GROWTH AND YIELD OF MUSTARD AS AFFECTED BY AGRONOMIC MANAGEMENTS

BRISTY BASAK

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BRISTY BASAK

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Approved by:

.....	.....
Prof. Dr. Parimal Kanti Biswas	**Prof. Dr. Md. Shahidul Islam**
Supervisor	Co-supervisor

.....
Prof. Dr. Md. Shahidul Islam
Chairman
Examination committee

DEDICATED

TO

MY BELOVED PARENTS

CERTIFICATE

This is to certify that the thesis entitled **"Growth and Yield of Mustard as Affected by Agronomic Managements**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the results of a piece of *bona fide* research work carried out by **Bristy Basak**, Registration No. **13-05558** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)

Supervisor

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The Author

GROWTH AND YIELD OF MUSTARD AS AFFECTED BY AGRONOMIC MANAGEMENTS

ABSTRACT

A field experiment entitled "Growth and yield of Mustard as affected by agronomic managements" was carried out during Rabi season of 2018-19 at the Agronomy field of Sher-e-Bangla Agricultural University. The experiment was composed of two factors, viz., (i) Two varieties - V_1 = BARI Sarisha-14 and V_2 = BARI Sarisha-16 and (ii) Seven agronomic managements - M_1= Control (No management), M_2= No fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pesticides but all other managements, M_7 = Recommended management. The treatments were replicated thrice in split-plot design. The soil of experimental plot was loam in texture, having pH 6.0 to 6.3 and low in organic carbon. Results revealed that varieties, different agronomic managements and their interaction significantly affected the growth and different yield parameters of mustard. The tallest plant (11.75, 72.48, 94.86 & 124.60 cm at 20, 50, 65 DAS & at harvest respectively), longest leaf (7.10, 15.80, 14.13 & 14.36 cm at 20, 35, 50 & 65 DAS respectively), highest values for branches plant^{-1} (3.12, 4.19 & 5.15 at 50, 65 & at harvest respectively), dry matter accumulation (0.52, 1.49 & 5.65 g plant^{-1} at 20, 35 & 65 DAS respectively), SPAD value (49.55% at 50 DAS), no. of siliquae plant^{-1} (34.11), length of siliqua (4.09 cm), 1000-seed weight (3.94 g), seed yield (0.98 t ha^{-1}), stover yield (3.57 t ha^{-1}) and biological yield (4.5 t ha^{-1}) were observed higher in BARI Sarisha-16. Therefore, BARI Sarisha-16 performed superior than BARI Sarisha-14. But regarding plant population (189.38), leaf number (10.56, 14.41 & 20.59 at 35, 50 & 60 DAS), SPAD value (43.05% at 35 DAS) and seeds silliqua^{-1} (26.39), BARI Sarisha-14 performed better than BARI Sarisha-16. Among the agronomic managements, M_7 (recommended management) performed better that was similar with M_3, M_5 and M_6 in some parameters. The lowest result was observed from M_1 (no management) treatment. Compared to that of recommended management, the highest yield reduction was observed for no management (33.90 %) that followed by no fertilizer (32.20 %), no thinning (22.03 %), no irrigation (18.64 %), no weeding (13.56 %) and no pest management (5.08 %). The V_2M_7 (BARI Sarisha-16 with recommended management) performed better than all other combinations. So it may be concluded that highest priority should be given on fertilizer application, thinning and irrigation for mustard cultivation.

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LIST OF ACRONYMS

%	=	Percentage
AEZ	=	Agro ecological zone
B	=	Boron
CGR	=	Crop growth rate
cm	=	Centimeter
CV%	=	Percentage of co-efficient variation
DAS	=	Days after sowing
EA	=	Erucic Acid
g	=	Gram
ha	=	Hectare
HYV	=	High yield variety
K	=	Potassium
kg	=	Kilogram
LAI	=	Leaf Area Index
m^2	=	Meter square
N	=	Nitrogen
NAR	=	Net assimilation rate
P	=	Phosphorus
$plant^{-1}$	=	Per plant
PSB	=	Phosphate solubilizing bacteria
RSO	=	Rapeseed oil
S	=	Sulphur
SE	=	Standard error
t	=	Ton
TDM	=	Total dry matter
viz.	=	Videlicet (namely)
WUE	=	Water use efficiency
Zn	=	Zinc

CHAPTER I

INTRODUCTION

Several oil seed crops are cultivated in Bangladesh such as mustard-rapeseed, sesame, groundnut, linseed, niger, safflower, sunflower and soybean etc. of which Mustard-rapeseed (*Brassica spp*.) is one of the main oil seed crops that commonly cultivated during the winter season (October - February) and contributes approximately 70% to the overall production of oil seeds. It currently ranks as the world's third most oil crops after palm and soybean in terms of production and area (Zhang and Zhou, 2006). Mustard under the family Brassicaceae is a potential oil producing crop in winter (Rabi) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee, 2010). The crop is well suited to nearly all agro-climatic areas of the country. It accounts for nearly 27% of total oilseeds and 31% total vegetable oil production (Shekhawat *et al.,* 2012). Compared to other countries, the yield of mustard is very low in Bangladesh. Seeds of *Brassica spp* contain 40-45% oil and 20-25% protein (Mondal and Wahhab, 2001). The oil, still in many places, is squeezed from the seeds by using traditional grinding mills, called "Ghanee", which is pulled by a bull through long hours of the day and even throughout the night. Average 33% oil may be extracted by using local oil-extraction machine. In human diet, mustard oil plays a crucial role. It is also an important raw material for industrial use such as; soaps, paints, varnishes, hair oil, lubricants, etc. Moreover, farmers are very well acquainted with it. Mustard oil has been used as a cooking medium since time immemorial (Khaleque, 1985). Mustard oil cake used as animal feeds also as manure. The low yield of mustard in Bangladesh is correlated with several factors.

Rapeseed and mustard belong to Brassicaceae family and genus *Brassica*. Locally, rapeseed is referred as sarson, toria, yellow toria, while, mustard is called as rai or laha. Though, rapeseed and mustard belong to the same family and genus, they vary according to characteristic of their plants. Rapeseed-mustard group of crops is the major oilseed crop of Bangladesh. Among the

seven annual edible oilseeds, rapeseed-mustard contributes about 23% acreage and over 25 % production for the last five years. Bangladesh produces good number of oilseed crops of which rapeseed and mustard is considered as the major one (Razzaque and Karim, 2007). It occupies first position of the list in respect of area and production among the oilseed crops grown in this country. In the year of 2016-17, it covered 386437 hectares land and the production was 363000 metric ton (Mt) whereas, the total oilseed production was 975000 metric ton (Mt) and total area covered by oilseed crops was 484210 acres in the year of 2016-2017 (BBS, 2017).

Yellow mustard has a yellow seed coat and is primarily grown for the North American condiment industry, where it is used to produce traditional yellow mustard condiment, mayonnaise and certain salad dressings. The seed of yellow mustard also contains a water-binding mucilage that has been used as a binding agent and protein extender in prepared meats. Brown mustard has a reddish brown to dark brown seed coat. Throughout the life cycle, mustard plants have eight principle growth stages: germination, leaf development, stem elongation, inflorescence emergence, flowering, fruit development, ripening and senescence. Staging of crops is important for optimal timing of harvest and pest management strategies.

The primary source of nutritionally needed fatty acids in the human diet is edible vegetable oils. Among the edible vegetable oils mostly consumed mustard, soybean, sunflower and groundnut oil in Bangladesh. However, as recommended by health agencies, none of these oils alone provide many of the lipid soluble nutrients as per. A high volume of selenium and magnesium is found in rapeseed oil, which has anti-inflammatory properties. It also serves to activate sweat glands and helps decrease the temperature of the body. It is used to alleviate the discomfort associated with inflammation, muscle sprains and strains (Sood *et al*., 2010). Each gram oil /fat supplies 9 kilocalorie energy while each gram of carbohydrate/ protein furnishes 4 kilocalorie (Stryer, 1980). Among the cooking oils, rapeseed oil (RSO) is the most useful and it contains a significant amount

of ω-3 and ω-6 fatty acids. RSO contains fatty acid such as oleic, linoleic, linolenic, palmitic and strearic acid (Gunstone *et al*., 1994 and Hui, 1996).

The major source of EA is the seed oils of the Brassicaceae family, which includes rapeseed, mustard, crambe and wallflower, all containing about 45% to 60% EA (Sonntag, 1991). Higher erucic acid intake can increase adrenal cholesterol concentration, leading to fibrotic changes in myocardium, liver weight and cholesterol (Beare-Rogers *et al*., 1972). In developing countries, elevated doses of erucic acid are not appropriate for human food as well as erucic acid in animals also showed significant pathological alterations in the heart and skeleton (Technical Report, 2003). EA is a very valuable raw material in the oleo chemical industry, despite questions about its protection for human use and its derivatives have varieties of superior properties in sliding, softening, antifoaming, emulsifying and inhibiting corrosion (Carlson and Van Dyne, 1992).

Mustard is a cold loving crop and grows during Rabi (cold) season (October-February) usually under rainfed condition and low input condition in this country. Its poor yield can be due to several factors, the nutritional deficiency, among others is highly important. There is very little scope of expansion for mustard and other oilseed acreage in the country, due to competition from more lucrative substitute crops such as boro rice. The cultivation of mustard has to compete with other food grain crops have shifted to subsidiary lands of poor productivity. The demand for edible oil is growing day by day, with an increasing population growth trend. It is also widely agreed that, in order to satisfy the country's demand, the production of edible oil should be considerably increased. The main reasons for our country's poor yield of rapeseed-mustard are due to the lack of high yielding varieties, insufficient fertilizer usage and lack of knowledge of good management practices.

Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University, Bangladesh Institute of Nuclear Agriculture (BINA) and Sher-e-

Bangla Agricultural University (SAU) has implemented a range of new high yielding rapeseed/mustard varieties for farmer's cultivation. The yield of HYV cultivars range from 1.3 to 2.1 t ha^{-1} (BARI, 2018). But due to the lack of good management practices, the yield in farmer's fields are still low compared to the capacity. The importance of any crop is judged by its yield potential, nutrients content, keeping quality and market value. The low production and productivity of rapeseed-mustard have been due to several constraints like cultivation on marginal lands, improper seedbed preparation and irrigation facility at the critical stages of crop growth, imbalanced and ultimately use of fertilizers, inadequate plant protection measures adopted by the farmers and poor post-harvest technology including storage, processing and poor marketing support. These have adverse effect on productivity of rapeseed-mustard. The poor productivity of mustard might be the resultant of a variety of factors viz. agronomic, edaphic, genetic and others. Proper control of weeds can be a very severe problem among the agronomic variables (Singh, 1992). The area and production of oilseeds are gradually declining due to low yield potential of oilseed varieties, high infestation of diseases and pests, compared to other crops, instability of yield due to micro-climatic fluctuation, expansion of irrigation facilities and more profitable crops are available in place of in the cropping patterns. Most oilseeds crops respond positively with high management, yet they cannot compete with other high value crops. Usually, farmers do not allocate their good piece of land and also they do not follow modern cultural practices for oil crops. So, their yields are low.

Hence, keeping the above facts in view, the present investigation entitled was undertaken to quantify the response of growth and yield of mustard to different agronomic managements with the following objectives-

- **i** To compare the performance of two mustard varieties.
- **ii** To compare the role of agronomic management on yield reduction of mustard.
- **iii** To determine the interaction of variety and agronomic management on growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

A significant number of researchers have paid considerable attention to different aspects of the development and use of *Brassica spp*. which is the most common oil crop in Bangladesh and many other countries in the world. In several countries around the world, various studies have been performed on *Brassica spp*. Cultural practices of rapeseed must be improved to increase the yield of this crop under Bangladesh situation. But the research works done on this crop with respect to agronomic practices are inadequate. The research work so far done in Bangladesh is not satisfactory and definitive. However, some of the significant and insightful works and research findings have been discussed in this chapter.

Effect of variety

Ferdous *et al.* (2017) conducted an field experiment on Effect of plant density and fertilizer rate on the performance of short duration mustard cv. BARI Sarisha-14 from October, 2015 to June, 2016 at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The experiment was laid out in split plot design with three replications. The experiment consisted of four plant densities: P_1: 56 plants/m^2 (30 cm × 6 cm), P_2: 67 plants/m^2 (25 cm × 6 cm), P_3: 80 plants/m^2 (25 cm × 5 cm), P_4: 100 plants/m^2 (25 cm × 4 cm) and four rates of fertilizer : F_0: Control (no fertilizer) F_1: 100% of fertilizer recommended rate (Fertilizer Recommendation Guide-2012), F_2: 120% of fertilizer recommended rate F_3: 140% of fertilizer recommended rate. The highest seed yield was obtained (1.60 t/ha) in plant density P_2: 67 plants m^{-2} (25 cm × 6 cm) with the combination of high rates of fertilizer F_3: 140% of recommended fertilizer rate. The next best result was (1.50 t/ha) recorded in case of plant density P_1: 56 plants/m^2 (30 cm × 6 cm) with the combination of fertilizer rate F_3: 140% of recommended fertilizer rate. It indicated, high plant density with combination of recommended fertilizer reduce yield.

It is concluded from the study that BARI Sarisha-14 in combination with plant density (25 cm x 6 cm) and high rates of fertilizer produced highest seed yield at agro- climatic condition of Mymensingh.

Akhter *et al.* (2015) carried out a field experiment to study the effect of sowing dates on phenology and accumulated heat units of rapeseed (*Brassica campestris* L.). Seeds of three varieties (BARI Sarisha-14, BINA Sarisha-5 and BINA Sarisha-6) were sown on four different dates from October to December (S_1-18 October, S_2-2 November, S_3-17 November and S_4-3 December). The results indicated that the number of days required to attain different phenological stages decreased with delay in sowing. For all the phenological stages, S_1 required higher heat units than that of other sowings. The plants of S_1 used heat more efficiently than S_2, S_3 and S_4. At the earlier phenological stages, phenothermal index decreased with delay in sowing, but increased at the later stages.

Al-Foysal *et al*. (2017) conducted an experiment on Validation of Rapeseed-mustard Varieties/Line in High Land for Development of Rapeseed/ Mustard-Fallow-T. Aman Pattern of Sylhet in Bangladesh. Results indicated that yield and yield contributing characters did not differ significantly due to irrigation levels because of rainfall at pod filling stage. Yield and yield contributing characters differed significantly among the varieties. The variety BARI Sarisha-16 produced the highest seed yield (993 kg ha^{-1}) which was significantly different from the others. BINA sarisha-4 produced the second highest seed yield (898 kg ha^{-1}) while the lowest (645 kg ha^{-1}) was produced by the variety Tori-7. BARI Sarisha-16 required the maximum days (89.3) for maturity but Tori-7 and BARI Sarisha-14 had the minimum days (76.3 & 77.5 days respectively). There was no significant variation due to combined effect of variety and irrigation level on yield and yield attributes. Seed yield was positively correlated with plant height, siliqua $plant^{-1}$ and 1000-seed weight.

Islam *et al.* (2018) conducted a field experiment on Effect of nitrogen (N) and sulphur (S) on yield and yield components of rapeseed (BARI Sarisha-14) was

studied at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during two consecutive Rabi seasons of 2014-15 and 2015-16. The experiment was laid out in split-plot design with three replications, consisted four levels of nitrogen viz., 0 (control), 60, 120, 180 kg ha^{-1}; and four levels of sulphur i.e., 0 (control), 15, 30, 45 kg ha^{-1}. Levels of N and S showed significant effect on yield and yield contributing characters of BARI Sarisha-14. Results showed that application of 120 kg N ha^{-1} with 45 kg S ha^{-1} gave the maximum yield. Results also revealed that the highest plant height, number of branches $plant^{-1}$, number of siliquae $plant^{-1}$, siliqua length, number of seeds $siliqua^{-1}$, 1000-seed weight, seed yield, stover yield, biological yield and harvest index were obtained from the combination of 120 kg N with 45 kg S ha^{-1}

Masum *et al*. (2019) conducted a study at (AEZ-20) Shiberbazar, Sylhet during November 2016- February 2017, to quantify the effect of boron on yield and yield attributes of mustard (BARI Sarisha-14), and different doses and form of B application. Randomized Complete Block Design (RCBD) was followed with three replications to design the study. Five B (boric acid) levels viz. T_1 = basal application of B @ 2kg ha^{-1}; T_2 = foliar spray (FS) of B @ 0.5% at vegetative stage (VS) ; T_3 = FS of B @ 1% at VS; T_4 = FS of B @ 0.5% at VS + pod formation stage (PFS) and T_5 = FS of B @ 1% at VS + PFS and T6 = control (no boron) were used. Results indicated that yield and yield attributes of mustard were significantly influenced by boron application. The effects of boron were significant on number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, seed yield, stover yield, 1000-seed weight, biological yield and harvest index (%). The highest number of siliquae $plant^{-1}$ (35.93), number of seeds $siliqua^{-1}$ (30.03), stover yield (1946.0 kg ha^{-1}) and 1000-seed weight (3.617 g) were obtained from the treatment T_5. The seed yield (801.17 kg ha^{-1}) was found also in the treatment T_5 which was over double than control (T_6). Therefore, two times foliar application of B @1% at VS and PFS is a good option to increase yield and yield contributing characters of BARI Sarisha-14 in AEZ 20.

Sultana *et al*. (2020) conducted an experiment on Response of sulphur and zinc nutrition to the seed yield and oil content of mustard (CV. BARI Sarisha-14). The role of different nutrient elements is well established in plant metabolism. However, different crops respond differently in relation to their growth and yield. An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the response of sulphur and zinc nutrition to the seed yield and oil content of mustard (cv. BARI Sarisha-14). It laid out in RCBD with three replications was consisted of four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) and Zn (0, 1, 2, 3 kg ha^{-1}). It was observed that 60 kg Sulphur ha^{-1} gave significantly highest seed yield, oil content and harvest index owing to the highest number of branches $plant^{-1}$, siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and 1000-seed weight. Conversely, 0 kg Sulphur ha^{-1} provided the lowest seed yield and oil content of mustard. Again, the highest number of branches $plant^{-1}$, siliqua $plant^{-1}$ and seeds $siliqua^{-1}$ was found at 3 kg zinc ha^{-1} which resulted in the highest seed yield, oil content and harvest index. The lowest performance of the yield components and yield was observed at 0 kg zinc ha^{-1}. Interaction effect between 60 kg sulphur ha^{-1} and 3 kg zinc ha^{-1} provided the highest seed yield and stover yield because of the highest number of branches $plant^{-1}$ and seeds $siliqua^{-1}$ and the worst yield performance was a observed at the control treatment. Therefore, the application of sulphur and zinc at the rate of 60 kg ha^{-1} and 3 kg ha^{-1}, respectively could be applied for BARI Sarisha-14 for higher seed yield.

Azam *et al.* (2018) conducted an experiment in RARS, BARI Hathazari during Robi season in 2014-2015 and 2015-2016 to find out the best variety and best sowing time of mustard under the agro ecological condition of Chittagong region. There were two varieties viz. V_1=BARI Sarisha 14 and V_1=BARI Sarisha 15 and six sowing date viz. S_1=10 November, S_2=20 November, S_3= 30 November, S_4=10 December, S_5=20 December and S_6=30 December. Significant variations due to different sowing time and varieties were observed in days to 50% flowering, days to maturity, plant height, branches $plant^{-1}$, siliqua $plant^{-1}$, length of siliqua, seeds $siliqua^{-1}$, 1000 seeds weight (g), yield $plot^{-1}$ and yield

kg ha^{-1} . Result showed that highest yield was 2083 kg ha^{-1} obtained from BARI Sarisha15 on 20 November (V_2S_2) followed by 1667 kg ha^{-1} obtained from BARI Sarisha14 on 20 November (V_1S_2). From the result it can be concluded that best variety is BARI Sarisha-15 and best sowing date is 20 November for Chittagong Region but both varieties can give satisfactory if they are sown from 10 November to 10 December.

Rashid *et al*. (2013) carried out a field experiment in non-Calcareous Floodplain Soil of Spices Research Sub-Station, Lalmonirhat under AEZ 2 during the rabi season of 2007- 2008 and 2008-09. The objectives were to evaluate the effect of boron on the yield of mustard and to screen out the suitable variety tested against different boron levels for maximizing yield. Three varieties of mustard viz., BARI Sharisha-11, 13, and 14 and 5 levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg/ha) along with a blanket dose of N_{120} P_{35} K_{65} S_{20} $Zn_{3.0}$ kg/ha were used in the study. Results revealed that BARI Sharisha-11 performed better with 1.5 kg B/ha which produced 1.82 t ha^{-1} seed. However, from regression analysis, a positive but quadratic relationship was observed between seed yield and boron levels. The optimum dose of boron was appeared to be 1.7 and 1.6 kg B ha^{-1} for Lalmonirhat during 2007-08 and 2008- 09, respectively

Effect of irrigation

Arora *et al*. (1993) reported that deep tillage and early irrigation enhanced the rooting density and the rate of dry matter accumulation of mustard and as a consequence, there was greater depletion of profile stored water and better plant water status, particularly in the low water retentive loamy sand.

