EFFECT OF FERTILIZER DOSES ON MORPHOLOGICAL AND YIELD PERFORMANCE OF MUSTARD VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF FERTILIZER DOSES ON MORPHOLOGICAL AND YIELD PERFORMANCE OF MUSTARD VARIETIES" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTERS OF SCIENCE in AGRICULTURAL BOTANY, embodies the result of a piece of bonafide research work carried out by MST. RASHIDA AKTAR, Registration No. 19-10354 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2021

Place: Dhaka, Bangladesh

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Dedicated

to

My Beloved Parents

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ABSTRACT

The experiment was carried out at Sher-e-Bangla Agricultural University Research Farm, Dhaka during Rabi season, December 2020 to February 2021 to find out the effect of fertilizer doses on morphological and yield performance of mustard varieties. The experiment comprised of two factors - the treatment consisted of four different levels of fertilizer application viz. F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended fertilization (204 kg ha^{-1} Urea, 136 kg ha^{-1} TSP, 68 kg ha^{-1} MoP and 119 kg ha^{-1} Gypsum), F_2 = BARC recommended fertilizer dose (100%) (240 kg ha^{-1} Urea, 160 kg ha^{-1} TSP, 80 kg ha^{-1} MoP and 140 kg ha^{-1} Gypsum) and F_3 = 115% fertilization compared to recommended fertilization (276 kg ha^{-1} Urea, 184 kg ha^{-1} TSP, 92 kg ha^{-1} MoP and 161 kg ha^{-1} Gypsum) and three different varieties viz. V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15. The experiment consisted of two factor and laid out in Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed and a significant variation among the treatments was found in respect of majority of the observed parameters. The highest plant population (66.33 m^{-2}) was recorded from F_3 treatment. The tallest plant was recorded from 115% fertilizer application (F_3). Significantly maximum branches $plant^{-1}$, dry matter weight $plant^{-1}$, siliqua $plant^{-1}$ and seed $siliqua^{-1}$ were recorded from F_2 and F_3 treatment with 100% and 115% fertilization, respectively. The maximum thousand seed weight (2.98 g) was recorded from V_3 (BARI Sarisha-15). The highest plant population (77.25 m^{-2}) was observed in case of BARI Sarisha-15. The tallest plant of mustard was found in case of with BARI Sarisha-15. The maximum branches $plant^{-1}$, dry matter weight $plant^{-1}$, siliqua $plant^{-1}$ and seed $siliqua^{-1}$ were obtained from BARI Sarisha-14 (V_2). The highest yield of seed (0.95 t ha^{-1}) was obtained from BARI Sarisha-14. The combinations of different fertilizer doses and varieties had significant effect on almost all the parameters. The higher yield of seed was obtained from F_2V_2 (1.15 t ha^{-1}), F_2V_3 (1.08 t ha^{-1}) and F_3V_2 (1.16 t ha^{-1}) treatment combination. The highest biological yield (4.02 t ha^{-1}) was obtained from F_2V_3 and the highest harvest index was obtained from F_2V_2 (30.75%) and F_3V_2 (29.37%) treatment combination. Considering the results, it can be concluded that both the variety BARI Sarisha-14 and BARI Sarisha-15 provided better yield than the other variety and F_2 and F_3 fertilizer dose provided better yield for most of the mustard varieties. Bari Sharisha-14 (V_2) with 100% (F_2) fertilization resulted comparatively better morphological, physiological and yield characteristics.

CHAPTER I

INTRODUCTION

Mustard (*Brassica* spp.) is an important oil seed crop in Bangladesh. It belongs to the family Brassicaceae (Cruciferae), is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Currently it ranks as the world third oil crops in terms of production and area (Nasim *et al.,* 2013). About 13.2% of the annual edible oil comes from this crop (FAO, 2021). *Brassica* oil crop is the most important group that supplies major edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country (Miah and Mondal, 2017). Bangladesh is running a short of 60-75% of the demand of edible oil (Fiedler *et al.*, 2015). Along with the COVID-19 pandemic, the conflict between Russia and Ukraine led to a severe shortage of edible oils like soybean, sunflower, and palm oil on the world market. Given the situation, expanding domestic oil production should be the top priority.

Oil seed rape (*Brassica napus* L.) has become one of the most important oil crops and at present it is the third largest source of vegetable oil all over the world (Miri, 2008; Nielsen *et al.*, 2012). Vegetable oil, which can be derived from plant sources through the growth of oil crops, that clearly significant as other crops. It is a key source of cooking oil in Bangladesh and widely used as edible oil in rural areas and to improve the flavor of a variety of foods, providing one-third of the country's edible oil needs (Ahmed and Kashem, 2017; Shaheenuzzamn *et al.,* 2015). Plant-based oil is easily digested and has a higher nutritional value than animal fats (FAO, 2012). Its oil not only serves as a fat substitute in our daily diet, but it also helps to feed the nation's economy. In the 2018-19 crop year, overall oilseed production was 996 thousand metric tons, with 1235 thousand acres covered by oilseed crops. Mustard was grown on 814 thousand acres of land in 2020-21, with a production of 397 thousand metric tons (BBS, 2022), which is very low compared to the yield of many mustard growing countries of the world. There are several reasons that can explain this yield variation, which cover abiotic and biotic factors. Among the biotic and abiotic factors, unavailability of high yielding varieties, nutrient deficiency and lack of cultural practices are responsible for lower productivity of mustard (Ajnar and Namdeo, 2021; Saud *et al.*, 2016; Sherawat *et al.*, 2021).

In Bangladesh, mustard (*Brassica* spp.) is a winter crop and grown during October-March. It's also a thermosensitive and photosensitive sensor (Miri, 2008). Planting time plays a vital role in a country like Bangladesh, where climatic conditions vary throughout the country. Time of sowing determine the time of flowering and also it has great influence on dry matter accumulation, siliqua formation seed set, seed yield and seed oil content (Barłóg and Grzebisz, 2004; Łukowiak and Grzebisz, 2020; Öztürk, 2010; Xie *et al.*, 2016). Mid October is the most suitable time of sowing of rapeseed and mustard in Bangladesh (Öztürk, 2010; Patel *et al.*, 2022). One of the main reasons for low yield of mustard in Bangladesh is delay sowing of seeds due to delay in recession of flood water and late monsoon rain especially in the low land areas (Shaker, 2011; Teymoori *et al.*, 2020). Bangladesh Agricultural research Institute (BARI) has developed and recommended a few high yield potentials as well as late sown varieties of rape and mustard (Begum *et al.*, 2020). These varieties may differ in their response to sowing dates for yield and yield components. The newly released high yielding potential varieties of mustard could not compensate the yield gap possibly due to nutrient deficiency in soil and lack of irrigation.

Winter, the rapeseed- mustard growing season being usually dry, the yield of these crops could be increased through fertilization (Sienkiewicz-Cholewa and Kieloch, 2015). Aphid infestation had also highly significant correlation with cultural practices like date of sowing, nitrogen levels (Patel *et al.*, 2021). Application of fertilizer has a positive effect in increasing the seed yield of rapeseed-mustard (Azam *et al.*, 2017; Dwivedi *et al.*, 2019; Hossain *et al.*, 2019; Keivanrad and Zandi, 2012; Raghuvanshi *et al.*, 2018; Sherawat *et al.*, 2021; Verma *et al.*, 2018).

Fertilizers play an important role in the environmental influences on crop production. Research workers have reported differential responses of different genotypes to fertilizer application (Raghuvanshi *et al.*, 2018). The application of suitable fertilizers in appropriate doses is considered as one of the most important factors for increasing crop yield per unit area. Among primary and secondary nutrients, nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) deficiency in soils especially in winter is a common phenomenon in Bangladesh (Sharma *et al.*, 2020). N, P, K, S fertilizer and varieties not only affect the growth and yield of mustard but also improve the quality of seed in terms of oil and other nutrients fatty acids content, which are essential in human and animal

diets. So far there was a very little research work had been done regarding the application of different fertilizer doses on late sown mustard varieties. Keeping in view of above facts, a field experiment was conducted during late rabi 2020-21 to fulfill the following objectives:

1. To study the effect of different fertilizer doses on morphological and yield parameters of mustard varieties.
2. To determine the optimum fertilizer doses for maximum yield of mustard varieties.

CHAPTER II

REVIEW OF LITERATURE

Prior to conducting comprehensive research, it is essential to review the previous research work related to the proposed study. The most common and relevant studies which have been conducted in the recent past are discussed below for clear and better understanding of the present study.

2.1 Effect of fertilizer doses on different crop characters of mustard

Ajnar and Namdeo (2021) laid out a field experiment during rabi-season 2019-2020 at Institute of Agriculture Sciences, SAGE university Indore (Madhya Pradesh) to find out the effect of two levels of RDF (100% and 75%) with two organic manure (poultry manure and vermicompost) and two biofertilizer (*Azotobacter* and *Azospirillium*) on Indian Hybrid Mustard NRCH B506 (*Brassica juncea* L.). The yield attributes like no. of siliqua per plant, no. of seed per plant, test weight of seed, and as well as stover yield significantly increased with the application of vermicompost over control.

Azam *et al.* (2017) conducted an experiment in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during 2014-2015 to know the combined effect of different levels of Sulphur (S) and Boron (B) on yield and yield contributing characters, nutrient and oil content of mustard and to find out the suitable combination of Sulphur (S) and Boron (B) for yield maximization of mustard. Results showed that the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) contributed positively for better performance of yield contributing characters of mustard. They concluded that the combination of S and B (20 kg S ha^{-1} and 3 kg B ha^{-1}) might be suitable dose for cultivation of mustard in Tejgaon series soils under agro-ecological zone of Madhupur Tract Bangladesh.

Barłóg and Grzebisz (2004) conducted a field experiment on the grey-brown podzolic soil in the four growing seasons (1998-2001) at Krzeslice Farm, central-western Poland comprised seven fertilization variants applied in split rates at the beginning of spring regrowth stem elongation and flower buds visible stages. Plants grown on these treatments have developed different patterns of growth to yield the seeds. These patterns were characterized by very high crop growth rate during flowering and negative at maturation.

Begum *et al.* (2013) conducted field experiments at the Central Research Station of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from November to February in 2004-05 and 2005-06 to evaluate the effect of different levels of Sulphur (0, 20, 40, 60, and 80 kg ha^{-1}) on rapeseed variety BARI Sarisha-15. Results showed that the growth parameters, yield and yield contributing characters were increased with the increasing levels of Sulphur fertilizer up to 60 kg ha^{-1} S and with the doses beyond that were found to decrease.

Beulah and Umesha (2022) led a study during Rabi season of 2021 at experimental field of the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj and Uttar Pradesh, India to determine the effect of row spacing and zinc on growth and yield of Mustard (variety was Varuna T-59). They concluded that the treatment with row spacing 30 cm and zinc at 15 kg ha^{-1} was found to be effective in highest gross return (126420 INR ha^{-1}), net return (89638.4 INR ha^{-1}) and benefit cost ratio (2.43).

Dwivedi *et al.* (2019) conducted a field trial with different levels of nitrogen and Sulphur on mustard sown. Nitrogen increased the yield of mustard but Sulphur was ineffective.

Hossain *et al.* (2019) carried out a field experiment at Sonapur of Muradnagar upazilla in Cumilla district under the Debidwar MLT (Multi-Location Testing) site during the rabi season of 2013-15. The treatments were: T_1= Soil Test Based (STB) Fertilizer dose (FRG 2012), T_2= T_1+ 15% STB, T_3= T_1+ 30% STB, T_4= 80% STB from inorganic fertilizer + 20% STB from CD/PM, T_5= Farmers' Practice and T_6= Control. Among the treatments, T_4 gave the maximum seed yield (1385.56 kg ha^{-1}).

Jankowski *et al.* (2020) conducted a field experiment with mixed 2^m3^{k-1} factorial design, where five factors were tested at two and three levels, was carried out in the Agricultural Experiment Station in Bałcyny in north-eastern Poland in 2016–2018. Two white mustard cultivars, including the traditional cultivar Radena and the canola-quality cultivar Warta, were sown on three dates: the optimal date (4–10 April), as well as 7 and 14 days past the optimal date. White mustard cultivars were grown at three levels of agricultural inputs (0, 1, 2) with different rates of nitrogen (80, 120 and 160 kg ha^{-1}). Delayed sowing (by 7 and 14 days) contributed to the greatest decrease in yield (32 % and 42 %, respectively) in a dry year (2018). In both analyzed cultivars, nitrogen fertilizer delivered yield-forming effects up to the rate of 80 kg ha^{-1} (in the dry year).

Keivanrad and Zandi (2012) investigated agronomical and qualitative features of Indian mustard in a semi-arid region. In their experiment, the highest seed yield and oil yield (2961 and 1159 kg ha^{-1}, respectively) were obtained for the crop utilized with 200 kg N ha^{-1} in plots with 80 plant m^{-2}.

Łukowiak and Grzebisz (2020) assumed that the management of both soil and fertilizer N in winter oilseed rape (WOSR) is crucial for N accumulation in seeds (Nse) and yield. This hypothesis was evaluated based on field experiments conducted in 2008/09, 2009/10, 2010/11 seasons, each year at two sites, differing in soil fertility, including indigenous N (Ni) supply. The experimental factors consisted of two N fertilizers: N and NS, and four Nf rates: 0, 80, 120, 160 kg ha^{-1}. Yield, as governed by site × Nf rate interaction, responded linearly to Nse at harvest. The maximum Nse (Nse_{max}), as evaluated by N input (Nin = Ni + Nf) to WOSR at spring regrowth, varied from 95 to 153 kg ha^{-1} and determined 80% of yield variability. They concluded that the N pool supports the N concentration in seeds, resulting in both seed density and a seed weight increase, finally leading to a yield increase.

Mishra and Singh (2022) conducted a field experimental trial to explore the effect of Nitrogen and Zinc levels on yield and economics of mustard (*Brassica juncea* L.) during rabi season (2021-2022) at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (Allahabad) (U.P.). The results revealed that the application of Nitrogen 100 kg ha^{-1} + Zinc 15 kg ha^{-1} recorded maximum siliqua length (5.20 cm), number of siliquae per plant (398.90), number of seeds per siliqua (24.40), test weight (3.53 g). The economic analysis demonstrates that Nitrogen 100 kg ha^{-1} + Zinc 15 kg ha^{-1} treatment produced higher grain yield (1.89 t ha^{-1}), stover yield (3.11 t ha^{-1}), gross returns (103650.00 INR ha^{-1}), net returns (70264.08 INR ha^{-1}) and B:C ratio (2.10).

