EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF MUSTARD (*Brassica napus*)

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CERTIFICATE

This is to certify that thesis entitled, “**EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF MUSTARD (*Brassica napus*)”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the result of a piece of Bonafede research work carried out by **MST. KULSUM ARA KHATUN, REGISTRATION NO. 19-10211** 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 availed of during the course of this investigation has duly been acknowledged.

..………...…………………

Dated: …………………… **(Prof. Mst. Afrose Jahan)**

Place: Dhaka, Bangladesh **Supervisor**

DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was undertaken at the research field of Sher-e-Bangla Agricultural University, during rabi season (October to March) of 2020-21 to study the effect of nitrogen and phosphorus on growth and yield of mustard (BARI Sarisha-15). In this experiment, the treatment consisted of three different N levels viz. N_0 = 0 kg ha^{-1}, N_1 = 100 kg ha^{-1} and N_2 = 120 kg ha^{-1} and three different level of P viz. P_0 = 0 kg ha^{-1}, P_1 = 25 kg ha^{-1} and P_2 =35 kg ha^{-1}. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There were 9 treatment combinations formulated with 3 levels of nitrogen and phosphorus. The seeds were sown at the rate of 8 kg ha^{-1}. The highest plant height, number of leaves per plant, number of branches per plant, length of siliquae, number of siliquae per plant, number of seed per siliquae, thousand seed weight and yield of seed per hectare (1.57 t) was obtained from 120 kg N ha^{-1} . Again the highest plant height, number of siliquae per plant, thousand seed weight, seed yield (1.54 t) was recorded along with 35 kg P ha^{-1}. The interaction between different levels of N and P was found statistically significant for almost all morphological parameters and yield contributing characters including seed yield. In most of the casas of morphological parameters, yield contributing characters and seed yield of mustard were observed the highest value with treatment T_6 (the combined dose of 100 kg ha^{-1} N along with 35 Kg ha^{-1} P) whereas the lowest values were obtained from treatment T_1 (control condition, 0 kg/ha N and 0 kg ha^{-1} P). The maximum yield of seed per hectare (1.59 t) was also obtained from T_6 (100 kg ha^{-1} N with 35 Kg ha^{-1} P treatment combination). The highest stover yield and biological yield was recorded from T_6 (100 kg ha^{-1} N with 35 kg ha^{-1} P). The second highest crop performance was recorded from T_9 (combination of 120 kg ha^{-1} N with 35 Kg ha^{-1} P) which was statistically similar with T_6. But from the economic point of view treatment package, T_6 appeared to be the suitable for the cultivation of mustard

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
N	=	Nitrogen
B	=	Boron
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Murate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	Gram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Mustard belongs to the family Cruciferae or Brassicaceae, is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Brassicaceae family includes many economic species, especially edible ones, those cultivated for industrial oil, spices, forage plants, and vegetable species. The most important of these species are rapeseed and mustard.

The Brassica has three species that produce edible oil, *B. napus, B. campestris and B. juncea.* Of these, *B. napus* and *B. campestral* have the greatest importance in the world's oilseed trade. In this subcontinent, *B. juncea* is also an important oilseed crop. Until recently, mustard varieties such as Tori-7, Sampad (both are *B. campestris)* and Doulat (*B. juncea*) were mainly grown in this country. Recently, MM-2-16-98. MM-34-7, MM-38-6-98, MM-49-3-98, Binasarisha-4 are high yielding mutants/Varieties have been developed by the scientists of Bangladesh Institute of Nuclear Agriculture (BINA). It, have a significant role in agriculture since almost each part of the plant is consumed either by human beings or animals depending upon the crop and its growth stage. Mustard is an important oilseed crop of the world and contributes more than 80% of the total rapeseed-mustard production of the country. The oil content of mustard seed remain in between 30 to 45.7%.

It has a remarkable demand for edible oil in Bangladesh. It occupies first position of the list in respect of area and production among the oilseed crops grown in this country. In the year of 2019-20, it covered 2.94 hectare (ha) land and the production was 3.12 lakhs metric ton (Mt), whereas the total oilseed production was 4.07 lakhs Mt and total area covered by oilseed crops was 5.89 lakhs ha. In the year of 2019-20, it covered 5.95 lakhs ha land and the production was 5.79 lakhs Mt. (BBS, 2020).

Rapeseed and mustard are popularly called 'Mustard' which is a leading oilseed crop, covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh. It is a cold loving crop which is grown during Rabi season. Oilseed crops occupy an important place in agricultural economy as well as in human life. They are not only rich sources of energy and carriers of fat soluble vitamins A, D, E and K but they form the ingredients of foods and flavors; cosmetics and condiments; soap and detergents; lubricants and laxatives and also known for their medical and therapeutic use. Rapeseed mustard is the third most important edible rainfall. Mustard oil is mainly used for cooking, frying and in pickles. Oil is also used in preparing vegetable ghee, hair oil, medicines, soaps, lubricating oil and in tanning industries. The oil cake left after extraction is utilized as cattle feed and manure. Its oil cake contains 5.2, 1.8 and 1.2 per cent N, P and K, respectively. The green tender plant is used for preparing vegetable commonly called "Sarsonkasaag". The whole seed is used in preparing pickle and flavoring vegetable and curries.

Mustard seeds contain 40-45% oil and 20-25% protein (Mondal and Wahhab, 2001). Using local ghani on an average 33% oil may be extracted. Oil cake is a nutritious food item for cattle and fish. Oil cake is also used as a good organic fertilizer. Dry mustard plants may be used as fuel.

Rapeseed and mustard are popularly called 'Mustard' which is a leading oilseed crop, covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh. It is a cold loving crop which is grown during Rabi season.

Mustard (sarisha) herbs that give oil from its seeds, such as *Brassica napus* (rape), and *Brassica nigra* (black mustard), of the family Cruciferae. Only a few decades ago, mustard oil was the exclusive cooking oil in Bangladesh. The oil, still in many places, is squeezed from the seeds by using traditional grinding mills, called 'Ghanee', which is pulled by a bull through long hours of the day and even throughout the night; the tradesman in the business is called kolu. At present about 0.24 million hectares of land are put to mustard cultivation in Bangladesh with yield of mustard oil in the order of 0.19 million m tons per year. This quantity meets only a fraction of the country's cooking oil needs. Therefore, large quantity of soybean and sunflower oil is to be imported. Imported soybean oil is cheaper than local mustard oil, which has been further reducing mustard acreage in the country. Although mustard is grown in almost all the districts, Chittagong, Sylhet, Dhaka, Tangail, Jessore, Bogura, Sirajganj, and Pabna have comparatively higher acreage of land for cultivation of this Rabi crop.

In Bangladesh, 2.5 lakh to 3 lakh tons of mustard seeds are imported every year, and about 1 lakh tons of oilseed is produced in the country. Currently, the annual demand for mustard oil stands at 1.5 lakh tons. Bangladesh is deficit in edible oil, which costs valuable foreign currency for importing seeds and oil. Annually country is producing about 2.80 Lac m tons of edible oil as against the requirement of 9.80 Lac m tons thus import oil is regular phenomenon of this country (BBS, 2010). Every year Bangladesh imports 7 lac m tons of edible oil to meet up the annul requirement of the country, which costs Tk. 64430 million (BBS, 2007). Both the acreage and production of the crop have been decreasing since 1990 mainly due to ingression of cereal crops like-rice, maize, wheat etc. Delayed harvest of transplanted aman rice and wetness of soil are another reason which hinders mustard cultivation in rabi season (BARI, 2008). Chemical fertilizers have contributed significantly towards the pollution of water, air and soil. So the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones which are eco-friendly and cost effective.

The global production of rapeseed-mustard and its oil is around 38-42 and 12-14 m t. The major constraint attributing to low production of mustard are scare and untimely water supply, poor fertility status of soil and weed management. General practices of growing it crop under fields are kept fallow during rainy season to conserve moisture and farmers generally give one or two irrigations depending on the availability of water even though the crop grown on conserved moisture.

Scientific schedule based on IW/CPE ratio is difficult for farmer to undertaken. Yadav et al., (2010) observed that when water supply at the most critical growth stages (at flower initiation stage and siliquae development stage) achieved the maximum growth and yield attributes. Thus, scheduling water supply at the most critical growth stage would boost plant production efficiency on one-hand and water economy on the other hand. If crop is generally grown on marginal lands with poor fertility status and therefore it suffers from nutrient stress. Among three primary nutrients (N, P and K) rapeseed mustard a cruciferous crop, responds remarkably well to nitrogen fertilization mainly due to its exhaustive nature and deep rooting system.

Presently, most of the farmers are using exhaustive high yielding varieties of mustard. Mustard is varied heavy withdrawal of nutrient from the soil and fertilizer consumption remained much below as compared to removal. Application of nitrogen enhances growth and development of crop and results in higher seed yield. Despite the sufficient availability of irrigation water and fertilizer nutrients, higher yields are realized only when the selection of suitable cultivars under the particular agro climatic conditions are made.

Irrigation and fertility levels influence to a great extent of growth, yield attributes and yield (Bharati et al., 2003). Irrigation requirement of mustard varies with crop conditions, moisture storage in the soil profile and prevailing weather condition of the area. Nutrient management is most important parameter effecting the growth and productivity of mustard. Keeping in view the above facts the experiment was conducted on “growth and productivity of hybrid mustard as influenced by irrigation and nitrogen management”.

Fertilizer is the depending source of nutrient that high yielding varieties of rapeseed are very responsive to fertilizers especially nitrogen (Gupta et al., 1972; Ali and Rahman, 1986; Sharawat et al., 2002 and Patel et al., 2004). Nitrogen (N) is the most important nutrient, and being a constituent of protoplasm and protein, it is involved in several metabolic processes that strongly influence growth, productivity and quality of crops (Kumar et al., 2000). The N fertilizer application accounts for significant crop production cost. Rapeseed-mustard group of crops have relatively high demand for N than many other crops owing to larger N content in seeds and plant tissues (Malagoli et al., 2005). Yield increases in 2 Indian mustard at various locations in India have been reported with application of N as high as 150 kg/ha or more (Singh et al., 2008). Brassicas are known to remove higher amount of N until flowering with relatively lower amount taken up during reproductive growth phase (Bhari et al., 2000).

