EFFECTS OF IRRIGATION FREQUENCY ON GROWTH AND YIELD OF DIFFERENT MUSTARD VARIETIES

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This is to certify that the thesis entitled **"EFFECTS OF IRRIGATION FREQUENCY ON GROWTH AND YIELD OF DIFFERENT MUSTARD VARIETIES"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY** embodies the result of a piece of bonafide research work carried out by **MD SIFAT HASAN SOJIB**, Registration No. **19-10132** 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.

December, 2021

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Dedicated to
My
Beloved Parents

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EFFECTS OF IRRIGATION FREQUENCY ON GROWTH AND YIELD OF DIFFERENT MUSTARD VARIETIES

ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to determine the effect of irrigation frequency on growth and yield of different mustard varieties during the period from November 2019 to February 2020. The experiment consisted of two factors. Factor A- Different mustard varieties; BARI sarisha-10, BARI sarisha-13 and BARI sarisha-15. Factor B- Four levels of irrigation *viz*. control- no irrigation (I_0), one irrigation at 45 DAS (I_1), Two irrigations at 45 and 60 DAS (I_2) and Three irrigations at 45, 60 and 75 DAS (I_3); The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Regarding varietal performance, BARI sarisha-10 gave the highest plant height (96.36 cm), number of leaves plant^{-1} (47.88), number of branches plant^{-1} (7.96) and number of siliqua plant^{-1} (112.67), whereas the highest length of siliqua (6.54 cm), number of seeds siliqua^{-1} (34.67), 1000 seed weight (3.7 g), Seed yield (1.13 ton ha^{-1}), Stover yield (1.92 ton ha^{-1}) and harvest index (35.32%) were found from the variety BARI sarisha-13. Among different irrigation levels I_3 (Three irrigations at 45, 60 and 75 DAS) treatment performed the highest plant height (94.58 cm), number of leaves plant^{-1} (48.39), number of branches plant^{-1} (8.17), length of siliqua (6.25 cm), number of siliqua plant^{-1} (108.83), number of seeds siliqua^{-1} (32.87), 1000 seed weight (3.8 g), seed yield (1.12 t ha^{-1}), stover yield (1.87 t ha^{-1}) and harvest index (34.58%) compared to control (I_0), I_1 and I_2 treatments. In terms of variety and irrigation treatments interaction, V_1I_3 gave the highest plant height (95.47 cm), number of leaves plant^{-1} (47.58), number of branches plant^{-1} (7.92), number of siliqua plant^{-1} (106.96), whereas V_2I_3 showed the highest length of siliqua (6.38 cm), number of seeds siliqua^{-1} (31.77), 1000 seed weight (3.7 g), seed yield (1.12 ton ha^{-1}), stover yield (1.86 ton ha^{-1}) and harvest index (34.93%). Hence, the variety BARI sarisha-13 with irrigation frequency at 45, 60 and 75 DAS were the suitable combination for higher mustard yield.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
AIS	=	Agricultural Information Service
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)
ha	=	Hectare
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
M.S.	=	Master of Science
MT	=	Metric ton
N	=	Nitrogen
No.	=	Number
pH	=	Potential of hydrogen
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
GM	=	Geometric mean
Mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
USDA	=	United States Department of Agriculture
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, 2005). *Brassica* 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). Bangladesh is running a short of 60-75% of the demand of edible oil (Rahman, 2002).

In Bangladesh, it occupies first position of the list in respect of area and production among the oil seed crops (BBS, 2019). In the year 2017-18, the total oilseed production was 927 thousand metric ton and total area covered by oilseed crops was 975 thousand acre. In the year of 2017-18, mustard covered 760 thousand acres land and the production was 352 thousand metric ton (BBS, 2018). Major mustard growing districts of Bangladesh are Comilla, Tangail, Jessore, Sirajgong, Sylhet, Faridpur, Pabna, Madaripur, Jamalpur, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka (BBS 2019).

At present about 0.24 million hectares of land are put to mustard cultivation in Bangladesh with yield of mustard oil in the order of 0.19 million m tons per year. This quantity meets only a fraction of the country's cooking oil needs. Therefore, large quantity of soybean and sunflower oil is to be imported. Imported soybean oil is cheaper than local mustard oil, which has been further reducing mustard acreage in the country. Although mustard is grown in almost all the districts, Chittagong, Sylhet, Dhaka, Tangail, Jessore, Bogra, Sirajganj, and Pabna have comparatively higher acreage of land for cultivation of this Rabi crop. Mustard is the major oil seed crop of Bangladesh that covers more than 60% of the total area cultivated for oil seed (BBS, 2011) and it contributes a major share to the total edible oil production of the country. It is cultivated throughout the semi-arid

climate zone of Bangladesh and commonly known as sarisha (Miah and Alam, 2009). At present, about 0.25 M ha of land is put to mustard cultivation in Bangladesh with a total production of mustard oil of 0.24 Mt year^{-1} (BBS, 2011).

Among the oilseed crops, mustard is the major oilseed crop, which covers about 60% of the oilseed production in Bangladesh (BBS, 2019). It is an important source of cooking oil in Bangladesh and it meets one third of the edible oil requirement of the country (Ahmed *et al*., 1988). Edible oil is an essential integral part of the daily diet of the people in Bangladesh. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. More energy is supplied by plant products than by animal products (USDA, 2014).

Mustard is rich in minerals like calcium, magnesium, iron, vitamin A, Candproteins.100 g mustard seed contains 508 kilocalories energy, 28.09 g carbohydrates, 26.08 g proteins, 36.24 g total fat, 12.2g dietary fiber, 31 I.U. vitamin A, 7.1 mg vitamin C, 266 mg calcium, 9.21 mg iron, 370 mg magnesium and 738 mg potassium (USDA, 2014). The average yield of mustard in Bangladesh is low (0.70 t ha^{-1}) (BBS, 2011) compared to that of other oilseeds growing countries of the world. In addition, the area under mustard cultivation is decreasing because it has to compete with other high value winter crops (Miah and Alam, 2009). Since Bangladesh has been in short of 65–70% of the demand of the edible oil, a huge amount of foreign currency is being spent every year for importing oil and oil seeds (Miah and Alam, 2009). The shortage of edible oil may be minimized either by increasing area under mustard cultivation or by increasing yield per unit area. Possibility of increasing area under mustard cultivation is meager, but there is scope to increase yield by cultivating high yielding variety under best management practices. The production may also be increased by

applying irrigation water at right time (Kahlown *et al*., 2009) as this crop is grown in dry winter season.

Irrigation is one of the key factors making the country self-sufficient in food grain production and contributes greatly towards agriculture GDP (Gross Domestic Production). Irrigation particularly ground water irrigation plays an important role for alleviating rural poverty in Bangladesh. In context of Bangladesh, mustard (*Brassica* spp.) is popular edible oil in rural area and is considered important for improving the taste of a number of food items (Aziz *et al*., 2011). Bangladesh is principally an agricultural country and produces a good number of oil seed crops like mustard, sesame, groundnut, linseed, safflower, sunflower, soybean, castor etc. The first three of these are considered as the major oil seed crops.

Rapeseed-mustard are the major cold loving oilseed crops in Bangladesh, contributes about 70% to the total oil production of the country. They produce annually a total of 494 thousand tons of seed from an area of 606 thousand hectares in the world. Rapeseed-mustard covers 67% of total oil seed cropped area of Bangladesh and produces about 56% of the total seed requirement. At present, the local production of edible oil cannot meet the demand of the increasing population. Bangladesh imports more or less 1.9 million ton of edible oil and on an average 31,685 MT mustard seed was imported from 2006 to 2010 annually. As a result, a huge amount of foreign exchange involving over 160 million US Dollar is being spent every year for importing edible oils in Bangladesh. In Bangladesh, the average yield of mustard is very low (0.74 t ha^{-1}) compared to advanced countries like UK (3.43 t ha^{-1}), France (2.68 t ha^{-1}), Poland (2.04 t ha^{-1}) and Japan (1.73 t ha^{-1}). 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 yielding varieties.

So far there was a very little research work had been done regarding the effect of different irrigation frequency on growth and yield of mustard in Bangladesh. Keeping in view of above facts, a field experiment entitled, “effects of irrigation frequency on growth and yield of different mustard varieties” was conducted with the following objectives:

1. To study the effect of different irrigation frequency on growth and yield of mustard varieties.
2. To study the suitable irrigation frequency for higher mustard yield.

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 irrigation on the growth and yield of mustard varieties have been progressed in many countries of the world. The proper agronomic practices like irrigation management accelerates its growth and influenced its yield. Therefore, available findings of the effect of variety and irrigation relevant to the present study have been briefly reviewed under the following heads.

2.1 Varietal performance of mustard

Sarker *et al*. (2021) conducted a research to investigate the growth and yield performance of mustard varieties. The experiment was arranged in a randomized complete block design consisting of eight mustard varieties (*viz*. BARI Sarisha-8, BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16, Rai and Tori-7) as treatment and replicated thrice. All the growth, yield attributes and yield were substantially influence among the mustard varieties except the phenological parameters. Results of the experiment showed that the highest plant height (131.33 cm), seed yield (1813.33 kg ha^{-1}) and stover yield (3876.67 kg ha^{-1}) were found in BARI Sarisha-16. BARI Sarisha-11 was found better in respect of maximum siliqua $plant^{-1}$, weight of seeds $plant^{-1}$, 1000-seed weight and harvest index. Besides this, BARI Sarisha-14 showed the maximum number of seeds $siliqua^{-1}$. Therefore, findings of this study suggested that BARI Sarisha-16 would be suitable for better productivity and recommended for cultivation in the medium highland of Khulna region of Bangladesh.

Lal *et al*. (2020) conducted an experiment with four mustard varieties (RGN-73, RGN-229, RH-30 and Pusa bold) in two growing environments (open environment and neem shade). Pusa bold gave significantly higher plant height

than other varieties. Among varieties, RGN-73 had significantly higher number of branches per plant, dry matter accumulation per plant, siliquae per plant, seed yield, stover yield, biological yield, harvest index and heat use efficiency than other varieties. However, significantly higher test weight was in Pusa bold variety. Under open environment condition, significantly higher growth, yield attributes, yield, harvest index and heat use efficiency were found as compared to neem shade environment. The results revealed that variety RGN-229 took more days for completion of life cycle as compared to other varieties, hence RGN-229 variety required significantly more degree days than other varieties. The pheno-thermal index was significantly higher in open condition.

Priyanka *et al*. (2020) carried out a research to approximate the significance of interactive effects of varieties × fertilizer doses in mustard crop with saline water irrigation undersemi-arid conditions of Haryana. The experiment comprised of mustard varieties *viz*. Kranti, Giriraj, CS-54 and CS-58 and three fertilizer doses *viz*. recommended fertilizer dose (RDF), i.e., 60:20:20, 125% of recommended fertilizer dose and 150% of recommended fertilizer dose under semi-arid conditions of Haryana. Statistical analysis devised that both variety and fertilizer doses had significant effect on plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, seed and straw yield. The interaction of variety and fertilizer dose had significant effect only on the seed yield. Amongst four varieties CS-58 was better performer for all the growth and yield parameters with application of 150% recommended fertilizer dose under saline water irrigation.

Ahmed and Kashem (2017) conducted a varietal trial of mustard to find out the suitable mustard variety/varieties. A total of five varieties viz. BADC 1, SAU Sarisha-3, BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-15 were tested in the farmer's field. The experiment was carried out in a randomized complete block design with three replications. Significant differences were found among the

mustard varieties for number of branches plant^{-1}, number of capsules plant^{-1}, capsule length, 1000-seed weight and seed yield. The mustard var. BARI Sarisha-11 produced the highest number of branches plant^{-1}, number of capsules plant^{-1}, 1000-seed weight resulting the highest seed yield (1.64 t ha^{-1}), followed by BARI Sarisha-15 (1.47 t ha^{-1}). The seed yield of BARI Sarisha-11 and BARI Sarisha-15 was not differed significantly, but the growth duration of BARI Sarisha-15 was shorter than the others.

Helal *et al*. (2016) conducted an experiment of rapeseed-mustard to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, growth as well as yield and yield attributes of rapeseed mustard were significantly differed. The variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 produced the highest seed yield and took minimum days to mature and their growth parameters were also highly significant and positive correlation was observed in seed yield with siliqua/plant, straw yield, biological yield, 1000 seed weight and harvest index. So, Improved Tori, BARI Sarisha-8, BARI Sarisha-14 and BARI Sarisha-15 are suitable for cultivation in north-east region (Sylhet) of Bangladesh.

Salam *et al*. (2014) conducted a field experiment to find out the effect of irrigation and variety on the yield of mustard. The experiment consisted of three levels of irrigation viz., no irrigation-I0, one irrigation-I_1, two irrigations-I_2 and three varieties of Tori-7-V_1, BARI Sarisha-14-V_2 and BARI Sarisha-15-V_3. The experiment was laid out in a split-plot design where irrigation level was allocated in the main plot and variety was allocated in the subplot. The treatments were replicated thrice. It is observed that the irrigation had significant effect on most of

the yield and yield contributing characters of mustard except effective siliquas plant^{-1} and harvest index. The highest seed yield (1.53 t ha^{-1}) was obtained from two irrigations which was statistically identical with one irrigation. All the yield and yield contributing characters except plant height was significantly affected by the varieties studied. The highest seed yield (1.61 t ha^{-1}) was obtained from the variety BARI sarisha-14 which was statistically identical with BARI sarisha-15. The lowest seed yield (1.20 t ha^{-1}) was obtained from the variety Tori-7. Interaction of irrigation and variety had significant effect on the yield and yield contributing characters of mustard. The highest seed yield (1.75 t ha^{-1}) was obtained from the interaction of two irrigations × BARI Sarisha-14 which was statistically identical with two irrigations × BARI Sarisha-15, one irrigation × BARI Sarisha-14 and one irrigation × BARI Sarisha-15. The lowest seed yield (1.17 t ha^{-1}) was recorded from the interaction of no irrigation × Tori-7. The results of the study indicate that one irrigation with BARI Sarisha-14 or BARI Sarisha-15 could be cultivated for obtaining highest seed yield. Significant differences were observed among the varieties in respect of plant height (cm), number of branches plant^{-1}, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, 1000-seed weight (g), seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (t ha^{-1}), harvest index (%) and days to maturity. Among the varieties, BARI sarisha-16 produced the tallest plant (127.7 cm) compared with the other varieties whereas BARI sharisa-14 produced the shortest plant (60.1 cm) which was statistically similar to Tori-7 (60.5 cm).

