EFFECT OF SOWING TIME AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF MUSTARD (*Brassica napus* L.)

A THESIS

BY

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CERTIFICATE

*This is to certify that the thesis entitled, **"EFFECT OF SOWING TIME AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF MUSTARD"** 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 **MASTER OF SCIENCE IN AGRICULTURAL BOTANY,** embodies the results of a piece of bonafide research work carried out by **MD. ALAMIN** Registration No. **12-05181** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2019

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DEDICATED TO
MY
BELOVED MOTHER

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The Author

EFFECT OF SOWING TIME AND IRRIGATION FREQUENCY ON GROWTH AND YIELD OF MUSTARD (*Brassica napus* L.)

BY

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ABSTRACT

The experiment was conducted at the experimental field of Agricultural Botany of Sher-e-Bangla Agricultural University during November 2017 to February 2018 to evaluate the effect of sowing time and irrigation frequency on the growth and yield of mustard. The treatments consisted of three different sowing times (*viz*., T_1 = Early sowing (1 November), T_2 = Optimum sowing (15 November), T_3 = Late sowing (30 November), and four irrigation frequency (*viz*., I_0=No irrigation, I_1= 1 irrigation (20 DAS), I_2 =2 irrigations (20, 40 DAS) and I_3= 3 irrigations (20,40,55 DAS). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The collected data were statically analyzed for the evaluation of the treatment effects. There were a significant variation among the treatments in respect of major parameters studied. The tallest plant was recorded from the treatment of optimum sowing time. The maximum number of leaves, number of branches plant^{-1}, number of siliquae plant^{-1} and length of siliqua were obtained from the treatment of optimum sowing time. The maximum yield (1.12 t ha^{-1}) of seed was exhibited from optimum sowing time. The tallest plant was found from the plants which were provided with three irrigations. The maximum branches plant^{-1}, siliqua plant^{-1} and seed silliqua^{-1} were recorded from three irrigations treatment. The highest (1.05 t ha^{-1}) yield of seed was obtained from three irrigations treatment. The combinations of sowing time and irrigation had significant effects on most of the parameters. The highest yield (1.42 t ha^{-1}) of seed was obtained from the combination of three irrigations and optimum sowing. The highest stover and biological yield were obtained from the combination of three irrigations and optimum sowing time under the climatic and edaphic condition of SAU.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
LAI	=	Leaf area index
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
G	=	gram (s)
Kg	=	Kilogram
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Mustard belongs to the family Brassicaceae (Cruciferae), is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). *Brassica napus*, *B. campestris* and *B. juncea are* the three species of mustard those produce edible oil. Oil seed rape (*Brassica napus* L.) has become one of the most important oil crops (Miri, 2007) and at present, is the third largest source of vegetable oil all over the world (Starner *et al*., 1999). In Bangladesh context, mustard (*Brassica spp*.) is a popular edible oil in rural area and is considered important for improving the taste of a number of food items (Aziz *et al*., 2011a). 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. Mustard and rapeseed are quietly significant in Bangladesh economy. It is an important oil seed crop in Bangladesh. Rapeseed (*Brassica campestris* L.) commonly known as mustard oil seed crop in Bangladesh, is a cool season crop. It is also a thermo sensitive as well as photosensitive crop (Ghosh and Chatterjee, 1988). It also serves as an important raw material for industrial use such as in soap, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals, etc. Its oil not only plays a great role as fat substitute in our daily diet but also nourish the economy of the nation. It is widely used as a cooking ingredient, condiment and for its medicinal value. Moreover, mustard oilcake is utilized as cattle feed and small quantities are also used as manure. It accounts about 72% of total oil seed production in the country.

Mustard is one of the most important oilseed crops throughout the world after soybean and groundnut (FAO, 2004). It has a remarkable demand for edible oil in Bangladesh. It occupies first position of the list in respect of area and production among the oilseed crops grown in this country (BBS, 2004). Oilseeds are important in the economy of Bangladesh. They constitute the most important group of crop next to cereals occupying 4.22% of the total cropped area (BBS, 2009). In the year 2011-12, the total oilseed production was 8.44 Mt and total area covered by oilseed crops was 7.23 ha and yield 1.17 Mt ha^{-1}. In the year of 2011-12, mustard covered 4.83 ha land and the production was 5.25 Mt and yield 1.09 Mt ha^{-1} (Krishi Diary, 2013).

Mustard is rich in minerals like calcium, magnesium, iron, vitamin A, C and proteins. 100 g mustard seed contains 508 kcal energy, 28.09 g carbohydrates, 26.08 g proteins, 36.24 g total fat, 12.2 g 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).

Rapeseed-mustard is grown more or less all over Bangladesh, but more particularly in the districts of Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur, Dhaka (BBS, 2012).

Days to flowering and maturity were different at different planting times. Date of sowing significantly influenced plant height, siliquae plant^{-1}, seeds siliqua^{-1}, seed yield, and oil content of seed. Interaction effect of variety and sowing date significantly influenced plant height, number of siliquae plant^{-1}, number of sees siliqua^{-1}, seed yield, and strover yield (Alam *et al.*, 2014) . Research finding shaveal so shown that sowing date is one of the critical components affecting mustard crop productivity. It is one of the most important agronomic factor and non-monetary input which pave the way for better-use of time and play an important role to fully exploit the genetic potentiality of a variety as it provides optimum growth conditions such as temperature, light, humidity and rainfall. Sowing period in formation is needed for various other purposes like adjusting crop rotations; cropping patterns, crop growth simulations and climate change impact studies. Sowing time is also important in deciding the environmental conditions of crop, timing and rate of organ appearance while in crop growth analysis predicting of phenology is of prime importance. Since the temperature and solar radiation play an important role in partitioning of biomass between various organs of plant which is related to, and often governed by phonological phase of the plant and the way in which a crop develops can affect the yield and this therefore an aspect with which agronomists are much concerned. The crop is mainly grown during the winter season (October-March). The growth yield attributes and yield of mustard increased significantly with the increase in number of irrigation. Applications of three irrigations significantly increased seed yield by 15.5% and 52.8% over two and one irrigations, respectively. Adequate supply of moisture in soil helps in proper utilization of plant nutrients, resulting in proper growth and high yield (Verma *at al.,* 2014). If the mustard is sown late, duration is reduced due to the high temperature during the reproductive phase with concomitant reduction in yield (Kumari *et al*., 2005). Some researchers demonstrated that the yield of mustard crop sown in second fortnight of September was significantly higher than that sown in first fortnight of October (Iraddi, 2008). In general, it was observed that the mustard crop sown after October 30th resulted in lower yields (Panwar *et a*l., 2000; Singh *et al*., 2002a; Sonani *et al*, 2002; Panda *et al*., 2004b). Understanding of physiological and phenological causes of yield reduction with reference to date of sowing can help to develop strategies for improvement in the seed yield. Further, it will help in the assertion that productivity is constrained by development pattern and process physiology in response to environment.

The frequency of irrigation and the amount of water required depend on such factors as cultivar, soil type, season, amount of rainfall and diseases; therefore, it is difficult to give definite recommendation. Over irrigation, as well as under irrigation may lower yields. Efficient water management thus plays a vital role in mustard production. This can be achieved by adopting improved irrigation practices. Although both timing and the amount of water applied affect irrigation efficiency, timing has greater effect on the yield and quality of a crop. Therefore, a judicious irrigation schedule is needed to avoid over or under irrigation and for profitable mustard cultivation.

Delayed sowing influences both the productivity of seed and oil yield to a great extent. It would influence adversely the crop performance owing to change in abiotic and biotic environmental conditions (Singh *et al.,* 2011). Irrigation had significant effect on all the yield and yield contributing characters (Hossain *et al.*, 2013). Optimum sowing time plays an important role to fully exploit the genetic potentiality of a variety as it provides optimum crop growing environment such as temperature, humidity and light etc. Sowing time is one of the most important non-monetary input which influences to a great extent on both the quality and economics of mustard (Singh *et al.*, 2017).

Keeping in view of above facts, a field experiment entitled, “effect of sowing time and irrigation frequency on growth and yield of mustard” was conducted during *rabi* season 2017-18 with following objectives:

i. To observe the effect of different sowing times on growth and yield of mustard.
ii. To investigate the growth and yield of mustard under varying levels of irrigation.
iii. To evaluate the combined effect of sowing times and irrigations on growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

Mustard and rapeseed is important oil crop of Bangladesh which contributes to a large extent in the national economy. But the research works done on this crop with respect to agronomic practices are inadequate. Its growth and yield are determined by various factors of which sowing time is one of the most important. A very limited works have been done involving the sowing time with the mustard (rapeseed) varieties. Some of the work applicable to the present study has been reviewed below:

2.1 Effect of sowing time

Appropriate sowing date is the most important non-monetary input which contributes towards the improved yield of a crop. As different cultivars of mustard have different optimum sowing dates, this also indicates the flexibility in sowing dates for fitting a particular cultivar in multiple cropping systems. Moreover, response of different cultivars may differ under various sowing dates. Thus, optimum sowing date for a particular cultivar under consideration may play a great role in exploiting the yield potential of that cultivar (Patel, 2013).

The genetic potential of a plant is fully expressed only under optimum environment conditions, which depends upon various factors viz., temperature and radiation exposure, plant age, stage of development etc., under actual field conditions. However, environmental conditions change continuously and rarely the plant experiences optimum conditions at all stages of growth. Out of all possible environmental factors, radiation, temperature, water and nutrients have been recognized as the most important factors influencing course of plant growth and development.

2.1 .1 Plant height

Tomar and Mishra (1991) reported that the plant height of mustard was significantly higher with 30th October (173.1 cm) sowing as compared to 10th November (162.9 cm) and 20th November (155.8 cm) sowings.

Kumar and Shaktawat (1992) revealed higher plant height with 8th September sowing (112.7 cm) as compared to 22nd September sowing (108.8 cm). Chandrakar and Urkurkar (1993) reported that plant height was significantly higher with 23rd November sowing (158 cm) as compared to 14th December sowing (129 cm). Yadav *et al*. (1994b) observed that crop sown on 5th October recorded significantly higher plant height (178 cm) as compared to 25th October (146 cm) sown mustard crop. Surekha and Reddy (1996) emphasized that plant height was higher with 5th October sowing as compared to 5th and 20th November sowing. Shahidullah *et al.* (1997) at Dhaka (Bangladesh) conducted a field experiment and reported that plant height was higher with 16th November sowing as compared to 27th October sowing.