Clarke and Simpson (1978) observed in an analysis of yield components of rapeseed from field trial that irrigation scarcely affected the number of branches per plant.

Vikram and Prasad (2001) conducted an experiment to determine the effect of irrigation and sulphur levels on the growth and yield of rai (*Brassica juncea*

L.). They reported that there was a significant effect of irrigation levels and sulfur rates on growth and yield attributes but significant increase was only up to IW:CPE ratio of 0.4 and 15 S ha^{-1} over rain fed and control treatments respectively.

Fateh *et al.* (2002) conducted an experiment to study the effect of irrigation schedule on the growth, yield and yield contributing characters of Indian mustard. They reported that one irrigation at the vegetative stage recorded higher yield than one irrigation at flowering or pod formation of seed filling stages.

Singh *et al*. (2002a) tested four genotypes of *Brassica spp*. (*B. juncea, B. carinata, B. napus, and B. campestris*) under 2 moisture regimes, i.e. normal irrigation and limited irrigation. They reported that growth, development and yield of all *Brassica spp*. were adversely affected under limited water conditions. They also reported that under normal irrigated condition the expression of yield was highest in *B. juncea.*

According to Panda *et al.* (2004), successive increase in irrigation levels had significant positive effect on leaf area index (LAI) at 72 and 102 days after sowing (DAS), total dry matter (TDM) accumulation at 72,102 DAS and at harvest, crop growth rate (CGR) AT 42-72 and 72-102 DAS, net assimilation rate (NAR) at 42-72 and 72-102 DAS, days taken to maturity, biological yield, seed yield and harvest index.

Piri and Sharma (2006) reported that the seed yield of mustard increased significantly with increasing levels of irrigation and application of sulfur also significantly increased the plant height, dry matter accumulation, leaf area index, relative growth rate, primary and secondary branches per plant and seed yield of Indian mustard.

Gouranga *et al.* (2007) conducted an experiment on three oil seed crops viz. linseed, safflower and mustard grown in a representative soil under rain fed water at phenological stages. They reported that three supplemental irrigations,

the highest water use efficiency (WUE) was achieved by safflower followed by linseed whereas with one irrigation the highest WUE was achieved for safflower followed by linseed. Of the three crops studied, safflower withdraw maximum water followed by mustard.

Piri *et al.* (2012) reported that two irrigations significantly increased plant height and number of primary and secondary branches per plant over one irrigation, which resulted in significantly higher dry matter accumulation and forage yield with two irrigations as compared to one irrigation.

Belal (2013) reported that the highest plant height, number of branches plant^{-1}, filled siliquae plant^{-1}, siliqua length, number of seeds siliqua^{-1}, 1000-seed weight and stover yield were obtained from two irrigations and consequently, it produced the highest seed yield.

Husen *et al.* (2014) reported that drought stress reduced the growth rate of root and shoot, number of leaves, dimension (width, length and area) of leaves and the biomass accumulation in different plant parts. With increase in drought stress, the relative water content, chlorophyll content were reduced.

Patel and Patel (1999) conducted an experiment to find out the response of mustard (*Brassica juncea*) to irrigation, spacing and growth regulators. They reported that the interaction effects among irrigation, spacing and plant growth regulators were significant for seed yield.

Kumar and Rao (2001) from a two years field experiment reported that the mustard crop was found to be highly sensitive to evapotranspiration deficits at flowering, pod initiation and pod filling periods and their combination growth sub periods, which significantly reduced the seed yield in comparison to fully irrigation control. They also reported that the lowest seed yield resulted from severe evapotranspiration deficits from flowering to maturity period.

Kantwa and Meena (2002) conducted field experiment to study the effects of irrigation, phosphorus rate and PSB (Phosphate solubilizing bacteria) on

growth and yield of mustard. They reported that the application of three irrigations at different growth stages resulted in a significant increase in growth parameters, yield attributes, seed and stover yields.

Piri and Sharma (2007) reported that increasing the number of irrigation resulted in better yield attributing characters and seed yield and stover yield as compared to no irrigation in mustard.

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.

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).

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.

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).

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).

Effect of mulching

Sachan *et al*. (1997) revealed that the paddy straw mulch in between rows significantly improved growth, yield attributes, seed yields and water use efficiency of mustard.

Rathore *et al.* (1998) revealed that straw mulch enhanced soil moisture conservation and moisture availability during crop growth period than no mulch. Availability of soil moisture during the crop growth period maintained better plant water status, oil temperature and lowered soil mechanical resistance, leading to better root growth, yield components (plant stand, number of siliquae plant^{-1} and plant height) and seed yield of both chickpea and mustard in straw mulch than in no much plots.

Effect of weeding

Bhan and Mishra (1993) reported that in Indian mustard, weeds cause the maximum damage at the initial 20-40 days stage.

Singh (1995) reported that on an average, 25% seed yield was reduced by weeds due to competition for moisture and nutrients.

Prusty *et al.* (1996) reported that weed infestation during early stages of crop growth ended up with yield reduction and upto an extend of 58% in indian mustard.

Singh *et al.* (2001) reported from Hisar that Indian mustard suffers from weed competition in early growth stage. Yield losses due to weeds varied from 25 to 45%, depending on the type of weed flora and their intensity, stage, nature and duration of crop-weed competition.

Sharma *et al.* (2007) reported 57.3 and 47.4 percent yield reduction in gobhi sarson during first and second year, respectively due to weed infestation from the experiment conducted at palampur, Himachal Pradesh.

Yadav *et al*. (1995) reported from Morena that the highest number of siliquae and seed weight plant^{-1} were recorded in weed-free plot which was closely followed by pre-plant application of isoproturon 1.0 kg ha^{-1}.

Singh *et al*. (2002b) reported that hoeing improved nitrogen use efficiency under all nitrogen levels and water expense efficiency of the crop. With two hoeings the optimal nitrogen use efficiency was for 100 and 150 kg ha^{-1}. One hoeing was sufficient for mustard grown without irrigation with 50 kg N ha^{-1} and two hoeings for that grown with two irrigations as well as 100 and 150 kg N ha^{-1}. A decrease in dry matter of weeds by 37.3 percent with one hoeing and 54.2 percent with two hoeings increased the mustard yield by 13.1 and 18.1 percent respectively.

Power *et al.* (2003) reported that hand weeding twice, fluchloralin or oxadiazon followed by one hand weeding combined with soil test-based fertilizer application showed the highest yield. The highest weed control efficiency (82.93 and 72.25%) was obtained with hand weeding twice during both the years.

Pal *et al*. (2000) conducted a field experiment on cultural and chemical method of weed control in Indian mustard. The treatments were, hand weeding at DAS, hand weeding 20 & 40 DAS, fluchloralin 1.0, pendimethalin 1.0 kg ha^{-1}, weed free and weed control. The most problematic weeds were Chenopodium album, Cyperus rotundus, Cynodon dactylon and Melilotus alba. All the weed control treatment increased crop yield over the untreated plot. However, hand weed in twice gave maximum yield (11.06 q ha^{-1}), fluchloralin was more effective than pendimmethalin.

Singh and Pandey (1973) noted hand weeding as an effective method of weed control and was comparable to application of linuron 1.0 kg ha^{-1} as pre-emergence. Hand weeding gave an effective control of weeds and increased seed yield of mustard from 310 kg ha^{-1} in control plots to 370 kg ha^{-1}.

Anonymous (1983) Results on weed control in mustard that one hand weeding at 4 weeks of sowing was most effective in reducing the weed population of all type of weeds in sandy-clay loam soils of Jabalpur.

Anonymous (1987) reported that two hand weeding at 30 and 60 DAS gave the highest seed yield (3.29 q ha^{-1}). It was at par to herbicidal method of weed control by isoproturon.

A field experiments was conducted by Gupta *et al.* (2018) during two consecutive rabi seasons of 2013-14 and 2014-15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard under semi-arid conditions of Rajasthan. The experiment consist of 10 treatments viz. T_1: weedy check, T_2: Pendimethalian 30 EC @ 0.75 kg ha^{-1}, T_3: pendimethalian 38.7 CS @ 0.75 kg ha^{-1}, T_4: Oxadiargyl 6EC @ 0.09 kg ha^{-1}, T_5: Pendimethlian 30 EC+ Imazethapyr 2 EC (ready mix) @ 0.75 k ha^{-1}, T_6: Oxyflurofen 23.5 EC @ 0.15 kg ha^{-1}, T_7: Quizalofop-pethyl 5EC @ 0.06 kg ha^{-1}, T_8: Clodinafop-p- ethyl 15WP @ 0.06 kg ha^{-1}, T_9: one hand weeding (HW) at 25-30 DAS and T_{10}: Two hand weeding at 25-30 and 40-45 DAS were evaluated in randomized block design with three replications. They revealed that the maximum seeds siliqua^{-1} (13.07) was observed in two hand weeding and the minimum one (9.32) from T_5 (Pendimethlian 30 EC+ Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}) treatment which was statistically similar with T_1 (weedy check) treatment.

An experiment was conducted by Awal and Fardous (2014) at the Crop Botany field laboratory, Bangladesh Agricultural University, Mymensingh , from November 2010 to February 2011 to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica* campestris. The experiment comprised 4 treatments from the combination of two weeding regimes viz. weeding and without weeding conditions with two species of mustard viz. *Brassica napus* and *Brassica campestris*, represented by the cultivars Binasarisha -5 and Binasarisha -6, respectively. The experiment was

laid out following a randomized complete block design with three replications. Results showed that the highest 1000 seed weight (2.98 g) obtained from the weeding condition along with species *Brassica napus* whereas the lowest 1000 seed weight (2.52 g) was found in no weeding along with *Brassica campestris.*

The experiment was carried out by Akhter *et al.* (2016) at the experimental field of Rajshahi University Campus, Bangladesh) during from October, 2006 to March, 2007 12 and October, 2008 to March, 2009 growing seasons. The experiment was laid out in a split-split plot design with three replications. Each replicated field was divided into four main plots for sowing treatments (S_1 = 18 October, S_2 = 2 November, S_3 = 17 November, S_4 = 3 December). Each main plot was divided into three sub-plots for weeding treatment (W_0 = no weeding, W_1 = one hand weeding, W_2 = two hand weeding). They found that Binasarisha -5 produced highest branches plant^{-1} (5.54) followed by BARI Sarisha -14 (4.22) and Binasarisha -6 (3.83). Comparison of the treatment means reflected that maximum branches plant^{-1} (5.39) was recorded where two weeding were conducted, while minimum number (3.39) was counted in the no weeding.

Field investigation was carried out by Bamboriya *et al.* (2017) during rabi season of 2014-15 at Udaipur to evaluate the effect of different weed management practices on yield and nutrient uptake of mustard. The experiment comprises of 10 treatments, which consisted of weedy check, one hand weeding at 20 DAS, two hand weeding at 20 and 40 DAS, fenoxaprop-p-ethyl 0.075 kg ha-1 at 10 DAS, fluazifop-p-butyl 0.055 kg ha^{-1} at 10 DAS, quizalofop-p-ethyl 0.050 kg ha^{-1} at 30 DAS, fenoxaprop-p-ethyl 0.075 kg ha^{-1} at 10 DAS + one hoeing at 40 DAS, fluazifop-p-butyl 0.055 kg ha^{-1} at 10 DAS + one hoeing at 40 DAS, isoproturon 1.25 kg ha^{-1} at 30 DAS and weed free check. The experiment was laid out in a randomized block design and replicated four times. They reported that the maximum biological yield (7523.50 kg ha^{-1}) was recorded from two hand

weeding treatment while the minimum biological yield (5109.75 kg ha^{-1}) was recorded from weedy check treatment.

The competition effect of some weed species on the yield of winter oilseed rape was studied by Adoezewski (1990). In 7 year trials he observed that in oil seed rape at winnagora, *Anthamis arvensis* as a competitive weed. He also found large infestations causing up to 50% yield reduction.

Wahmhoff (1990) conducted an experiment on weed control in winter rape and concluded that rape yields were affected more by climatic factors, local site conditions, crop cover and the composition of the weed population than the total weed cover.

Donovan and Sharma (1994) conducted an experiment on oilseed crops and reported that factors associated with crop losses due to weeds. They found that the yield loss generally increased with increasing wild oat population. Crop quality was reduced due to weeds

Gaffer (1984) observed that the weed free condition produced the maximum seed yield and yield components of rapeseed. He also found that yield reduction was 23.0% in control as compared to weed free plots.

Ghosh *et al*. (1994) conducted an experiment on sandy loam at Kharagpur on weed control on mustard and reported that all weed control methods increased Indian mustard seed yield over untreated one.

Effect of fertilization

Ali *et al*. (1990) reported that different levels of nitrogen significantly increased plant height of mustard.

Allen and Morgan (1972) found that increasing rate of nitrogen 0-211 kg N ha^{-1} increased plant height, LAI, plant dry matter, pod dry matter, number of pods $plant^{-1}$, number of seeds pod^{-1} and seed yields.

Mir *et al*. (2000) noted in an experiment that fertilizer dose had significant effect on the yield and yield contributing characters of mustard. The maximum height of plant, number of primary branches, weight of seed plant^{-1}, dry matter weight of plants and the yield of seed were obtained highest at the rate of 78.46 kg N ha^{-1}.

Mondal and Gaffer (1983) stated that nitrogen is the most spectacular of all essential nutrients in its effect on plant growth and yield of this crop. The literature shows that nitrogen has significant effect on plant height, branches plant^{-1}, pods plant^{-1} and other growth factors and yield of mustard. Nitrogen increases the vegetative growth and delayed maturity of plants.

Abdin *et al.* (2003) conducted a field experiments in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (V_1) and rape cv. Pusa Gold (V_2). The treatments comprised: T_1 [(S0:N (50 + 50)]; T_2 [S40:N (50 + 50)] for V_1 and [S40:N (50 + 25 + 25) for V_2]; and T_3 [(S20 + 20):N (50 + 50) for V_1] and S (20 + 10 + 10):N (50 + 25 + 25) for V_2]. Split application of S and N (T_3) resulted in a significant increase in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t ha^{-1} for V_1 and 3.06 t ha^{-1} for V_2 under T_3. The average oil yield under T_3 was 1.71 t ha^{-1} for V_1 and 1.42 t ha^{-1} in V_2. The oil and protein contents in the seeds of V_1 and V_2 also increased with the split application of S and N. It may be concluded from these results that the yield and quality of mustard can be optimized with the split application of 40 kg S ha^{-1} and 100 kg N ha^{-1} during the appropriate phenological stages of crop growth and development.

Banueles *et al*. (1990) recorded significant differences on seed yield of mustard for different level of sulphur application.

Behera *et al.* (2002) conducted a field experiment to study the effect of plant population and sulfur levels on yield of mustard (*B. juncea*) and found

interaction effects of variety and plant population significant on pooled seed yield and recorded the maximum seed yield at the intermediate population level of 14.8 plants m^{-2}.

Greath and Schweiger (1991) have shown that cultivars of mustard may differ in nitrogen uptake and translocation. They classified cultivars into three types: type the higher the nitrogen application, the higher the yield; type II- as nitrogen is increased, yield increases at first, then remains stable; type III- as nitrogen is increased, yield increases at first, is stable for a while and then decreases. Nitrogen requirement varies from place to place. More cultivation of legume crops in the preceding year will not fulfill the requirement of nitrogen for normal growth and yield of rape.

Patel *et al*. (2004) conducted a field experiment was during the rabi season of 1999-2000 in Gujarat, India to investigate the effects of irrigation schedule, spacing (30 and 40 cm) and N rates (50, 75 and 100 kg ha^{-1}) on the growth, 16 yield and quality of Indian mustard cv. GM-2. In combination treatments, 3 irrigation + N at 100 kg ha^{-1} + spacing of 45 cm resulted in a significant increase in yield. Growth, yield attributes and seed yield increased with increasing N levels, while oil content decreased with increasing rates. The highest benefit cost ratio was also obtained with N at 100 kg ha^{-1}

Prakash *et al*. (2002) set an experiment with the effect of sulphur rate (0, 20, 40 and 60 kg ha^{-1}) on three Indian mustard cultivars (Varuna, PMB-16, Rohini and Pusa Bahar), where sulphur used as gypsum into the soil one month before sowing. Pusa Bahar recorded the highest seed yield, protein and oil contents, whereas Rohini gave the highest number of leaves $plant^{-1}$, seed yield, protein, and oil contents increased with the increase in sulphur rate up to 40 kg ha^{-1} only.

Rahman *et al.* (1984) observed significant increase of mustard seed yield in trials conducted on the Darsona series of calcareous brown flood plain soils of Jessore with the increasing application of sulphur upto 20 kg S ha^{-1}.

Sarker *et al.* (1992) carried out an experiment at the Bangladesh Agricultural University, Mymensingh with four high yielding 17 varieties of mustard BAU-M/12 (Sampad), BAU- M/248 (Sambol), M-257 and SS-75 (Sonali Sarisha) to investigate their response to five levels of sulphur viz. 0, 10, 20, 30 and 40 kg S ha^{-1}. The seed yield was maximum in BAUM/248 (Sambol) when fertilized with sulphur at the rate of 40 kg S ha^{-1} in comparison to other varieties and rate of sulphur. The variety "Sampad" followed "Sambol" in respect of seed yield at this level of sulphur fertilizer. The seed yield of M/257 and SS-75 (Sonali Sarisha) were found to be maximum at 30 kg S ha^{-1}.

Singh *et al.* (1999) stated that sulphur has been reported to influence productivity of oil seed and application of S fertilizer increased the seed yield of mustard. .

Kjellstrom (1993) studied that the most biological yield was produced with increase in use of nitrogen manure.

Babu and Sarkar (2002) reported that mustard cultivars responded to N application up to 80 kg ha^{-1}. Dry matter yield, N content and N uptake by mustard cultivars significantly increased with an increase in the level of fertilizer N. Successive levels of N also increased significantly the uptake of soil N by mustard cultivars clearly establishing the 'priming' or 'added nitrogen interaction effect' of applied nitrogen

Budzynski and Jankowski (2001) investigated the effects of pre-sowing application of NPK (161 kg ha^{-1}) + S (30 kg ha^{-1}) or Mg (5 kg ha^{-1}) and top dressing of N (0, 30, 25 + 5 and 60 kg ha^{-1}) on the yield, yield components and morphological features of white mustard [*Sinapis alba*] and Indian mustard seeds in an experiment conducted in Poland. N top dressing (30, 25 + 5 and 60 kg ha^{-1}) increased the height, diameter of stem base and branching of Indian mustard and white mustard stems. Both crops, however, exhibited lodging. The effects of NPKS and NPKMg on the yield potential of white mustard were not dependent on weather conditions. N applied at 30 kg ha^{-1} at the start of the

flowering period gave the best results among the methods of white mustard top dressing. Splitting this rate to 25 kg N ha^{-1} as a solid fertilizer and 5 kg N ha^{-1} in a solution gave results similar to that of the whole rate of 30 kg N ha^{-1} as a solid fertilizer. N at 60 kg ha^{-1} appeared to be less productive. N applied as a solid fertilizer at a rate of up to 60 kg ha^{-1} increased the seed yield.

A field experiment was conducted by Sinsinwar *et al*. (2004) during the 1999/2000 and 2000/01 rabi seasons in Bharatpur, Rajasthan, India, to determine the best cropping sequence and N fertilizer application rate (0, 30, 60 and 90 kg ha^{-1}) of Indian mustard cv. RH-30 under brackish water situation. The cropping sequences did not affect the growth, yield and yield components (i.e. plant height, number of primary and secondary branches per plant, number of siliquae $plant^{-1}$), 1000-seed weight and seed yield in both years. The seed yield of Indian mustard significantly increased with each increment of N fertilizer up to 60 kg ha^{-1}, beyond which the increase was marginal. On an average, the increase in seed yield compared to the control was 33.3 and 83.8% with 30 and 60 kg N ha^{-1}, respectively.

Effect of pest management

Mishra *et al*. (2001) examined the effects of intercrop (wheat, barley, gram, and fenugreek) on the yield of Indian mustard and the incidence of L. erysimi. They found that only Indian mustard + chickpea had lower mean pest incidence (24.61) than the sole Indian mustard (25.50).

Saha *et al.* (2000) intercrops of linseed cv. Garima and Indian mustard (*Brassica juncea*) cv. Varuna and linseed cv. Garima and tomato cv. Pusa Ruby were infested with different species of insect pests of which the mustard aphid, *Lipaphis erysimi*, linseed gall midge, *Dasyneura lini*, black aphid, *Aphis craccivora*, and tomato fruit borer, *Helicoverpa armigera*, showed significant differences in infestation levels in various intercrop situations in Varanasi, Uttar Pradesh, India, during rabi season of 1996-97. However, there was a general downward trend in infestation level of different pests in intercrop combinations compared to their numbers in sole crops of preferred host.

