant and seed yield and harvest index (Srivastava *et al*.,1988) of this crops. Mondal *et al*., (1988) reported that one irrigation at flowering and pod development stage gave the highest yield (2.56 ton ha^{-1}).Irrigation has also an effect in increasing the fertilizer uptake (Reddy and Sinha,1987) thus increased biomass ,which ultimately increase the yield.

Nitrogen increases yield by influencing different growth parameters and by producing more vigorous growth and development as reflected via increasing plant height, number of flowering branches, total plant weight, number and weight of siliquae and seeds $plant^{-1}$ (Alien and Morgan, 1972). Nitrogen fertilizer requirements can differ very much according to soil type, climate, management practice, timing of nitrogen application, cultivars etc. (Holmes and Ainsley, 1977). Bani (2001) stated that nitrogen, by reducing flower abscission and consequently affecting thousand seed weight (TSW), increasing the number of siliquae unit $area^{-1}$ and decreasing the number of seeds $siliquae^{-1}$, caused more seed yield $hectare^{-1}$. Excessive use of this element may produce too much vegetative growth 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)

The high yielding varieties of rape seed 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 number of irrigation for getting higher yield of rapeseed .
2. To find out the optimum dose of nitrogen for getting higher yield of Rapeseed and
3. To fine out the interaction effect of irrigation and nitrogen on the Growth, yield attributes and yields of rapeseed.

Chapter 2
Review of literature

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:

Effect of irrigation

Seed yield of *Brassica* was 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

Hossain *et al.* (2013) carried out an experiment to investigate the effect of irrigation and sowing method on yield of mustard. They observed that plant height increased with the increase of irrigation frequencies. The tallest plant (97.97 cm) was obtained from two irrigations and the shortest plant (92.91 cm) was found at control treatment (no irrigation).

Kibbria (2013) reported that plant height was found to be highest when one irrigation at 20 DAS was applied. But three irrigations applied at 20, 40 and 60

DAS produced more plant height (101.00 cm) than under no irrigation. There was a significant relationship between irrigation levels and plant height. Piri *et al*. (2011) showed that application of two irrigations at 45 DAS and 90 DAS significantly increased plant height.

Sultuna (2007) carried out an experiment on rapeseed in Sher-e - Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She showed that plant height maximum at three irrigation (20, 35, 50 DAS).

Latif (2006) found a relationship between irrigation levels and plant height of rapeseed. In an experiment, plant height was increased with the increasing levels of irrigation. Plant height was maximum (104.46) cm with three irrigations at 30, 50, and 65 DAS.

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.

2.1.2 Plant Dry matter

Kibbria (2013) 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 siliquae formation) and three irrigation (one at pre-flowering, siliquae formation stage and seed maturation). Significant increase in dry matter was found up to three irrigations. The maximum dry matter production was found to be 102.37 g with three irrigations while one irrigation and control (no irrigation) produced 90.61 g and 67.75 g dry matter per plant respectively.

Sultuna (2007) conducted an experiment on rapeseed in Sher-e-Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She showed that plant dry matter maximum at three irrigation (20, 35, 50 DAS).

Latif (2006) showed that total dry matter weight of different irrigation treatment at successive stage of growth of rapeseed was significant. The plant receiving continuous irrigation throughout the growing period had the highest dry weight at 30, 50 and 65 DAS. Two irrigations also increased dry matter production.

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 DAS (1.2 g per plant). 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.

2.1.3 Number of branches plant^{-1}

Kibbria (2013) reported that number of primary branches of mustard was significantly increased with irrigation levels. They found maximum number of primary branches (7.70) per plant with two irrigations at 20 and 40 DAS which was followed by 7.61 and 7.61 with one irrigation at 30 DAS and without irrigation respectively.

Piri *et al*. (2011) reported that the maximum number of branches per plant of mustard with one irrigation at 45 DAS than two irrigations at 45 and 90 DAS followed by no irrigation.

Sultuna (2007) stated no. of branches per plant higher at three irrigation (20, 35, 50 DAS). Giri (2001) showed that branches per plant increased with the increasing irrigation level in mustard plant. He also observed that when one irrigation was applied it produced more branches per plant compared to that of two irrigations. But the difference was not significant.

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 plant^{-1} 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 plant^{-1} 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 plant^{-1}. 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.

2.1.4 Number of siliquae plant^{-1}

kibbria (2013) found in experiment with mustard that he number of siliquae plant^{-1} increased with increasing irrigation frequency. He reported that siliquae plant^{-1} (138.8) increased by two irrigation at 20, 40 DAS than no irrigation (111.9).

Hossain *et al.* (2013) carried out an experiment to investigate the effect of irrigation and sowing method on yield of mustard. They observed that number of siliquae plant^{-1} increased with the increase of irrigation frequencies. The highest number of siliquae (71.80) plant^{-1} was obtained from two irrigations.

Sultuna (2007) found no. of siliquae per plant higher at three irrigation (20, 35, 50 DAS. Latif (2006) conducted an experiment to observe the effect of irrigation treatments *viz.,* no irrigation, one irrigation (at pre-flowering stage), two irrigation (one at pre-flowering and one at siliquae formation) and three irrigation (one at pre-flowering, at siliquae formation and seed maturation stage). Maximum number of siliquae (136.24) was found when three irrigations were applied. One irrigation and without irrigation produced lower siliquae plant^{-1}.

Patel *et al.* (2004) reported that one irrigation produced 465 siliquae plant^{-1} 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 siliquae plan^{-1}. The highest number of siliquae (261) was found with two irrigations at branching and siliquae development stages.

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

2.1.5Number of seeds siliqua^{-1}

Kibbria (2013) reported that seeds per siliqua were also significantly increased with irrigation. Maximum number of seeds (20.06) siliqua^{-1} was found when two irrigations were applied (one at pre-flowering stage and one at siliquae formation).

Hossain *et al.* (2013) carried out an experiment to investigate the effect of irrigation and sowing method on yield of mustard. They observed that number of seeds siliqua^{-1} increased with the increase of irrigation frequencies. The highest number of seeds (17.50) siliqua^{-1} was obtained from two irrigations.

Sultuna (2007) conducted an experiment on rapeseed in Sher-e-Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She showed that number of seeds siliqua^{-1} were higher at three irrigation (20, 35, 50 DAS).

Latif (2006) conducted an experiment to observed the effect of irrigation on the growth and yield of rapeseed (*Brassica campertries*). He tested four irrigation treatments *viz.,* no irrigation, one irrigation (at pre-flowering stage), two irrigation (one at pre-flowering stage and siliquae formation) and three irrigation (one at pre-flowering stage, siliquae formation and seed maturation stage). Maximum number of seed (27.20) was found per siliquae from three irrigations.

2.1.6 Length of siliqua

Kibbria (2013) concluded that length of siliqua of rapeseed was significantly increased with irrigation. Length of siliqua (5.23 cm) was highest with two irrigation compared to one irrigation or without irrigation (control).

Latif (2006) conducted an experiment to observe the effect of irrigation treatments *viz.,* no irrigation, one irrigation (at pre-flowering stage), two irrigation (one at pre-flowering and one at siliquae formation) and three irrigation (one at pre-flowering, at siliquae formation and seed maturation stage) Highest siliquae length (7.65 cm) was found when three irrigations were applied. One irrigation and without irrigation produced lower siliqua length.

Singh and Saran (1992) observed in an experiment with *Brassica campestris* during the winter seasons of 1987-1989 that irrigation at 1W and CPE ratio of 0.4 and 0.2 (two and one irrigation, respectively) gave average siliqua 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, siliqua length significantly increased only up to 0.2 IW: CPE ratio.

2.1.7 Weight of 1000 seeds

Kibbria (2013) reported that weight 1000 seeds were also significantly increased with irrigation. Maximum weight of 1000 seeds (3.16 g) $siliquae^{-1}$ was found when two irrigations were applied (one at pre-flowering stage and one at siliquae formation.

Piri *et al.* (2011) showed that application of two irrigations at 45 and 90 DAS significantly increased 1000 seeds weight. Sultana (2007) found that 1000 seeds weight higher with three irrigations at 20, 35 and 50 DAS. Least weight of 1000 seed was found without irrigation

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.

2.1.8 Seed yield

Kibbria (2013) reported that the growth characters and yield rapeseed was significantly increased with irrigation levels. He found that seed yield highest (1.98 ton ha^{-1}) by two irrigations at 20, 40 DAS (before flowering and siliquae formation stage.

Hossain *et al.* (2013) carried out an experiment to investigate the effect of irrigation and sowing method on yield of mustard. They observed that seed yield increased with the increase of irrigation frequencies. The maximum seed yield (1.8 ton $ha^{-1)}$ was obtained from two irrigation.

Sultuna (2007) studied with an experiment on rapeseed in Sher-e-Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She reported that seed yield highest (1827.0 kg ha^{-1}) at three irrigation (20, 35, 50 DAS).

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.

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.

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.

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 siliqua 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.

Mondal *et al.* (1988) conducted a field trials in the rabi (winter) seasons on *Brassica juncea* cv. T-59 was sown in the I 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}.

2.1.9 Stover yield

Kibbria (2013) reported that the stover yield of rapeseed was significantly increased with irrigation levels. He found that stover yield was (1.98 ton ha^{-1}) highest by two irrigation at 20, 40 DAS (Just before flowering and siliquae formation stage.

Hossain *et al.* (2013) carried out an experiment to investigate the effect of irrigation and sowing method on yield of mustard. They observed that stover yield increased with the increase of irrigation frequencies. The maximum stover yield (31.8 ton $ha^{-1)}$ was obtained from two irrigation.

Piri *et al* .(2011) found that application of two irrigations recorded significantly higher stover yield than one irrigation which in turn gave significantly higher stover yield than no irrigation. The increase in stover yield also may be attributed to higher plant height than more number of total branches.

2.1.10 Biological yield

Kibbria (2013) found that the different dose of irrigation had effect on the biological yield per hectare. The biological yield ton per hectare obtained by the 4 different irrigation treatment differed significantly from one other and the highest biological yield ton per hectare (3.97) was obtained from the treatment I_2 (1st at 20DAS + 2nd at 40 DAS) and the lowest (3.44t) was obtained I_0 (no irrigation.