Alam (2004), Ali *et al*. (1996) and Bhuiyan (1989) observed significant variations in terms of plant height in different varieties of rapeseed-mustard. Khaleque (1989) found different number of branches of 3.9 and 3.1 plant^{-1} in TS-72 and Sonali sarisha, respectively. Length of siliqua, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, 1000-seed weight and seed yields significantly differed among the varieties and advanced line. Pooran *et al*.

(2000), Hossain *et al*. (1996), Jahan and Zakaria (2010) and Mondal *et al*. (2008) found that the highest number of siliqua plant^{-1} (187.3) in BLN-900 and the lowest (150.4) in Semu 249/84. They also noted the lowest number of siliqua plant^{-1} (45.9) in the variety SS-75.

Pooran *et al*. (2000) studied six cultivars of mustard and found that among the mustard cultivars, GM-1 gave the highest seed yield (1050 kg ha^{-1}), followed by Kranti and Pusa Bold (790 and 760 kg ha^{-1}, respectively) and Varuna and Sita produced comparably lower yields (680 and 610 kg ha^{-1}, respectively).

Pradhan *et al*. (2014) obtained significantly different yield of three mustard varieties. Interaction effects of irrigation treatments and varieties. The interaction effect of irrigation treatments and varieties on the seed yield of mustard was significant. The three-irrigation treatment (T_3) produced higher seed yield for all varieties studied. The highest seed yield was 2.67 t ha^{-1} for the combination of three-irrigation treatment (T_3) and BARI sarisha-13. The lowest seed yield was 1.34 t ha^{-1} under irrigation at the vegetative stage (T_0) for BARI sarisha-10. It appears that for producing seed yield BARI sarisha-13 was the most responsive to the irrigation treatments. The highest biological yield was 2.95 t ha^{-1} for the combination of three-irrigation treatment and BARI sarisha-13. The highest harvest index was 4% under control treatment (no irrigation) for BARI sarisha-13. Results also showed that plant height increased with the increase of irrigation frequencies. It might be due to the soil moisture availability for the plant was sufficient. Similar result was reported by Rathore *et al.* (2019), Rathore *et al.* (2019), Latif (2006), Sultana (2007) and Kibbria (2013).

2.2 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, 2016). 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 yields is greatly increased by the presence of adequate soil moisture in different growth stages (Prasad and Eshanullah, 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.

Rana *et al*. (2020) conducted a field experiment to evaluate the effect of sulfur fertilization and irrigation scheduling on mustard hybrids. Experiment comprised 18 treatment combination involving three irrigation scheduling (0.4, 0.6 and 0.8 IW/CPE) and two hybrids (NRCHB-506 and PAC 432) as main plot treatment and three sulfur (S) levels (0, 30 and 60 kg S ha^{-1}) as sub-plot treatment in split-plot design replicated thrice during rabi season (Oct-March) of 2015-16 and 2016-17. Statistical analysis of the results revealed that individually irrigation scheduling at 0.8 IW (Irrigation water)/CPE (Cumulative pan evaporation), mustard variety 'PAC 432' and sulfur application at 60 kg ha^{-1} reported to have maximum plant height, number of primary and secondary branches, dry matter accumulation, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, siliqua length and seed yield. Similar results were also obtained in relation to dry matter heat use efficiency

(DM-HUE) at different stages and seed yield HUE. However, the variation in most of the parameters observed with either 0.6 or 0.8 IW/CPE and application of 30 or 60 kg S ha-1 was found non-significant during the course of the trial. In terms of interaction, mustard variety 'PAC 432' irrigated at 0.8 and 0.6 IW/CPE and fertilized with 60 or 30 kg S ha-1 proved significantly superior over other treatments and recorded the highest plant height, better yield constituents and maximum yield, while the lowest values for the same were recorded in 'NRCHB-506' irrigated at 0.4 IW/CPE with no sulfur application during both the years of experimentation.

Singh *et al*. (2019) conducted field experiments for two consecutive rabi seasons during 2014-15 and 2015-16 to evaluate growth and yield parameters of yellow sarson (*Brassica rapa* L.) affected by different irrigation levels, planting methods and mulching. Significantly higher numbers of leaves per plant and dry matter accumulation in leaves and stem were reported at 1.2 IW (Irrigation water)/CPE (Cumulative pan evaporation) ratio over 0.6 and 0.3 IW/CPE ratio in both the years of study. Seed yield of yellow season increased significantly up to 0.9 IW/CPE ratio as compared to remained irrigation levels. In both the years, yellow sarson planted on raised bed produced 11.5 and 7.1 per cent higher seed yield with higher number of leaves over flatbed planting method, respectively. Application of rice straw mulch recorded 11.7 and 12.3 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 irrigation frequency (*viz*., I_0=No irrigation, I_1= 1 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-1were 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 highest yield (1.42 t ha^{-1}) of seed was obtained from the combination of three irrigation and optimum sowing time. The highest stover and biological yield was obtained from the combination of three irrigation and optimum sowing time.

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

Shivran *et al*. (2018) conducted a field experiment during rabi season of 2013-2014 to study the effect of various irrigation schedule and Sulphur levels on productivity and water use efficiency of Indian mustard [*Brassica Juncea* (L.)]. The pH of soil of experiment field was 7.3 with available N 129.0, P_2O_5 17.1 and K_2O 187 kg ha^{-1}. The treatment consisted of six irrigation stages IR0 (no sown irrigation), IR_1 (30-35 DAS), IR_2 (flowering), IR_3 (30-35 DAS and flowering), IR_4 (30-35 and siliqua development) and IR_5 (30-35, flowering + siliqua development) in main plot. And three levels of Sulphur S_0 (no sulphur), S_1 (20 Kg ha^{-1}) and S_2 (30 kg ha^{-1}) in sub plot were tested in split plot design (SPD) with three replications. Results showed that the maximum seed yield was observed with the three irrigation levels IR5 (30-35 + F + SD) which were higher by 20.47, 25.51, 47.01, 54.65 and 123.90 percent over IR_4, IR_3, IR_2, IR_1 and IR_0 respectively.

Jat *et al*. (2018) conducted a field experiment and evaluated the effect of differential irrigation regimes and confirmed about the significant positive impact of irrigation on agronomic traits such as plant height, dry matter plant^{-1}, number of primary and secondary branches plant^{-1}.

Roy *et al*. (2017) conducted an experiment during October 2013 to February 2014 to evaluate the effect of irrigation and sulphur (S) application on the growth, yield and oil content of rapeseed *(Brassica napus).* There were three levels of irrigation *viz*. no irrigation, one irrigation at 25 days after sowing and two irrigation at 25 days after sowing and 53 days after sowing, and three levels of S *viz*. 15, 30 and 45 kg S ha^{-1} as gypsum. The experiment was laid out in a split plot design with three replications assigning irrigation in the main plots and S levels in the subplots. Irrigation and added S significantly influenced plant height, number of primary and secondary branches per plant, number of siliquae per plant, siliqua length, seeds per siliqua, seed yield and seed oil content. Seed yield was mainly influenced by number of siliquae per plant and seeds per siliqua. Two irrigations had better performances on all parameters under study. The highest seed yield (1527 kg ha^{-1}) was obtained with two irrigations coupled with application of 45 kg S ha^{-1} which was statistically similar to two irrigations with 30 kg S ha^{-1}. Sulphur application greatly influenced seed oil content showing the highest oil content due at 45 kg Sha^{-1}.

Parmar *et al.* (2016) studied the yield attributing traits such as number of siliquae plant^{-1}, number of seeds siliquae^{-1}and 1000-seed weight as affected by irrigation regimes and found considerable increase in them with increase in IW: CPE ratio from 0.60 to 1.0.

Hossain *et al*. (2013) carried out an experiment to study the effect of irrigation and sowing method on yield and yield attributes of mustard. The experiment consists of two factors i) irrigation *viz*. no irrigation (I_0), one irrigation (I_1)and two irrigations (I_2) ii) sowing method *viz*. line sowing method (M_1) and broadcasting

method (M_2). Irrigation had significant effect on all the yield and yield contributing characters. The highest plant height, number of branches plant^{-1}, filled siliqua plant^{-1}, sliqua length, number of seed siliqua^{-1}, 1000-seed weight and stover yield were obtained from I_2 (two irrigations) and consequently it producedthehighest seed yield. Sowing method also had significant influence on almost all the yield and yield contributing characters. All the yield contributing characters except number of unfilled siliqua plant^{-1}were found best at line sowing method (M_1) and consequently it produced the highest seed yield. However it could be noted from the study that the combination of two irrigations with line sowing method is better to get higher yield of mustard.

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, siliquae formation stage and seed maturation). Three irrigations applied at 20, 40 and 60 DAS produced more plant height (101.00 cm) than under no irrigation. Significant increase in dry matter was found up to three irrigations. The maximum number of primary branches (7.70) per plant with two irrigations compared to without irrigation. The highest siliquae plant^{-1} (138.8) increased by two irrigations than no irrigation (111.9). 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). Length of siliqua (5.23 cm) was highest with two irrigations compared to one irrigation or without irrigation (control). Maximum weight of 1000 seeds (3.16 g) siliquae^{-1} was found when two irrigations were applied. The highest seed yield (1.98 t ha^{-1}), stover yield was (1.98 t ha^{-1}) and biological yield (3.97) was by two irrigations (before flowering and siliquae formation stage) whereas the lowest was from control (no irrigation). The maximum harvest index (51.16 %) was obtained from two irrigations and the minimum harvest index (48.72%) was obtained from no irrigation.

Piri *et al.* (2011) showed that application of two irrigations at 45 and 90 DAS significantly increased plant height. 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 noirrigation. Application of two irrigations at 45 and 90 DAS significantly increased 1000 seeds weight, seed yield, stover yield than one irrigation and no irrigation. The increase in stover yield also may be attributed to higher plant height than more number of total branches.

Meena (2011) noted improvement in total number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1}, test weight and seed yield with increasing IW/CPE ratio and maximum values of these parameters were recorded under 0.8 IW (Irrigation water)/CPE (Cumulative pan evaporation) ratio.

Meena (2010) observed that with application of three irrigations at branch initiation, 50% flowering and 50% pod development stages of mustard, significantly higher values of nitrogen, phosphorus and potassium content in seed and stover as well as nitrogen uptake by respective parts were noticed.

Sultana *et al*. (2009) carried out a study during November 2006 to March 2007 to evaluate the effect of irrigation and variety on growth, yield attributes and yield of rapeseed. The treatment comprised of three levels of irrigation *viz*. no irrigation, one irrigation at 20 DAS, one irrigation at 35 DAS, two irrigations at 20 and 35 DAS and three irrigations at 20, 35 50 DAS and three varieties *viz*. SAU Saris ha^{-1}, Kollania and Improved Tori-7. Three irrigations (at 20, 35 and 50 DAS) increased economic yield with higher values of harvest index as the yield attributes like branches plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1}and 1000 seed weigh were higher. The seed yield with three irrigations was 111.93% and 10.73% higher than no irrigation and two irrigations, respectively. The variety SAU Sarisha-1 showed its superiority by producing 1.4 % and 45.94 % higher yield than Kollania and Improved Tori-7, respectively. This variety (SAU Sarisha-1) also showed higher

branches plant^{-1}, seeds siliqua^{-1}, 1000 seed weight, biological yield and harvest index. In most of the cases interaction of three irrigations with SAU Sarisha-1 performed best in respect of grain yield as well as other studied parameters. The highest seed yield (1827.0kgha^{-1}) was obtained with the interaction of three irrigation with SAU Sarisha-1. This was achieved due to the maximum number of branches plant^{1}, seeds siliquae^{-1}and 1000 seed weight in this interaction.

Nagdive *et al.* (2007) conducted a study at three irrigations given to mustard crop at branching, flowering and siliquae development stages and recorded marked improvement in yield and quality of seed and showed higher content of oil and protein.

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. The maximum plant height was found at three irrigation (20, 35, 50 DAS) compared to other treatments including control (no irrigation). The highest plant dry matter, maximum number of branches per plant, number of siliquae per plant and number of seeds siliqua^{-1} were found at three irrigation (20, 35, 50 DAS) compared to other treatments including control (no irrigation). It was also found that the 1000 seeds weight, seed yield (1827.0 kg ha^{-1}), biological yield and harvest index were higher at three irrigation (20, 35, 50 DAS) than control treatment (no irrigation).

Ghanbahadur and Lanjewar (2006) observed higher number of siliquae plant^{-1}, pod length, number of seeds pod^{-1} and test weight with irrigation at 0.6 IW: CPE than at 0.4 IW: CPE resulting in increment of seed, stover and biological yield over 0.4 IW: CPEratio.

Piri and Sharma (2006) when made an assessment of effect of different irrigation regimes in north western plains vouched for the fact that increasing the frequency of irrigation from 0 to 2 and applying them at 30 and 60 DAS culminated in

significantly better performance of mustard with respect to plant height, dry matter accumulation, secondary branches plant^{-1} and relative growth rate.

Latif (2006) conducted an experiment to observe 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 (104.46 cm) with three irrigations compared to no irrigation (control). Maximum number of seeds per siliquae (27.20), siliquae length (7.65 cm) and number of siliquae (136.24) were found when three irrigations were applied compared to no irrigation (control).

Yadav (2005) 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, dry matter accumulation Plant^{-1}, chlorophyll content, number of primary and secondary branchesplant^{-1}.

Kumawat (2004) conducted a field study with the application of three irrigations at branching, flowering and siliqua development stages significantly increased N, P and K concentrations in seed and stover as well as their uptake in comparison to less frequent irrigation. Similar effect of irrigation regimes was also noticed by Ghanbahadur and Lanjewar (2006) who observed significantly higher uptake of both N and P in 0.6 IW: CPE ratio as compared to 0.4 IW:CPE.

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 irrigations. In case of two irrigation, siliquae

number (277) was found in irrigation at flowering and siliquae formation stagefollowed by siliquae per plant (324) with one irrigation at flowering stage. But the difference was not significant.

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}). Plant height was significantly influenced by the levels of irrigation. The tallest plant height was found in the treatment of irrigation at the flowering stage (I_3) and the smallest plant height in the treatment of no irrigation (T_0). Irrigation application at the flowering stage increased plant height significantly, so did by treatment T_2 and T_3.

Begum and Paul (1993) conducted an experiment on the influence of soil moisture on growth, yield and water use efficiency of mustard. They also found that plant height at harvest and numbers of pods/plant were increased by irrigation. The maximum weight of 1000-seed was 0.42 g for the treatment T_3 and T_4 and the lowest weight of 1000-seed was 0.36 g for the treatment T_1 (control). It has been concluded that 1000-seed weight was decreased by the lack of soil water availability for crop. The highest pod length was found in treatment T_3 and the smallest pod length was obtained by the treatment T_0. Irrigation at vegetative stage was helpful for increasing pod length, but two-irrigation treatment (vegetative and flowering stage) was more effective to increase pod length.