Poor translocation of N from vegetative parts to seed during reproductive growth results in low nitrogen use efficiency. Since N fertilizers are costly, poor NUE is of great concern and therefore, attempts are needed to improve the contribution of applied N to production of grain and this approach will reduce the environmental and production costs in agriculture. Therefore, they are mostly grown under rain fed condition at residual soil moisture on marginal and sub marginal land. However, crop under such condition result in poor yield. Several agronomical manipulations are needed to harness the maximum yield potential depending on the climatic and resource management.

Nitrogen (N) and phosphorus (P) are the most important nutrients for crop production. The N contributes to the structural component, generic, and metabolic compounds in a plant cell. N is mainly an essential part of chlorophyll, the compound in the plants that is responsible for photosynthesis process. The plant can get its available nitrogen from the soil by mineralizing organic materials, fixed-N by bacteria, and nitrogen can be released from plant as residue decay. Soil minerals do not release an enough amount of nitrogen to support plant; therefore, fertilizing is necessary for high production. Phosphorous contributes in the complex of the nucleic acid structure of plants. The nucleic acid is essential in protein synthesis regulation; therefore, P is important in cell division and development of new plant tissue. P is one of the 17 essential nutrients for plant growth and related to complex energy transformations in the plant. In the past, growth in production and productivity of crops relied heavily on high-dose application of N and P fertilizers. However, continues application of those chemical fertilizers over time may result in diminishing returns regarding no improvement in crop productivity. Applying high doses of chemical fertilizers is a major factor in the climate change in terms of nitrous oxide gas as one of the greenhouse gas and eutrophication that happens because of P pollution in water streams. This chapter speaks about N and P use efficiency and how they are necessary for plant and environment.

OBJECTIVES

The main objectives of this experiment as follows

1. To study the effect of nitrogen and phosphorus on the growth and yield of mustard.

2. To study the interaction effect of nitrogen and phosphorus on the growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

Rapeseed-mustard is one of the principle oil crops in Bangladesh. The proper fertilizer management accelerates its growth and influences its yield as well as oil content. The literatures cited here are pertaining to the effect of nitrogen on the yield and yield attributes of the crops belonging to the group rapeseed and mustard. Also, some research works relating to the effect of different form of nitrogen on growth and yield component of various crops specially mustard are reviewed in this chapter.

2.1. Effect of N on the growth and yield contributing characters

Nikhil *et al.* (2018) reported that the 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. Highest mustard seed yield recorded with 120 kg N ha^{-1} and variety NDR-8501. Interaction of nitrogen levels and varieties in case of yield was found significant.

Randomized complete block design (RCBD) with 4 treatments and 3 replications was used. The analysis of variance (ANOVA) showed T_3 (150 kg urea ha^{-1}) and T_2 (100 kg urea ha^{-1}) was statistically insignificant. However a significant difference was noticed with T_1 (50 kg urea ha^{-1}) and T_0 (control) in shoot height, leaf area, shoot fresh weight, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua and finally seed yield per hector. The results revealed that the application of 100 kg urea ha-1 were judicial for commercial mustard green production at Bangladesh Agricultural University experimental farm reported by Shorna S.I. et at. (2020).

Canola (*Brassica napus L.*) was planted for two consecutive seasons (2004-05 and 2005-06) in the Arid Land Agricultural Research Station, King Abdul Aziz University at Hada Al-Sham to determine the effect of different rates of nitrogen fertilizer (0, 60, 120 and 180 kg N ha^{-1}) on crop growth, seed yield, yield components and seed quality. Nitrogen was applied in three equal splits, 2 weeks, 4 weeks and 8 weeks after planting during each crop season. Randomized complete block design, with four replications was used. Statistical analysis of the obtained data presented that nitrogen at a rate of 180 kg N ha^{-1} dominated other N rates of 120, 60, 0 kg N ha^{-1} for plant growth, yield and quality parameters except seed oil content that were higher at 120 kg N ha^{-1} level. An overall improvement of 59% in plant height, 112% in number of branches, 111% in number of fruits/plant, 87% in 1000 seed weights and 19% in crude protein content were documented for 180 kg N ha^{-1} . On contrary a reduction of 5% in oil content was recorded by increasing from 120 kg N ha^{-1} to 180 kg N ha^{-1}. Current results suggested that N at a rate of 180 kg ha^{-1} can be adopted as the best level of nitrogen fertilizer for canola cultivation under arid land conditions of Saudi Arabia (Sulaiman et al, 2015).

Narits (2010) carried out at the Jõgeva Plant Breeding Institute in 2007-2008 and 2008-2009. Ammonium nitrate (nitrogen content 34.4%) was used as top fertilizer. Three different nitrogen rates: 120, 140 and 160 kg ha^{-1} (in active ingredient) and three different application timings were used: A) once at the beginning of spring vegetation, B) A + when the main stem was 10 cm, C) B + start of flowering in equal portions. Results revealed that the amount of fertilizer had not as strong impact to seed yield and quality as fertilizer application time. The highest yields of seed and raw oil were obtained from the variant of split-N treatment (40+40+40) of 120 kg per ha.

Kazemeini et al. (2010) carried out to evaluate the effect of N fertilization and additive materials including wheat residue and compost on growth, yield and yield components of canola. The experiment was conducted at the Experimental Farm of College of Agriculture, Shiraz University, Shiraz, Iran, located at Badjgah in 2006-2007 and 2007-2008 growing seasons. The experimental design was split plot with three replications. Seed yield responded to the application of both compost and wheat straw and the maximum seed yield was recorded at 50 ton ha^{-1} of compost treatment. Increasing N caused a significant increase in seed yield. Seed yield showed a significant increase by increasing N from 0 to 100 kg ha^{-1} at 50 ton ha^{-1} compost treatment; however increasing N beyond 100 kg ha^{-1} had no significant effect on canola seed yield. Application of 100 kg ha^{-1} of N fertilizer at 50 ton ha^{-1} compost was adequate for attain optimum seed yield. Results of stepwise regression analysis showed that contribution of yield component of canola varies with change in N fertilizer and organic matter application rates. Soil organic carbon was also shown to increase following application of different types of organic matter.

Sah *et al*., (2006) and Dawson e*t al.*, (2009) reported that application of 100 kg N/ha (N2) reported significantly higher seed (2485 kg/ha) and stover (5208 kg/ha).On an average, the application of 100 kg N/ha (N_3) and 75 kg N/ha (N_2) increased seed yield to the tune of 15.6 and 10.8 per cent over the 50 kg N/ha (N_1), respectively. Higher yield in these 3 treatments might be due to cumulative effect of elevated growth structure as well as yield structure. Increase in seed yield was mainly because of remarkable improvement in growth and yield attributing characters and ultimately resulted from higher nitrogen levels that provide nutrition to the plant ultimately resulted in maximum seed yield and stover yield.

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

Singh *et al*. (2004) reported that nitrogen application did not affect the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application increased the seed yield of mustard. 18 Nitrogen and sulphur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N/ha over its preceding rates. The increased nitrogen and sulphur content enhanced the total uptake of nitrogen and sulphur.

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

An experiment was conducted by Tripathi (2003) in Uttar Pradesh, India in 1994- 95 and 1995-96 to investigate the effects of N levels (80, 120, 160 and 200 kg/ha) on the growth, yield and quality of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and at 60 days after sowing. Results showed that all the yield characters except number of branches increased with increasing N levels up to 160 kg N/ha, The number of branches per plant increased up to 200 kg N/ha. Net returns were maximum (Rs. 19,901/ha) at 160 kg N/ha because seed yield was also maximum at this N rate. The benefit: cost ratio increased up to 160 kg N/ha.

Singh *et al.* (2003) stated that N at 120 kg/ha produced 4.51 times higher number of branches, 48.03 times higher siliqua number, 2.09 g siliqua weight, 2.05 g higher seed weight per plant and 2.55 q/ha higher seed yield compared to 60 kg N/ha. The N level higher than 120 kg/ha did not increase the yield and yield attributes significantly. The basis of N application did not significantly affect the performance of the plants.

Khan *et al.* (2003) observed that cycocel at 400 ppm + 60 kg N/ha and ethrel at 200 ppm + 80 kg N/ha enhanced leaf photosynthetic rate, water use efficiency, leaf area and leaf dry mass 80 days after sowing. The highest stem, pod and plant dry mass were noted 120 days after sowing. At maturity, pod number and seed yield increased.

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

Sharawat *et al*., (2002) observed that the yield and oil content generally increased with the increase in N and S rate. N at 120 kg/ha resulted in the highest number of siliquae per plant (397.25), weight of siliquae per plant (33.32 g), number of seeds per siliquae (14.80), seed yield per plant (368.75 g), 1000-grain weight (17.33 g), seed yield per ha (17.33 quintal) and oil content (38.39%).

Meena *et al*. (2002) reported that the application of 60 kg N/ha registered significantly higher seed and stover yield of mustard over control and 30 kg N/ha and found statistically at par with 90 kg N/ha.

Budzynski and Jankowski, (2001) investigated the effects of pre-sowing application of NPK (161 kg/ha)+S (30 kg/ha) or Mg (5 kg/ha) and top dressing of N (0, 30, 25+5 and 60 kg/ha) on the yield, yield components and morphological features of white mustard [Sinapis alba] and Indian mustard seeds in an experiment conducted in Poland. N top dressing (30, 25+5 and 60 kg/ha) increased the height, diameter of stem base and branching of Indian mustard and white mustard stems. Both crops, however, exhibited lodging. The effects of NPKS and NPKM g on the yield potential of white mustard were not dependent on weather conditions. N applied at 30 kg/ha at the start of the flowering period gave the best results among the methods of white mustard top dressing. Splitting this rate to 25 kg N/ha as a solid fertilizer and 5 kg N/ha in a solution gave results similar to that of the whole rate of 30 kg N/ha as a solid fertilizer. N at 60 kg/ha appeared to be less productive. N applied as a solid fertilizer at a rate of up to 60 kg/ha increased the seed yield.