Sultana (2007) found that biological yield higher at three irrigation (20,35,50 DAS) than control treatment.

2.1.11 Harvest index

Kibbria (2013) observed that the different irrigation had no significant effect on harvest index of mustard. Numerically, the maximum harvest index (51.16 %) was obtained from two irrigations and the minimum harvest index (48.72%) was obtained from no irrigation.

Sultana (2007) reported that harvest index higher at three irrigation (20, 35, 50 DAS) than control treatment (no irrigation).

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.

2.2 Effect of nitrogen

2.2.1 Plant height

Ara *et al.* (2014) performed an experiment to investigate the effect of N levels (0, 60, 120, 180 kg N ha^{-1}) and different levels of B (0, 1, 2 kg ha^{-1}) of rapeseed (*Brassica campestris* L.). They observed that plant height increased progressively with increase in nitrogen up to 120 kg^{-1}

Aminpanah (2013) studied two canola (*Brassica napus* L.) cultivars with five levels of nitrogen (0, 50, 100, 150 and 200 kg ha^{-1}). He observed that plant height increased with the application of nitrogen up to 200 kg ha^{-1}.

Ozturk (2010) conducted an experiment to determine with five levels N levels doses (0, 50, 100, 150 and 200 kg N ha^{-1}). He showed that maximum plant (131.0 cm) was observed with 150 kg N ha^{-1}).

A field experiment was conducted by Patel *et al.* (2004) during the rabi season to investigate the effects of irrigation schedule, spacing (30 and 40 cm) and N rates (50, 75 and 100 kg ha^{-1}) of Indian mustard cv. GM-2. They observed that plant height increased significantly with successive increase in nitrogen up to 100 kg ha^{-1}.

2.2.2 Plant dry matter

Ara *et al.* (2014) worked on *Brassica campestris* with 0, 60, 120 and 180 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.

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 (*Brassica 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 $ha^{-1.}$

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. Ara *et al.* (2014) conducted an experiment with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) followed by the cropping system that the application of 120 kg N ha^{-1} resulted the highest number of branches.

Ozturk (2010) conducted an experiment with five levels of nitrogen (0, 50, 100, 150 and 200 kg ha^{-1}) followed by the cropping system that the application of 150 kg N ha^{-1} resulted the highest number of branches (8.5) per plant .

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 (*Brassica 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}).

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

Keivanrad and Zandi(2014) worked on *Brasicca juncea* L. with (0,100,150 and 200 kg N ha^{-1}) under different plant densities.They reported that maximum siliquae (108.66) per plant was obtained at 200 kg N $ha^{-1}$and minimum number of siliquae (50.10) was produced in control(no nitrogen application).

Ozturk (2010) conducted an experiment with five levels of nitrogen (0, 50, 100, 150 and 200 kg ha^{-1} followed by the cropping system that the application of 150 kg N ha^{-1} resulted the highest number of siliquae (283.4) $plant^{-1}$.

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 60cm) 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) 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 $plant^{-1}$ (260. 9).

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 siliquae $plant^{-1}$ of rapeseed.

2.2.5 Number of seeds $siliquae^{-1}$

Keivanrad and Zandi (2014) reported that number of seeds (17.32) $siliquae^{-1}$ increased at 200kg N ha^{-1} significantly than control treatment (no nitrogen). 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 $siliqua^{-1}$ (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 siliquae. 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

(*Brassica juncea*). They obtained maximum number of seeds per siliqua when nitrogen was applied at 120 kg $ha^{-1.}$

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

2.2.6 Length of siliqua

Ara *et al*. (2014) reported from an experiment conducting for determining the effect of nitrogen and Boron on seed yield of mustard Brassica campestris and found that the length siliqua plant increased with the combination of nitrogen 120 kg N/ha and 2 Kg B/ha.

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 siliqua 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}.

2.2.7 Weight of 1000 seeds

Ara *et al*. (2014) conducted an experiment with four levels of nitrogen (0, 60, 120 and 180 kg ha^{-1}) followed by the cropping system that the application of 120 kg N ha^{-1} resulted the maximum weight of 1000 seeds.

Mozaffari *et al.* (2012) carried out an experiment to investigate the effect of N levels (0, 75, 150, and 225 kg N ha^{-1}) and potassium (0, 45, 90 and 135 kg ha^{-1}). They observed that increased amount of nitrogen and potassium up to 225 kg N $ha^{-1}$and 135 kg ha^{-1} respectively positive effect on 1000-seed weight. Application of 225 kg N ha^{-1} the 1000-seed weight (3.27 g) was increased.

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 (*Brassica juncea*). They obtained maximum 1000-seed weight with the application of 120 kg N ha^{-1}.

2.2.8 Seed yield

Ara *et al.* (2014) studied with the effect of born with four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) of rapeseed. He observed that adequate N fertilization is important in seed yield of rapeseed and suggested that the rate of 120 kg N ha^{-1} gave highest seed yield. Aminpanah (2013) reported that seed yield increased significantly as N application rate increased from 0 to 200 kg ha^{-1}.

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.

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 obtain from 20-25 October sown crops with 40 cm row spacing and supplied with 150 kg N 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; 30kg 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$^{-1.}$

2.1.10 Biological yield

Keivanrad and Zandi (2014) reported that application of 200 kg N ha^{-1} produced the maximum biological yield (12840 kg ha^{-1}) and minimum biological yield (4823 kg ha^{-1}) was recorded in control treatment (no nitrogen).

2.2.11 Harvest index

Keivanrad and Zandi (2014) reported that harvest index was highly affected by nitrogen rates. They found that harvest index was increased at 50 kg N ha^{-1} than 0,100,150 and 200 kg N ha^{-1}.

Mozaffari *et al.* (2012) 0bserved that harvest index (21.33%) was increased with application of nitrogen at 225 kg N ha^{-1}. 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.

Shukia 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.

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

2.3.1 Plant height

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that the plant height significantly increased with the increasing levels of irrigation and N.

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 + 10 kg Zn + 90 kg S ha with two irrigations (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 Plant dry matter

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that the plant dry matter significantly increased with the increasing levels of irrigation and N.

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 siliqua plant^{-1}

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that number of siliqua (186.33) significantly increased with the increasing levels of irrigation and N (three irrigation and 120 kg N ha^{-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 siliqua $plant^{-1}$ significantly increased with the increasing levels of N and P up to 120 and 60 kg ha^{-1} with two levels of irrigation respectively.

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 + 10 kg Zn + 90 kg S ha^{-1} with two irrigations (at 30 and 60 DAS) significantly increased the number of siliqua $plant^{-1}$.

2.3.4 Number of seeds $siliquae^{-1}$

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that the number of seeds (30.43) $siliqua^{-1}$ significantly increased with the increasing levels of irrigation and N.

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 siliqua.

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}) an 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 $siliqua^{-1}$ significantly increased with increasing levels of N and P up to 120 and 60 kg ha $^{-1}$with two levels of irrigation respectively.

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 + 10 kg Zn + 90 kg S ha^{-1} with two irrigations (at 30 and 60 DAS) significantly increased the number of seeds $siliqua^{-1}$.

2.3.5 Weight of 1000 seeds

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that the highest weight of 1000 seeds (3.65 gm) increased with increasing levels of irrigation (three irrigations) and nitrogen (120 kg N $ha^{-1)}$

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.

Abadi *et al.* (2001) reported that the weight of 1000 seed increased significantly with successive increase in two levels of irrigation (at 30 and 60 DAS) along 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 weights of 1000 seed were obtained by the application 2 levels of irrigation (at 30 and 60 DAS) along with 80 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_20_5 + 10 kg Zn + 90 kg S ha^{-1} with two irrigations (at 30 and 60 DAS) significantly increased the weight of 1000 seed.

2.3.6 Seed yield

Latif (2006) studied on three irrigations (at 30, 50, 65 DAS) and four levels (at 0, 40, 80 and 120 kg N ha^{-1}) on growth and yield of rapeseed. He observed that highest seed yield (2130 kg ha^{-1}) significantly increased with the increasing levels of irrigation and N (three irrigation and 120 kg N 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 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 live 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.

Mondal *et al.* (2000) conducted an experiment to study 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 highest seed yields were obtained by the application 2 levels of irrigation (at 30 and 60 DAS) along with 80 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 + 10 kg Zn + 90 kg S ha-1 with two irrigations (at 30 and 60 DAS) significantly increased seed yield.

Singh *et al.* (1997) conducted an experiment with four levels of irrigation (30, 45, 60 and 75 DAS) and live 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

MATERIALS AND METHODS

The experiment was undertaken during rabi season (November to February) of 2013-14 to find out the effect of irrigation and nitrogenous fertilizer on the yield components and yield of rapeseed (BARI sarisha-15) at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at $90^{0}22'$ E longitude and 23°41' N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28 (Appendix I).

3.2 Climatic condition

The experimental area under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, October-March and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season April-September. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Weather Station of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka presented in Appendix II.

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). 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 III.

3.4 Variety

A newly developed, moderately salinity tolerant and high yielding variety of rapeseed, BARI Sarisha-15 (*Brassica campestries*) developed by the Bangladesh Agricultural Research Institute (BARI); Joydebpur, Gazipur was used in the experiment as a planting material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI); Joydebpur, Gazipur. Before sowing germination test was done in the laboratory and percentage of germination was over 95%.

3.5 Experiment treatments

Factor A: Irrigation levels - 4

I_0 = No irrigation (Control)

I_1 = One irrigation at 25 DAS (Before flowering)

I_2 =Two irrigation, at 25 + 50 DAS (Siliqua formation)

I_3 =Three irrigation, at 25 + 50 + 70 DAS (Seed maturation stage)

Factor B: Nitrogen levels- 4

N_0 = Control

N_1 = 58 kg N ha^{-1} (Half of recommended dose)

N_2 = 115 kg N ha^{-1}(Recommended dose)

N_3 = Urea super granule (USG 1.8 gm placed at 50 cm distance at 5 cm depth in the row)

3.6 Design and layout

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. In the experiment there was three replications and the total plots were $16 \times 3 = 48$. The unit plot size was 4 m × 2.5 m = 10 m^2. The distance between block to block is 1 m and plots to plot is 0.5 m and plant spacing is 30 cm × 10 cm.