Öztürk (2010) conducted a study to determine the effect of year, N sources and doses on the yield and quality traits of winter rapeseed in a cereal system in calcareous soils over two seasons, 2000-2001 and 2001-2002, in Central Anatolia. Mean values of both seasons indicated that 100 and 150 kg N ha^{-1} rate increased significantly yield and quality traits with regard to other N treatments. The results highlighted the practical importance of adequate N fertilization and true N source in seed yield in winter rapeseed and suggest that ammonium sulfate at 150 kg N ha^{-1} would be adequate to meet crop N requirements.

Patel *et al.* (2022) carried out a field investigation at the Rajaula Research Farm, Faculty of Agricultural Science, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalay, Chitrakoot - Satna (M.P.) during Ravi season 2019-20. Their findings suggested that application of 30kg phosphorus with 20kg sulphur ha^{-1} proved the most optimum and beneficial fertility management for the Pusa Mahak veriety mustard.

Sharma *et al.* (2020) conducted a field experiment at Agricultural Research Station, Kota during the Rabi seasons 2019-20 to find out suitable nutrient management levels of nitrogen, phosphorous and potassium in irrigated condition of south- eastern Rajasthan. The application of 100 kg N with 50 kg P_2O_5 and 30 kg K_2O ha^{-1} was found beneficial for obtaining high seed yield in irrigated conditions of south- eastern Rajasthan.

Sienkiewicz-Cholewa and Kieloch (2015) conducted three-year strict experiments with winter rapeseed in three experimental stations. Sulphur at 40 and 60 kg S ha^{-1} doses affected the increase in oilseed rape grain yield by 11-12% compared to the not fertilized treatment. A significant increase in fat content, in relation to not fertilized treatment, ranking from 1.0-1.4% dry matter, was recorded after fertilization with the highest sulphur dose - 60 kg S ha^{-1}, as well as after application of boron and copper fertilization.

Wang *et al.* (2019) discussed the effects of mulching and nitrogen (N) fertilizer on the soil environment and crop yield to inform food security. Nitrogen fertilization can markedly improve soil fertility and crop yield. However, nitrogen use efficiency (NUE) and the environment may be negatively affected by the improper application of N fertilizers. The improvement of NUE has been an important focus in field management for the more sustainable use of valuable N fertilizers.

2.2 Effect of variety on different crop characters of mustard

Ahmed and Kashem, (2017) conducted a varietal trial of mustard at Noagaon village of Dekhar *haor* areas of South Sunamganj upazila of Sunamganj district, during November 2015 to March 2016, to find out the suitable mustard variety/varieties. A total of five varieties viz. BADC 1, SAU Sarisha-3, BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-15 were tested in the farmer's field. The mustard var. BARI Sarisha-11 produced the highest number of branches $plant^{-1}$, number of capsules $plant^{-1}$, 1000-seed weight resulting the highest seed yield (1.64 t ha^{-1}), followed by BARI Sarisha-15 (1.47 t ha^{-1}), but the growth duration of BARI Sarisha-15 was shorter than the others.

Begum *et al.* (2020) studied to assess socioeconomic factors determining farmers' decisions to adopt BARI mustard-14. They found that the rate of adoption of BARI mustard-14 was 38.95% at farm level but adoption rate was higher in Tangail compared to Cumilla and Rajshahi districts. Profitability analysis showed that the yield of BARI mustard-14 variety is much higher compared to BARI old variety (Tori-7). The average net return of BARI mustard-14 variety was Tk. 14,450 per ha which was also significantly higher (20.77%) than BARI old mustard variety. The BCR of improved variety (1.23) was significantly higher (85.58%) compared to that of old variety.

Biswas *et al.* (2002) conducted an experiment to find a suitable management practice to boost up the yield of late sown rapeseed-mustard. The results revealed that mustard variety Dhali (*Brassica campestris*) yielded the highest and it was significantly different from those of Daulat (*B. juncea*) and BARI sharisa-8 (*B. napus*).

Biswas *et al.* (2020) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques. The planting techniques were as conventional sowing and sowing seeds in puddle soil that assigned to the main plot and five varieties viz. Improved Tori-7, BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU SR-3 in the sub-plots. The Improved Tori-7 variety gave the maximum seed yield (2.24 t ha^{-1}) followed by BARI Sarisha-16 (1.96 t ha^{-1}). The highest seed yield was given by the variety BARI Sarisha-16 in conventional planting method (2.39 t ha^{-1}) that was similar to Improved Tori-7 variety irrespective of planting techniques.

Hashim and Mahmood (2021) conducted a study at Grdarasha Research Field / College of Agricultural Engineering Sciences - Salahaddin University - Erbil during the winter growing season (2014-2015), to investigate the effect of sowing dates, seeding rates on growth parameters, yield and its component of different rapeseed genotypes (Pactol, Raja and Rendy). In their study, Pactol genotype obtained the highest seed yield, 4.49 kg ha^{-1}, when sown on 15th October with seeding rate of 4 kg ha^{-1}.

Helal *et al.* (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI

Sarisha-14, BARI Sarisha-15, and BinaSarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, growth as well as yield and yield attributes of rapeseed mustard were significantly differed. The variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 produced the highest seed yield and took minimum days to mature and their growth parameters were also highly significant and positive correlation was observed in seed yield with siliqua/plant, straw yield, biological yield, 1000 seed weight and harvest index.

Jawad *et al.* (2017) conducted a field experiment at Bacha Khan University Agricultural Research Farm, Bacha Khan University Charsadda, during winter-2015 to determine the growth and yield attributes of canola varieties under different seed rates. Four seed rates (4, 6, 8 and 10 kg ha^{-1}) and two varieties (Durr-e-NIFA and Zahoor Swati) were tested in the experiment. The results showed that maximum emergence m^{-2} (82) was recorded for the variety Zahoor Swati. The variety Durr-e-NIFA produced maximum plant height (145 cm) and 1000-grains weight (3.69 g). Biological yield (3751 kg ha^{-1}) and grain yield (2228 kg ha^{-1}) increased with increasing seed rate from 4 to 10 kg ha^{-1} in case of Durr-e-NIFA variety.

Jogi *et al.* (2018) observed the effect of various seed rate on the growth, seed yield and oil content of mustard variety Mehran Raya. They concluded that regardless the variation in the values of different growth and seed yield traits of mustard crop, the seed yield was markedly higher (1386 kg ha^{-1}) under seed rate 3.0 kg ha^{-1}.

Razzaque *et al.* (2007) carried out an experiment at Multi Location Testing site Barguna to determine suitable variety of mustard (*Brassica* species) for the late sowing condition for the coastal area of Bangladesh during rabi season of 1998-1999 and 1999-2000. Four varieties of mustard such as Daulat, Rai-5, Improved tory-7, and Ishurdi local with four sowing dates viz.15 Nov, 23 Nov, 30 Nov. and 7 Dec. were used for the experiment. The results revealed that the variety Daulat (1035 kg ha^{-1}) and Ishurdi local (1014 kg ha^{-1}) produced identically superior yield irrespective of sowing time. They concluded that Daulat and Ishurdi local variety sowing could be delayed up to 30 November to obtain a profitable yield of (872 kg ha^{-1}) and (940 kg ha^{-1}) respectively which was economically profitable.

Sarkar *et al.* (2020) conducted the study in four major BinaSarisha-4 growing areas of Bangladesh, namely Jashore, Kushtia, Magura and Faridpur district to estimate the socio-economic profile, profitability and technical efficiency of the variety. Farmers faced some constraints in cultivating of the variety. Out of them the major constraints were inadequate supply of quality seeds, higher price of fertilizers & insecticides, lack of training, lack of technical know-how, natural calamities, higher charge of irrigation and Infestation of insects.

Teymoori *et al.* (2020) studied on the effect of drought stress on seed yield and some physiological traits of promising lines of rapeseed at different sowing dates for two years (2015-2017) in a semi-arid region of Iran. Results showed that delayed sowing and drought stress increased carbohydrate content and decreased seed yield.

Zhang and Zhou (2006) analyzed the heritability, the number of segregating genes and the type of gene interaction of nine agronomic traits based on F2 populations of synthetic oilseed *Brassica napus* produced from interspecific hybridization of *B. campestris* and *B. oleracea* through ovary culture. The nine traits – plant height, stem width, number of branches, length of main raceme, number of pods per plant, number of seeds per pod, length of pod, seed weight per plant and 1000-seed weight – had heritabilities of 0.927, 0.215, 0.172, 0.381, 0.360, 0.972, 0.952, 0.516 and 0.987 respectively, while the mean numbers of controlling genes for these characters were 7.4, 10.4, 9.9, 12.9, 11.5, 21.7, 20.5, 19.8 and 6.4 respectively.

2.3 Interaction of fertilizer dose and variety on different crop characters of mustard

Abdulkhaleq *et al.* (2018) conducted a field investigation during the winter seasons of 2016-2017 at The Qlyasan Agricultural Research Station, College of Agricultural Sciences, University of SuLAmani to study the effect of three levels of zinc fertilizer on the growth, yield and yield component of rapeseed varieties (i.e., Serw, Hybrid and Reandy). The results of this investigation confirm that variety Reandy produced the best values for most characters, and the application 40Kg Zn ha^{-1} was found to be the best level for this crop. The character seed yield showed positive and highly significant correlation with most characters including plant height, number of leaves per plant, number of pods per plant, the weight of pod per plant, average pod weight, 1000-seed weight, dry matter weight per plant and biological yield.

Beenish and Lal (2019) conducted a study at the Central Research Field of Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during 2016-17 and 2017-18 to explore the oil yield and quality different varieties of Indian mustard (*Brassica juncea*) influenced by organic manures and biofertilizers. The experiments consisting of two factors viz., 5 varieties and 10 fertilizer treatments. The results of the study revealed that application of 75% N through vermicompost produced significantly highest oil content and oil yield, protein content and protein yield in Rani variety.

Carter and Schipanski (2022) explored the effects of rapeseed (*Brassica napus*) genotypic diversity on N uptake from organic and inorganic N sources. Ten varieties were grown in a full factorial experiment with four treatments, including combinations of high and low N fertilizer and SOM. They concluded that integrating plant reliance on SOM-N sources into crop breeding and NUE estimates has potential to improve crop productivity and improve overall system N use efficiency.

Farahbakhsh *et al.* (2006) carried out an experiment to investigate the influence of nitrogen (150 and 300 kg ha^{-1}) and Sulphur (0, 100 and 200 kg ha^{-1}) fertilizers on yield, yield components and oil content of two cultivars of oilseed rape (*Brassica napus* L.), Hyola 308 and PF7045. Result showed that two cultivars were significantly different for oil contents. Nitrogen affected the oil content negatively and decreased it by 3.3%. Increasing the amount of sulphur fertilizer from zero to 200 kg ha^{-1} resulted in an increase in oil content.

Govahi and Saffari (2006) conducted an experiment during 2004 to study effects of potassium and sulphur fertilizers on yield, yield components and seed quality in canola (*Brassica napus* L.) CV, Hayola 401 at experimental farm in research station of agricultural college of Shahid Bahonar University of Kerman. They found that the increase of 3.89 and 6.0% in seed oil content was respectively realized with increasing the rate of 0 to 40 and 40 to 80 kg S ha^{-1}, but the increased of application S from 80 to 120 kg S ha^{-1} showed no significant increase in oil content, seed oil content was insignificantly affected by increasing the levels of K.

Masum *et al.* (2019) conducted a study at Shiberbazar, Sylhet (AEZ-20) during November 2016 to February 2017, to quantify the effect of boron (B) on yield and yield attributes of mustard (BARI Sarisha-14), and different doses and form of B application. The results from the experiment suggested that two times foliar application of 1% B at vegetative stage and pod formation stage is a good option to increase yield and yield contributing characters of BARI Sarisha-14 in AEZ 20.

Mishra and Singh (2022) undertaken a field experimental trial to explore the effect of nitrogen and zinc levels on yield and economics of mustard (*Brassica juncea* L.) during Rabi season (2021-2022) at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (Allahabad) (U.P.). The results revealed that the application of Nitrogen 100 kg ha^{-1} + Zinc 15 kg ha^{-1} recorded maximum siliqua length (5.20 cm), number of siliquae per plant (398.90), number of seeds per siliqua (24.40), test weight (3.53 g).

Mozaffari *et al.*, (2012) carried out a field experiment at Qazvin-Iran during 2009-2010 to assess the effect of different levels of nitrogen (N_0, N_{75}, N_{150} and N_{225} kg ha^{-1}) and potassium (K_0, K_{45}, K_{90} and K_{135} kg ha^{-1}) on yield and some of the agronomical characteristics in Mustard (*Brassica juncea*). The results showed that increased amount of N and K up to 225 kg N ha^{-1} and 135 kg K ha^{-1}, respectively had a positive and significant ($P<0.01$) effect on thousand seed weight (TSW), seed yield (SY) and seed oil yield (SOY). Moreover, the results indicate that the interaction effect of N and K on all of the characters being studied was significant ($P<0.01$).

Nath *et al.* (2018) conducted field experiments at the farm of Krishi Vigyan Kendra Jaunpur, Uttar Pradesh during rabi season of 2014–15 and 2015–16 in randomize block design with mustard variety NDR-8501 with six treatments. The application of sulphur had significant influence on yield attributes, grain yield, sulphur uptake and oil percent in mustard. Therefore, application of sulfur 90% WP @ 25kg ha^{-1} + sulfur 80WP @1.25kg ha^{-1} foliar sprayed at 75% DAS were recommended for improving yield, yield attributes, oil percent and sulphur uptake of Indian mustard.

Nouriyani (2015) conducted a field experiment in order to evaluate the effect of different levels of nitrogen on yield, yield components and some quality characteristics of two cultivars of rapeseed (Hyola 308 and Hyola 401), in Dezfoul, southwest of Iran during 2011-2012. The regression analysis showed that the highest grain yield could be obtained from Hyola 308 (1998 kg ha^{-1}) and Hyola 401 (2375 kg ha^{-1}) using 225 & 228 kg N ha^{-1}, respectively.