Ozer (2003) studied the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}) on two cultivars of rapeseed. He observed that adequate N fertilization is important in yield formation in summer oilseed rape and suggested that the rate of 160 kg N ha^{-1} will be about adequate for the crop to meet its N requirements.

2.2. Effect of phosphorus on the yield and yield contributing characters

Zalak Chauhan and Patel (2020) reported that different levels of phosphorus failed to exert significant differences for biological yields, nitrogen and sulphur content and uptake from seed and stover. An application of phosphorus 75 kg P_2O_5/ha (P_2) was recorded significantly the maximum phosphorus content in seed (0.60 %) and stover (0.21 %) and phosphorus uptake by seed (14.37 kg/ha) and stover (10.56 kg/ha). Higher phosphorus content in seed and stover might be due to phosphorus being responsible for synthesis of DNA and RNA and as an ingredient of phospho proteins plays a central role in synthesis of proteins. Improvement in nutrient concentration in seed and stover due to N and P. The considerable increase in P uptake by seed and stover could be attributed to the fact that P stimulates the early root development and growth and thereby efficient utilization of nutrients from the deeper soil layer.

Solanki et al. (2018) concluded that with 50kg/ha P_2O_5 the highest seed yield (19.7 q/ha) and stover yield was (50.4 q/ha) and high grain yield with use of phosphorus, sulphur and phosphorus solublizing bacteria at Rajasthan in mustard crop. Upadhyay et al. (2018) concerned that the taller plant height, siliqua no. per plant, dry matter per plant, no. of siliqua per plant, stover yield and seed yield with application of 50 kg P/ha and 40 kg S/ha than lower doses or no doses at Uttar Pradesh in Indian mustard.

The oil content in mustard seed was significantly improved with application of 60 kg P_2O_5 ha^{-1} over control and it was at par with 40 kg P_2O_5 ha^{-1}. Oil yield of mustard was enhanced significantly up to 60 kg P_2O_5 ha^{-1} over rest of the phosphorous levels. An increase in the oil content in mustard seed might be because of synthesis of fatty acids in plants in presence of ATP and phosphate. These fatty acids play an important role in increasing the oil content of seed. The results are in obedience given by Bharose et al. (2011) and Chouksey et al. (2017).

An application of phosphorus @ 75 kg P_2O_5/ha (P_1) recorded significantly higher available P_2O_5 (39.77 kg/ha) in the soil. These might be due to enhanced microbial activity by P application in rhizosphere through development of fibrous and deep root system of plant there by recycled the nutrients from deeper layer to upper layer of soil. Similar results were observed by Trivedi et al. (2013) and Jadav et al. (2016).

Singh et al. (2016) revealed, economic parameters, oil attributes in mustard. Solanki et al. (2016) observed that at Uttar Pradesh the application of phosphorus 60 kg/ha and sulphur 40kg/ha observe the higher yield and at Rajasthan on supply of 40 kg P/ha apply in mustard increase the seed yield, stover yield, B:C ratio 19.6 q/ha, 50.5 q/ha, 1.85 respectively and application of 50 kg P/ha increase the plant height, dry matter, siliquae/plant, branches/plant, seed/siliquae and apply 40 kg S/ha increase the test weight, seed yield, stover yield, branches/plant, siliquae/plant, B:C ratio 1.92.

The growth and yield attributes of mustard were significantly affected by different levels of phosphorus. Application of phosphorus @ 60 kg P_2O_5 ha^{-1} resulted in the significantly higher plant height, number of branches per plant, dry matter accumulation $plant^{-1}$, number of siliquae $plant^{-1}$, number of seed $siliquae^{-1}$ and test weight of mustard over control and at par with 40 kg P_2O_5 ha^{-1}. Significantly higher seed and straw yield of mustard was reported by 60 kg P_2O_5 ha^{-1} over control and it was at par with 40 kg P_2O_5 ha^{-1}. The seed and straw yield was enhanced by 36.00 and 35.13 per cent, respectively with use of 60 kg P_2O_5 ha^{-1} over control in pooled mean. This might be due to the fact that the increased supply of phosphorus might have help in early root initiation and establishment of the crop thereby leading to increase growth parameters (Gangwal et al., 2011).

A field trial conducted during the winter season of 2003-2004 revealed that the growth, yield attributes and seed as well as stover yields of Indian mustard (*Brassica juncea* toss) showed linear increase in these characters upto 60 kg P/ha. Similarly, all these parameters were found to increase with increasing level of S upto 45 kg/ha and all above parameters were recorded significantly higher over control and 15 kg S/ha was non-significantly more than 30 kg S/ha (Varun. 2008).

Ratikanta Sahoo, Vikram Singh and Dhananjay Tiwari reported (2008) that the yield attributes of yellow mustard were significantly influenced with increasing the levels of phosphorus. Significantly the maximum (94.67) number of siliqua/plant was obtained with the application of 60 kg Phosphorus and 50 kg sulpher that among all the treatment. 60 kg phosphorus was considered to be the best treatment combination for achieving maximum seed yield (1893.33 kg/ha), stover yield (4323.33kg/ha), gross return (126853.11/ha), net return (66396.11/ha) and benefit cost ratio (1.09) in yellow mustard plant with variety (NRCYS-05- 02).

Mir et al. (2007) was conducted an experiment on mustard (*Brassica cicajuncea L*. Czem & Coss var. Alankar) at Aligarh to study the effect of different combinations of phosphorous and potassium applied as mono calcium superphosphate and muriate of potash. Respectively (each at the rate of 30, 60, 90 kg P_20_5 and K_20 $ha^{-1)}$ on yield and yield attributes of mustard. In addition, a uniform dose of urea at the rate of 80 kg N ha^{-1} 'was applied. At harvest, various yield characteristics including number of pods plant' number of seed pod, seed yield and oil yield were studied. The effect of phosphorus alone as well as in combination with potassium was significant. Treatments 60 kg P_2O_5 ha^{-1}" and 60 kg P_20_5 - 60 kg K_20 ha^{-1}" proved optimum and the increase in seed yield was due to increase in pods plant' and seeds pod".

Bhat *et al*. (2006) conducted a pot experiment to study the effect of three levels of nitrogen and phosphorus combinations, i.e. No P_20_3 kg $ha^{-1'}$, $NSOP_40$ kg ha^{-1} and N3

(P 50 kg ha^{-1} on growth. yield and quality of two cultivars of mustard *(Brassica juncea*). The data revealed that cultivar Pusa Bold gave higher plant height, leaf number, leaf area, number of primary branches and plant dry weight than Kranti. Application of higher dose of NP fertilizers. i.e N($P_2 0_5$ kg ha^{-1}' proved significantly better in improving all these parameters. Higher fertilizer dose also resulted in a significant increase in number of siliquae $plant^{-1}$'. Length of siliquae and number of seeds $siliqua^{-1}$, which consequently resulted in a marked increase in harvest index and seed yield of both the cultivars. N, $P_2 0_5$ kg ha^{-1} also resulted in an overall increase in leaf N, P and K contents and seed protein content. Oil content was found to be decreased with increased dose of NP fertilizers, however, extent of decrease in seed oil content was lower than increase in seed yield and thus total edible oil production was still higher with higher fertilizer dose as compared to the normal recommended dose.

Premi (2004) conducted a field experiment during winter to study the effect of nitrogen and phosphorus levels on growth, yield attributes, yield and oil content of Indian mustard *brassica juncea*. Significant increase in number of siliquae per plant upto 120 kg N/ha and number of seeds per siliquae upto 80 kg N ha^{-1}' resulted in significant increase in seed yield upto 120 kg N/ha. N levels did not affect Siliquae length and 1000-seed weight. With addition of nitrogen above 80 kg N ha^{-1} reduced the oil content. Response to phosphorus was observed up to 80 Kg $P_2 0_5$ ha^{-1}' with respect to seed yield and oil content.

2.3. Combined effect of nitrogen and phosphorus

Randeep (2019) reported that plant height increased linearly with successive increment in nitrogen levels at all the crop growth stages. At 45, 90, 135 DAS and at harvest plant height with 130 kg N ha^{-1} was significantly higher than 70 kg N ha^{-1} but at par with 130 kg N ha^{-1}. Flowering time (50% flowering) occurred earlier with nitrogen application whereas maturity was delayed with increasing nitrogen levels up to130 kg N ha^{-1}. Yield contributing characters like number of primary and secondary branches, siliquae per plant increased significantly up to 100kg N ha^{-1}. Highest seeds per siliquae were also obtained in 70 kg N ha^{-1}, whereas test weight was maximum with 130 kg N ha^{-1}. Seed yield of 22.71 q ha^{-1} was obtained with the application of 100 kg N ha^{-1} , which was at par with 130 kg N ha^{-1} but significantly higher than 70 kg N ha^{-1} . However, straw yield was significantly higher with 130 kg N ha^{-1}. Maximum harvest index value was registered with 100 kg N ha^{-1}. Growth and yield contributing characters of Canola *B. napus* remained unaffected with phosphorus application except siliquae bearing branches which increased significantly upto 30 kg P_2O_5 ha^{-1}. Therefore, siliquae bearing branches, siliquae per plant, seeds per siliquae and thousand seed weight were main parameters which contribute towards increased seed yield. Hence, it may be concluded that the maximum yield of Canola *B. napus* was obtained with application of 130 kg N ha^{-1} on clayey soil, low in available nitrogen status. However, the optimum economic dose of nitrogen was 100 kg N ha^{-1} as both the treatments were at par. Phosphorus did not show any positive influence on seed yield due to the high initial phosphorus status of the soil.