The intercrops were thus, found to be more suitable for natural suppression of pest populations

Singh and Kothari (1997) reported that the mustard intercropped with aromatic plant species that could provide an environmentally safe method for aphid control, aphid infestation on a monocrop of *B. juncea cv. Rohini* was compared with infestation under intercropping with *Artemisia annua*, *Coriandrum sativum, Matricaria chamomilla (Chamomilla recutita), Foeniculum vulgare and Anethum sow*a and intercropping with *F. vulgare* resulted in a significantly lower aphid infestation.

Singh *et al.* (2003) reported an integrated pest management (IPM) module, involving the timely sowing of the crop, seed treatment with carbendazim at 2 g kg^{-1} seed, soil application of the fungal biological control agent Trichoderma 50 viride at 1 kg $acre^{-1}$, mechanical removal of aphid-infested twigs at the initial stage of attack and 3 inoculative releases of aphid predator (*Chrysoperla carnea*) larvae, was validated at farmers' fields in Bhora Khurd village, Guargon district, Haryana, India during 1997-98, for the management of pests and diseases of mustard. The IPM module reduced the pest attack on the crop and gave higher yield compared to untreated plots.

Reza *et al.* (2004) find out the efficacy of profenofos (0.02 and 0.05% a.i.), triazophos (0.02 and 0.05% a.i.), dimethoate (0.2 and 0.05% a.i.) oxydemetonmethyl (0.025 and 0.05% a.i.) and quinalphos + cypermethrin (0.023 and 0.046% a.i.) in controlling aphids (L. erysimi) infesting mustard cv. B-85 was determined in a field experiment conducted in West Bengal, India. Spraying with 0.05% a.i. oxydemeton-methyl resulted in the lowest mean aphid population and highest mean aphid mortality during the first spraying followed by spraying with 0.05% a.i. dimethoate.

Second spraying with both treatments resulted in the total control of the aphid population. Spraying with 0.05% a.i. oxydemeton- methyl resulted in the highest crop yield (13.82 q/ha) and gain in yield over the control (87.26%),

whereas spraying with 0.025% a.i. oxydemeton-methyl resulted in the highest cost:benefit ratio (1:13.64).

A trial was conducted by Gupta (2005) with mustard cv. Pusa Bold in Madhya Pradesh, India, during 1999-2000 and 2000-01 to investigate the efficacy of neem (*Azadirachta indica*) leaf extracts (NLE) and neem kernel extracts (NKE) in cow urine, neem oil, phosphamidon, dimethoate and their combinations were evaluated against the mustard aphid (*Lipaphis erysimi*) along with their impact on the activity of coccinellid beetles (biological control agents of mustard aphid). The treatments comprised NLE at 1% (5 l cow urine +1.25 kg neem leaves ha^{-1}), NLE at 2% (10 l cow urine + 2.50 kg neem leaves ha^{-1}), NLE at 3% (15 l cow urine + 3.75 kg neem leaves ha^{-1}), NKE at 1% (5 l cow urine + 500 g neem kernels ha^{-1}), NKE at 2% (10 l cow urine + 1 kg neem kernels ha^{-1}), NKE at 3% (15 l cow urine + 1.50 kg neem kernels ha^{-1}), Neem oil at 1% (5 l neem oil ha^{-1}), phosphamidon (Phosphamidon 85 EC) at 0.04% (240 ml ha^{-1}) and untreated control. These treatments were framed on the basis of preliminary studies conducted at this station during 1998-99. During 2000-01, dimethoate at 0.045% was taken in place of phosphamidon at 0.04%. Three combination treatments were added: NLE (in cow urine) at 3% + dimethoate at 0.03%, NKE (in cow urine) at 3% + dimethoate at 0.03% and neem oil at 1% + dimethoate at 0.03%. The treatments significantly reduced the incidence of mustard aphid and increased the grain yield of mustard.

CHAPTER III

MATERIALS AND METHODS

This section deals with details on the subject of materials and methods used to perform the experiment. It consists of a brief overview of location of the experimental site, soil characteristics, environment, the materials used in the experiment, the layout and design of the experiment, land preparation, manuring and fertilizing, seed sowing, intercultural practices, harvesting, data recording process and statistical analysis etc., which are provided as follows:

3.1 Duration of the experiment

The experiment was carried out during rabi season (November to march) of 2018-19 to determine the impact of different agronomic managements on growth and yield of two different varieties of mustard (BARI Sarisha-14 and BARI Sarisha-16) at Sher-e- Bangla Agricultural University, Sher-e- Bangla Nagar, Dhaka-1207.

3.2 Experimental site

The experiment was performed at plot no. 31, Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. The location is placed at 90°22′ E longitude and 23°41′ N latitude at an altitude of 8.6 meters above the sea level. The land is part of Agro-ecological zone of Modhupur Tract, AEZ-28.

3.3 Soil characteristics

The experimental site's soil belongs to the general soil type, shallow red brown terrace soils under Tejgaon series. The soil was loam in texture. The experimental site was medium high land and the pH was 6 to 6.3 and organic carbon content was 0.84%. The experimental field was flat, effectively supporting irrigation and drainage scheme. Appendix III represents the physicochemical properties of the soil.

3.4 Climate

The experimental site was situated under the subtropical climatic zone, characterized by three distinct seasons, the monsoon or rainy season from November to February and the pre- monsoon period or hot season from March to April and monsoon period from May to October and also characterized by heavy precipitation during the month of May to August and scanty precipitation from October to March. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from Bangladesh Mateorological Department (climate and weather division), Agargaon, Dhaka-1207 (Appendix II).

3.5 Experimental crop

The healthy seeds of two varieties (BARI Sarisha-14 and BARI Sarisha-16) were collected from BARI, Joydebpur, Gazipur and used as experimental materials. The plant materials used in that experiment is shown in Table 1.

Table 1. Major characteristics of the planting materials used in the experiment

Scientific name	Varieties	Major characteristics
Brassica campestris	BARI Sarisha-14	Short duration variety, plant height: 75-85 cm, leaf: light green, waxy smooth, siliquae plant^{-1}: 80-102, two chambers are present in pod but as like as four chambers, seeds siliqua^{-1}: 22-26, seed color brown, 1000-seed weight: 3.5-3.8 g, crop duration: 75-80 days, yield: 1.4-1.6 tha^{-1}. This variety is under rapeseed.
Brassica juncea	BARI Sarisha-16	Late planting potential, plant height: 175-195 cm, leaf-greenish, rough and hairy, siliquae plant^{-1}: 180- 200, two chamber are present in pod, seed siliqua^{-1}: 9-11, seed color pink, 1000-seed weight: 4.7-4.9 g, crop duration: 105-115 days, yield: 2-2.5 t ha^{-1}. This variety is under mustard.

3.6 Treatments

Factor A: Variety - 2

BARI Sarisha-14 (V_1)

BARI Sarisha-16 (V_2)

Factor B: Agronomic Managements - 7

Control (No Management) (M_1)

No Fertilizer but all other managements (M_2)

No weeding but all other managements (M_3)

No irrigation but all other managements (M_4)

No thinning but all other managements (M_5)

No pest managements but all other managements (M_6)

Recommended management (M_7)

3.7 Design and layout

The experiment was set up in a split-plot design with three replications where varieties were assigned in the main plot and agronomic managements in the sub plot. There were 2 x 7 = 14 treatment combinations. The unit plot size was 2.7 m x 1.3 m. Layout of the experiment was given in Plate 1.

3.8 Operational practices

3.8.1 Plot 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 cleaned properly. The final ploughing and land preparation were done on 09 November, 2018. According to the design of the experiment, the entire area was divided into blocks and subdivided into plot for the sowing of seeds.

3.8.2 Fertilization

The land was fertilized with 300-180-100-180-7 and 15 kg ha^{-1} of Urea-TSP-MoP-Gypsum-Zinc sulphate and Boric acid, respectively in all plots except no management and no fertilizer plots. Half amount of urea, total TSP, MoP, Gypsum, Zinc sulphate and Boric acid were applied during final land preparation on 10 November, 2018 and incorporated into the soil. The rest amount of urea was applied as top dressing after 20 days of sowing (DAS) as per treatment.

3.8.3 Sowing of seed

After the final land preparation the seeds of mustard/rapeseed were sown as per treatment maintaining a row distance of 30 cm. The sowing was done in furrows, opened with the help of hand rake. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods affect the germination of seeds.

3.8.4 Tagging

Total experimental plot was tagging on 2 December, 2018 by bamboo stick for maintaining variety, agronomic management and replications.

3.9 Intercultural operations

3.9.1 Weeding

The experimental plots were found to be infested with different kinds of weeds. Weeding was done two times manually with nirani as per treatment. First weeding was done on 26 November, 2018 which was 16 days after sowing and the second weeding was done after 30 days of sowing.

3.9.2 Thinning

Thinning of plants was done after 20 days of sowing as per treatment in order to keep only one robust and healthy plant at a distance of 10 cm to maintain proper plant population.

3.9.3 Irrigation

Irrigation was applied to the crop as per treatment as and when necessary. Irrigation was given with cane after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. A good drainage system was maintained for immediate release of excess water from the experimental plot during the growing period.

3.9.4 Crop protection

The experimental crop was not infected with any serious disease but to combat the damage caused by the most serious pest of mustard (aphids), Dimethoate (30 EC) was sprayed @1000 ml ha^{-1} in 800 litre of water once during early pod formation stage as per treatment.

3.10 Crop harvesting and threshing

The crop was harvested in different dates according to maturity. Harvesting was started from 2nd week of February 2019 and continued to first week of March, 2019 depending upon the maturity. When 80% of the plants showed maturity symptoms like straw color of siliquae, leaves, stem and desirable seed color in the matured siliquae, the crop was assessed to attain maturity. Except the boarder lines the plants were harvested by uprooting and then they were tagged properly. Previous randomly selected ten plants $plot^{-1}$, those were considered for the growth analysis was collected from each plot to record the yield and other crop characters. 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.

3.11 Drying and weighing

The seeds and stover thus collected were dried in the sun for couple of days. Dried seeds and stover of each plot was weighed and subsequently converted into t ha^{-1} basis.

3.12 Observations recorded

For recording biometric observation at regular interval, two sampling area i.e. one for destructive and the other for non-destructive harvest were marked. The observations like plant height and branches were taken from non-destructive area i.e., net plot area while observation like dry matter production per plant^{-1} were taken from destructive area i.e., apart from harvest area. Five plants plot^{-1} were selected randomly for recording growth parameter 20, 35, 50, 65 days after sowing and at harvest. Yield and yield attributing characters were recorded after harvest.

3.12.1 Crop growth parameters

(i) Plant population m^{-2}
(ii) Plant height
(iii) Leaf number plant^{-1}
(iv) Leaf length
(v) Branches plant^{-1}
(vi) Dry matter production plant^{-1}
(vii) SPAD value

3.12.2 Yield and other crop characters

(i) No. of siliquae plant^{-1}
(ii) Length of siliqua
(iii) Seeds silliqua^{-1}
(iv) 1000-seed weight
(v) Seed yield
(vi) Stover yield
(vii) Biological yield
(viii) Harvest index

3.13 Procedure for data collection

3.13.1 Plant population m^{-2}

The observation was recorded at 20 days after sowing (DAS). On the basis of plant population m-1 row length the mathematical calculation was done in each plot and an average value m^{-2} was calculated.

3.13.2 Plant height

Five plants were selected randomly from each plot and tagged. The height was measured in cm with the help of scale from base to the top of the plant at 20, 35, 50, 65 DAS (days after sowing) and at harvest. The average of five plants was recorded as the plant height in cm.

3.13.3 Leaf number $plant^{-1}$

The number of functional green leaves $plant^{-1}$ were counted on the five representative plants at 20, 35, 50 and 65 DAS and expressed as average number of leaf $plant^{-1}$.

3.13.4 Leaf length

Length of one leaf from each five representative plant was recorded at 20, 35, 50 and 65 days after sowing. Then the average was recorded as leaf length and expressed in cm.

3.13.5 Branches $plant^{-1}$

Five randomly tagged plants were used for counting the number of branches. All primary and secondary branches were counted at 50, 65 DAS and at harvest. The average number of branches $plant^{-1}$ was worked out.

3.13.6 Dry matter production $plant^{-1}$

For recording dry matter production, 10 plants from each plot cut from the ground level of second rows. Sampled plants were sun dried first then dried in an oven for 72 hours to get constant dry weight. Thereafter, the average dry weight was recorded in g $plant^{-1}$.

3.13.7 SPAD value

The SPAD value of leaves was measured by placing the SPAD meter in middle point of any 5 leaves of each 5 tagged plants plot^{-1} and then the reading showed by the SPAD502 plus meter was recorded. Two times reading was recorded and then the average of 5 leaves plot^{-1} reading was recorded.

3.13.8 No. of siliquae plant^{-1}

Total number of siliquae present on tagged plants at harvest were separated, counted, averaged and then reported as number of siliquae plant^{-1}.

3.13.9 Length of siliqua

Length of 10 siliqua of each five plants was measured with a linear scale and expressed a mean length of siliqua in cm.

3.13.10 Seeds siliqua^{-1}

Ten siliquae of each five plants used for measuring siliqua length were split open and number of seed was counted and the mean was recorded.

3.13.11 1000-seed weight

From the representative sample of each plot one thousand seeds were counted and weighted to record 1000 seeds in gram.

3.13.12 Seed yield

The seed yield of net plot after cleaning and proper drying was recorded in grams and then converted into t ha^{-1} basis.

3.13.13 Stover yield

After threshing stem and chaff weight were recorded and added treatment wise and converted to t ha^{-1} basis.

3.13.14. Biological yield

Harvested plants were dried, weighed and noted plot wise. Biological yield is the summation of seed yield and stover yield.

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

3.13.15 Harvest index (%)

Harvest index was calculated by the formula given below by Donald and Hamblin, 1978:

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

Here, Economic yield = Seed yield (t ha^{-1})

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

3.14 Statistical analysis

For determining the significance between the treatment means and to draw the valid conclusion, statistical analysis was done .The data collected on various characters were analyzed separately and statistically by using analysis of variance (ANOVA) technique with the help of computer package Statistrix 10 program for judging the effect of agronomic managements on growth and yield of mustard/rapeseed. The significance of difference among the treatments mean were tested by using Duncan‟s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez,1984)

CHAPTER IV

RESULTS AND DISCUSSION

An investigation entitled "Growth and yield of mustard/rapeseed as affected by agronomic managements" was conducted during Rabi season of 2018-2019 at the Agronomy farm, Sher- e-Bangla Agricultural University, Dhaka-1207. In this chapter, an attempt has been made to study the magnitude of variations in treatments exhibited at successive stages of growth and development. The findings obtained during the course of investigation have been presented in this chapter with the help of tables and illustrated in graphs at appropriate places where ever considered necessary. The results of present investigation were presented under appropriate headings-

4.1. Plant population m^{-2}

Observations of plant population m^{-2} were recorded at 20 days after sowing. The mean plant population m^{-2} as affected by different treatments is given in Tables and shown graphically in Figures.

Effect of variety

Significant variation was observed in plant population m^{-2} after 20 days after sowing between the varieties for varietal variation (Appendix III and Figure 1). Between the two varieties, the variety V_1 (BARI Sarisha -14) had the higher plant population m^{-2} (189.38) and the lower plant population m^{-2} (175.24) was observed with V_2 (BARI Sarisha -16).

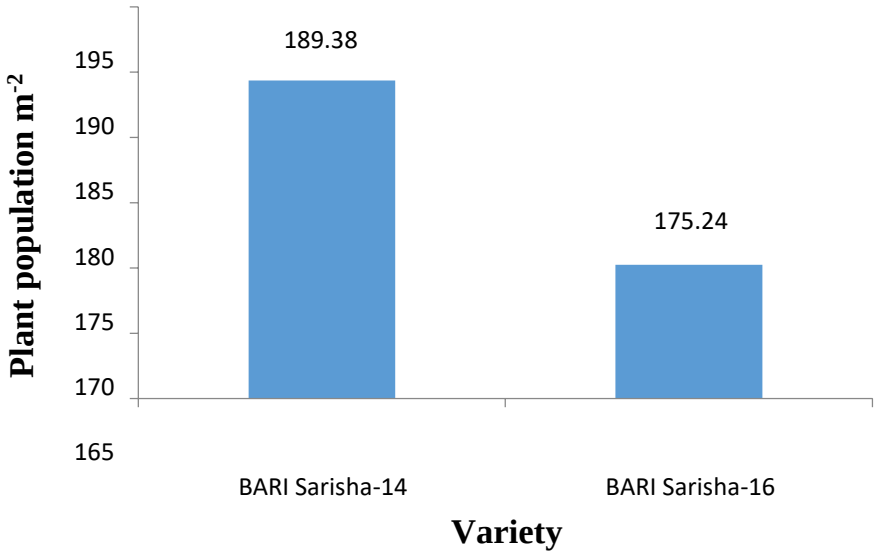
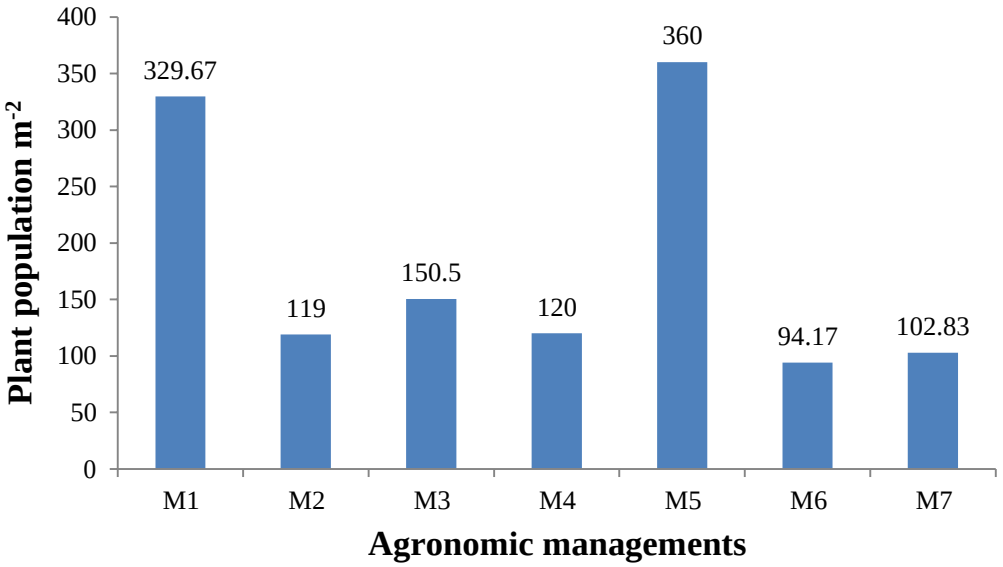


Figure 1. Effect of variety on the plant population m^{-2} of mustard at 20 days after sowing (SE= 1.93).

Effect of agronomic managements

There was significant variation observed in plant population m^{-2} due to various agronomic managements (Figure 2). The highest plant population m^{-2} was observed in M_5 treatment (360) and lowest plant population m^{-2} was obtained with M_6 (94.17) and M_7 (102.83). The M_6 and M_7 treatment were statistically similar. The other treatments such as M_1, M_2, M_3 & M_4 attained plant population m^{-2} as 329.67, 119, 150.5 and 120, respectively. But M_2 and M_4 were statistically similar. So, the highest plant population m^{-2} was recorded in M_5 (No thinning but all other managements) treatment.



M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

Figure 2. Effect of Agronomic managements on the plant population m^{-2} of mustard at 20 days after sowing (SE=3.89).

Interaction effect of variety and agronomic managements

Plant population m^{-2} was significantly affected by the interaction of variety and agronomic managements that shown in Table 2. The highest number of plant population m^{-2} (371.00) was recorded from the interaction of V_1M_5 (BARI Sarisha-14 and no thinning but all other managements. The lowest plant population m^{-2} (75.00) was recorded from the combination of V_2M_6 (BARI Sarisha-16 and no pesticides but all other managements). The V_2M_5 (349) and V_1M_1 (338.33) were statistically similar but lower than V_1M_5. Again, V_1M_2, V_2M_3, V_1M_6 and V_2M_7 had 115.67, 113.67, 113.33 and 111.67 plant population m^{-2} which were statistically similar.

Table 2. Interaction effect of variety and different agronomic managements on the plant population $m^{-2}$of mustard at 20 DAS

Treatment combinations	Plant population (no. m^{-2})
V_1M_1	338.33 b
V_1M_2	115.67 fg
V_1M_3	187.00 d
V_1M_4	106.00 gh
V_1M_5	371.00 a
V_1M_6	113.33 fg
V_1M_7	94.00 h
V_2M_1	321.00 c
V_2M_2	122.33 ef
V_2M_3	113.67 fg
V_2M_4	134.00 e
V_2M_5	349.00 b
V_2M_6	75.00 i
V_2M_7	111.67 fg
SE	5.267
CV (%)	4.21

Figures in a column with common letter(s) do not differ significantly at 5% probability level V_1 = BARI Sarisha -14, V_2 = BARI Sarisha -16; M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

4.2 Plant height

Height of the plant is an important growth parameter. It exhibits the vigor of the plants. Measurement of the height of plant was started from 20 days after sowing with an interval of 15 days up to 65 DAS and at harvest. The data of subsequent observations are shown graphically below and in Table.

