EFFECTS OF DIFFERENT NITROGEN DOSES AND VARIOUS IRRIGATION LEVELS ON GROWTH AND YIELD OF MUSTARD

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF DIFFERENT NITROGEN DOSES AND IRRIGATION LEVELS ON GROWTH AND YIELD OF MUSTARD"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, impartial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bona fide research work carried out by **NUSRAT JAHAN KONOK**, Registration No. **19-10125** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2021 Dhaka,

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Dedicated to

My

Beloved Parents

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EFFECTS OF DIFFERENT NITROGEN DOSES AND VARIOUS IRRIGATION LEVELS ON GROWTH AND YIELD OF MUSTARD

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to determine the effect of different nitrogen fertilizer doses and various irrigation levels on growth and yield of mustard during the period from November 2019 to February 2020. The experiment consisted of four levels of nitrogen *viz.*control-0 kg N ha^{-1}(N_0), 90 kg N ha^{-1}(N_1),120 kg N ha^{-1}(N_2) and 150 kg N ha^{-1} (N_3) and 3 levels of irrigation *viz.* control - no irrigation (I_0), one irrigation at 25 DAS (I_1) and two irrigations at 25 and 50 DAS (I_2). The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Considering the application of nitrogen, N_2 (120 kg N ha^{-1}) showed the best results in terms of yield and yield contributing parameters such as number of siliqua plant^{-1} (78.30), length of siliqua (4.57 cm), number of seeds siliqua^{-1} (32.96), 1000 seed weight (4.53 g), seed yield (1.40 t ha^{-1}) and harvest index (35.35%) whereas control treatment N_0 (0 kg N ha^{-1}) gave the lowest yield. Considering irrigation treatments I_2 (Two irrigations at 25 and 50 DAS) gave best results on growth, yield and yield contributing parameters. The highest number of siliqua plant^{-1} (78.78), length of siliqua (4.58 cm),number of seeds siliqua^{-1} (32.80), 1000 seed weight (4.46 g), seed yield (1.41tha^{-1}), stover yield (2.62 t ha^{-1}) and harvest index (34.95%) were recorded from I_2 whereas control treatment I_0 gave the lowest yield. Regarding combined effect, N_2I_2 showed the highest number of siliqua plant^{-1} (87.63), length of siliqua (4.81 cm), number of seeds siliqua^{-1} (37.63), 1000 seed weight (5.00 g), seed yield (1.61 t ha^{-1}), stover yield (2.73 t ha^{-1}) and harvest index (37.62%) followed by N_3I_2 treatment. Hence, the results summarized that different Nitrogen and/or irrigation levels had significant and positive effect on growth, yield and yield contributing parameters of mustard and these can be considered as essential practices for higher mustard production.

LIST OF CONTENTS

LIST OF CONTENTS(Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
Cm	=	Centimeter
CV%	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
Et.al.	=	And others
e.g.	=	Exempli gratia(L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
G	=	Gram(s)
i.e.	=	Idest (L), that is
Kg	=	Kilogram(s)
LSD	=	Least Significant Difference
m^2	=	Square meter
Ml	=	Milliliter
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
Mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
Mg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Mustard (*Brassica spp.*) is an important oil seed crop in Bangladesh. It is the second most important edible oil in the world. About 13.2% of the annual edible oil comes from this crop (FAO, 2016). Mustard oil crop is the most important group that supplies major edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country (AIS, 2010).

Mustard belongs to the family Brassicaceae (Cruciferae), is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Currently it ranks as the world third oil crops in terms of production and area (Adnan *et al*., 2013). *Brassica napus*, *B. campestris* and *B. junceae* the three species of mustard those produce edible oil which ranks the third most important sources of edible vegetable oil in the world after palm and soybean (Zhang and Zhou, 2006 and Adnan *et al*., 2013). Among the species, *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. Oil seed rape (*Brassica napus* L.)has become one of the most important oil crops (Miri, 2007) and at present it is the third largest source of vegetable oil all over the world (Starner *et al*., 1999).

Mustard is the most important oilseed crop in Bangladesh, accounting for around 60% of total oilseed production (BBS, 2019). It is a key source of cooking oil in Bangladesh, providing one-third of the country's edible oil needs (Ahmed *et al*., 1988). In Bangladesh, edible oil is an important element of the people's daily food. Fats and oils come from a variety of sources, including animal and plant sources. Animal fats are derived from milk, ghee, butter, and other dairy products, however they are relatively expensive when compared to oil derived from other oil crops. Plant-based oil is easily digested and has a higher nutritional value than animal fats. Plant products provide more energy than animal items (USDA, 2014). For example, oil produced from mustard, coconut or peanut contains 900 kilocalories (energy), compared to 729 and 273 kilocalories in butter and fist, respectively. Vegetable oil, which can be derived from plant sources through the growth of oil crops, that clearly significant as other crops. In Bangladesh, mustard (*Brassica spp*.) is a widely used as edible oil in rural areas and to improve the flavor of a variety of foods (Aziz *et al*., 2013). Bangladesh is mostly an agricultural country that grows a variety of oil seed crops such as mustard, sesame, soyabean, sunflower, peanut, linseed, safflower, castor and others. The first three are regarded to be the most important oil seed crops. In the 2018-19 crop year, overall oilseed production was 928 thousand metric tons, with 986 thousand acres covered by oilseed crops. Mustard was grown on 765 thousand acres of land in 2017-18, with a production of 366 thousand metric tons (BBS, 2018).

In Bangladesh, mustard (*Brassica spp*.) is a winter crop. It's also a thermos sensitive and photosensitive sensor (Ghosh and Chatterjee, 1986). It's also used as a raw material in soap, varnishes, paints, medicines, hair oils, lubricants, textile auxiliaries, and other products. Its oil not only serves as a fat substitute in our daily diet, but it also helps to feed the nation's economy. It's popular as a cooking component, a condiment and for medicinal purposes. Furthermore, mustard oilcake is used as a fish and cow feed, as well as a little amount of manure. It accounts for over 73% of the country's total oil seed production (Alamin *et al*., 2019). Moreover mustard oilcake is utilized as cattle feed and small quantities are also used as manure. It accounts about 72% of total oil seed production in the country. Mustard is one of the most important oilseed crops throughout the world after soybean and groundnut (FAO, 2012).

In Bangladesh, it occupies first position of the list in respect of area and production among the oilseed crops (BBS, 2019). Oil seeds are important in the economy of Bangladesh which constitutes the most important group of crops next to cereals occupying 4.22% of the total cropped area (BBS, 2009). The average yield of the crop stands at 990 kg/ha (BBS, 2009), which is very low compared to the yield of many mustard growing countries of the world. There are several reasons that can explain this yield variation, which cover abiotic and biotic factors. Among the biotic and abiotic factors, unavailability of high yield in varieties (Akber *et al*., 1994), nutrient deficiency

(Varma *et al*., 2002) and lack of cultural practices like irrigation (Hossain *et al*., 2013) are responsible for lower productivity of mustard. The newly released high yielding potential varieties of mustard could not compensate the yield gap possibly due to boron deficiency in soil and lack of irrigation.

The crop is mainly grown during the winter season (October-March). The growth yield attributes and yield of mustard increased significantly with the increase in number irrigation (Verma *et al*., 2014). Applications of three irrigations significantly increased seed yield by 15.5% and 52.8% over two and one irrigations, respectively (Kibbria, 2013). Similarly, it was reported that two irrigations once at flowering and others at siliqua formation stage increased the seed yield by 28% over rainfed plot. The highest plant height, branches plant^{-1}, filled siliquap lant^{-1}, seedssiliqua^{-1}, 1000 seed weight and stover yield were obtained from two irrigations and consequently it produced the highest seed yield (Ghosh *et al*., 1994 and Hossain *et al*., 2013).

A sufficient amount of moisture in the soil aids in the proper usage of plant nutrients, resulting in optimal development and output (Verma *et al*., 2014). Because the frequency of irrigation and the amount of water required are dependent on factors such as cultivar, soil type, season, rainfall, and diseases, it is impossible to make a specific suggestion. Overwatering as well as under watering might reduce yields (Sultana, 2007). As a result, efficient water management is essential in mustard cultivation. Irrigation had a considerable impact on all yield and yield-related characteristics (Hossain *et al*., 2013).Nitrogen plays a crucial role in seed protein and plant physiological processes. By implementing better cultural practices, it is feasible to boost yield per unit area. Nitrogen (N) deficiency is a common problem in Bangladesh, and it has the most dramatic effect of all the essential elements on plant development and productivity in this crop. Nitrogen has a substantial effect on plant height, branches plant-1, pods plant-1, and other growth variables as well as mustard production, according to the research (Mondol and Gaffer; 1983; Allen and Morgan; 1972). Nitrogen promotes plant vegetative development and postpones maturity.

Keeping in view of above facts, a field experiment entitled, “effects of different nitrogen doses and various irrigation levels on growth and yield of mustard” was conducted during *rabi* season to fulfill the following objectives:

1. To evaluate the effect of different nitrogen doses on growth and yield of mustard.
2. To determine the optimum irrigation levels for mustard cultivation.

CHAPTER II

REVIEW OF LITERATURE

Mustard is an important oil crop in Bangladesh, which can contribute largely in the national economy. Investigation on the influence of nitrogen application and irrigation on the growth and yield of mustard have been progressed in many countries of the world. The proper fertilizer management and also agronomic practices like irrigation management accelerates its growth and influence yield. Therefore, available findings of the effect of irrigation and nitrogen fertilizer and combined effect relevant to the present study have also been briefly reviewed under the following heads:

Effect of nitrogen on mustard

The importance of nitrogen fertilizer to achieve the higher production potential in mustard is well recognized. Nitrogen is an important metabolic element for growth and development of plants. It is considered essential for metabolic activities and transformation of energy and essential for metabolism of protein and other biochemical product such as nucleic acid, chlorophyll and protoplasm. It is, thus the basic constituent of plant life. Its application favors cell division, cell elongation, growth and development of all the living plant tissues. It increases size and number of leaves, number of branches and shoot height and fruit development.

The application of nitrogen (N) has been essential element for plant growth, and plant response to added N has proven to be a valuable agronomic practice since time immemorial. The N supply of oilseed rapeseed is of central importance to ensure high yields. As rapeseed are heavy users of N, and available N is the most limiting source in many areas of the world (Kessel, 2005 and Rossato *et al*., 2002), therefore, mineral N fertilization is a crucial factor in oilseed rapeseed production (Dreccer *et al*., 2000; Rathke and Schuster, 2004 and Abdullah *et al*., 2012), and because of low harvest index of rapeseed, higher rates of N fertilizer are usually applied to mustard in order to seed yield maximization in diverse and contradicting conditions (Behrens, 2002; Behrens *et al*., 2004).

Chowdhary and Bhogal (2018) conducted a field experiment to study the response of mustard cultivars to nitrogen application at Directorate of Rapeseed Mustard Research, Sewar, Bharatpur (Rajasthan). The experiment was laid out in split plot design with three cultivars of mustard (Aravali, Laxmi and Vardan) and five levels of nitrogen (0, 90, 120, and 150 kg ha^{-1}) with three replications. The results revealed that the mustard cultivar produced higher mean seed yield (16.32qha^{-1}) followed by Aravali (15.30 q ha^{-1}) and Vardan (14.05 q ha^{-1}). The seed yield of mustard was significantly influenced with the increase in the levels of N the highest yield (17.59 q ha^{-1}) was recorded with 2kgNha^{-1}, which was significantly at par with 120 kg N ha^{-1}.

Kumararaja *et al.* (2015) conducted a field experiment to assess the effects of different levels of nitrogen in N- deficient calcareous soil on yield and some yield components of Indian mustard (cv. Varuna). Application of nitrogen significantly influenced the yield by improving the yield attributing characters. Application of16 kg Borax/ha resulted in maximum seed yield under both the years. Nitrogen application improves the yield by 35-39% over the control. The dose response curve followed by first order derivative egression showed that optimum fertilized do sewas120kgN/ha. Nitrogen contents in stem, leaves and seed increased significantly within increase N application.

Kumar *et al*. (2001) observed the significant increase in plant height, branches per plant, Siliquae per plant, seed per siliqua, 1000 seed weight, harvest index, seed yield and stover yield with increasing doses of nitrogen upto 120 kg N h^{-1} in Indian mustard (*Brassica juncea L.*), same results reported by Premi and Kumar (2004) Kumar *et al*. (2002) reported significant increase in seed yield with nitrogen application up to 100 kg N h^{-1}. The increase in seed yield with 75, 100 and 125 kg N h^{-1} was 70.0, 86.5 and 95.70 kg seed yield h^{-1}, respectively over the control.

De *et al*. (2007) reported that nitrogen up to 120 kg N h^{-1} increases the yield component of Indian mustard significantly over 0, 40, 60 kg N h^{-1} and at par with the 90 kg N h^{-1}.

Keivanrad and Zandi (2014) Sah *et al*. (2006) reported that the plant and primary branches per plant increased significantly up to 80 kg N h^{-1}, while secondary branches and dry matter per plant increased up to 120 kg h^{-1}. Kumar *et al*. (2002) reported that the seed yield and oil yields of Brassica spp. increased significantly with each successive increase in nitrogen level up to 100 kg h^{-1} maximum seed yield was reported as 16.6 q h^{-1}. Rana (2002) reported that mustard response significantly to 90 kg N h^{-1} under rain fed conditions and up to 120 kg N h^{-1} under irrigated conditions.