3.7 Crop husbandry

3.7.1 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were clean properly. The final ploughing and land preparation were done on 25 October, 2013. According to the layout of the experiment the entire experimental area was divided into blocks and subdivided into plot for the sowing of rapeseed. In addition, irrigation and drainage channels were prepared around the plot.

3.7.2 Fertilizer application

The experimental plots were fertilized with a recommended dose 180, 100, 5 and 10 kg ha^{-1} of P_2O_5, K_2O, Zno, and Boric acid respectively (BARI 2002). N was applied as per treatments. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil during final land preparation. Rest of the urea was top dressed according to treatments. When Urea super granule was applied 7 days after sowing.

3.7.3 Sowing of seed

Sowing was done on 6th November, 2013 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 9 kg ha^{-1}. After sowing the seeds were covered with the soil and slightly pressed by hand. Plant population were kept constant through maintaining plant to plant distant 10 cm in row.

3.7.4 Weeding and thinning

The optimum plant population was maintained by thinning excess plant at 15 DAS. The plant to plant distance was maintained as 10 cm. One weeding with khurpi was given on 25 DAS .Thinning was done in the entire plots with specials care as to maintain a constant plant population in the entire plot .one weeding with khurpi was given 25 days after sowing.

3.7.5 Irrigation

Irrigations were given as per treatment.

3.7.6 Crop protection

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

3.7.7 General observation of the experimental field

The field was investigated frequently in order to reduce losses with weeds competition and insect's infestation and diseases infection.

3.7.8 Harvesting and Processing

At maturity when 80% of siliquae turned straw yellowish in color, the experimental crop was harvested. Harvesting was done in the morning to avoid shattering. One m^2 area (1.25 m ×0.8 m) was harvested from each plot. The harvested plant from the centre of each sub plot were bundled separately, tagged and brought to a clean cemented threshing floor. The crop was sun dried by spreading them over the floor and seeds were separated from the siliqua by beating the bundles with bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed about 9% levels. The yield of 1 m^2 was converted to kg ha^{-1}.

3.8 Data collection

Five plants of each plot were selected outside the sample area and marked with tags. All the growth data were collected from that selected plants. At harvest 10 sample plants were collected randomly from each plot outside the sample area and tagged them. All the plant and yield attributes data were collected from that 10 plants. For taking yield data plants of central 1 m^2 area were harvested. All the yield data were collected from that 1 m^2 area.

Data were collected on the following parameters

a) Growth data

1. Plant height (cm) at 30, 45, 60, 75, DAS and at harvest
2. Plant dry matter weight(gm) at 30, 45, 60 and 75 DAS

b) Plant and yield attributes data

1. Number of branches plant^{-1}
2. Number of siliquae plant^{-1}
3. Length of siliqua
4. Number of seeds siliqua^{-1}
5. Weight of 1000 seeds

c) Yield harvest index (%)

1. Grain yield (kg ha^{-1})
2. Stover yield (kg ha^{-1})
3. Biological yield (kg ha^{-1})
4. Harvest index (%)

3.8.1 Plant height (cm)

At different stages of crop growth (30, 45, 60, 75 DAS and at harvest) height of the plants was measured from the 5 pre- selected plants from base to the tip of the plant. Plant height was measured from the line and mean plant height was determined. The plant height was measured at 30, 45, 60, 75 DAS and at harvest.

3.8.2 Total dry matter

For taking dry weight 3 plants were collected randomly from each plot. The plants were oven dried and weighted. The mean weight of 3 plants was termed as dry matter plant^{-1}. Dry matter was taken at 30, 45, 60, and 75 DAS.

3.8.3 Number of branches per plant

Number of branches was counted from 10 randomly selected plants at harvest and averaged them to have branches per plant.

3.8.4 Number of siliquae plant^{-1}

Number of siliquae was counted from randomly selected ten plants at harvest and averaged them to have number of siliquae plant^{-1}.

3.8.5 Length of siliqua (cm)

Ten siliquae were taken from each plot and was measured. The average was termed as length of siliqua^{-1}.

3.8.6 Number of seeds siliqua^{-1}

Total number of seed was counted from the selected 10 siliquae and averaged them to have number of seeds siliqua^{-1}.

3.8.7 Weight of 1000 seeds (g)

From the seed stock of each plot 1000 seed were randomly counted. Then weighted the seed by digital balance. 1000 seed weight was recorded in gram.

3.8.8 Yield (kg ha^{-1})

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

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

Straw obtained from 1 m^2 was sun-dried and weighed carefully. The dry weight of straw of central 1m^2 area was used to record the final stover yield plot^{-1} which was finally converted to kg ha^{-1}.

3.8.10 Biological yield (kg ha^{-1})

Grain and stover yields were altogether regarded as biological yield. The biological yield was calculated with the following formula

Biological yield (kg ha^{-1}) = Seed yield + Stover yield.

3.8.11 Harvest index (%)

Harvest index was calculated by dividing the seed yield from the by the biological yield (seed + stover) from the same area (Donald 1963) and multiplying by 100

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

3.9 Data analysis

The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program. The mean values for all the parameters were calculated and the analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least significant different (LSD) at 5 % levels of probability .

Chapter 4
Results and Discussion

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 2013-2014 are presented here. The yield and yield components included plant height (cm), plant dry matter ,number of primary branches per plant, number of siliquae plant^{-1}, siliqua length, number of seeds siliqua^{-1}, 1000-seed weight, seed yield ha^{-1}, stover yield ha^{-1}, biological yield and harvest index have been presented in different tables and figures. The analyses of variance in respect of all the characters under study have been presented in Appendix IV-VII. 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

The plant height of rapeseed was significantly influenced by irrigation at 30, 45, 60, 75 days after sowing (DAS) and at harvest (Appendix III and Fig. 1). The figure indicated that plant height showed an increasing trend with an advancement of growing period up to 90 DAS for all irrigation levels. The rate of increase was found more rapid up to 45 DAS after that plant height slowly increased up to 90 DAS irrespective of irrigation levels. It could be inferred from the figure that three irrigations showed the tallest plant (44.58, 98.5, 104, 105.2 and 106.2 cm) and control treatment showed the shortest plant (35.66, 86.03, 89.36, 89.97 and 91.03 cm) for the sampling dates of 30, 45, 60, 75 and at harvest respectively. No significant difference was found between the treatment I_2 and I_3 because the third irrigation was applied after 75 DAS. It might be due to the soil moisture availability for the plant was which sufficient before third time irrigation at 75 DAS. Similar result was reported by Latif (2006), Sultana (2007) and Kibbria (2013) .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), Piri *et al.* (2011) and Hossain *et al.* (2013) reported maximum plant height when two irrigations were applied during branching and siliquae development stage.

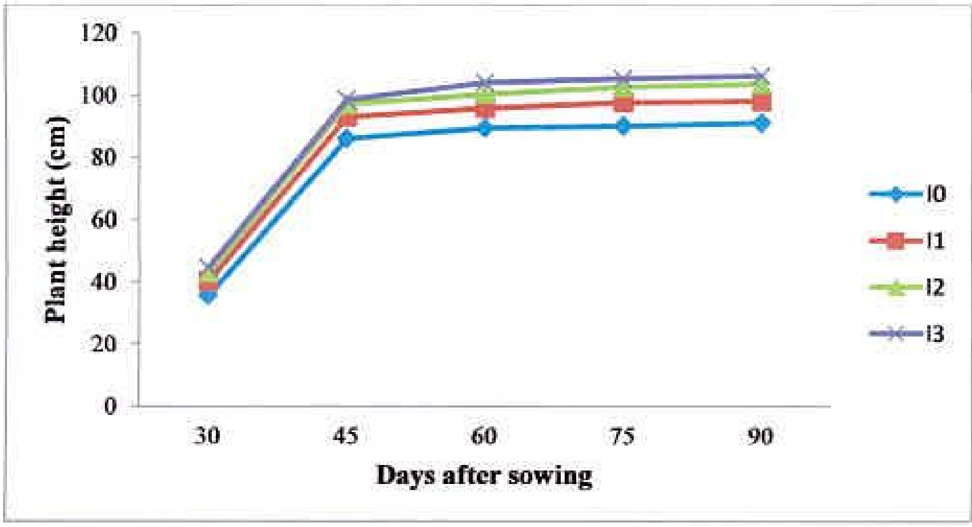

Fig. 1. Effect of different irrigation levels on plant height of rapeseed at different DAS (LSD value = 1.36, 4.66, 3.55, 4.23, 2.48 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.1.2 Effect of nitrogen

Significant variation of plant height was found due to nitrogen treatment in all the sampling dates (Appendix III and Fig. 2). The figure demonstrated that plant height showed an increasing trend with increasing the age of plant up to 90 DAS for all nitrogen levels. The rate of increase was found more swift up to 45 DAS after that plant height increased gradually up to 90 DAS irrespective of all nitrogen levels. It can be deduced from the figure that, the recommended dose of nitrogen (115 kg N ha^{-1}) showed the tallest plant (42.31, 101.3, 105.7, 106.7 and 107.2 cm) and without nitrogen produced the shortest plant (37.39, 85.36, 87.92, 89.64 and 90.89 cm) for sampling dates of 30, 45, 60, 75 and at harvest respectively. This might be due to the fact that nitrogen plays vital role in both cell division and cell enlongation. These findings were in agreement with those of Singh *et al.* (2002), Singh *et al.* (2003) and Tripathi and Tripathi (2003) who obtained tallest plant height of mustard with the application of N at 120 kg ha^{-1}. Maximum plant height was recorded at 200 kg N ha^{-1} reported by Ozturk (2010) and Aminpanah (2013) revealed taller plant height at 150 kg N ha^{-1}.