Effect of variety

Plant height of mustard significantly varied for varietal variation throughout the growing period. In case of variety, at 20, 50, 65 DAS and at harvest BARI Sarisha -16 attained higher plant height (11.75 cm,72.47 cm, 94.86 cm and

124.6 cm) than BARI Sarisha-14 (11.2 cm, 53.8 cm, 63.51 cm and 70.77 cm). At 35 DAS, plant height was higher in BARI Sarisha -14 (44.0 cm) than BARI Sarisha -16 (37.15 cm). Opposite trend of higher plant height in BARI Sarisha -16 was observed at 50 and 65 DAS and at harvest compared to that of BARI Sarisha -14(Figure 3).The results could be due to variation of mustard variety.

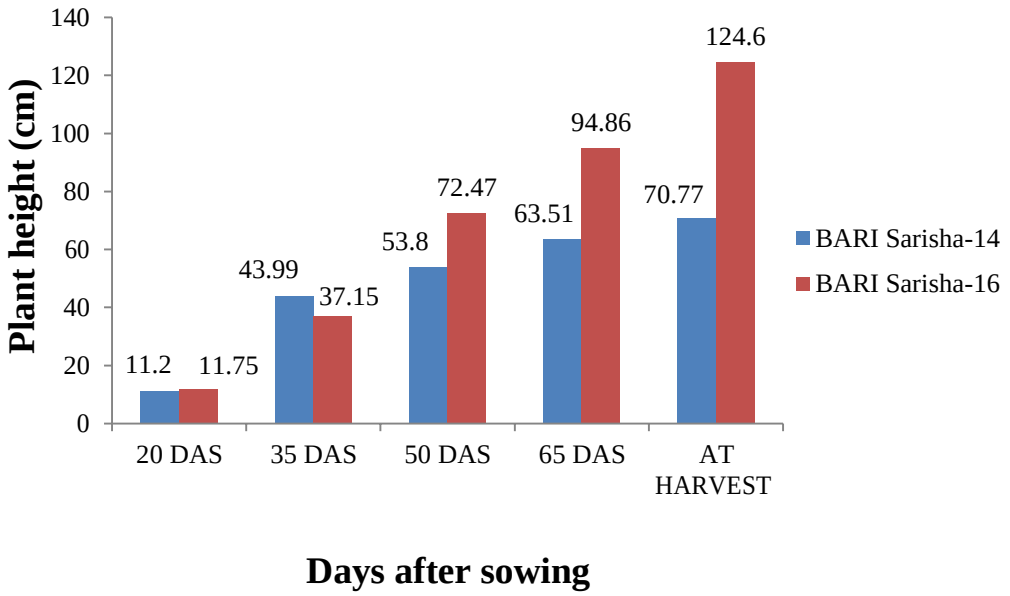
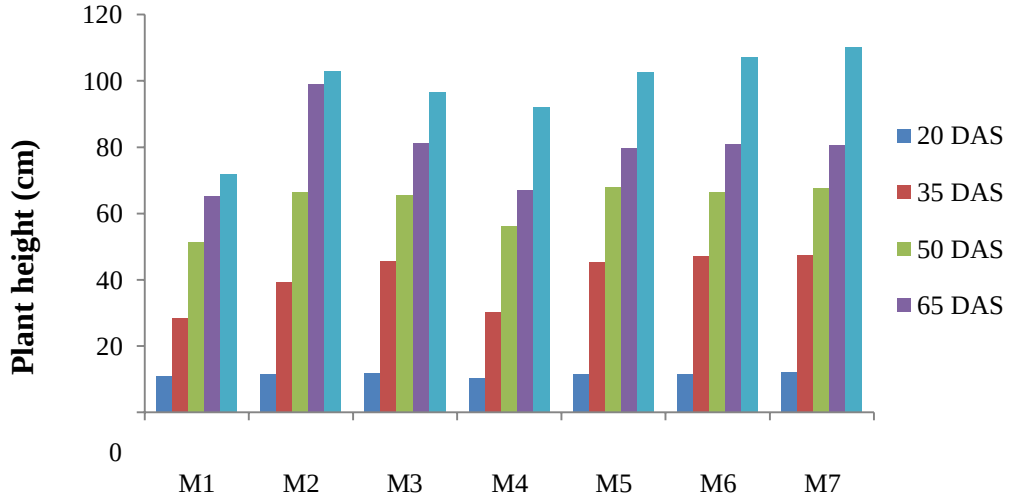


Figure 3. Effect of variety on the plant height (cm) of mustard at different days after sowing (SE= 0.06, 038, 0.83, 0.22 and 1.72 at 20, 35, 50, 65 and at harvest, respectfully).

Effect of agronomic managements

Due to agronomic managements, there was significant variation was observed for plant height (Figure 4). At 20 DAS, the highest plant height was recorded from M_7 (complete management) treatment (12.31 cm) and lowest plant height was observed from M_4 treatment (10.5 cm). Plant height due to M_5 (11.52 cm) and M_2 (11.4 cm) treatment was statistically similar. At 35 DAS, highest plant height was recorded from M_7 treatment (47.47 cm) and lowest plant height was observed from M_1 treatment (28.49 cm). But M_4 (30.24 cm) was statistically similar to M_1 treatment. At 50 DAS, highest plant height was recorded from M_5 treatment (68.08 cm) and lowest plant height was observed from M_1 treatment (51.35 cm) but M_5 was statistically similar with M_2 (66.55 cm), M_6 (66.45 cm) and M_7 (67.77 cm).At 65 DAS, highest plant height was recorded

from M_2 treatment (99.1 cm) and lowest plant height was observed from M_1 treatment (65.33 cm). But M_1 treatment was statistically similar to M_4 (67.01 cm). Moreover, M_3 (81.28 cm), M_5 (79.86 cm), M_6 (81.16 cm) and M_7 (80.57 cm) treatment was statistically similar. At harvest, highest plant height was recorded from M_7 treatment (110.16 cm) and lowest plant height was observed from M_1 treatment (72.07 cm).



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3** = No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 4. Effect of Agronomic managements on the plant height (cm) of mustard at different days after sowing (SE=0.18, 0.83, 4.58, 2.62 & 2.24 at 20, 35, 50, 65 and at harvest respectively).

Interaction effect of variety and agronomic managements

Significant variation was observed for plant height under different variety and agronomic management combinations (Table 3). The highest plant height was observed from the combination of BARI Sarisha-14 and M_7 (13.45 cm) and lowest plant height was observed from BARI Sarisha-14 and M_1 (9.33 cm) at 20 DAS. Moreover V_2M_1 (12.66 cm), V_2M_3 (12.44 cm), V_2M_6 (12.68)

combinations & V_1M_2 (11.36 cm), V_1M_3 (11.48 cm), V_1M_5 (11.59 cm), V_2M_2 (11.46 cm), V_2M_5 (11.47 cm), V2M7 (11.17 cm) combinations were statistically similar. At 35 DAS, V_1M_7 (53.5 cm) attained the highest plant height and V_2M_4 attained the lowest plant height (24.38 cm), but V_1M_7 was statistically similar with V_1M_6 (52.43 cm), V_1M_3 (46.47 cm) & V_2M_3 (45.06 cm), V_1M_4 (36.09 cm) & V_2M_2 (34.48 cm), V_1M_1 (28.55 cm) & V_2M_1 (28.43 cm) were also statistically similar. At 50 DAS, V_2M_3 attained the highest plant height (78.53 cm) and lowest plant height was observed in V_1M_1 (36.42 cm). The V_2M_6 (77.2 cm) was statistically similar to V_2M_3. At 65 DAS, V_2M_2 (124.53 cm) attained the highest plant height (124.53 cm) and lowest plant height was observed from V_1M_1 (42.65 cm). Therefore, V_1M_2 (73.67 cm), V_1M_7 (73.13 cm), V_1M_6 (68.4 cm), V_1M_3 (68.17 cm), V_1M_5 (67.3 cm) were statistically similar. At harvest, V_2M_6 attained the highest plant height (143.01 cm) which was statistically similar to V_2M_7 (141.33 cm) and lowest plant height was observed from V_1M_1 (50.08 cm).

Table 3. Interaction effect of variety and agronomic managements on plant height of mustard

Treatment combinations	Plant height (cm)				
	20 DAS	**35 DAS**	**50 DAS**	**65 DAS**	**At harvest**
V_1M_1	9.33 e	28.55 g	36.42 g	42.65 f	50.08 h
V_1M_2	11.36 c	44.11 cde	63.22 b-e	73.67 d	77.46 ef
V_1M_3	11.48 c	46.47 bc	52.52 ef	68.17 d	76.55 ef
V_1M_4	10.62 d	36.09 f	43.84 fg	51.27 e	63.37 g
V_1M_5	11.59 c	46.82 b	60.64 cde	67.30 d	77.47 ef
V_1M_6	10.59 d	52.43 a	55.69 def	68.40 d	71.45 f
V_1M_7	13.45 a	53.5 a	64.25 b-e	73.13 d	78.98 e
V_2M_1	12.66 b	28.43 g	66.29 a-d	88.00 bc	94.05 d
V_2M_2	11.46 c	34.48 f	69.87 abc	124.53 a	128.67b
V_2M_3	12.44 b	45.06 bc	78.53 a	94.39 b	116.92 c
V_2M_4	10.38 d	24.38 h	68.64 abc	82.76 c	120.67 c
V_2M_5	11.47 c	44.26 bcd	75.52 ab	92.42 b	127.53b
V_2M_6	12.68 b	42.01 de	77.2 a	93.92 b	143.01 a
V_2M_7	11.17 c	41.43 e	71.30 abc	88.01 bc	141.33 a
SE	**0.25**	**1.211**	**6.484**	**3.711**	**3.175**
CV (%)	**2.67**	**3.65**	**12.58**	**5.74**	**3.98**

Figures in a column with common letter(s) do not differ significantly at 5% probability level
V_1 = BARI Sarisha -14**,** V_2 = BARI Sarisha -16**;** M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

4.3 Leaf number

Effect of variety

In case of variety, at 20 DAS, significant variation was not observed for leaf number plant^{-1} due to varietal variation shown in Figure 5. Numerically the highest and lowest leaf number (4.72 and 4.57) was found from BARI Sharisha-16 (V_2) and BARI Sharisha-14 (V_1), respectively at 20 DAS. At 35 DAS, the highest leaf number was observed from V_1 (10.56) and lowest leaf number observed from V_2 (9.17 cm). At 50 DAS, highest leaf number was attained in V_1 (14.41) and lowest leaf number was attained in V_2 (11.36). At 65 DAS, highest leaf number was attained in V_1 (20.59) and lowest leaf number was attained in V_2 (14.00).

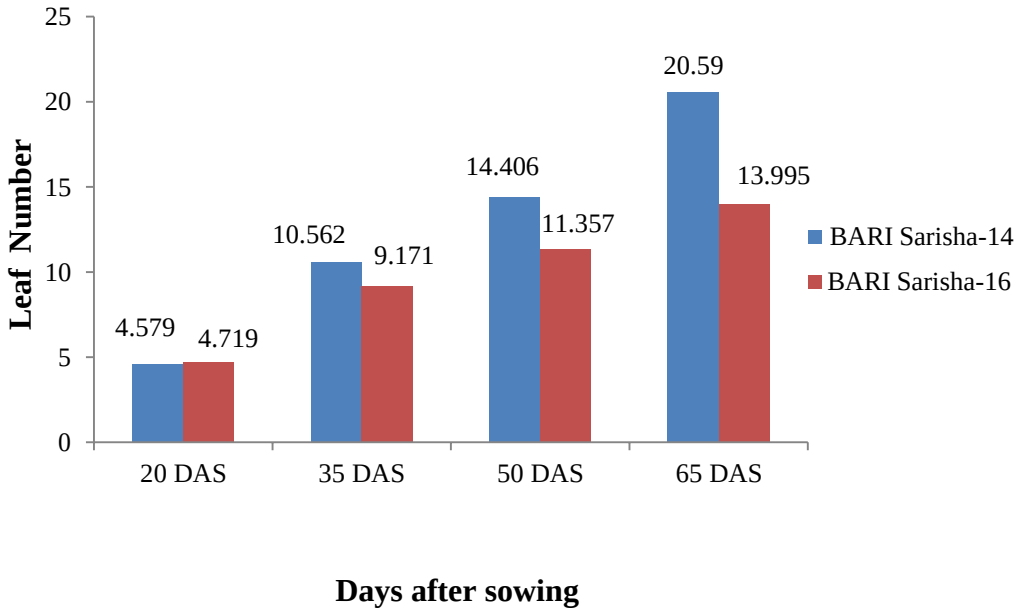
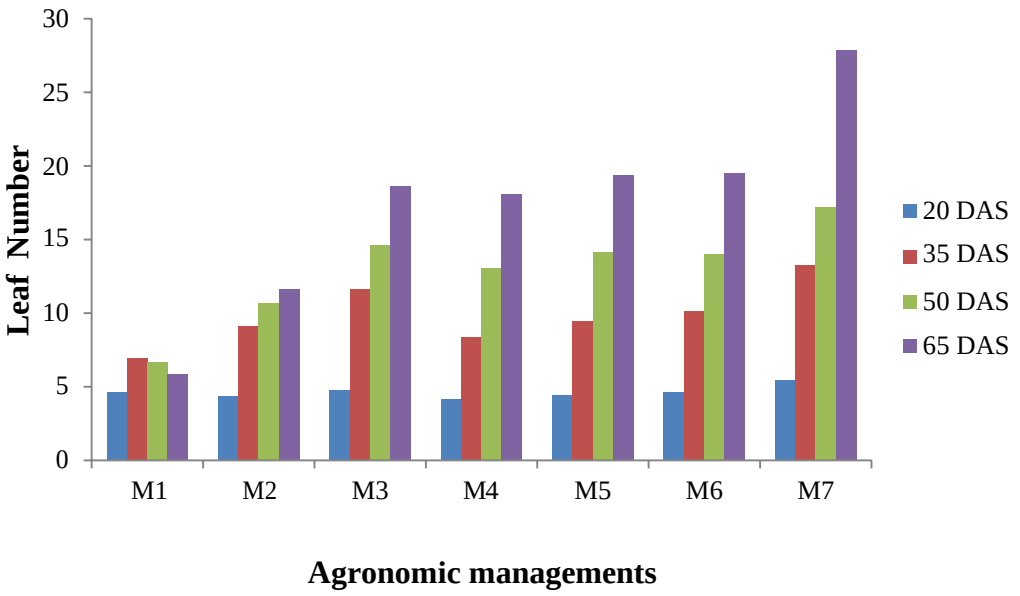


Figure 5. Effect of variety on Leaf number plant^{-1} of mustard at different days after sowing (SE=0.19,0.31.0.13 and 0.76 at 20,35,50 and 65 DAS respectively)

Effect of agronomic managements

In case of agronomic managements, there was significant variation in leaf number plant^{-1} (Figure 6)**.** At 20 DAS, highest leaf number was recorded in M_7 (5.45) and lowest leaf number was recorded in M_4 (4.15) treatment. At 35, 50 and 65 DAS, highest leaf number was recorded in M_7 (13.32, 17.22 and 27.94) and lowest leaf number was recorded in M_1 (6.93, 6.65 and 5.85) treatment. But At 35 DAS, M_5 and M_2 was statistically simillar. At 50 DAS, M_5 and M_6 treatments were statistically simillar. At 65 DAS, M_3, M_4, M_5 and M_6 were statistically similar.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3** = No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 6. Effect of Agronomic managements on leaf number plant^{-1} of mustard at different days after sowing (SE=0.3,0.58,1.34 and 1.79 at 20,35,50 and 65 DAS repectively)

Interaction effect of variety and agronomic managements

In case of interaction, highest leaf number plant^{-1} was observed in V_1M_7 (5.47, 14.50, 22.30 and 41.33) combination at 20, 35, 50 and 60 DAS (Table 4). At 20 DAS, lowest leaf number observed in V_2M_4 (3.83). At 35 DAS, lowest leaf number was recorded in V_2M_1 (6.50). At 50 DAS, lowest leaf number was recorded in V_1M_1 (6.60) which was statistically simillar to V_2M_1 (6.70). At 65 DAS, lowest leaf number was recorded in V_1M_1 (5.86).

Table 4. Interaction effect of variety and agronomic managements on leaf number plant^{-1} of mustard

Treatment combinations	Leaf Number plant^{-1}			
	20 DAS	35 DAS	50 DAS	65 DAS
V_1M_1	4.5b-e	7.367ghi	6.6e	5.867f
V_1M_2	4.6667a-e	10.533cde	12.967c	16.233cde
V_1M_3	4.3cde	10.7b-e	14bc	19.333bcd
V_1M_4	4.4667b-e	9.5def	17.067b	23.2b
V_1M_5	4.0667de	10.167cde	14.6bc	19.967bcd
V_1M_6	4.5bcde	11.167bcd	13.867bc	18.2b-e
V_1M_7	5.4667a	14.5a	22.3a	41.333a
V_2M_1	4.7333a-d	6.5i	6.7e	5.833f
V_2M_2	4.1333de	7.7f-i	8.433de	7.133f
V_2M_3	5.3abc	12.567ab	15.233bc	18b-e
V_2M_4	3.8333e	7.267hi	9.1de	12.933e
V_2M_5	4.8a-d	8.833e-h	13.667bc	18.733bcd
V_2M_6	4.8a-d	9.2d-g	14.233bc	20.8bc
V_2M_7	5.4333ab	12.133bc	12.133cd	14.533de
SE	**0.4248**	**0.8322**	**1.8956**	**2.5433**
CV(%)	**11.20**	**10.33**	**17.97**	**18.01**

Figures in a column with common letter(s) do not differ significantly at 5% probability level
V_1 = BARI Sarisha -14, V_2 = BARI Sarisha -16; M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

4.4 Leaf length

Effect of variety

In case of variety, highest leaf length was observed in BARI Sarisha-16 and lowest was observed in BARI Sarisha-14 at different days after sowing (Figure 7).