Butter and Aulakh (1999) reported that plant height was higher with early sowing of 25th October. Khichar *et al.* (2000) reported that greater plant height was recorded under 20th October sowing (185 cm) as compared to other sowings. Singh *et al*. (2001) revealed that mustard sown on second week of October recorded significantly higher plant height (188 cm) as compared to first week of November (171 cm). Singh and Singh (2002) suggested that higher plant height was recorded with October sowing as compared to 29th October, 13th November and 28th November sowing. Singh *et al.* (2002b) at Ludhiana (Punjab) quoted that early sowing on 10th and 30th October were recorded higher plant height as compared with 20th November and 10th December sowings. Kurmi (2002) reported that greater plant height was observed with 17th November sowing (97 cm) as compared to 14th December (77 cm) sowing. Panda *et al.* (2004a) conducted a field experiment at IARI, New Delhi and reported that plant height was higher with 16th October sowing as compared to 31st October and 15th November sowing. Kumari *et al*. (2005) reported that the plant height was significantly higher (160.2 cm) with 1st October sowing as compared to 15th September (157.4 cm), 15th October (153.6 cm) and 1st November (143.9 cm) sowings.

Sharma *et al*. (2006) reported that the significantly greater plant height was observed at 75 DAS with 29th October sowing (160.6 cm) as compared to 22nd October (158.5 cm), 12th October (145.7cm) and 6th October (140.4 cm) sowings. Sultuna (2007) studied on rapeseed in Sher-e-Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She revealed that seed yield highest (1827.0 kg ha^{-1}) at three irrigation (20, 35, 50 DAS). Bhuiyan *et al.* (2008) reported significantly higher plant height under 10th November sowing (115 cm) as compared to 30th October (105 cm), 20th November (104 cm), 20th October (100 cm), 30th November sowings. Shah *et al*. (2009) observed significantly higher plant height with 15th September (212.5 cm) sowing as compared to 25th September (203.8 cm), 5th October (183.2 cm), 15th October (188.3cm), 25th October (181.1 cm), 5th November (155.6 cm), and 15th November (126.1cm) sowings.

Lallu *et al*. (2010) revealed that November sowing caused the significant reduction in plant height (100.5 cm) as compared to October sowing (152.8 cm). Afroz *et al.* (2011) at Mymensingh (Bangladesh) observed that significantly higher plant height was found under 10th November sowing (99.4 cm) as compared to 20th November (93.0 cm) and 30th November (78.0 cm) sowings. Aziz *et al.* (2011) at Khagrachari (Bangladesh) also reported that 15thNovember sown mustard crop produced the maximum plant height (162 cm) as compared to 25th November, 5th December and 15th December. Mondal *et al.* (2011) reported that plant height was significantly higher with 20th November sowing (104.2 cm) 20th October (102.9 cm) as compared to 10th November (100.7 cm), 1st November (100.1 cm) and 30th November (98.3 cm) sowings. Kumari *et al.* (2012) observed that 10th October sowing resulted into significantly higher plant height (217 cm) over 20th October sowing (208 cm) and 30th October sowing (187 cm).

Patel *et al.* (2017) reported that plant height increased successively till 90 DAS under different dates of sowing. Different dates of sowing had no significant influence on plant height at 30 DAS which might be due to similar growth pattern at initial growth period. Whereas at 60 DAS, 90 DAS and at harvest, plant height was found to be highest with crop shown on 14th November which was at par with 30th October and significantly higher over 15th October and 29th November. The varieties had no significant influence on plant height at 30 DAS which might be due to similar growth pattern at initial growth period whereas at 60, 90 DAS.

2.1.2 Primary branches plant^{-1}

Vasi *et al*. (1986) quoted that number of secondary branches (plant^{-1}) recorded higher under 27th September sowing (18.9) as compared to 18th October sowing (13.7). Tomar and Mishra (1991) reported that the number of primary and secondary branches of mustard crop (5.93, 9.75) was significantly greater with 30th October sowing as compared to 10th November (5.39, 8.15) and 20th November (4.52, 6.12) sowings. Kumar and Shaktawat (1992) reported that number of primary and secondary branches recorded higher with 22nd September sowing (6.9 and 13.6 branches plant^{-1}) as compared to 8th September sowing (6.3 and 12.2 branches plant^{-1}).

Choudhary and Thakuria (1994) revealed that number of secondary branches were significantly higher with 15th November sowing (12 plant^{-1}) as compared to 5th December sowing (3 plant-1). Yadav *et al.* (1994b) observed that number of primary and secondary branches (plant-1) were significantly higher under 5th October (6.9 and 13.4 cm) sown crop as compared to 25th October (5.4 and 11.2). Surekha and Reddy (1996) reported that the crop sown on 5th October recorded higher number of primary and secondary branches as compared to 5th and 20th November sowings.

Bhatnagar *et al*. (1997) quoted that number of primary branches (plant^{-1}) recorded higher with 15th October sowing (9.2 plant^{-1}) as compared to 30th November sowing (5.9 plant^{-1}). Shahidullah *et al*. (1997) at Dhaka (Bangladesh) reported that 27th October sowing recorded higher number of primary and secondary branches (plant^{-1}) as compared to 6th or 16th November sowing. Reddy and Kumar (1997) observed that number of primary branches recorded higher with 4th October sowing (4.6 plant^{-1}) as compared to 5th November sowing (3.5 plant^{-1}). Thakur and Singh (1998) reported that number of primary and secondary branches (plant^{-1}) recorded higher under 5th October sowing (6.7, 14.1) as compared to 19th November sowing (5.5, 7.7). Buttar and Aulakh (1999) quoted that the number of secondary branches (plant^{-1}) were higher with early sowing of 25th October.

Singh *et al.* (2001) reported that crop sown on third week of October recorded significantly higher number of primary branches (5.87 plant^{-1}) as compared to first week of November sowing (4.57 plant^{-1}). Singh *et al.* (2002b) reported that number of primary and secondary branches (plant^{-1}) were higher with 10th and 30th October sowing as compared to 20th November to December sowing. Kurmi (2002) conducted an experiment and quoted that number of primary and secondary branches (plant^{-1}) recorded higher in 17th November sowing (4, 9) as compared to December (3, 6) sowing. Shivani and Kumar (2002) emphasized that crop sown on 25th September and 5th October recorded significantly higher number of primary and secondary branches than 15th October, 25th October and 4th November sown crop. Singh and Singh (2002) suggested that number of primary and secondary branches (plant^{-1}) recorded higher with 14th October sowing as compared to 29th October, 13th November and 28th November sowing.

Kumar *et al.* (2004) quoted that crop sown on 21st October recorded higher number of primary and secondary branches (plant^{-1}) as compared to 7th and 17th October sowing. Panda *et al.* (2004a) suggested that delayed sowing beyond 16thOctober reduced the number of primary and secondary branches (plant^{-1}). Sharma et al. (2006) at Nagpur (Maharashtra) reported that the significantly higher number of branches was observed at 75 DAS with 29th October sowing (10.4 plant^{-1}) as compared to 22nd October (10.1 plant^{-1}), 12th October (9.27 plant^{-1}) and 6th October (8.64 plant^{-1}) sowings.

Kumar *et al.* (2008) reported that the number of branches plant^{-1} were significantly greater in mustard were with 30th September (22.2 plant^{-1}) sowing as compared to 15th October (19.7 plant^{-1}), 30th October (16.6) and 14th November (14.3 plant^{-1}) sowings. Bhuiyan *et al.* (2008) reported significantly higher primary branches in 20th October (6.85 plant-1), as compared to 30th October (6.72 plant^{-1}), 20th November (6.25 plant^{-1}), 10th November (6.22 plant^{-1}) and 30th November (6.20 plant^{-1}) sowings.

Lallu *et al.* (2010) observed that November sowing caused the significant reduction in total number of branches (21.4 plant^{-1}) as compared to October sowing (31.6 plant^{-1}). Afroz *et al.* (2011) observed that significantly higher branches were found in 10th November sowing (2.94 plant^{-1}) as compared to 20th November (2.50 plant^{-1}) and 30th November (1.89 plant^{-1}) sowings. Kumari e*t al.* (2012) observed that 10th October sowing recorded significantly higher primary and secondary branches plant^{-1} (7.8, 19.9) over 20th October sowing (7, 17.6) and 30th October sowing (6.4, 14.1).

2.1.3 Siliquae plant^{-1}

Tomar and Mishra (1991) observed that the number of siliquae were significantly greater with 30th October (199.8 plant^{-1}) sowing as compared to 10th November (169.6 plant^{-1}) and 20th November (149.9 plant^{-1}) sowings. Kumar and Shaktawat (1992) reported that mustard sown on 22nd September recorded higher number of siliquae (169.0 plant^{-1}) as compared to 8th September (151.7 plant^{-1}) sown crop. Kurmi and Kalita (1992) observed that number of siliquae was recorded higher with 17th November (192.1 plant^{-1}) sowing as compared to 2nd December (150.4 plant^{-1}) sowing. Chandrakar and Urkurkar (1993) reported that the number of siliquae were recorded higher under 23rd November sowing (146 plant^{-1}) compared to 14th December sowing (74 plant^{-1}).

Choudhary and Thakuria (1994) observed that number of siliquae was recorded significantly higher under 15th November sowing (224 plant^{-1}) as compared to 5th December sowing (50-81 plant^{-1}). Reddy and Kumar (1997) suggested that the number of siliquae (plant^{-1}) were recorded higher under 4th October sowing (142) compared to 5 November sowing (93). Similarly, Yadav *et al.* (1994a) reported that crop sown on 5 October recorded significantly higher number of siliquae (454 plant^{-1}) as compared to 25 October sowing (264 plant^{-1}).

Surekha and Reddy (1996) observed that the number of siliquae (plant^{-1}) was recorded higher with 5th October sowing as compared to 5thand 20th November sowings. Shahidullah *et al.* (1997) reported that the number of siliquae (plant^{-1}) was decreased with delay in sowing from 27th October to 6th and 16th November.

Thakur and Singh (1998) quoted that number of siliquae (plant^{-1}) was recorded higher with 5th October sowing (268.6) as compared to 19th November sowing (172.9). Zekatte (1999) conducted a field experiment at the Perloja Research Station, Lithuania on sandy loam soil and reported that early springsown mustard crop produced more siliquae plant^{-1} (63.7 – 66.0). Buttar and Aulakh (1999) reported that the number of siliquae (plant^{-1}) was recorded highest in early sowing (25th October). Singh *et al.* (2001) reported that the number of siliquae (plant^{-1}) was recorded significantly higher under third week of October sowing (209) as compared to first week of November sowing (173). Singh *et al.* (2002b) observed that number of siliqua (plant^{-1}) was higher in 10 and 30 October sowings compared to 20th November and 10th December sowings. Shivani and Kumar (2002) emphasized that crop sown on 25th September and 5th October recorded higher number of siliquae (plant^{-1}) as compared to 15th October, 25th October and 4th November sowing. Kurmi (2002) conducted a field experiment and quoted that number of siliquae (plant^{-1}) recorded higher with 17th November sowing (104) as compared to 14th December sowing (86).

Panda *et al*. (2004a) emphasized that delayed sowing beyond 16th October reduced the number of siliquae (plant^{-1}). Kumar *et al.* (2004) quoted that the number of siliquae (plant^{-1}) were recorded higher when mustard crop sown on 21st October as compared to 7th and 14th October. Sharma *et al.* (2006) reported that the significantly higher siliquae (plant^{-1}) were observed with 29th October sowing (139.7) as compared to 22nd October (129.1), 12th October (103.1) and 6th October (97.1) sowings.