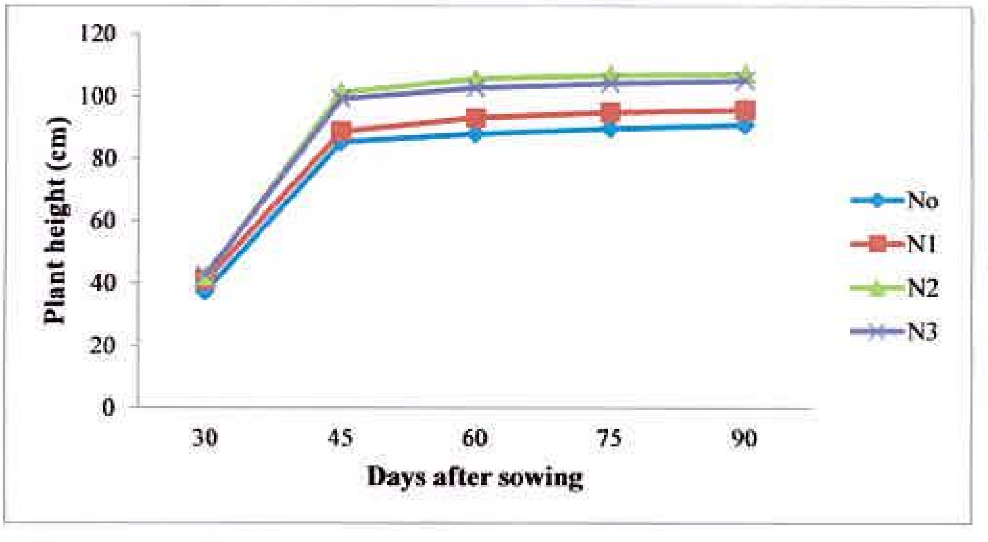

Fig. 2. Effect of different nitrogen levels on plant height of rapeseed at different DAS (LSD value = 2.51, 3.24, 3.35, 2.62, 3.49 at 30, 45, 60, 75 DAS and at harvest, respectively)

4.1.3 Interaction effect of irrigation and nitrogen

Significant interaction effect between the irrigation and nitrogen on plant height was observed at 30, 45, 60, 75 DAS and at harvest (Appendix III and Table 1). Every stages of growth showed significant different except at the early stage (up to 25 DAS). This was due to the slow growth rate and also for the reason of no irrigation before 25 DAS. The results revealed that at 30 DAS the tallest plant (49.61 cm) was obtained from I_3N_2 treatment which was statistically similar with I_3N_3, I_3N_1, I_2N_3, I_2N_0 and I_1N_2 and shortest plant height (35.95 cm) from control treatment (I_0N_0). At 45 DAS, the tallest plant height (106.4 cm) was observed from I_3N_2 treatment which was statistically similar with I_3N_3, I_2N_3, I_2N_2, I_1N_3 and I_1N_2 and shortest plant height (77.89 cm) found from control treatment which was statistically similar with I_0N_1 and I_1N_0. At 60 DAS, the tallest plant height (110.4 cm) obtained from I_3N_2 treatment which was statistically similar with I_3N_3, I_2N_3, I_2N_2 and I_1N_3. The shortest plant (79.33 cm) was found from control treatment which was statistically similar with I_0N_1 and I_1N_0. At 75 DAS, the tallest plant height (112.7 cm) was found from I_3N_2 treatment which was statistically similar with I_3N_3, I_2N_3 and I_2N_2. The shortest plant height (80.22 cm) was observed control treatment which was statistically similar with I_0N_1. At harvest, maximum plant height (112.7 cm) was observed from the treatment I_3N_2 (three irrigations and 115 kg N ha^{-1}) which were statistically similar with I_3N_3, I_2N_3, I_2N_2 and I_1N_3. The shortest plant height (82 cm) was found from the treatment I_0N_0 (control) which was statistically similar with I_0N_1 and I_1N_0. 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}.

Table 1. Plant height of rapeseed at different days after sowing as affected by interaction of irrigation and nitrogen levels.

Treatment combination	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_0N_0	30.95 d	77.89 g	79.33 i	80.22 h	82.00 h
I_0N_1	35.02 cd	83.00 e-g	85.00 hi	85.22 gh	86.89 gh
I_0N_2	39.33 c	90.78 cd	95.33 e-g	96.22 f	96.33 ef
I_0N_3	37.33 c	92.44 cd	97.78 de	98.22 ef	98.89 d-f
I_1N_0	35.78 cd	81.89 fg	85.67 hi	87.11 g	88.00 gh
I_1N_1	40.34 bc	86.78 d-f	89.33 gh	93.42 f	93.45 fg
I_1N_2	45.94 a	100.6 ab	102.3 b-d	104.2 cd	104.3 b-d
I_1N_3	39.00 bc	102.6 a	105.9 a-c	105.7 b-d	106.3 a-c
I_2N_0	45.00 ab	89.00 cde	90.33 fg	94.00 f	95.33 f
I_2N_1	39.33 c	94.49 bc	96.33 d-f	98.44 e	99.33 d-f
I_2N_2	39.56 bc	101.2 a	105.9 a-c	107.6 a-d	108.8 a-c
I_2N_3	47.95 a	103.6 a	109.0 ab	110.1ab	111.0 ab
I_2N_0	37.83 c	92.67 cd	96.33 d-f	97.22 ef	98.22 d-f
I_3N_1	44.94 ab	90.55 cd	102.0 c-e	102.3 de	103. 0 c-e
I_3N_2	49.61 a	106.4 a	110.4 a	112.7 a	112.7 a
I_3N_3	45.94 a	104.3 a	107.1 a-c	108.7 a-c	111.0 ab
LSD (0.05)	4.36	6.482	6.693	5.232	6.99.
CV(%)	7.30	4.11	4.08	3.14	4.16

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly y LSD at 0.05 level of probability.

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25,50 DAS), I_3 =Three irrigation (at 25,50,70 DAS). N_0 = Control, N_1 = Half of recommended dose,N_2 = Recommended dose,N_3= Urea super granule.

4.2 Plant dry matter weight

4.2.1 Effect of irrigation

Total dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first prerequisite for high yield. Significant variation was found in total plant dry matter due to irrigation (Appendix IV and Fig. 3). The figure indicated that plant dry matter increased with advancement of growth stage irrespective of irrigation levels. It can be concluded from the figure that three irrigations produced the maximum amount of plant dry matter (4.17, 22.03, 33.96 and 41.84) and control treatment showed the minimum (2.67, 12.24, 22.06 and 29.6) for sampling dates of 30, 45, 60 and 75 DAS, respectively. 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. Similar result was reported by Latif (2006), Sultana (2007) and Kibbria (2013). Giri (2001) found more dry matter weight per plant in mustard with two irrigations than with one irrigation.

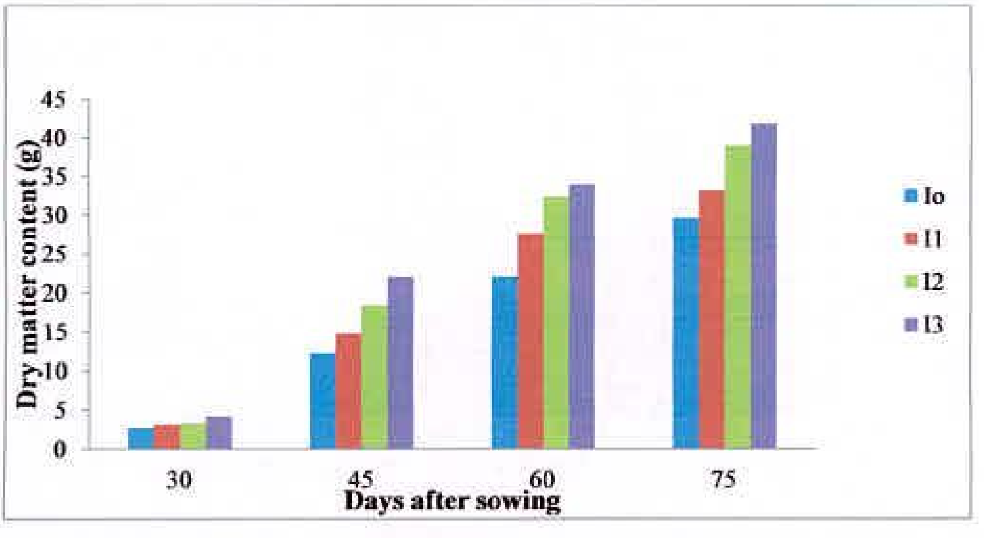

Fig. 3. Effect of different irrigation levels on plant dry matter weight of rapeseed at different DAS (LSD $_{0.05}$ = 0.91, 1.17, 1.11, 2.63 at 30, 45, 60 and 75 DAS, respectively)

4.2.2 Effect of nitrogen

Significant variation of plant dry matter was found due to nitrogen in all the studied durations (Appendix IV and Fig. 4). The figure indicated that plant dry matter weight showed an increasing trend with advances of time for all nitrogen levels. The rate of increase was found slow up to 30 DAS after that dry weight increased sharply up to harvest irrespective of nitrogen levels. The figure that, the recommended dose of nitrogen (115 kg N ha^{-1}) produced the highest plant dry matter weight (3.5, 20.33, 35.51 and 42.53 g) and without nitrogen (control) showed the lowest weight (2.93, 11.46, 21.82 and 28.00 g) for sampling dates of 30, 45, 60, and 75 DAS, respectively. 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 city 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), Upasani and Sharma (1986), and Tomar and Mishra (1991). Murtaza and Paul (1989), Vyas *et al*. (1995), Singh *et al.* (2002) and Shukla *et al.* (2002b) and Bharati and Prasad (2003), also obtained highest result at the rate of 120 kg N ha^{-1} on dry matter production. Brar *et al*. (1998) observed highest result at the rate of 200 kg N ha^{-1} on dry matter production.