Zangani (2021) reported that the effects of nitrogen and phosphorus levels on the physiological traits, yield, and seed yield of rapeseed (*Brassica napus L.*), were studied in a farm research project of Zanjan University. Three levels of nitrogen (0, 100, and 200 kg/ha) and three levels of phosphorus (0, 75, and 150 kg/ha) were considered. The results showed that an increase in nitrogen level caused an increase in the leaf chlorophyll content so that the application of 200 kg/ha of nitrogen increased the chlorophyll content of the leaves until the mid-grain filling stage. Nitrogen application lowered leaf stomatal conductance in the early flowering stage whereas the stomatal conductance was increased during the late flowering stage. Nitrogen application (100 and 200 kg/ha) also increased the quantum yield of photosystem II. On the other hand, with the application of 150 kg/ha and 75 kg/ha of phosphorus, the leaf stomatal conductance and the quantum yield of photosystem II in the early flowering stage increased respectively. The results showed that the application of 200 kg/ha of nitrogen and 75 kg/ha of phosphorus significantly increased seed and oil yield compared to the control. In addition, the number of siliquae per plant and the weight of 1000 seeds showed an increasing trend that was affected by nitrogen and phosphorus levels. This study demonstrated that nitrogen enhanced the chlorophyll content, leaf area, and consequently, the quantum yield of photosystem II. Nitrogen also augmented the seed filling duration, seed yield, and oil yield by increasing gas exchange. As a result, the application of 100 kg/ha of nitrogen together with 75 kg/ha phosphorus showed the greatest effect on the qualitative and quantitative yield of rapeseed. However, the application of 200 kg/ha of nitrogen alone or in combination with different levels of phosphorus did not significantly increase many of the studied traits.

Khan et al, (2000) conducted an experiment to determine the effect of nitrogen alone and in combination with phosphorus on the growth and yield of *Brassica juncea L Cv*. The N-P levels (kg ha^{-1}) 0-0, 50-0, 100-0, 50-50, 100-50 and 150-50 were applied. The results revealed that plant height at maturity, number of branches, number of pods per plant, number of seed per pod and 1000 seed weight were influenced significantly by N, P and N-P levels. Application of N-P @ 100-50 kg ha^{-1} gave the highest seed yield. It was also noted that application of nitrogen over 100 kg ha^{-1} did not produces higher seed yield then 100-50 kg ha^{-1} N-P application.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during November-February, 2020-2021 to examine the effect of nitrogen (N) and phosphorus (P) on the growth and yield of mustard (BARI Sorisha-15). This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recordings and their analyses.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at 90^0 22′ E longitude and 23°41′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September). The experiment was carried out during rabi season, 2020-21. Temperature during the cropping period ranged from 20^0 C to 29.2^0 C. The humidity varied from 61.72% to 70.45%. The day length was reduced to 10.5-11.0 hours only and there was no rainfall from the beginning of the experiment to harvesting.

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.64. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Materials

3.4.1 Seed

The high yielding varieties of mustard were BARI Sarisha-15 developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and was used as an experimental planting material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2 Fertilizers

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

3.5 Methods

3.5.1 Factors of the experiment

Factor A: Level of nitrogen	Factor B: Level of phosphorus
N_0 = 0 kg/ha (control)	P_0 = 0 kg/ha (control)
N_1 = 100 kg/ha	P_1 = 25 kg/ha
N_2 = 120 kg/ha	P_2 = 35 kg/ha

3.5.2 Treatment combinations

There were 9 treatment combinations of different levels of nitrogen and phosphorus used in the experiment under as following:

T_1 (N_0P_0) = Control (without N and P application)

T_2 (N_0P_1) = 0 kg N/ha+25kg P/ha

T_3 (N_0P_2) = 0 kg N/ha+35 kg P/ha

T_4 (N_1P_0) = 100 kg N/ha+0 kg P/ha

T_5 (N_1P_1) = 100 kg N/ha+25 kg P/ha

T_6 (N_1P_2) = 100 kg N/ha+35 kg P/ha

T_7 (N_2P_0) = 120 kg N/ha+0 kg P/ha

T_8 (N_2P_1) = 120 kg N/ha+25 kg P/ha

T_9 (N_2P_2) = 120 kg N/ha+35 kg P/ha

3.5.3 Design and layout

The experiment consisted of 9 treatment combinations and was laid out in 2 factor Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 9 × 3 = 27. The unit plot size was 2.5 m × 2 m = 5 m^2. The distance between blocks was 1 m and distance between plots was 0.5 m.

3.5.4 Land preparation

The land was first ploughed with a tractor drawn disc plough on 7 November 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 15 November 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.5.5 Fertilization

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

Name of Nutrients	**Name of Fertilizers**	**Rate of Application (kg/ha)**
Nitrogen (N)	Urea,	As per treatment
Phosphorus (P)	Triple Super Phosphate	As per treatment
Potash (K)	Muriate of Potash	80
Sulpher (S)	Gypsum	150
Boron (B)	Boric acid	7.5

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum and boric acid required per plot were calculated. The triple super phosphate, muriate of potash, gypsum and boric acid was applied during final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after sowing (DAS) and 45 DAS respectively.

3.5.6 Sowing of seed

Sowing was done on 16 November, 2020 as per treatment. Sowing, seeds were sown as per treatment in rows following broadcast methods at a rate of 8 kg/ha. The seeds were covered with the soil and slightly pressed by hand, and applied little amount water for better germination of seeds.

3.5.7 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 30 November 2020. At the same time first thinning was done. The final weeding and thinning were done after 25 days of sowing, on 10 December 2020. Care was taken to maintain constant plant population per plot.

3.5.8 Irrigation

Irrigation was done at four times. The first irrigation was given in the field on 1 December 2020 at 15 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (30DAS), on 11 December 2020.The third irrigation was given on 40 DAS, 21 December 2020. The final irrigation was given at the stage of seed formation (50 DAS), on 5 January 2021. After irrigation when the plots were in optimum (joe) condition, spading was done uniformly and carefully to conserve the soil moisture for proper growth and development of plants.

3.5.9 Crop protection

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

3.5.10 General observation of the experimental field

The field was investigated frequently in order to reduce losses with weedcompetition and insect infestation and diseases infection.

3.5.11 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 08 February 2021. The harvestedplants were tied into bundles and carried to the threshing floor. The crop were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the pod by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.6 Data collection

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

3.6.1 Plant height

Plant height in cm was measured five times a t day interval such as 25, 45 and 60 DAS. The height of the plant was measured by scale considering the distance from the soil surface to the tip of the randomly selected ten plants and mean value was calculated for each treatment.

3.6.2 The number of leaves per plant

Leaf no. of plant was counted 2 times at 45 and 60 DAS.

3.6.3 Primary branches per plant

Primary branches plant^{-1} was counted two times at 45 DAS and 60 DAS of mustard plants. Mean value of data were calculated and recorded for each treatment.

3.6.4 Secondary branches of per plant

Secondary branches plant^{-1} was counted at 60 DAS of mustard plants. Mean value of data were calculated and recorded for each treatment.

3.6.5 Number of siliquae per plant

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

3.6.6 Length of siliquae

The length of 10 siliquae from each sample was recorded randomly and the mean number was expressed as per siliquae basis.

3.6.7 Number of seeds per siliquae

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

3.6.8 Thousand seed weight

A composite sample was taken from the yield of ten plants. The thousand seeds of each plot were counted and weighed with a digital electric balance. The thousand seed weight was recorded in g.

3.6.9 Yield

After threshing, cleaning and drying, total seed weight of the harvested area were recorded and was converted to t/ ha.

3.6.10 Biological yield

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

3.7 Post harvest soil sampling

After the harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.7.1 Methods for Soil Analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P and K contents. The soil samples were analyzed by the following standard methods as follows:

3.7.2 Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method. The textural class was determined by plotting the values of % sand, % silt and % clay using Marshell's Triangular co-ordinate as designated by USDA.

3.7.3 Organic carbon (%)

Soil organic carbon was estimated by Walkley and Black's wet oxidation method as outlined by Jackson (1973).

3.7.4 C/N ratio

The C/N ratio was calculated from the percentage of organic carbon and total N.

3.7.5 Soil organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page et al., 1982). Soil organic matter content was calculated by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724.

% organic matter = % organic carbon × 1.724

3.7.6 Soil pH

The pH of the soil was determined with the help of a glass electrode pH meter using Soil: water ratio 1:2.5 (Jackson, 1973).

3.7.7 Total nitrogen (%)

Total nitrogen content in soil was determined by Kjeldahl method by digesting the soil sample with conc. H_2SO_4, 30% H_2O_2 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 10:1:0.1) followed by distillation with 40% NaOH and by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Black, 1965).

The amount of N was calculated using the following formula:

% N = (T-B) × N × 0.014 × 100 / S

Where,

T = Sample titration (ml) value of standard H2SO4

B = Blank titration (ml) value of standard H2SO4

N = Strength of H2SO4

S = Sample weight in gram

3.7.8 Available sulphur (ppm)

Available S in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page et al., 1982). The S content in the extract was determined turbid metrically and the intensity of turbid was measured by spectrophotometer at 420 nm wave length.

3.7.9 Available phosphorus (ppm)

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ solution, pH 8.5 (Olsen et al., 1954). Phosphorus in the extract was measured spectrophotometrically after development of blue color (Black, 1965). It was determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page et al. 1982).

3.7.10 Exchangeable potassium (meq/100 g soil)

Exchangeable potassium (K) content of the soil sample was determined by flame photometer on the NH_4OAc extract (Black, 1965).