Recently, Awal *et al*. (2020) conducted an experiment to explore the effect of agronomic bio fortification of nitrogen nutrients on the growth and yield of mustard crop. Nitrogen fertilizations significantly influence the plant height, production of branches and leaves per plant, dry matter accumulation and yield attributes and yield of mustard crop. The mustard crop fertilized with 120 kg N ha^{-1} produced taller plant, higher number of branches, leaves in each plant and higher amount of dry matter per plant while these plant traits were found as minimum when the growing the mustard crops in control plots i.e. the plants received neither Sulphur or nitrogen. Application of nitrogen @ 120 kg ha^{-1} produced the highest seed yield (1.40 t ha^{-1}) whereas the lowest seed yield (1.11tha^{-1}) was found where no nitrogen was applied. The result concluded that Sulphur and nitrogen@ 900and120 kg per hectare, respectively was found to be most effective dose in enhancing growth and yield of mustard crop. Nitrogenous fertilizer is a good source of nutrients for soil that implies a positive effect on growth, development and yield of vegetables when applied at optimal doses. Considering this fact, the present research was designed to study the effect of different levels of nitrogenous fertilizer (from urea source) on the growth and yield of mustard Green.

The researchers (Awal *et al.*, 2020) employed a split-plot layout within a randomized complete block design (RCBD) with four treatments and three replications. T_3 (150 kg urea ha-1) and T_2 (100 kg urea ha-1) were statistically insignificant, according to the analysis of variance. Shoot height, leaf area, shoot fresh weight, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua, and ultimately seed yield per hector were all significantly different between T_1 (50 kg urea ha-1) and T_0 (control). At the Bangladesh Agricultural University experimental farm, the application of 100 kg urea h-1 was found to be beneficial for commercial mustard green production.

Effect of irrigation on mustard

Bangladesh Agricultural Research Institute (BARI) developed a number of Brassica oilseed varieties with high yield potentials and improved management practices, the yield range being between 1.4 and 2.1 t ha^{-1} (BARI, 2018). Therefore, there is a scope to increase the yield level by using High Yielding Variety (HYV) and adopting proper management practices like spacing, weeding, irrigation, seed rate, fertilizer application etc. In Bangladesh, both rapeseed and mustard are grown on the residual soil moisture in winter season. Irrigation is a vital factor for proper growth and development of rapeseed and mustard crops in dry season. Because requires water 60 to 169 mm water throughout its life cycle (Rahman, 1989; Sarkar *et al*., 1989). In fact, *Brassica* is an irrigated crop since its yield is greatly increased by the presence of adequate soil moisture in different growth stages (Prasad and Ehsanullah, 1988). 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.

Singh *et al*. (2019) conducted field experiments for two consecutive rabi seasons in 2015-16 and 2017-18 to assess how changing irrigation levels, planting methods, and mulching affected the growth and yield metrics of yellow season (*Brassica rapa L*.). At 1.2 CPE (Cumulative pan evaporation) ratio, significantly more leaves per plant and dry matter buildup in leaves and stem were recorded than at 0.6 and 0.3 CPE ratio in both years of study. When compared to irrigation levels that remained constant, yellow sarson seed output increased dramatically, reaching a ratio of 0.9 CPE. On both years, yellow sarson planted in a raised bed yielded 12.8 and 7.4 percent more seed and had a higher number of leaves than yellow sarson planted in a flat bed. Application of rice straw mulch recorded 12.7 and 13.3 percent significantly higher seed yield than no mulch, respectively.

Alamin *et al*. (2019) conducted an experiment to evaluate the effect of sowing time and irrigation frequency on the growth and yield of mustard. The treatment consisted of three different sowing times (*viz.*, T_1 = Early sowing, T_2 = Optimum sowing, T_3 = Late sowing), and four irrigations frequency (*viz.*, I_0 = No irrigation, I_2 = 2 irrigation and I_3= 3 irrigation). There was a significant variation among the treatments in respect of major parameters studied. The tallest plant was recorded with optimum sowing time. The maximum number of leaves, number of branches plant^{-1}, and number of siliquae plant^{-1}and length of siliqua was found with optimum sowing time. The maximum yield (1.12 t ha^{-1}) of seed was exhibited from optimum sowing time. The tallest plant was produced with three irrigations. The maximum branches plant^{-1}, siliqua plant^{-1} and seed silliqua^{-1} were recorded from three irrigation. The highest (1.05 t ha^{-1}) yield of seed was obtained from three irrigation. The combinations of sowing time and irrigation had significant effects on most of the parameter. The combination of three irrigation and the optimum sowing time resulted in the maximum seed production (1.42 t ha^{-1}). The combination of three irrigation and the optimum sowing time yielded the highest stover and biological yield.

Rathore *et al.* (2019) conducted a field experiment to assess the effect of different irrigation regimes on mustard and discovered that irrigation had a significant positive effect on plant height, dry matter plant^{-1}, number of primary and secondary branches plant-1, grain yield, stover yield, and harvest index.

In a field experiment, Jat *et al.* (2017) assessed the influence of different irrigation regimes on agronomic characteristics such as plant height, dry matter plant^{-1}, and number of primary and secondary branches plant^{-1} in mustard.

Hossain *et al.* (2012) conducted an experiment to see how irrigation and seeding method affected mustard yield and yield parameters. There are two components to the experiment. I irrigation: I_1 (no irrigation), I_1 (one irrigation), and I_2 (two irrigations) ii) sowing methods, such as line sowing and broadcasting. Irrigation had a considerable impact on all yield and yield-related characteristics. The highest plant height, number of branches plant^{-1}, number of seed siliqua^{-1}, number of filled siliqua plant^{-1}, siliqua length, 1000-seed weight and stover yield were obtained from I_2 (two irrigations) and consequently it produced the highest seed yield. Sowing method also had significant influence on almost all the yield and yield contributing characters.

Kibbria (2013) conducted an experiment with no irrigation, one irrigation at pre-flowering and two irrigation (one at pre-flowering and siliquae formation) and three irrigations (one at pre-flowering, two irrigations siliquae formation stage and three irrigations seed maturation). Three irrigations applied at 20, 40 and 60 DAS produced more plant height (103.08 cm) than under no irrigation. Significant increase in dry matter was found up to three irrigations. When comparing two irrigations to no irrigation, the maximum number of primary branches per plant (7.70) was obtained. Irrigation boosted the maximum siliquae plant^{-1} (136.8) by two times compared to no irrigation (112.3). When two irrigations were used, the maximum number of seeds (22.06) siliqua^{-1} was discovered (one at pre-flowering stage and one at siliquae formation). Two irrigations resulted in the longest siliqua (5.23 cm) when compared to one irrigation or no irrigation (control). When two irrigations were used, the maximum weight of 1000 seeds (3.18 g) siliquae^{-1} was discovered. Two irrigations (before blooming and siliquae formation stage) produced the largest seed yield (1.98 t ha^{-1}), stover yield (1.98 t ha^{-1}), and biological yield (3.97), whereas control produced the lowest (no irrigation).Two irrigations yielded the highest harvest index (51.16 percent), whereas no irrigation yielded the lowest harvest index (48.72 percent).

Piri *et al*. (2011) found that applying two irrigations at 45 and 90 DAS boosted plant height considerably. With one irrigation at 45 DAS, mustard plants may produce the most branches per plant, followed by two irrigations at 45 and 90 DAS and no irrigation. Two irrigations at 45 and 90 DAS enhanced 1000 seed weight, seed yield, and stover yield substantially more than one irrigation or no irrigation. The increase in stover yield could also be related to the fact that the plant height is greater than the total number of branches.

Sultana (2007) conducted a rapeseed experiment at the Sher-e-Bangla Agriculture University field, Dhaka-1207 to see how different varieties and irrigation frequency affected growth and productivity. When compared to other treatments, including control, the maximum plant height was found at three irrigation levels (20, 35, and 50 DAS), as well as the largest plant dry matter, maximum number of branches per plant, number of siliquae per plant, and number of seeds siliqua^{-1}. The 1000 seed weight, seed yield (1827.0 kg ha^{-1}), biological yield(1422.8 kg ha^{-1}) and harvest index(34.67 %) were likewise shown to be greater at three irrigation treatments (20, 35and 50 DAS) than in the control treatment (no irrigation).

Ghanbahadur and Lanjewar (2006) found that irrigation at 0.6 CPE increased the number of siliquae plant^{-1}, pod length, number of seeds pod^{-1}, and test weight compared to irrigation at 0.4CPE, results in an increase in seed, stover, and biological yield above the 0.4CPE ratio.

Piri and Sharma (2006) found that increasing the frequency of irrigation from 0 to 2 and applying them at 30 and 60 DAS resulted in significantly better performance of mustard in terms of plant height, dry matter accumulation, secondary branches plant^{-1}, and relative growth rate when assessing the effect of different irrigation regimes in the north western plains.

Latif (2008) 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). Plant height was maximum (104.58 cm) with three irrigations compared to no irrigation (control). Maximum number of seeds per siliquae (26.20), siliquae length (7.75 cm) and number of siliquae (126.24) were found when three irrigations were applied compared to no irrigation (control).

Yadav (2007) conducted a study in arid area of Bikaner, irrigation was observed to improve growth characters and application of irrigation at three stages of crop growth *viz*., branching, flowering and pod filling recorded higher plant height, chlorophyll content, dry matter accumulation Plant^{-1}, number of primary and secondary branches plant^{-1}.

Giri (2001) 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. In case of two irrigation, siliquae number (277) was found in irrigation at flowering and siliquae formation stage followed by siliqua per plant (365) with one irrigation at flowering stage. But the difference was not significant. Raut *et al*. (1999) investigated the impact of irrigation on the dry matter production and yield of Indian mustard.

Kumaw at (2004) conducted a field study with the application of three irrigations at branching, flowering and siliqua development stages significantly increased by N, P and K concentrations in seed and stover as well as their uptake in comparison to less frequent irrigation. Similar effect of different irrigation frequency was also noticed by Ghanbahadur and Lanjewar (2006).

Combined effect of different Nitrogen doses and various irrigation levels;

Riaj *et al*. (2018) conducted a field experiment at the Agronomy Research Field of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during the period from November, 2016 to February 2017 to find out the effect of nitrogen and irrigation on the yield and yield attributes of mustard. The experiment consisted of two factors. Factor-A: nitrogen (N) doses: 4doses, N_0 = without Nitrogen, N_1=90 kg N ha^{-1}, N_2 = 120 kg N ha^{-1}, N_3 = 150kg N ha^{-1} and factor-B: irrigation doses: 3 doses, I_0= without irrigation, I_1= one irrigation at 20 DAS, I_2 = Two irrigation at 25 and 50 DAS. Data on different parameters related to seed yield and quality was recorded and statistically significant variation was found nitrogen and irrigation. In terms of nitrogen fertilizer, 120 kg N ha^{-1} produced the highest in respect of plant height (76.38 cm), number of branches per plant (9.65), number of Siliqua per plant (78.30), number of seeds per siliqua (32.96), 1000 seed weight (4.58 g), seed yield (1.42 t ha^{-1}), stover yield (2.57 t ha^{-1}), harvest index (35.38 %) and the lowest value found at control in most of the parameters. Due to the interaction effect of nitrogen and irrigation in mustard, the plant height (83.36 cm), number of branches per plant (10.53), number of Siliqua per plant (87.63), number of seeds per siliqua (37.63), 1000 seed weight (5.00 g), seed yield (1.62 t ha^{-1}), stover yield (2.63 t ha^{-1}), harvest index (37.74%) were highest in nitrogen @ 120 kg N ha^{-1} combined with three irrigations.

Non-significant interaction effect among weed control moisture regimes was reported by

Naik *et al*. (1997) and Singh and Bahan(1998). In the winter seasons of 1986/87 and 1987/88, Haryana Agricultural University, India, investigated the response of late-sown mustard (*Brassica juncea L*.) to four rates of irrigation (ratio of irrigation depth to cumulative pan evaporation, CPE = 02, 04, 06, and and nitrogen (0, 30, 60, and 90 kg/ha). Increases in water and nitrogen fertilizer application enhanced leaf water potential, stomatal conductance, light absorption, leaf area index, seed yield, and evapotranspiration, while lowering canopy temperature.

The seed production from a combination of 06 CPE and 60 kg N/ha was much higher than lower rates and it was comparable to the greatest irrigation and N treatment combinations. Regardless of treatment, the mustard crop's water consumption dropped as the soil depth increased. The maximum yield of wheat was obtained when 4 irrigations were supplemented at CRI, tillering, flowering and milk stage. But maximum weed control efficiency was obtained when 6 irrigations were applied at CRI, tillering, late jointing, flowering, milk stage and dough stage with 120 kg N (Naik *et al*., 1997).