2.3 Interaction effect of variety and irrigation level on mustard

There was no significant variation due to combined effect of variety and irrigation level on yield and yield attributes. Sultana *et al*. (2009) carried out a study during November 2006 to March 2007 to evaluate the effect of irrigation and variety on growth, yield attributes and yield of rapeseed. The treatment comprised of three levels of irrigation viz. no irrigation, one irrigation at 20 DAS, one irrigation at 35 DAS, two irrigations at 20 and 35DAS and three irrigations at 20, 35 50 DAS and three varieties *viz*. SAU Saris ha^{-1}, Kollania and Improved Tori-7. Three irrigations (at 20, 35 and 50 DAS) increased economic yield with higher values of harvest index as the yield attributes like branches $plant^{-1}$, siliqua $plant^{-1}$, seeds $siliqua^{-1}$and 1000 seed weigh were higher. The seed yield with three irrigations was 111.93% and 10.73% higher than no irrigation and two irrigations, respectively. The variety SAU Sarisha-1 showed its superiority by producing 1.4% and 45.94% higher yield than Kollania and Improved Tori-7, respectively. This variety (SAU Sarisha-1) also showed higher branches $plant^{-1}$, seeds $siliqua^{-1}$, 1000 seed weight, biological yield and harvest index. In most of the cases interaction of three irrigations with SAU Sarisha-1performed best in respect of grain yield as well as other studied parameters. The highest seed yield (1827.0 kg ha^{-1}) was obtained with the interaction of three irrigations with SAU Sarisha-1. This was achieved due to the maximum number of$branches plant^{1}$, seeds $siliquae^{-1}$ and 1000 seed weight in this interaction.

Khatun *et al*. (2015) conducted a study to study the effect of irrigation on the yield and yield attributes of three newly developed mustard varieties, namely Binasarisha-7 (*Brassica juncea* L), Binasarisha-8 (*Brassica juncea* L), and Binasarisha-4 (*Brassica napus* L). The experimental soil was silty clay with a bulk density of 1.43 g cm^{-3}. There were four irrigation treatments (T_1: no irrigation; T_2: irrigation at vegetative stage; T_3: irrigation at flowering stage; T_4: irrigation at vegetative and flowering stage), each replicated three times in a split plot design.

Irrigation showed significant effect on the yield attributes of the mustard varieties. The highest yield of 1.43 t ha^{-1} (46% higher over control) was obtained in treatment T_4 of variety Binasarisha-7. The lowest yield of 0.63 t $ha^{-1}$was obtained in treatment T_1 (control) of variety Binasarisha-4. For producing seed yield Binasarisha-4 was the most responsive to the irrigation treatments (T_2–T_4). In contrast, the yield differences among the stage-wise irrigation treatments (T_2–T_4) were not statistically significant for Binasarisha-8. The highest water use efficiency of 0.48 ha^{-1} cm^{-1} was obtained in treatment T_1 and the lowest of 0.28 t ha^{-1} cm^{-1} was in treatment T_4. For cultivation of the mustard varieties Binasarisha-4, Binasarisha-7 and Binasarisha-8 in this type of climate, irrigation at vegetative and flowering stage may be recommended to produce higher yield.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to study the effect of irrigation frequency on growth and yield of different mustard varieties (BARI sarisha-10, 13 & 15). 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 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.

3.3 Soil

The soil of the experimental area belongs to the Modhupur 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, Khamarbari, Dhaka. The details of morphological and chemical properties

of initial soil of the experiment plot were presented in Appendix III.

3.4 Test crop

Seeds of BARI sarisha-10, 13 & 15 as plant material were used for the present study.

3.5 Experimental details

3.5.1 Treatments of the experiment

Factor A: Different mustard varieties (3)

1. V_1 = BARI sarisha 10
2. V_2 = BARI sarisha 13
3. V_3 = BARI sarisha 15

Factor B: Irrigation levels (4)

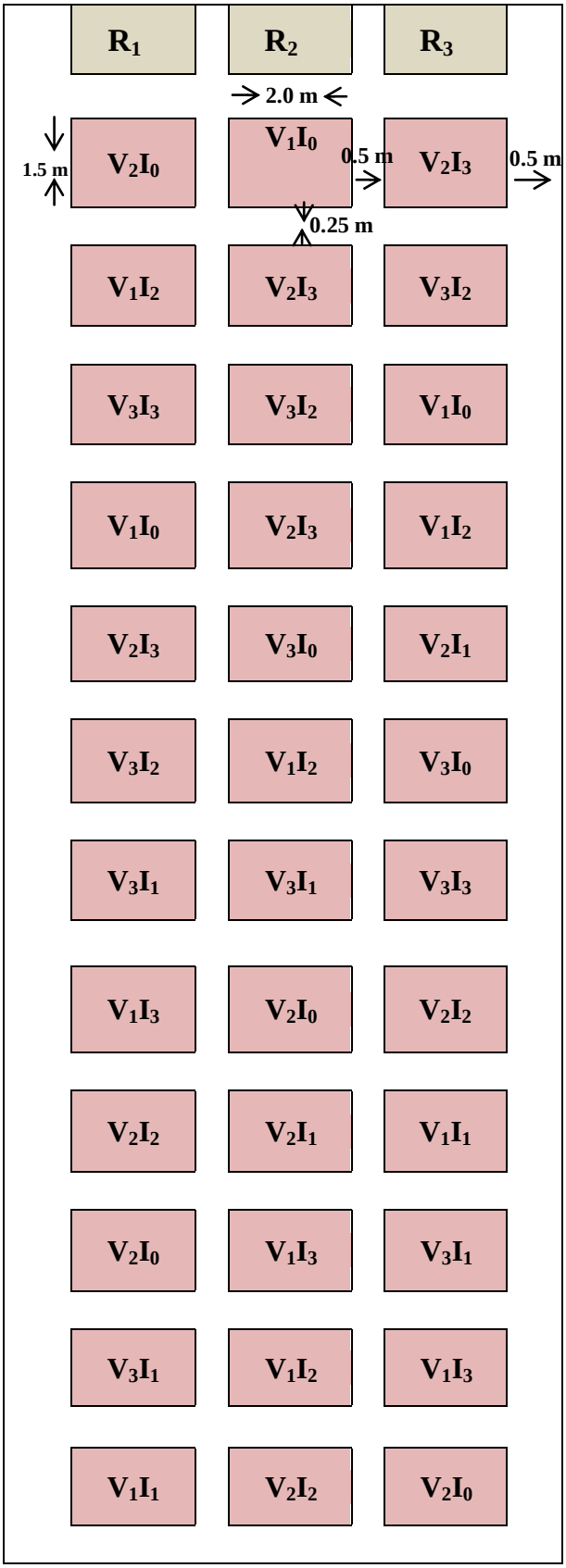
1. I_0 = Control (No irrigation)
2. I_1 = One irrigation at 45DAS
3. I_2 = Two irrigations at 45 and 60 DAS
4. I_3 = Three irrigations at 45, 60 and 75 DAS

Treatment combinations – Twelve (12) treatment combinations

I_0V_1, I_0V_2, I_0V_3, I_1V_1, I_1V_2, I_1V_3, I_2V_1, I_2V_2, I_2V_3, I_3V_1, I_3V_2 and I_3V_3.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the of different levels of irrigations. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot was 1.50 m × 2 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.



Legend

N
W
E
S

Treatments

Factor A: Mustard varieties - 3

1. V_1 = BARI sarisha-10
2. V_2 = BARI sarisha-13
3. V_3 = BARI sarisha-15

Factor B: Irrigation– Four irrigations

1. I_0 = Control (No irrigation)
2. I_1 = One irrigation at 45DAS
3. I_2 = Two irrigations at 45 and 60DAS
4. I_3 = Three irrigations at 45, 60 and 75DAS

Fig. 1. Layout of the experimental plot

3.6 Collection of seeds

Seeds of BARI sarisha-10, 13 & 15 were collected from BARI, Joydebpur, Gazipur.

3.7 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 land operation was completed on 4 November 2019. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.8 Fertilizers and manure application

The N, P, K, S, Zn and B nutrients were applied through urea, Triple super phosphate (TSP), Muriate of potash (MoP) Gypsum, $ZnSO_4$ and Boric acid, respectively. Boron (B) 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	10 t
N	Urea	220 kg
P	TSP	160 kg
K	MoP	80 kg
S	Gypsum	130 kg
Zn	$ZnSO_4$	4 kg
B	Boric acid	As per treatment

One third (1/3) of whole amount of Urea and full amount of TSP, MoP, $ZnSO_4$ and Gypsum were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 20 days after transplanting (DAT) and 50 DAT, respectively.

3.9 Sowing of seeds

Seeds were sown continuously @ 7 kg ha^{-1} on 5 November 2019 by hand as uniform as possible in the 30 cm apart 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.

3.10 Intercultural operation

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

3.10.1 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 29 November 2019. The final weeding and thinning were done after 24 days of sowing, on 29 November 2019. Care was taken to maintain constant plant population per plot**.**

3.10.2 Irrigation

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

3.10.3 Plant protection

The crop was infested with aphids (*Lipaphiserysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2ml 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.

3.11 Harvesting

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 10 February 2020. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried 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.

3.12 Data collection

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of seeds and straw were taken plot wise. The following parameters were recorded during the study:

3.12.1 Growth parameters

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

3.12.2 Yield contributing parameters

1. No. of siliqua plant^{-1}
2. Length of siliqua (cm)
3. No. of seeds siliqua^{-1}
4. Weight of 1000 seeds (g)

3.12.3 Yield parameters

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

3.13 Procedure of recording data

3.13.1 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.

3.13.2 Number of leaves $plant^{-1}$

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

3.13.3 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 $branchesplant^{-1}$.

3.13.4 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.

3.13.5 Length of siliqua

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

3.13.6 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.

3.13.7 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.

3.13.8 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.

3.13.9 Stover yield

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

3.13.10 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 = Grain yield + Stover yield

3.14 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 difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect of irrigation frequency on growth and yield of different mustard varieties. The results have been presented and discusses with the help of table and graphs and possible interpretations were done under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Effect of variety

Remarkable variation was identified on plant height in different mustard varieties (Figure 2 and Appendix IV). The highest plant height (96.36 cm) was recorded from the variety BARI sarisha-10 which was followed by BARI sarisha-13, whereas the lowest plant height (72.38 cm) was recorded from the variety BARI sarisha-13 followed by the variety BARI sarisha-10. Rathore *et al.* (2019) and Kibbria (2013) also found similar result with the present study and reported that plant height varied significantly due to varietal difference.

Effect of irrigation levels

Different levels of irrigation exhibited a great difference for plant height of mustard (Figure 3 and Appendix IV). It was found that I_3 (Three irrigations at 45, 60 and 75 DAS) treatment showed highest plant height (94.58 cm) which was significantly different from other treatments followed by I_1 (One irrigation at 45 DAS) and I_2 (Two irrigations at 60 DAS) whereas the lowest plant height (65.67 cm) was recorded from the control treatment I_0 (No irrigation). Similar result was also observed by Piri *et al*. (2011) and Hossain *et al*. (2013) and they reported maximum plant height when two irrigations were applied during branching and siliquae development stage.