Raghuvanshi *et al.* (2018) investigated on the effect of nitrogen levels on growth and yield of mustard (*Brassica juncea* Curzen and Cross.) varieties under late sown condition. The current study showed that all growth parameter like, Plant height, Dry matter accumulation, number of branches, LAI and stover yield significantly highest recorded with 160 kg ha^{-1}nitrogen and that was at par with 120 kg N ha^{-1} and with NDR-8510 variety is superior in all growth and yield followed by Vardan and Maya.

Sherawat *et al.* (2021) conducted an investigation to find out the effect of various levels of nitrogen and sulphur on mustard variety Varuna. The experiment suggests that Varuna variety of mustard crop showed significantly superior distinguishable growth characters, yield attributes and oil contents when supplied with 120 Kg ha^{-1} of nitrogen and 30 Kg ha^{-1} of sulphur.

Sultana *et al.* (2020) conducted an experiment 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). The experiment reflected on using 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.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during December 2020 to February 2021 to examine the effect of fertilizer doses on morphological and yield performance of mustard varieties.

3.1 Experimental site and soil

The experimental site was located at 23°77′ N latitude and 90°33′ E longitude with an elevation of 8.2 meter from sea level (Appendix I). The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ - 28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are shown in Appendix II & III.

3.2 Climate

The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm, the average maximum temperature is 30.3°C and average minimum temperature is 21°C. The average mean temperature is 25.8°C. The experiment was carried out during rabi season, 2020-21. Temperature during the cropping period ranged from 16.57°C to 27.4°C. The humidity varied from 45% to 60%. the sun shine hour was reduced to 7.4-7.6 hours only and there was no significant rainfall from the beginning of the experiment to harvesting (Appendix IV).

3.3 Seeds and variety

BARI Sharisha-9, BARI Sharisha-14 and BARI Sharisha-15; three different high yielding and short duration varieties of mustard (*Brassica campestris*) developed by Bangladesh Agriculture Research Institute (BARI), Gazipur was used as experiment crop. The seeds were collected from Bangladesh Agriculture Research Institute (BARI), Gazipur.

3.4 Design and layout of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications each. Fertilizer were applied on 3 different high yielding mustard varieties (BARI Sharisha-9, BARI Sharisha-14 and BARI Sharisha-15) designated as V_1, V_2 and V_3, respectively. Fertilizer are essential plant nutrint for proper growth and sustainable crop production. The application of suitable fertilizers in appropriate doses is considered as one of the most important factors for increasing crop yield per unit area. Among primary and secondary nutrients, nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are the major ones. Coming after Nitrogen (N), Potassium (K) is the second most absorbed mineral element by the plants and in some cases calcium. Another soil nutrient, Phosphorus (P) is generally deficient in majority of our soils and need much attention for maintenance of soil fertility. Mustard is also responsive to sulphur (S) in comparison to other crops. Sulphur is essential for the growth and development of oilseed crops. Researchers suggested that maintaining these soil nutrients at proper level is essential for imparting higher yield of any oilseed crop, especially mustard. In this study, fertilizer doses were carefully chosen considering the suggested doses for normally sown mustard varieties (Farahbakhsh *et al.*, 2006; Mozaffari *et al.*, 2012). Here, the fertilizer treatments consisted of 4 levels of inclusion, 0%, 85%, 100% and 115% designated as F_0 (Control), F_1, F_2 and F_3, respectively. 0% fertilizer inclusion means no fertilizer were applied during the study (Control) and 100% fertilizer inclusion indicates previously recommended fertilizer application ratio for mustard varieties (BARC, 2018). Details fertilizer inclusion is shown in Table 1.

Table 1. Fertilizer application - four levels.

Manure and fertilizer		Cow dung	Urea	TSP	MoP	Gypsum	$ZnSO_4$	Boric acid
Plant nutrients		--	N	P	K	S	Zn	B
Fertilizer level	F_0 (Control)	10 t	0 kg	0 kg	0 kg	0 kg	5 kg	8 kg
	F_1 (85%)	10 t	204 kg	136 kg	68 kg	119 kg	5 kg	8 kg
	F_2 (100%)	10 t	240 kg	160 kg	80 kg	140 kg	5 kg	8 kg
	F_3 (115%)	10 t	276 kg	184 kg	92 kg	161 kg	5 kg	8 kg

The layout of the experiment was prepared for distributing the combination of different doses of fertilizer on three different mustard varieties. There were 12 treatment combinations. The treatment combinations were as follows:

F_0V_1	F_0V_2	F_0V_3
F_1V_1	F_1V_2	F_1V_3
F_2V_1	F_2V_2	F_2V_3
F_3V_1	F_3V_2	F_3V_3

The 12 treatment combinations of the experiment were assigned at random into 36 plots. Fertilizer treatments were randomly distributed in each block. Each block consisted of 12 plots and individual plot was 3 m × 1.5 m i.e. 4.5 m^2 in size. The row-to-row and seed to seed distance were 30 and 5 cm respectively accommodating 250 plants in each plot. The adjacent block and neighboring plots were separated by 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Appendix V.

3.5 Collection and processing of soil sample

Soil samples from the experimental field were collected before land preparation to a depth of 0 – 15 cm from the surface of the basis of composite sampling method. The collected soil was air dried, ground and passed through a 2 mm sieve and stored in a clean, dried plastic container for physical and chemical analysis.

3.6 Land preparation

The land was first ploughed with a tractor drawn disc plough on 01 December, 2020. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land operation was completed on 8 December, 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Application of fertilizers

The N, P, K, S, Zn and B fertilizer were applied through Urea, Triple super phosphate (TSP), Muriate of potash (MP), Gypsum $ZnSO_4$ and Boric acid respectively. N, P, K and S were applied in the plot as per treatment (Table 1), where rest of the nutrients were applied according to Krishi Projukti Hat Boi (BARI, 2020). One third (1/3) of whole amount of Urea, TSP, MP, Gypsum and full amount of $ZnSO_4$ and Boric acid were applied at the time of final land preparation. The remaining Urea, TSP, MP and Gypsum were top dressed in two equal installments at 25 days after sowing (DAS) and 45 DAS, respectively.

3.8 Seed sowing

Seeds were sown continuously at the rate of 7 kg ha^{-1} on 8 December, 2020 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept about 200 per plot. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 02 January, 2021. At the same time first thinning was done. The final weeding and thinning were done after 35 days of sowing, on 12 January, 2021. Care was taken to maintain constant plant population per plot.

3.10 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 02 January, 2021 at 25 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (35 DAS), on 12 January, 2021. The final irrigation was given at the stage of seed formation (50 DAS), on 27 January, 2021.

3.11 Pest management

The insect aphids (*Lipaphis erysimi*) at the time of siliqua filling were protected successfully by spraying Malathion 50 EC at the raye of 2 ml L^{-1} water. The insecticide was sprayed twice, the first on 28 December, 2020 and the last on 17 January, 2021. The crop was kept under constant observations from sowing to harvesting.

3.12 Harvesting and threshing

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

3.13 Collection of experimental data

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

3.13.1 Morphological and physiological parameters

1. Days to 1st emergence of seedling
2. Days to 50% emergence of seedling
3. Days to 100% emergence of seedling
4. Population density (m^{-2})
5. Plant height (cm)
6. Number of branches plant^{-1}
7. Days to 1st flowering
8. Days to 50% flowering
9. Days to maturity
10. Dry Matter weight plant^{-1}

3.13.2 Yield contributing parameters

11. Number of Siliqua plant^{-1}
12. Length of Siliqua (cm)
13. Number of Seeds siliqua^{-1}
14. Weight of 1000 Seeds (g)

3.13.3 Yield parameters

15. Grain yield (kg ha^{-1})
16. Stover yield (kg ha^{-1})
17. Biological yield (kg ha^{-1})
18. Harvest index (%)

3.14 Procedure of recording data

3.14.1 Days to 1st emergence of seedling

Days to 1st emergence of seedling were recorded by counting the number of days required from sowing date to start emergence of seedling of mustard plant in each plot.

3.14.2 Days to 50% emergence of seedling

Days to 50% emergence of seedling were recorded from sowing date to the date of 50% emergence of seedling of every entry.

3.14.3 Days to 100% emergence of seedling

Days to 100% emergence of seedling were recorded by counting the number of days required from sowing date to 100% emergence of seedling of mustard plant in each plot.

3.14.4 Population density

The data on population density were collected from 1 m^{-2} for each plot. The number was counted population of mustard.

3.14.5 Plant height

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

3.14.6 Number of branches plant^{-1}

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

3.14.7 Days to 1st flowering

Days to 1st flowering were recorded by counting the number of days required from sowing date to start flower initiation of mustard plant in each plot.

3.14.8 Days to 50% flowering

Days to 50% flowering were recorded from sowing date to the date of 50% flowering of every entry.

3.14.9 Days to maturity

Days to maturity were recorded by counting the number of days required from sowing date to maturity of mustard plant in each plot.

3.14.10 Dry Matter weight plant^{-1}

Total dry matter of plant at harvest was calculated by aggregating the dry matter weight of leaves, stems, roots, siliquae cover and other immature reproductive parts.

3.14.11 Number of siliquae plant^{-1}

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

3.14.12 Length of siliqua

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

3.14.13 Number of seeds siliqua^{-1}

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

3.14.14 Weight of 1000 seeds

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

3.14.15 Grain yield

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

3.14.16 Stover yield

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

3.14.17 Biological yield

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

3.14.18 Harvest index

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

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

Where, Biological Yield = Stover Yield + Grain Yield

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the IBM SPSS Statistics version 23. The collected data were statistically analyzed by using the ANOVA technique. The test of significance of all parameters was done. The Duncan's Multiple Range Test (DMRT) with Least Significant Difference value was determined with appropriate levels of significance and the means were tabulated. The mean comparison was carried out by DMRT technique.

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect fertilizer doses on growth and yield of three mustard varieties (BARI Sarisha-9, BARI Sarisha-14, BARI Sarisha-15). The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following headings:

4.1 Days to 1st emergence of seedling

There was no significant variation in the case of days to 1st emergence of seedling. The maximum time required for the 1st emergence of seedling (2.67 days) was recorded from the treatment F_0 (Control). Emergence of seedling in case of 100% fertilizer application (F_2) were the earliest in the 1st emergence of seedling, 2.44 days (Figure 1).

There was significant difference among the varieties in the days to 1st emergenceof seedlings. Delayed 1st emergence of seedling (3.25 days) was found in BARI Sarisha-9 and 1st emergence of seedling was the earliest (2.17 days) in BARI Sarisha-14, which was statistically similar to BARI Sarisha-15 (Figure 2).

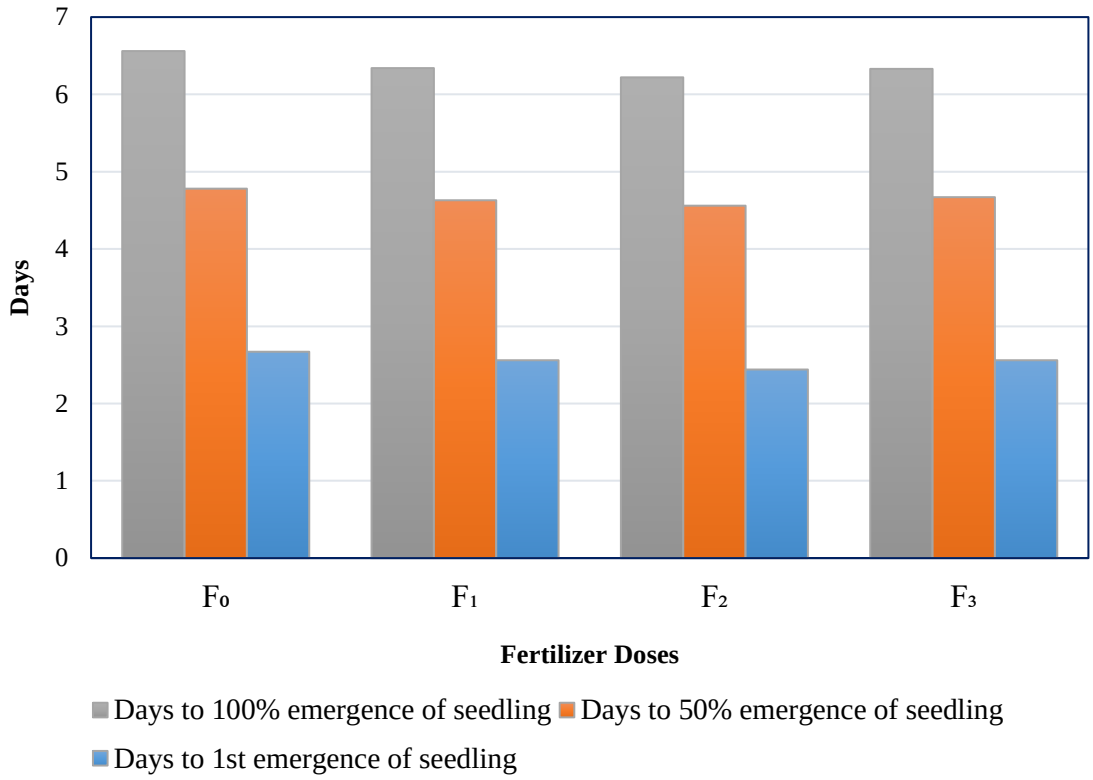
The combined effect of different fertilizer doses and different varieties on days to 1st emergence of seedling was found to be significant. Data in Table 2 Shows that, the days to 1st emergence of seedling was minimum (2 days) in F_2V_2, F_3V_2, and F_2V_3 while it was maximum (3.67 days) in F_0V_1 treatment, which was statistical similar with F_0V_3.

4.2 Days to 50% emergence of seedling

The different level of fertilizer application showed no significant variation in the days to 50% emergence of seedling. The maximum days of 50% emergence of seedling (4.78 days) was recorded from F_0 (no fertilizer) treatment. 100% fertilizer application (F_2) was the earliest in 50% emergence of seedling (4.56 days) (Figure 1).

There was significant difference among the varieties in the days to 50% emergence of seedling. Delayed 50% emergence of seedling (5.5 days) was found in BARI Sarisha-9 (V_1) and 50% emergence of seedling was earliest (4.17 days) in BARI Sarisha-14 (V_2), which was statistical similar with BARI Sarisha-15 (V_3) (Figure 2).