3.7.11 Statistical Analysis

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 (Gomez and Gomez, 1984)

3.8 Harvest index (%)

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

3.9 Data analysis

The data obtained from the experiment on various parameters were statistically analyzed in STATISTIC-10 computer program. The mean values for all the parameters were calculated and the analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test at 5 % levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

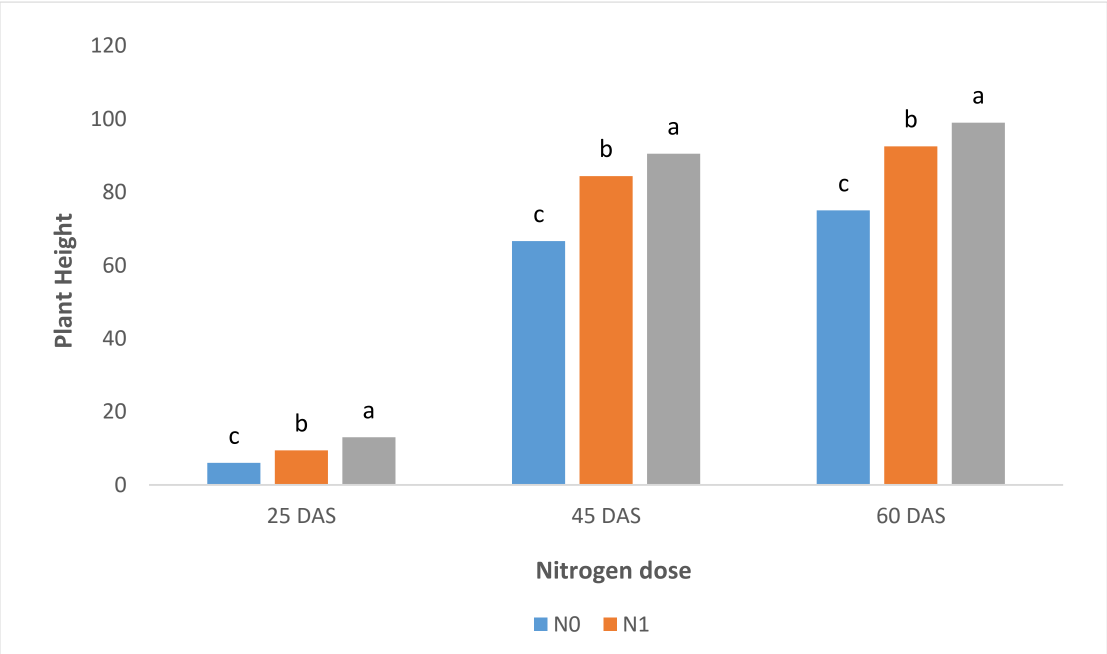
The results obtained with different levels of nitrogen (N) and Phosphorus (P) and their combination are presented and discussed in this chapter. Data about morphological parameters, yield contributing characters, seed yield of mustard have been presented in both Tables and Figures.

4.1 Plant height

The results of this study showed that nitrogen (N) levels showed significant effect on rapeseed plant height (Fig. 1). The plant height of mustard cv. BARI Sarisha-15 was significantly influenced with the application of nitrogen fertilizer. It was observed that in case of plant height significant difference was found at N_0, N_1 and N_2.

The height of mustard plant significantly influenced at 25, 45, 60 days after sowing (DAS) (Fig. 1),The tallest plant (10.20, 89.50 and 98.97 cm at 25, 45, and 60 DAS, respectively) was recorded with T_2 treatment. In contrast, the shortest plant (6.73, 73.60 and 78.97 cm at 25, 45, and 60 DAS, respectively) was recorded from T_0 (Control condition).

Figure 1: Effect of nitrogen (N) on the Plant height of mustard

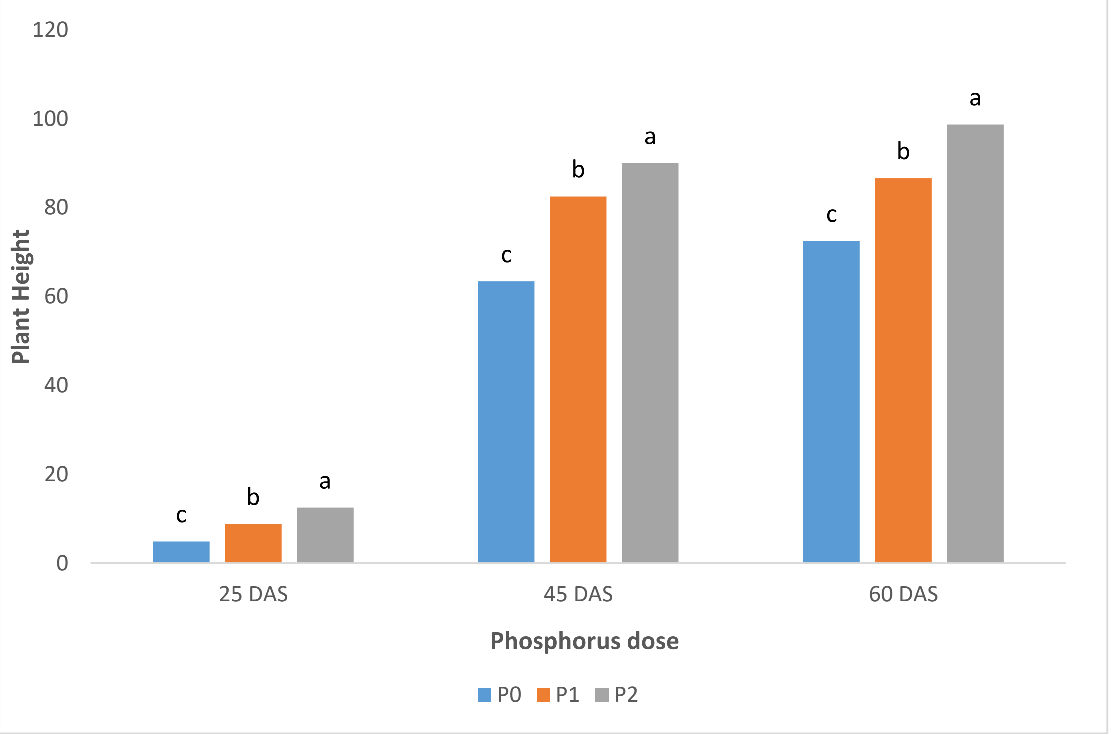


Where: N_0 = Control condition N_1 = 100 kg/ha N_2 = 120 kg/ha

The N fertilizer's requirements can differ very much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc. These findings are in agreement with those of Singh et al. (2003), Tripathi and Tripathi (2003), Singh (2002). Similar findings were also reported by Tomar et al. (1996), FAO (1999), Ali and Ullah (1995), Shamsuddin et al. (1987), Ali and Rahman (1986) and Hasan and Rahman (1987). All together, these results suggest that higher doses of N increase mustard plant height.

There is significant difference among the different doses of phosphorus. The tallest plant (9.90, 88.60 and 98.20 cm, at 25, 45, and 60 DAS, respectively) was found in treatment P_2 and shortest plant (6.68, 73.63 and 77.93 cm at 25, 45,and 60 DAS, respectively) was found in T_0 (Control condition). Data pertaining to Fig. 2 revealed that plant height was not significantly affected by different doses of P. However, plant height increased with increasing levels of P up to higher level.

Figure 2: Effect of Phosphorus (P) on the Plant height of mustard



Where:

P_0= 0 kg/ha P_1= 25 kg/ha P_2= 35 kg/ha

The plant height of mustard significantly increased with the by the interaction between N and P (Table 1). The combined use of N and P had significant effect on plant height at 25, 45, and 60 days after sowing (DAS). The tallest plant (10.40, 90.00 and 100.33 cm at 25, 45, and 60 DAS, respectively) was found in treatment T_6 (N_1P_2 combination), whereas the shortest plant (7.00, 74.67 and 80.00 cm at 25, 45, and 60 DAS, respectively) was observed in T_1 (N_0P_0 combination). Singh (2002) reported that plant height increased significantly with successive increase in nitrogen up to 100 kg/ha. All together these results indicate that plant height of mustard increase with combined use of N and P.

Table 1: Interaction effect of nitrogen (N) and Phosphorus (P) on the plant height of mustard

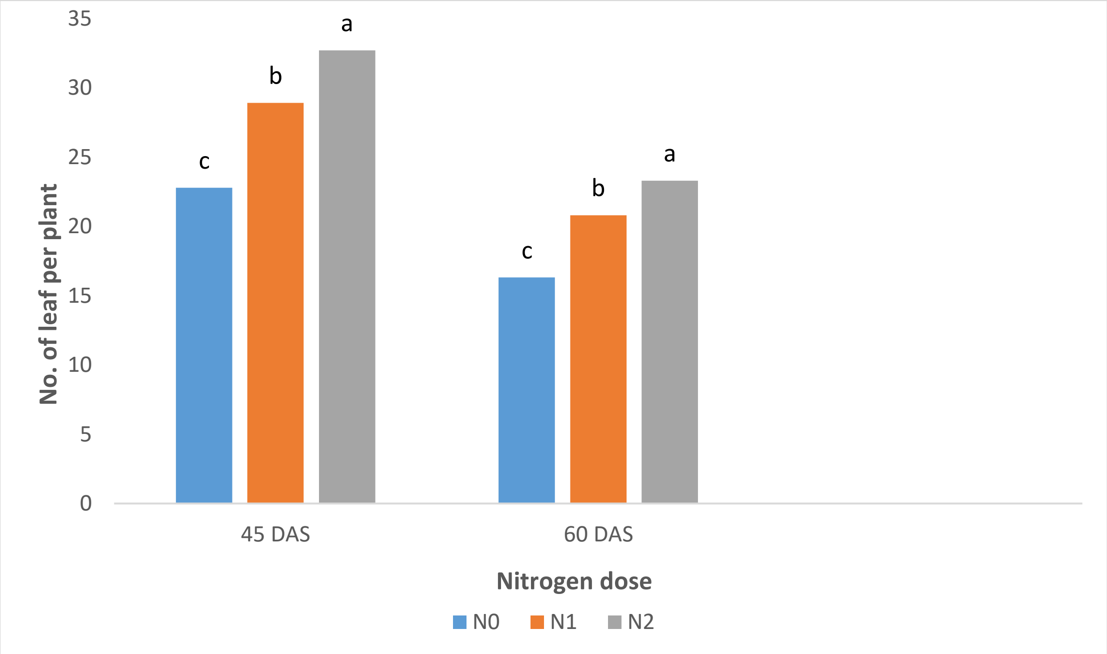
Treatments	Plant Height(cm)		
	25 DAS	45 DAS	60 DAS
T_1	7.00 e	74.67 f	80.00 f
T_2	7.510 de	76.50 ef	81.67 f
T_3	7.82 d	78.00 e	83.67 e
T_4	8.58 c	80.00 d	85.00 de
T_5	8.73 c	83.33 c	86.67 d
T_6	10.40 a	90.00 a	100.33 a
T_7	9.00 bc	84.67 c	93.00 c
T_8	9.33 b	86.67 b	95.67 b
T_9	10.34 a	88.33 a	99.33 a
LSD (0.05)	0.52	1.82	1.83
CV (%)	3.43	5.50	1.18

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

4.2. Number of leaves per plant

Application of N showed significant variation in the number of leaves per plant (Figure 3). The maximum number of leaves per plant (32.89 and 22.87 at 45 and 60 DAS respectively) was produced by 120 kg N/ha and without N produced the lowest number of leaves per plant (25.78 and 17.22 in 45 and 60 DAS respectively). It is reported that better growth and development of crop depend on a good number of leaves and producing more foliage related to the yield of rapeseed (through higher siliquae yield and stover yield) to the seed production those are linked to use of amount of N fertilizer and suggesting that the greater number of leaf, the greater the photosynthetic area which may result higher seed yield. These indicate number of leaves per plant increased with increasing N levels; those are consistent with Patil et al., (1997) findings.