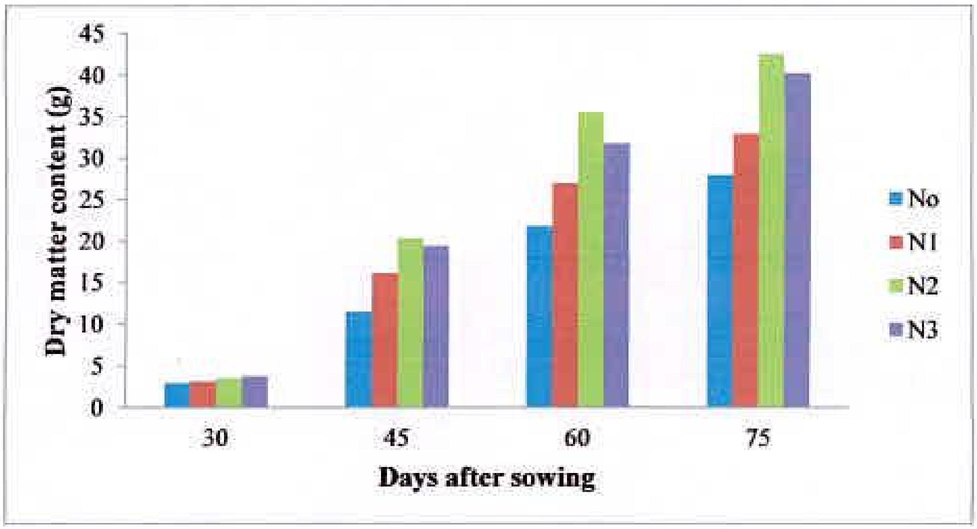

Fig 5.4. Effect of different nitrogen levels on plant dry matter weight of rapeseed at different DAS (LSD $_{0.05}$ = 0.31, 1.03, 1.28, 3.19 at 30, 45, 60 and 75 DAS, respectively)

4.2.3 Interaction effect of irrigation and nitrogen

It was revealed from (Appendix IV and Table 2) that the combined effect of three levels of irrigation (25, 50 and 70 DAS) with 115 kg N ha^{-1} gave the significant highest weight of dry matter per plant at all growth stages. The results revealed that at 30 DAS, the maximum plant dry matter (4.37 g) was found from I_3N_2 treatment which was statistically similar with I_3N_3, I_3N_1, I_3N_0, I_2N_3, I_2N_0 and I_1N_0. The lowest plant dry matter (2.12 g) was found from control treatment which was statistically similar with I_0N_1, I_1N_2, I_2N_1 and I_2N_2. The maximum plant dry matter (26.96 g) was recorded at 45 DAS from I_3N_2 treatment which was statistically similar with I_3N_3 and lowest dry matter (8.79 gm) was found from I_0N_0 treatment. At 60 DAS the maximum plant dry matter (41.13 g) was observed from I_3N_2 which was statistically similar with I_2N_3. The lowest plant dry matter (14.98 g) was found from I_0N_0. At 75 DAS the maximum plant dry matter was observed from I_3N_2 (49.17 g) which was statistically similar with I_3N_3, I_2N_3 and I_2N_2. The lowest plant dry matter (21.45 g) was obtained from I_0N_0 which was statistically similar with I_0N_1 and I_1N_0. Abadi *et al*. (2001) and Tomar *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}.

Table 2. Plant dry matter of rapeseed at different days after sowing as affected by of interaction irrigation and nitrogen levels.

Treatment combination	Plant dry matter (g)			
	30 DAS	45 DAS	60 DAS	75 DAS
I_0N_0	2.12 e	8.79 g	14.98 l	21.45 g
I_0N_1	2.67 de	11.79 f	21.79 jk	27.80 e-g
I_0N_2	3.03 cd	13.86 ef	23.56 ij	32.94 b-e
I_0N_3	2.84 d	14.54 e	27.92 fg	36.22 b-d
I_1N_0	3.67 a-c	9.49 g	20.47 k	25.51 fg
I_1N_1	2.83 d	14.88 de	25.06 hi	31.35 c-f
I_1N_2	2.38 de	16.73 cd	30.93 e	37.70 bc
I_1N_3	3.63 bc	17.64 c	34.08 d	38.07 b
I_2N_0	4.16 ab	11.98 f	25.19 hi	30.67 d-f
I_2N_1	2.78 de	17.28 c	29.75 ef	34.23 b-d
I_2N_2	2.42 de	22.10 b	35.67 cd	44.54 a
I_2N_3	4.03 ab	22.19 b	38.91 ab	46.64 a
I_2N_0	3.89 ab	15.59 c-e	26.64 gh	34.37 b-d
I_3N_1	4.19 ab	20.49 b	31.36 e	38.10 b
I_3N_2	4.37a	26.96 a	41.13 a	49.17 a
I_3N_3	4.21 ab	25.08 a	36.71 bc	45.72 a
LSD (0.05)	0.6305	2.562	2.562	6.365
CV(%)	11.24	5.24	5.24	10.52

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25,50 DAS), I_3 =Three irrigation (at 25,50,70 DAS). N_0 = Control, N_1 = Half of recommended dose,N_2 = Recommended dose,N_3= Urea super granule.

4.3 Number of branches plant^{-1}

4.3.1 Effect of irrigation

From the study it was found that irrigation had great influence on the number of branches plant^{-1} in rapeseed (Appendix V and Table 3). Number of irrigation significantly increased the number of branches plant^{-1}. The maximum numbers of branches (6.89) were found from a plant subjected to three irrigations (25, 50, and 70 DAS) which was statistically similar with two irrigations. The lowest numbers of primary branches (4.99) were found from control treatment. Tomar *et al.* (1992), Giri (2001), Sultana (2007) and Kibbria (2013) reported that significant increase in the number of branches per plant up to three irrigations. Rahman (1994) also reported that two irrigations gave the highest number branches plant^{-1} and the lowest number of branches plant^{-1} was found in case of without irrigation. Probably irrigation water supported the plant to initiate more branches.

4.3.2 Effect of nitrogen

Nitrogen fertilizer had significant effect on number of branches per plant. The levels of nitrogen (115 kg N ha^{-1}) produced higher number of primary branches over control (Appendix V and Table 4). Increasing rates of nitrogen increased the number of primary branches plant^{-1} and successive treatment differences were also significant. The maximum numbers of primary branches (7.46) were found from a plant subjected to recommended dose of nitrogen (250 kg urea ha^{-1}). The lowest numbers of primary branches (4.49) were found from control treatment. So, number of branches plant^{-1} influences the yield of rapeseed and it gradually increased with the increase in nitrogen fertilizers. This findings were supported by Sharma and Jain (2002), Singh *et al.* (2002), Shukla *et al.* (2002b), Tripathi and Tripathi (2003), Ozer (2003), Singh *et al.* (2003) and Ara *et al.* (2014) who obtained significant by higher number of branches plant^{-1} by applying nitrogen up to 120 kg ha^{-1}. Tripathi and Tripathi (2003) found significantly higher number branches plant^{-1} by applying nitrogen up to 200 kg N ha^{-1} and Mondal *et al.* (1996) up to 250 kg N ha^{-1}.

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 branches plant^{-1} (Appendix V and Table 5). The effect of irrigation interacts better with nitrogen when sufficient moisture was supplied. In the study the maximum number of branches plant^{-1} (7.89) was found from the interaction between three irrigations (25, 50 and 70 DAS) with 115 kg N ha^{-1} which was statistically similar with I_3N_3, I_2N_3, and I_1N_3 .The least number of branches (3.01) were found from the interaction of control treatment.

4.4 Number of siliquae plant^{-1}

4.4.1 Effect of irrigation

Number of siliquae is an important factor for increasing yield, which was adversely affected by the soil moisture. So, irrigation plays an important role in increasing the yield and yield attributes. In the present study, number of irrigation showed significant variation in producing siliquae plant^{-1} (Appendix V and Table 3). Among the treatment I_3 (three irrigations at 25, 50 and 70 DAS) produced the highest number of siliquae (98.64) which was statistically similar with I_2 (two irrigation) from other treatments. The treatment I_0 (control) which was received no irrigation throughout the life cycle thus produced the lowest number of siliquae (63.97). 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 plant^{-1}. 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. Tomar *et al.* (1992), Latif (2006), Sultana (2007) and Kibbria (2013) concluded that number of siliquae plant^{-1} was significantly increased up to three irrigation irrigations at pre-flowering, siliquae formation stage and seed maturation stage.

4.4. 2 Effect of nitrogen

Nitrogen fertilizer had significant effect on number of siliquae plant^{-1} (Appendix V and Table 4). The use of 115 kg N ha^{-1} showed highest number of siliquae plant^{-1} (105.1) and control treatment gave the lowest one (58.14). Similar results were also obtained by Keivanrad and Zandi (2014) at 200 kg urea ha^{-1}. On the other hand, higher number of siliquae plant^{-1} obtained at 120 kg N ha^{-1} by Sharma and Jain (2002) and Khan *et al.* (2003). Seed yield increased mainly due to greater number of siliquae plant^{-1} and seeds siliqua^{-1}. The number of siliquae plant^{-1} 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.

4. 4 .3 Interaction effect of Irrigation and nitrogen

Irrigation and nitrogen showed significant effect on number of siliquae plant^{-1} (Appendix V and Table 5). The highest number of siliquae plant^{-1} (117.3) was produced with the interaction of three levels of irrigation and 115 kg N ha^{-1} (I_3N_2) which was statistically similar with I_2N_3. Three levels of irrigations (25, 50 and 70 DAS) with the rate of 115 kg N ha^{-1} showed significant difference to produce the number of siliquae plant^{-1}. Lowest number of siliquae plant^{-1} (35.89) was given by the combination I_0N_0 (without irrigation and no nitrogen). Singh *et al.* (1998) and Tomar *et al.* (2001) also obtained highest number of siliquae plant^{-1} with two irrigations and at 120 kg N ha^{-1}. This 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.

4.5 Length of siliqua (cm)

4.5.1 Effect of irrigation

Irrigation had significant effect on the siliqua length (Appendix V and Table 3). Three irrigations gave the highest siliqua length (5.15 cm) which was statistically similar of treatment I_2 (two irrigations). The lowest siliqua length (3.60 cm) was found from the control treatment. Latif (2006) and Kibbria (2013) concluded that length of siliqua was significantly increased up to three irrigations at pre-flowering, siliqua formation stage and seed maturation stage.