The combined effect of different fertilizer doses and mustard varieties on days to 50% emergence of seedling was found to be significant (Table 2). The days to 50% emergence of seedling was minimum (4.00 days) in F_2V_3 and F_3V_2, while it was maximum (5.67 days) in F_0V_1 and F_1V_1 treatment, which was statistical similar with F_0V_1, F_0V_3, F_1V_2 and F_1V_3.



Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

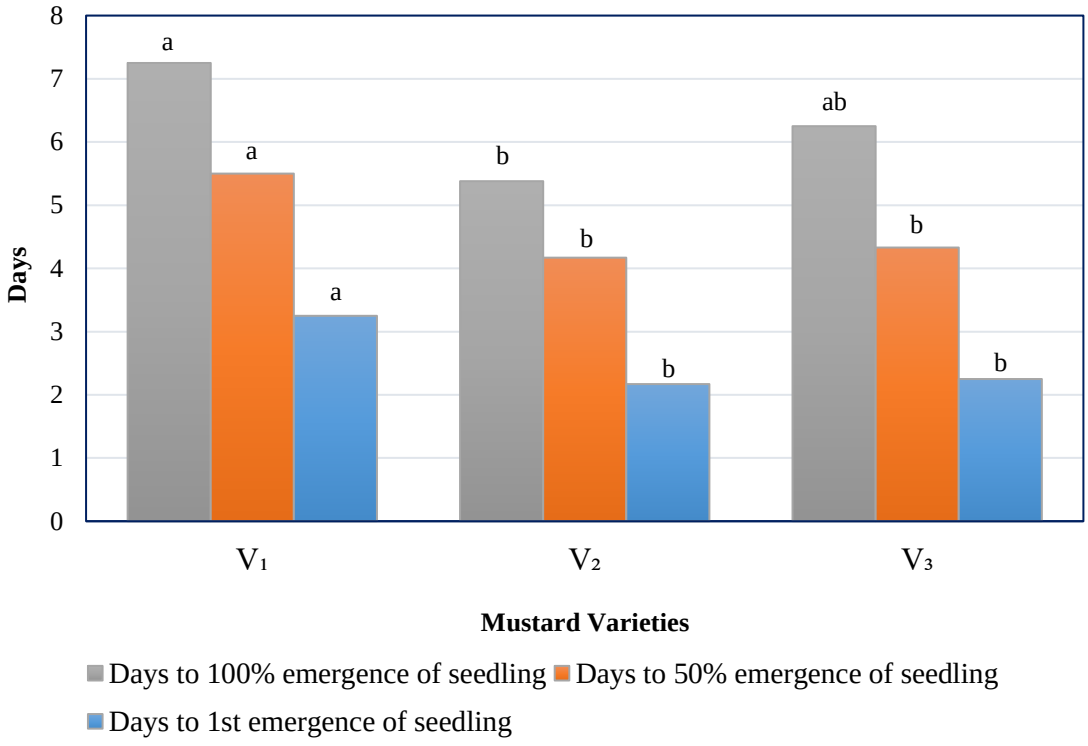
Figure 1: Effect of fertilizer doses on days to 1st emergence of seedling, 50% emergence of seedling and 100% emergence of seedling of mustard.

4.3 Days to 100% emergence of seedling

The different fertilizer doses showed no significant variation in the days to 100% emergence of seedling. The maximum days of 100% emergence of seedling (6.56 days) was recorded from F_0 (Control) treatment. 100% fertilization (F_2) were the earliest in 100% emergence of seedling (6.22 days) (Figure 1).

There was significant difference among the varieties in the days to 100% emergence of seedling. Delayed 100% emergence of seedling (7.25 days) was found in BARI Sarisha-9 (V_1) and 100% emergence of seedling was earliest (5.38 days) in BARI Sarisha-14 (V_2) (Figure 2).

The combined effect of fertilizer application and different mustard varieties on days to 100% emergence of seedling was found to be significant (Table 2). The days to 100% emergence of seedling was minimum (5.33 days) in F_3V_2 and F_3V_3, while it was maximum (7.33 days) in F_0V_1, F_0V_2, F_0V_3 and F_1V_2 treatment.



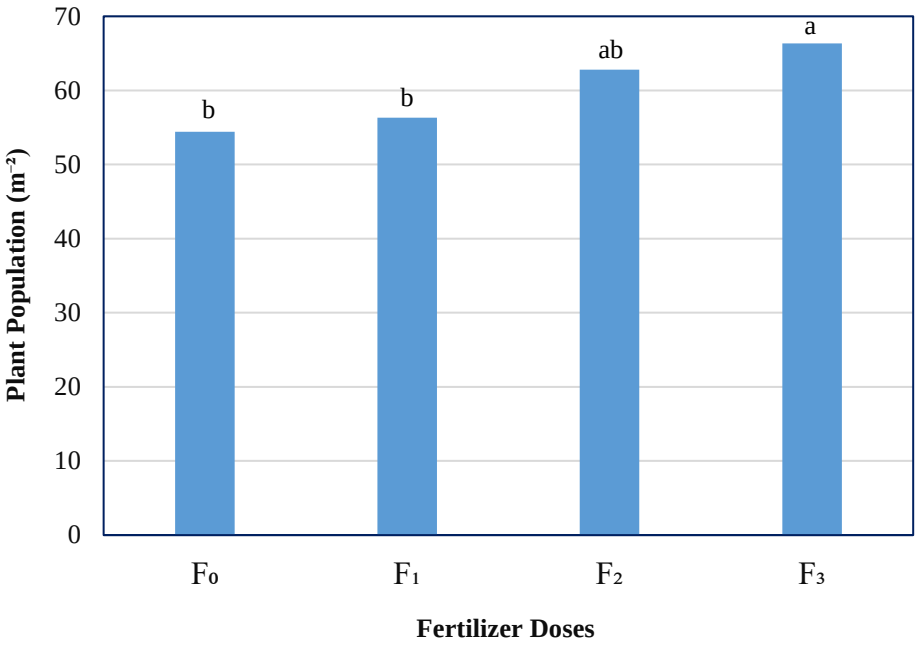
Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 2: Effect of mustard varieties on days to 1st emergence of seedling, 50% emergence of seedling and 100% emergence of seedling of mustard.

4.4 Population density

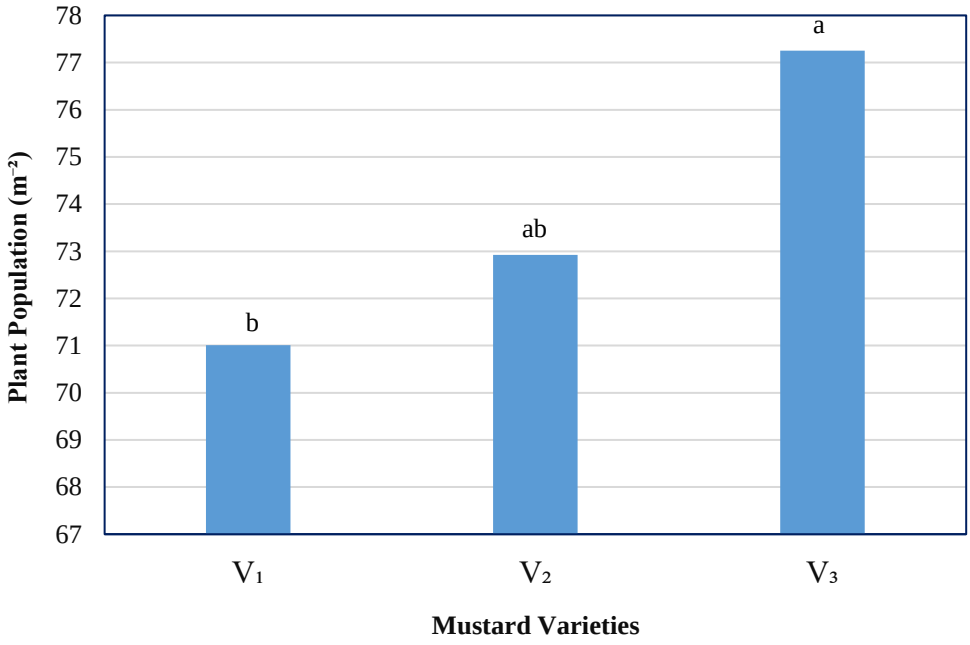
There was significant variation observed on population density per square meter due to variation in fertilizer doses (Figure 3). The highest plant population (66.33 m^{-2}) was recorded from 115% fertilizer dose and lowest plant population (54.44 m^{-2}) recorded from control treatment where no fertilizer was applied (F_0), which was statistically similar with F_1.



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

Figure 3: Effect of fertilizer doses on plant population (m^{-2}) of mustard.



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 4: Effect of mustard varieties on plant population (m^{-2}) of mustard.

Significant variation was observed on population density throughout the growing period for different variety treatments (Figure 4). The highest plant population (77.25 m^{-2}) was observed in BARI Sarisha-15 (V_3). The lowest number of plant population (71.01 m^{-2}) was observed in BARI Sarisha-9 (V_1).

The effect of fertilizer does and variety on number of plant population was statistically significant (Table 2). The maximum total number of plant population (70.00 m^{-2}) was found from F_3V_3 which is similar to F_3V_2 (69.67 m^{-2}) and minimum number of plant population (51.31 m^{-2}) from F_0V_1.

Table 2. Interaction effect of fertilizer doses and mustard varieties on days to 1st emergence of seedling, 50% emergence of seedling, 100% emergence of seedling and plant population (m^{-2}) of mustard.

Treatments	Days to 1st emergence of seedling	Days to 50% emergence of seedling	Days to 100% emergence of seedling	Plant population (m^{-2})
F_0V_1	3.67a	5.67a	7.33a	51.31d
F_0V_2	3.00ab	5.33a	7.33a	53.10cd
F_0V_3	3.33a	5.33a	7.33a	54.12bcd
F_1V_1	3.00ab	5.67a	7.00ab	52.00d
F_1V_2	2.33bc	5.33a	7.33a	53.67cd
F_1V_3	3.00ab	5.33a	7.00ab	57.67bc
F_2V_1	2.33bc	4.67ab	6.33bc	54.67bcd
F_2V_2	2.00c	4.33b	6.00c	55.33bcd
F_2V_3	2.00c	4.00b	6.33bc	60.33b
F_3V_1	2.33bc	4.33b	5.67c	59.33bc
F_3V_2	2.00c	4.00b	5.33c	69.67a
F_3V_3	2.33bc	4.33b	5.33c	70.00a
LSD (0.05)	0.75	0.85	0.88	5.59
CV (%)	7.44	12.47	8.17	11.01

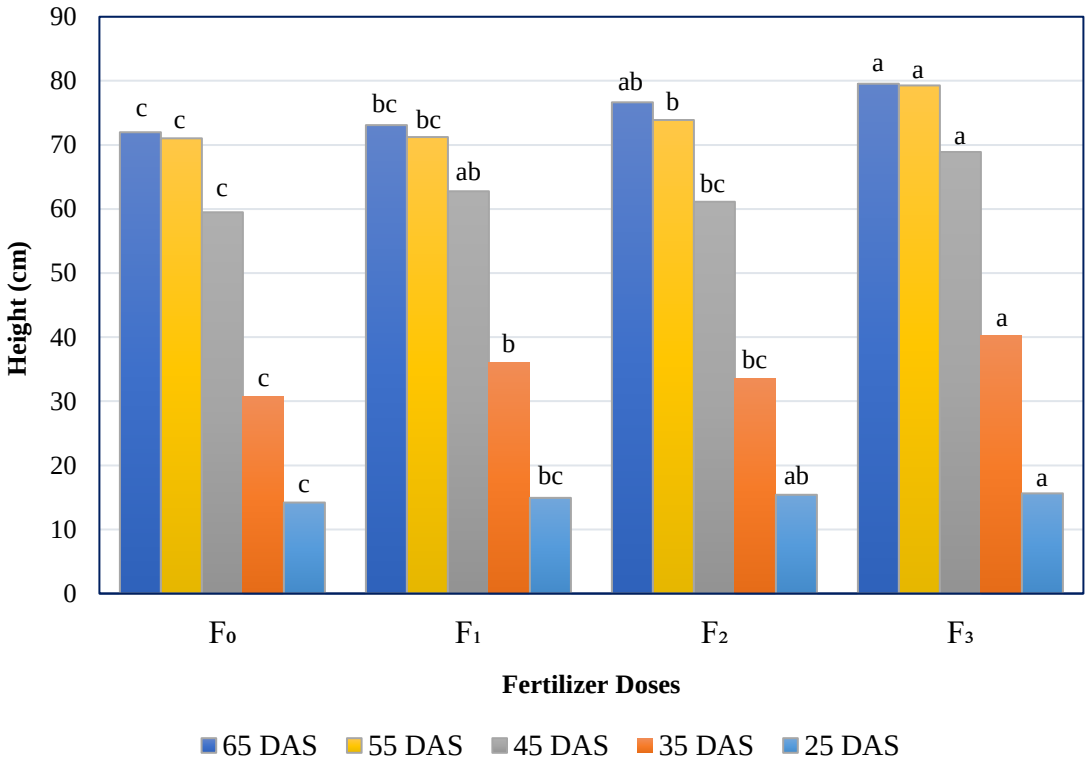
Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.
V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

4.5 Plant height

Different fertilizer application significantly influenced the height of mustard plant at 25, 35, 45, 55 and 65 days after sowing (DAS) (Figure 5). The tallest plant (15.63, 40.31, 68.90, 79.28 and 79.55 cm at 25, 35, 45, 55 and 65 DAS, respectively) was recorded with F_3 treatment. In contrast, the shortest plant (14.20, 30.68, 59.49, 71.03, 71.98 cm at 25, 35, 45, 55 and 65 DAS, respectively) was recorded from F_0. Grekhova *et al.* (2021) and Sarkees (2013) also found significant variation in plant height of rapes and mustard at different fertilizer doses.