The maximum yield of wheat was obtained when 4 irrigations were supplemented at CRI, tillering, flowering and milk stage. But maximum weed control efficiency was obtained when 6 irrigations were applied at CRI, tillering, late jointing, flowering, milk stage and dough stage with 120 kg N (Naik *et al*., 1997). In the deeper soil layers, the percentage of total moisture use was greater under less irrigated than under more frequently irrigated plots. Leaf area index showed a significant positive linear relationship with evapotranspiration and light absorption and a negative linear relationship with canopy temperature. Seed yield was linearly related to leaf area index and light absorption coefficient.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the research field of Agricultural Botany at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to study the effect of nitrogen fertilizer and various irrigation levels on growth and yield of mustard. The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher- e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Madhapur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory SRDI, Kamarhati, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix III.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix II.

3.4 Plant Material

Seeds of BARI Sarisha-14 were used as plant material for the present study.

3.5 Experimental details

3.5.1Treatments of the experiment

Factor A: Nitrogen used as urea fertilizer– Four levels

1. N_0 = Control (0 kg N ha^{-1})
2. N_1 = (90 kg N ha^{-1})
3. N_2 = (120kgNha^{-1})
4. N_3 = (150kgNha^{-1})

Factor B: Irrigation levels – (3)

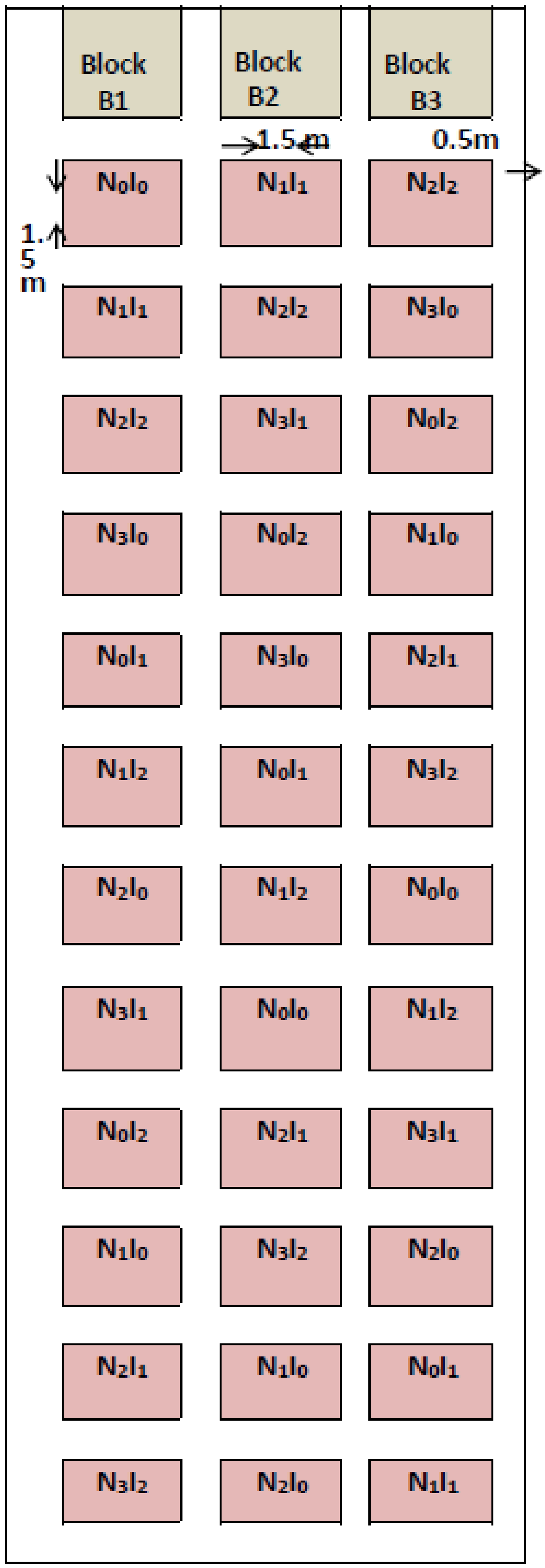
1. I_0 = Control(No irrigation)
2. I_1 = One irrigation at 25 DAS (Days After Sowing)
3. I_2 = Two irrigations at 25 and 50 DAS (Days After Sowing)

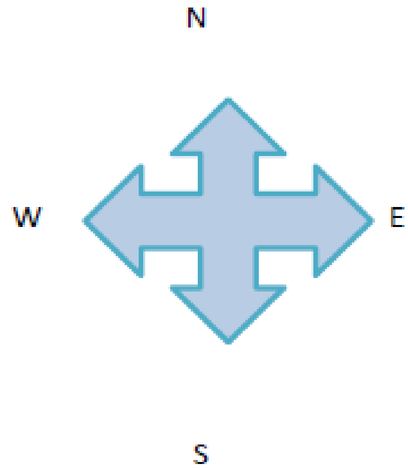
Treatment combinations – Twelve (12)

N_0I_0	N_2I_0
N_0I_1	N_2I_1
N_0I_2	N_2I_2
N_1I_0	N_3I_0
N_1I_1	N_3I_1
N_1I_2	N_3I_2

3.5.2 Experimental design and layout

The experiment was laid out in a two factorial Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of different doses of nitrogen (N) and irrigation. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot was 1.5 m × 1.5 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The layout of the experiment field is presented in figure 1;





Plot size: 1.5 m × 1.5 m

Factor A: Different nitrogen doses (4)

N_0= 0 kgNha^{-1} (control)
N_1= 90 kgNha^{-1}
N_2= 120 kgNha^{-1}
N_3= 150 kg Nha^{-1}

Factor B: Irrigation (3)

I_0= No irrigation (control)
I_1= One irrigation at 25 DAS
I_2=Two irrigation at 25 and 50 DAS

Fig. 1. Layout of the experimental plot

3.5.3 Collection of seeds

BARI sarisha-14, a high yielding variety of mustard developed by Bangladesh Agricultural Research Institute (BARI), Gazipur was used as test crop. Seeds were collected from BARI, Joydebpur, Gazipur.

3.6 Preparation of the main field

The plot selected for the experiment remained opened with a power tiller, and was exposed to the sun for a few days, after that the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing seeds. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral run off irrigation water.

3.7 Fertilizers and manure application

The P, K, S, Zn and B nutrients were applied through urea, Triple superphosphate (TSP), Muriate of potash (MoP) Gypsum, $ZnSO_4$ and Boric acid, respectively. Nitrogen was applied in the plot as per treatment where rest of the nutrients was applied according to Krishi Projukti Hat Boi, BARI, 2016. Name and doses of nutrients were as follows:

Plant nutrients	Manure and fertilizer	Doses ha^{-1}
--	Cowdung	10t
P	TSP	160kg
K	MoP	80kg
S	Gypsum	130kg
Zn	$ZnSO_4$	4kg
N	Urea	As per treatment

Whole amount of Cow dung and full amount of TSP, MoP, $ZnSO_4$ and Gypsum were applied at the time of final land preparation.

3.8 Sowing of seeds

Seeds were sown continuously @ 7 kg ha^{-1} by hand as uniform as possible in the 30 cm a part lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept about 120 per plot. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mustard.

Irrigation

Irrigation was done as per treatments. Three irrigation treatments including control were used under the present study. Maximum two irrigations were applied according to treatments followed by one irrigation.

Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field. The final weeding and thinning were done after 24 days of sowing. Care was taken to maintain constant plant population per plot**.**

Plant protection

The crop was infested with aphids (*Lipa phiserysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2 ml L^{-1} water. The insecticide was sprayed twice, the first on 25 November 2019 and the last on 10 January, 2020. The crop was kept under constant observations from sowing to harvesting.

3.10 Harvesting

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sundried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds and stover were put in desiccators for chemical analysis.

3.11 Data collection

Ten plants were selected randomly from each unit plot for recording data on crop parameters and yield. The following parameters were recorded during harvest.

Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

Yield contributing parameters

4. Number of Siliqua plant^{-1}
5. Length of Siliqua (cm)
6. Number of Seeds siliqua^{-1}
7. Weight of 1000 Seeds (g)

Yield parameters

8. Grain yield (kg ha^{-1})
9. Stover yield (kg ha^{-1})
10. Harvest index (%)

3.12 Procedure of recording data

Plant height

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of 10 plants of each plot. The height was measured from the ground level to the tip of the leaves and average was recorded.

Number of leaves $plant^{-1}$

Number of leaves were calculated from randomly selected 10 sample plants and the mean data was recorded.

Number of siliquae $plant^{-1}$

Number of total siliquae of ten plants from each unit plot was noted and the mean number was expressed as per plant basis.

Number of branches $plant^{-1}$

The total number of branches was counted from randomly selected 10 plants of each plot. The average branches number was calculated which is termed as number of branches $plant^{-1}$.

Number of seeds $siliqua^{-1}$

Number of total seeds of ten randomly selected samples of siliquae from each plot was noted and the mean number was expressed as per siliqua basis.

Length of siliqua

The length of 10 siliqua from each sample were collected randomly and the mean length was expressed as per siliqua basis (cm).

Weight of 1000 seeds

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance and the mean weight were expressed in gram.

Seed yield

Dry weight of seed (at 10% moisture level) from harvested area of each plot was taken and then converted to ton per hectare.

Stover yield

Dry weight of straw (sun dried) from harvested area of each plot was taken and then converted to ton per hectare.

Harvest index

The harvest index was calculated on the ratio of grain yield to biological yield and expressed into percentage. It was calculated by using the following formula:

$$\text{Harvest Index} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

Where, Biological yield = Stover yield + Grain yield

3.13 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance differences among the treatment means were estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984)

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect nitrogen fertilizer and irrigation frequency on growth and yield of mustard (BARI Sarisha-14). The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following headings:

4.1 Growth parameters

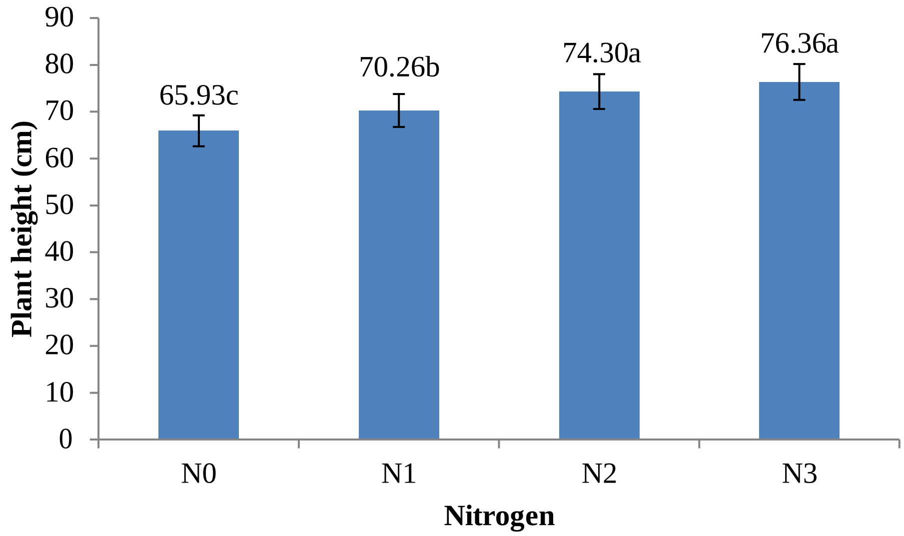
4.1.1 Plant height (cm)

Effect of nitrogen doses

Different nitrogen treatment showed a statistically significant variation for plant height of mustard (Figure 2). Results showed that the treatment N_3 (150 kg N ha^{-1}) gave the highest plant height (76.36 cm) significantly different from other treatment followed by treatment N_2 (120 kg N ha^{-1}), whereas the lowest plant height (65.93 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). This finding was agreed with the result of Riaj *et al*. (2018) and Awal *et al*. (2020). Results showed that plant height was increased with the increasing of nitrogen levels. Riaj *et al*. (2018) achieved the highest plant height of mustard at 120 kg N/ha^{-1} compared to control and 0 kg N/ha^{-1}.

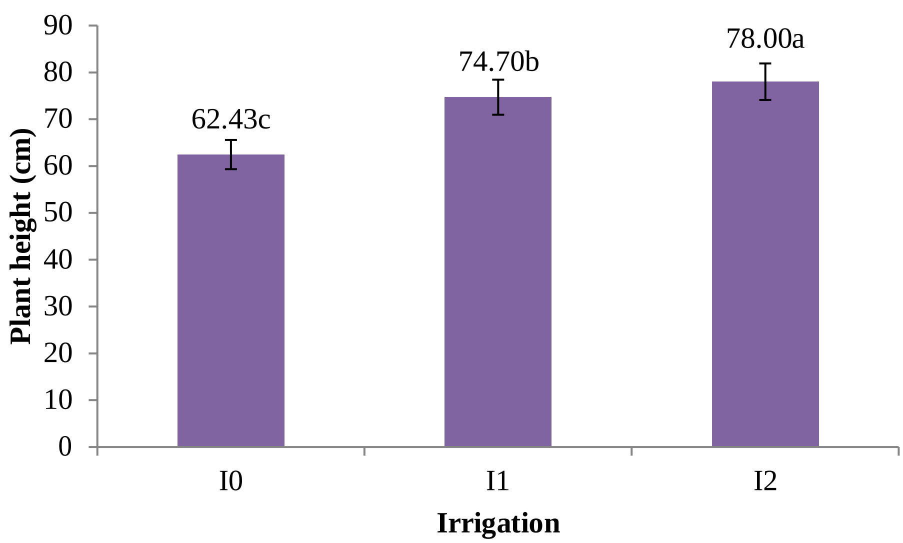
Effect of Irrigation levels

Different levels of irrigation exhibited statistically significant differences for plant height of mustard (Figure 3). It was found that I_2 (Two irrigations at 25 and 50 DAS) treatment showed highest plant height (78.00 cm) which was significantly different from other treatments followed by treatment I_1 (One irrigation at 25 DAS) whereas the lowest plant height (62.43 cm) was recorded from the control treatment I_0 (No irrigation).