Table 3. Effect of different irrigation levels on yield contributing parameters of rapeseed

Irrigation levels	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliqua length (cm)	Seeds siliquae^{-1} (no.)	1000-seed weight (g)
I_o	4.99 c	63.97 c	3.61 c	18.25 c	3.08 b
I_1	6.11 b	88.99 b	4.12 b	19.73 b	3.16 b
I_2	6.32 ab	96.21 a	5.01 a	21.09 a	3.39 a
I_3	6.89 a	98.64 a	5.15 a	21.53 a	3.41 a
$LSD_{(0.05)}$	0.7461	3.073	0.2583	0.5084	0.2197
CV (%)	7.21	4.23	3.69	2.65	3.78

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25, 50 DAS),
I_3 = Three irrigation (at 25,50,70 DAS).

4.5.2 Effect of nitrogen

Nitrogen had significant effect on the siliqua length (Appendix V and Table 4). It was observed that 115 kg N ha^{-1} gave highest siliqua length (4.75 cm) which was significantly different from other treatments. The control treatment gave the shortest siliqua length (4.18 cm) which was significantly lowest from other treatments. Singh (2002), Shukla *et al.* (2002b) and Singh *et al.* (2002) who reported the highest length of siliqua at the rate of 120 kg N ha$^{-1.}$

4. 5 .3 Interaction effect of irrigation and nitrogen

In this study, interaction effect of irrigation and nitrogen showed significant effect on siliqua length (Table 5). Significant highest siliqua length (5.33 cm) was found from the combination treatment of I_3N_2 (three irrigations with 115 kg N ha^{-1}) Which was statistically similar with I_3N_3, I_3N_1, I_2N_3, and I_2N_2 treatments. The lowest siliqua length (3.32 cm) was found from control treatment (I_0N_0) which was statistically similar with I_0N_1.

4.6 Number of seeds siliqua^{-1}

4.6.1 Effect of irrigation

Numbers of seeds siliquae^{-1} were significantly affected by irrigation levels. The number of seeds siliqua^{-1} was increased with the increase of irrigation number (Appendix V and Table 3). The significant highest number of seeds siliquae^{-1} (21.53) was found from three irrigations at 25, 50 and other at 70 DAS which was statistically similar with two irrigations. The lowest number of seeds siliquae^{-1} (18.25) was found from the control treatment. Seed siliquae^{-1} increased with the increasing levels of irrigation due to the supply of adequate soil moisture which helped to elongate the siliqua length and have more number of seeds. Latif (2006), Sultana (2007) and Kibbria (2013) concluded that number of seeds siliqua^{-1} was significantly increased up to three irrigation irrigations at pre-flowering, siliquae formation stage and seed maturation stage. Tomer *et al*. (1993) and Hossain *et al*. (2013) found a significant increase of seeds per siliquae with two irrigations one at pre-flowering stage and another at fruiting stage. A number of researchers Sharma and Kumar (1989b) and Dobariya and Metha (1995) also observed that irrigation increased number of the seeds siliqua^{-1}.

4.6.2 Effect of nitrogen

Nitrogen rates significantly influenced the number of seeds siliquae^{-1}. The number of seeds per siliqua was increased with the increase of nitrogen rates (Appendix V and Table 4). The significant highest number of seeds siliquae^{-1} (21.88) was found with the rate of the 115 kg N ha^{-1} while the lowest number of seeds siliqua^{-1} (18.41) 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 o seed per siliquaethat were obtained by Singh (2002) and Shukla *et al.* (2002b) showed significant effect on number of seeds siliquae^{-1} increased at the rate of nitrogen of 120 kg ha^{-1}. Keivanrad and Zandi (2014) reported that number of seeds siliquae^{-1} increased at 200 kg N ha^{-1}. Hossain and Gaffer (1997) observed that number of siliquae plant^{-1} increased at 250 kg urea ha^{-1}. It might be due to the fact that vigorous vegetative growth due to nitrogen resulted in adequate supply of photosynthates for the formation of siliquae.

4.6.3 Interaction effect of irrigation and nitrogen

Irrigation as well as nitrogen interact each other to produce seeds siliquae^{-1} in rapeseed. Significant variations in the number of seeds siliquae^{-1} were found with the different interaction of irrigation and nitrogen in the study (Appendix V and Table 5). The highest number of seeds siliquae^{-1} (22.67) was found when three irrigations were applied with 115 kg N ha^{-1} which was statistically similar with I_3N_3, I_3N_1, I_2N_3, I_2N_2 and I_1N_3. The lowest numbers of seeds per siliqua (15.93) were found from the treatment I_0N_0 (control). Latif (2006), Tomar *et al.* (2001) and Meena *et al.* (2002) obtained higher number of seed siliqua^{-1} when two irrigations were applied in combination with 120 kg N ha^{-1}.

4.7 Weight of 1000 seeds (g)

4.7.1 Effect of irrigation

From the (Appendix V and Table 3), it can be seen that the irrigation levels had significant effect on 1000-seed weight. Three irrigations at 25, 50 and 70 DAS produced the highest 1000 seed weight of 3.41 g, which was statistically similar with two irrigations. The lowest 1000 seed weight (3.09 g) was produced by plants without irrigation but statistically similar with one 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 Sharma and Kumar (1989b) and Sarker *et al*. (2000) who reported that increasing the frequency of irrigation increased 1000 seed weight. Latif (2006), Sultana (2007) and Kibbria (2013) concluded that weight of 1000-seeds was significantly increased up to three irrigation irrigations at pre-flowering, siliquae formation stage and seed maturation stage. Tomer *et al*. (1993) and Hossain *et al*. (2013) found a significant increase 1000-seed weight with two irrigations one at pre-flowering stage and another at fruiting stage.

4.7.2 Effect of nitrogen

It was revealed that the application of nitrogen at 58, 115 kg N ha^{-1} and urea super granule (USG) had significant effect on 1000 seed weight (AppendixV and Table 4). The 1000-seed weight increased with the increase of nitrogen levels. At the rate of 115 kg N ha^{-1} produced maximum seed weight (3.45 g) and control treatment gave the lowest one (3.11 g) which was statistically similar with half of recommended dose nitrogen (125 kg N ha^{-1}). Mozaffari *et al*. (2012) obtained highest 1000 seed weight at 225 kg N ha^{-1}. Singh *et al*. (2002), Shukla *et al*. (2002b), Ozer (2003) and Ara *et al*. (2014) 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 ha^{-1}. So seed yield of rapeseed was greatly influenced by 1000-seed weight.

Table 4. Effect of different nitrogen levels on yield contributing parameters of rapeseed

Nitrogen levels	Branches $plant^{-1}$ (no.)	Siliquae $plant^{-1}$ (no.)	Siliqua length (cm)	Seeds $siliqua^{-1}$ (no.)	1000-seed weight (g)
N_0	4.49 d	58.14 d	4.18 d	18.41 d	3.11 c
N_1	5.78 c	89.93 c	4.40 c	19.36 c	3.18 c
N_2	7.46 a	105.1 a	4.75 a	21.88 a	3.45 a
N_3	6.58 b	94.65 b	4.56 b	20.96 b	3.29 b
$LSD_{(0.05)}$	0.3692	3.098	0.1385	0.4506	0.1032
CV (%)	7.21	4.23	3.69	2.65	3.78

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

N_0 = Control, N_1 = Half of recommended dose,N_2 = Recommended dose,N_3 = Urea super granule

4.7.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen was found significant in relation to 1000 seed weight of rapeseed (Appendix V and Table 5). The highest weight of 1000 seed (3.80 g) was found from the combination I_3N_2 of three irrigations (at 25, 50 and 70 DAS) with 250 kg urea ha^{-1}. The lowest weight of 1000 seed (3.01 g) from control treatment which statistically similar with I_3N_0, I_2N_0, I_1N_2, I_1N_1, I_1N_0, I_0N_3, I_0N_2 and I_0N1. The 1000-seed weight increased with the increasing levels of irrigation and nitrogen reported by Mondal *et al.* (2000), Abadi *et al.* (2001), Tomar *et al.* (2001) and Latif (2006) obtained 120 kg N ha^{-1}.

Table 5. Interaction effect of different irrigation and nitrogen levels on yield contributing parameters of rapeseed

Treatment combination	Branch plant^{-1}(no.)	Siliquae plant^{-1}(no.)	Siliqua length (cm)	seed siliqua^{-1}(no.)	1000 seed weight(g)
I_0N_0	3.01 h	35.89 i	3.32 j	15.93 f	3.02 g
I_0N_1	4.45 g	64.22 gh	3.44 ij	17.27 e	3.06 fg
I_0N_2	5.49 ef	68.78 g	3.69 hi	19.07 d	3.10 fg
I_0N_3	7.04 bc	87.00 f	3.98 fg	20.73 b	3.18 e-g
I_1N_0	4.43 g	62.11 h	3.83gh	17.67 e	3.07 hg
I_1N_1	5.69 ef	95.17 e	4.11 e-g	18.90 d	3.12 f g
I_1N_2	6.77 cd	97.89 de	4.20 ef	20.47 bc	3.17 e-g
I_1N_3	7.54 ab	100.8 c-e	4.35 e	21.87 a	3.26 d-f
I_2N_0	4.99 fg	66.22 gh	4.73 d	19.80 cd	3.20 e-g
I_2N_1	6.20 de	98.45 de	4.90 b-d	20.40 bc	3.33 c-e
I_2N_2	6.72 cd	104.9 bc	5.11 a-c	21.93 a	3.47 bc
I_2N_3	7.37 a-c	115.2 a	5.33 a	22.23 a	3.57 b
I_3N_0	5.56 ef	68.33 g	4.85 cd	20.23 bc	3.17 e-g
I_3N_1	6.81 b-d	101.9 b-d	5.16 ab	20.87 b	3.23 b-d
I_3N_2	7.89 a	117.3 a	5.33 a	22.67 a	3.50 a
I_3N_3	7.34 a-c	107.0 b	5.26 a	22.37 a	3.43 b-d
LSD (0.05)	0.7384	6.196	0.2769	0.9012	0.2064
CV(%)	7.21	4.23	3.69	2.65	3.78

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25,50 DAS), I_3 =Three irrigation (at 25,50,70 DAS). N_0 = Control, N_1 = Half of recommended dose, N_2 = Recommended dose,N_3 = Urea super granule

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

4.8.1 Effect of irrigation

Irrigation treatment significantly increased the seed yield per hectare in rapeseed. Seed yield per hectare increased with the increase of irrigation levels (Appendix VI and Table 6.) Maximum seed yield per hectare (1589 kg ha^{-1}) was found from three irrigations (at 25, 50 and 70 DAS) which were statistically similar with two irrigations (1543 kg ha^{-1}). The lowest seed yield ha^{-1} was found from control treatment (1095 kg ha^{-1}). In control high mortality of seedlings resulting from shortage of soil moisture drastically reduced the yield. 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 I_o (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 siliquae, and 1000-seed weight (Tomer *et al.*, 1992). These results corroborated with Latif (2006), Sultana (2007) and Kibbria (2013).