There is significant difference among the variety in respect of plant height at 25, 35, 45, 55 and 65 days after sowing (DAS) (Figure 6). The tallest plant (18.45, 38.65, 66.03, 80.00, 83.94 cm at 25, 35, 45, 55 and 65 DAS, respectively) was produced with V_3 (BARI Sarisha-15) and shortest plant (14.68, 29.75, 59.66, 68.60 and 69.78 cm at 25, 35, 45, 55 and 65 DAS, respectively) was found in V_2 (BARI Sarisha-14). Ahmed and Kashem (2017) and Jogi *et al.* (2018) also found significant variation in plant height of different varieties of rapes and mustard.

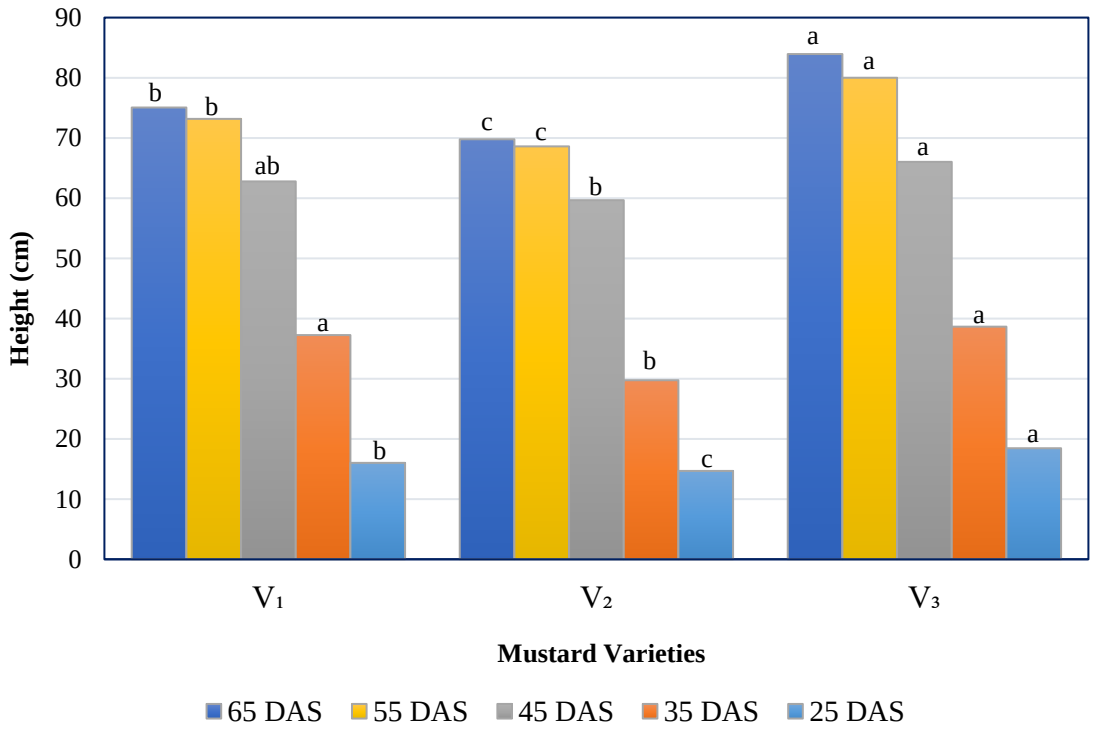


Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

Figure 5: Effect of fertilizer doses on plant height (cm) of mustard.

The combined use of different fertilizer application and variety had significant effect on plant height at 25, 35, 45, 55 and 65 days after sowing (DAS) (Table 3). The tallest plant (16.67, 46.48, 69.35, 87.39, 88.37 cm at 25, 35, 45, 55 and 65 DAS, respectively) was found in F_2V_3 treatment combination, whereas the shortest plant (13.74, 24.35, 54.91, 64.57, 67.14 cm) was observed in F_0V_2 treatment combination. Azam *et al.* (2017), Dwivedi *et al.* (2019), Farahbakhsh *et al.* (2006), Keivanrad and Zandi (2012), McKenzie *et al.* (2006), Raghuvanshi *et al.* (2018) and Verma *et al.* (2018) also reported the similar results from their experiment. They reported that different levels of nitrogen, phosphorus, potassium, sulphur significantly increased plant height of mustard but the rate was different among varieties.



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 6: Effect of mustard varieties on plant height (cm) of mustard.

Table 3. Interaction effect of fertilizer doses and mustard varieties on plant height (cm) of mustard.

Treatments	25 DAS	35 DAS	45 DAS	55 DAS	65 DAS
F_0V_1	14.64abc	32.71cd	57.79cd	66.72cde	68.03e
F_0V_2	13.74c	24.35e	54.91d	64.57e	67.14e
F_0V_3	14.51abc	32.04d	57.31cd	66.74cde	68.42e
F_1V_1	14.23bc	34.99cd	65.76ab	78.54b	80.78bcd
F_1V_2	14.64abc	41.25ab	68.73a	75.23bcd	76.72de
F_1V_3	15.02abc	38.51bc	66.19ab	77.02bc	81.36abc
F_2V_1	15.58abc	33.20cd	68.62a	75.23bcd	76.55cd
F_2V_2	14.71abc	34.41cd	60.64bcd	76.75bc	77.65cd
F_2V_3	16.67a	46.48a	69.35a	87.39a	88.37a
F_3V_1	14.88abc	29.41de	57.81cd	65.84de	67.02e
F_3V_2	14.88abc	38.28bc	60.42bcd	72.45bcde	73.64de
F_3V_3	15.89ab	34.63cd	62.71abc	77.04bc	85.25ab
LSD $_{(0.05)}$	1.84	5.26	6.66	8.40	6.76
CV (%)	10.52	8.87	10.79	6.71	5.28

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.
V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

4.6 Branches plant^{-1}

Variation in fertilizer doses significantly influenced number of branches per plant (Table 4). The maximum number of branches per plant (7.61) was produced by F_3, which was statistically identical with other treatment and F_0 treatment was produced the lowest number of branches per plant (4.50).

Number of branches per plant was significantly influenced by mustard variety (Table 5). The BARI Sarisha-14 (V_2) had the highest number of branches per plant (7.56). However, the lowest number of branches per plant (5.32) was obtained from the BARI Sarisha-15 (V_3). Biswas *et al.* (2020) have reported that BARI Sarisha-15 performed well in terms of branches plant^{-1} (6.14).

A significant variation in the number of branches per plant was found between the fertilization level and variety (Table 6). The maximum number of branches per plant (9.57) was found in 100% fertilization with BARI Sarisha-14 treatment (F_2V_2), whereas the lowest number of branches per plant (3.90) was found in control treatment (0% fertilization) and BARI Sarisha-9 treatment (F_0V_1). McKenzie *et al.* (2006) and Verma *et al.* (2018) also reported the similar results from their experiment. They reported that different levels of nitrogen significantly increased branches per plant of mustard. Nitrogen has a substantial effect on plant height, branches plant^{-1}, pods plant^{-1}, and other growth variables as well as mustard production, according to the previous research (Verma *et al.*, 2018). It increases size and number of leaves, number of branches and shoot height and fruit development.

Table 4. Effect of fertilizer doses on number of branches plant^{-1}, days to 1st flowering days to 50% flowering, days to maturity and dry weight plant^{-1} of mustard.

Treatments	Branches plant^{-1}	Days to 1st flowering	Days to 50% flowering	Days to maturity	Dry weight plant^{-1} (g)
F_0	4.50c	34.33	41.33	91.44b	9.97b
F_1	5.94b	35.89	43.33	94.33a	11.22ab
F_2	6.81ab	33.67	43.00	94.89a	14.63a
F_3	7.61a	34.22	44.00	95.11a	14.82a
LSD $_{(0.05)}$	1.26	NS	NS	0.96	4.28
CV (%)	12.34	5.44	4.29	5.24	10.22

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

NS = Non-significant.

4.7 Days required to 1st flowering

Days required to 1st flowering of mustard showed statistically non-significant variation due to different fertilizer doses (Table 4). The minimum days required to 1st flowering (33.67) was found from F_2 treatment and the maximum days to 1st flowering (35.89) was recorded from F_1 treatment.

Different mustard varieties showed no significant variation in terms of days required to flowering. The minimum days required to 1st flowering (33.33) was recorded from V_3, while the maximum days (36.25) was obtained from V_2 (Table 5). Ahmed and Kashem (2017) reported the maximum days to 1st flowering (32 days) were found in BARI Sharisha-11 variety and minimum in BARI Sarisha-15 and BARI Sarisha-14 (29 days).

Interaction effect of fertilizer application and mustard varieties showed significant differences on days required to flowering. The minimum days required to flowering (33.00) was observed from F_1V_2, F_2V_1, F_2V_2, F_2V_3 and F_3V_2 and the maximum days required to 1st flowering (39.00) was found from F_0V_1 treatment combination (Table 6).

4.8 Days to 50% flowering

The different fertilizer doses showed no significant variation in the days to 50% flowering. 115% fertilization required the maximum time to 50% flowering (44.00 days). On the other hand, no fertilizer application resulted in the earliest in flowering (41.33 days) (Table 4).

There was not significantly varied among the varieties in the days to 50% flowering (Table 5). Delayed flowering (45.25 days) was found in BARI Sarisha-14 and flowering was earliest (41.00 days) in BARI Sarisha-15. This difference in flower initiation was due to mustards varietal characters and available soil nutrient level (Miri, 2008; Nasim *et al.*, 2013; Sarkar *et al.*, 2020; Sarkees, 2013; Shaker, 2011; Sultan, 2017; Sultana *et al.*, 2020; Verma *et al.*, 2018).

The combined effect of fertilizer doses and varieties on days to 50% flowering was found to be significant. Data in Table 6 Shows that, the days to 50% flowering was minimum (40 days) in F_1V_2, F_2V_2, F_2V_3, F_3V_2 and F_3V_3, while it was maximum (46.00days) in F_0V_1, F_0V_3 and F_1V_1.

4.9 Days required to maturity

Days required to maturity of mustard showed statistically significant variation due to different fertilizer doses. The minimum days required to maturity (91.44) was observed from F_0, whereas the maximum days required to maturity (95.11) from F_3 (Table 4).

Table 5. Effect of mustard varieties on number of branches plant^{-1}, days to 1st flowering, days to 50% flowering, days to maturity and dry weight plant^{-1} of mustard.

Treatments	Branches plant^{-1}	Days to 1st flowering	Days to 50% flowering	Days to maturity	Dry weight plant^{-1} (g)
V_1	5.78b	34.00	41.00	93.00b	10.67b
V_2	7.56a	36.25	45.25	93.92ab	15.64a
V_3	5.32b	33.33	42.50	94.92a	11.69ab
LSD $_{(0.05)}$	1.29	NS	NS	1.71	4.60
CV (%)	12.34	5.44	4.29	5.24	10.22

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

NS = Non-significant.

Table 6. Interaction effect of fertilizer doses and mustard varieties on number of branches plant^{-1}, days to 1st flowering, days to 50% flowering and days to maturity of mustard.

Treatments	Branches plant^{-1}	Days to 1st flowering	Days to 50% flowering	Days to maturity
F_0V_1	3.90d	39.00a	46.00a	95.33a
F_0V_2	4.73cd	35.67ab	45.00ab	94.67a
F_0V_3	4.67cd	35.67ab	46.00a	95.33a
F_1V_1	4.93cd	35.33ab	46.00a	95.33a
F_1V_2	5.97bc	33.00b	40.00d	94.67a
F_1V_3	5.87bc	35.00b	44.00bc	94.67a
F_2V_1	6.50b	33.00b	44.00bc	95.33a
F_2V_2	9.57a	33.00b	40.00d	89.67c
F_2V_3	8.60a	33.00b	40.00d	90.33c
F_3V_1	5.97bc	34.33ab	44.00bc	94.67a
F_3V_2	7.13b	33.00b	40.00d	93.00b
F_3V_3	6.77b	34.33ab	40.00d	94.33a
LSD $_{(0.05)}$	1.30	3.18	0.91	1.12
CV (%)	12.34	5.44	4.29	5.24

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Different mustard varieties showed significant variation in terms of days required to maturity. The minimum days required to maturity (93.00) was observed from V_1, while the maximum days required maturity (94.92) was recorded from V_3 (Table 5).

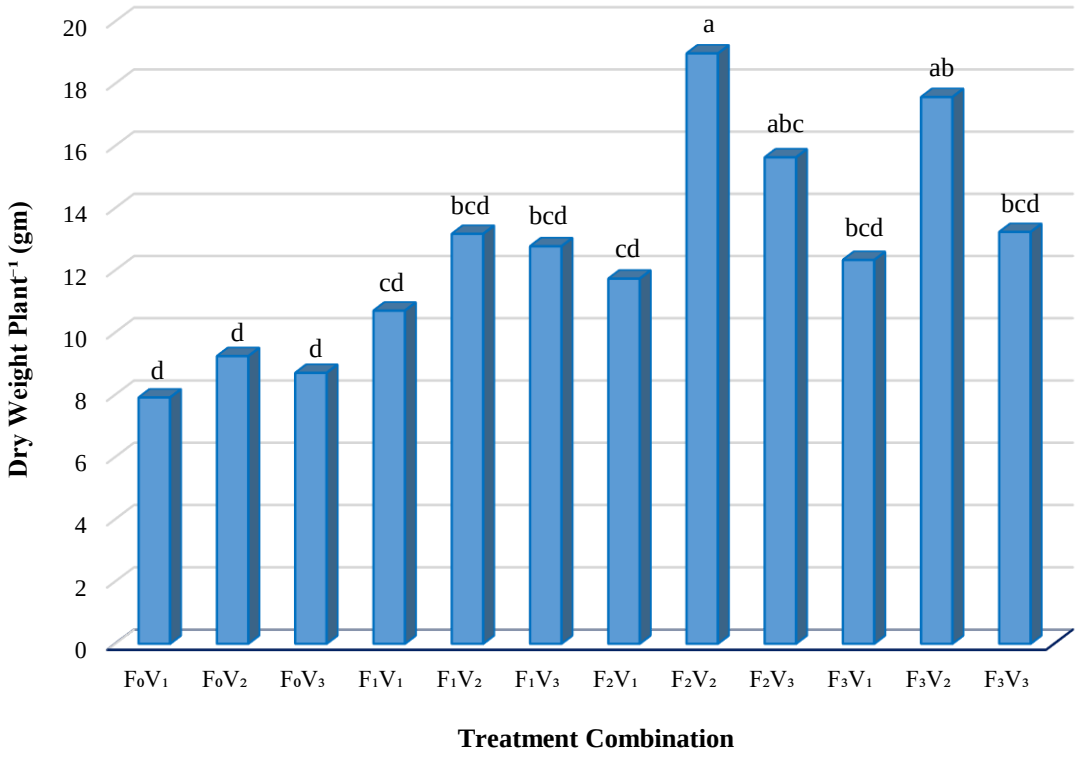
Interaction effect of fertilizer application and mustard varieties showed significant differences on days required to maturity. The minimum days required to maturity (89.67) was found from F_2V_2, whereas the maximum days (95.33) were recorded from F_0V_1, F_0V_3, F_1V_1 and F_2V_1 treatment combination (Table 6).