Figure 3: Effect of nitrogen (N) on the no. of leaves per plant of mustard



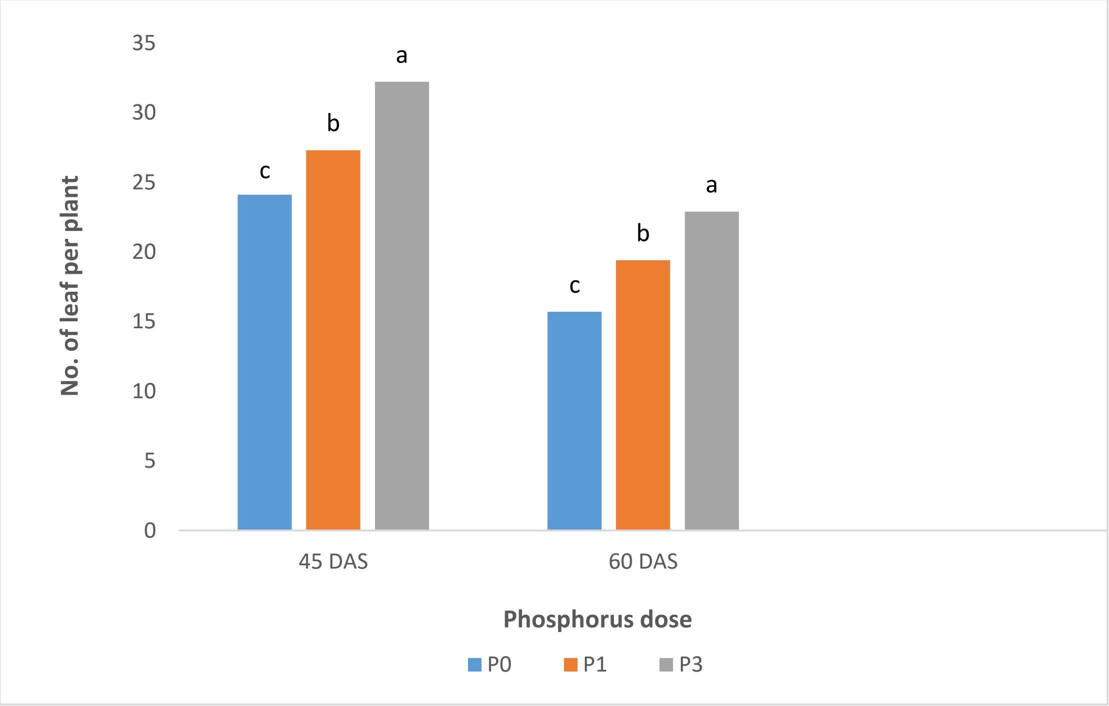
Where:

N_0 = Control condition N_1 = 100 kg/ha N_2 = 120 kg/ha

Number of leaves per plant due to the influence of P was significant (figure 4). With the 35 kg P/ha had the highest number of leaves per plant (32.10 and 22.77 at 45 and 60 DAS respectively). However, the lowest number of leaves per plant (25.13 and

16.80 in 45 and 60 DAS respectively) was obtained from the control. So, P has important role on increasing number of rapeseed leaves.

Figure 4: Effect of phosphorus (P) on the no. of leaves per plant of mustard



Where:

P_0= 0 kg/ha P_1= 25 kg/ha P_2= 35 kg/ha

A significant variation in the number of leaves per plant was found between the N and P (Table 2). The maximum number of leaves per plant (33.57 and 23.23 in 45 and 60 DAS respectively) was found in combined use of 100 kg/ N and 35 kg P/ha, N_1P_2 treatment, whereas the lowest number of leaves per plant (26.00 and 17.70 at 45 and 60 DAS respectively) was found in control treatment. It is well established that mineral nutrition influences plant growth and absorption of elements, proper N application enhance P accumulation in plants which trigger both vegetative growth and reproductive development (Hemlin et al. 2003). The result of leaves number plant^{-1} of this study is consistent with the plant height (Table 2) and suggesting that combined use of N and P might increase mustard canopy structure.

Table 2: Interaction effect of Nitrogen (N) and Phosphorus (P) on the no. of leaves per plant of mustard

Treatments	Leaves no. per plant	
	45 DAS	**60 DAS**
T_1	26.00 e	17.70 g
T_2	26.83 de	18.27 f
T_3	27.47 d	18.87 e
T_4	28.97 c	19.57 d
T_5	29.50 c	19.90 d
T_6	33.57 a	23.23 a
T_7	31.10 b	21.83 c
T_8	31.93 b	22.43 b
T_9	32.6 ab	22.90 a
LSD (0.05)	0.83	0.46
CV (%)	2.73	6.96

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

4.3. Number of Primary branches per plant

The Nitrogen management had significant effect on number of primary branches of plant. In general, the maximum number of branches per plant was obtained at 60 DAS. The maximum number of branches per plant (6.96 and 7.41 in 45 and 60 DAS respectively) was produced by 120 kg N ha^{-1}. Control produced the minimum number of branches per plant (5.04 and 6.14 in 45 and 60 DAS respectively) (Table 2). Tomar et al. (1991, 1996), Ali and Ullah (1995) also obtained highest number of branch per plant with 120 kg N ha^{-1}. In contrast, Mondal and Gaffer (1983) also reported that N fertilizer application had no significant effect on number of primary branches per plant of rapeseed. Altogether, it suggests that N involve in initiating primary branches by sprouting lateral buds of mustard plants.

Similarly P influenced significantly on number of primary branches per plant (Table 4) The highest number of branches per plant (6.61 and 7.10 in 45 and 60 DAS respectively) was obtained from P_2, 35 kg P ha^{-1} and the lowest number of branches per plant (4.90 and 5.97 in 45 and 60 DAS respectively) was obtained from the control, P_0 and indicating that P increased number of primary branches per plant as dose dependent manner.

Table 3: Effect of nitrogen (N) on the number of branches per plant of mustard

Treatments	No. of primary branches		No. of secondary branches
	45DAS	60 DAS	
N_0	5.04 c	6.14 c	2.13 c
N_1	6.35 b	7.13 b	2.79 b
N_2	6.96 a	7.41 a	3.02 a
LSD (0.05)	.048	0.08	0.13
CV (%)	2.80	3.42	6.25

Where:

N_0 = (Control condition), N_1 = (100 kg/ha), N_2 = (120 kg/ha)

Interaction effect between N and P was found significant on the number of primary branches per plant (Table 5). The maximum number of branches per plant (7.07 and 7.73 in 45 and 60 DAS respectively) was found in N_1P_2 (treatment combination 100 kg N/ha and 35 kg P/ha) whereas the lowest number of branches per plant (5.73 and 6.50 in 45 and 60 DAS respectively) was found in N_0P_0, control treatment, that are correlate with Murtuza and Paul (1989) findings, they observed significant effect of nitrogen on the number of primary branches $plant^{-1}$. Altogether, the result of this study suggests that N and P application showed synergistic effect on primary branches per plant of mustard.

4.4 Number of Secondary branches per plant

The different levels of N had significant effect on the number of primary branches per plant (Table 3). The maximum number of branches per plant (3.02) was produced by 120 kg N ha^{-1}. Control produced the minimum number of branches per plant (2.1278).

The P influenced significantly on number of primary branches per plant (Table 4). The highest number of branches per plant (2.96) was obtained from P_3, 35 kg P ha^{-1} and the lowest number of branches per plant (2.01) was obtained from the control, P_0 and indicating that P increased number of primary branches per plant as dose dependent manner.

Table 4: Effect of phosphorus (p) on the number of branches per plant of mustard

Treatments	No. of primary branches		No. of secondary branches
	45DAS	60 DAS	
P_0	4.90 c	5.97 c	2.01 c
P_1	6.02 b	6.67 b	2.50 b
P_2	6.61 a	7.10 a	2.96 a
LSD (0.05)	0.12	0.11	0.07
CV (%)	2.80	3.42	6.25

Where:

P_0= control P_1= 25 kg/ha P_2= 35 kg/ha

Interaction effect between N and P was found significant on the number of primary branches per plant (Table 5). The maximum number of branches per plant (3.20) was found in N_1P_2 treatment combination, 100 kg N/ha and 35 kg P/ha whereas the lowest number of branches per plant (2.10) was found in N_0P_0, control treatment. The second highest number of branches per (3.13) was recorded in T_9 (N_2P_2), which was statistically identical to T_6 and T_8 but significantly higher than rest of the treatment combination.