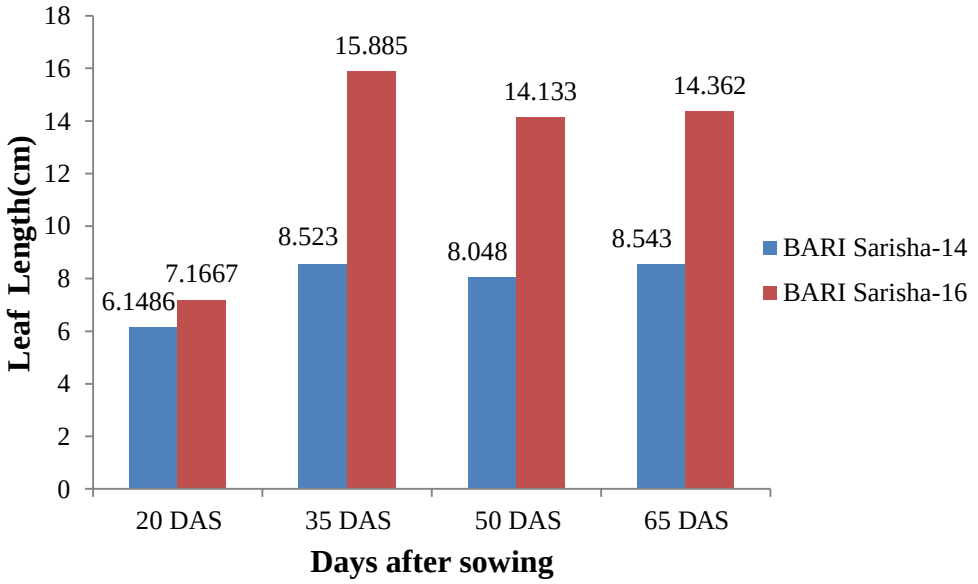
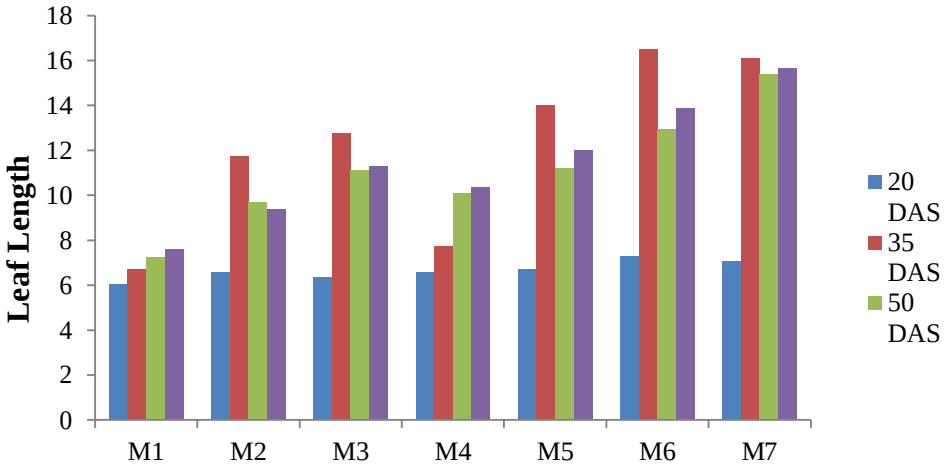


Figure 7. Effect of variety on leaf length (cm) of mustard at different days after sowing (SE=0.08,0.55,0.27 and 0.3 at 20,35,50 and 65 DAS respectively)

Effect of agronomic managements

At 20 DAS, highest leaf length was recorded in M_6 treatment (7.27) and lowest was observed in M_1 treatment (6.03 cm), rest all of the treatments were statistically similar. At 35 DAS, highest leaf length was recorded in M_6 treatment (16.48 cm) which was statistically similar to M_7 treatment and lowest was observed in M_1 treatment (6.68 cm) which was statistically similar to M_4. At 50 and 65 DAS, highest leaf length was observed in M_7 and lowest was observed in M_1 that was shown in figure 8.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 8. Effect of agronomic managements on leaf length (cm) of mustard at different days after sowing (SE=0.53,0.6,0.59 and 0.51 at 20,35,50 and 65 DAS respectively)

Interaction effect of variety and agronomic managements

Interaction effect of treatments had significant influence on leaf length. The highest leaf length was observed in V_2M_6 treatment at 20 DAS and V_2M_7 treatment at 35.50 and 65 DAS days after sowing. At 20 DAS, lowest leaf length was observed in V_1M_3 (5.50 cm) treatment. At 35 and 50 DAS, lowest leaf length was observed in V_1M_1 treatment. At 65 DAS, lowest leaf length was recorded in V_1M_1 treatment (6.40 cm) but it was statistically similar to V_1M_4

Table 5. Interaction effect of variety and agronomic managements on leaf length of mustard

Treatment combinations	Leaf length (cm)			
	20 DAS	**35 DAS**	**50 DAS**	**65DAS**
V_1M_1	5.67 d	5.23 h	5.73 h	6.40 g
V_1M_2	6.51 bcd	8.38 f	7.13 gh	7.07 fg
V_1M_3	5.50 d	8.49 f	8.23 fg	8.73 ef
V_1M_4	6.40 bcd	6.13 gh	7.00 gh	6.80 g
V_1M_5	6.15 cd	9.03 f	8.22 fg	8.87 e
V_1M_6	6.39 bcd	11.00 e	9.03 f	9.83 e
V_1M_7	6.42 bcd	11.39 e	10.97 e	12.01d
V_2M_1	6.39 bcd	8.13 fg	8.73 fg	8.80 ef
V_2M_2	6.67 a-d	15.06 d	12.23 de	11.67 d
V_2M_3	7.21 abc	16.99 c	13.93 cd	13.83 bc
V_2M_4	6.75 a-d	9.29 ef	13.20 cd	13.93 b
V_2M_5	7.29 abc	18.95 b	14.17 c	15.17 b
V_2M_6	8.15 a	21.96 a	16.90 b	17.93 a
V_2M_7	7.70 ab	20.82 a	19.77 a	19.20 a
SE	**0.758**	**0.855**	**0.835**	**0.729**
CV(%)	**13.95**	**8.58**	**9.22**	**7.79**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14**, V_2 =** BARI Sarisha -16**; M_1 =** Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

4.5 Branches plant^{-1}

Effect of variety

In case of variety, BARI Sarisha-16 produced higher number of branches at different days after sowing than BARI Sarisha-14 (Figure 9).

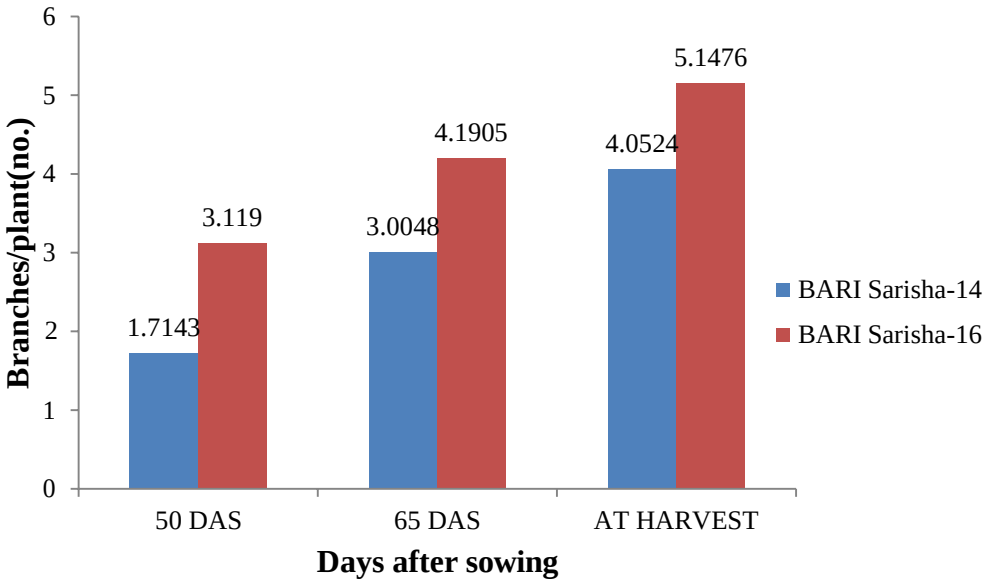
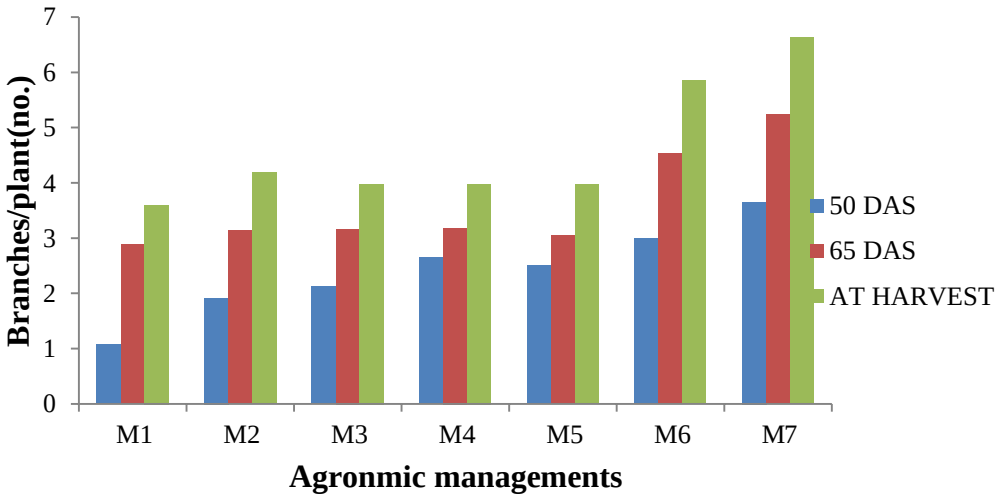


Figure 9. Effect of variety on branches plant^{-1} of mustard at different days after sowing (SE=0.06)

Effect of agronomic managements

In case of agronomic managements, M_7 recorded the highest branches plant^{-1} at different day after sowing. At 50 DAS, lowest branches plant^{-1} was recorded in M_2 treatment. At 65 DAS, lowest branches was observed in M_1, M_2, M_3, M_4, M_5 treatment. They are statistically similar. But at harvest, lowest branches plant^{-1} was observed in M_1 treatment (Figure 10).



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 10. Effect of Agronomic managements on Branches plant^{-1} of mustard at different days after sowing (SE=0.19)

Interaction effect of variety and agronomic managements

In case of interaction V_2M_7 produced higher branches plant^{-1} and V_1M_1 produced lower branches plant^{-1} for all the studied duration. Data on treatment combinations was shown in table 6.

Table 6. Interaction effect of variety and agronomic managements on branches plant^{-1} of mustard

Treatment combinations	Branches plant^{-1} (no.)		
	50 DAS	65 DAS	At harvest
V_1M_1	0.0 i	1.70 j	3.00 h
V_1M_2	1.33 gh	2.93 gh	4.10 f
V_1M_3	1.07 h	2.40 i	3.23 gh
V_1M_4	1.67 fg	2.13 ij	3.20 gh
V_1M_5	2.27 e	2.53 hi	3.53 g
V_1M_6	2.57 de	4.27 cd	5.23 c
V_1M_7	3.10 bcd	5.07 ab	6.07 b
V_2M_1	2.17 e	4.07 de	4.20 f
V_2M_2	2.5e	3.33 fg	4.27 ef
V_2M_3	3.17 bc	3.93 de	4.73 de
V_2M_4	3.63 ab	4.23 d	4.77 cd
V_2M_5	2.73 cde	3.57 ef	4.40 def
V_2M_6	3.43 b	4.80 bc	6.47 b
V_2M_7	4.2a	5.40 a	7.20 a
SE	**0.280**	**0.258**	**0.229**
CV (%)	**14.19**	**8.78**	**6.09**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14**, V_2 =** BARI Sarisha -16**; M_1 =** Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management.

4.6 Dry matter production plant^{-1}

Effect of variety

At 20, 50 and 65 DAS, dry matter accumulation plant^{-1} was higher in BARI Sarisha-16 but lower than BARI Sarisha-14 at 35 DAS (Figure 11).

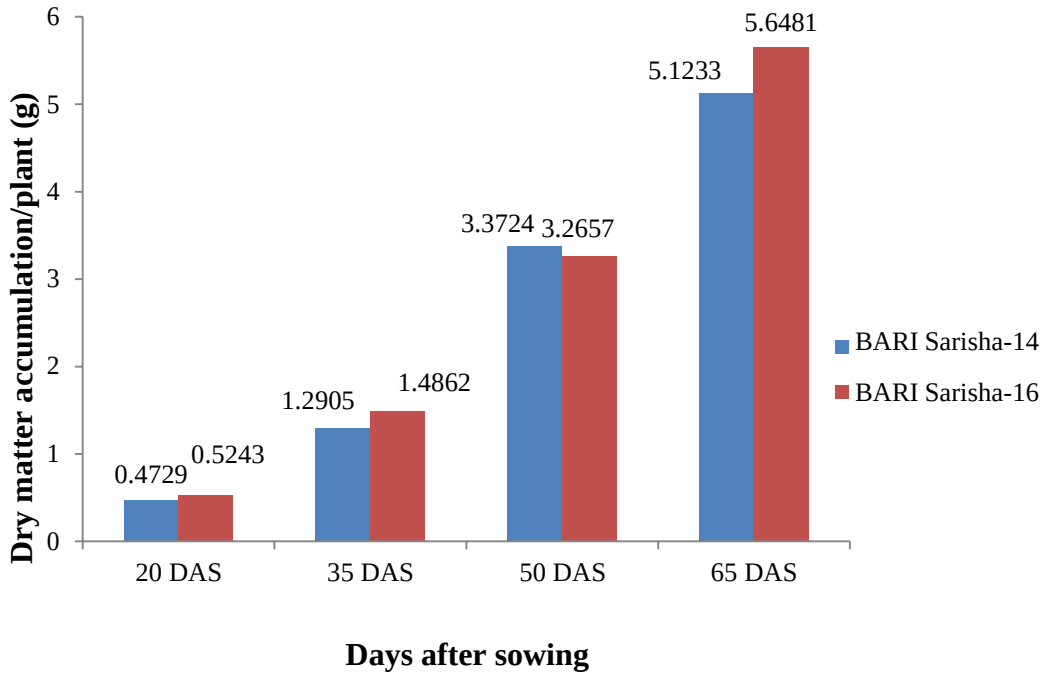
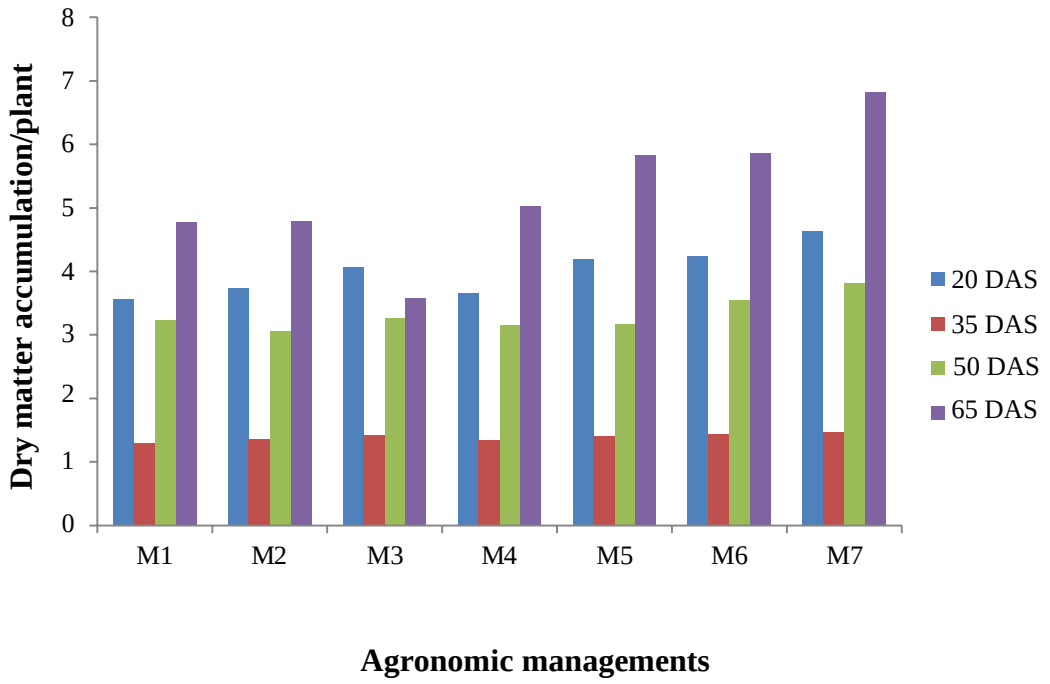


Figure 11. Effect of variety on dry matter accumulation plant^{-1} of mustard at different days after sowing (SE=0.03,0.04 AND 0.1 at 50,65 DAS and at harvest respectively)

Effect of agronomic managements

Significant variation was found in dry matter accumulation at different agronomic management level. The treatment M_7 produced the highest dry matter accumulation plant^{-1} at different DAS. The treatment M_1, M_2 and M_4 produced the lowest dry matter accumulation plant^{-1} at 20 DAS. At 35 and 65 DAS, the lowest dry matter production plant^{-1} was observed in M_1 treatment. At 50 DAS, lowest was observed in M_2, M_3, M_4 and M_5.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3** = No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 12. Effect of Agronomic managements on dry matter production plant^{-1} (g) of mustard at different days after sowing (SE=0.05,0.14 and 0.17 at 50,65 DAS and at harvest respectively)

Interaction effect of variety and agronomic managements

In case of interaction, highest dry matter was observed in V_2M_7 treatment at 20, 35 and 65 DAS and lowest was observed in V_1M_1 at 20, 50 and 65 DAS. But at 50 DAS, highest was observed in V_1M_7 treatment and at 35 DAS lowest was observed in V_1M_5.

Table 7. Interaction effect of variety and agronomic managements on dry matter production plant^{-1} of mustard

Treatment Combinations	Dry matter plant^{-1} (g)			
	20 DAS	35 DAS	50 DAS	65 DAS
V_1M_1	0.20 h	1.25 cd	2.77 e	4.11 g
V_1M_2	0.40 f	1.27 cd	3.21 cde	4.65 ef
V_1M_3	0.68 b	1.35 bcd	3.36 bcd	4.76 ef
V_1M_4	0.39 f	1.26 cd	3.11 cde	4.57 ef
V_1M_5	0.57 cd	1.23 d	3.30 cd	6.18 b
V_1M_6	0.51 de	1.29 cd	3.89 ab	5.26 cd
V_1M_7	0.57 cd	1.38 a-d	3.96 a	6.33 b
V_2M_1	0.44 ef	1.32 cd	3.69 abc	5.44 c
V_2M_2	0.31 g	1.45 abc	2.90 de	4.94 de
V_2M_3	0.63 bc	1.50 ab	3.18 cde	4.40 fg
V_2M_4	0.53 d	1.43 a-d	3.21 cde	5.49 c
V_2M_5	0.39 f	1.57 a	3.03 de	5.49 c
V_2M_6	0.51 de	1.58 a	3.20 cde	6.48 b
V_2M_7	0.86 a	1.56 a	3.66 abc	7.30 a
SE	**0.037**	**0.082**	**0.254**	**0.206**
CV(%)	**9.13**	**7.20**	**9.37**	**4.68**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14**, V_2 =** BARI Sarisha -16**; M_1 =** Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

4.7 SPAD value

Effect of variety

At 35 DAS, highest SPAD reading was observed in BARI Sarisha-14 (43.05 %) and lowest was recorded in BARI Sarisha-16 (40.27 %). But at 50 DAS, highest SPAD value was observed in BARI Sarisha-16 (49.55 %) and lowest was recorded in BARI Sarisha-14 (46.46 %).It was graphically presented in Figure 13.

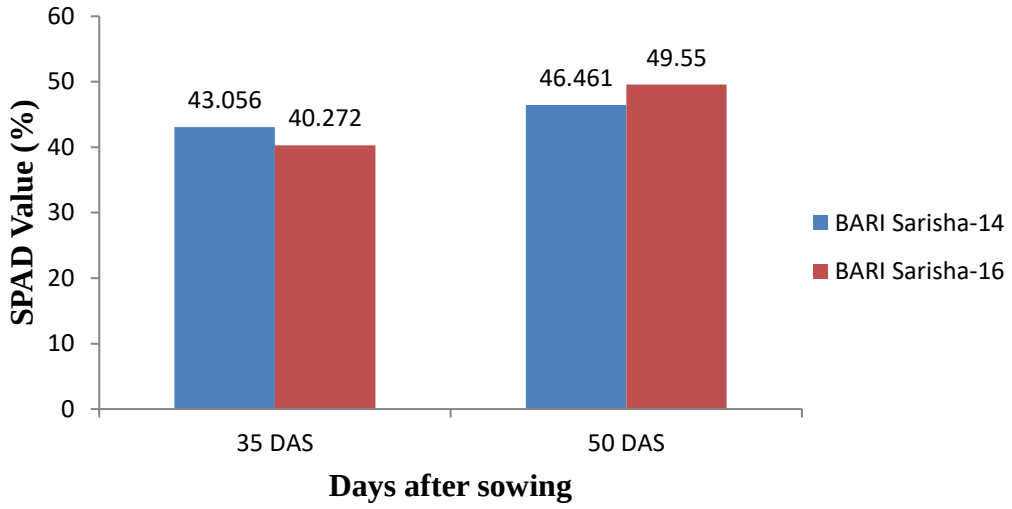
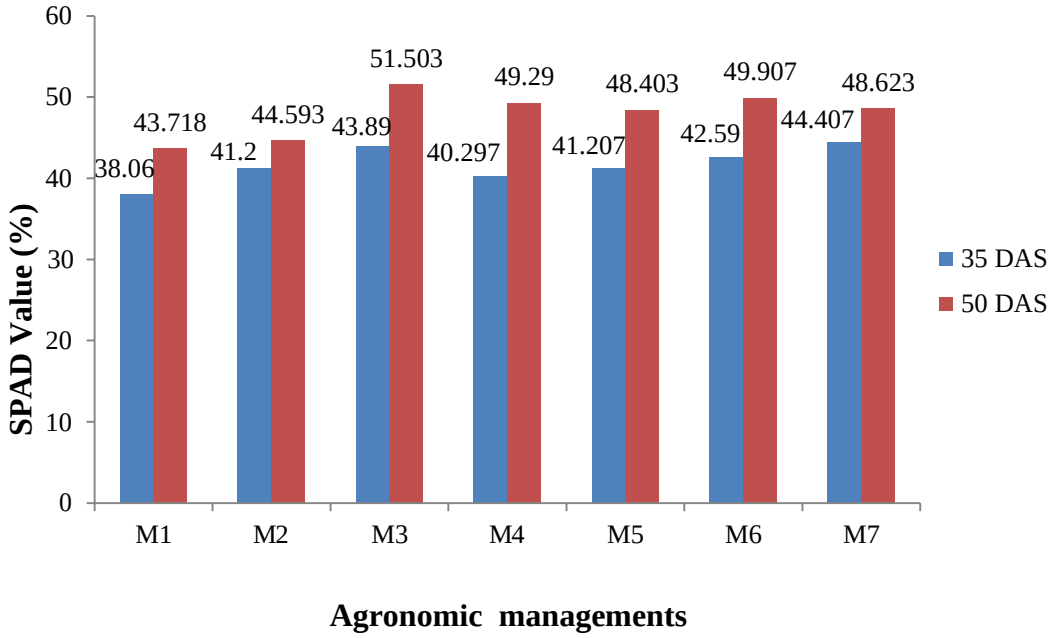


Figure 13. Effect of variety on SPAD value (%) of mustard at different days after sowing (SE=0.2 and 0.21 at 35 and 50 DAS respectively)

Effect of agronomic managements

At 35 DAS, the highest SPAD value was observed in M_7 (44.41%) treatment which was statistically similar to M_3 (43.49 %) and lowest was recorded in M_1 (38.06 %). At 50 DAS, highest SPAD value was observed in M_3 (51.50 %) treatment and lowest was recorded in M_1 (43.72 %) treatment which was statistically similar to M_2 treatment (44.59 %)



M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

Figure 14. Effect of Agronomic managements on SPAD value (%) of mustard at different days after sowing

Interaction effect of variety and agronomic managements

The combined effect of V_1M_7 (45.91%) treatment gave the highest SPAD value and V_2M_1 (34.81%) gave the lowest reading at 35 DAS (Table 8). At 50 DAS, highest reading was recorded from V_2M_6 treatment (53.63 %) and lowest was observed in V_1M_1 treatment (42.657 %).