4.10 Dry weight plant^{-1} (g)

Dry matter (g) production was significantly affected by different fertilizer doses throughout the lifecycle (Table 4). The maximum dry matter weight (14.82 g) was gained at F_3 treatment, which was statistically similar with F_2 treatment and minimum dry matter weight (9.97 g) was recorded at F_0 treatment.

Dry matter (g) weight was significantly influenced by variety throughout the lifecycle (Table 5). The maximum dry matter weight (15.64 g) was gained at BARI Sarisha-14 and minimum dry matter weight (10.67 g) was recorded at BARI Sarisha-9.

Dry matter weight (g) was significantly influenced by the interaction of fertilization rate and variety (Figure 7). The maximum dry matter (18.97 g) accumulation was recorded at the combination of 100% fertilization application with BARI Sarisha-14 (F_2V_2) and minimum dry matter (7.91 g) accumulation was observed at the combination of zero fertilization and BARI Sarisha-9 (F_0V_1).



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 7: Interaction effect of fertilizer doses and mustard varieties on dry weight plant^{-1} (g) of mustard.

4.11 Siliquae plant^{-1}

Number of siliquae per plant is one of the most important yield contributing characters in mustard. The fertilizer doses showed significantly variation in the number of siliquae per plant (Table 7). The maximum number of siliquae per plant (69.07) was produced by F_3 treatment and F_0 produced the minimum number of siliquae per plant (28.87). Ajnar and Namdeo (2021) also stated that there was marked statistical variation in number of siliquae plant^{-1} with different level of fertilizer application.

Table 7. Effect of fertilizer doses on yield contributing characters of mustard.

Treatments	Siliqua plant^{-1} (no.)	Length of siliqua (cm)	Seed siliqua^{-1} (no.)	Weight of 1000 seed (g)
F_0	28.87c	4.05	20.08b	2.62
F_1	54.41b	4.30	20.27b	2.81
F_2	68.42a	4.26	22.94a	2.97
F_3	69.07a	4.28	20.31b	2.84
LSD $_{(0.05)}$	8.33	NS	2.39	NS
CV (%)	8.19	4.87	8.27	5.19

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.
Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.
NS = Non-significant.

There was a significant difference among the variety in the number of siliquae per plant (Table 8). The maximum number of siliquae per plant (68.59) was produced in V_2 treatment and the minimum number of siliquae per plant (47.38) was produced in V_1 treatment, which was statistically similar with V_3 treatment. Das *et al.* (2020), Helal *et al.* (2016), Jawad *et al.* (2017), Razzaque *et al.* (2007) and Shah *et al.* (2020) also stated that there was marked statistical variation in number of siliquae plant^{-1} for different mustard varieties.

A significant variation was found in the treatment combinations of fertilizer doses and variety on number of siliquae per plant (Table 9). The maximum number of siliquae per plant (94.30) was found in F_2V_3, which was statistically similar with F_2V_2, whereas the minimum number of siliquae per plant (24.27) was found in F_0V_1 treatment combination, which was statistically similar with F_1V_1. Azam *et al.* (2017), Dwivedi *et al.* (2019), McKenzie *et al.* (2006) and Raghuvanshi *et al.* (2018) also reported the similar findings from their experiment.

4.12 Length of siliqua

The fertilizer doses did not show any significant variation in the length of siliqua (Table 7). The maximum length of siliqua (4.30 cm) was produced by F_1 treatment, whereas F_0 produced the minimum length of siliqua (4.05).

There was a no significant difference among the variety in the length of siliqua (Table 8). The maximum length of siliqua (4.30) was produced in V_2 treatment. The minimum length of siliqua (4.13) was produced in V_1 treatment. Masum *et al.* (2019) reported that BARI sharisha-14 performed better in terms of siliqua length. Helal *et al.* (2016) observed significantly longer siliqua (8.07 cm) in BARI Sharisa-14 (5.53 cm) and BARI Sharisa-15 (5.59 cm) and shorter in BARI Sharisa-9 (4.83 cm).

Table 8. Effect of mustard varieties on yield contributing characters of mustard.

Treatments	Siliqua plant^{-1} (no.)	Length of siliqua (cm)	Seed siliqua^{-1} (no.)	Weight of 1000 seed (g)
V_1	47.38b	4.13	18.85b	2.58b
V_2	68.59a	4.30	23.12a	2.88ab
V_3	49.61b	4.23	20.73ab	2.98a
LSD $_{(0.05)}$	11.80	NS	2.82	0.37
CV (%)	8.19	4.87	8.27	5.19

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

NS = Non-significant.

Length of siliqua indicated a significant variation among the treatment combinations of fertilizer doses and variety (Table 9). The maximum length of siliqua (4.46) was found in F_2V_3, which was statistically similar with F_3V_3 treatment combination, whereas the minimum length of siliqua (4.01) was found in F_1V_1 treatment, which was statistically similar with F_0V_1.

4.13 Seed per siliqua^{-1}

The fertilizer doses showed variation in the number of seed per siliqua (Table 7). The maximum number of seed per siliqua (22.94) was produced by F_2, whereas F_0 produced the minimum number of seed per siliqua (20.08), which was statistically similar with F_1 and F_3.

There was a significant difference among the variety in the number of seed per siliqua (Table 8). The maximum number of seed per siliqua (23.12) was produced in V_2 treatment. The minimum number of seed per siliqua (18.82) was produced in V_1 condition. Jogi *et al.*, (2018) and Shah *et al.* (2020) also reported that there was significant difference among the varieties with respect to number of seeds siliqua^{-1}.

Table 9. Interaction effect of fertilizer doses and mustard varieties on yield contributing characters of mustard.

Treatments	Siliqua plant^{-1} (no.)	Length of siliqua (cm)	Seed siliqua^{-1} (no.)
F_0V_1	24.27d	4.02b	17.22f
F_0V_2	54.70b	4.14ab	18.07ef
F_0V_3	46.50bc	4.29ab	19.74cdef
F_1V_1	27.93d	4.01b	18.71def
F_1V_2	60.30b	4.29ab	20.59bcde
F_1V_3	57.40b	4.30ab	20.93bcde
F_2V_1	55.50b	4.08ab	21.40bcd
F_2V_2	83.63a	4.18ab	23.52ab
F_2V_3	94.30a	4.46a	22.41abc
F_3V_1	34.40c	4.11ab	20.18cdef
F_3V_2	62.03b	4.30ab	25.02a
F_3V_3	61.33b	4.45a	23.00abc
LSD $_{(0.05)}$	17.00	0.35	2.93
CV (%)	8.19	4.87	8.27

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

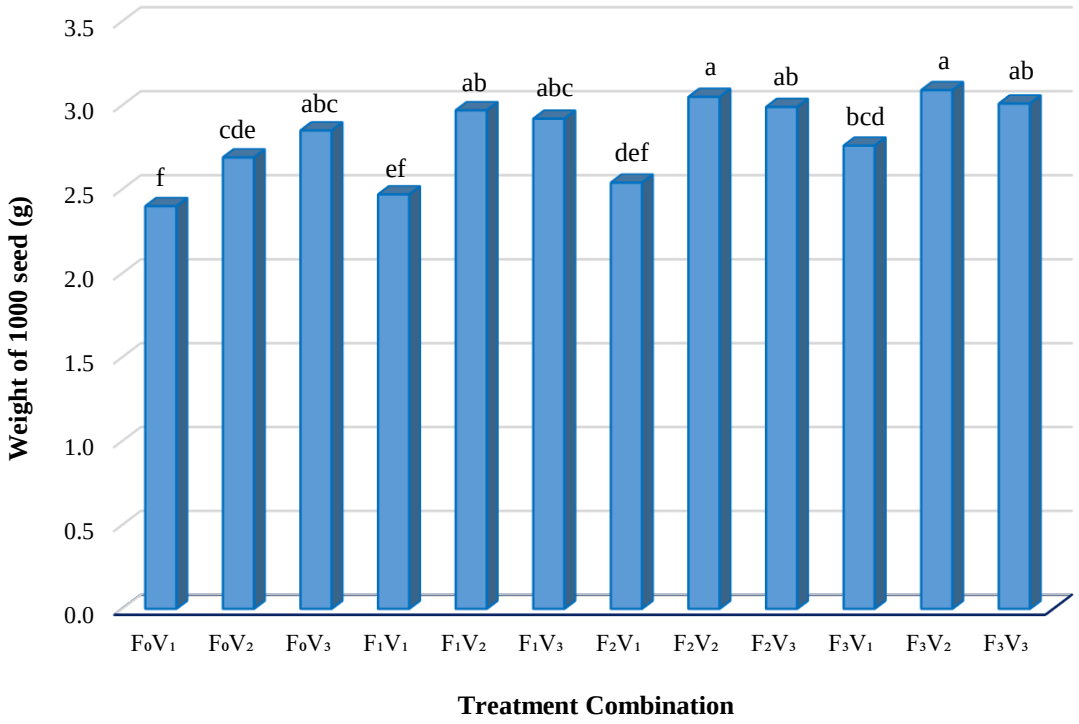
Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Number of seed per siliqua indicated a significant variation among the treatment combinations of fertilizer application and variety (Table 9). The maximum number of seed per siliqua (25.02) was found in F_3V_2 treatment combination, whereas the minimum number of seed per siliqua (17.22) was found in F_0V_1 treatment.

4.14 Thousand seed weight

Fertilizer doses did not significantly influenced on the thousand seed weight (Table 7). The maximum thousand seed weight (2.97 g) was produced in F_2 treatment and the lowest thousand seed weight in F_0 (2.62 g). The result was supported by Ahmed and Kashem (2017), Govahi and Saffari (2006), Hossain *et al.* (2012), Jawad *et al.* (2017), Nath *et al.* (2018), Sharma *et al.* (2020), Sultana *et al.* (2020), Xie *et al.* (2016) and Zhang and Zhou (2006).



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 8: Interaction effect of fertilizer doses and mustard varieties on weight of 1000 seed (g) of mustard.

The weight of thousand seed was significantly influenced with variety (Table 8). The highest thousand seed weight (2.98 g) was obtained from V_3 treatment. The lowest thousand seed weight (2.58 g) was obtained from V_1 treatment.

Thousand seed weight was significantly affected by both fertilizer application and variety (Figure 8). The highest thousand seed weight (3.09 g) was found in F_3V_2 treatment combination, which is not significantly different from F_2V_2, whereas the lowest thousand seed weight (2.40 g) was found in F_0V_1 treatment. Abdulkhaleq *et al.* (2018), Azam *et al.* (2017), Carter and Schipanski (2022), Dwivedi *et al.* (2019), Keivanrad and Zandi (2012), McKenzie *et al.* (2006), Naderi *et al.* (2017), Nath *et al.* (2018), Raghuvanshi *et al.* (2018), Sherawat *et al.* (2021), Singh *et al.* (2018) and Verma *et al.* (2018) also reported the similar results from their experiment.

4.15 Seed yield (t ha^{-1})

The seed yield of mustard per plot was converted into per hectare, and has been expressed in metric tons (Table 10). The different fertilizer doses had significant effect on the yield of seed per hectare. The maximum yield of seed (1.11 t ha^{-1}) was obtained from F_3 treatment (115% fertilizer application), whereas the minimum yield of seed (0.59 t ha^{-1}) was obtained from F_0 treatment (no fertilizer application). Ajnar and Namdeo (2021), Hashim and Mahmood (2021), Ozturk *et al.* (2006) and Sarkees (2013) also reported that different fertilizer doses had significant influence on seed yield.

The total yield of mustard varied significantly due to different variety (Table 11). The highest yield of seed (0.95 t ha^{-1}) was obtained from V_2 (BARI Sarisha-14) while V_1 gave the lowest (0.72 t ha^{-1}) yield. Ahmed and Kashem (2017), Begum *et al.* (2020) and Vincze and Pepó (2018) also showed that seed yield was dissimilar due to varietal differences.

The combined effect of fertilizer doses and variety was significant on yield of seed per hectare (Table 12). The highest yield of seed (1.16 t ha^{-1}) was obtained from F_3V_2 (115% fertilization with BARI Sarisha-14) treatment combination, which is not significantly different from F_2V_2 (1.15 t ha^{-1}) and F_2V_3 (1.08 t ha^{-1}) treatment. The lowest yield of seed per hectare (0.44 t ha^{-1}) was obtained from F_0V_1 (Zero fertilizer application and BARI Sarisha-9) treatment. These results are in conformity with that of Beenish *et al.* (2018), Beenish and Lal (2019), Mishra and Singh (2022), Mozaffari *et al.* (2012), Raghuvanshi *et al.* (2018), Shamala and Umesha (2021), Shirzad *et al.* (2020) and Verma *et al.* (2018) who have observed increased seed yield of mustard by increasing rate of fertilizer. However, seed yield of mustard was influenced remarkably by date of sowing and reduced gradually by 11.7, 21.5, 43.4 and 62.9%, respectively for each week delayed sowing after 2nd November (Biswas *et al.*, 2002; Saud *et al.*, 2016). Keivanrad and Zandi (2012) investigated agronomical and qualitative features of Indian mustard in a semi-arid region. In their experiment, the highest seed yield and oil yield (2.96 and 1.16 t ha^{-1}) were obtained for the crop utilized with 200 kg N ha^{-1} in plots with 80 plant m^{-2}.

Table 10. Effect of fertilizer doses on yield parameters of mustard.