Kumar *et al*. (2008) reported that the number of siliquae (plant^{-1}) in mustard were found significantly greater under 30th September (201) as compared to15th October (197), 30th October (175) and 14th November (170) sowings.

Bhuiyan *et al*. (2008) reported that significantly higher number of siliquae (plant^{-1}) were observed in 30th October (85) sowing as compared to 20th October (84), 10th November (77), 20th November (77), and 30th November (66) sowings. Lallu *et al.* (2010) observed that November sown mustard crop resulted into significant reduction in siliquae (plant^{-1}) as compared to October sowing (plant^{-1}).

Afroz *et al*. (2011) quoted that significantly higher siliquae (plant^{-1}) were found in 10th November sowing (161.2) as compared to 20th November (148.0) and 30th November (128.9) sowings. Aziz *et al.* (2011) reported that 15 November sowing mustard crop produced the maximum number of siliquae (254 plant^{-1}) as compared to 25th November, 5th December and 15th December. Mondal *et al.* (2011) reported that number of siliquae (plant^{-1}) were significantly higher with 1st November (97) as compared to 20th October (86), 10th November (71.0), 20th November (57.3) and 30th November (69.7) sowings. Kumari *et al.* (2012) suggested that 10th October sowing recorded significantly higher number of siliquae (323 plant^{-1}) over 20th October sowing (302 plant^{-1}) and 30th October sowing (238 plant^{-1}).

2.1.4. Seeds siliqua^{-1}

Singh *et al*. (2001) reported that the number of seeds (siliqua-^{1}) were higher with third week of October sowing (13.6) as compared to first week of November sowing (11.8).

Singh *et al*. (2002b) observed that the number of seeds (siliqua^{-1}) were higher in 10th and 30th October sowing as compared to 20th November and 10th December sowing. Kurmi (2002) suggested that the number of seeds (siliqua^{-1}) were recorded higher with 17th November sowing (17) as compared to 14th December sowing (14). Singh *et al.* (2002a) quoted that crop sown on 5th October resulted into higher number of seeds (13 siliqua^{-1}) as compared to 5th November sowing (11 siliqua^{-1}). Shivani and Kumar (2002) reported that sowings on 25th September and 5th October resulted into significantly higher number of seeds (siliqua^{-1}) as compared to 15th October, 25th October and 4th November sowings.

Kumar *et al.* (2008) observed that the number of seeds (siliqua^{-1}) in mustard were significantly higher with 30th September (18) sowing as compared to 15th October (16), 30th October (15) and 14th November (14) sowings. Bhuiyan *et al.* (2008) reported that the number of seeds (siliqua^{-1}) were found significantly higher in 30th October (24) sowing as compared to 20th October (21.3), 10th November (22.8), 20th November (21.8), and 30th November (18.8) sowings.

Afroz *et al.* (2011) observed significantly higher number of seeds (siliqua-1) under 20th November sowing (18.4) as compared to 10th November (16.7) and 30th November (16.1) sowings. Aziz *et al.* (2011) reported that 15th November sown mustard crop produced more seeds (13.4 siliqua^{-1}) as compared to 25th November, 5th December and 15th December sowings. Mondal *et al.* (2011) reported that number of seeds (siliqua-1) were significantly higher with 1st November (21.8) as compared to 20th October (19.1), 10th November (20.5), 20th November (18.3) and 30th November (16.9) sowings. Kumari *et al.* (2012) observed that 10th October sowing recorded significantly higher number of seeds (14.2 siliqua^{-1}) over 20th October sowing (13.4 siliqua^{-1}) and 30th October sowing (11.4 siliqua^{-1}).

Singh *et al.* (2001) observed that crop sown on third week of October recorded higher 1000- seeds weight (4.51 g) as compared to first week of November sowing (3.77 g). Singh *et al.* (2002a) observed that mustard sown on 5th October resulted into significantly higher 1000-seeds weight (5.7 g) as compared to 5th November sown crop (4.4 g).

Singh *et al.* (2002b) revealed that 1000-seeds weight was recorded higher in 10th and 30th October sowings as compared to 20th November and 10th December sowing. Shivani and Kumar (2002) suggested that 1000-seeds weight was recorded higher under 25th September and 5th October sowing as compared to 15th October, 25th October and 4th November sowing. Panda *et al.* (2004a) observed that delay in sowing beyond 16thOctober reduced 1000-seeds weight.

Kumar *et al*. (2008) reported that the 1000-seeds weight in mustard was found significantly higher with 30th September (4.42 g) as compared to15th October (4.13 g), 30th October (3.58 g) and 14th November (3.29 g) sowings.

Bhuiyan*et al*. (2008) reported that 1000-seeds weight was found significantly higher under 30th October (3.80 g) sowing as compared to 20th October (3.68 g), 10th November (3.68 g), 20th November (3.28 g), and 30th November (3.24 g) sowings. Lallu *et al* (2010) observed that November sowing caused the significant reduction in 1000-seeds weight (3.5 g) as compared to October sowing (4.8 g).

In Mymensingh (Bangladesh), Afroz *et al*. (2011) observed that 1000-seeds weight was found significantly higher in 20th November sowing (20.0 g) as compared to 10th November (18.1 g) and 30th November (17.9 g) sowings.

Similarly, Aziz *et al*. (2011) reported that 15 November sown mustard crop produced the higher 1000–seeds weight (3.87 g) as compared to 25 November, 5 December and 15 December sowings. Mondal *et al.* (2011) observed that 1000-seeds weight was significantly higher with 1st November and 20th October (3.70 g) as compared to 10th November (3.30 g), 20th November (3.00 g) and 30th November (2.80 g) sowings. Kumari *et al.* (2012) observed that 10th October sowing resulted into significantly higher 1000-seeds weight (4.25 g) over 20th October sowing (3.78 g) and 30th October sowing (3.42 g).

2.1.5 Seed yield

Tomar and Mishra (1991) reported that the seed yield of mustard crop was significantly greater with 30th October (8.44 q ha^{-1}) sowing as compared to 10th November (6.88 q ha^{-1}) and 20th November (5.97 q ha^{-1}) sowings. Jadhav and

Singh (1992) observed that seed yield was significantly higher with 18th October sowing (1360 kg ha^{-1}) as compared to 17th November sowing (750 kg ha^{-1}).

Kumar and Shaktawat (1992) quoted that the mustard sown on 22nd September exhibited higher seed yield (1370 kg ha^{-1}) as compared to 8th September sowing (1157 kg ha^{-1}).

Chandrakar and Urkurkar (1993) reported that seed yield was recorded higher with 23rd November sowing (1154 kg ha^{-1}) as compared to 14th December sowing (661 kg ha^{-1}). Chaudhary and Thakuria (1994) reported that the mustard cultivar TM 2 recorded significantly higher seed yield (1262 kg ha^{-1}) when sown on 15th November as compared to 5th December sowing (219 kg ha^{-1}). Yadav *et al* .(1994a) reported that the seed yield was found higher with 5th October sowing (14.2 q ha^{-1}) as compared to 25th October sowing (11.1q ha^{-1}).

Kumar and Singh (2003) at Patna (Bihar) reported that there was a significant decreased in the seed yield with the early sowing date. The greater seed yield was observed with 20th to 25th October sown crop (1735 kg ha-1). Sihag *et al.* (2003) at Bikaner (Rajasthan) and observed that the higher seed yield was obtained in 15th October sowing (2150 kg ha-1). Kumar *et al.* (2004) emphasized that greater seed yield of 2980 kg ha^{-1} was observed when the mustard crop was shown on 21st October and seed yield increased by 6.5% and 3.5% over that planted on 7th and 14th October. Panda *et al.* (2004a) quoted that delayed sowing after 16th October reduced the seed yield. The crop sown on 16th October resulted into higher seed yield (1945 kg ha^{-1}) than the crops sown on 31st October (1556kg ha^{-1}) and 15th November (872 kg ha^{-1}).

Khushu and Singh (2005) revealed that 24th October sown crop recorded higher seed yield than 8th November sown. Kumari *et al.* (2005) reported that the significantly higher seed yield with 1st October sowing (602 kg ha^{-1}) as compared to 15th October (559 kg ha^{-1}), 1st November (432 kg ha^{-1}) and 15th September (331kg ha^{-1}) sowings in mustard crop. Charak *et al.* (2006) reported that the seed yield in toria crop was significantly higher with first week of September sowing

(1.73 t ha^{-1}) as compared to second week of September (1.15 t ha^{-1}), third week of September (1.12 t ha^{-1}) and fourth week of September (0.97 t ha^{-1}) sowings.

Sharma *et al.* (2006) revealed that the seed yield was significantly higher with 29th October sowing (14.1 q ha^{-1}) as compared to 22nd October (13.4 t ha^{-1}), 12th October (8.67 t ha^{-1}) and 6th October (4.83 t ha-1) sowings.

Kumar *et al.* (2008) emphasized that the seed yield in mustard was significantly higher with 30th September (1740 kg ha^{-1}) sowing as compared to 15th October (1511 kg ha^{-1}), 30th October (1131 kg ha-1) and 14th November (909 kgha^{-1}) sowings. Bhuiyan et al. (2008) reported significantly higher seed yield with 30th October (1.86 t ha^{-1}) sowing as compared to 20th October (1.59 t ha-1), 10th November (1.56 t ha^{-1}), 20th November (1.52 t ha-1), 30th November (1.47 t ha^{-1}) sowings.

Shah and Rahman (2009) conducted a field experiment and observed that the seed yield was found significantly higher with 25th September (3657 kg ha^{-1}) sowing as compared to 5th October (2856.3B), 15th October (2393.5C), 15th September (1736 kg ha^{-1}), 25th October (1336 kg ha^{-1}) , 5th November (1058 kgha^{-1}), and 15th November (548 kg ha^{-1}) sowings. Lallu *et al.* (2010) observed that mustard sown in November caused the significant reduction in seed yield (11.7 g plant^{-1}) as compared to October sowing (19.7 g plant^{-1}). Adak *et al.* (2011) observed that the seed yield in mustard was significantly higher with 15th October sowing (2.86 t ha^{-1}) as compared to 30th October (2.3 t ha^{-1}) sowing.