Table 6. Effect of different irrigation levels on yield and harvest index of rapeseed

Irrigation levels	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
I_o	1095 c	1714 c	2809 c	39.12 b
I_1	1311 b	1922 b	3233 b	39.84 ab
I_2	1543 a	2304 a	3847 a	39.96 ab
I_3	1589 a	2359 a	3949 a	40.11 a
$LSD_{(0.05)}$	91.59	71.68	159.8	0.8929
CV (%)	3.53	3.16	2.47	2.88

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25,50 DAS), I_3 =Three irrigation (at 25,50,70 DAS).

4.8.2 Effect of nitrogen

Different rates of nitrogen significantly increased the seed yield per hectare. Nitrogenous fertilizer urea at 115 kg N ha^{-1} significantly increased the seed yield (1712 kg ha^{-1}) over 125 kg ha^{-1} (1290 kg ha^{-1}) and urea super granule (1475 kg ha^{-1}) and control (1061 kg ha^{-1}) (Appendix VI and Table 7). Seed yield decreased with the decreasing rates of nitrogen fertilizer application. Aminpanah (2013) reported that seed yield increased at 200 kg N ha^{-1}. Higher seed yield was also obtained at of rate 120 kg N ha^{-1} as reported by Shukla *et al*. (2002b), Singh (2002), Shukla *et al*. (2002a), Singh *et al*. (2002), Singh and Prasad (2003), Singh *et al*. (2003) and Ara *et al*. (2014). 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 fertilizer.

Table 7. Effect of different nitrogen levels on yield and harvest index of rapeseed

Nitrogen levels	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
N_0	1061 d	1725 d	2786 d	38.25 c
N_1	1290 c	1976 c	3267 c	39.35 b
N_2	1712 a	2395 a	4106 a	41.34 a
N_3	1475 b	2203 b	3678 b	40.07 b
$LSD_{(0.05)}$	41.17	55.33	72.06	0.9636
CV (%)	2.53	3.16	2.47	2.88

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

N_0 = Control, N_1 = Half of recommended dose, N_2 = Recommended dose, N_3 = Urea super granule

4.8.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen influenced the seed yield per hectare (Appendix VI and Table 8). Seed yield (2065 kg ha^{-1}) was significantly superior observed from the combination I_3N_2 treatment (at three levels of irrigations with 115 kg N ha^{-1}) which was statistically similar with I_2N_3. But control treatment gave the lowest yield (1039 kg ha^{-1})) which was statistically similar with I_0N_1 and I_0N_2. Tomar *et al.* (2001) and Meena *et al.* (2002) 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}.

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

4.9.1 Effect of irrigation

The number of irrigations 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 Appendix VI and Table 6). The treatment I_3 (irrigations at 25, 50 and 70 DAS produced the highest stover yield (2359 kg ha^{-1}) which was statistically similar with I_2 (two irrigation). In the previous discussion it was shown that I_3 (irrigations at 25, 50 and 70 DAS) treatment produced the tallest plant height, number of branches per plant and number of siliquae $plant^{-1}$, which cumulatively increased the stover yield. The treatment I_0 (no irrigation) produced the lowest stover yield (1714 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) and Kibbria (2013) reported that two irrigations gave the highest stover yield per plant while the lowest yield was found from zero irrigation.

4.9.2 Effect of nitrogen

The different dose of nitrogen had the effect on the stover yield per hectare (Appendix VI and Table 7). The maximum stover yield 2395 kg ha^{-1} was obtained from N_2 treatment (115 kg N ha^{-1}), whereas the minimum stover yield per hectare (1725 kg) was obtained from N_0. It is interesting that nitrogen helped to produce tallest plant, more number of branches $plant^{-1}$ and number of siliquae $plant^{-1}$ which ultimately increased stover yield. These findings were in agreement with that of Singh *et al.* (2002). But Meena *et al.* (2002) Singh and Prasad (2003) 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.

4.9.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen had significant effect on stover yield (Table 8). The highest stover yield (2749 kg ha^{-1}) was obtained from I_3N_2 treatment which was statistically similar with I_2N_3. The lowest stover yield (1419 kg ha^{-1}) was observed by control treatment.

Table 8. Interaction effect of different irrigation and nitrogen levels on yield and harvest index of rapeseed

Treatment combination	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield(kg ha^{-1})	Harvest index(%)
I_0N_0	1039 g	1419 h	2458 h	36.67 e
I_0N_1	1073 fg	1712 f	2786 g	38.55 de
I_0N_2	1109 e-g	1791 f	2900 fg	38.24 de
I_0N_3	1157 e	1934 e	3091 e	37.37 de
I_1N_0	912 h	1578 g	2491 h	39.15 cd
I_1N_1	1141 ef	1920 e	3060 e	37.28 de
I_1N_2	1571 bc	2013 de	3584 d	42.90 a
I_1N_3	1620 b	2177 c	3797 c	42.67 ab
I_2N_0	1122 ef	1905 e	3027 ef	37.05 e
I_2N_1	1450 d	2104 cd	3554 d	40.79 bc
I_2N_2	1597 b	2487 b	4084 b	39.08 cd
I_2N_3	2004 a	2719 a	4723 a	42.43 ab
I_2N_0	1172 e	1996 de	3168 e	36.98 e
I_3N_1	1497 cd	2170 c	3666 cd	40.80 bc
I_3N_2	2065 a	2749 a	4814 a	43.83 a
I_3N_3	1623 b	2522 b	4145 b	42.32 ab
LSD (0.05)	82.33	110.7	144.1	1.93
CV(%)	2.53	3.16	2.47	2.88

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability

I_0 = No irrigation, I_1 = One irrigation (at 25 DAS), I_2 =Two irrigation (at 25,50 DAS), I_3 =Three irrigation (at 25,50,70 DAS). N_0 = Control, N_1 = Half of recommended dose, N_2 = Recommended dose,N_3 = Urea super granule

4.10 Harvest index (%)

4.10.1 Effect of irrigation

It was observed from the (Appendix VI and Table 6) that different irrigation levels had significant effect on harvest index. The three irrigations at 25, 50 and 70 DAS gave the highest harvest index (40.11%) and it was significantly different from the other treatments. The lowest value of harvest index (39.12%) was obtained from the treatment I_o (no irrigation). Three irrigations (at 25, 50 and 70 DAS) produced higher seed yield, which increased the 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 also found the lowest harvest index was given by I_o (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.

4.10.2 Effect of nitrogen

From Table 7 it revealed that the different nitrogen levels had significant effect on harvest index. Application of N at 115 kg ha^{-1} significantly increased the harvest index (41.34%). The lowest harvest index (38.25%) was obtained from control treatment (no nitrogen). Similar result was also observed by Shukla and Kumar (1997) at the 120 kg N ha^{-1}. Mozaffari *et al.* (2012) observed highest harvest index at 200 N kg ha^{-1}.

4.10.3 Interaction effect of irrigation and nitrogen

It was observed that irrigation and nitrogen interaction had significant effect on harvest index (Table 8). Harvest index was significantly higher (43.83%) from the treatment combination of I_3N_2 which was statistically similar with I_3N_0 I_2N_3, I_1N_3 and I_1N_2 The lowest harvest index (36.67%) was recorded from the treatment combination of I_0N_0 which was statistically similar with I_0N_1, I_0N_2, I_0N_3, I_1N_1 and I_2N_0.

4.11. Biological yield (kg ha^{-1})

4.11.1 Effect of irrigation

Irrigation had significant effect on the biological yield hectare^{-1} (Appendix VI and Table 6). The maximum biological yield (3949 kg ha^{-1}) was obtained from I_3 treatment which was statistically similar with two irrigations. The minimum biological yield (2809 kg kg ha^{-1}) was obtained from I_0.

4.11.2 Effect of nitrogen

Different rates of nitrogen significantly increased the biological yield per hectare (Appendix VI and Table 7). The maximum biological yield (4106 kg ha^{-1}) was obtained from N_2 treatment which was significantly different from other treatment. The minimum biological yield (2786 kg ha^{-1}) was obtained from N_0. Keivanrad and Zandi (2014) reported that stover yield highest at 200 kg N ha^{-1}.

4.11.3 Interaction effect of irrigation and nitrogen

Interaction effect of irrigation and nitrogen had significant effect on biological yield(Table 8) . The highest biological yield (4814 kg ha^{-1}) was obtained from I_3N_2 treatment which was statistically similar with I_2N_3. The lowest biological yield (2458 kg ha^{-1}) was observed by treatment of I_0N_0 (control treatment) which was statistically similar with I_1N_0.

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

An experiment entitled "Influence of irrigation and nitrogen on the growth and yield of rapeseed (*Brassica campestries*) was conducted during Rabi season (October-February, 2013-2014) 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 25 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 115 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 irrigation along with 115 Kg N ha^{-1} showed highest plant height, but on the other hand, lower plant height were observed at control treatment. 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, thereafter, 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 25 DAS. As the second irrigation (50 DAS) continued soil moisture at siliquae formation stage, and third irrigation (70 DAS) continued at seed maturation stage, three irrigations 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 115 kg ha^{-1} maintained highest dry matter.