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_0	0.59c	1.84c	2.43c	24.28b
F_1	0.82bc	2.41b	3.23b	25.39ab
F_2	0.86ab	2.17b	3.03bc	28.38a
F_3	1.11a	3.43a	4.54a	24.45b
LSD $_{(0.05)}$	0.26	0.35	0.80	1.06
CV (%)	10.79	6.84	5.05	10.37

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.

4.16 Stover yield (t ha^{-1})

The stover yield of mustard per plot was converted into per hectare, and has been expressed in metric tons (Table 10). The different dose of fertilizer application had effect on the stover yield per hectare. The maximum yield of stover (3.43 t ha^{-1}) was obtained from F_3, whereas the minimum yield of stover (1.84 t ha^{-1}) was obtained from F_0.

The total stover yield of mustard varied significantly as a result of using different variety (Table 11). The highest yield of stover (2.32 t ha^{-1}) was obtained from V_3, while V_1 gave the lowest yield (2.16 t ha^{-1}).

The combined effect of fertilizer doses and variety was significant on yield of seed per hectare (Table 12). The highest yield of stover per hectare (2.94 t ha^{-1}) was obtained from F_2V_3 treatment combination. The lowest yield of stover per hectare (1.36 t ha^{-1}) was obtained from F_0V_1 treatment.

Table 11. Effect of mustard varieties on yield parameters of mustard.

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	0.72b	2.16b	2.88b	25.00b
V_2	0.95a	2.25ab	3.20a	29.69a
V_3	0.87a	2.32a	3.19a	27.27ab
LSD $_{(0.05)}$	0.16	0.31	0.66	2.13
CV (%)	10.79	6.84	5.05	10.37

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

4.17 Biological yield (t ha^{-1})

The different dose of fertilizer application had effect on the biological yield per hectare. The maximum biological yield per hectare (4.54 t ha^{-1}) was obtained from F_3 treatment, whereas the minimum yield of seed per hectare (2.43 t ha^{-1}) was obtained from F_0 treatment (Table 10).

The biological yield of mustard varied significantly due to the variety (Table 11). The highest yield of stover (3.20 t ha^{-1}) was obtained from V_3, which was not significantly different while V_1 gave the lowest (2.88 t ha^{-1}) stover yield.

The combined effect of fertilization doses and variety was significant on biological yield per hectare (Table 12). The highest biological yield per hectare (4.02 t ha^{-1}) was obtained from F_2V_3 treatment combination. The lowest biological yield per hectare (1.80 t ha^{-1}) was obtained from F_0V_1 treatment. Addition of NKP fertilizers increase the biological yield as well as nutritional quality generally, for example fertilizers nitrogen and potassium increased oil concentration in oil seed crops (Wang *et al.*, 2008). When phosphorus was applied in conjunction with nitrogen and potash, there was significant increase in the yield of mustard (Singh *et al.*, 2018). Sulphur is also a key component of balanced nutrient application for higher yields and superior quality produce (Begum et al., 2012). Oleiferous *Brassica* crops in general have high sulphur requirement owing to higher seed and oil yield (Dwivedi *et al.*, 2019; Puy and Győri, 2003).

Table 12. Interaction effect of fertilizer doses and mustard varieties on yield parameters of mustard.

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})
F_0V_1	0.44f	1.36f	1.80f
F_0V_2	0.70de	1.94def	2.64de
F_0V_3	0.70de	1.85def	2.55de
F_1V_1	0.58ef	1.76ef	2.34ef
F_1V_2	0.95abc	2.70bcd	3.65c
F_1V_3	0.81cd	2.07def	2.88de
F_2V_1	0.76cde	2.30cde	3.06d
F_2V_2	1.15a	2.59cd	3.74bc
F_2V_3	1.08a	2.94a	4.02a
F_3V_1	0.81cd	2.05def	2.86de
F_3V_2	1.16a	2.79bc	3.95ab
F_3V_3	1.02ab	2.92ab	3.94ab
LSD $_{(0.05)}$	0.20	0.69	0.84
CV (%)	10.79	6.84	5.05

Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

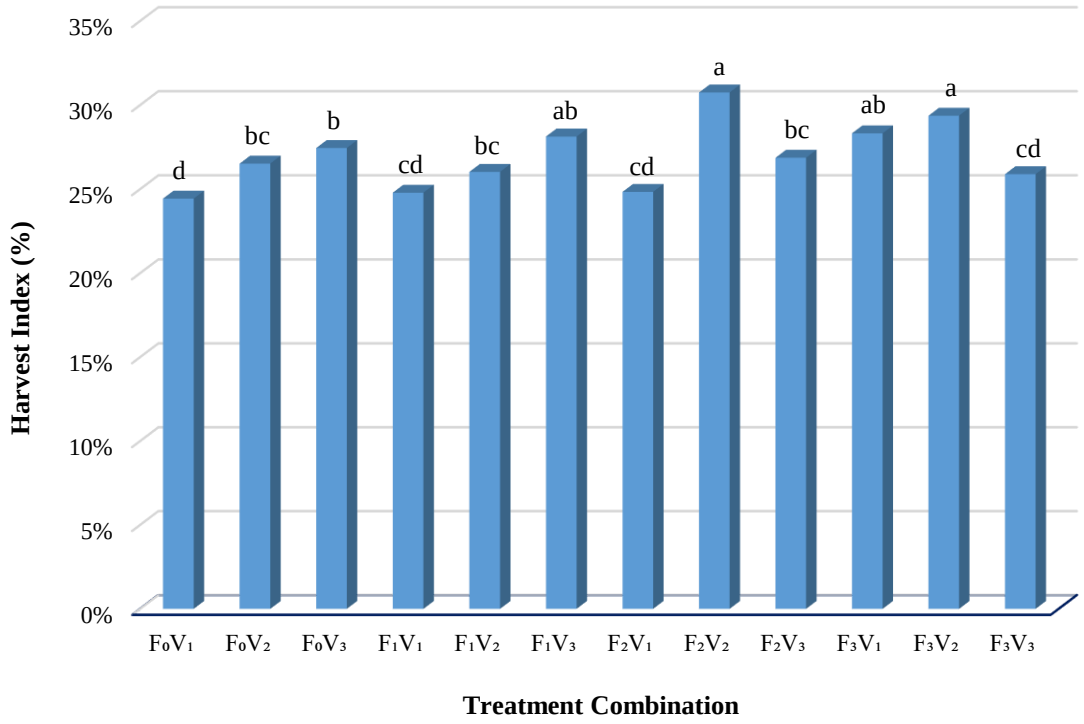
Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.
V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

4.18 Harvest index (%)

The different fertilizer doses had effect on the harvest index of mustard. The maximum harvest index (28.38%) was obtained with F_2, and the minimum harvest index (24.28%) was obtained from F_0 treatment, which is not significantly different from F_3 treatment (24.45%) (Table 10).

The harvest index varied significantly due to the application of different variety (Table 11). The highest harvest index (29.69%) was obtained from V_2 while V_1 gave the lowest (25.00%) harvest index.

The combined effect of fertilizer application and variety was significant on harvest index (Figure 9). The highest harvest index (30.75%) was obtained from F_2V_2 treatment combination, which was insignificant to F_3V_2 treatment (29.37%). The lowest harvest index (24.44%) was obtained from F_0V_1 treatment. Supported result was also observed by Masum *et al.* (2019), Saud *et al.* (2016) and Sultana *et al.* (2020).



Mean values followed by same letter(s) are statistically identical and dissimilar letter(s) differ significantly from each other by LSD at 5% level of significance.

Here, F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended dose, F_2 = recommended fertilizer dose and F_3 = 115% fertilization compared to recommended dose.
V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15.

Figure 9: Interaction effect of fertilizer doses and mustard varieties on harvest index (%) of mustard.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary of the findings

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh during rabi season, December 2020 to February 2021 to examine the effect of different fertilizer doses and varieties on the yield performance of mustard varieties. The experiment comprised of two factors; the treatment consisted of four fertilizer doses viz. F_0 = Control (no fertilization), F_1 = 85% fertilization compared to recommended fertilization, F_2 = recommended fertilizer dose (100%) and F_3 = 115% fertilization compared to recommended fertilization and three different varieties viz. V_1 = BARI Sarisha-9 V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters.

The different fertilizer doses show no significant variation in the days to 1st emergence of seedling, days to 50% emergence of seedling and days to 100% emergence of seedling. The maximum time of 1st emergence of seedling (2.67 days) and days of 100% emergence of seedling (6.56 days) were recorded from F_0 (no fertilizer) treatment. There was significant variation observed on population density per square meter due to fertilization variation. The highest plant population (66.33 m^{-2}) was recorded from 115% fertilizer application (F_3). Different fertilizer doses influenced the height of mustard plant significantly at 25, 35, 45, 55 and 65 days after sowing (DAS). The tallest plant (15.63, 40.31, 68.90, 79.28 and 79.55 cm at 25, 35, 45, 55 and 65 DAS, respectively) was recorded with F_3 treatment. Variation in fertilizer application had significant influence on number of branches per plant. The maximum number of branches per plant (7.61) was produced by F_3. Days required to 1st flowering, days to 50% flowering of mustard showed statistically not significant variation due to different fertilizer doses. The minimum days required to 1st flowering (33.67 days) was found from F_2 treatment. 115% fertilizer application (F_3) required the maximum time of 50% flowering (44.00 days). Days

required to maturity of mustard showed statistically significant variation due to different doses of fertilizer application. The minimum days required to maturity (91.44 days) was observed from F_0. Dry matter production was significantly affected by fertilizer application throughout the lifecycle. The maximum dry matter weight (14.82 g) was gained at F_3 treatment, which was not significantly different with F_2 treatment (14.63 g). The fertilizer application showed significant variation in the number of siliquae per plant. The maximum number of siliquae per plant (69.07) was produced by F_3 treatment, which is statistically similar to F_2 treatment (68.42). Fertilizer application did not show significant variation in the length of siliqua. The maximum length of siliqua (4.30 cm) was produced by F_1 treatment. The fertilizer dose showed variation in the number of seed per siliqua. The maximum number of seed per siliqua (22.94) was produced by F_2. Fertilizer doses had no significant influence on the thousand seed weight. The maximum thousand seed weight (2.97 g) was produced by F_2. Different fertilizer doses had effect on the yield of seed per hectare. The maximum yield of seed per hectare (1.11 t ha^{-1}) was obtained from F_3 (115% fertilization) treatment. The different dose of fertilization had effect on the stover yield per hectare. The maximum yield of stover per hectare (3.43 t ha^{-1}) was obtained from F_3 treatment. The different level of fertilizer application had effect on the biological yield per hectare. The maximum biological yield per hectare (4.54 t ha^{-1}) was obtained from F_3. The different fertilizer doses had effect on the harvest index of mustard. The maximum harvest index (28.38 %) was obtained with F_2.

There was significant difference among the varieties in the days to 1st emergence of seedling, the days to 50% emergence of seedling and days to 100% emergence of seedling. Delayed 1st emergence of seedling (3.25 days), 50% emergence of seedling (5.50 days) and 100% emergence of seedling (7.25 days) were found in BARI Sarisha-9 (V_1). Significant variation was observed on population density throughout the growing period for different variety treatments. The highest plant population (77.25 m^{-2}) was observed in BARI Sarisha-15 (V_3). There is significant difference among the variety in respect of plant height at 25, 35, 45, 55 and 65 days after sowing (DAS). The tallest plant (18.45, 38.65, 66.03, 80.00 and 83.94 cm at 25, 35, 45, 55 and 65 DAS, respectively) was produced with V_3 (BARI Sarisha-15). Number of branches per plant was significantly influenced by variety. The BARI Sarisha-14 (V_2) had the highest number of branches per plant (7.56). Different mustard varieties showed no significant variation in terms of days

required to flowering. The minimum days required to 1st flowering (33.33 days) was recorded from V_3. There was no significant variation among the varieties in the days to 50% flowering. Delayed flowering (45.25 days) was found in BARI Sarisha-14 (V_2). Different mustard varieties showed significant variation in terms of days required to maturity. The minimum days required to maturity (93.00) was observed from V_1. Dry matter (g) production was significantly influenced by variety throughout the lifecycle. The maximum weight (15.64 g) was gained at BARI Sarisha-14 (V_2). There was a significant difference among the variety in the number of siliquae per plant. The maximum number of siliqua per plant (68.59) was produced in V_2 treatment. There was no significant difference among the variety in the length of siliqua. The maximum length of siliqua (4.30 cm) was produced in V_2 treatment. There was a significant difference among the variety in the number of seed per siliqua. The maximum number of seed per siliqua (23.12) was produced in V_2 treatment. The weight of thousand seed was significantly influenced by variety. The highest thousand seed weight (2.98 g) was obtained from V_3 treatment. The total yield of mustard varied significantly due to the use of different variety. The highest yield of seed (0.95 t ha^{-1}) was obtained from V_2 (BARI Sarisha-14). The total stover yield of mustard varied significantly due to the use of different variety. The highest yield of stover (2.32 t ha^{-1}) was obtained from V_3. The biological yield of mustard varied significantly due to the variety. The highest biological yield (3.20 t ha^{-1}) was obtained from V_2, which was statistically similar to V_3 (3.19 t ha^{-1}). The harvest index varied significantly due to the application of different variety. The highest harvest index (29.69%) was obtained from V_2.