N_0= Control(0 kg N ha^{-1}), N_1=90 kg N ha^{-1}, N_2=120 kg N ha^{-1}, N_3=150 kg N ha^{-1}

Figure 2. Plant height of mustard as influenced by different nitrogen doses



I_0= Control (No irrigation), I_1=One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 3. Plant height of mustard as influenced by different irrigation levels

Combined effect of nitrogen doses and Irrigation

Significant interaction effect was also recorded between different nitrogen doses and irrigation levels in consideration of plant height in mustard under the present experiment (Table 1). Results revealed that the highest plant height (83.36 cm) was recorded from the treatment combinationN_3I_2 which was statistically similar with the treatment combination N_2I_2. Whereas the lowest plant height (58.67 cm) was recorded from the treatment combination of N_0I_0.

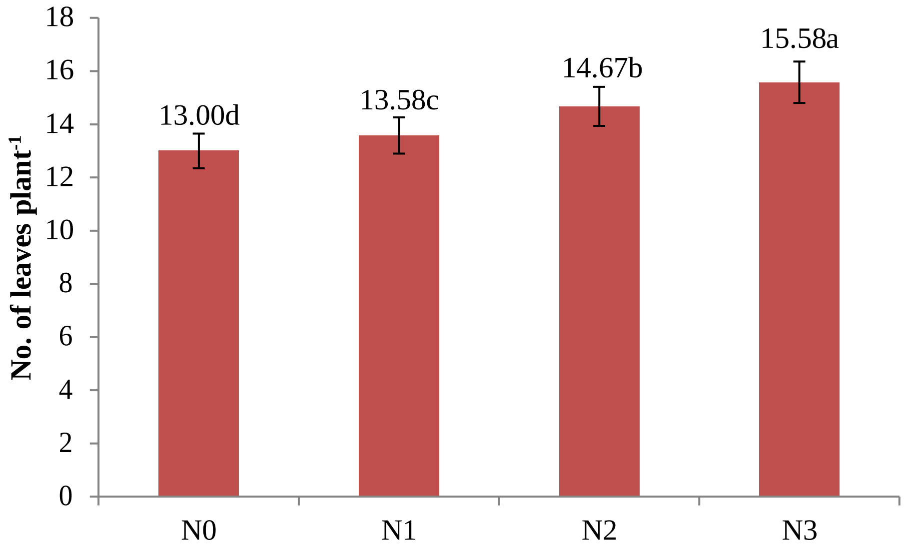
4.1.2 Numberofleavesplant^{-1}

Effect of nitrogen doses

A statistically significant variation for number of leaves plant^{-1} of mustard was recorded for the effect of Nitrogen (Figure 4). The highest number of leaves plant^{-1} (15.58) was recorded from the treatment N_3 (150 kg N ha^{-1}) which was statistically identical with N_2 (120 kg N ha^{-1}). On the other hand, the lowest number of leaves plant^{-1} (13.00) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_1 (90 kg N ha^{-1}). Supported result was also observed by Awal *et al*. (2020)

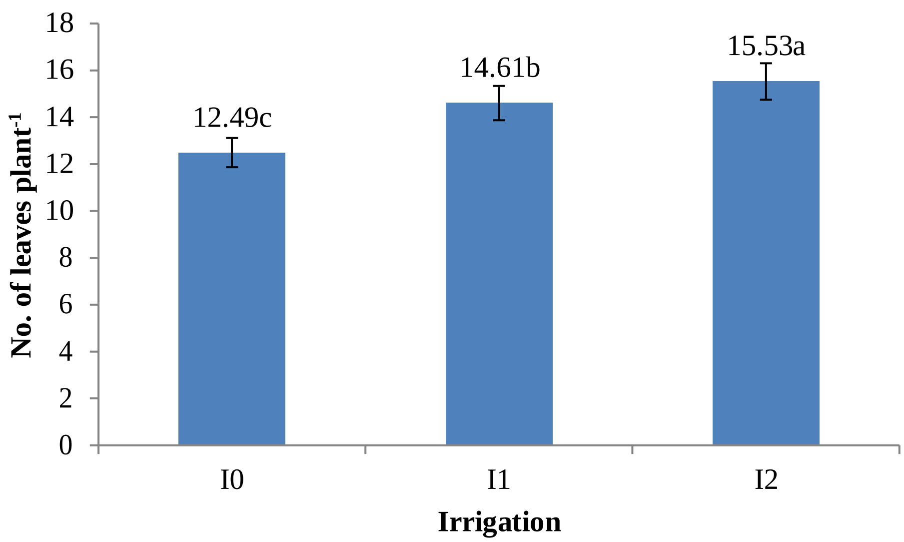
Effect of Irrigation levels

Number of leaves plant^{-1} for different levels of irrigation showed statistically significant variation (Figure 5). The highest number of leavesplant^{-1} (15.53) was recorded from I_2 (Two irrigations at 25 and 50DAS) which was significantly different from other treatments followed by I_1 (One irrigation at25 DAS) whereas the lowest number of leaves plant^{-1} (12.49) was recorded from the control treatment I_0 (No irrigation). Similar result was also observed by Singh *et al*. (2019) and Alamin *et al*. (2019) who observed increased number of leaves plant^{-1} with increased the increase of irrigation levels.



N_0=Control(0 kg N ha^{-1}), N_1=90 kg N ha^{-1}, N_2=120 kg N ha^{-1}, N_3=150 kg N ha^{-1}

Figure 4. Number of leaves $plant^{-1}$ of mustard as influenced by different doses of nitrogen



I_0=Control (No irrigation), I_1=One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 5. Number of leaves $plant^{-1}$ of mustard as influenced by different irrigation levels.

Combined effect of nitrogen doses and Irrigation

Combined effect of different nitrogen doses and irrigation levels showed a significant difference for the number of leaves plant^{-1} under the present experiment (Table 1). Results indicated the highest number of leaves plant^{-1} (17.58) was recorded from the treatment combination of N_3I_2 which was statistically similar with the treatment combination of N_3I_1 and N_2I_2. The lowest number of leaves plant^{-1} (11.67) was recorded from the treatment combination of N_0I_0 which was statistically similar with the treatment combination of N_1I_0 and N_2I_0.

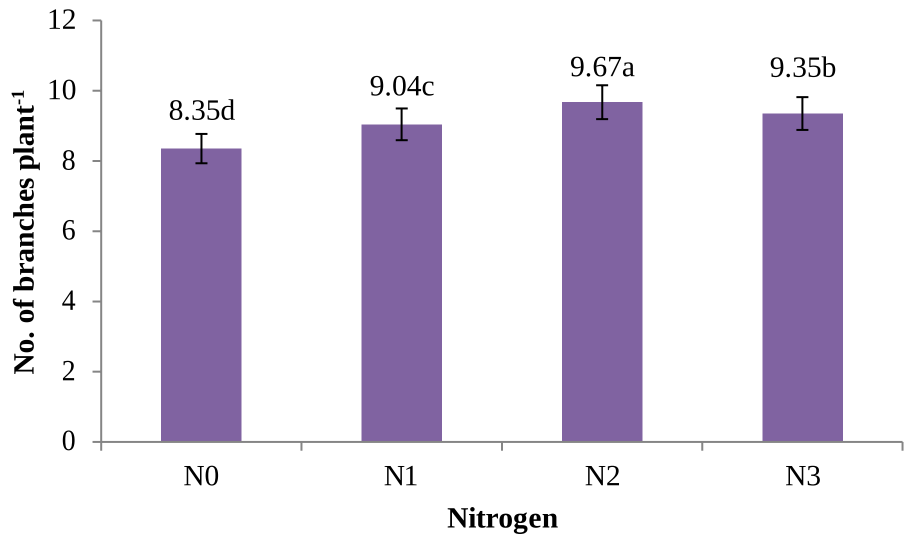
4.1.3 Number of branches plant^{-1}

Effect of nitrogen doses

Remarkable variation was identified on number of branches plant^{-1} due to the effect of different levels of nitrogen application (Figure 6). It was observed that the treatment N_2 (120 kg N ha^{-1}) showed highest number of branches plant^{-1} (9.67) which was significantly different from other treatments followed by N_1 (90 kg N ha^{-1}) whereas the lowest number of branches plant^{-1} (8.35) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically same with N_3 (150 kg N ha^{-1}). Riaj *et al*. (2019) also found similar result with the present study who observed higher number of branches plant^{-1} with higher N application.

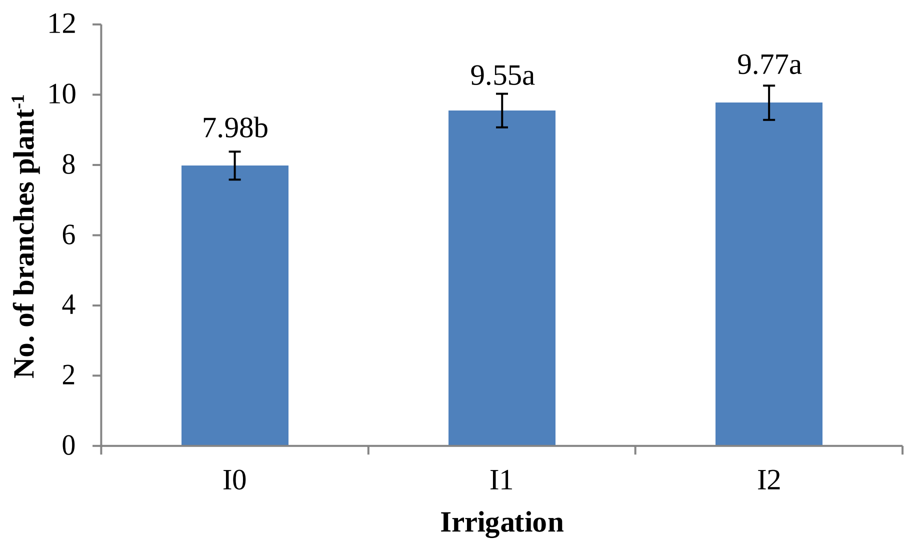
Effect of Irrigation levels

Variation on number of branches plant^{-1} was found influenced by different irrigation levels (Figure 7). Results showed that the treatment I_2 (Two irrigations at 25 and 50 DAS) gave the highest number of branches plant^{-1} (9.77) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of branches plant^{-1} (7.98) was recorded from the control treatment I_0 (No irrigation). Singh *et al.* (2002) found that growth and development of *brassica* were adversely affected under limited irrigation condition. Rana *et al*. (2020), Singh *et al*. (2019) and Alamin *et al*. (2019) also found similar result with the present study. Rathore *et al.* (2019) found significant positive effect of irrigation on number of primary and secondary branches plant^{-1} of mustard.



N_0 = Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2= 120 kg N ha^{-1}, N_3= 150 kg N ha^{-1}

Figure 6. Number of branches plant^{-1} of mustard as influenced by different nitrogen doses



I_0=Control (No irrigation), I_1= One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 7. Number of branches plant^{-1} of mustard as influenced by different irrigation levels.

Combined effect of nitrogen doses and Irrigation

The recorded data on number of branches plant^{-1} was significantly influence by the combined effect of different nitrogen doses and irrigation levels (Table 1) . Results exhibited that the highest number of branches plant^{-1} (10.53) was recorded from the treatment combination of N_2I_2 which was statistically similar with the treatment combination of N_2I_1. The lowest number of branches plant^{-1} (7.11) was recorded from the treatment combination of N_0I_0 which was statistically similar with the treatment combination of N_1I_0.