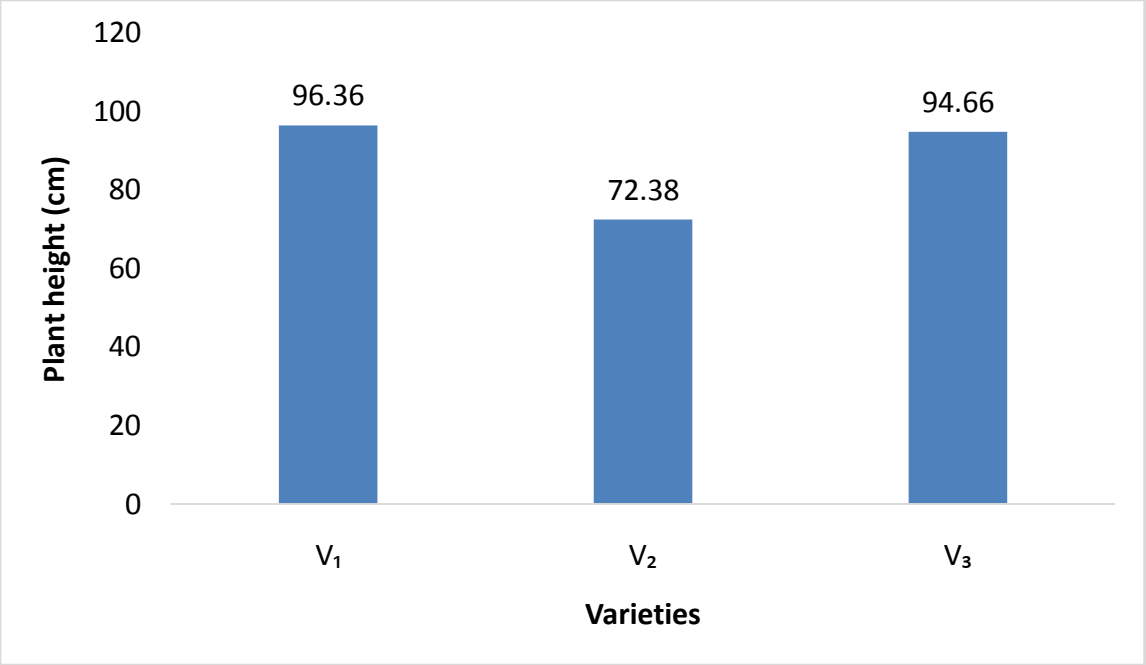


Figure 2. Plant height of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

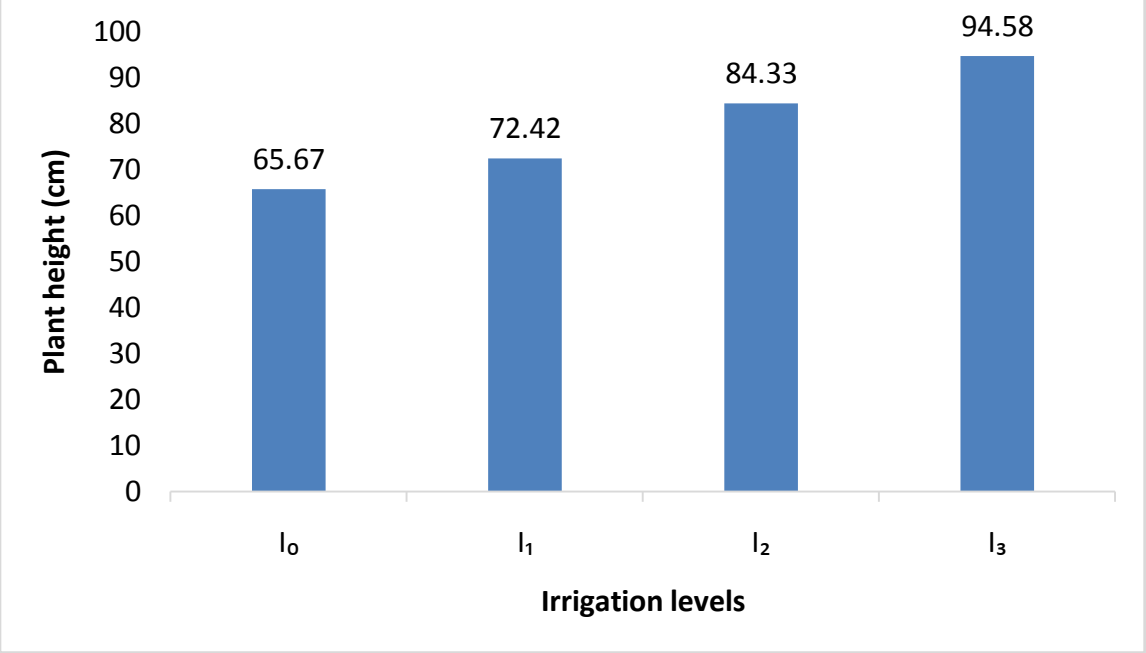


Figure 3. Plant height of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

There was a significant difference between the treatment combinations of different mustard varieties and irrigation levels on plant height (Table 1 and Appendix IV). The treatment combination of V_1I_3 showed the highest plant height (95.47 cm) which was significantly higher than any other treatment combinations and it was significantly similar to the treatment combinations of V_3I_3 and V_3I_2. The plant height (67.28 cm) was recorded in treatment combination of V_2I_0 which was significantly lowest than other treatment combination which was significantly similar to the treatment combinations of V_2I_1.

4.1.2 Number of branches plant^{-1}

Effect of variety

Remarkable variation was identified on number of branches plant^{-1} due to the effect of different mustard varieties (Figure 4 and Appendix IV). The highest number of branches per plant (7.96) was recorded from the variety BARI sarisha-10 which was followed by BARI sarisha-15. Whereas the lowest number of branches per plant (4.66) recorded from the variety BARI sarisha-13.

Effect of irrigation levels

Different levels of irrigation exhibited a great differences for number of leaves plant^{-1} in different mustard varieties (Figure 5 and Appendix IV). It was found that I_3 (Three irrigations at 45, 60 and 75 DAS) showed highest number of branches plant^{-1} (8.17) which was followed by I_1 treatment (One irrigation at 45 DAS), whereas the lowest number of branches plant^{-1} (4.77) was recorded from the control treatment (I_0). Lal *et al*. (2020) and Ahmed and Kashem (2017) also observed similar result with the present study and they found significant variation on branches number among different mustard varieties.

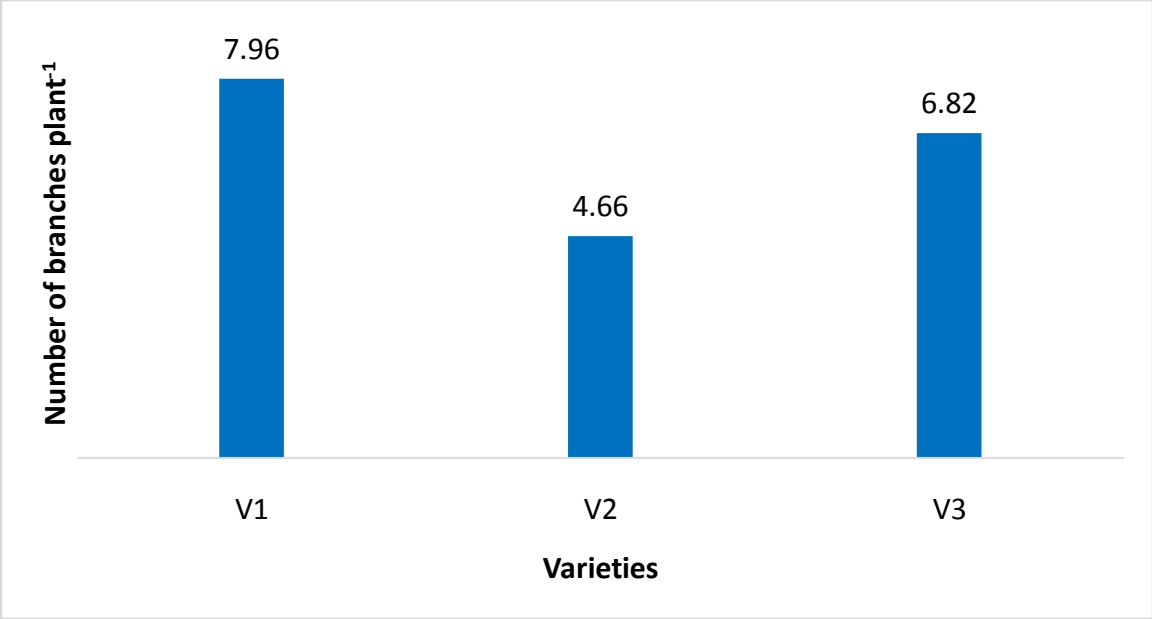


Figure 4. Number of branches plant^{-1} of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

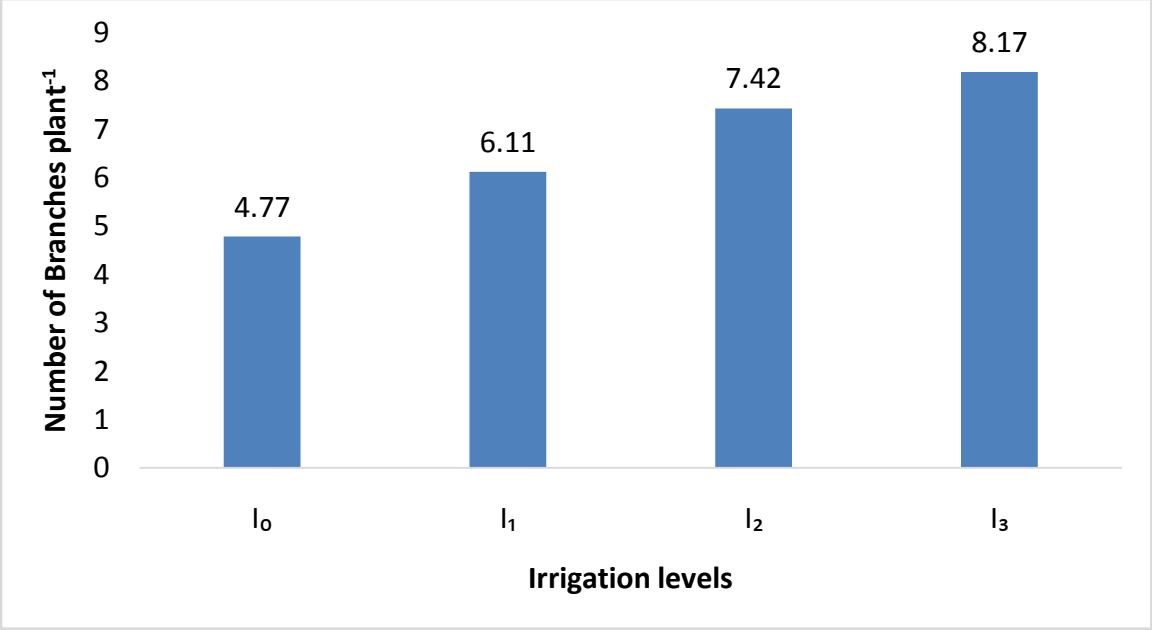


Figure 5. Number of branches plant^{-1} of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

There was a significant difference among the treatment combinations of different mustard varieties and irrigation levels on number of branches plant^{-1} (Table 1 and Appendix IV). The treatment combination V_1I_3 gave the highest number of branches plant^{-1} (7.92) which was significantly higher than rest of the treatment combinations which was followed by V_3I_3. The treatment combination V_2I_0 gave the lowest number of branches plant^{-1} (3.66) which was statistically similar with the treatment combination of V_2I_1.

4.1.3 Number of leaves plant^{-1}

Effect of variety

Remarkable variation was identified on number of leaves plant^{-1} in different mustard varieties (Figure 6 and Appendix IV). The highest number of leaves plant^{-1} (47.88) was recorded from the variety BARI sarisha-10 which was followed by BARI sarisha-13, whereas the number of leaves plant^{-1} (36.22) was lowest recorded from the variety BARI sarisha-13 followed by others varieties BARI sarisha-10 and BARI sarisha-15.

Effect of irrigation levels

Different levels of irrigation exhibited a great difference for number of leaves plant^{-1}in different mustard varieties (Figure 7 and Appendix IV). It was found that I_3 (Three irrigations at 45, 60 and 75 DAS) showed highest plant height (48.39) which was followed by other treatment I_1 (One irrigation at 45 DAS), whereas the lowest number of leaves plant^{-1} (33.78) 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 irrigation frequencies.

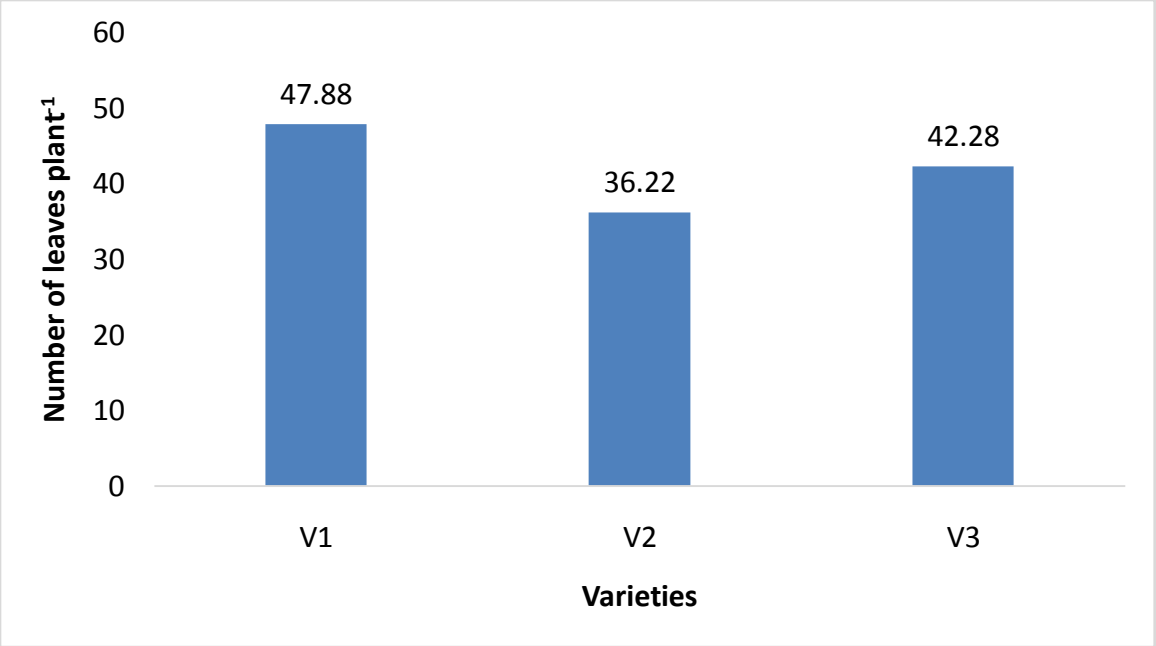


Figure 6. Number of leaves plant^{-1} of mustard as influenced by different mustard varieties.

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

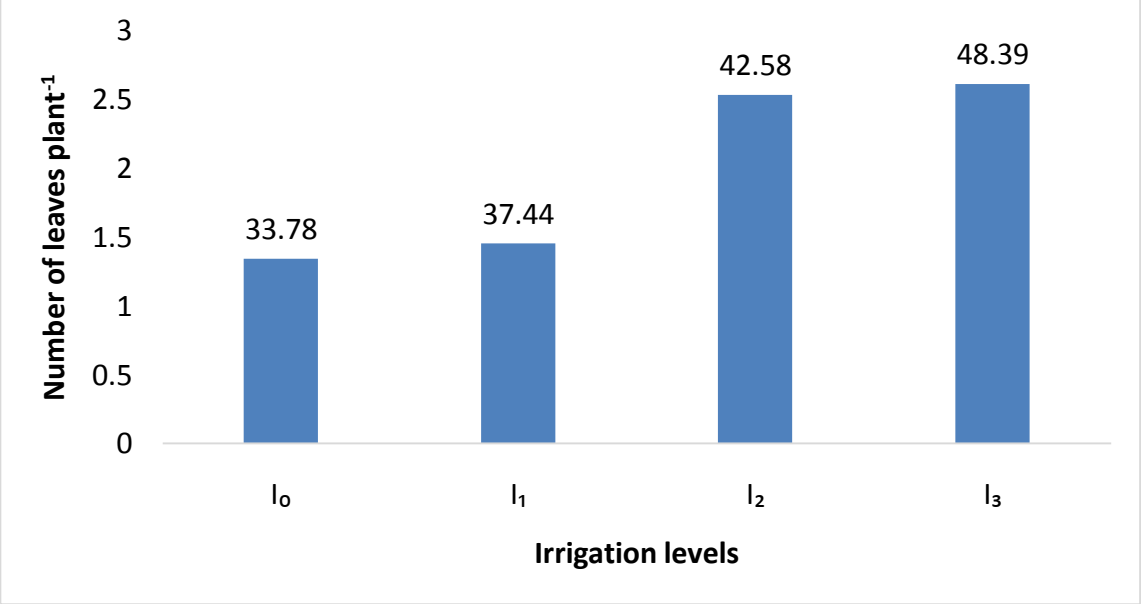


Figure 7. Number of leaves plant^{-1} of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

There was a significant difference among the treatment combinations of different mustard varieties and irrigation levels on number of leaves plant^{-1} (Table 1 and Appendix IV). Results showed that the treatment combination V_1I_3 showed the highest number of leaves plant^{-1} (47.58) which was statistically similar to the treatment combination of V_3I_3 which was followed by V_1I_2. The lowest number of leaves plant^{-1} (32.94) was recorded in treatment combination V_2I_0 which was significantly lower than any other treatment combination that was statistically similar to the treatment combination V_3I_0 and V_2I_1.