Table 8. Interaction effect of variety and agronomic managements on SPAD value of mustard/rapeseed

Treatment combinations	SPAD value (%)	
	35 DAS	**50 DAS**
V_1M_1	41.31 b-e	42.66 g
V_1M_2	42.45 a-d	44.43 fg
V_1M_3	44.65 ab	50.51 abc
V_1M_4	42.32 a-d	49.05 cde
V_1M_5	43.13 a-d	45.57 fg
V_1M_6	41.72 b-e	46.83 def
V_1M_7	45.91 a	46.83 def
V_2M_1	34.81 f	44.78 fg
V_2M_2	39.95 cde	44.76 fg
V_2M_3	43.13 a-d	52.49 ab
V_2M_4	38.27 ef	49.53 bcd
V_2M_5	39.38 de	51.23 abc
V_2M_6	43.4abc	53.63 a
V_2M_7	42.90 a-d	50.42 abc
SE	**1.838**	**1.593**
CV(%)	**5.40**	**4.06**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14**, V_2 =** BARI Sarisha -16**; M_1 =** Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

4.8 No. of siliquae plant^{-1}

Number of siliquae plant^{-1} were recorded at maturity. Average no. of siliquae plant^{-1} as affected by different treatments had been presented in Table 9 and graphically shown in Figure 15 and 16.

Effect of variety

Variety had significant effect on number of siliquae plant^{-1}.In case of variety, BARI Sarisha-16 (34.11) had the highest no. of siliquae plant^{-1} than BARI Sarisha-14 had the lowest no. of siliquae plant^{-1} (25.76).

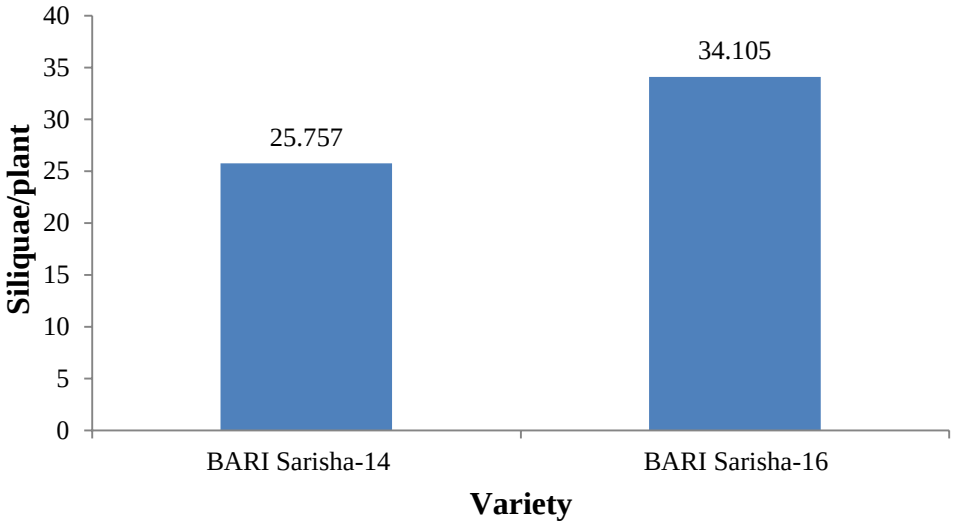
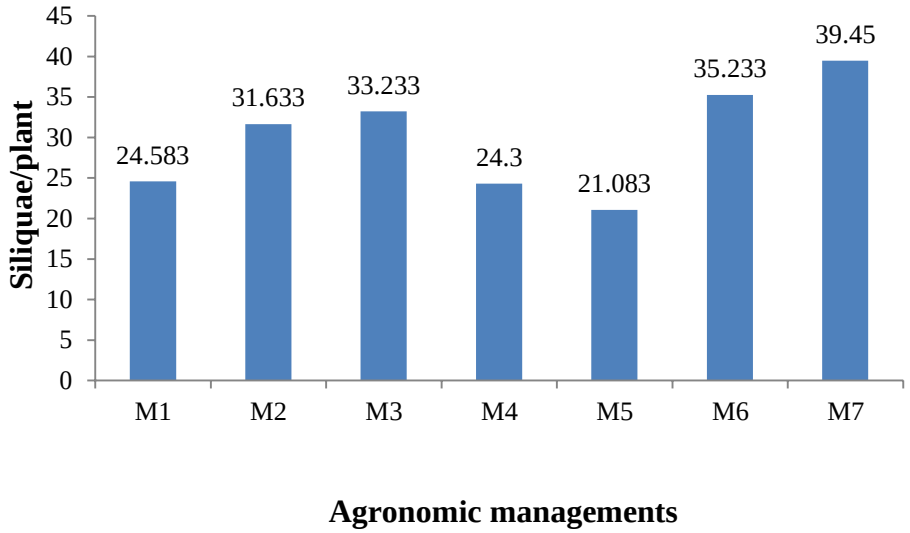


Figure 15. Effect of variety on siliquae plant^{-1} of mustard (SE=1.01)

Effect of agronomic managements

No. of siliquae is an impotant factor for increasing yield.Agronomic management showed significant variation in no. of siliquae plant^{-1}.Among the treatments,the highest number of siliquae plant^{-1} was observed in M_7(39.45) treatment and lowest was observed in M_4(24.3) treatment but M_1(24.58) was statistically similar to M_4 (Figure 16). No thinning reduced the highest number of siliquae plant^{-1} (46.57%) that followed by no irrigation (38.40%) and no management (37.69%).



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 16. Effect of agronomic managements on siliquae plant^{-1} of mustard (SE=1.94)

Interaction effect of variety and agronomic managements

Variety and agronomic management showed significant effect on no. of siliquae plant^{-1}.In case of interaction, the highest no. of silliquae plant^{-1}was observed in V_2M_7-BARI Sarisha-16 & complete management (41.63) treatment and lowest was observed in V_1M_1 treatment-BARI Sarisha-14 & control (9.7).Therefore,V_1M_4 and V_1M_5 treatment combinations were statistically similar.

4.9 Length of siliqua

Length of siliqua was recorded at maturity. Average length of siliqua was affected by different treatments that presented in Table 9 and graphically shown in Figure 17 and Figure 18.

Effect of variety

Variety had significant effect on the siliqua length.In case of variety,BARI Sarisha-16 gave highest length of siliqua (4.09 cm) which was significantly different from BARI Sarisha-14 (3.94 cm).It was graphically presented in Figure 17.

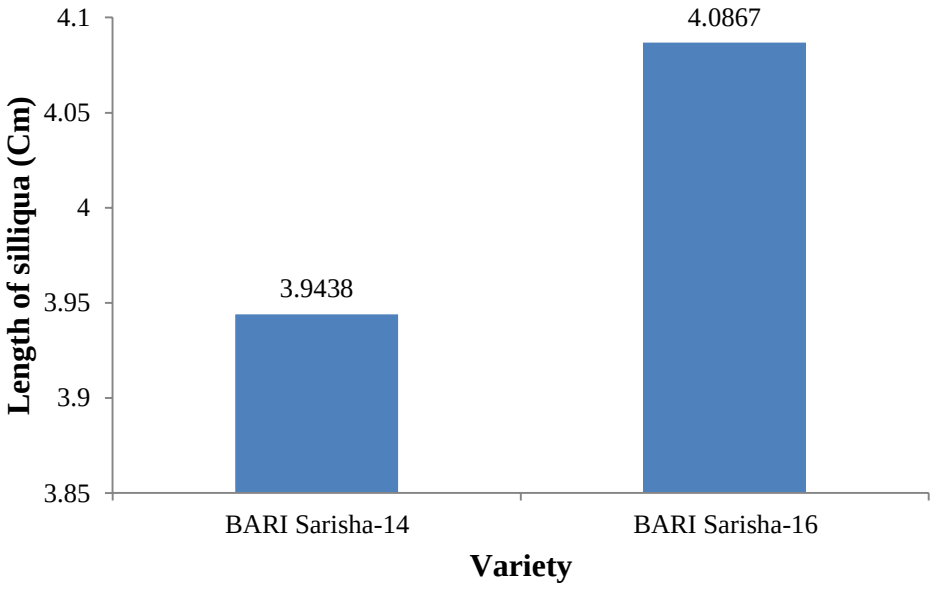
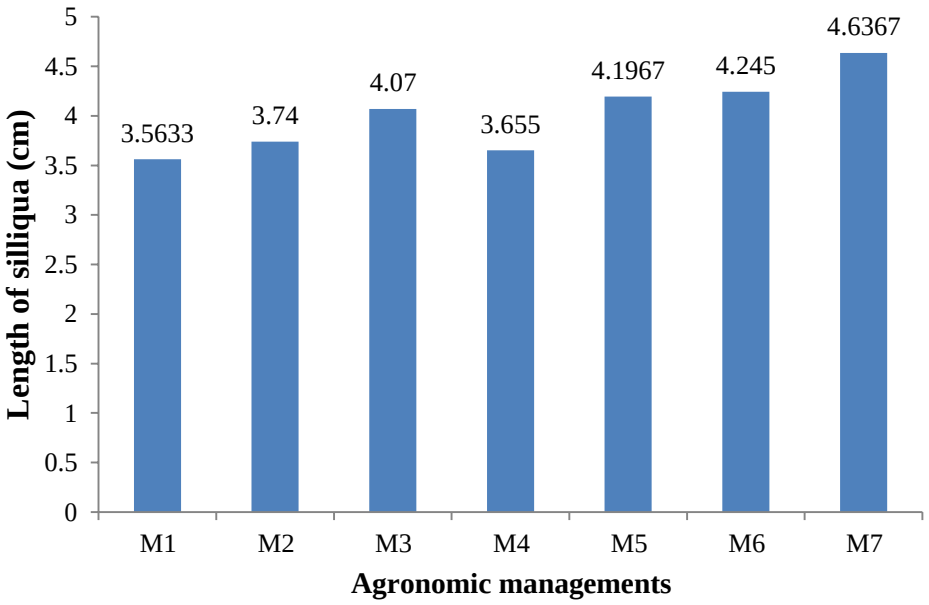


Figure 17. Effect of variety on silliqua length (cm) of mustard (SE=0.04)

Effect of agronomic managements

Agronomic management had significant effect on siliqua length.M_7-Complete management (4.63 cm) gave the highest length of silliqua and lowest was observed in M_1 treatment-Control (3.56 cm).The length of siliqua due to other treatments was shown in figure 18



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 18. Effect of Agronomic managements on Length of silliqua (cm) of mustard (SE=0.11)

Interaction effect of variety and agronomic managements-

In case of interaction, the highest length of silliqua was observed in V_2M_7 treatment (4.66 cm) which was statistically simillar to V_1M_7 (4.61 cm) and lowest was observed in V_1M_1 treatment (3.44 cm) which was similar to V_1M_4 (3.35 cm)

4.10. Seeds silliqua^{-1}

Average seeds silliqua^{-1}as affected by different treatments had been presented in Table 9 and graphically shown in Figure 19 & 20

Effect of variety-

In case of variety, results revealed that V_1(26.386) Produced highest seed per silliqua whereas V_2 (8.305) produced lowest number of seeds per silliqua. It was graphically shown in Figure 19

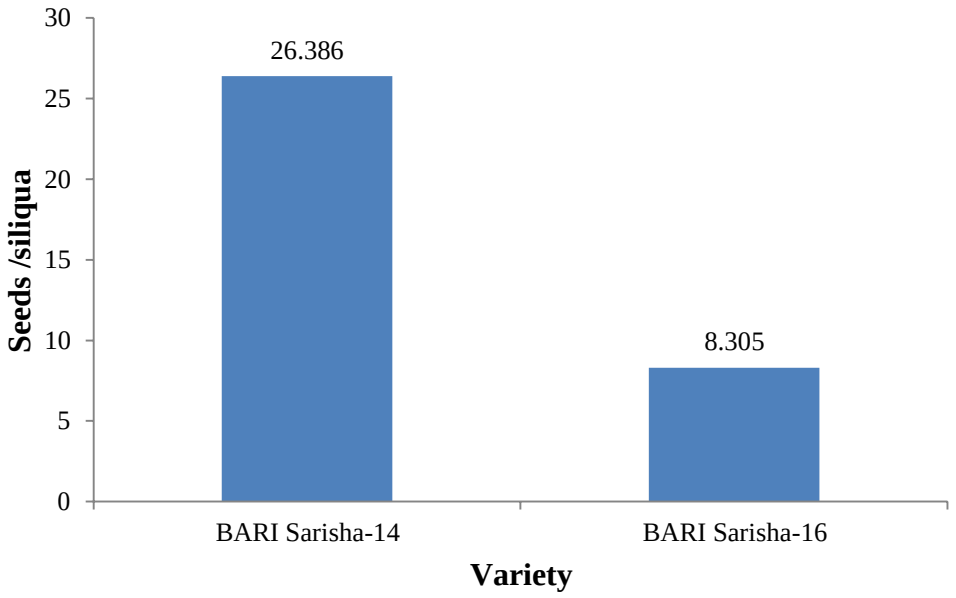
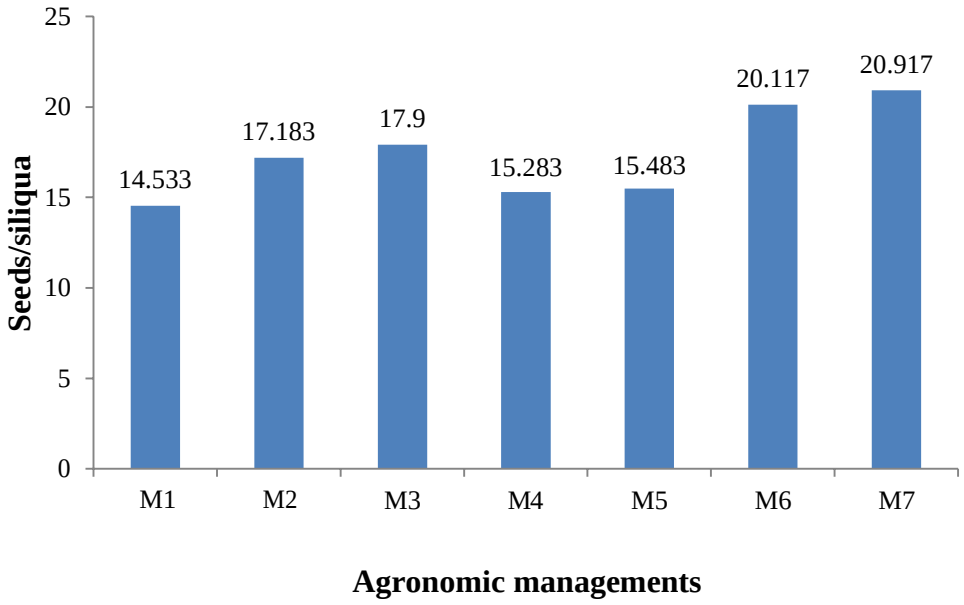


Figure 19. Effect of variety on seeds siliquae^{-1} of mustard (SE=0.86)

Effect of agronomic managements

Significant variation was found in seeds silliqua^{-1} at different agronomic management. The treatment M_7 (20.92) had the highest seeds silliqua^{-1}. The treatment M_1 (14.53) had the lowest number of seeds silliqua^{-1}. It was graphically shown in Figure 20.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3** = No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 20. Effect of agronomic managements on seeds siliquae^{-1} of mustard (SE=0.9)

Interaction effect of variety and agronomic managements

The highest number of seeds siliqua^{-1} was observed in V_1M_7 (29.97) treatment which was statistically simillar to V_1M_2 (28.07), V_1M_3 (27.07) and V_1M_6 (29.4) combinations and lowest seeds siliqua^{-1} was observed in V_1M_7 , V_2M_1, V_2M_2, V_2M_3 and V_2M_4 which were statistically similar (Table 9).

4.10 1000-seed weight

The data gathered in respect to 1000-seed weight as affected by different treatments had been summarized and presented in Table 9 and graphically presented in Figure 21 and Figure 22.

Effect of variety

Two varieties significantly influence on the 1000-seed weight of mustard. In case of variety, V_2 (3.94 g) had the higher 1000-seed weight than V_1 (2.719 g). It was graphically shown in Figure 21.

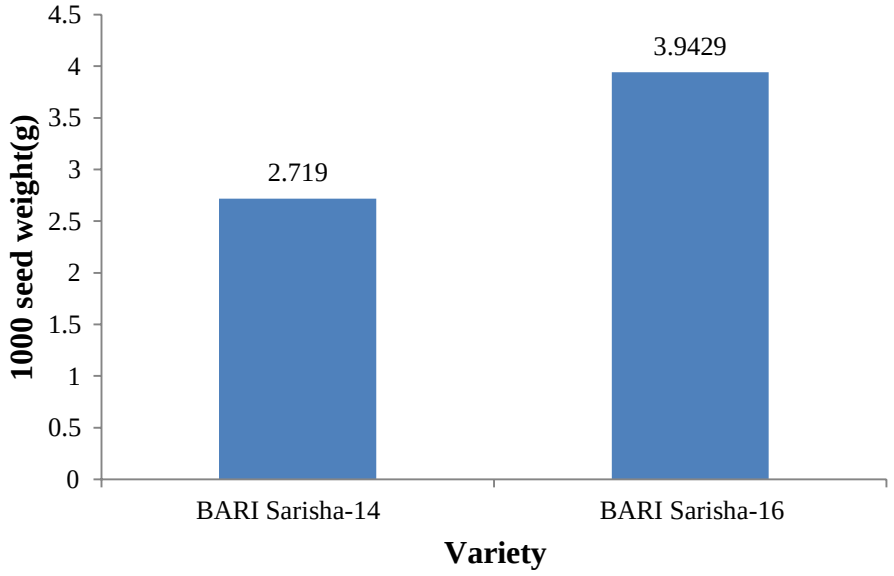
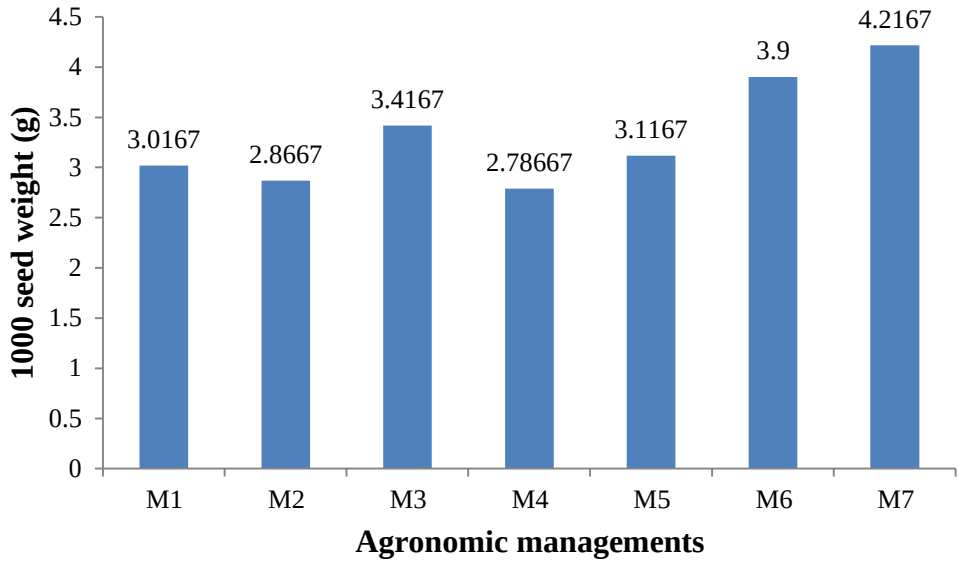


Figure 21. Effect of variety on 1000-seed yield of mustard (SE=0.1)

Effect of agronomic managements

Significant variation was found in 1000-seed weight at different agronomic managements. The treatment M_7 had the highest 1000-seed weight (4.22 g). The treatment M_4 (2.79 g) had the lowest seed weight. It was graphically shown in Figure 22.