Table 1. Growth parameters of mustard as influenced by different doses of nitrogen and irrigation levels

Treatment combinations	**Growth parameters**		
	Plant height (cm)	**Number of leaves plant^{-1}**	**Number of branches plant^{-1}**
N_0I_0	58.67 j	11.67 h	7.11 h
N_0I_1	68.33 fg	13.48 def	8.81 ef
N_0I_2	70.78 ef	13.87 de	9.13 de
N_1I_0	60.92 ij	12.40 gh	8.00 g
N_1I_1	73.40 de	14.00 cde	9.50 cd
N_1I_2	76.46 cd	14.33 cd	9.62 cd
N_2I_0	63.86 hi	12.72 fg	8.33 fg
N_2I_1	77.62 bc	14.95 c	10.15 ab
N_2I_2	81.43 ab	16.33 b	10.53 a
N_3I_0	66.28 gh	13.15 efg	8.50 fg
N_3I_1	79.45 bc	16.00 b	9.75 bc
N_3I_2	83.36 a	17.58 a	9.81 bc
$LSD_{0.05}$	**3.82**	**0.96**	**0.51**
CV%	**6.77**	**11.22**	**11.02**

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

N_0= Control (0 kg N ha^{-1}), N_1= 90 kg N ha^{-1}, N_2= 120 kg N ha^{-1} and N_3= 150 kg N ha^{-1}

I_0= Control (No irrigation), I_1= One irrigation at 25 DAS and I_2= Two irrigation at 25 and 50 DAS

4.2 Yield contributing parameters

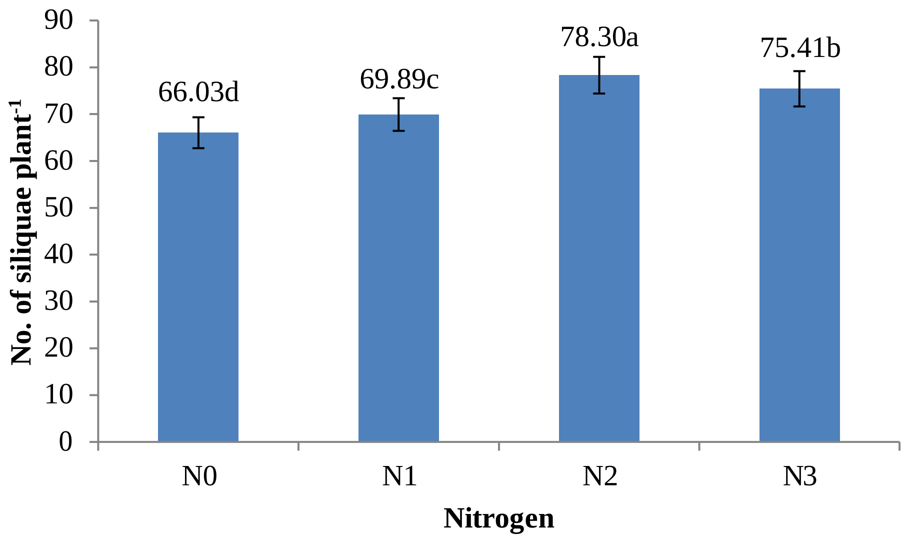
4.2.1 Number of Siliqua plant^{-1}

Effect of nitrogen doses

Statistically significant variation for number of siliqua plant^{-1} of mustard was recorded for due to the effect of different nitrogen doses (Figure 8). The treatmentN_2 (120 kg N ha^{-1}) gave the highest number of siliqua plant^{-1} (78.30) which was significantly different from other treatments followed by N_1 (90 kg N ha^{-1}) and N_3 (150 kg N ha^{-1}) whereas the lowest number of siliqua plant^{-1} (66.03) was recorded from the control treatment N_0 (0 kg N ha^{-1}). The result obtained from the present study on number of siliqua plant^{-1} was similar with the findings of Masum *et al*. (2020), Yadav *et al*. (2017) and Riaj *et al*. (2018).

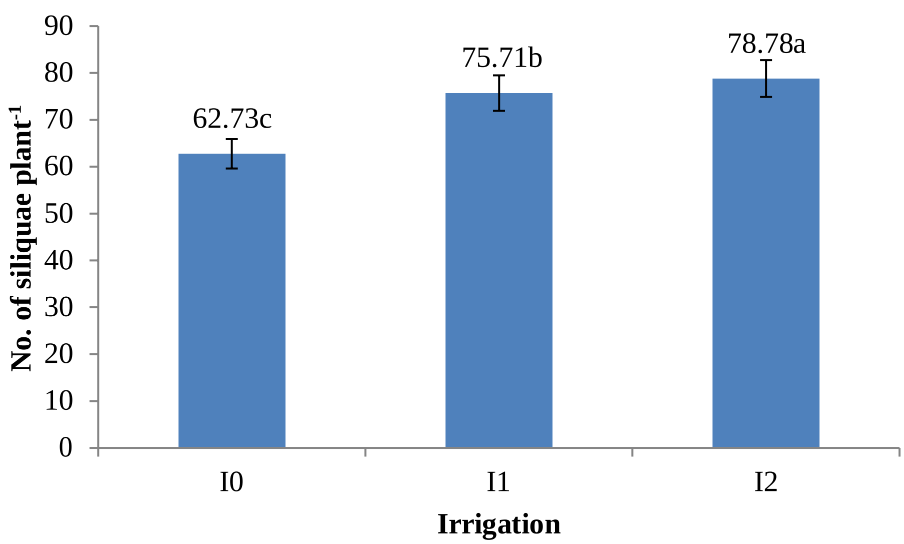
Effect of Irrigation levels

Number of siliqua plant^{-1} for different levels of irrigation also showed statistically significant variation (Figure 9). The highest number of siliquaplant^{-1} (78.78) was recorded from I_2 (Two irrigations at 25 and 50DAS) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of siliqua plant^{-1} (62.73) was recorded from the control treatment I_0 (No irrigation). The results obtained from the study were supported by Latif (2008), Sultana (2007) and Kibbria (2014) who concluded that number of siliquae plant^{-1} was significantly increased higher irrigation frequencies. Supported result was also observed by Alamin *et al*. (2019) and Roy *et al*. (2017).



N_0 = Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2 = 120 kg N ha^{-1}, N_3 = 150 kg N ha^{1}

Figure 8. Number of siliqua plant^{-1} of mustard as influenced by different nitrogen doses



I_0= Control (No irrigation), I_1= One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 9. Number of siliqua plant^{-1} of mustard as influenced by different irrigation levels.

Combined effect of nitrogen doses and Irrigation

Combined effect of different nitrogen doses and irrigation levels showed a significant difference for number of siliqua plant^{-1} under the present study (Table-2). Results indicated that the treatment combination of N_2I_2 gave the highest number of siliqua plant^{-1} (87.63) which was statistically same with the treatment combination of N_2I_1. The lowest number of siliqua plant^{-1} (58.67) was recorded from the treatment combination of N_0I_0 which was statistically identical with the treatment combination of N_1I_0.

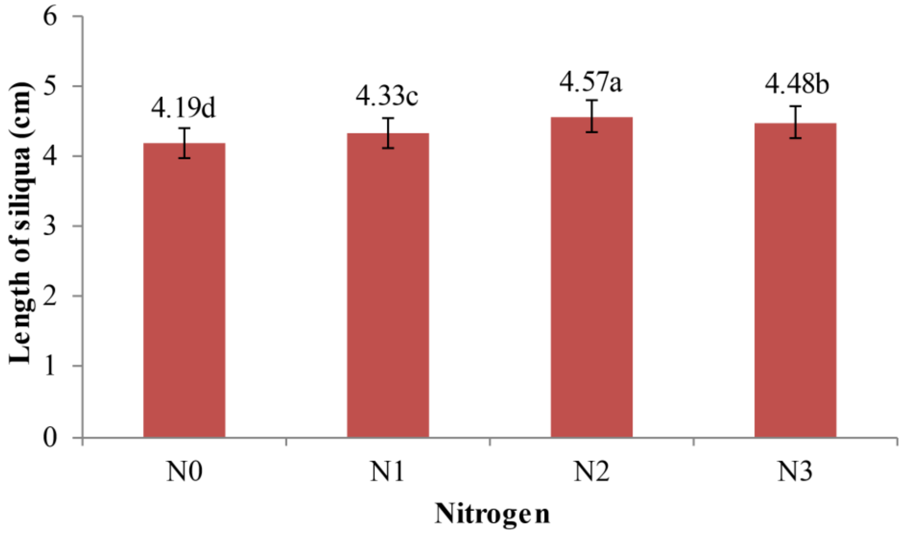
4.2.2 Length of siliqua (cm)

Effect of nitrogen doses

Length of siliqua was varied significantly due to different doses of nitrogen application (Figure 10). It was observed that the highest length of siliqua (4.57 cm) was recorded from the treatment N_2 (120 kg N ha^{-1}) followed by N_1 (90 kg N ha^{-1}) and N_3 (150 kg N ha^{-1}) whereas the lowest length of siliqua (4.19 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which supported by Yadav *et.al*. (2016) and Hossain *et.al*. (2012) ,they found varied siliqua length with N application compared to control.

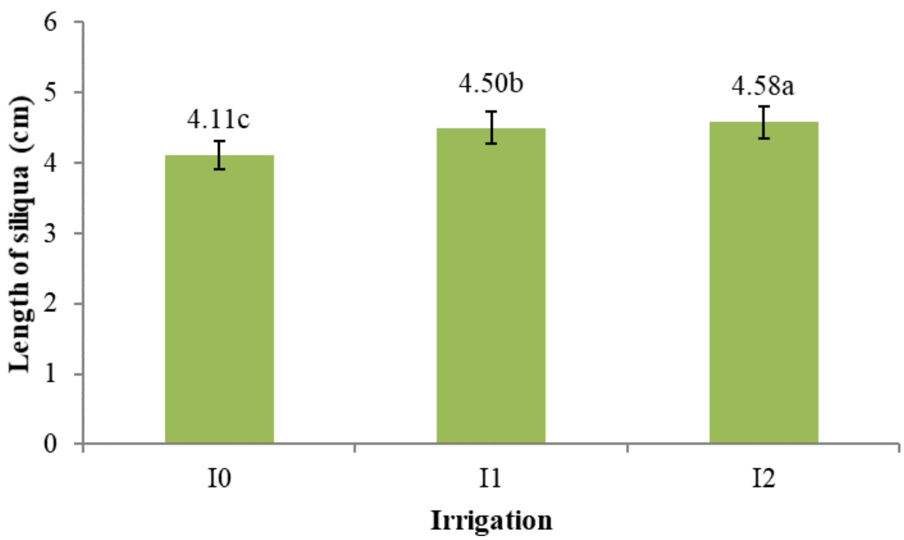
Effect of Irrigation levels

Different irrigation levels had significant influence on length of siliqua (Figure. 11). The highest length of siliqua (4.58 cm) was recorded from I_2 (Two irrigations at 25 and 50 DAS) which was statistically same with I_1 (One irrigation at 25 DAS) whereas the lowest length of siliqua (4.11 cm) was recorded from the control treatment I_0 (No irrigation). Kibbria (2013) and Latif (2006) concluded that length of siliqua was significantly increased upto three irrigations at pre-flowering, siliqua formation stage and seed maturation stage. Similar result was also observed by Alamin *et al*. (2019), Roy *et al*. (2017) and Hossain *et al*. (2013).



N_0= Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2 = 120 kg N ha^{-1}, N_3 = 150 kg N ha^{-1}

Figure 10. Length of siliqua $plant^{-1}$ of mustard as influenced by different doses of nitrogen



I_0= Control (No irrigation), I_1=One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 11. Length of siliqua $plant^{-1}$ of mustard as influenced by different irrigation levels

Combined effect of nitrogen doses and Irrigation

Length of siliqua was significantly influenced by combined effect of different nitrogen doses and irrigation levels (Table 2). The highest length of siliqua (4.81 cm) was recorded from the treatment combination of N_2I_2 which was statistically similar with the treatment combination of N_2I_1 and N_1I_1. The lowest length of siliqua (3.92 cm) was recorded from the treatment combination of N_0I_0 which was statistically identical with the treatment combination of N_1I_0.

4.2.3 Number of seeds siliqua^{-1}

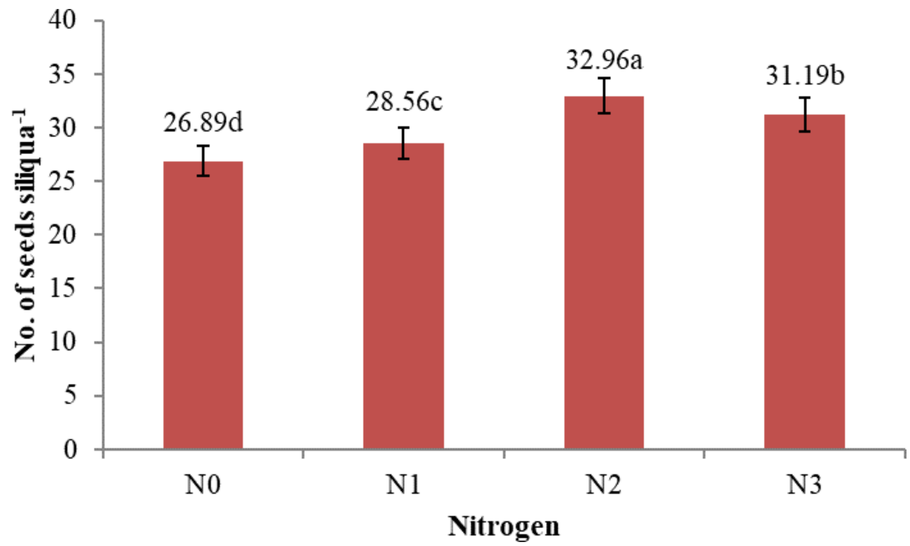
Effect of nitrogen doses

Remarkable variation was identified on number of seeds siliqua^{-1} due to the effect of different nitrogen doses (Figure. 12). The highest number of seeds siliqua^{-1} (32.96) was recorded from the treatment N_2 (120kg N ha^{-1}) which was significantly different from other treatments followed by N_1 (90 kg N ha^{-1}) and N_3 (150 kg N ha^{-1}) whereas the lowest number of seeds siliqua^{-1} (26.89) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Similar result was also observed by Masum *et al*. (2020), Yadav *et al.* (2017) and Riaj *et al*. (2018) which supported the present study.