Table 1. Growth parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Treatment combinations	Growth parameters		
	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}
V_1I_0	81.02 d	5.86 c	36.12 ef
V_1I_1	83.76 cd	6.12 c	39.87 d
V_1I_2	87.11 bc	6.74 b	44.22 b
V_1I_3	95.47 a	7.92 a	47.58 a
V_2I_0	67.28 g	3.66 g	32.94 g
V_2I_1	68.82 fg	3.94 fg	34.62 efg
V_2I_2	72.14 ef	4.08 f	36.25 e
V_2I_3	73.58 e	4.65 e	41.77 c
V_3I_0	82.33 d	4.96 de	34.32 fg
V_3I_1	88.25 b	5.25 d	38.52 d
V_3I_2	91.15 ab	5.77 c	43.88 b
V_3I_3	94.66 a	6.76 b	46.28 a
$LSD_{0.05}$	4.394	0.394	1.860
Significant level	*	**	**
CV(%)	7.96	9.85	9.31

In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15, I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS, NS=Non-significant, * =Significant at 5% level, **= Significant at 1% level

4.2 Yield contributing parameters

4.2.1 Number of siliqua plant^{-1}

Effect of variety

Remarkable variation was recorded on number of siliqua plant^{-1} in different mustard varieties (Figure 8 and Appendix V). The highest number of siliqua plant^{-1} (112.67) was recorded from the variety BARI sarisha-10 (V_1) which was followed by BARI sarisha-15 (V_3), whereas the lowest number of siliqua plant^{-1} (68.33) was recorded from the variety BARI sarisha-13 (V_2). Similar result was also observed by Salam *et al*. (2014) and reported significant difference on siliqua plant^{-1} due to varietal difference.

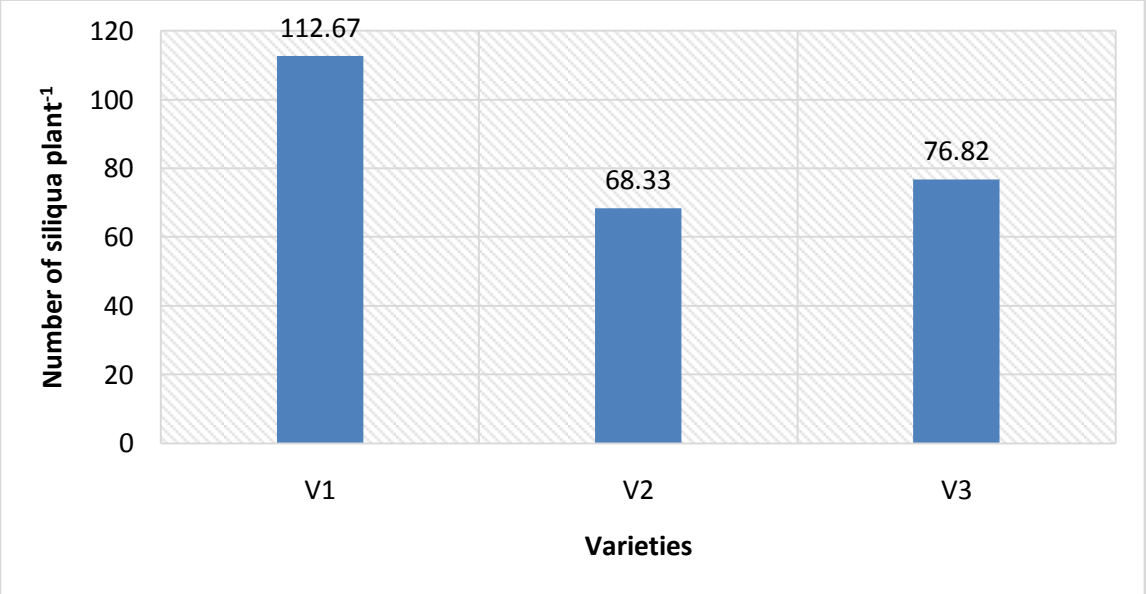


Figure 8. Number of Siliqua plant^{-1} of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

Statistically a great difference identified for number of siliqua plant^{-1} of mustard due to the effect of different levels of irrigation (Figure 9 and Appendix V). The highest number of siliqua plant^{-1} (108.83) was recorded from I_3 (Three irrigations

at 45, 60 and 75 DAS) which was followed by I_2 (Two irrigations at 45 and 60 DAS) whereas the lowest number of siliqua plant^{-1} (71.52) was recorded from the control treatment I_0 (No Irrigation). The results obtained from the study were supported by results of Latif (2006), Sultana (2007) and Kibbria (2013) who concluded that number of siliqua plant^{-1} was significantly increased with higher irrigation frequencies. Similar result was also observed by Alamin *et al*. (2019) and Roy *et al*. (2017).

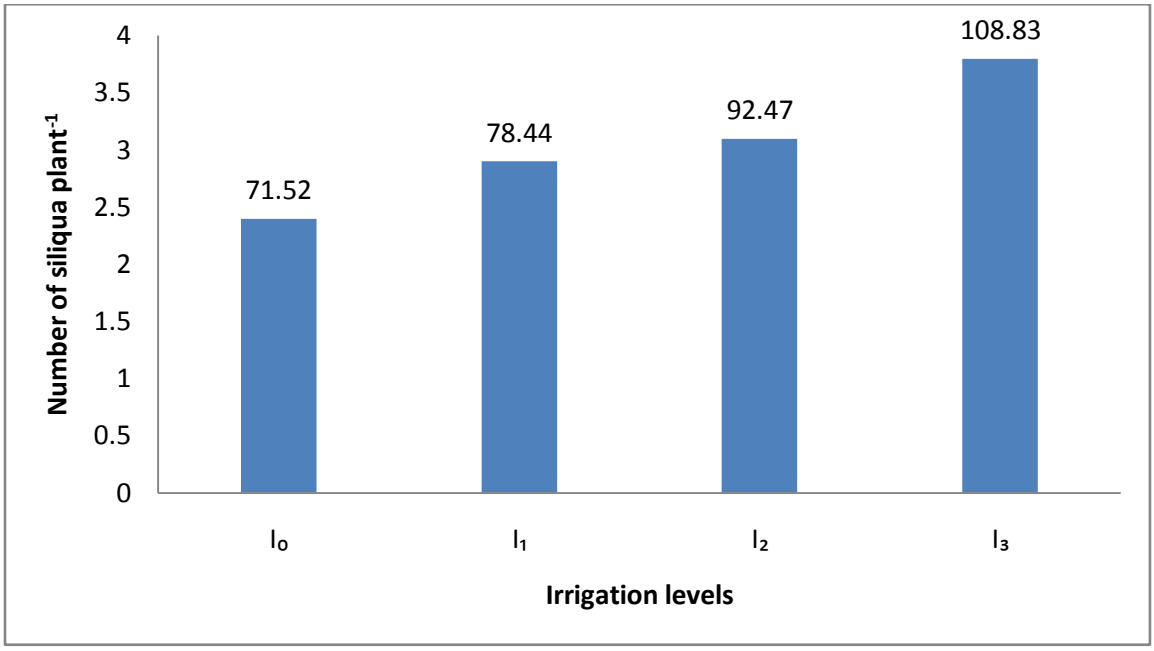


Figure 9. Number of siliqua plant^{-1} of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

There was a significant differences among the treatment combinations of different mustard varieties and irrigation levels on number of siliqua plant^{-1} (Table 2 and Appendix V). Results indicated that the treatment combination V_1I_3 showed the highest number of siliqua plant^{-1} (106.96) which was statistically similar to the treatment combination of V_1I_2. The lowest number of siliqua plant^{-1} (71.31) was recorded in treatment combination V_2I_0 which was statistically similar to the

treatment combination V_2I_1, V_3I_0 and V_2I_2.

4.2.2 Length of siliqua

Effect of variety

Remarkable variation was observed on length of siliqua due to varietal difference (Figure 10 and Appendix V). The highest length of siliqua (6.54 cm) was recorded from the variety BARI sarisha-13 which was followed by BARI sarisha-15, whereas the lowest length of siliqua (5.38 cm) was recorded from the variety BARI sarisha-10. The difference in siliqua length among different varieties is genetically controlled.

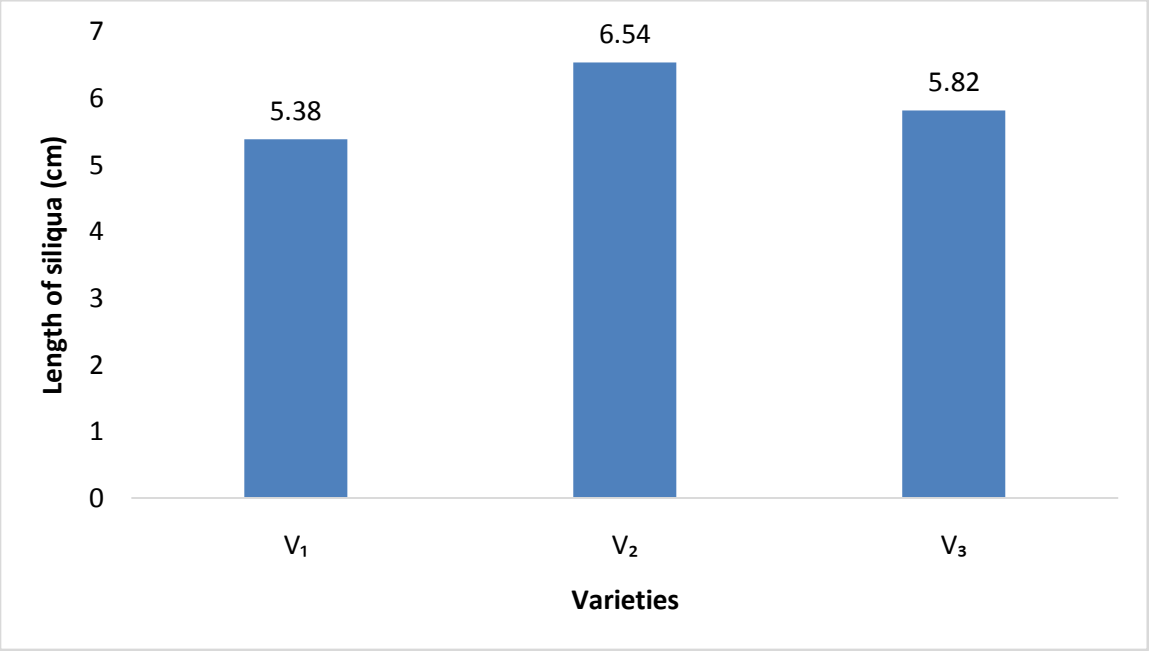


Figure 10. Length of siliqua of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

Different irrigation levels had great influence on length of siliqua (Figure 11 and Appendix V). The highest length of siliqua (6.25 cm) was recorded from I_3 treatment (Three irrigations at 45, 60 and 75 DAS) which was followed by I_2 (Two irrigations at 45 and 60 DAS), whereas the lowest length of siliqua (4.28 cm) was

recorded from the control treatment I_0 (No irrigation). Kibbria (2013) and Latif (2006) concluded that the length of siliqua was significantly increased up to 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).

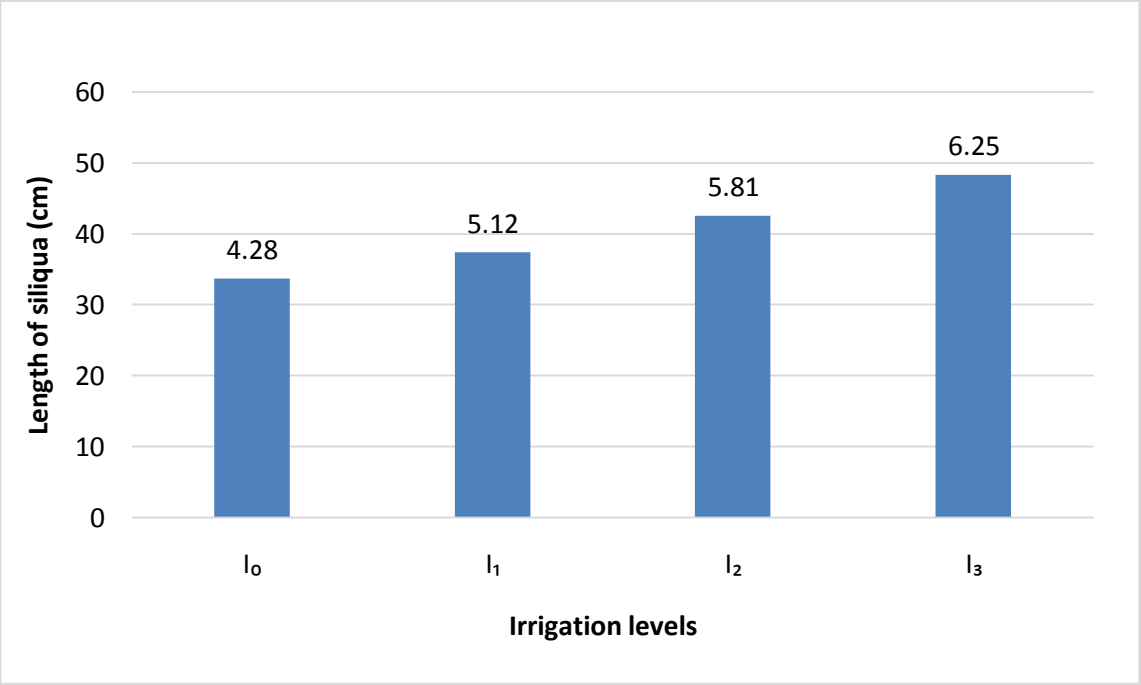


Figure 11. Length of siliqua of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

There was a significant difference among the treatment combinations of different mustard varieties and irrigation levels on length of siliqua (Table 2 and Appendix V). The highest length of siliqua (6.38) was observed in the treatment combination V_2I_3 which was followed by V_2I_2. The lowest length of siliqua (5.14) was recorded in treatment combination V_2I_0 which was statistically similar with the treatment combination V_1I_0.

4.2.3 Number of seeds siliqua^{-1}

Effect of variety

Remarkable variation was found on number of seeds siliqua^{-1} due to the effect of different mustard varieties (Figure 12 and Appendix V). The highest number of seeds siliqua^{-1} (34.67) was recorded from the variety BARI sarisha-13 which was followed by BARI sarisha-15, whereas the lowest number of seeds siliqua^{-1} (14.50) was recorded from the variety BARI sarisha-10.