Table 5: Interaction effect of Nitrogen (N) and Phosphorus (P) on the number of branches of mustard

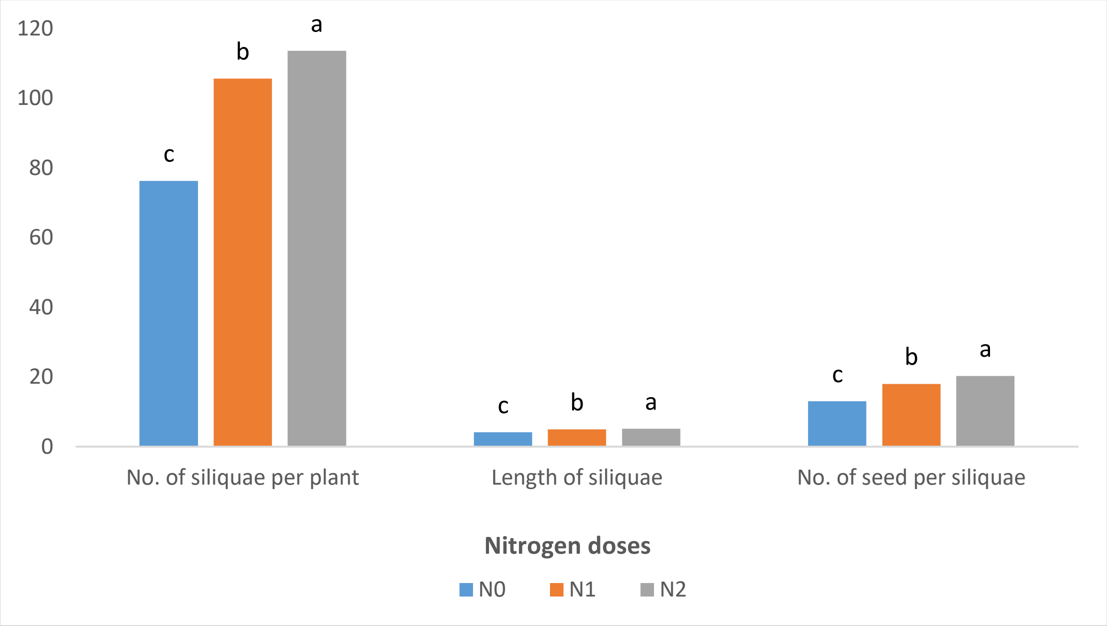
Treatments	No. of primary branches		No. of secondary branches
	45DAS	60 DAS	
T_1	5.73 f	6.50 d	2.10 h
T_2	5.97 e	6.67 cd	2.27 g
T_3	6.17 de	6.80 cd	2.50 f
T_4	6.23 d	6.93 cd	2.60e f
T_5	6.37 cd	7.40 bc	2.73 de
T_6	7.07 a	7.73 a	3.20 a
T_7	6.57 bc	7.43 b	2.87 cd
T_8	6.77 b	7.60 ab	3.00 bc
T_9	7.00 a	7.63 ab	3.13 ab
LSD (0.05)	0.20	0.43	0.
CV (%)	2.80	3.42	6.25

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

4.5. Number of siliquae per plant

The number of siliquae per plant of mustard was highly affected by nitrogen rates and their interaction. The N showed significance variation in the number of siliquae per plant (figure 5). The maximum number of siliquae per plant (113.59) was obtained in plots which received 120 kg N ha^{-1}. The minimum number of siliquae per plant (76.29) produced in control condition (no nitrogen application). Similar result also obtained by Shukla et al. (2002), Singh et al. (2003) in rapeseed. These are consistent with the length of siliquae of rapeseed. Here treatment N_1 also gives close result of T_2. The significance difference between T_2 and T_1 is very low.

Figure 5: Effect of nitrogen (N) on the different growth factor mustard



Where:

N_0= Control N_1= 100 kg/ha N_2= 120 kg/ha

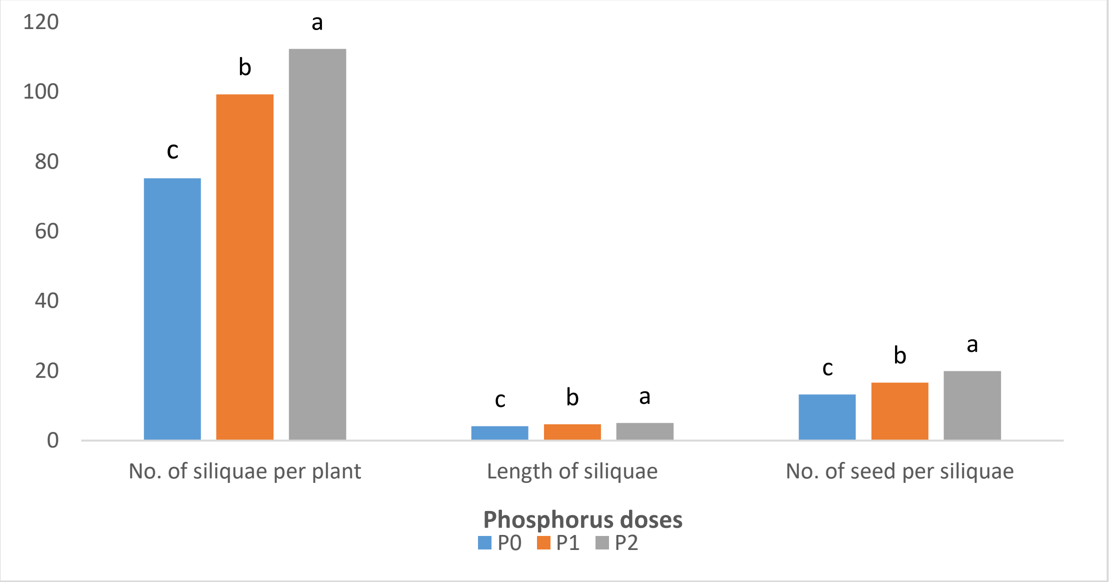
There was a significant difference among the P doses in the number of siliquae per plant (Figure 6). The maximum number of siliquae per plant (112.31) was produced in P_3 (with 35 kg P ha^{-1}) and the minimum number of siliquae per plant (75.19) was produced in P_0 or control condition. A significant difference found among the treatment combinations of N and P in number of siliquae per plant (Table 6). The maximum number of siliquae per plant (115.30) was found in N_1P_2, whereas the minimum number of siliquae per plant (78.37) was found in N_0P_0 treatment combination.

4.6 Length of siliquae

The N showed significant variation in the length of siliquae (figure 5). The longest length of siliquae (5.02 cm) was produced by 120 kg N ha^{-1} whereas N_3 and N_0 treatment produced the shortest length of siliquae (4.12 cm).

There was no significant difference among the P treatments in the length of siliquae (figure 6). As evident from fig 8, the maximum length of siliquae (5.00 cm) was produced from 35kg P ha^{-1}. The minimum length of siliquae (4.10 cm) was produced in control.

Figure 6: Effect of phosphorus (p) on the different growth factor of mustard



Where:

P_0= Control P_1= 25 kg/ha P_2= 35 kg/ha

A significant indicated variation among the treatment combinations in length of siliquae. The maximum length of siliquae (5.15 cm) was found in N_1P_2 treatment combination, 100 kg N ha^{-1} and 35 kg P ha^{-1} whereas the minimum length of siliquae (4.23 cm) was found in control (Table 6).

4.7 Number of seed per siliquae

The number of seed per siliquae of rapeseed was highly affected nitrogen rates and their interaction. The N showed significant variation in the number of seed per siliquae (Figure 5). The Maximum number siliquae per plant (20.25) was obtained in plots which received 120 kg N ha^{-1}. The minimum number of seed per siliquae (13.09) produced in control plots (no nitrogen application).

There was a significant difference among the P in the number of seed per siliquae (Figure 6). The maximum number of seed per siliquae (19.87) was produced in P3 or with 35 kg P ha^{-1} and the minimum number of seed per siliquae (13.17) was produced in P_0 or control condition.

Table 6: Interaction effect of Nitrogen (N) and Phosphorus (P) on the different growth factor of mustard

Treatments	Number of siliquae plant^{-1}	Length of siliquae(cm)	Number of seed siliquae^{-1}
T_1	78.37 h	4.23 f	13.83 g
T_2	84.13 g	4.40 e	15.00 f
T_3	87.97 f	4.53 d	15.63 ef
T_4	94.93 e	4.57 d	16.27 de
T_5	103.63 d	4.73 c	16.97 d
T_6	115.30 a	5.17 a	21.00 a
T_7	106.47 c	4.87 b	18.43 c
T_8	111.47 b	5.07 a	19.83 b
T_9	114.97 a	5.15 a	20.87 a
$LSD_{(0.05)}$	2.59	0.11	0.77
CV (%)	4.25	3.38	8.39

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

A significant variation indicated among the treatment combinations of N and P in number of seed per siliquae (Table 6).The highest result comes from treatment 6 (N_1P_2).

The maximum number of seed per siliquae (20.87) was found in N_1P_2, whereas the minimum number of siliquae per plant (13.83) was found in N_0P_0 treatment combination. The treatment 9 also gives almost same result with treatment 6.

4.8 1000- Seed weight

The application of nitrogen was not influenced significantly on the thousand seed weight (Table 7). The maximum thousand seed weight (3.52 g) was produced by N_2, and N0 produced the lowest thousand seed weight (2.91 g). Ozer (2003), Singh (2002) and Shamsuddin et al. (1987) also obtained highest 1000 seed weight with 120 kg N ha^{-1}.

Table 7: Effect of nitrogen (N) on yield and thousand seed of mustard

Treatments	1000 seed weight(g)	Yield (t/ha)
N_0	2.91 c	0.93 c
N_1	3.27 b	1.46 b
N_2	3.52 a	1.57 a
LSD (0.05)	4.38	0.03
CV (%)	2.46	1.34

Where:

N_0= Control N_1= 100 kg/ha N_2= 120 kg/ha

The weight of thousand seed was not significantly influenced by P (Table 8). The highest thousand seed weight (3.40 g) was obtained from P_2 treatment. The lowest thousand seed weight (2.87 g) was obtained from without P.