Effect of Irrigation levels

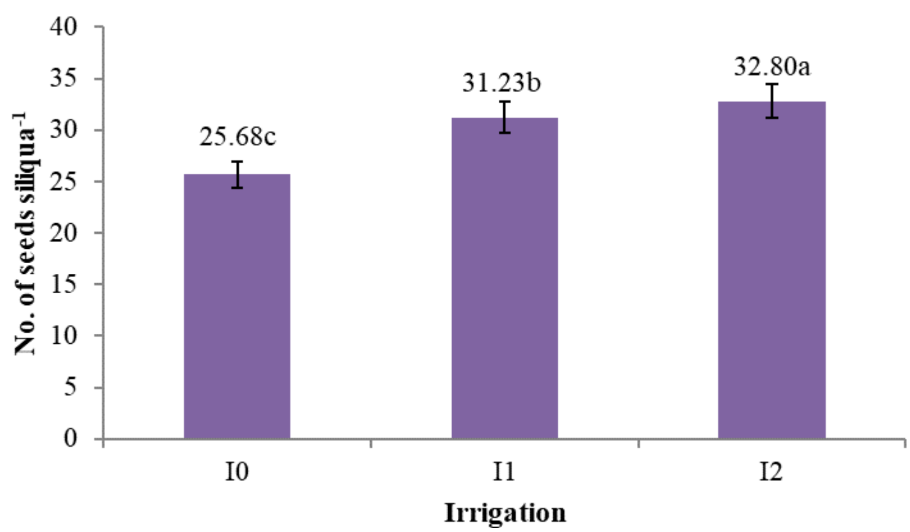
The recorded data on number of seeds siliqua^{-1} was significantly influence by different irrigation levels (Figure 13). The treatment I_2 (Two irrigations at 25 and 50 DAS) gave the highest number of seeds siliqua^{-1} (32.80) which was statistically identical with I_1 (One irrigation at 25 DAS) whereas the lowest number of seeds siliqua^{-1} (25.68) was recorded from the control treatment I_0 (No irrigation). 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 irrigations at pre-flowering, siliquae formation stage and seed maturation stage. 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. Similar result was also observed by Alamin *et al*. (2019), Roy *et al*. (2017) and

Parmar *et.al.* (2016) which supported the present study.



N_0= Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2 = 120 kg N ha^{-1}, N_3 = 150 kg N ha^{-1}

Figure 12. Number of seed $siliqua^{-1}$ of mustard as influenced by different doses of nitrogen.



I_0= Control (No irrigation), I_1= One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure13. Number of seed $siliqua^{-1}$ of mustard as influenced by different irrigation levels.

Combined effect of nitrogen doses and Irrigation

Variation on number of seeds siliqua^{-1} was found as significant as influenced by combined effect of different nitrogen doses and irrigation levels (Table 2). The highest number of seeds siliqua^{-1} (37.63) was recorded from the treatment combination of N_2I_2 which was statistically similar with the treatment combination of N_1I_1 and N_2I_1. The lowest number of seeds siliqua^{-1} (24.50) was recorded from the treatment combination N_0I_0 which was statistically similar with the treatment combination of N_1I_0 and N_3I_1.

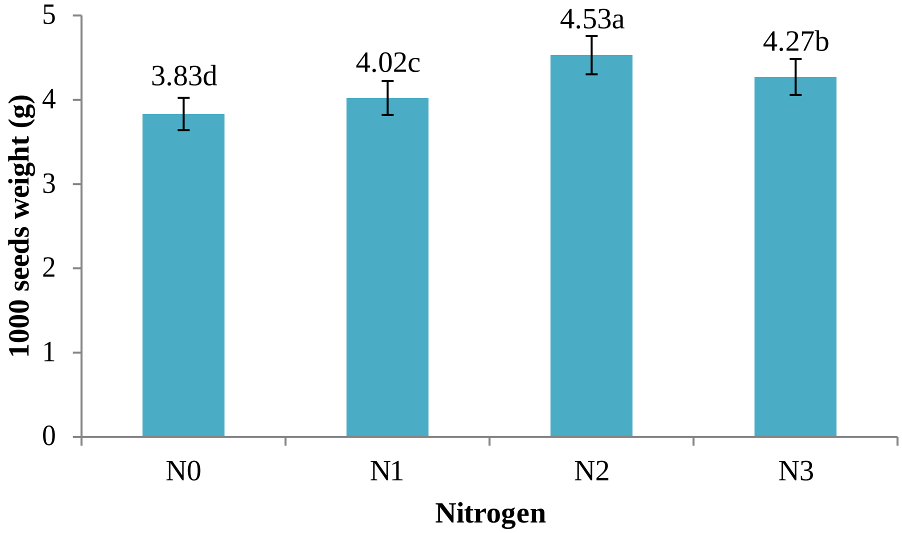
4.2.4 Weight of 1000 seeds (g)

Effect of nitrogen doses

Different doses of nitrogen showed statistically significant differences for weight of 1000 seeds of mustard in the present study (Figure 14). The highest 1000 seeds weight (4.53 a) was recorded from the treatment N_2 (120 kg N ha^{-1}) followed by treatment N_1 (90 kg N ha^{-1}) and treatment N_3 (150 kg N ha^{-1}) whereas the lowest 1000 seed weight (3.83 g) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Supported result was also observed by Masum *et al*. (2020), Riaj *et al*. (2018), Hossain *et al*. (2012) and Kaisher *et al.* (2010) who found higher 1000 seed weight with various levels of N application compared to control.

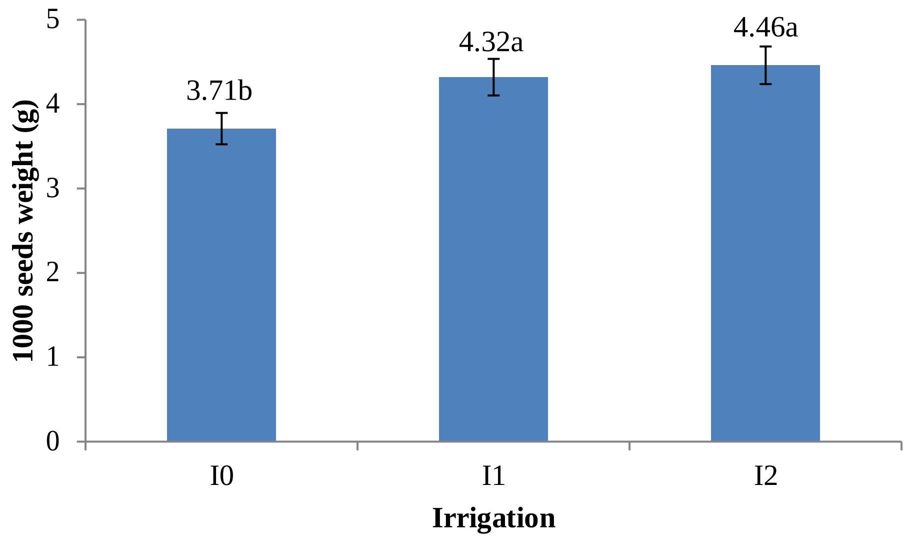
Effect of Irrigation levels

Different irrigation levels exhibited statistically significant variation for weight of 1000 seed of mustard (Figure 15). The highest weight of 1000 seeds (4.46 g) was recorded from treatment I_2 (Two irrigations at 25 and 50 DAS) which was statistically identical with treatment I_1 (One irrigation at 25 DAS) whereas the lowest weight of 1000seeds (3.71 g) was recorded from the control treatment I_0 (No irrigation). The results obtained in the study were supported by Parmar *et al.* (2016), Hossain *et al*. (2014), Kibbria (2013), Sultana (2007) and Latif (2006) who reported that increasing the frequency of irrigation increased 1000 seed weight. Hossain *et al*. (2013) found a significant increase of 1000-seed weight with two irrigations; one at pre-flowering stage and another at fruiting stage.



N_0= Control (0 kg N ha^{-1}), N_1=90 kg N ha^{-1}, N_2=1.0 kg N ha^{-1}, N_3=1.5 kg N ha^{-1}

Figure 14. 1000 seed weight of mustard as influenced by different nitrogen doses.



I_0=Control (No irrigation), I_1=One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 15. 1000 seed weight of mustard influenced by different levels of irrigation.

Combined effect of nitrogen doses and Irrigation

Combined effect of different nitrogen doses and irrigation levels showed a significant variation for the weight of 1000 seed of mustard under the present experiment (Table-2). The highest weight of 1000 seed (5.00 g) was recorded from the treatment combination N_2I_2 which was significantly different from other treatment combinations followed by N_2I_1. The lowest weight of 1000 seed (3.58 g) was recorded from the treatment combination N_0I_0 which was statistically identical with the treatment combination of N_1I_0, N_2I_0 and N_3I_0.

Table 2. Yield contributing parameters of mustard as influenced by different doses of nitrogen and irrigation

Treatment combinations	**Yield contributing parameters**			
	Number of siliquae plant^{-1}	**Length of siliqua (cm)**	**Number of seeds siliqua^{-1}**	**1000 seeds weight (g)**
N_0I_0	58.67 i	3.92 j	24.50 g	3.58 i
N_0I_1	69.00 ef	4.31 fg	27.47 ef	3.92 fgh
N_0I_2	70.42 ef	4.36 efg	28.70 e	4.00 efg
N_1I_0	60.92 hi	4.11 i	25.67 fg	3.67 hi
N_1I_1	72.33 de	4.41 ef	29.33 de	4.15 def
N_1I_2	76.42 cd	4.48 de	30.67 d	4.24 de
N_2I_0	63.78 gh	4.17 hi	26.00 fg	3.75 ghi
N_2I_1	83.50 ab	4.74 ab	35.25 b	4.83 ab
N_2I_2	87.63 a	4.81 a	37.63 a	5.00 a
N_3I_0	67.55 fg	4.24 gh	26.53 f	3.83 ghi
N_3I_1	78.00 c	4.55 cd	32.85 c	4.39 cd
N_3I_2	80.67 bc	4.67 bc	34.20 bc	4.59 bc
$LSD_{0.05}$	**4.74**	**0.12**	**1.92**	**0.28**
CV%	**9.54**	**8.04**	**10.32**	**10.79**

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

N_0= Control (0 kg N ha^{-1}), N_1= 90 kg N ha^{-1}, N_2= 120 kg N ha^{-1} and N_3= 150 kg N ha^{-1}

I_0= Control (No irrigation), I_1= One irrigation at 25 DAS and I_2= Two irrigations at 25 and 50 DAS

4.3 Yield parameters

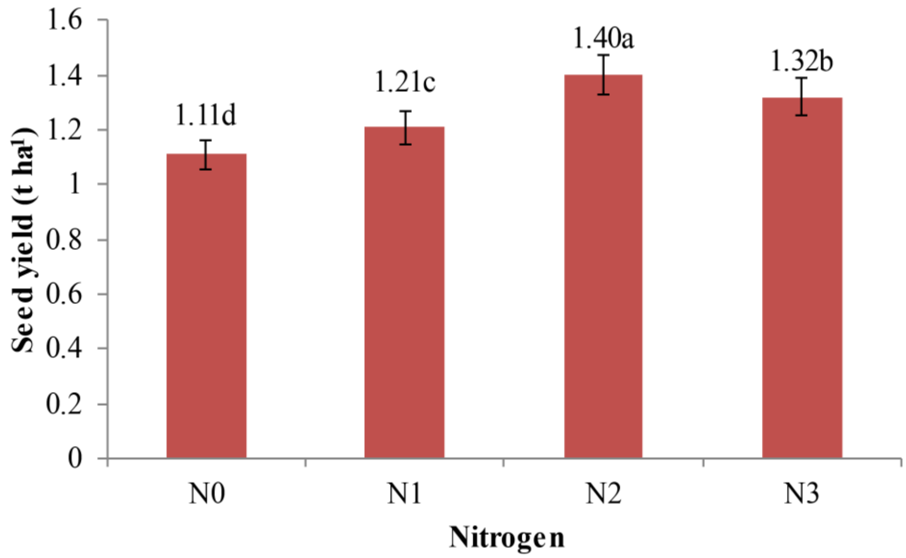
4.3.1 Seed yield (kg ha^{-1})

Effect of nitrogen doses

Statistically significant variation for seed yield of mustard was recorded for the effect of different nitrogen doses (Figure 16). The highest seed yield (1.40 t ha^{-1}) was recorded from the treatment N_2 (120 kg N ha^{-1}) followed by treatment N_1 (90 kg N ha^{-1}) and treatment N_3 (150 kg N ha^{-1}), whereas the lowest seed yield (1.11 t ha^{-1}) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Direct effects of different nitrogen doses are reflected by the close relationship between nitrogen supply and pollen producing capacity of anthers as well as the viability of the pollen grains (Agarwala *et al*., 1981).