The combined effect of different fertilizer doses and varieties on all parameter was found to be significant. The days to 1st emergence of seedling was minimum (2 days) in F_2V_2, F_2V_3 and F_3V_2. The days to 50% emergence of seedling was significantly minimum 4 days in F_2V_3, F_3V_2 and 4.33 days in F_2V_2, F_3V_1, F_3V_3. The days to 100% emergence of seedling was significantly minimum 5.33 days (F_3V_2, F_3V_3), 5.67 days (F_3V_1) and 6 days (F_2V_2). Significantly maximum total number of plant population 69.67 and 70 m^{-2} was found from F_3V_2 and F_3V_3, respectively. The tallest plant (16.67, 46.48, 69.35, 87.39, 88.37 cm at 25, 35, 45, 55 and 65 DAS, respectively) was found in F_2V_3 treatment combination. The maximum number of branches per plant (9.57) was found in combined use of 100% fertilization with BARI Sarisha-14 (F_2V_2), which was not significantly

different from F_2V_3 (8.60). The minimum days required to flowering (33.00) was observed from F_1V_2, F_2V_1, F_2V_2, F_2V_3 and F_3V_2. The days to 50% flowering was minimum (40 days) in F_1V_2, F_2V_2, F_2V_3, F_3V_2 and F_3V_3. Significantly minimum 89.67 and 90.33 days required to maturity was found from F_2V_2 and F_2V_3, respectively. The maximum dry matter (18.97 g) accumulation was recorded at the combination of 100% fertilization with BARI Sarisha-14 (F_2V_2). Significantly higher number of siliquae per plant was found in F_2V_2 (83.63) and F_2V_3 (94.30). The maximum length of siliqua was found in F_2V_3 (4.46) and F_3V_3 (4.45). The maximum number of seed per siliqua (25.02) was found in F_3V_2 treatment combination. The highest thousand seed weight was found in F_2V_2 (3.05 g) and F_3V_2 (3.09 g). The higher yield of seed was obtained from F_2V_2 (1.15 t ha^{-1}), F_2V_3 (1.08 t ha^{-1}) and F_3V_2 (1.16 t ha^{-1}) treatment combination. The highest yield of stover (2.94 t ha^{-1}) was obtained from F_2V_3 treatment combination. The highest biological yield (4.02 t ha^{-1}) was obtained from F_2V_3 treatment combination. The highest harvest index was obtained from F_2V_2 (30.75%) and F_3V_2 (29.37%) treatment combination.

5.2 Conclusions

- Different doses of fertilizer had a great effect on morphological and yield parameter of mustard varieties.
- Plant population, plant height, branches $plant^{-1}$, flowering time, maturation period, dry weight $plant^{-1}$, siliqua $plant^{-1}$, weight of 1000 seed, seed yield, biological yield and harvest index were affected by the application of different fertilizer dose. However, the effect of fertilizer on various mustard varieties differed significantly.
- Both the variety BARI Sarisha-14 and BARI Sarisha-15 provided better yield than the other variety and F_2 (240 kg ha^{-1} Urea, 160 kg ha^{-1} TSP, 80 kg ha^{-1} MoP and 140 kg ha^{-1} Gypsum) and F_3 (276 kg ha^{-1} Urea, 184 kg ha^{-1} TSP, 92 kg ha^{-1} MoP and 161 kg ha^{-1} Gypsum) fertilizer dose provided better yield for most of the mustard varieties.

CHAPTER VI

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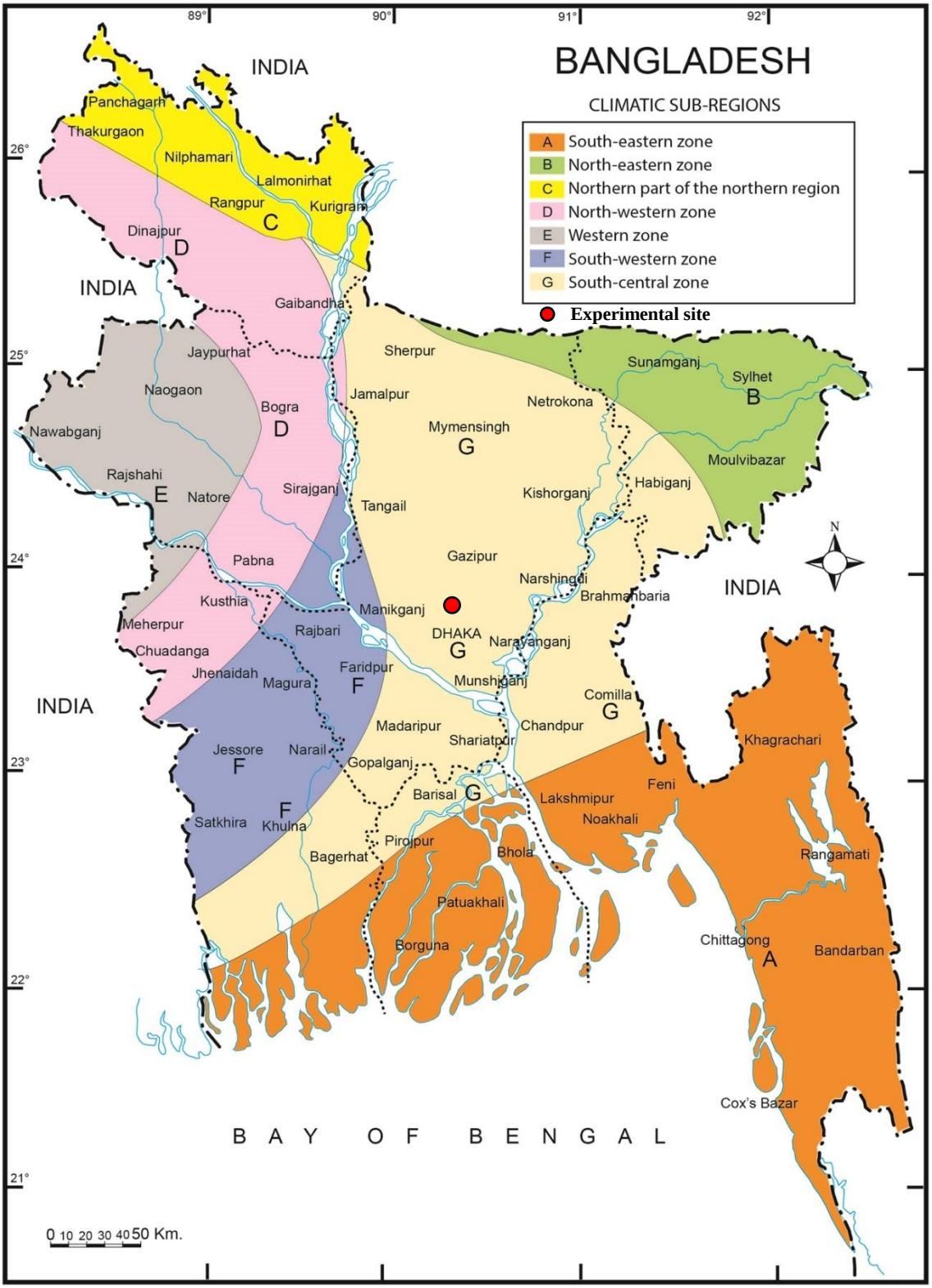
APPENDICES

Appendix I. Location of the study area.



Appendix II. Morphological Characteristics of experimental field.

Morphological Features	Characteristics
Location	Sher-e Bangla Agril. University Farm, Dhaka
AEZ No. and name	AEZ-28, Modhupur Tract
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Appendix III. Physical and chemical properties of the experimental soil.

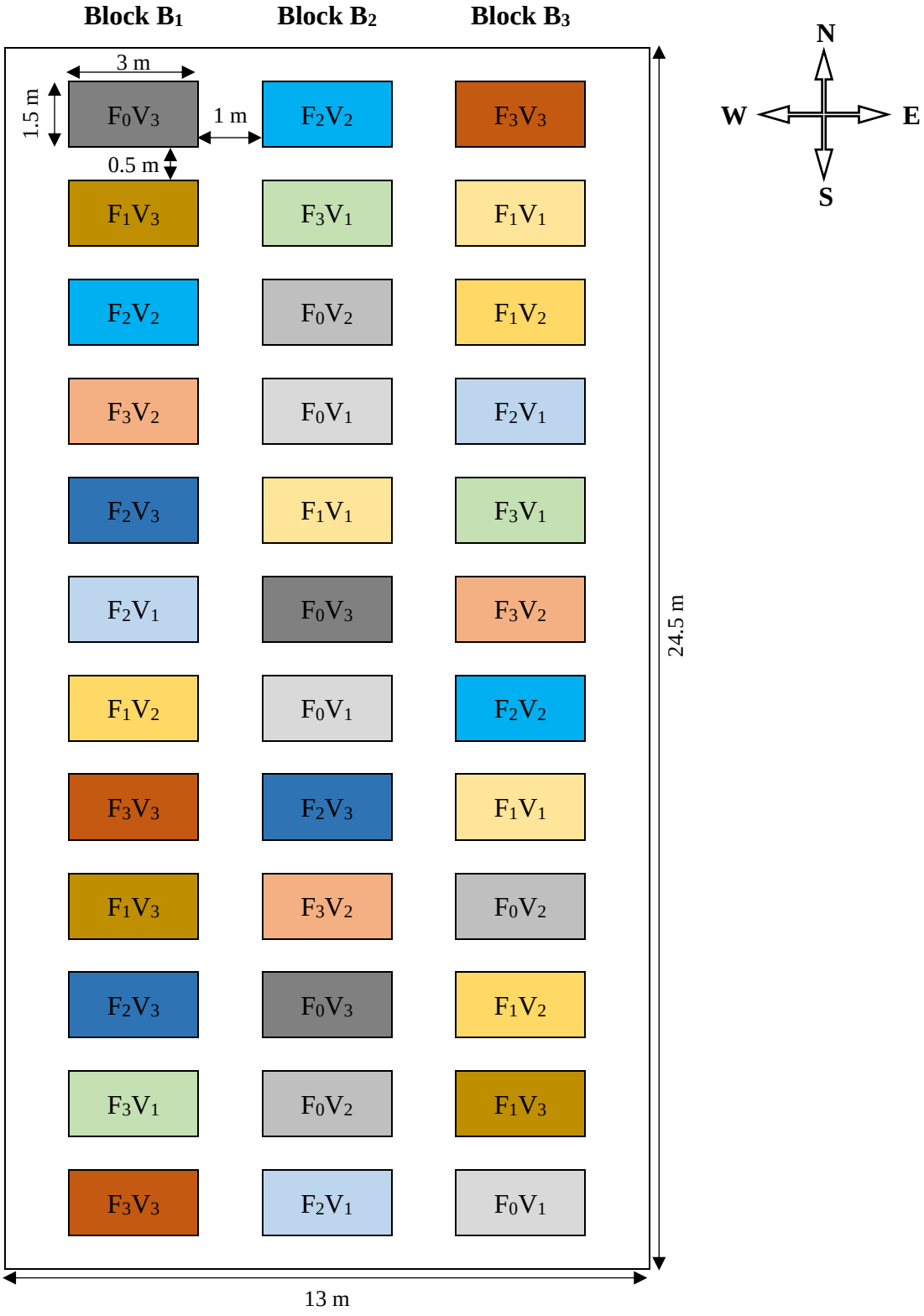
Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	29.04
% Silt	41.80
% Clay	29.16
2. Soil texture	Clay loam
B. Chemical properties	
1. Soil pH	5.8
2. Organic carbon (%)	0.78
3. Organic matter (%)	1.35
4. Total N (%)	0.08
5. C:N ratio	9.75:1
6. Available P (ppm)	35
7. Exchangeable K (mg/100g soil)	0.18
8. Available S (ppm)	40

Appendix IV. Monthly records of average air temperature, relative humidity, total rainfall and sun shine hours of the experimental site during the period from December 2020 to February 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Total rainfall (mm)	Sun shine (hour)
		Max.	Min.	Mean			
2020	December	26.4	17.0	21.70	60	9	7.4
2021	January	26.0	15.3	20.65	53	10	7.6
	February	29.8	17.4	23.60	45	25	7.5

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

Appendix V. Layout of the experimental plot.



Appendix VI. Analysis of variance of the data on days to 1st emergence of seedling, 50% emergence of seedling, 100% emergence of seedling and plant population per square meter of mustard as influenced by fertilizer doses and varieties.

Source	Degrees of Freedom	Means square			
		Days to emergence of seedling	Days to 50% emergence of seedling	Days to 100% emergence of seedling	Plant population per square meter
Replication	2	0.194	0.583	0.028	42.361
Factor A	3	0.028*	0.074*	0.176*	7845.8*
Factor B	2	3.694*	6.333*	8.444*	123.03*
AB	6	0.139*	0.074*	0.148*	30.176*
Error	22	0.194	0.25	0.27	111.91

*Significant at 5% level of probability.

Appendix VII: Analysis of variance of the data on plant height of mustard as influenced by fertilizer doses and varieties.

Source	Degrees of Freedom	Means square				
		Plant height (cm)				
		25 DAS	35 DAS	45 DAS	55 DAS	65 DAS
Replication	2	2.643	2.618	11.731	112.78	32.872
Factor A	3	2.245*	146.15*	168.86*	131.36*	100.36*
Factor B	2	1.022*	260.65*	37.229*	393.99*	653.35*
AB	6	1.782*	18.237*	45.131*	24.114*	23.477*
Error	22	2.498	9.644	45.468	24.603	15.952

*Significant at 5% level of probability.

Appendix VIII: Analysis of variance of the data on number of branch plant^{-1}, dry weight, days to first flowering, 50% flowering and maturity of mustard as influenced by fertilizer doses and varieties.

Source	Degrees of Freedom	Means square				
		Number of branch plant^{-1}	Dry weight (g)	Days to first flowering	Days to 50% flowering	Days to maturity
Replication	2	2.303	11.201	4.861	1.75	0.861
Factor A	3	15.957*	53.551*	8.176*	11.583*	25.963*
Factor B	2	16.831*	82.607*	28.028*	55.75*	11.028*
AB	6	1.406*	9.717*	4.176*	15.083*	4.435*
Error	22	0.589	8.11	3.528	3.386	4.437

*Significant at 5% level of probability.

Appendix IX: Analysis of variance of the data on yield contributing characters of mustard as influenced by fertilizer doses and varieties.

Source	Degrees of Freedom	Means square			
		Siliquae plant^{-1}	Length of siliqua	Seed siliqua^{-1}	1000 seed weight
Replication	2	565.44	0.021	5.577	0.014
Factor A	3	3183.5*	0.12*	16.784*	0.194*
Factor B	2	1631*	0.083*	54.829*	0.502*
AB	6	195.28*	0.04*	2.846*	0.046*
Error	22	100.77	0.042	2.991	0.021

*Significant at 5% level of probability.

Appendix X: Analysis of variance of the data on yield and yield contributing character of mustard as influenced by fertilizer doses and varieties.

Source	Degrees of Freedom	Means square			
		Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.125	0.903	1.625	14.04
Factor A	3	0.409*	4.706*	7.804*	25.294*
Factor B	2	0.17*	1.897*	3.004*	22.128*
AB	6	0.028*	0.193*	0.195*	23.127*
Error	22	0.014	0.168	0.244	7.366

*Significant at 5% level of probability.