In case of interaction effect, the treatment combination of three irrigations along with 115 ka N ha^{-1} produced higher dry matter at different growth stages and at harvest. Three irrigation in combination with 115 kg N ha^{-1} produced maximum dry matter at 75 DAS. The number of primary branches per plant,

plant, number of siliquae plant^{-1} increased progressively with the increasing level of irrigation. The maximum numbers of primary, number of siliquae per plant were found when where irrigations were applied at 25, 50 and 70 DAS. The lowest results results were found from the control treatment. The number of primary branches plant^{-1}, number of siliquae plant^{-1} increased progressively with the increasing level of nitrogen. The average numbers of primary, number of siliquae plant^{-1} were found at higher rate of 115 kg N ha^{-1} . Interaction of irrigation and N significantly influenced branch number, siliquae number plant^{-1}. Application of three levels of irrigation with 115 kg N ha^{-1} gave significantly highest number of branches (7.89), and siliquae number plant^{-1} (117.3). Irrigations had significant effect on the siliqua length and seeds per siliqua. Among the irrigation treatments, three irrigations at 25, 50 and 70 DAS produced the highest siliqua length (5.15 cm) and seeds siliqua^{-1} (21.53). The highest siliqua length (4.75 cm) and seeds per siliqua (21.88) was obtained at 115 kg N ha^{-1}. Interaction effect of irrigation and N significantly influenced the siliqua length and seeds siliqua^{-1}. Application of three levels of irrigation with 115 kg N ha^{-1} gave significantly highest number of siliqua length(5.33) and seeds siliqua^{-1} (22.67) and lowest was found from the control treatment.

The 1000 seed weight slightly influenced with application of irrigation. But 115 kg N ha^{-1} produced highest 1000 seed weight (3.45 g) and lowest 1000 seed weight (3.11 g) were obtained at N control treatment. The highest 1000 seed weight obtained at the application of three levels of irrigation in combination with 115 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 (1589 kg ha^{-1}) and stover yield (2359 kg ha^{-1}) and lowest seed yield (1095 kg ha^{-1}) and stover yield (1714 kg ha^{-1}) were obtained at unirrigated condition. The seed and stover yield were increased significantly up to 115 kg N ha^{-1}. The highest seed yield (1712 kg ha^{-1}) and stover yield (2395 kg ha^{-1}) was found at higher rate of 115 kg N ha^{-1}, and lowest seed yield (1061 kg ha^{-1}) and stover yield (1725 kg ha^{-1})was found at control treatment. Seed yield and stover yield were increased significantly by the interaction effect of irrigation and N application. Significant seed yields of 2065 kg ha^{-1} and stover yield 2749 kg ha^{-1} were obtained at three levels of irrigations along with 115 kg N $ha^{-1.}$

Harvest index was influenced by the application of irrigation, higher harvest index (40.11%) was obtained at three irrigations, and lowest (39.12%) was found at unirrigated condition. Higher harvest index (41.34%) was obtained at 115 kg N ha^{-1} and lowest harvest index (38.25%) was found at control. All the levels of nitrogen significantly differ to increasing the harvest index. Higher HI of 43.83% was obtained at three levels of irrigation along with 115 kg N ha^{-1}.

From the present study, it may be concluded three irrigations (at 25, 50 and 70 DAS) gave the best results. Application of 115 kg N ha^{-1} gave the best result. The interaction effects of three irrigations and 115 kg N ha^{-1} showed most effective in respect of seed yield.

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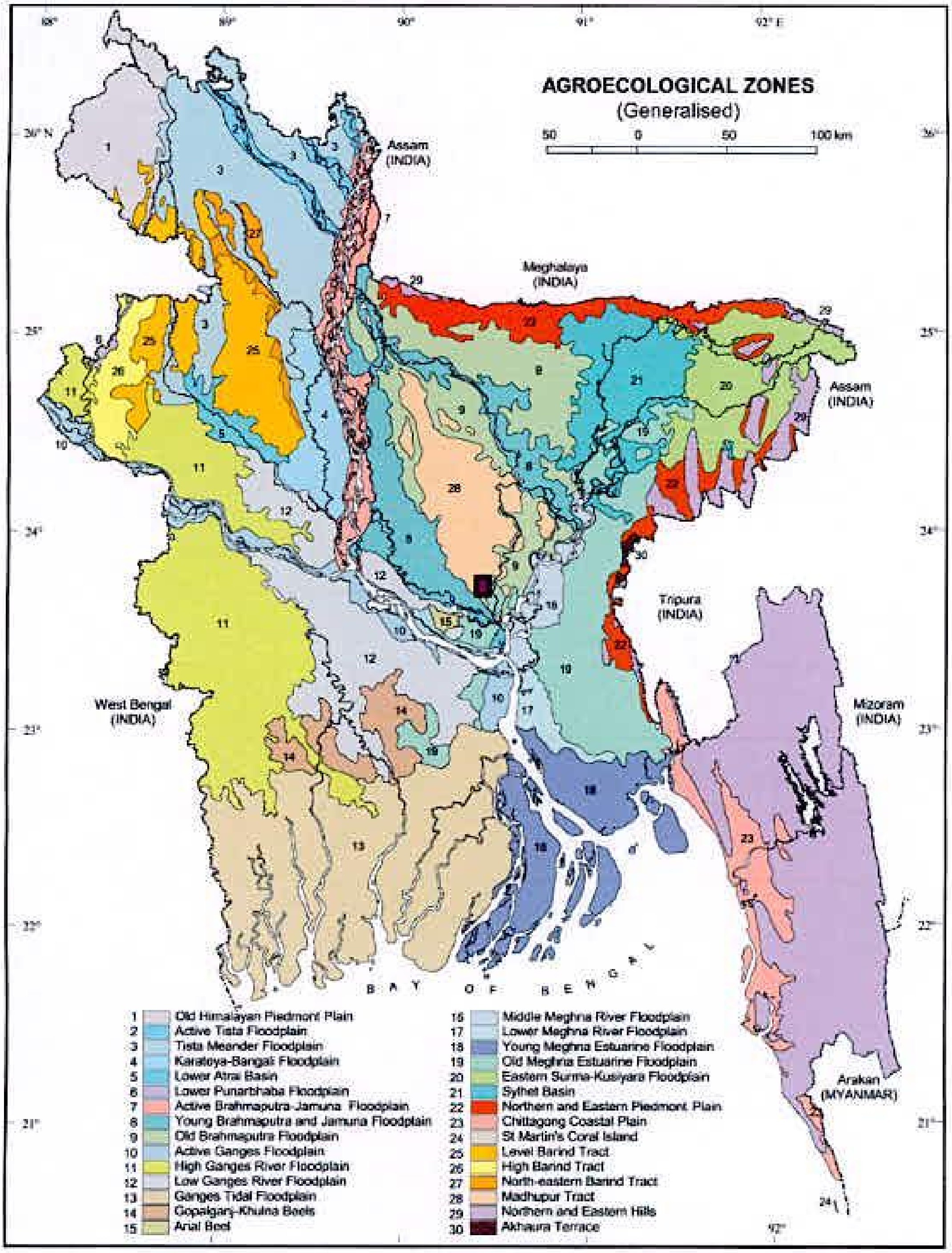
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Weather data Monthly record of average air temperature, relative humidity and total rainfall of the experimental site during the period from November 2013 to March 2014

Month	Average Relative Humidity (RH)	Average Temperature (^0C)		Total Rainfall (mm)
		Minimum	Maximum	
November	58.18	6.88	28.10	1.56
December	54.30	5.21	25.36	0.63
January	64.02	15.46	21.17	0.00
February	53.07	19.12	24.30	2.34
March	48.66	22.37	29.78	0.12

Source: Weather station, Sher-e-Bangla Agricultural University, Dhaka-1207.

Appendix III . Mean square values for plant height at different days after sowing of rapeseed.

Sources of variation	Degrees of freedom	Mean square values				
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	34.37	101.37	49.62	13.71	31.30
Irrigation	3	182.69**	375.14**	477.49**	537.87**	543.42**
Error (a)	6	2.62*	30.56*	17.71*	25.15*	8.67*
Nitrogen	3	70.19**	727.86**	817.46**	60.61**	719.14**
Irrigation x Nitrogen	9	49.79*	15.77*	8.82*	4.11*	2.22*
Error (b)	24	8.91*	14.79*	15.78*	9.64*	17.205*

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix IV. Mean square values of plant dry weight at different days after sowing of rapeseed.

Sources of variation	Degrees of freedom	Mean square values			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.02	2.77	3.17	22.68
Irrigation	3	4.76**	220.40**	344.05**	368.81**
Error (a)	6	0.13*	1.94*	1.73*	9.76*
Nitrogen	3	1.65**	193.67**	421.50**	536.75**
Irrigation xNitrogen	9	0.80**	4.76*	2.36*	4.73*
Error (b)	24	0.14	1.52	2.31	14.27

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

Appendix V . Means square values for yield contributing characters of rapeseed.

Sources of variation	Degrees of freedom	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Siliqua length (cm)	Seeds siliqua^{-1} (no.)	1000 seed weight (g)
Replication	2	0.39	5.58	0.19	11.89	0.03
Irrigation	3	7.59*	3018.17	6.51**	26.36**	0.32**
Error (a)	6	0.78*	13.30*	0.09*	0.36*	0.07*
Nitrogen	3	18.98**	4908.58 **	0.70**	29.16**	0.26**
Irrigation xNitrogen	9	0.39*	34.29*	0.02*	0.78*	0.03*
Error (b)	24	0.19*	13.518	0.03	0.29	0.01

*Significant at 5% level

NS=Non Significant

**Significant at 1% level

Appendix VI. Means square values for yield and harvest index of rapeseed

Source of variation	Degrees of freedom	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Replication	2	1050.89	8150.02	7294.19	1.67
Irrigation	3	626069.91 **	1147672.06**	3456911.91**	2.31*
Error (a)	6	11814.79*	7236.49*	35985.24*	2.31*
Nitrogen	3	913758.58**	1004458.00**	3827486.24**	20.15**
Irrigation xNitrogen	9	85405.02**	26486.06**	154772.95**	23.15**
Error (b)	24	2387.12	4311.54	7313.31	1.31

*Significant at 5% level

**Significant at 1% level

NS=Non Significant

PLATES

Plate 1. Field view during interculture operation

Plate 2. Field view at flowering stage

Plate 3. Field view at ripening stage