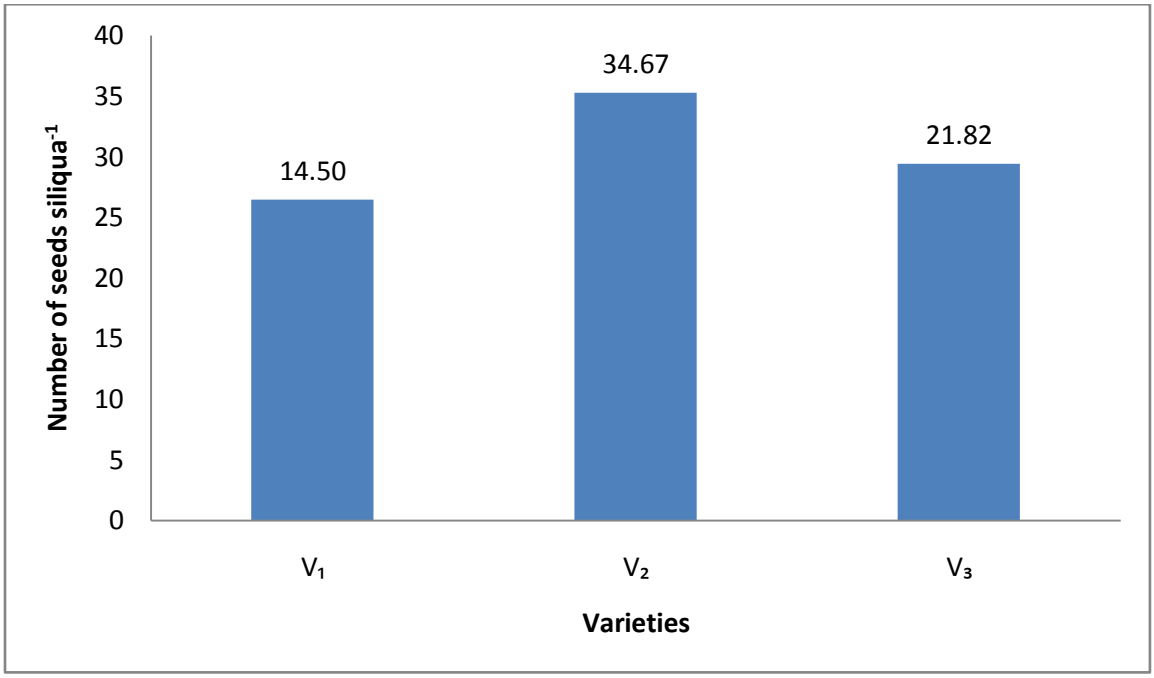


Figure 12. Number of seeds siliqua^{-1}of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

The recorded data on number of seeds siliqua^{-1} was also influenced by different irrigation levels (Figure 13 and Appendix V). The treatment I_3 (Three irrigations at 45, 60 and 75 DAS) gave the highest number of seeds siliqua^{-1} (32.87) which was followed by I_2 (Two irrigations at 45 and 60 DAS), whereas the lowest number of

seeds siliqua^{-1} (16.25) was recorded from the control treatment I_0 (No irrigation). Seeds siliquae^{-1} increased with the increasing the level 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 the 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).

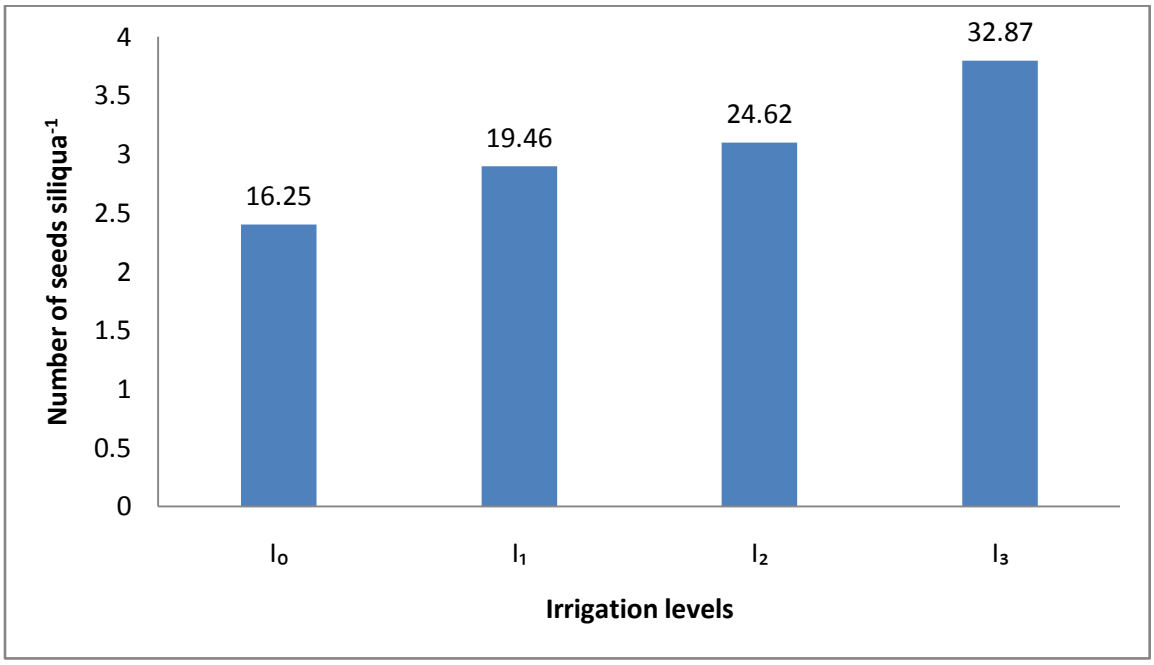


Figure 13. Number of seeds siliqua^{-1} of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

Significant interaction effect among the different mustard varieties and irrigation levels on number of seeds siliqua^{-1} was observed (Table 2 and Appendix V). The

number of seeds siliqua^{-1} was recorded highest (31.77) from V_2I_3. On the other hand the lowest number of seeds siliqua^{-1} (14.68) was recorded from the interaction effect of V_1I_0 that was statistically similar with the treatment combinations of V_1I_1.

4.2.4 Weight of 1000 seeds

Effect of variety

Remarkable variation was recorded on weight of 1000 seeds in different mustard varieties (Figure 14 and Appendix V). The highest weight of 1000 seeds (3.70 g) was recorded from the variety BARI sarisha-13 which was followed by BARI sarisha-15, whereas the lowest weight of 1000 seeds (2.30 g) was recorded from the variety BARI sarisha-10. The variation on 1000 seed weight among different varieties of mustard might be due to genotypic characters of the varieties.

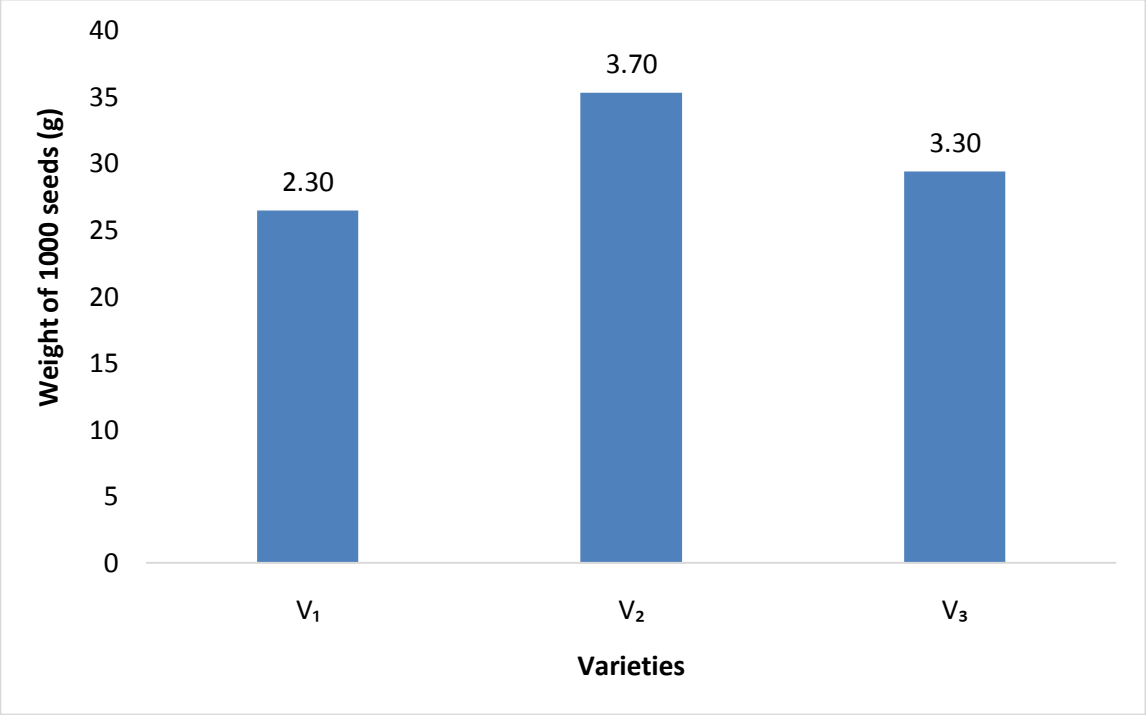


Figure 14. 1000 seed weight of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

Different irrigation levels exhibited significant variation for 1000 seed weight of mustard (Figure 15 and Appendix V). The 1000 seed weight (3.8 g) was recorded highest from I_3 (Three irrigations at 45, 60 and 75 DAS) treatment which was statistically identical with I_2 (Two irrigation at 45 and 60 DAS) and I_1 (One irrigation at 45 DAS), whereas the lowest 1000 seed weight (2.4 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*. (2013), 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 1000-seed weight with two irrigations; one at pre-flowering stage and another at fruiting stage.

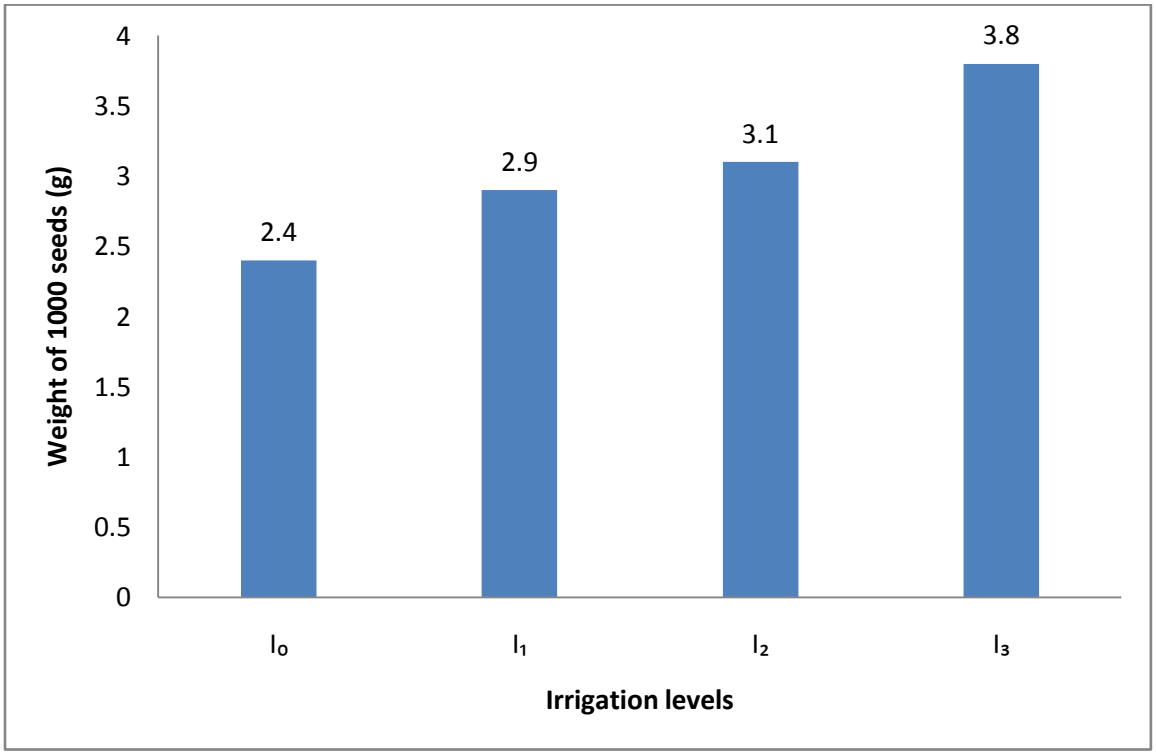


Figure 15. 1000 seed weight of mustard influenced by different irrigation levels

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

Significant interaction effect among the different mustard varieties and irrigation levels on 1000 seeds weight was observed (Table 2 and Appendix V). The maximum 1000 seeds weight (3.70 g) was recorded from the interaction effect of V_2I_3 which was significantly higher than the rest of the treatment combinations which was followed by V_3I_3. On the other hand, the lowest 1000 seed weight (2.20 g) was recorded from the treatment combination of V_1I_0 which was statistically similar with the treatment combination of V_1I_1 and V_1I_2.

Table 2. Yield contributing parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Treatment combinations	Yield contributing parameters			
	Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	Weight of 1000 seeds (g)
V_1I_0	96.24 c	5.27 gh	14.68 h	2.20 f
V_1I_1	101.80 b	5.31 g	15.42 gh	2.30 ef
V_1I_2	104.30 ab	5.36 fg	17.25 fg	2.30 ef
V_1I_3	106.96 a	5.48 ef	19.18 f	2.40 e
V_2I_0	71.31 f	5.14 h	21.71 e	3.10 d
V_2I_1	74.25 ef	5.80 cd	23.59 de	3.30 c
V_2I_2	75.11 def	6.00 b	28.33 b	3.40 bc
V_2I_3	78.66 d	6.38 a	31.77 a	3.70 a
V_3I_0	73.47 ef	5.60 e	22.61 e	3.00 d
V_3I_1	75.57 de	5.64 de	25.52 cd	3.10 d
V_3I_2	76.26 de	5.92 bc	27.17 bc	3.40 bc
V_3I_3	78.62 d	6.04 b	28.89 b	3.50 b
$LSD_{0.05}$	4.257	0.161	2.149	0.131
Significant level	*	**	*	**
CV(%)	10.74	5.92	8.73	6.28

In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15, I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS, NS=Non-significant, * =Significant at 5% level, **= Significant at 1% level

4.3 Yield parameters

4.3.1 Seed yield

Effect of variety

Remarkable variation was observed on seed yield in different mustard varieties (Figure 16 and Appendix VI). Results revealed that the seed yield (1.13 t ha^{-1}) was recorded highest from the variety BARI sarisha-13 (V_2) which was significantly higher than other varieties which was followed by BARI sarisha-15 (V_3), whereas the seed yield (0.75 t ha^{-1}) was recorded lowest from the variety BARI sarisha-10 (V_1). This result indicated that variety plays a significant role for yield performance of mustard. The result obtained from the present study was similar with the findings of Salam *et al*. (2014) and Pradhan *et al*. (2014) who reported significant variation of mustard seed yield among different varieties of mustard.