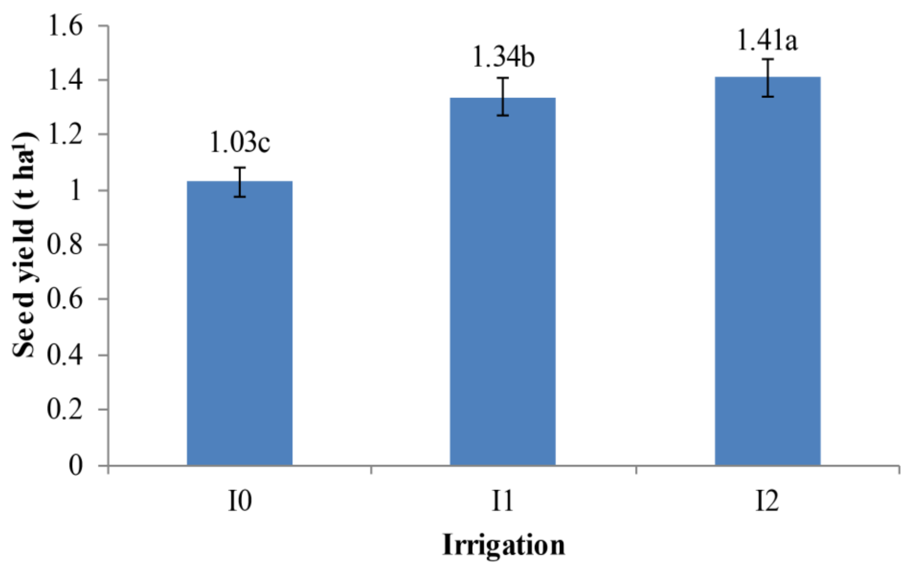
Effect of Irrigation levels

Seed yield for different levels of irrigation showed statistically significant variation on mustard (Figure 17). The highest seed yield (1.41 t ha^{-1}) was recorded from treatment I_3 (Two irrigations at 25 and 50 DAS) which was significantly different from other treatments followed by treatment I_1 (One irrigation at 25 DAS) whereas the lowest seed yield (1.03 t ha^{-1}) was recorded from the control treatment I_0 (No irrigation). Alamin *et al*. (2019) and Shivran *et al*. (2018) observed that seed yield was increased with increasing the frequency of irrigation. Rathore *et al.* (2019) found significant positive effect of irrigation on seed yield of mustard. Roy *et al*. (2017) reported that highest seed yield was produced by two irrigations. The lowest yield was produced by no irrigation and this was statistically inferior to one irrigation.



N_0 = Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2 = 1.0 kg N ha^{-1}, N_3 = 1.5 kg N ha^{-1}

Figure 16. Seed yield of mustard as influenced by different nitrogen doses.



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 17. Seed yield of mustard influenced by different levels of irrigation.

Combined effect of different nitrogen doses and Irrigation levels

Combined effect between different nitrogen doses and irrigation levels showed a significant difference for the seed yield in the present study (Table 3). The highest seed yield (1.61 t ha^{-1}) was recorded from the treatment combination N_2I_2 which was significantly different from other treatment combinations followed by N_2I_1. The lowest seed yield (0.96 t ha^{-1}) was recorded from the treatment combination N_0I_0 which was close to the treatment combinationN_1I_0.

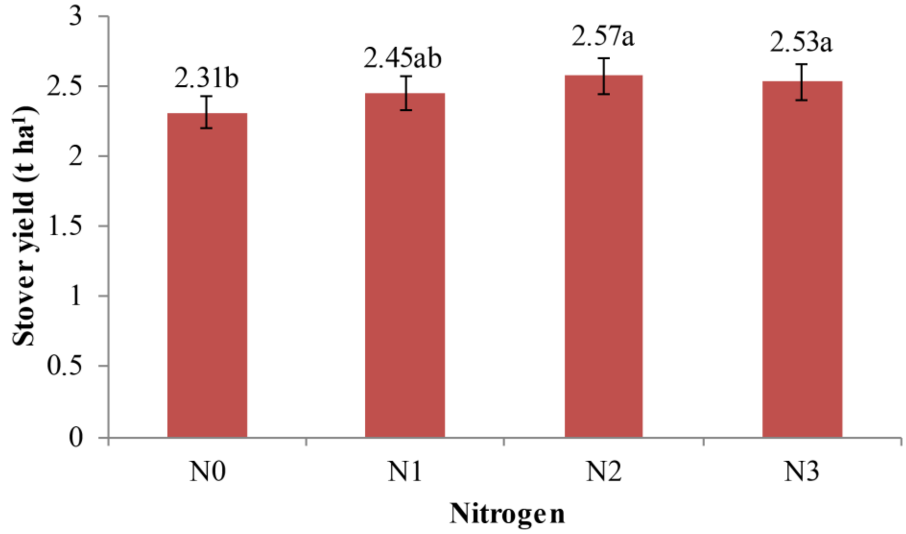
4.3.2 Stover yield (kg ha^{-1})

Effect of nitrogen doses

Statistically significant variation for stover yield of mustard was recorded due to the effect of different nitrogen doses (Figure 18). The highest stover yield (2.57 t ha^{-1}) was recorded from the treatment N_2 (120 kg N ha^{-1}) followed by treatment N_3 (150 t N ha^{-1}), whereas the lowest stover yield (2.31 t ha^{-1}) was recorded from the control treatment N_0 (0 kg N ha^{-1}). The results obtained from the study were supported by Masum *et al*. (2020), Yadav *et al*. (2016) and Riaj *et al*. (2018). Malewar *et al*., (2003) reported that with increasing levels of nitrogen, stover yield increased from 9.47 to 14.41 percent in mustard.

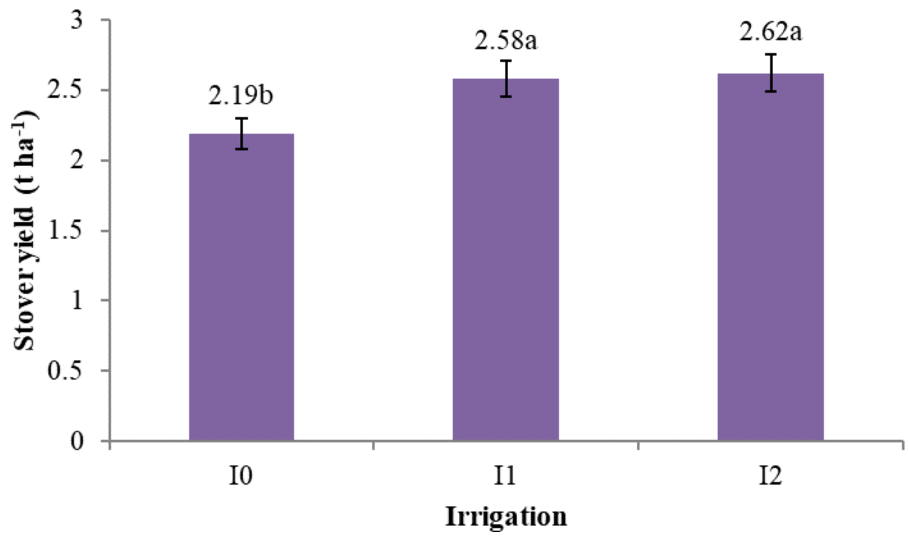
Effect of Irrigation levels

Stover yield for different levels of irrigation also showed statistically significant variation (Figure 19). The highest stover yield (2.62 t ha^{-1}) was recorded from treatment I_2 (Two irrigations at 25 and 50 DAS) followed by treatment I_1 (One irrigation at 25 DAS), whereas the lowest stover yield (2.19 t ha^{-1}) was recorded from the control treatment I_0 (No irrigation). Similar result was also observed by Alamin *et al*. (2019), Rathore *et al.* (2019), Hossain *et al*. (2013), Kibbria (2015) and Piri *et al.* (2011).



N_0 = Control (0 kg N ha^{-1}), N_1 = 90 kg N ha^{-1}, N_2 = 1.0 kg N ha^{-1}, N_3 = 1.5 kg N ha^{-1}

Figure 18. Stover yield of mustard as influenced by different doses of nitrogen



I_0 = Control (No irrigation), I_1 = One irrigation at 25 DAS, I_2 = Two irrigations at 25 and 50 DAS

Figure 19. Stover yield of mustard influenced by different irrigation levels

Combined effect of different nitrogen doses and Irrigation levels

Combined effect of different nitrogen doses and irrigation levels showed a significant difference for stover yield under the present study (Table 3). The highest stover yield (2.73 t ha^{-1}) was recorded from the treatment combination N_2I_2, whereas the lowest stover yield (2.09 t ha^{-1}) was recorded from the treatment combination of N_0I_0.

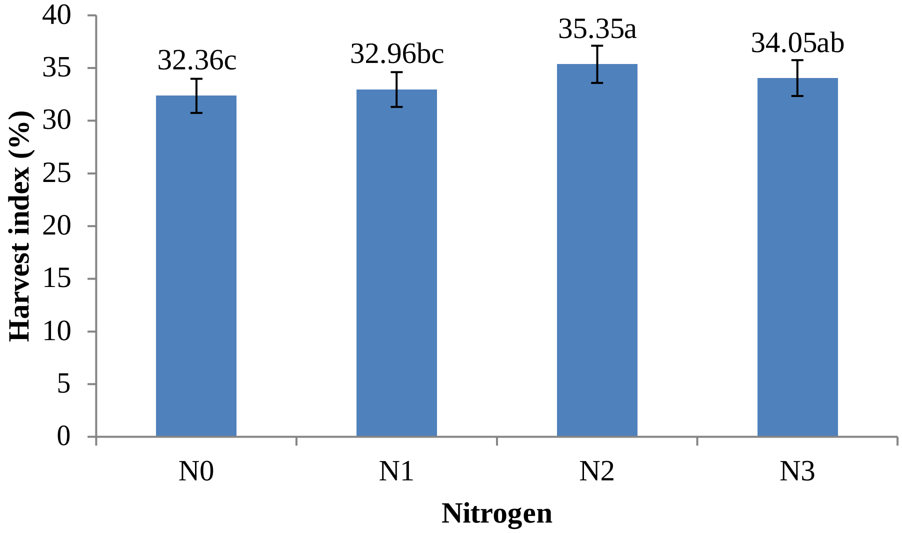
4.3.3 Harvest index (%)

Effect of nitrogen doses

Remarkable variation was identified on harvest index due to the effect of different nitrogen doses (Figure 20). The highest harvest index (35.35%) was recorded from the treatment N_2 (120 kg N ha^{-1}) followed by treatment N_1 (90 kg N ha^{-1}), whereas the lowest harvest index (32.36%) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Supported result was also observed by Masum *et al.* (2020), Riaj *et al*. (2018) and Nandini *et al.* (2012).

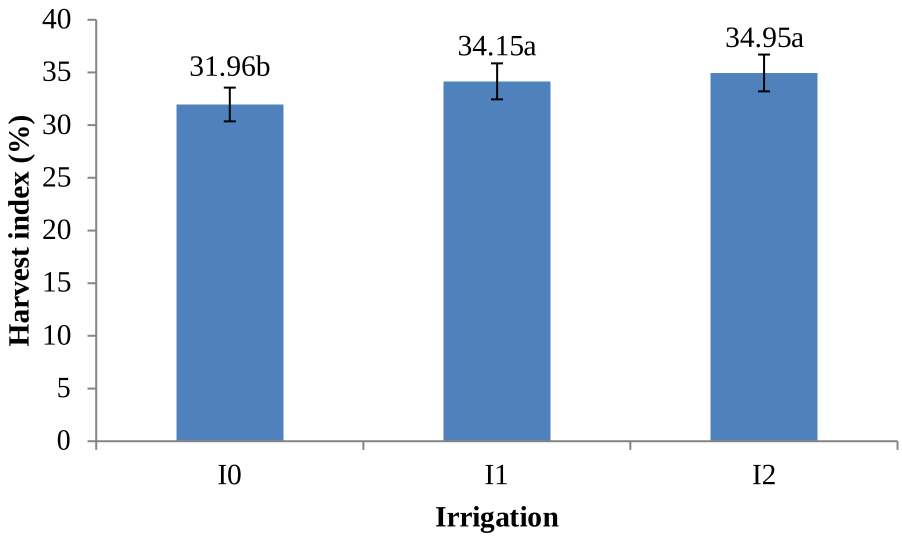
Effect of Irrigation levels

The recorded data on harvest index was significantly influence by different irrigation levels (Figure 21). The highest harvest index (34.95%) was recorded from treatment I_2 (Two irrigations at 25 and 50 DAS) which was statistically identical with treatment I_1 (One irrigation at 25 DAS), whereas the lowest harvest index (31.96%) was recorded from the control treatment I_0 (No irrigation). The result obtained from the present study on harvest index was similar with the findings of Rathore *et al.* (2019), Kibbria (2013) and Sultana *et al*. (2009).



N_0=Control (0 kg N ha^{-1}), N_1=90 kg N ha^{-1}, N_2=120 kg N ha^{-1}, N_3=150 kg N ha^{-1}

Figure 20. Harvest index of mustard as influenced by different nitrogen doses.



I_0=Control (No irrigation), I_1=One irrigation at 25 DAS, I_2= Two irrigations at 25 and 50 DAS

Figure 21. Harvest index of mustard as influenced by different levels of irrigation

Combined effect of different nitrogen doses and Irrigation levels

Variation on harvest index was found as significant as influenced by combined effect of different nitrogen doses and irrigation levels (Table-3). The highest harvest index (35.35%) was recorded from the treatment combination of N_2I_2, which was statistically identical with the treatment combination of N_1I_1 and N_2I_1, whereas the lowest harvest index (32.36%) was recorded from the treatment combination N_0I_0 which was statistically similar with the treatment combination ofN_1I_0.