M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

Figure 22. Effect of agronomic managements on 1000-seed weight of mustard. (SE=0.1)

Interaction effect of variety and agronomic managements

Interaction effect of varieties and agronomic managements influenced the 1000-seed weight. The maximum 1000-seed weight was obtained from V_2M_7 (4.83 g) treatment, whereas the minimum 1000-seed weight was obtained from V_1M_1 (2.17 g) treatment. The V_1M_1 treatment combination was statistically simillar to V_1M_2 (2.43 g) ,V_1M_4 (2.23 g) and V_1M_5 (2.4 g).The treatment combinations were shown in Table 9.

Table 9. Interaction effect of variety and different agronomic managements on the yield contributing characters of mustard

Treatment combinations	Yield contributing characters of mustard			
	No. of siliquae plant^{-1}	Length of siliqua (cm)	Seeds siliqua-1 (no.)	1000-seed weight (g)
V_1M_1	9.70 g	3.44 f	22.93 b	2.17 g
V_1M_2	27.63 de	3.64 ef	28.07 a	2.43 g
V_1M_3	35.80 abc	4.02 bcd	27.40 a	2.87 f
V_1M_4	18.30 f	3.35 f	23.10 b	2.23 g
V_1M_5	20.37 f	4.23 b	23.83 b	2.40 g
V_1M_6	31.23 cd	4.32 ab	29.40 a	3.33 ef
V_1M_7	37.27 ab	4.61 a	29.97 a	3.60 cde
V_2M_1	39.47 ab	3.69 def	6.13 e	3.87 c
V_2M_2	35.63 bc	3.84 cde	6.30 e	3.30 ef
V_2M_3	30.67 cd	4.12 bc	8.40 de	3.97 c
V_2M_4	30.30 cd	3.96 b-e	7.47 e	3.33 ef
V_2M_5	21.80 ef	4.16 bc	7.13 e	3.83 cd
V_2M_6	39.23 ab	4.17 bc	10.83 cd	4.47 b
V_2M_7	41.63 a	4.66 a	11.87 c	4.83 a
SE	**2.750**	**0.169**	**1.279**	**0.155**
CV(%)	**11.25**	**5.16**	**9.03**	**5.7**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14, V_2 = BARI Sarisha -16; M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

4.12. Seed yield

The seed yield as affected by different treatments in given in Table 10 and graphically shown in Figure 23 and Figure 24.

Effect of variety

Two varieties had not significantly influence on the seed yield of mustard though numerically V_2 (BARI Sarisha-16) had the higher seed yield (0.99 t ha^{-1}) than V_1 (0.95 t ha^{-1}).It was graphically shown in Figure 23.

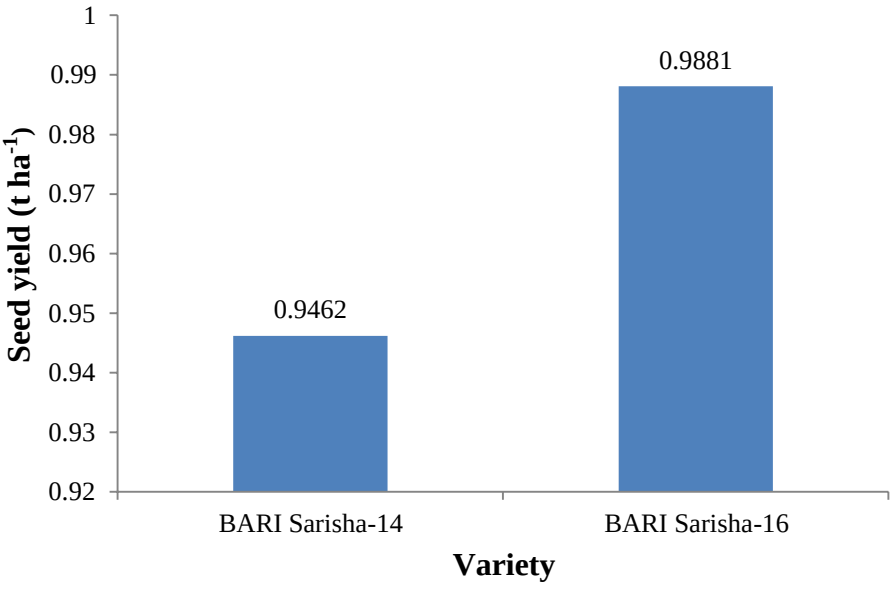
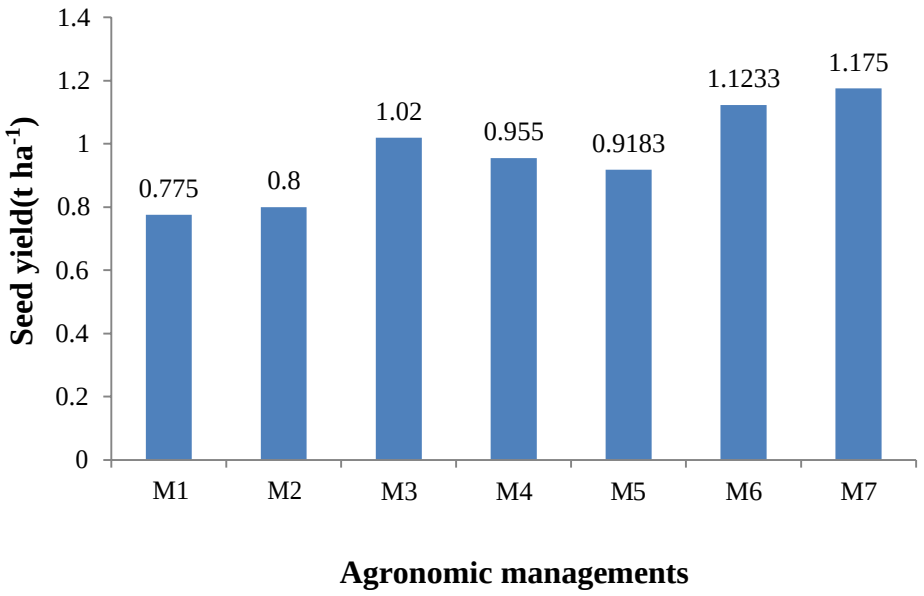


Figure 23. Effect of variety on seed yield (t ha^{-1}) of mustard (SE=0.03)

Effect of agronomic managements

Significant variation was found in seed yield at different agronomic managements (Figure 24). The treatment M_7 produced the highest seed yield (1.18 t ha^{-1}). The treatment M_1 (0.78 t ha^{-1}) produced the lowest seed yield which was statistically simillar to M_2 (0.80 t ha^{-1}) but numerically higher than M_1. Compared to that of complete management, the magnitude of seed yield reduction was varied for different agronomic managements where the highest reduction (33.90%) was observed for no management that followed by no fertilizer (32.20%), no thinning (22.03%), no irrigation (18.64%), no weeding (13.56%) and no pesticides application (5.08%).



M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

Figure 24. Effect of agronomic managements on seed yield (t ha^{-1}) of mustard (SE=0.05)

Interaction effect of variety and agronomic managements-

Interaction effect of varieties and agronomic managements influenced the seed yield of mustard/rapeseed. The highest seed yield (1.19 t ha^{-1}) was obtained from V_2M_7 treatment, whereas the lowest seed yield (0.52 t ha^{-1}) was obtained from V_1M_1 treatment.Therefore,V_1M_3, V_1M_5 and V_1M_6 treatments were statistically similar (Table 10)

4.13. Stover yield

The data collected on stover yield was shown in Table 10 and graphically presented in Figure 25 and Figure 26.

Effect of variety

Two varieties had significantly influence on the stover yield of mustard. In case of variety, V_2 (BARI Sarisha-16) had the higher stover yield (3.57 t ha^{-1}) than V_1(BARI Sarisha-14)-3.03 t ha^{-1} .It was graphically shown in Figure 25.

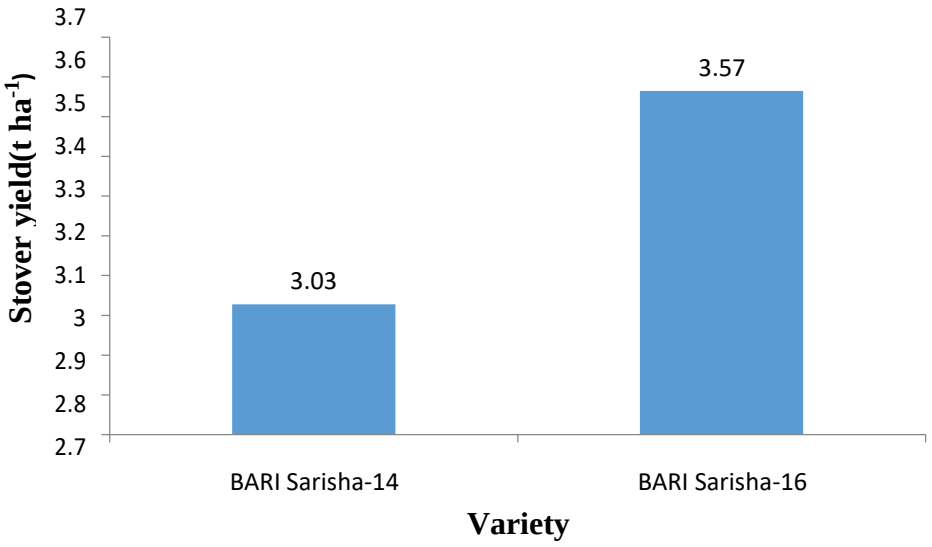
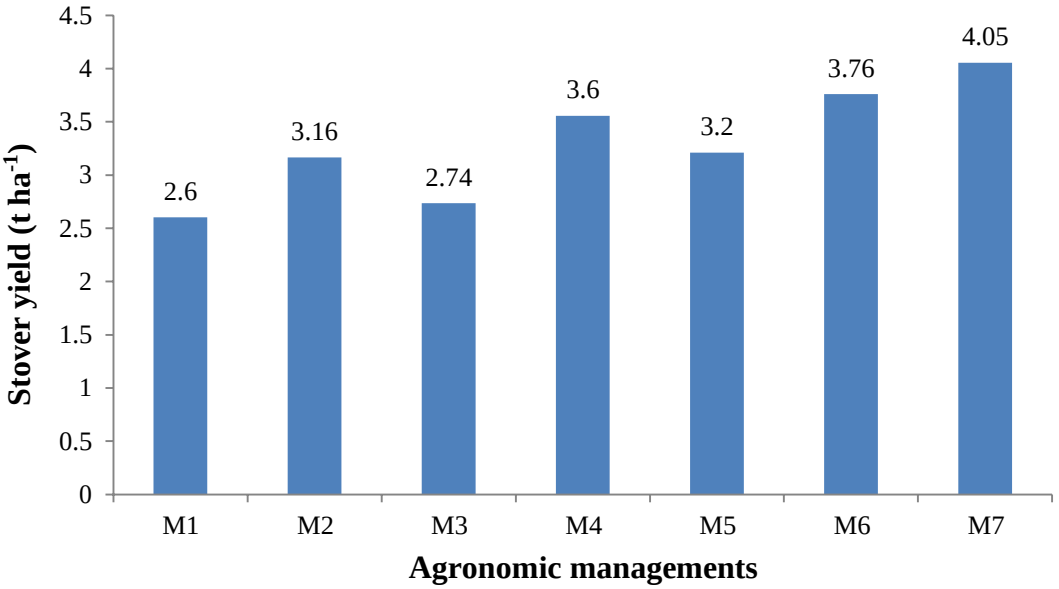


Figure 25. Effect of variety on stover yield (t ha^{-1}) of mustard (SE=0.053)

Effect of agronomic managements

Significant variation was found in stover yield at different agronomic managements. The treatment M_7 produced the highest stover yield (4.05 t ha^{-1}). The treatment M_1 produced the lowest stover yield (2.60 t ha^{-1}) which was statistically similar to M_3 (2.74 t ha^{-1}) but numerically higher than M_1.Therefore, M_5 (3.2 t ha^{-1}) and M_2 (3.16 t ha^{-1}) were statistically similar.It was also observed that M_4 (3.6 t ha^{-1}) and M_6 (3.76 t ha^{-1}) were also statistically similar. It was graphically shown in Figure 26.



M_1 = Control (No Management), M_2 = No Fertilizer but all other managements, M_3 = No weeding but all other managements, M_4 = No irrigation but all other managements, M_5 = No thinning but all other managements, M_6 = No pest managements but all other managements, M_7 = Recommended management

Figure 26. Effect of Agronomic managements on Stover yield (t ha^{-1}) of mustard (SE=0.12)

Interaction effect of variety and agronomic managements

Interaction effect of variety and agronomic managements had significant effect on Stover yield (Table 3.7.4). The highest stover yield (4.13 t ha^{-1}) was obtained from V_2M_7 treatment which was statistically similar to V_2M_6 (4.08 t ha^{-1}). The lowest stover yield was observed from V_1M_1 (2.47 t ha^{-1}) treatment which was statistically similar to V_1M_3 (2.52 t ha^{-1}).

4.14. Biological yield

Biological yield per plot was an important parameter of mustard. The data gathered in respect to biological yield as affected by different treatments had been summarized and presented in Table 10 and graphically illustrated in Figure 27 and Figure 28.

Effect of variety

The different varieties affected the biological yield. Results showed that V_2 (BARI Sarisha- 16) had the highest biological yield (4.50 t ha^{-1}) than V_1 (BARI Sarisha-14) having biological yield of 3.92 t ha^{-1}. It was graphically shown in Figure 27.

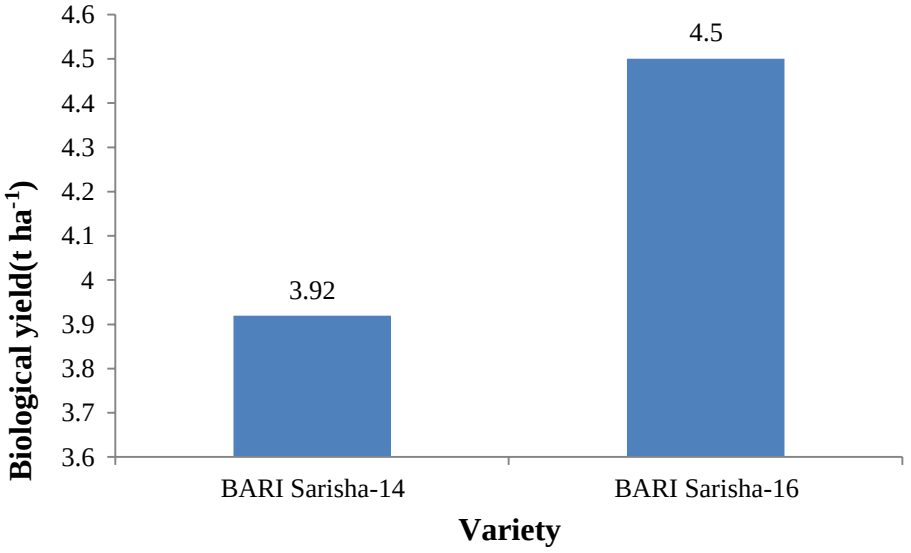
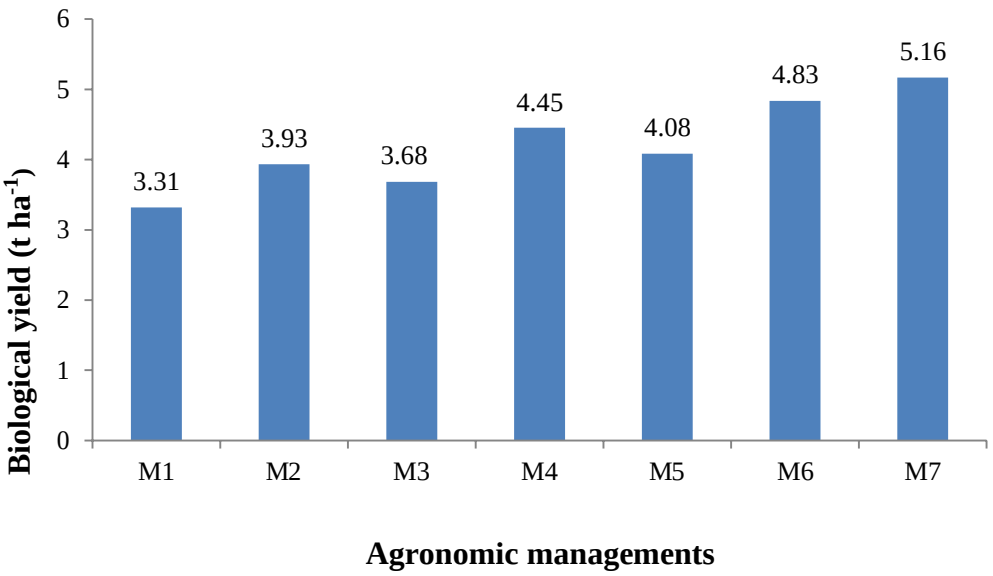


Figure 27. Effect of variety on Biological yield (t ha^{-1}) of mustard (SE=0.07)

Effect of agronomic managements

Significant variation was found in biological yield at different agronomic managements. The M_7 (Complete management) had the highest biological yield (5.16 t ha^{-1}) and the lowest biological yield was observed in M_1 (3.31 t ha^{-1}) treatment.It was graphically shown in Figure 28.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 28. Effect of Agronomic managements on Biological yield (t ha^{-1}) of mustard (SE=0.14)

Interaction effect of variety and agronomic managements

In case of interaction, V_2M_7 had the highest biological yield (5.32 t ha^{-1}) which was statistically similar to V_2M_6 (5.22 t ha^{-1}). The lowest biological yield was observed in V_1M_1 (2.93 t ha^{-1}). The V_1M_3 (3.53 t ha^{-1}) and V_1M_2 (3.61 t ha^{-1}) was statistically similar but lower than that of V_1M_1.Therefore V_1M_6,V_2M_5 and V_2M_2 treatments were also statistically similar (Table 10) .

4.15 Harvest index

Harvest index was worked out using the seed yield and biological yield. The data affected by different treatments was given in Table 10 and Figure 29 and Figure 30.

Effect of variety

Considering varieties, significant variation was not found on harvest index of mustard/rapeseed. The variety BARI Sarisha-14 had numerically the higher harvest index (25.37%) than BARI Sarisha-16 (23.06%). But they were statistically similar (Figure 29).

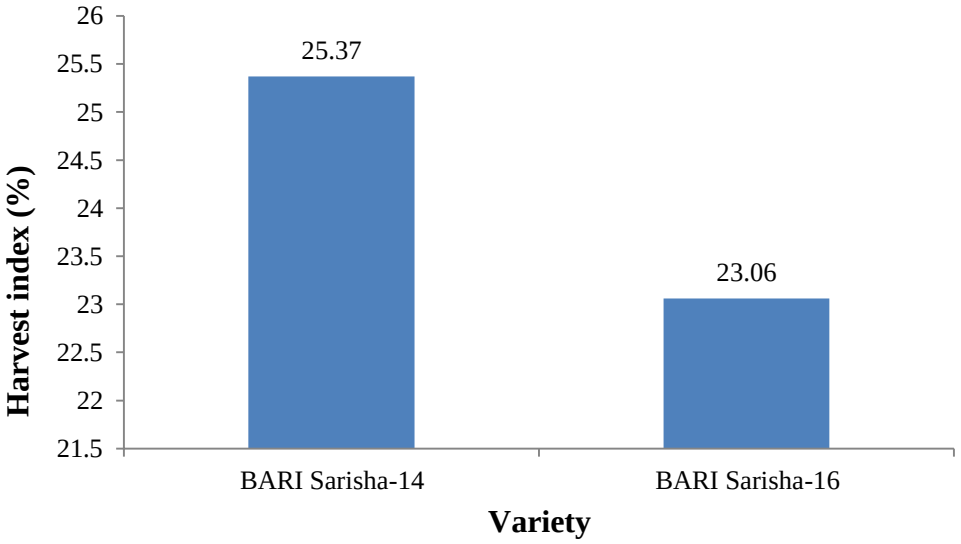
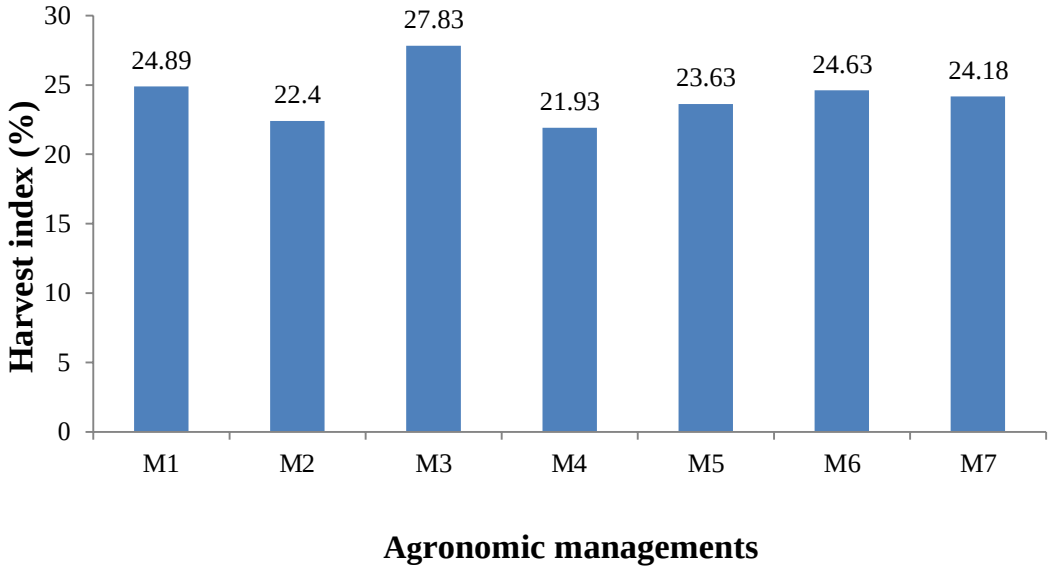


Figure 29. Effect of variety on harvest index (%) of mustard (SE=0.69)

Effect of agronomic managements

In case of agronomic managements, the highest harvest index was observed in M_3 (27.83%) and lowest was recorded in M_4 (21.93%) which was similar to M_2 (22.4%).Therefore, M_1 (24.89 %), M_5 (23.63 %) ,M_6 (24.63 %) and M_5 (23.63 %) were statistically similar.It was graphically shown in Figure 30.