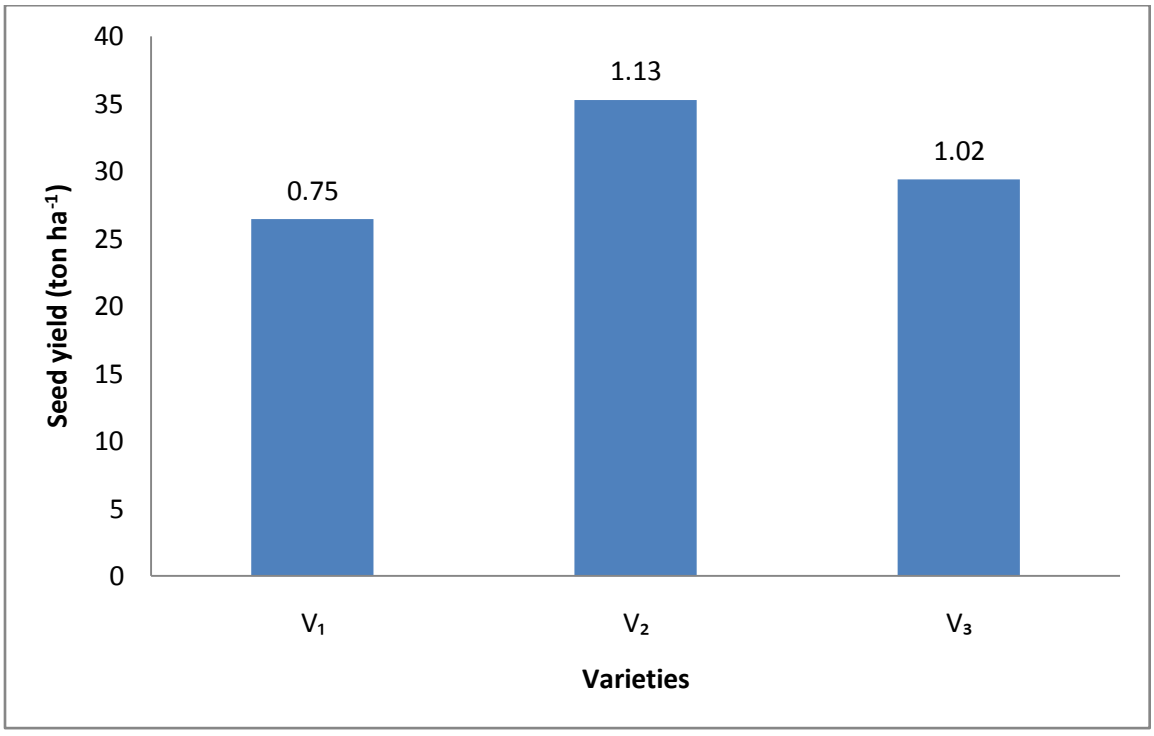


Figure 16. Seed yield of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

Seed yield for different levels of irrigation showed significant variation (Figure 17 and Appendix VI). The seed yield (1.12 t ha^{-1}) was recorded highest from I_3 treatment (Three irrigations at 45, 60 and 75 DAS) which was significantly similar to I_2 (Two irrigations at 45 and 60 DAS) treatment, whereas the lowest seed yield (0.84 ton 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. 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 (Roy *et al*., 2017, Rathore *et al.*, 2019, Hossain *et al*.,2013). These results corroborated with Latif (2006), Sultana (2007), Kibbria (2013), Piri *et al.* (2011) and Singh *et al*. (2019).

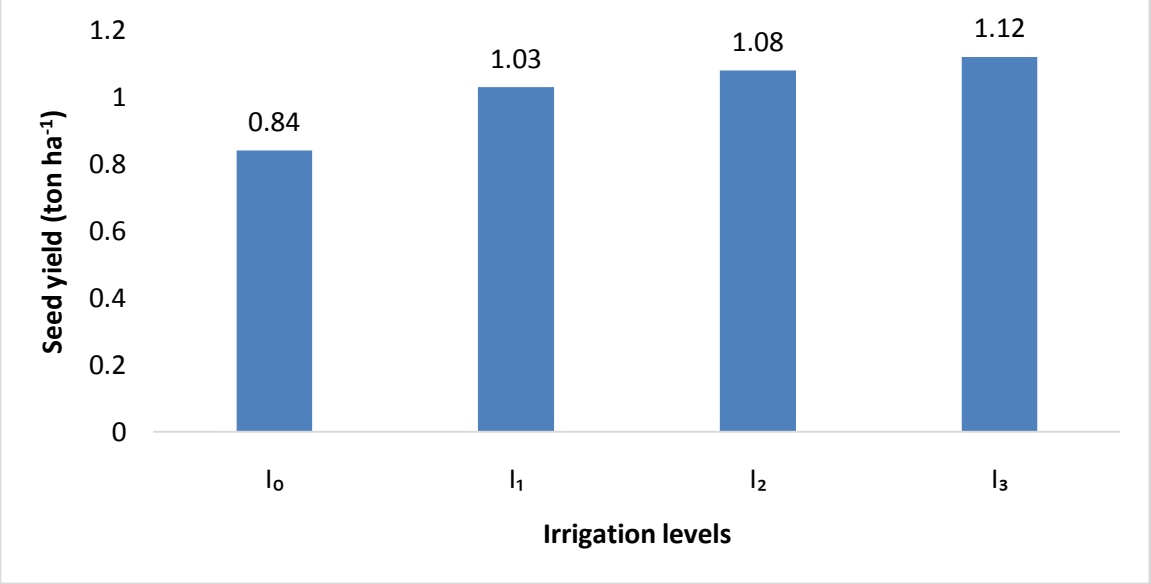


Figure 17. Seed yield of mustard influenced by different irrigation levels

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

Significant interaction effect among the different mustard varieties and irrigation levels on seed yield was observed (Table 3 and Appendix VI). The highest seed yield (1.12 t ha^{-1}) was recorded from the interaction effect of V_2I_3 that was statistically similar with treatment combination of V_2I_2, V_3I_2 and V_3I_3. On the other hand the lowest seed yield (0.76 t ha^{-1}) was recorded from the interaction effect of V_1I_0 which was statistically similar to V_1I_1 and V_1I_2.

4.3.2 Stover yield

Effect of variety

Remarkable variation was identified on stover yield in different mustard varieties (Figure 18 and Appendix VI). The stover yield (1.92 t ha^{-1}) was recorded highest from the variety BARI sarisha-13 which was followed by BARI sarish-15, whereas the stover yield (1.72 tha^{-1}) was recorded lowest from the variety BARI sarisha-10. Significant variation on stover yield of mustard was also obtained by Pradhan *et al*. (2014) which supported the present study.

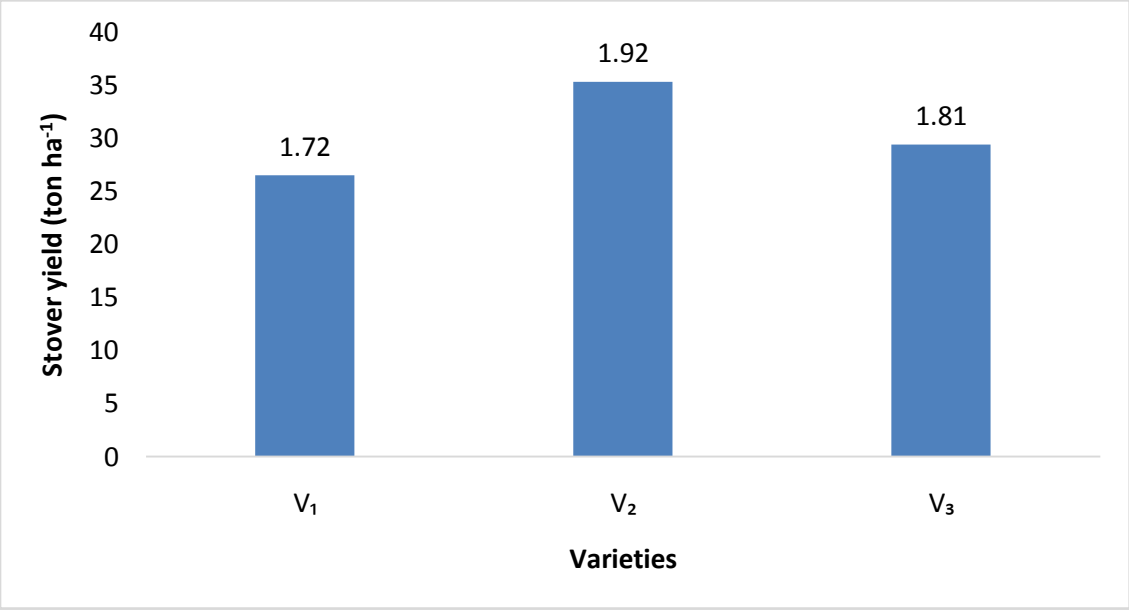


Figure 18. Stover yield of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of irrigation levels

Stover yield for different levels of irrigation also showed significant variation (Figure 19 and Appendix VI). The highest stover yield (1.87 t ha^{-1}) was recorded from I_3 (Three irrigations at 45, 60 and 75 DAS) which was statistically similar to I_2 (Two irrigations at 45 and 60 DAS), whereas the lowest stover yield (1.64 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 (2013) and Piri *et al.* (2011).

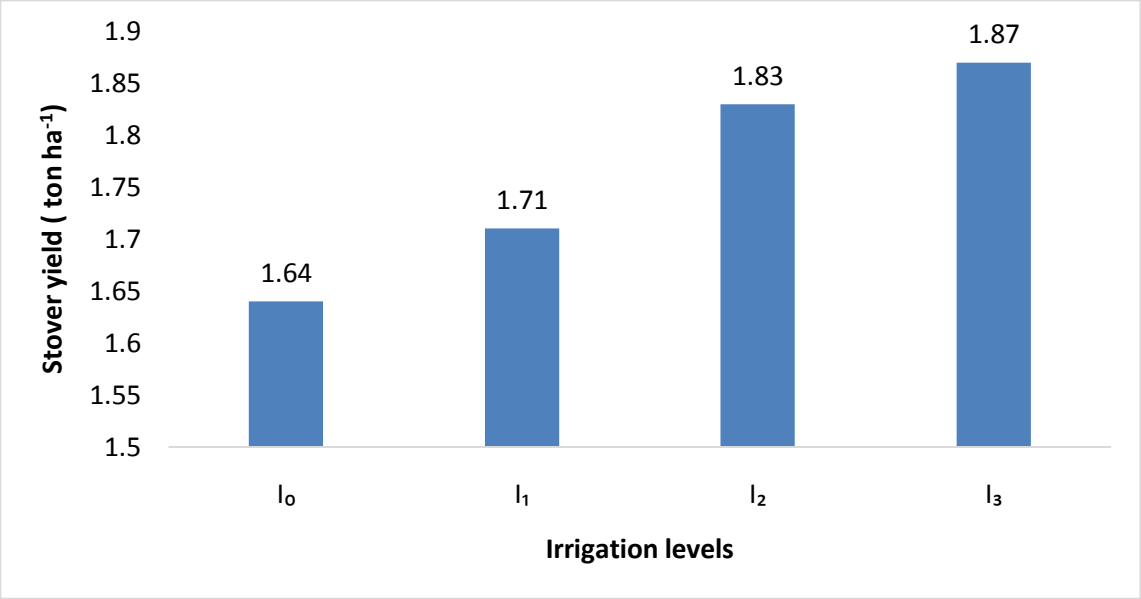


Figure 19. Stover yield of mustard influenced by different irrigation levels

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

Significant interaction effect among the different mustard varieties and irrigation levels on stover yield was observed (Table 3 and Appendix VI). The highest stover yield (1.86 t ha^{-1}) was recorded from the interaction effect of V_2I_3 which was statistically similar with V_2I_2, V_3I_2 and V_3I_3. On the other hand, stover yield was recorded lowest (1.68 t ha^{-1}) from the interaction effect of V_1I_0 which was statistically similar with V_1I_1.

4.3.3 Harvest index

Effect of variety

Remarkable variation was identified on harvest index in different mustard varieties (Figure 20 and Appendix VI). The highest harvest index (35.32%) was recorded from the variety BARI sarisha-13 followed by BARI sarisha-15 whereas the lowest harvest (26.48%) was recorded from the variety BARI sarisha-10. Salam *et al*. (2014) also found similar result with the present study and found significant variation on harvest index among different varieties of mustard.

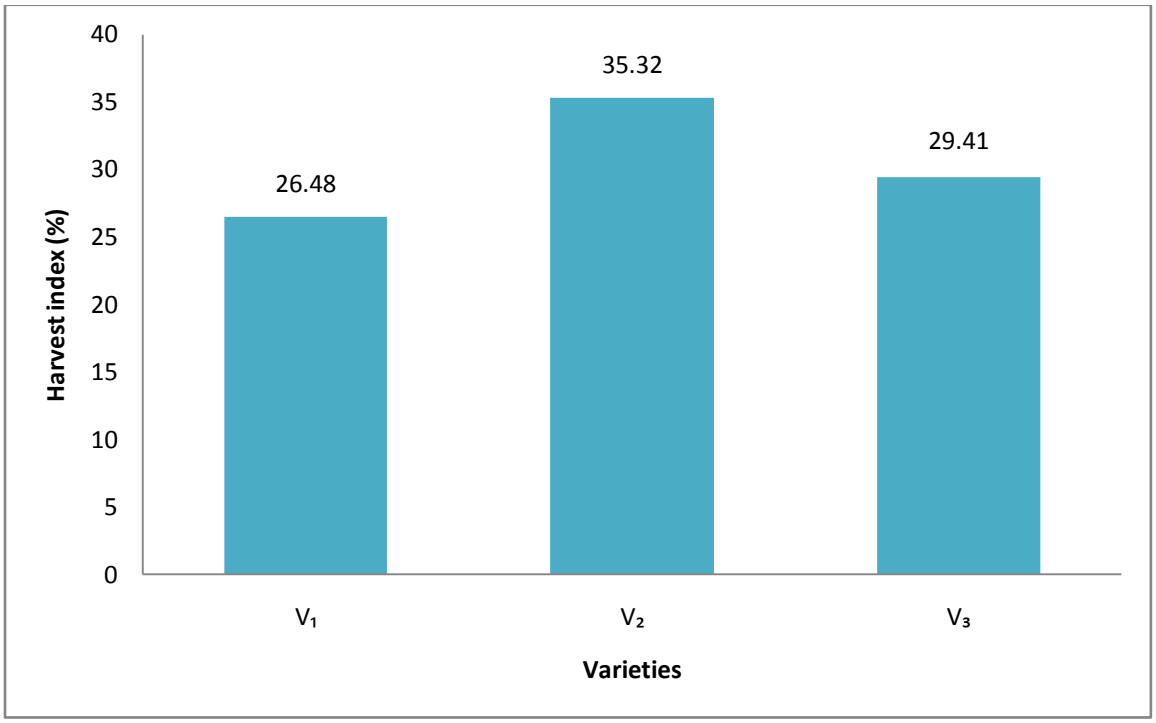


Figure 20. Harvest index of mustard as influenced by different mustard varieties

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

Effect of Irrigation levels

The recorded data on harvest index was greatly influenced by different irrigation levels (Figure 21 and Appendix VI). The highest harvest index (35.32%) was recorded from I_3 (Three irrigations at 45, 60 and 75 DAS) which was significantly higher than rest of the treatments which was followed by I_2 (Two irrigations at 45

and 60 DAS), whereas the lowest harvest index (29.78%) 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).