Biswas *et al*. (2011) revealed that the seed yield was found significantly higher with 10th October sowing (2.28 t ha^{-1}) as compared to 17th October (2.20 t ha^{-1}), 24th October (1.81 t ha^{-1}), 1st November (1.69 t ha^{-1}), 8th November (1.37 t ha^{-1}) and 15th November (1.07 t ha^{-1}) sowings. Afroz *et al.* (2011) observed that significantly higher seed yield was found in 10th November sowing (2.77 t ha^{-1}) as compared to 20th November (2.70 t ha^{-1}) and 30th November (2.69 t ha^{-1}) sowings. Similarly, Aziz *et al.* (2011) reported that 15th November sown mustard crop produced the maximum seed yield (2.75 t ha^{-1}) as compared to 25th November, 5th

December and 15th December. Mondal *et al.* (2011) suggested that seed yield was significantly higher with 1st November (1.72 t ha^{-1}) as compared to 20th October (1.53 t ha^{-1}), 10th November (1.44 t ha^{-1}), 20th November (1.40 t ha^{-1}) and 30th November (1.32 t ha^{-1}) sowings. Kumari *et al.* (2012) observed that 10th October sowing recorded significantly higher seed yield (1.93 t ha^{-1}) over 20th October sowing (1.73 t ha^{-1}) and 30th October sowing (1.36 t ha^{-1}). Tobe *et al.* (2013) reported significant variation in seed yield among different sowing dates of *B. napus* and revealed that 30th March sown crop resulted into significantly higher seed yield (2432 kg ha^{-1}) as compared to 14th April (1943 kg ha^{-1}), 29th April (619 kg ha^{-1}) and 14th May (9.43 kg ha^{-1}) sown crops.

2.1.6 Stover yield

Bhuiyan *et al*. (2008) reported that stover yield was found significantly higher with 20th October (6.06 t ha^{-1}) sowing, as compared to 30th October (5.98t ha^{-1}), 10th November (5.40 t ha^{-1}), 20th November (5.04 t ha^{-1}), and 30th November (4.80 t ha^{-1}) sowings. Afroz *et al*. (2011) observed that significantly higher stover yield was found in 10th November sowing (1.53 t ha^{-1}) as compared to 20th November (1.48 t ha-1) and 30th November (1.41 t ha^{-1}) sowings. Mondal *et al.* (2011) reported that stover yield was significantly higher with 1st November (4.15 t ha^{-1}) as compared to 20th October (3.60 t ha^{-1}), 10th November (3.33), 20th November (3.20 t ha^{-1}) and 30th November (3.10 t ha^{-1}) sowings.

2.2 Effect of irrigation

Seed yield of Brassica was greatly affected by water stress during flower initiation and siliquae filling stage (Richard and Thurling, 1978). Singh *et al.* (2002) tested four *Brassica spp.* (*Brassica carinata*, *Brassica napus*, *Brassica juncea* and *Brassica campestris*) under 2 moisture regimes, i.e. normal irrigation (3 irrigations at branching, bolting and siliquae filling stages) and limited irrigation (one irrigation at branching stage). Results revealed that growth, development and yield of all *Brassica spp.* were adversely affected under limited irrigation condition. This clearly indicates that yield expression of *Brassica spp.* differs under varying soil water environment.

2.2.1 Plant Height

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

Kibbria (2013) reported that plant height was found to be highest when one irrigation at 20 DAS was applied. But three irrigations applied at 20, 40 and 60 DAS produced more plant height (101.00 cm) than under no irrigation. Piri *et al.* (2011) showed that application of two irrigations at 45 DAS and 90 DAS significantly increased plant height.

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

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

Siag *et al.* (1993) found a relationship between irrigation levels and plant height of Tori. The plant height was increased with the increasing levels of irrigation. Plant height was 120.5 cm with 2 irrigations at branching and siliquae development stage and it was the highest compared to 113.0 cm and 108.7 cm with one irrigation at branching stage and without irrigation respectively.

2.2.2 Plant Dry matter

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

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

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

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

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

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

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

2.2.3 Branches $plant^{-1}$

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

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

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

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

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

Tomer *et al.* (1992) concluded that branches plant^{-1} of rapeseed were significantly increased with irrigation. Branches per plant were highest with two irrigation compared to one irrigation or without irrigation (control). They reported that branches plant^{-1} were 40.29 when two irrigations were applied at pre-flowering and fruiting stage. When one irrigation was applied at pre-flowering stage it produced 33.00 branches plant^{-1}. The least number of branches (26.56) was produced at control treatment.

2.2.4 Siliquae plant^{-1}

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

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

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

Patel *et al.* (2004) reported that one irrigation produced 465 siliquae plant^{-1} while 327 siliquae were produced per plant without irrigation.

Giri (2001) stated that in case of two irrigations at flowering and siliquae formation stage 277 siliquae were found in mustard followed by 324 siliquae plant' with one irrigation at flowering stage.

2.1.5 Seeds siliquae-^{1}

Clarke and Simpson (1978) found the increasing number of seeds per siliquae with irrigation application than rainfed condition.

Joarder *et al.* (1979) conducted an experiment with mustard cv. Rai 7, Laha 101 and Rai 5 cultivated under irrigated or rainfed condition and observed that irrigation increased the number of seeds per siliquae and therefore, increased yield per plant and yield per ha by 65 and 59% compared to the rainfed treatments respectively. Seedling and seed development stages and 1.59 to 3.45% when irrigation was applied at the seed development stage compared with irrigation applied at all these stages. However, early water stress from flowering to seed development stages decreased the yield by 4.83 to 15.46% compared with irrigation at all 3 stages.

Samadder *et al.* (1997) studied the *Brassica juncea* cv. Bhagirathi with non irrigated condition and irrigation at flowering or at flowering + seed formation stages and found that seed yield was highest (1.49 t ha^{-1}) with 2 irrigations.

Mahal *et al.* (1995) reported that maximum seed yield (1.96 t ha^{-1} in 1987 and 1.66 t ha^{-1} in 1988) was recorded with 2 irrigations (at 3-4 weeks and at 9-10 weeks after sowing). Tiwari and Chaplot (1993) conducted a field experiment on the effect of irrigation levels on mustard (Brassica juncea cv. Varuna) which was irrigated at vegetative, flowering, siliquae development or seed filling stage corresponding 3, 6, 9, or 12 weeks after sowing (WAS) or at various combinations of these dates. Seed yields increased with increase in irrigation frequency. The highest mean seed yield of 1.09 t ha^{-1} was obtained from irrigating the crop at 3, 6 and 9 WAS.

Tomer *et al.* (1993) conducted an experiment to find out the effect of irrigation levels on the growth and yield of mustard (*Brassica juncea*). They worked with three irrigation treatments viz., no irrigation, one irrigation (at pre-flowering stage) and two irrigation (one at pre-flowering and another at fruiting stage). They concluded both levels of irrigation significantly increased the seed yield over no irrigation.

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

Tomer and Singh (1990) studied the effects of 0, 1 or 2 irrigations on the yield of *Brassica juncea* cv. Varuna. They found that increasing irrigation levels increased seed and oil yields. In another experiment on mustard, Sharma and Kumar (1990) observed that one or two levels of irrigation produced the seed yields of 1 .11 and 1.37 t ha^{-1} respectively in 1984-1985. The corresponding values were 1.26 and 1 .38 t ha^{-1} in 1985-1986. Yields were obtained 0.95 and 0.71 t ha^{-1} without irrigation those years respectively.

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

Lal *et al.* (1989) reported that mustard (*Brassica juncea* cv. Varuna) gave seed yields of l.11-1.36 t ha^{-1} with 1-3 irrigations applied at different growth stages, compared with 0.97 t ha^{-1} under rainfed conditions. Applying one irrigation at the flowering stage gave the highest yields.

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

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

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

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

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

2.2.6 Length of siliqua

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

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

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

Kibbria (2013) reported that weight1000 seeds were also significantly increased with irrigation. Maximum weight of 1000 seeds (3.16 g) $siliquae^{-1}$ was found when two irrigations were applied (one at pre-flowering stage and one at siliquae formation.

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

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

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

2.2.7 Seed yield

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

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

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

2.2.8 Stover yield

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

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

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

2.2.9 Biological yield

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

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

2.2.10 Harvest index

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

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

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

Chapter III

MATERIALS AND METHODS

The experiment was conducted during *rabi* season, November 2017 to February 2018 to find out the effect of sowing time and irrigation frequency on growth and yield of mustard.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at $90^{0}22^{\prime}$ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during *rabi* season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during *kharif* season (April-September).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Materials

3.4.1 Seed

The high yielding variety of mustard is Tori-7 developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and was used as a experimental planting material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2 Fertilizers

The recommended doses of urea as a source of Nitrogen (N), Triple super phosphate (TSP) as a source of phosphorus (P), Muriate of Potash (MP) as a source of Potash (K), Gypsum as a source of Sulpher (S) and Boric acid as a source of Boron (B) were added to the soil of experimental field.

3.5 Methods

3.5.1 Treatments

Factor A: Sowing time	**Factor B: Irrigation**
T_1= Early sowing(1 november)	I_0 = No irrigation
T_2= Optimum sowing(15 november)	I_1 = 1 irrigation(20 DAS),
T_3= Late sowing(30 november)	I_2 = 2 irrigation(20,40 DAS)
	I_3 = 3 irrigation(20,40,55 DAS)

3.5.2 Treatment combinations

There are 12 treatment combinations of different sowing times and irrigations used in the experiment under as following:

1. T_1I_0
2. T_1I_1
3. T_1I_2
4. T_1I_3
5. T_2I_0
6. T_2I_1
7. T_2I_2
8. T_2I_3
9. T_3I_0
10. T_3I_1
11. T_3I_2
12. T_3I_3

3.5.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 12×3 = 36. The unit plot size was 2.5 m × 1.25 m = 3.13 m^2. The distance between blocks was 1 m and distance between plots was 0.5 m.

3.5.4 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were clean properly. The final ploughing and land preparation were done on 10 October, 2017. According to the layout of the experiment the entire experimental area was divided into blocks and experimental plot for the sowing of mustard seed. In addition, irrigation and drainage channels were made around the plot.

3.5.5 Fertilization

In this experiment fertilizers were used according to the recommendation of Bangladesh Agricultural Reserch Institute (BARI) which is mentioned as follows:

Name of Nutrients	**Name of Fertilizers**	**Rate of Application ($kg\ ha^{-1}$)**
Nitrogen (N)	Urea,	250
Phosphorus (P)	Triple Super Phosphate	160
Potash (K)	Muriate of Potash	110
Sulpher (S)	Gypsum	160
Boron (B)	Boric acid	7.5
Zinc (Zn)	Zinc Oxide	15

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum and boric acid required per plot were calculated. The triple super phosphate, muriate of potash, gypsum, boric acid was applied during final land preparation. Half of urea was also applied in each experimental plot according to treatment and incorporated into soil before sowing seed. Rest of the urea was top dressed after 30 days of sowing (DAS).

3.5.6 Sowing of seed

Sowing was done as per treatment. Sowing seeds were sown as per treatment in rows and broadcasting methods at a rate of 8 kg ha^{-1}. The seeds were covered with the soil and slightly pressed by hand, and applied little amount water for better germination of seeds.

3.5.7 Thinning and weeding

The optimum plant population was maintained by thinning excess of plants at 15 DAS. One weeding was done with khurpi was given on 25 DAS.

3.5.8 Irrigation

Irrigations were given as per treatment.

3.5.9 Crop protection

As a preventive measure of aphid infestation, Malathion 57 EC @ 2 ml $litre^{-1}$ of water was applied twice first at 25 DAS and second at 50 DAS.