M_1 = Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3** = No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

Figure 30. Effect of agronomic managements on harvest index (%) of mustard (SE=2.5)

Interaction effect of variety and agronomic managements

The interaction treatment V_2M_1 had the highest harvest index (32.00%) and lowest harvest index (17.79%) was observed in V_1M_1. The V_1M_1 was statistically similar to V_2M_2 (18.15%) and V_2M_5 (19.31%).Therefore V_1M_5 (27.96 %),V_1M_2 (26.66 %) & V_1M_6 (27.34 %) were statistically similar that was shown in the table 10

Table 10.. Interaction effect of variety and different agronomic managements on the Yield characters of mustard

Treatment combinations	Yield characters of mustard			
	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1M_1	0.52 g	2.47 g	2.93 g	17.79 d
V_1M_2	0.81 ef	2.72 fg	3.53 f	26.66 abc
V_1M_3	1.09 abc	2.52 g	3.61 f	31.03 ab
V_1M_4	0.87 def	3.33 de	4.20 de	21.91 cd
V_1M_5	1.05 abc	2.75 fg	3.80 ef	27.96 abc
V_1M_6	1.10 abc	3.43 cd	4.53 cd	27.34 abc
V_1M_7	1.16 ab	3.97 ab	5.13 ab	24.91 a-d
V_2M_1	1.02 bcd	2.74 fg	3.76 ef	32.00 a
V_2M_2	0.79 ef	3.60 cd	4.39 cd	18.15 d
V_2M_3	0.94 cde	2.95 ef	3.89 ef	24.64 bcd
V_2M_4	1.03 a-d	3.77 abc	4.83 bc	21.96 cd
V_2M_5	0.78 f	3.66 bcd	4.44 cd	19.31 d
V_2M_6	1.14 ab	4.08 a	5.22 a	21.92 cd
V_2M_7	1.19 a	4.13 a	5.32 a	23.46 cd
SE	**0.075**	**0.181**	**0.198**	**3.549**
CV(%)	**9.50**	**6.72**	**5.77**	**17.95**

Figures in a column with common letter(s) do not differ significantly at 5% probability level

V_1 = BARI Sarisha -14**, V_2 =** BARI Sarisha -16**; M_1 =** Control (No Management), **M_2** = No Fertilizer but all other managements, **M_3 =** No weeding but all other managements, **M_4** = No irrigation but all other managements, **M_5** = No thinning but all other managements, **M_6** = No pest managements but all other managements, **M_7** = Recommended management

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried during November 2018 to February 2019 to evaluate the effect of agronomic management on growth and yield of two varieties of mustard. In this experiment, the treatment combination of two varieties viz., V_1 = BARI Sarisha -14, V_2 = BARI Sarisha -16, and seven agronomic managements viz., (i) M_1 = Control (No management), (ii) M_2 = No fertilizer but all other managements, (iii) M_3 = No weeding but all other managements, (iv) M_4 = No irrigation but all other managements, (v) M_5 = No thinning but all other managements, (vi) M_6 = No pesticides but all other managements and (vii) M_7 =Recommended management. The treatments are replicated thrice in split-plot design. Two mustard varieties were assigned to the main plot and different agronomic managements were assigned to sub plot. There were 14 treatment combinations. Collected data on different growth, yield contributing characters and yield were recorded from the experimental field and analyzed statistically for evaluation of the treatment effect. Results revealed that a significant variation observed among the treatments in majority of parameters.

The data on various parameters were collected from 20 DAS to 65 DAS at an interval of 15 days interval and at harvesting time. The data on growth parameters viz., plant height, plant population m^{-2}, number of leaves $plant^{-1}$, leaf length etc. were recorded during the period from 20 DAS to at harvest. Yield contributing characters and yield parameters viz., siliquae $plant^{-1}$, seeds $siliqua^{-1}$, siliqua length, 1000-seed weight, seed yield, straw yield, biological yield and harvest index were recorded.

Results revealed that higher plant population m^{-2} was recorded from BARI Sarisha -14 (189.38) and lower was observed in BARI Sarisha-16(175.24). In case of agronomic managements, highest plant population was observed from M_5(360) and lowest was observed in M_6 (94.17) and in case of interaction V_1M_5 (371) showed higher plant population $m^{-2}$and lowest in V_2M_6 (75).

Higher plant height was recorded from V_2 (BARI Sarisha -16) and lower was observed in V_1. In case of agronomic managements, highest plant height was observed from M_7 and lowest was observed in M_1 and in case of interaction, variation was observed at different DAS for highest plant height but lowest plant height was observed in V_1M_1 treatment.

Higher leaf number was recorded from V_1 (BARI Sarisha -14) and lower was observed in V_2 (BARI Sarisha-16). In case of agronomic managements, highest leaf number was observed from M_7 and lowest was observed in M_1 and in case of interaction, V_1M_7 performed better at different DAS.

Higher leaf length was recorded from V_2 (BARI Sarisha -16) and lower in V_1 (BARI Sarisha-16).In case of agronomic managements, highest leaf length was observed from M_6 and lowest was observed in M_1 and in case of interaction, V_2M_7 performed better.

Higher branches plant^{-1} was recorded from V_2 (BARI Sarisha -16) and lower was observed in V_1 (BARI Sarisha -14). In case of agronomic managements, higher branches was observed from M_7 and lowest was observed in M_1 and in case of interaction, V_2M_7 performed better.

Higher dry matter production plant^{-1} was recorded from V_2 (BARI Sarisha -16) and lower observed in V_1 (BARI Sarisha -14). In case of agronomic managements, highest dry matter production plant^{-1} was observed from M_7 and lowest was observed in M_1 and in case of interaction, V_2M_7 treatment combination was found better than other combinations.

Higher SPAD reading (45.05%) was recorded from V_1 (BARI Sarisha -16) and lower in V_2 (40.27%) at 35 DAS but opposite result was found at 50 DAS. In case of agronomic managements, highest SPAD value was observed from M_7 (44.41%) and lowest was observed in M_3 (43.49%) and in case of interaction, variation was observed for highest SPAD value and lowest SPAD value at different DAS. No. of siliqua per plant and length of siliqua was higher in V_2 and lowest in V_1,

No. of siliqua per plant and length of siliqua was higher in V_2 (34.11 and 4.08 cm respectively) and lowest in V_1 (25.76 and 3.96 respectively)

Higher seeds siliqua^{-1} (26.38) was recorded from V_1 (BARI Sarisha -14) and lower (8.3) was observed in V_2(BARI Sarisha-16). In case of agronomic managements, highest seeds siliqua^{-1} was observed from M_7(20.91) and lowest was observed in M_1 (14.53) and in case of interaction, V_1M_7(29.96) combination was better and lowest observed in V_2M_1 (6.1)

Higher 1000-seed weight (3.94 g) was recorded from V_2 (BARI Sarisha -16) and lower (2.71 g) observed in V_1. In case of agronomic managements, highest 1000-seed weight was observed from M_7 (4.21 g)and lowest was observed in M_4 (2.78 g) and in case of interaction, V_1M_7 (4.83 g) combination was better and lowest observed in V_1M_1 (2.16 g)

In case of seed yield, there was no variation observed between two varieties. But in case of agronomic managements, seed yield was highest in M_7 (1.17 t ha^{-1}) treatment and lowest was observed in M_1(0.77 t ha^{-1}) treatment. In case of interaction, V_2M_7 (1.19 t ha^{-1}) performed better and lowest yield was recorded from V_1M_1 (0.52 t ha^{-1}) treatment. Higher stover yield (3.57 t ha^{-1}) was recorded from V_2 (BARI Sarisha -16) and lower in V_1 (3.02 t ha^{-1}). In case of agronomic managements, highest stover yield was observed from M_7 (4.05 t ha^{-1}) and the lowest observed in M_1 (2.6 t ha^{-1}) and in case of interaction,V_2M_7 (4.13 t ha^{-1}) combination was better and lowest was observed in V_1M_1 (2.46 t ha^{-1}). Higher biological yield (4.5 t ha^{-1}) was recorded from V_2 (BARI Sarisha -16) and lowest observed in V_1 (3.91 t ha^{-1}). In case of agronomic managements, highest biological yield was observed from M_7 (5.16 t ha^{-1}) and lowest in M_1 (3.31 t ha^{-1}) and in case of interaction, V_2M_7 (5.26 t ha^{-1}) combination was better and lowest (2.93 t ha^{-1}) observed in V_1M_1

In case of harvest index, there was no variation observed between varieties. But in case of agronomic managements, harvest index was highest in M_3 (27.83) treatment and lowest was observed in M_4 (21.93) treatment. In case of interaction, V_2M_1 (32) performed better and lowest reading was recorded from V_1M_1 (17.79) treatment.

Compared to that of complete management, the highest yield reduction for was observed for no management (33.90 %) that followed by no fertilizer (32.20 %), no thinning (22.03 %), no irrigation (18.64%), no weeding (13.56 %) and no pest management (5.08 %). The V_2M_7 (BARI Sarisha-16 with complete management) performed better than all other combinations. So it may be concluded that highest priority should be given on fertilizer application, thinning and irrigation for mustard cultivation.

RECOMMENDATION

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 mustard.
3. It needs to conduct more experiments with different agronomic managements whether it can regulate the growth, yield and seed quality of mustard

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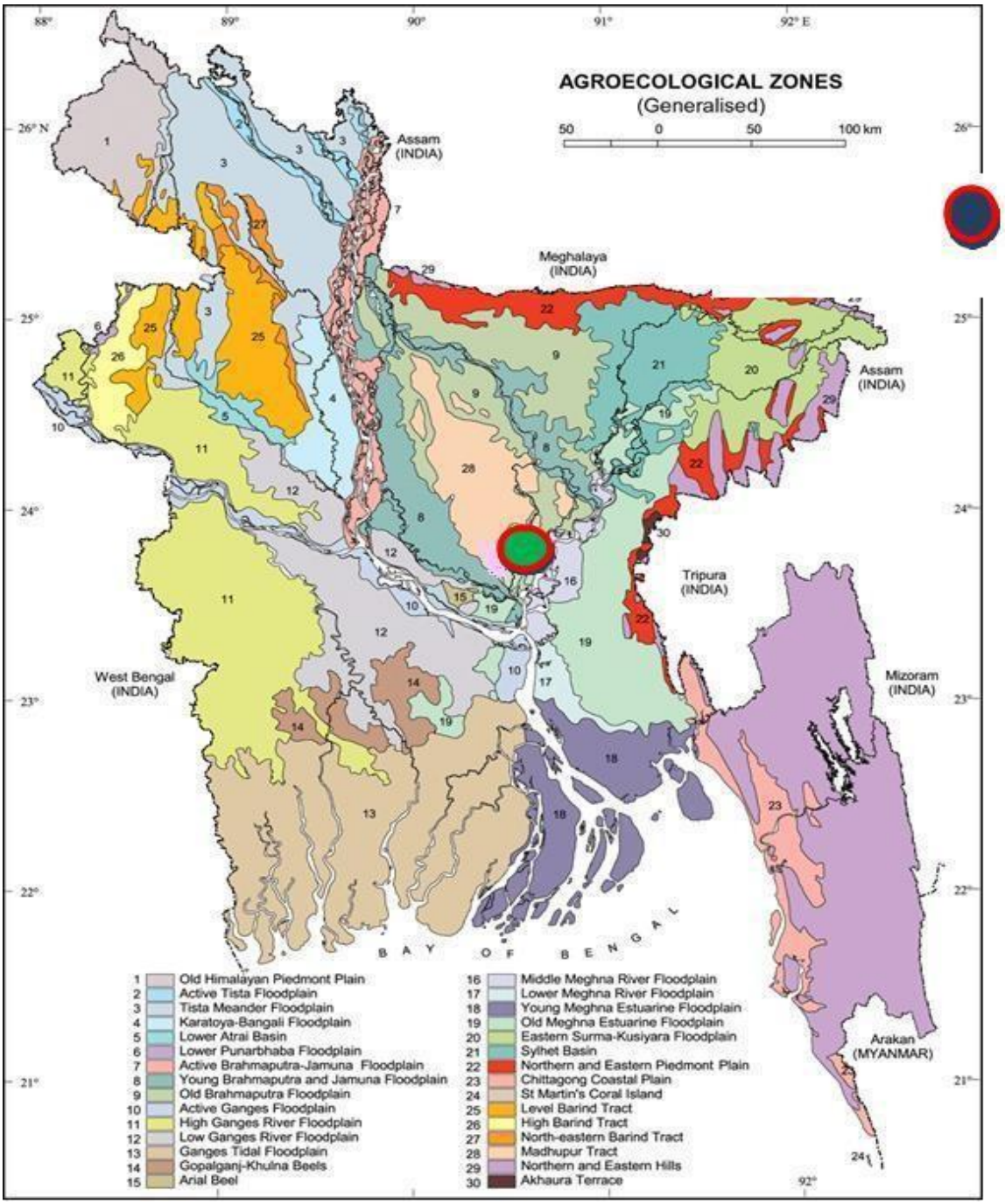
APPENDICES

Appendix I- Map showing the experimental site under the study



Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during November 2018- February 2019

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Minimum	Maximum	Mean			
2018	November	19.2	29.6	24.4	53	34.4	11
2018	December	14.1	26.4	20.25	50	12.8	11
2019	January	12.7	25.4	19.05	46	7.7	11
2019	February	15.5	28.1	21.8	37	28.9	11

Source: Bangladesh Mateorological Department(climate and weather division), Agargaon, Dhaka-1207

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract (28)
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
pH	6.00-6.63
Organic matter	0.84
Total (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41meq/ 100 g soil

Source: Soil Research and Development Institute (SRDI), Dhaka

Appendix IV. Analysis of variance of the data on plant population m^{-2} of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on plant population m^{-2}
Replication	2	55.2
Variety (A)	1	2100.2*
Error-1	2	39.2
Agronomic managements (B)	6	76276.1*
A×B	6	1855.3*
Error-2	24	58.9

*Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on plant height of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on plant height at different days after sowing (DAS)				
		20	35	50	65	At harvest
Replication	2	0.25055	1.552	184.95	5.1	23.6
Variety (A)	1	3.15429*	491.933*	3663.90*	10318.4*	30427.1*
Error-1	2	0.0827	1.502	7.31	0.5	31.3
Agronomic managements (B)	6	12.8568*	397.921*	260.57*	757.5*	988.1*
A×B	6	29.3588*	41.174*	129.75***	236.9*	174.7*
Error-2	24	2.2498	2.198	63.07	20.7	15.1

* Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on Leaf number plant^{-1} of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on leaf number plant^{-1} at different days after sowing (DAS)			
		20	35	50	65
Replication	2	2.06595	1.0431	2.837	7.149
Variety (A)	1	0.22881**	20.3010*	102.774*	456.720*
Error-1	2	0.41595	1.0088	0.180	6.217
Agronomic managements(B)	6	1.02206*	26.6256*	68.357*	287.215*
A×B	6	0.55048*	3.7410*	30.350*	153.009*
Error-2	24	0.27067	1.0387	5.390	9.702

* Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on leaf length of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on leaf length at different days after sowing (DAS)			
		20	35	50	65
Replication	2	3.5945	1.228	0.560	0.952
Variety (A)	1	10.8834*	569.002*	388.877*	355.544*
Error-1	2	0.0833	3.248	0.816	0.989
Agronomic managements(B)	6	1.038*	87.935*	39.657*	44.246*
A×B	6	0.5949*	15.759*	5.304*	5.624*
Error-2	24	0.8624	1.097	1.046	0.797

* Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on branches plant^{-1} of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on branches plant^{-1} at different days after sowing (DAS)		
		50 DAS	65 DAS	AT HARVEST
Replication	2	0.3031	0.1667	0.0029
Variety (A)	1	20.7202*	14.7621*	12.5952*
Error-1	2	0.0388	0.06	0.041
Agronomic managements(B)	6	4.0406*	4.9341*	8.0322*
A×B	6	0.6747*	1.036*	0.333*
Error-2	24	0.1176	0.0997	0.0786

* Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on dry matter production plant^{-1} of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on dry matter Production plant^{-1} at different days after sowing (DAS)			
		20	35	50	65
Replication	2	0.00581	0.1133	0.3509	0.17436
Variety (A)	1	0.02777*	0.40219**	0.11947**	2.89148*
Error-1	2	0.00044	0.01198	0.10802	0.01752
Agronomic managements(B)	6	0.12365*	0.2264***	0.42006*	3.9854*
A×B	6	0.04608*	0.01219**	0.38629*	0.9481*
Error-2	24	00.207	0.01	0.9675	0.0636

- Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data on SPAD value of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of data on SPAD value	
		35 DAS	50 DAS
Replication	2	0.6175	10.378
Variety (A)	1	81.3708*	100.131*
Error-1	2	0.4241	0.471
Agronomic managements (B)	6	28.6176*	48.062*
A×B	6	9.6066***	10.627**
Error-2	24	5.0692	3.805

* Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data on yield contributing characters of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of			
		Siliquae plant^{-1}	Seeds siliqua^{-1}	Length of siliqua	1000-seed weight
Replication	2	6.397	3.45	0.4667	0.1817
Variety (A)	1	731.669*	3432.67*	0.21429***	15.726*
Error-1	2	10.75	7.85	0.02034	0.1217
Agronomic managements(B)	6	271.116*	36.39*	0.88462*	1.7758*
A×B	6	179.437*	6.05**	0.0934***	0.1093**
Error-2	24	11.345	2.45	0.04291	0.0361

* Significant at 0.05 level of probability

Appendix XII. Analysis of variance of the data on yield characters of mustard as influenced by variety, agronomic managements & their interaction

Source of variation	df	Mean square of			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.00074	0.35225	0.39452	61.416
Variety (A)	1	0.1844**	3.02949*	3.54381*	55.9598***
Error-1	2	0.1412	0.03031	0.06167	5.0662
Agronomic managements (B)	6	0.13668*	1.67418*	2.52937*	22.5883**
A×B	6	0.09158*	0.127**	0.09159**	96.0983*
Error-2	24	0.00845	0.04915	0.05893	18.8923

* Significant at 0.05 level of probability

PLATES

V_2M_3		V_2M_6		V_2M_7		V_2M_2		V_2M_1		V_2M_4		V_2M_5
V_1M_1		V_1M_4		V_1M_5		V_1M_7		V_1M_6		V_1M_3		V_1M_2
V_1M_3		V_1M_5		V_1M_6		V_1M_4		V_1M_2		V_1M_7		V_1M_1
V_2M_6		V_2M_2		V_2M_4		V_2M_3		V_2M_7		V_2M_1		V_2M_5
V_2M_4		V_2M_7		V_2M_3		V_2M_1		V_2M_2		V_2M_5		V_2M_6
V_1M_2		V_1M_6		V_1M_1		V_1M_5		V_1M_3		V_1M_4		V_1M_7

Plate 1. Layout of the experiment

Plate 2. Photograph showing final land preparation

Plate 3. A view of experimental plot in 3 Days after sowing

Plate 4. Tagging of all experimental sub plot with bamboo stick

Plate 5. Field view of the experimental plot at flowering stage

Plate 6. Data recording of different parameters

Plate 7. Application of fertilizer in the experimental plot