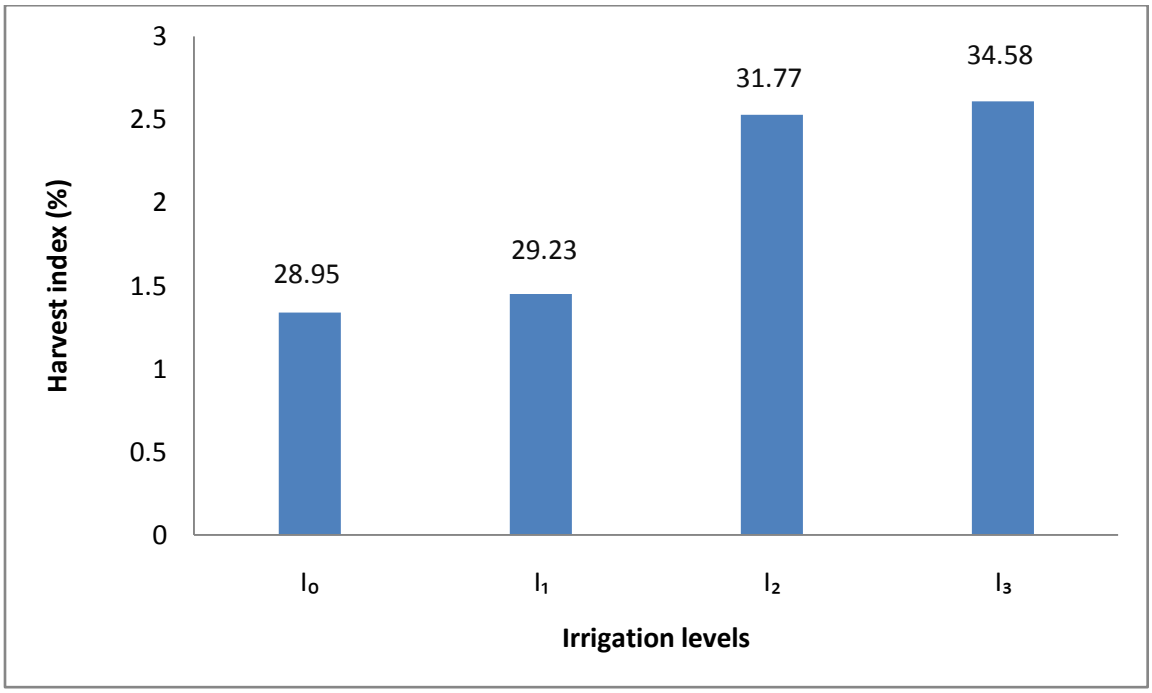


Figure 21. Harvest index of mustard as influenced by different levels of irrigation

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

Interaction effect of variety and irrigation levels

Significant interaction effect among the different mustard varieties and irrigation levels on harvest index was found (Table 3 and Appendix VI). The harvest index was highest (34.93%) from the interaction effect of varieties and irrigation level of V_2I_3 which was statistically similar to V_1I_3. On the other hand, the harvest index was recorded lowest (26.44 %) from the interaction of V_3I_0 that was statistically similar with V_1I_0.

Table 3. Yield parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Treatment combinations	Yield parameters		
	Seed yield (ton ha^{-1})	Stover yield (ton ha^{-1})	Harvest index (%)
V_1I_0	0.76 g	1.68 c	26.44 ef
V_1I_1	0.79 fg	1.71 bc	29.77 c
V_1I_2	0.83 efg	1.74 abc	32.33 b
V_1I_3	0.88 def	1.76 abc	34.50 a
V_2I_0	0.97 bcd	1.77 abc	26.67 de
V_2I_1	1.00 bc	1.80 abc	28.42 cd
V_2I_2	1.05 ab	1.83 ab	32.22 b
V_2I_3	1.12 a	1.86 a	34.93 a
V_3I_0	0.92 cde	1.77 abc	24.58 f
V_3I_1	0.96 bcd	1.81 abc	26.87 de
V_3I_2	1.03 ab	1.82 ab	29.50 c
V_3I_3	1.05 ab	1.84 ab	31.82 b
$LSD_{0.05}$	0.093	0.131	1.880
Significant level	**	**	*
CV(%)	6.83	8.94	7.49

In a column means having similar letters are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BARI sarisha-10, V_2 = BARI sarisha-13, V_3 = BARI sarisha-15

I_0 = Control (No irrigation), I_1 = One irrigation at 45 DAS, I_2 = Two irrigations at 45 and 60 DAS and I_3 = Three irrigations at 45, 60 and 75 DAS

NS=Non-significant * =Significant at 5% level **= Significant at 1% level

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to determine the effect of irrigation frequency on growth and yield of different mustard varieties. The experiment consisted of two factors *viz*. Factor A: Different mustard varieties (3) - BARI sarisha-10, BARI sarisha-13 and BARI sarisha-15; Factor B: Irrigation (4 levels) i.e. control - no irrigation (I_0), one irrigation at 45 DAS (I_1), two irrigations at 45 and 60 DAS (I_2) and three irrigations at 45, 60 and 75 DAS (I_3). There were 12 treatments combinations. The experiment was laid out in two factors 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 different mustard varieties and irrigation levels.

Most of the parameters affected significantly due to varietal difference. In case of growth parameter the highest plant height (96.36 cm), number of leaves plant^{-1} (47.88), number of branches plant^{-1} (7.96) and number of siliqua plant^{-1} (112.67) was recorded from the variety BARI sarisha-10 followed by other variety BARI sarisha-15, whereas the highest length of siliqua (6.54 cm), number of seeds siliqua^{-1} (34.67), 1000 seeds weight (3.7 g), seed yield (1.13 ton ha^{-1}), stover yield (1.92 ton ha^{-1}) and harvest index (35.32%) were found from the variety BARI sarisha-13 followed by the variety BARI sarisha-15.

Considering the application of different irrigation levels, I_3 (Three irrigations at 45, 60 and 75 DAS) treatment showed best results in terms of growth, yield and yield contributing parameters. The highest plant height (94.58 cm), number of

leaves plant^{-1} (48.39), number of branches plant^{-1} (8.17), length of siliqua (6.25 cm), number of siliqua plant^{-1} (108.83), number of seeds siliqua^{-1} (32.87), 1000 seeds weight (3.8 g), seed yield (1.12 t ha^{-1}), Stover yield (1.87 t ha^{-1}) and harvest index (34.58%) were recorded from highest irrigation application I_3 whereas control treatment I_0 gave the lowest results.

In case of interaction effect of variety and irrigation levels, the highest plant height (95.47 cm), number of leaves plant^{-1} (47.58), number of branches plant^{-1} (7.92), number of siliqua plant^{-1} (106.96) was recorded from the interaction effect of V_1I_3. On the other hand, interaction of V_2I_3 gave the highest length of siliqua (6.38 cm), number of seeds siliqua^{-1} (31.77), 1000 Seed weight (3.7 g), Seed yield (1.12 t ha^{-1}), stover yield (1.86 t ha^{-1}) and harvest index (34.93%).

From the above results, it can be concluded that the variety BARI sarisha-13 gave the best result on yield contributing parameters and yield compared to BARI sarisha-15 and BARI sarisha-10. Considering irrigation treatments, three irrigations I_3 at 45, 60 and 75 DAS gave the best performance on growth, yield contributing parameters and yield of mustard. In terms of interaction effect, BARI sarisha-13 treated with three irrigations at 45, 60 and 75 DAS gave best result on yield parameters and yield of mustard compared to the rest of the treatment combinations. So, the treatment combination of BARI sarisha-13 with three irrigations at 45, 60 and 75 DAS can be considered as best interaction compared to the rest of the interactions.

Conclusion

i. Considering varietal performance, BARI sarisha-13 considered as the best variety regarding higher yield of mustard
ii. Considering irrigation treatments, three irrigations frequencies at 45, 60 and 75 DAS considered as the best treatment regarding higher yield of mustard.

Recommendations

i. 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.

ii. Some other mustard varieties with irrigation frequencies can be included for further trial to justify varietal performance of mustard.

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APPENDICES

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

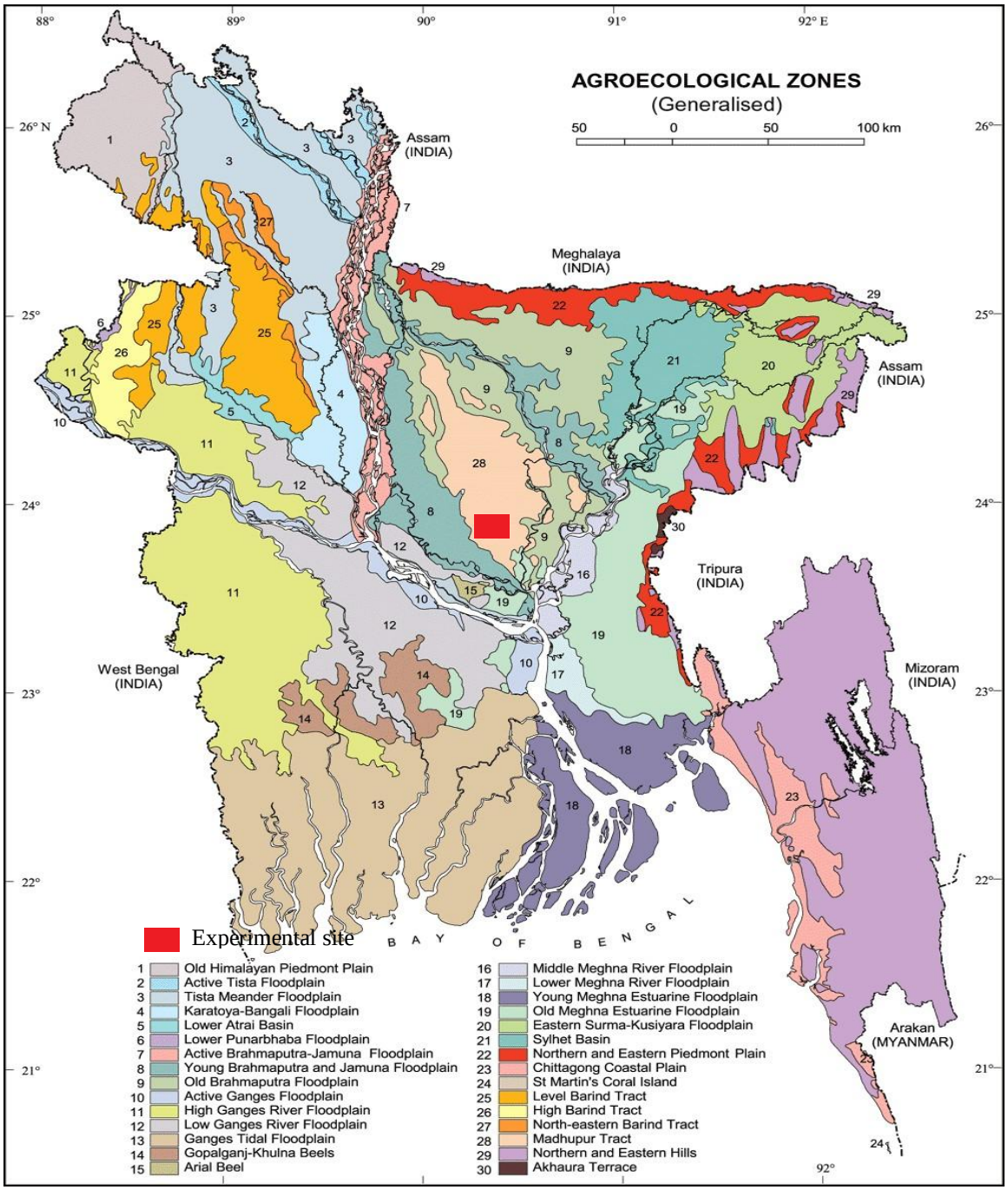

Figure 22. Experimental site

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	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of growth parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Sources of variation	Degrees of freedom	Mean square of growth parameters		
		Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}
Replication	2	3.073	1.806	0.513
Factor A	3	22.752*	11.342*	5.204*
Factor B	2	127.36*	48.378*	9.385*
AB	6	18.377*	14.385*	3.201**
Error	22	2.245	0.402	0.018

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of yield contributing parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	Weight of 1000 seeds (g)
Replication	2	2.758	0.314	1.807	0.417
Factor A	3	16.529*	5.209*	8.305*	3.074*
Factor B	2	103.43*	11.30*	22.403*	5.801*
AB	6	9.274*	4.207*	5.211*	2.377**
Error	22	2.107	0.003	0.537	0.002

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of yield parameters of mustard as influenced by different levels of irrigation on different BARI Sarisha varieties

Sources of variation	Degrees of freedom	Mean square of yield parameters		
		Seed yield (ton ha^{-1})	Stover yield (ton ha^{-1})	Harvest index (%)
Replication	2	0.107	0.117	1.244
Factor A	3	0.436*	1.304**	12.36*
Factor B	2	1.209*	3.053*	18.91*
AB	6	0.376**	0.874**	6.533**
Error	22	0.001	0.002	0.411

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level