3.5.10 General observation of the experimental field

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

3.5.11 Harvesting and threshing

Previous randomly selected ten plants, those were considered for the growth analysis was collected from each plot to analyse the yield and yield contributing characters. Rest of the crops was harvested when 80% of the siliquae in terminal raceme turned creamy white in color. After collecting sample plants, harvesting was started on February 10 and completed on March 12, 2018. For yield calculation 1 m area was selected for harvesting. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.5.12 Drying and weighing

The seeds and stovers thus collected were dried in the sun for couple of days. Dried seeds and stovers of each plot was weighted and subsequently converted into yield kg ha^{-1}.

3.6 Data collection

Ten (10) plants from each plot were selected at random and were tagged for the data collection. Some data were collected from sowing to harvesting with 10 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

3.6.1 Plant height

Plant height in cm was measured three times at 10 days interval such as 45, 55 and 65 DAS. The height of the plant was measured by scale considering the distance from the soil surface to the tip of the randomly ten selected plants and mean value was calculated for each treatment.

3.6.2 Leaves plant^{-1}

Leaves plant^{-1} was counted at harvest of mustard plants. Mean value of data were calculated and recorded.

3.6.3 Branches plant^{-1}

Primary branches plant^{-1} was counted at harvest of mustard plants. Mean value of data were calculated and recorded.

3.6.4 Root dry weight

Roots were carefully cleaned with running tap water and finally washed with distilled water. Then the root samples were oven-dried to a constant weight at 70^0 C. The mean root dry weight hill^{-1} was calculated for each treatment.

3.6.5 Shoot dry weight

After separation of roots, the samples of stem, leaf and panicle were oven-dried to a constant weight at 70^0 C. Then the shoot dry weight was calculated from the summation of leaf, stem and panicle.

3.6.6 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.

3.6.7 Length of siliqua

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

3.6.8 Number of seeds siliqua^{-1}

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

3.6.9 Yield

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

3.6.10 Stover yield

Dry weight of stover from harvested area of each plot was taken and then converted to ton ha^{-1}.

3.6.11 Biological yield

Biological yield was calculated by summing up the total seed yield and stover yield.

3.6.12 Harvest index (%)

Harvest index was calculated by dividing the economic seed yield from the net plot by the total biological yield of seed and stover from the same area and multiplying by 100.

3.6 Data analysis

The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program. The mean values for all the parameters were calculated and the analysis of variance was performed. The treatment means were adjusted by Least Significant Difference (LSD) Test at 5 % levels of probability (Gomez and Gomez, 1984).

Chapter IV

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. Experimental results pertaining to the effects of different treatments viz. irrigation and sowing time levels on the yield of mustard. The detailed experimental findings have been explained and discussed below with supporting references wherever possible.

4.1 Plant height (cm)

4.1.1 Effect of sowing time

Significant variation of plant height was found due to sowing time treatment in all the sampling dates (Fig. 1). The figure demonstrated that plant height showed an increasing trend with increasing the age of plant upto 75 DAS for all sowing time levels. It can be deduced from the figure that, the optimum of sowing time (T_2) showed the tallest plant (84.83, 101.00 and 103.92 cm) and late sowing time (T_3) produced the shortest plant (71.17, 74.33, 79.75 cm) for sampling dates of 45, 60, 75 respectively.

4.1.2 Effect of irrigation levels

The plant height of mustard was significantly influenced by irrigation at 45, 60, 75 days after sowing (DAS) (Fig. 2). The figure indicated that plant height showed an increasing trend with an advancement of growing period upto 90 DAS for all irrigation levels. It could be inferred from the figure that three irrigations showed the tallest plant (92.11, 101. 00 and 105.11cm) and no irrigation treatment showed the shortest plant (64.33, 77.44 and 91.03 cm) for the sampling dates of 45, 60 and 75 respectively. It might be due to the soil moisture availability for the plant was which sufficient before third time irrigation at 75 DAS. Similar result was reported by Latif (2006), Sultana(2007) and Kibbria (2013). Paul and Begum (1993) also found that one irrigation at bud initiation stage gave maximum plant height at harvest in mustard plant. Siag *et al.* (1993), Piri *et al.* (2011) and Hossain *et al.* (2013) reported maximum plant height when two irrigations were applied during branching and siliquae development stage.

4.1.3 Interaction effect of irrigation and sowing time

Significant interaction effect between the sowing time and irrigation on plant height was observed at 45, 60 and 75 DAS (Table 1). The tallest plant height (102.67, 114.33 and 119.67 cm at 45, 60 and 75 DAS, respectively) was obtained from T_2I_3 treatment and shortest plant height (63.67, 67.67 and 69.67 cm at 45, 60 and 75 DAS, respectively) found from T_3I_0 treatment

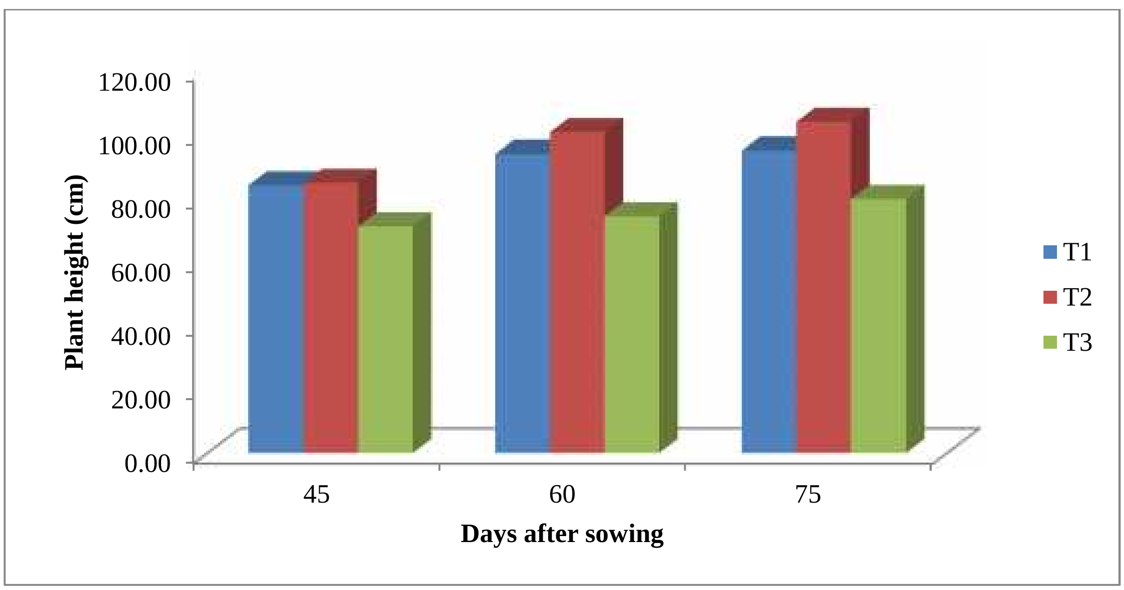

Fig.1. Effect of different sowing times on plant height of mustard at different DAS

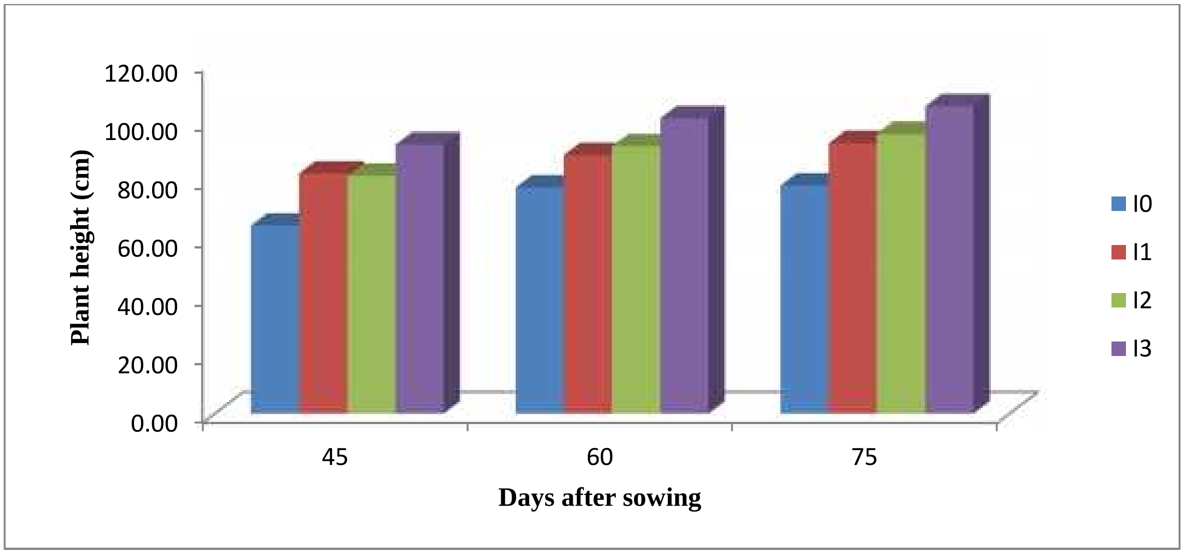

Fig. 2.Effect of different irrigation levels on plant height of mustard at different DAS

Table 1. Interaction effect of sowing time and irrigation levels on plant height of Mustard

Treatment	Plan height (cm)					
	45 DAS		60 DAS		75 DAS	
T_1I_0	64.00	e	81.67	d-f	88.00	bc
T_1I_1	83.00	ab	90.67	b-e	91.67	b
T_1I_2	84.00	bc	95.33	b-d	96.00	b
T_1I_3	95.33	ab	108.00	ab	108.00	a
T_2I_0	65.33	de	83.00	c-f	85.67	bc
T_2I_1	81.33	b-d	99.67	a-c	109.00	a
T_2I_2	90.00	ab	105.67	ab	110.33	a
T_2I_3	102.67	a	114.33	a	119.67	a
T_3I_0	63.67	e	67.67	f	69.67	d
T_3I_1	72.33	c-e	75.33	ef	77.00	cd
T_3I_2	70.33	c-e	73.67	ef	84.67	bc
T_3I_3	78.33	b-e	80.67	d-f	87.67	bc
$LSD_{(0.05)}$	15.3		15.86		12.81	
CV (%)	7.56		5.39		8.27	

4.2 Leaves plant^{-1}

4.2.1 Effect of sowing time

Sowing time had not significant effect on number of leaves plant$^{-1.}$ The optimum sowing time (T_2) produced higher number of leave over early sowing (Table 2). The maximum numbers of leaves (40.83) were found from optimum of sowing time (T_2). The lowest numbers of leaves (34.83) were found from early sowing (T_1) treatment.

4.2.2 Effect of irrigation levels

From the study it was found that irrigation had great influence on the number of leaves plant^{-1} in mustard (Table 2). Number of irrigation significantly increased the number of leaves plant^{-1}. The maximum numbers of leaves (46.72) were found from a plant subjected to three irrigations (I_3). The lowest numbers of leaves (31.39) were found from control (I_0) treatment, which was statistically similar with I_1 and I_2 treatment.