Table 3. Combined effect of nitrogen and irrigation on seed yield, stover yield and harvest index of mustard

Treatment combinations	Yield parameters		
	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
N_0I_0	0.96 h	2.09 e	31.45 f
N_0I_1	1.17 f	2.41 cd	32.65 def
N_0I_2	1.21 ef	2.45 bcd	33.00 def
N_1I_0	1.00 h	2.15 e	31.73 ef
N_1I_1	1.30 de	2.58 abc	33.42 cdef
N_1I_2	1.34 d	2.63 abc	33.75 cde
N_2I_0	1.05 gh	2.22 de	32.08 def
N_2I_1	1.54 ab	2.69 ab	36.36 ab
N_2I_2	1.61 a	2.73 a	37.62 a
N_3I_0	1.12 fg	2.31 de	32.56 def
N_3I_1	1.38 cd	2.65 abc	34.17 bcd
N_3I_2	1.46 bc	2.66 ab	35.43 abc
$LSD_{0.05}$	**0.11**	**0.24**	**2.25**
CV%	**5.30**	**11.42**	**8.66**

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

N_0= Control (0 kg N ha^{-1}), N_1= 90 kg N ha^{-1}, N_2= 120 kg N ha^{-1} and N_3= 150 kg N ha^{-1}

I_0= Control (No irrigation), I_1= One irrigation at 25 DAS and I_2= Two irrigation at 25 and 50 DAS

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during November 2019 to February 2020 to determine the effect of different nitrogen fertilizer doses and irrigation levels on growth and yield of mustard (BARI Sarisha-14). The experiment consisted of two factors *viz*. Factor A: Nitrogen (4 levels) i.e. control- 0 kg N ha^{-1} (N_0), 90 kg N ha^{-1} (N_1), 120 kg N ha^{-1} (N_2) and 150 kg N ha^{-1} (N_3) and Factor B: Irrigation (3 levels) i.e. control - no irrigation (I_0), one irrigation at 25 DAS (I_1) and two irrigations at 25 and 50 DAS (I_2). There were 12 treatments combinations. The experiment was laid out in a two factorial Randomized Complete Block Design (RCBD) with three replications. After emergence of mustard seedlings, various intercultural operations were accomplished for better growth. Data were collected in respect of the plant growth characters, yield and yield contributing parameters. The data obtained for different characters were statistically analyzed to find out the significance of the nitrogen and irrigation.

Most of the parameters affected significantly due to application of different nitrogen doses. In case of growth parameters, N_3 (150 kg N ha^{-1}) gave the highest plant height (76.36 cm) and number of leaves plant^{-1} (15.58) were recorded from the treatment N_3 (150 kg ha^{-1}) but the highest number of branches plant^{-1} (9.67) was recorded from the treatment N_2 (120 kg N ha^{-1}) whereas control treatment N_0 (0 kg N ha^{-1}) showed the lowest plant height (65.93 cm), number of leaves plant^{-1} (13.00) and number of branches plant^{-1} (8.35). Regarding yield and yield contributing parameters, influenced by N, the highest number of siliqua plant^{-1} (78.30), length of siliqua (4.57 cm), number of seedssiliqua^{-1} (32.96), 1000 seed weight (4.53 g), seed yield (1.40 t ha^{-1}) and harvest index (35.35%) and the highest stover yield (2.57 t ha^{-1}) was recorded from the treatment N_2 (120 kg N ha^{-1}) whereas the control treatment N_0 (0 kg N ha^{-1}) gave the lowest number of siliquaplant^{-1} (66.03), length of siliqua (4.19 cm), number of seeds siliqua^{-1} (26.89), 1000 seed weight (3.83 g), seed yield (1.11 t ha^{-1}), stover yield (2.31 t ha^{-1}) and harvest index (32.36%).

Different irrigation treatments showed significant variation on different studied parameters of the experiment. In case of growth parameters, the highest plant height (78.00 cm), number of leaves plant^{-1} (15.53) and number of branches plant^{-1}(9.77) were recorded from treatment I_2 (Two irrigations at 25 and 50 DAS) whereas the lowest plant height (62.43 cm), number of leaves plant^{-1} (12.49) and number of branches plant^{-1} (7.98) was recorded from the control treatment I_0 (No irrigation). Regarding yield and yield contributing parameters influenced by irrigation the highest number of siliqua plant^{-1} (78.78), length of siliqua (4.58 cm),number of seeds siliqua^{-1} (32.80), 1000 seed weight (4.46 g), seed yield (1.41 t ha^{-1}), stover yield (2.62 t ha^{-1}) and harvest index (34.95%) were recorded from treatment I_2 (Two irrigations at 25 and 50 DAS), whereas control treatment I_0 (No irrigation) gave the lowest number of siliqua plant^{-1} (62.73), length of siliqua (4.11cm), number of seeds siliqua^{-1} (25.68), 1000 seed weight (3.71 g), seed yield (1.03 t ha^{-1}), stover yield (2.19 t ha^{-1}) and harvest index (31.96%).

Treatment combination of different nitrogen doses and irrigation levels showed significant variation for maximum parameters of the study. In case of growth parameters, the highest plant height (83.36 cm) and number of leaves plant^{-1} (17.58) was recorded from the treatment combination N_3I_2 ,but the highest number of branches plant^{-1}(10.53) was recorded from treatment combination N_2I_2. On the other hand, the lowest plant height (58.67cm), number of leaves plant^{-1} (11.67) and number of branches plant^{-1} (7.11) were recorded fromN_0I_0. Regarding yield and yield contributing parameters, treatment combination N_2I_2 gave the highest number of siliqua plant^{-1} (87.63), length of siliqua (4.81 cm), number of seeds siliqua^{-1} (37.63), 1000 seed weight (5.00 g), seed yield (1.61 t ha^{-1}), stover yield (2.73 t ha^{-1}) and harvest index (37.62 %). On the otherand, the lowest number of siliqua plant^{-1} (58.67), length of siliqua (3.92 cm), number of seeds siliqua^{-1} (24.50), 1000 seed weight (3.58 g), seed yield (0.96 t ha^{-1}), stover yield (2.09 t ha^{-1}) and harvest index (31.45%) were recorded from treatment combination N_0I_0.

From the above results, it may be concluded that among the N treatments, treatment N_2 (120kg N ha^{-1}) gave better results in terms of yield and yield contributing parameters compared to other treatments including control. Similarly, regarding irrigation treatments I_2 (Two irrigations at 25 and 50 DAS) showed best results on yield and yield contributing parameters compared to other treatments including control. In terms of combined effect of nitrogen and irrigation N_2I_2 gave best performance regarding yield and yield contributing parameters. So, this treatment combination N_2I_2 (120 kg N ha^{-1} with two irrigations at 25 and 50 DAS) can be considered as best as compared to other treatment combinations. The present research work was carried out at the Sher-e-Bangla Agricultural University in one season only. Further trial of this work may be conducted in different AEZ of Bangladesh before the final recommendation. The results are required to substantiate further with different varieties of rapeseed and mustard.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

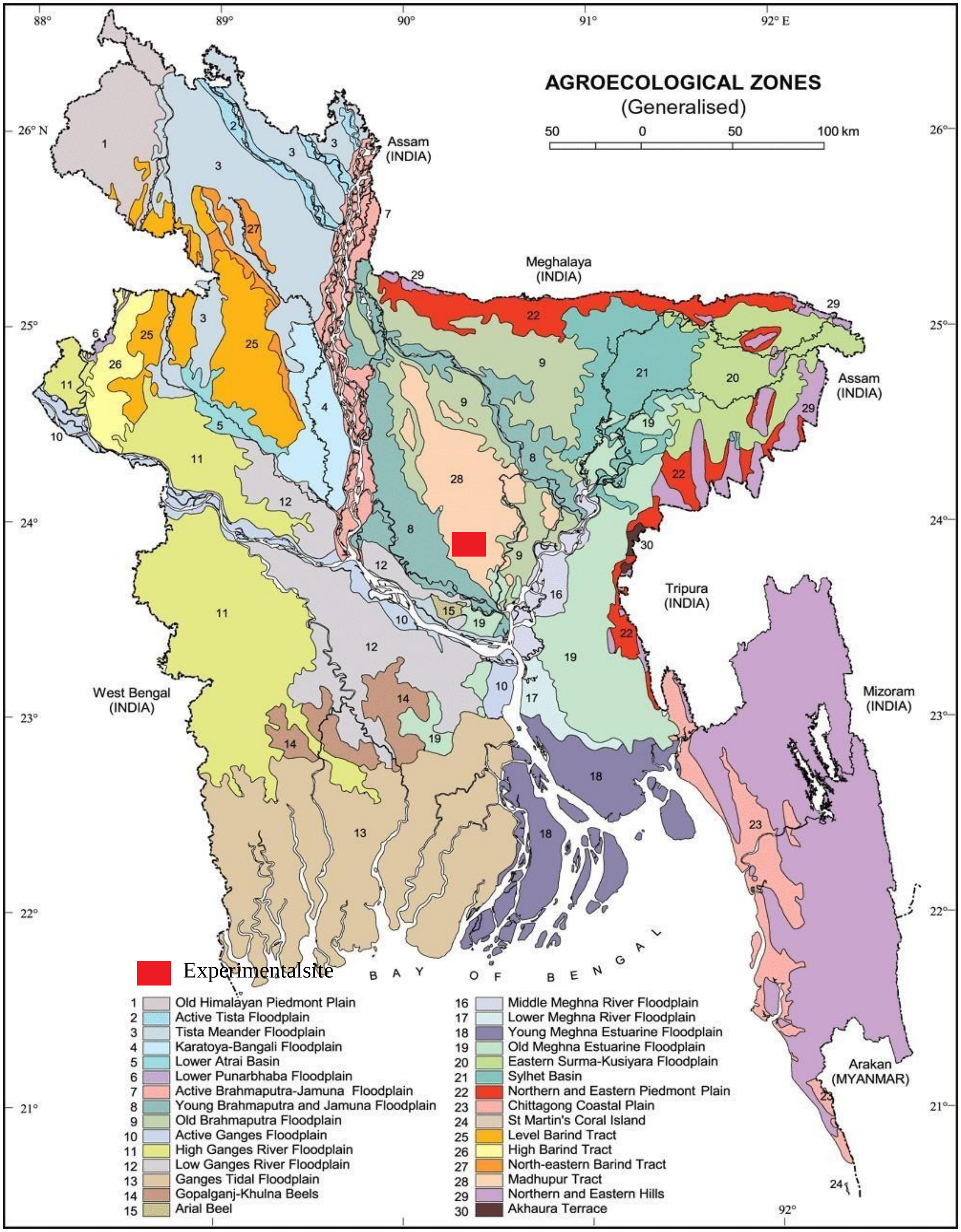

Fig.22. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2019 to February 2020.

Year	Month	Air temperature(°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research field of Agricultural Botany Farm,SAU,Dhaka
AEZ	Modhupur Tract(28)
GeneralSoilType	Shallow red brown terrace soil
Landtype	Highland
Soilseries	Tejgaon
Topography	Fairly leveled
Floodlevel	Above flood level
Drainage	Well drained
Croppingpattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis % Sand	27
%Silt	42
%Clay	32
Textural class	Silty Clay Loam (ISSS)
pH	5.7
Organic carbon(%)	0.48
Organic matter(%)	0.76
Available P(ppm)	20
Exchangeable K(m/100 g soil)	0.2
Available S (ppm)	46

Source: Soil Resource Development Institute (SRDI)

Appendix V. Mean square values of plant height, number of leaves plant^{-1} and number of branches plant^{-1} of mustard growing under the experiment

Sources of variation	**Degrees of freedom**	**Mean square of**		
		Plant height	**Number of leaves plant^{-1}**	**Number of branches plant^{-1}**
Replication	2	226.896	26.887	11.040
Factor A	3	191.850**	11.785**	2.865**
Factor B	2	807.961**	29.229**	11.401**
A × B	6	4.926*	1.066**	0.123*
Error	22	5.112	0.327	0.094

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of number of siliqua plant^{-1}, length of siliqua, number of seeds siliqua^{-1} and 1000 seeds weight of mustard growing during experimentation.

Sources of variation	Degrees of freedom	Mean square of			
		Number of siliquae plant^{-1}	Length of siliqua	Number of seeds siliqua^{-1}	1000 seeds weight
Replication	2	486.800	1.443	100.052	2.100
Factor A	3	272.341**	0.249**	65.703**	0.823**
Factor B	2	871.235**	0.762**	168.097**	1.923**
A × B	6	25.770**	0.015*	9.841**	0.123**
Error	22	7.838	0.005	1.286	0.029

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of seed yield, stover yield and harvest index growing during experimentation.

Sources of variation	Degrees of freedom	Mean square of		
		Seed yield	Stover yield	Harvest index
Replication	2	0.542	0.725	82.675
Factor A	3	0.141**	0.103**	15.519**
Factor B	2	0.483**	0.667**	28.856**
A × B	6	0.016**	0.006*	2.719*
Error	22	0.004	0.021	1.769

* significant at 5% level of significance
** significant at 1% level of significanc