4.2.3 Interaction effect of irrigation and sowing time

It was observed that combined effect of sowing time and irrigation levels had showed significant difference to produce leaves plant^{-1} (Table 2). The effect of irrigation interacts better with sowing time when sufficient moisture was supplied. In the study the maximum number of leaves plant^{-1} (53.67) was found from the interaction between optimum sowing time and three irrigations (T_2I_3). The least number of leaves (20.33) were found from T_3I_0 treatment.

4.3 Branches plant^{-1}

4.3.1 Effect of sowing time

Sowing time had not significant effect on number of branches plant^{-1}. The optimum sowing time (T_2) produced higher number of primary branches over early sowing (Table 2). The maximum numbers of primary branches (6.61) were found from optimum of sowing time (T_2). The lowest numbers of primary branches (5.13) were found from early sowing (T_1) treatment.

4.3.2 Effect of irrigation levels

From the study it was found that irrigation had great influence on the number of branches plant^{-1} in mustard (Table 2). The maximum numbers of branches (7.92) were found from a plant subjected to three irrigations (I_3). The lowest numbers of primary branches (4.44) were found from control (I_0) treatment, which was statistically similar with I_1 treatment. Tomar *et al.* (1992), Giri (2001), Sultana (2007) and Kibbria (2013) reported that significant increase in the number of branches plant^{-1} up to three irrigations. Rahman (1994) also reported that two irrigations gave the highest number branches plant^{-1} and the lowest number of branches plant^{-1} was found in case of without irrigation. Probably irrigation water supported the plant to initiate more branches.

4.3.3 Interaction effect of irrigation and sowing time

It was observed that combined effect of sowing time and irrigation had showed significant difference to produce branches plant^{-1} (Table 5). The effect of irrigation interacts better with sowing time when sufficient moisture was supplied. In the study the maximum number of branches plant^{-1} (7.37) was found from the interaction between optimum sowing time and three irrigations (T_2I_3). The least number of branches (4.00) were found from T_3I_0 and (T_1I_0) treatment.

4.4 Shoot dry weight plant^{-1}

4.4.1 Effect of sowing time

Significant variation of shoot dry weight plant^{-1} was found due to sowing time in all the studied durations (Table 2). The optimum sowing time (T_2) produced the highest shoot dry weight (35.94 g) which was statistically similar with T_1 and late sowing time showed the lowest weight (22.40g).

Table 2. Interaction effect of sowing time and irrigation on number of leaf, number of branch plant^{-1}, shoot dry weight plant^{-1}, root dry weight plant^{-1} of mustard

Treatment	Number of leaf plant^{-1}		Number of branch plant^{-1}		Shoot dry weight plant^{-1} (g)		Root dry weight plant^{-1} (g)	
	Effect of sowing time							
T1	37.54	ab	5.13	a	35.56	a	2.50	b
T2	40.83	a	6.61	a	35.94	a	3.23	a
T3	34.83	b	5.78	a	22.37	b	2.37	b
LSD(0.05)	5.99		2.99		4.71		0.43	
	Effect of irrigation							
I_0	31.39	b	4.44	c	30.04	a	2.47	a
I_1	36.89	b	4.83	c	30.57	a	2.60	a
I_2	35.94	b	6.17	b	31.35	a	2.67	a
I_3	46.72	a	7.92	a	33.20	a	3.06	a
LSD(0.05)	9.34		0.91		4.34		1.00	
	Interaction effect of sowing time and irrigation							
T_1I_0	23.33	de	4.50	de	33.47	b	2.18	ef
T_1I_1	36.00	b-d	4.00	e	36.07	ab	2.48	c-f
T_1I_2	42.33	a-c	4.93	de	36.75	ab	2.55	c-f
T_1I_3	48.50	ab	7.10	a-c	35.94	ab	2.81	b-e
T_2I_0	30.83	c-e	4.83	de	35.11	b	3.19	ab
T_2I_1	33.67	b-e	5.50	c-e	34.45	b	3.04	a-d
T_2I_2	45.17	a-c	7.37	ab	34.11	b	3.08	a-c
T_2I_3	53.67	a	8.73	a	40.08	a	3.60	a
T_3I_0	20.33	e	4.00	e	21.19	c	2.05	f
T_3I_1	41.00	a-c	5.00	de	21.53	c	2.29	ef
T_3I_2	40.00	a-c	6.20	b-d	23.18	c	2.40	d-f
T_3I_3	38.00	b-d	7.93	ab	23.59	c	2.76	b-e
$LSD_{(0.05)}$	13.43		1.704		4.414		0.5717	
$CV_{(0.5)}$	8.05		5.38		6.27		5.26	

4.4.2 Effect of irrigation

Shoot dry weight is the material which was dried to a constant weight. Shoot dry weight production indicates the production potential of a crop. No significant variation was found in shoot dry weight due to irrigation (Table2). Shoot dry weight increased with advancement of growth stage irrespective of irrigation levels. It can be concluded from the table that three irrigations produced the maximum amount of shoot dry weight (33.20 g) and control treatment showed the minimum (30.04g). The I_3 treatment produced highest number of branches which might have contributed in the accumulation of highest dry matter. It might be due to maximum plant height and stem thickness in this treatment. Similar result was reported by Latif (2006), Sultana (2007) and Kibbria (2013). Giri (2001) found more dry matter weight plant^{-1} in mustard with two irrigations than with one irrigation.

4.4.3 Interaction effect of irrigation and sowing time

The combined effect of three levels of irrigation with sowing time gave the significant highest weight of dry shoot plant^{-1} (Table2). The maximum shoot dry (40.08 g) was found from T_2I_3 treatment. The lowest root dry weight (21.19 g) was found from T_3I_0 treatment.

4.5 Root dry weight plant^{-1}

4.5.1 Effect of sowing time

Significant variation of root dry weight plant^{-1} was found due to sowing time in all the studied durations (Table. 2). The optimum sowing time (T_2) produced the highest root dry weight (2.23 g) and late sowing time showed the lowest weight (2.37g).

4.5.2 Effect of irrigation

Root dry weight is the material which was dried to a constant weight. Root dry weight production indicates the production potential of a crop. No significant variation was found in root dry weight due to irrigation (Table 2).Root dry weight increased with advancement of growth stage irrespective of irrigation levels. It can be concluded from the table that three irrigations produced the maximum amount of root dry weight (3.06 g) and control treatment showed the minimum (2.47g).

4.5.3 Interaction effect of irrigation levels and sowing time

The combined effect of three levels of irrigation with sowing time gave the significantly highest weight of dry root plant^{-1} (Table2). The maximum root dry (3.60 g) was found from T_2I_3 treatment. The lowest root dry weight (2.05 g) was found from T_3I_0 treatment.

4.6 Siliquae plant^{-1}

4.6. 1 Effect of sowing time

Sowing time had significant effect on number of siliquae plant^{-1} (Table 3). The T_2 treatment showed highest number of siliquaeplant^{-1} (198.83), which was statistically similar with T_3 and T_1 treatment gave the lowest one (152.33).

4.6.2 Effect of irrigation

Number of siliquae is an important factor for increasing yield, which was adversely affected by the soil moisture. So, irrigation plays an important role in increasing the yield and yield attributes. In the present study, number of irrigation showed significant variation in producing siliquaeplant^{-1} (Table 3). Among the treatment I_3 (three irrigations) produced the highest number of siliquae (252.33).

The treatment I_o (control) which was received no irrigation throughout the life cycle thus produced the lowest number of siliquae (108.44). In case of the three irrigation at siliquae formation stage helped in producing more number of siliquae. But in case of treatment I_1, when only one irrigation was applied at flowering stage and at later stage (siliquae formation) insufficient soil moisture reduced the number of

Table 3. Interaction effect of sowing time and irrigation on yield contributing character of mustard

Treatment	Siliquae plant^{-1}		Length of siliquae		Number of seed siliquae^{-1}	
	Effect of sowing time					
T_1	152.33	b	5.10		16.63	c
T_2	198.83	a	6.27		20.61	a
T_3	187.75	a	5.42		18.00	b
LSD(0.05)	22.86		ns		1.19	
	Effect of irrigation					
I_0	108.44	d	5.64	ab	16.00	c
I_1	162.33	c	5.46	ab	17.33	bc
I_2	195.44	b	5.06	b	18.50	b
I_3	252.33	a	6.23	a	21.81	a
LSD$_{(0.05)}$	31.00		0.87		2.20	
Treatment	Interaction effect of sowing time and irrigation					
T_1I_0	96.33	f	3.72	c	15.00	i
T_1I_1	127.33	d-f	5.50	a-c	16.00	h
T_1I_2	174.67	c-e	5.18	a-c	18.50	f
T_1I_3	211.00	bc	4.80	bc	17.00	g
T_2I_0	112.67	ef	6.03	ab	21.00	c
T_2I_1	166.67	c-e	6.18	ab	19.00	e
T_2I_2	225.00	bc	6.27	ab	20.00	d
T_2I_3	291.00	a	7.00	a	22.43	b
T_3I_0	116.33	ef	5.97	ab	12.00	j
T_3I_1	193.00	bc	5.00	bc	17.00	g
T_3I_2	186.67	cd	4.93	bc	17.00	g
T_3I_3	255.00	ab	6.68	ab	26.00	a
LSD$_{(0.05)}$	57.23		1.617		0.2004	
CV(%)	8.95		5.23		7.39	

siliquae plant^{-1}. Third irrigation also reduced the abortion of siliquae. The results obtained from the study were partially supported by Sarker and Hassan (1988), Sharma and Kumar (1989a) and Dobariya and Metha (1995) who reported that irrigation increased siliquae plant^{-1}. Tomar *et al.*, (1992), Latif (2006), Sultana (2007) and Kibbria (2013) concluded that number of siliquae plant^{-1} was significantly increased up to three irrigation irrigations at pre-flowering, siliquae formation stage and seed maturation stage.

4.6.3 Interaction effect of irrigation and sowing time

Sowing time and irrigation showed significant effect on number of siliquae plant^{-1} (Table 3). The highest number of siliquae plant^{-1}(291.00) was produced with the interaction of optimum sowing time with three irrigation (T_2I_3) treatment, which was statistically identical with other. Lowest number of siliquae plant^{-1} (96.33) was given by the combination T_1I_0 (early sowing and without irrigation).

4.7 Length of siliqua

4.7.1 Effect of sowing time

Sowing time had significant effect on the siliqua length (Table 3). It was observed that optimum sowing time gave highest siliqua length (6.27 cm) which was significantly different from other treatments. The early sowing time (T_1) treatment gave the shortest siliqua length (5.10cm).

4.7.2 Effect of irrigation levels

Irrigation had significant effect on the siliqua length (Table 3). Three irrigations (I_3) gave the highest siliqua length (6.23 cm) which was statistically identical with other. The lowest siliqua length (5.06 cm) was found from the control treatment (I_0). Latif (2006) and Kibbria (2013) concluded that length of siliqua was significantly increased up to three irrigations at pre-flowering, siliqua formation stage and seed maturation stage.

4.7 .3 Interaction effect of irrigation and sowing time

In this study, interaction effect of sowing time and irrigation showed significant effect on siliqua length (Table 3). Significant highest siliqua length (7.00cm) was found from the combination treatment of T_2I_3 which was statistically identical with other treatments. The lowest siliqua length (3.32 cm) was found from control treatment (T_1I_0).

4.8 Seeds siliqua^{-1}

4.8.1 Effect of sowing time

Sowing time rates significantly influenced the number of seeds siliquae^{-1}. The significant highest number of seeds siliquae^{-1} (20.61) was found from optimum sowing (T_2) the while the lowest number of seeds siliqua^{-1} (16.61) was found from the early sowing time (T_1).

4.8.2 Effect of irrigation levels

Numbers of seeds siliquae^{-1} were significantly affected by irrigation levels. The number of seeds siliqua^{-1} was increased with the increase of irrigation number (Table 3). The significant highest number of seeds siliquae^{-1} (21.81) was found from three irrigations. The lowest number of seeds siliquae^{-1} (16.00) was found from the control treatment. Seed siliquae^{-1}increased with the increasing levels of irrigation due to the supply of adequate soil moisture which helped to elongate the siliqua length and have more number of seeds. Latif (2006), Sultana (2007) and Kibbria (2013) concluded that number of seeds siliqua^{-1} was significantly increased up to three irrigation irrigations at pre-flowering, siliquae formation stage and seed maturation stage. Tomer *et al.* (1993) and Hossain *et al*. (2013) found a significant increase of seeds siliquae^{-1} with two irrigations one at pre-flowering stage and another at fruiting stage. A number of researchers Sharma and Kumar (1989b) and Dobariya and Metha (1995) also observed that irrigation increased number of the seeds siliqua^{-1}.

4.8.3 Interaction effect of irrigation and sowing time

Sowing time as well as irrigation levels interact each other to produce seeds siliquae^{-1}in mustard. Significant variations in the number of seeds siliquae^{-1}were found with the different interaction of irrigation and sowing time in the study (Table 3). The highest number of seeds siliquae^{-1} (26.00) was found when optimum sowing with three irrigations. The lowest numbers of seeds siliqua^{-1} (15.00) were found from the treatment T_1I_0 (control).

4.9 Seed yield

4.9.1 Effect of sowing time

Sowing time was significantly influenced on the seed yield of mustard. The maximum seed yield (1.12 t ha^{-1}) was obtained from optimum sowing time. The minimum seed yield (0.93 t ha^{-1}) was obtained from early sowing time (T_1) (Table 4).

4.9.1 Effect of irrigation levels

Irrigation treatment significantly increased the seed yield ha^{-1} in mustard. Seed yield ha^{-1} increased with the increase of irrigation levels (Table 4) Maximum seed yield ha^{-1} (1.05 t ha^{-1}) was found from three irrigations which were statistically identical with other treatment. The lowest seed yield ha^{-1} was found from control treatment (0.75 t ha^{-1}). In control high mortality of seedlings resulting from shortage of soil moisture drastically reduced the yield. Rahman (1994) reported that highest seed yield was produced by two irrigations. The lowest yield was produced by I_o (without irrigation) and this was statistically inferior to I_1 (one irrigation). Under non-irrigated condition internal moisture deficit led to lower plant height, failed to increase the growth parameters, which adversely affected the yield components, viz., dry matter accumulation, siliquae plant^{-1}, seeds siliquae^{-1}, and 1000-seed weight (Tomer *et al.,* 1992). These results corroborated with Latif (2006), Sultana (2007) and Kibbria (2013).

Table 4. Interaction effect of sowing time and irrigation on yield and yield component of mustard

Treatment	Seed Yield (t ha^{-1})		Stover yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index (%)	
Effect of sowing time								
T1	0.93	ab	1.57	c	2.50	a	37.20	a
T2	1.12	a	2.11	a	3.23	a	34.42	a
T3	0.53	b	1.84	b	2.37	a	22.41	b
$LSD_{(0.05)}$	0.42		0.19		0.86		4.66	
Effect of irrigation								
I_0	0.75	b	1.72	b	2.47	b	29.78	b
I_1	0.80	ab	1.89	a	2.69	ab	29.40	b
I_2	0.84	ab	1.86	a	2.69	ab	30.88	b
I_3	1.05	a	1.92	a	2.95	a	35.32	a
$LSD_{(0.05)}$	0.26		0.12		0.37		3.08	
Interaction effect of sowing time and irrigation								
T_1I_0	0.81	cd	1.47	e	2.27	ef	35.44	ab
T_1I_1	0.88	b-d	1.66	b-e	2.54	d-f	34.85	b
T_1I_2	0.94	bc	1.63	c-e	2.56	d-f	36.57	ab
T_1I_3	1.10	b	1.54	de	2.64	c-e	41.95	a
T_2I_0	1.00	bc	2.10	a-c	3.09	bc	32.34	b
T_2I_1	1.02	bc	2.12	ab	3.14	b	32.63	b
T_2I_2	1.02	bc	1.99	a-d	3.01	b-d	34.04	b
T_2I_3	1.42	a	2.24	a	3.67	a	38.65	ab
T_3I_0	0.44	e	1.61	de	2.05	f	21.55	c
T_3I_1	0.50	e	1.90	a-e	2.40	ef	20.72	c
T_3I_2	0.55	e	1.95	a-d	2.50	d-f	22.02	c
T_3I_3	0.65	de	1.90	a-e	2.54	d-f	25.36	c
$LSD_{(0.05)}$	0.24		0.42		0.4668		6.104	
CV (%)	5.25		6.38		7.35		8.23	

4.9.3 Interaction effect of irrigation and sowing time

Interaction effect of sowing time and irrigation influenced the seed yield ha^{-1} (Table 4). Seed yield (1.42 t ha^{-1}) was significantly superior observed from the combination T_2I_3 treatment (optimum sowing time with three levels of irrigations) which was statistically identical with T_1I_0.

4.10 Stover yield

4.10.1 Effect of sowing time

The different sowing time had the effect on the stover yield ha^{-1} (Table 4). The maximum stover yield 2.11 t ha^{-1} was obtained from T_2 treatment (optimum sowing time), whereas the minimum stover yield (1.57 t ha^{-1}) was obtained from T_1treatment.

4.10.2 Effect of irrigation

Significant variation was found in stover yield at different irrigation levels (Table 4). The treatment I_3 (three irrigations) produced the highest stover yield (1.92 tha^{-1}) which was statistically similar with I_1 and I_2. The treatment I_0 (no irrigation) produced the lowest stover yield (1.72 t ha^{-1}).

4.10.3 Interaction effect of irrigation and sowing time

Interaction effect of sowing time and irrigation had significant effect on biological yield (Table 4). The highest stover yield (2.24 t ha^{-1}) was obtained from T_2I_3 treatment. The lowest stover yield (1.47 t ha^{-1}) was observed by T_1I_0 treatment.

4.11 Biological yield

4.11.1 Effect of sowing time

The different sowing times affected the biological yield (Table 4). The maximum biological yield (3.23t ha^{-1}) was obtained from T_2 treatment (optimum sowing time), whereas the minimum biological yield (2.50 t ha^{-1}) was obtained from T_1treatment.

4.11.2 Effect of irrigation levels

Significant variation was found in biological yield at different irrigation levels (Table 4). The treatment I_3 (irrigations) produced the highest biological yield (2.95 tha^{-1}) which was statistically identical with other. The treatment I_0 (no irrigation) produced the lowest biological yield (1.72 t ha^{-1}).

4.11.3 Interaction effect of irrigation and sowing time

Interaction effect of sowing time and irrigation had significant effect on biological yield (Table 4). The highest biological yield (3.67 t ha^{-1}) was obtained from T_2I_3 treatment. The lowest biological yield (2.05 t ha^{-1}) was observed by T_3I_0 treatment.

4.12 Harvest index (%)

4.12.1 Effect of sowing time

From table 4 it revealed that the different sowing time had significant effect on harvest index. Early sowing time significantly increased the harvest index (37.20%). The lowest harvest index (22.41%) was obtained from late sowing time.

4.12.2 Effect of irrigation

It was observed from the (table 4) that different irrigation levels had significant effect on harvest index. The three irrigations gave the highest harvest index (35.32%) and it was significantly different from the other treatments. The lowest value of harvest index (29.78%) was obtained from the treatment I_o (no irrigation), which was statistically similar with I_1. Three irrigations produced higher seed yield, which increased the harvest index. Shrivastava *et al.* (1988) also found that two irrigations at pre-flowering and seed development stages produced higher harvest index. Similar results were obtained by Sarker (1994) who observed that two irrigations gave the higher harvest index and this was statistically superior to one irrigation. He also found the lowest harvest index was given by I_o (without irrigation) which was statistically inferior to two irrigations but statistically identical with one irrigation. It is evident from the results that increasing irrigation levels significantly increased harvest index. The cause of increase in harvest index might be due to higher seed yield compared to biological yield as obtained by increasing levels of irrigation.

4.12.3 Interaction effect of irrigation and sowing time

It was observed that sowing time and irrigation interaction had significant effect on harvest index (Table 4). Harvest index was significantly higher (41.95%) from the treatment combination of T_1I_2. The lowest harvest index (20.72 %) was recorded from the treatment combination of T_3I_1.

Chapter V

SUMMARY AND CONCLUSION

The experiment was undertaken during November 2017 to February 2018 to evaluate the effect of sowing time and irrigation frequency on growth and yield of mustard. In this experiment, the treatment consisted of three different Sowing time viz. T_1 = Early sowing, T_2 = Optimum sowing, T_3 = Late sowing, and four irrigation frequency of mustard viz. I_0=No irrigation, I_1= 1 irrigation, I_2 =2 irrigation and I_3= 3 irrigation. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid as a source of N, P, K, S, Zn and B respectively were applied according to treatment and area of experimental unit plot. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters.

Plant height, number of leaves and branches per plant show a statistical difference in response of different sowing time. The tallest plant (84.83, 101.00 and 103.92 cm) was recorded with T_2 treatment (Optimum sowing time). The maximum numbers of leaves (40.83), number of branches per plant (6.61), shoot dry weight (35.94 g), root dry weight (2.23 g), number of siliquae plant^{-1} (198.83), and length of siliqua (6.27 cm) was produced with T_2 (optimum sowing time). The maximum number of seed per silliqua (20.61) was produced in S_2. The maximum yield of seed per hectare (1.12 t) was obtained from T_2 (optimum time) treatment. The maximum yield of stover 2.11 t ha^{-1} was obtained from $T_{2,}$ treatment. The maximum biological yield 3.23 t ha^{-1} was obtained from T_2 treatment. The maximum harvest index (22.41%) was obtained with T_2.

There were significant variations among the treatments in respect of major parameters studied. The height plant height ((92.11, 101. 00 and 105.11cm)) was produced with I_3 (three irrigations). The three irrigation (I_3) had the highest number of leaves (46.72) number of branches per plant (7.92).Three irrigations produced the maximum amount of shoot dry weight (33.20 g). Three irrigations produced the maximum amount of root dry weight (3.06 g). The maximum number of siliqua per plant (252.33) was produced in I_3 treatment. The maximum length of silliqua (5.06 cm) was produced in I_3 treatment. The maximum of seeds siliquae^{-1} (21.81) was produced in I_3 treatment. The highest yield of seed (1.05 t ha^{-1}) was obtained from I_3 (three irrigations). The highest yield of stover (1.92 t ha^{-1}) was obtained from I_3. The highest yield of biological yield (2.95 t ha^{-1}) was obtained from I_3. The highest harvest index harvest index (35.32%) was obtained from I_3.

The combinations of irrigation levels and sowing times had significant effect on almost all parameter. The tallest plant (102.67, 114.33 and 119.67 cm at 45, 60 and 75 DAS, respectively) was found in T_2I_3. The maximum number of leaves plant^{-1}(53.67) number of branches per plant (7.37) and number of siliquae per plant (291.00) was found in T_2I_3 treatment. The maximum shoot dry (40.08 g) was found from T_2I_3 treatment. The maximum root dry (3.60 g) was found from T_2I_3 treatment. The maximum length of silliqua (7.00cm) was found in T_2I_3.The maximum number of seed per silliqua (26.00) was found in T_2I_3 treatment combination. The highest yield of seed per hectare (1.42 t ha^{-1}) was obtained from T_2I_3 (three irrigation and optimum sowing time) treatment combination. The highest yield of stover per hectare (2.24 t ha^{-1}) was obtained from T_2I_3treatment combination. The highest biological yield per hectare (3.67 t ha^{-1}) was obtained from T_2I_3 treatment combination. The highest harvest index (41.95%) was obtained from T_1I_2 treatment combination.

The maximum growth, morphological development, yield contributing parameters and highest yield (1.42 t ha^{-1}) of seed was obtained from the combination of three irrigations and optimum sowing (T_2I_3). The combinations of irrigation and sowing time had significant effect on almost all parameter. The combinations of sowing time and irrigation had also had significant effects on most of the other parameters. Considering the above results, it may be summarized that growth, seed yield contributing parameters of mustard is positively correlated with sowing time and irrigation levels. Therefore, the present experimental results suggest that the mustard variety of tori-7 with combined use of optimum sowing time with three irrigations would be beneficial to increase the seed yield under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. The results are required to substantiate further with different varieties of rape seed and mustard.
3. It needs to conduct more experiments with sowing time whether can regulate the morphological characters, yield and seed quality of mustard.

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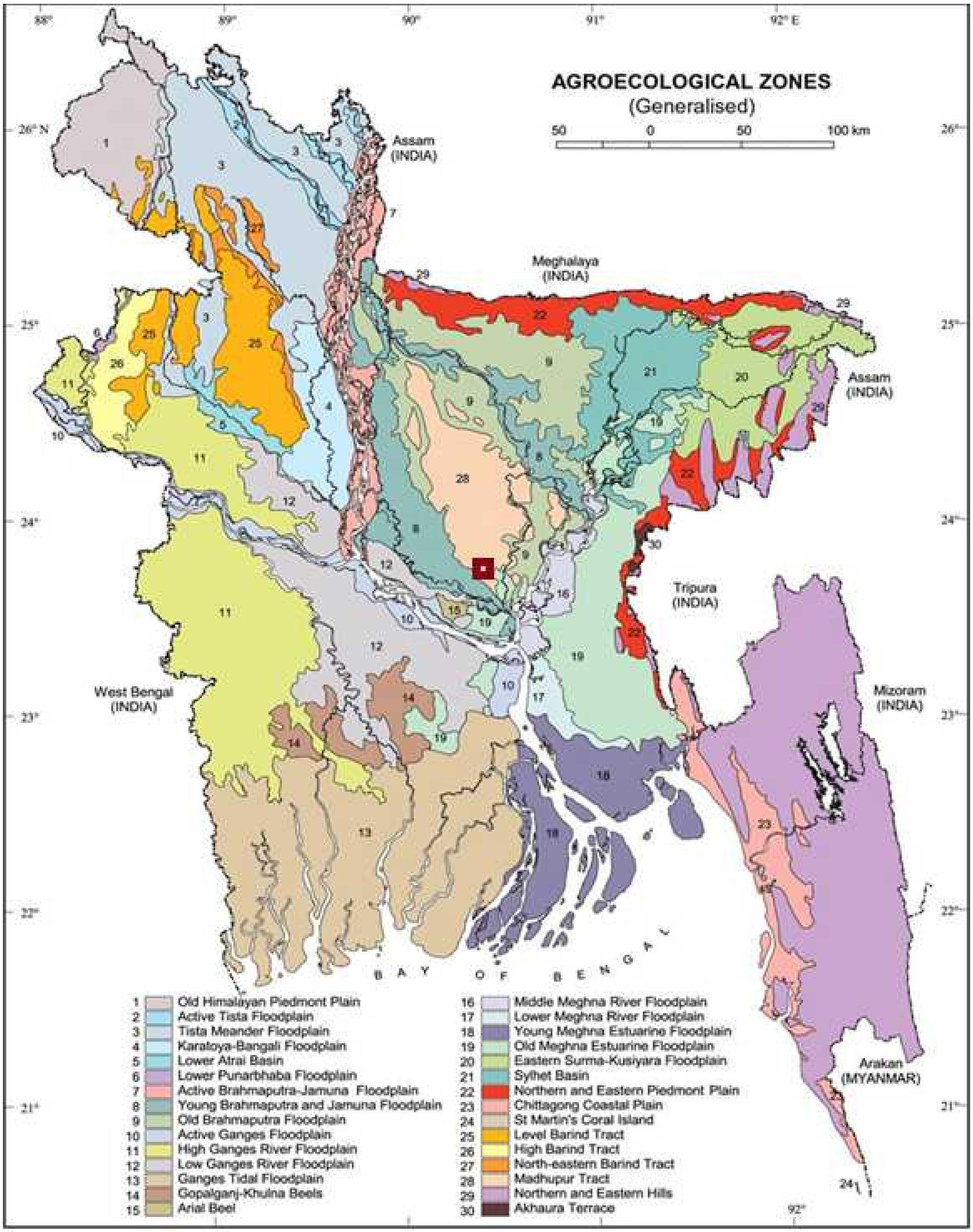
APPENDICES

Appendix I: Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II: **Morphological characteristics of the experimental field**

Morphological features	Characteristics
Location	Botany Research 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	**N/A**

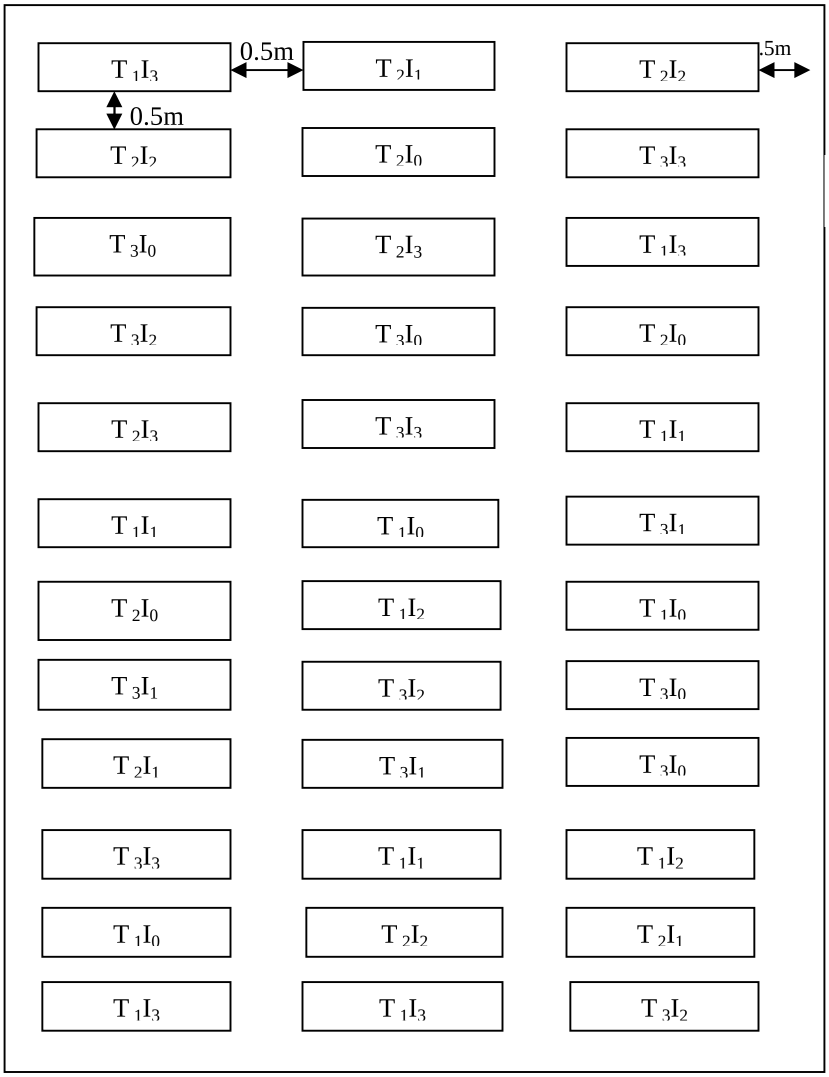
Source: SRDI

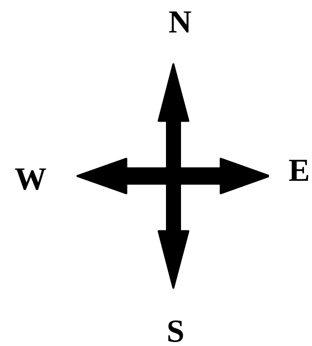
Appendix III. Physical and chemical characteristics of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Source: SRDI

Appendix IV. Layout and design of the experimental plot





Unit plot size:
2.5m x 1.25m

Factor-A: Sowing time

T_1 = Early sowing
V_2 = Optimum sowing
T_3 = Late sowing

Factor-B: Irrigation

I_0= No irrigation
I_1= 1 irrigation
I_2= 2 irrigation
I_3= 3 irrigation

Appendix V. Weather data Monthly record of average air temperature, relative humidity and total rainfall of the experimental site during the period from November 2017 to February 2018

Year	Month	Average Air temperature (^0C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	**Minimum**	**Mean**			
2017	November	29.7	20.1	24.9	5	65	192.20
	December	26.9	15.8	21.35	0	68	217.03
2018	January	24.6	12.5	18.7	0	66	171.01
	February	27.1	15.8	21.05	09	66	168.60

Source: Weather station, Bangladesh Metrological Department, Storm Warning Centre, Agargaon , Dhaka-1207

PLATES

Plate 1. Field view during field preparation and intercultural operation

Plate 2. Field view at flowering stage

Plate 3. Field visit of supervisor

Plate 3. Drying after harvesting and data collection