Table 8: Effect of phosphorus (p) on yield and thousand seed of mustard

Treatments	1000 seed weight(g)	Yield (t/ha)
P_0	2.87 b	0.92 c
P_1	3.03 b	1.32 b
P_2	3.40 a	1.55 a
LSD (0.05)	0.26	0.02
CV (%)	2.46	1.34

Where: P_0= Control P_1= 25 kg/ha P_2= 35 kg/ha

Thousand seed weight was significantly affected by both N and P (Table 9). The highest thousand seed weight (3.53 g) was found in T_6 (N_1P_2 treatment combination), 100 kg N/ha and 35 kg P/ha whereas the lowest thousand seed weight (2.98 g) was found in N_0P_0 treatment (Table 9). These results suggest that combined use of appropriate doses of N and P may produced maximum thousand seed weight than their single application.

4.9 Seed yield

The different dose of N had significant effect on rapeseed yield per ha (Table 7). The maximum yield of seed per ha (1.57 t) was obtained from N_2, 120 kg N ha^{-1} , whereas the minimum yield of seed per hectare (0.93 t) was obtained from N0, without N. Further increase in N level beyond 100 kg ha^{-1} could not improve the seed yield. These results is consistent with the N-induced increase of growth parameters along with number of siliquae $plant^{-1}$, and thousand seed weight (Table 7). The higher seed yield ha^{-1} was also obtained with same N rate reported by Singh and Prasad (2003), Singh et al. (2003), Shukla et al. (2002). Therefore, N can enhance the seed yield (t ha^{-1}) of mustard variety BARI sarisha-15.

The total yield of mustard varied significantly due to the application of different levels of P fertilizer (Table 8). The highest yield of seed (1.55 t ha^{-1}) was obtained from P_2, 35 kg P ha^{-1} while P_0 gave the lowest (0.92 t ha^{-1}) yield. This result showed that the yield of mustard increased gradually with the higher doses of P fertilizer. Interestingly, this result is consistent with the P-induced yield components such as number of siliquae $plant^{-1}$, thousand seed weight and seed yield (Table 8) rather than growth parameters. Therefore, higher dose of P can increase seed yield of rapeseed.

The combined effect of N and P fertilizer was significant on yield of seed per hectare (Table 9). The highest yield of seed per hectare (1.59 tones) was obtained from T_6 (N_1P_2 treatment combination, 100 kg N ha^{-1} and 35 kg P ha^{-1}). The lowest yield of seed per hectare (0.85 tones) was obtained from treatment 1 (control condition). These results are consistent with the results of plant height, number of leaves and primary branch and length of siliquae.

Table 9: Interaction effect of nitrogen (N) and phosphorus (P) on the yield and thousand seed of mustard

Treatments	1000 seed weight(g)	Yield (t/ha)
T_1	2.98 g	0.84 g
T_2	3.09 f	0.98 f
T_3	3.21 e	1.17 e
T_4	3.31 de	1.39 d
T_5	3.37 cd	1.41 d
T_6	3.54 a	1.59 a
T_7	3.43 bc	1.45 c
T_8	3.47 ab	1.55 b
T_9	3.53 a	1.58 ab
LSD (0.05)	0.08	0.03
CV (%)	2.46	1.34

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

Nitrogen (N) increases crop yield by influencing different growth parameters and by producing more vigorous growth and development as reflected via increasing plant height, number of flowering branches, and number of siliquae and seeds per plant (Alien and Morgan, 1972). Therefore, these results suggest that the combined use of 100 kg N ha^{-1} and 35 kg P ha^{-1} produce the highest seed yield of mustard.

4.10 Stover yield (t ha $^{-1}$)

The nitrogen and phosphorus application favorably influenced the stover yield and the differences among the treatments were significant (Table 10). Nitrogen and phosphorus increase the stover yield of mustard. In combined application, the highest stover yield (3.65 t ha^{-1}) was found at T6 (100 kg N ha^{-1} and 35 kg P ha^{-1}) and that was significantly similar with T_9 (120 kg N ha^{-1} and 35 kg P ha^{-1}). The lowest (2.61 t ha^{-1}) stover yield was found at T_1 (Control condition) that was statistically similar with T_2 and T_3.

These findings were an agreement with that of Singh and Prasad (2003), Singh et al. (2002) and Meena et al. (2002) who observed higher stover yield of mustard with successive increase of the nitrogen level.

Table 10: Interaction effect of nitrogen (N) and phosphorus (P) on the stover yield, biological yield and harvest index of mustard

Treatments	Stover Yield ($t\ ha^{-1}$)	Biological Yield ($t\ ha^{-1}$)	Harvest Index (%)
T_1	3.22 d	4.07 e	20.82 e
T_2	3.26 d	4.24 de	23.113 d
T_3	3.34 cd	4.5167 cd	26.052 c
T_4	3.45 bc	4.84 bc	28.719 bc
T_5	3.52 ab	4.93 ab	28.600 bc
T_6	3.65 a	5.24 a	30.344 a
T_7	3.55 ab	5.0067 ab	29.095 b
T_8	3.58 ab	5.1367 ab	30.305 ab
T_9	3.64a	5.2267 a	30.358 a
LSD	0.17	0.34	1.25
CV %	2.88	4.17	7.28

Where: T_1= N_0P_0 (control condition), T_2= N_0P_1 (N_0=0 kg/ha and P_1=25 kg/ha), T_3= N_0P_2 (N_0=0 kg/ha and P_2=35 kg/ha), T_4= N_1P_0 (N_1=100 kg/ha and P_1=0 kg/ha), T_5=N_1P_1 (N_1=100 kg/ha and P_1=25 kg/ha), T_6= N_1P_2 (N_1=100 kg/ha and P_2=35 kg/ha), T_7= N_2P_0 (N_2=120 kg/ha and P_0=0 kg/ha), T_8= N_2P_1 (N_2=120 kg/ha and P_1=25 kg/ha), T_9= N_2P_2 (N_2=120 kg/ha and P_2=35 kg/ha).

4.11. Biological yield (t ha $^{-1}$)

It was evident from the results (Table 10) that biological yield was significantly affected by the different doses of N fertilizer. Higher doses of nitrogen application gave the higher amount of biological yield. The phosphorus application also significantly affected the biological yield of mustard. The maximum biological yield (5.24 t ha^{-1}) was found from T_6 (100 kg N ha^{-1} and 35 kg P ha^{-1}) that was statistically similar with T_9 (120 kg N ha^{-1} and 35 kg P ha^{-1}). On the other hand, the lowest biological yield (4.07 t ha^{-1}) was obtained from T_1 (control condition) that was followed by T_2 and T_3. The biological yield increased with the increasing rate of nitrogen level stated by Shrirame et al. (2000).

4.12 Harvest index (%)

Harvest index is the ratio of economic yield and biological yield. Harvest index was significantly influence due to nitrogen and phosphorus doses (Table 10). The highest harvest index (30.36 %) was found in treatment T_9 (120 kg N ha^{-1} and 35 kg P ha^{-1}) and that was statistically similar with T_6 (100 kg N ha^{-1} and 35 kg P ha^{-1}) and T_8 (120 kg N ha^{-1} and 25 kg P ha^{-1}). The lowest harvest index (20.82 %) was found at T_1 (control condition) that was statistically lower than other treatments. It is again ascertained that higher partitioned of dry matter to sink might have happened of the nitrogen and phosphorus fertilizer use in mustard crop.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh during rabi season, November 2020 to February 2021, situated under the Modhupur Tract (AEZ-28). The research work was done to investigate the influence of nitrogen and phosphorus application on the growth and yield of mustard. In this experiment, the treatment consisted of three different N levels viz. N_0 = 0 kg N/ha, N_1 = 100 kg N/ha and N_2 = 120 kg N/ha, and three different level of P viz. P_0 = 0 kg/ha, P_1 =25 kg P/ha and P_2 =35 kg P/ha. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid as a source of N, P, K, S, and B respectively were applied according to treatment and area of experimental unit plot. Urea was applied two equal splits, the first one-half of urea was applied as basal and second one-half was applied at 30 DAS. After emergence of mustard seedlings, various intercultural operations such as thinning, weeding, irrigation, drainage and pest management were accomplished for better growth. The collected data were statistically analyzed for evaluation of the treatment effect (different levels of nitrogen and phosphorus). Results showed a significant variation among the treatments in respect majority of the observed parameters.

There is significant difference among the different levels of N in respect of almost all parameters. The tallest plant (98.96 cm) was recorded with N_2 (120 kg N ha^{-1}). The tallest plant height 10.20, 89.50 and 98.96 cm, respectively at 25, 45 and 60 DAS were produced with 120 kg N/ha treatment. The maximum number of leaves per plant (32.88) was also produced by N_2 (120 kg N ha^{-1}).The maximum number of primary branches per plant (6.96 and 7.41 at 45 DAS and 60 DAS respectively) was produced due to application of 120 kg N ha^{-1}. The maximum number of secondary branches per plant (3.02) was produced with 120 kg N ha^{-1}. The maximum number siliquae per plant (113.59) was obtained in plots which received 120 kg N ha^{-1}. The longest length of siliquae (5.02 cm) was produced by N_2, 120 kg N ha^{-1}. The maximum number seed per siliquae (20.246) was obtained in plots which received 120 kg N ha^{-1}. The maximum thousand seed weight (3.52 g) was also produced by N_2. The maximum yield of seed per hectare (1.57 t) was obtained from N_2 (120 kg N ha^{-1}), whereas the minimum yield of seed per hectare (0.93 t) was obtained from N_0 (without N). For all parameters treatment N_1 gives nearest result with treatment N_2.

The growth component like plant height, number of leaves, branches per plant and length of slliquae were influenced significant due to application of P. The tallest plant (98.2 cm) was produced with P_2 (35 kg P ha^{-1}). The maximum number of leaves per plant (32.10), number of primary branches per plant (6.61 and 7.10 in 45 DAS and 60 DAS respectively), number of secondary branches (2.96) per plant, length of siliquae (5.0 cm) was produced with P_2, 35 kg P ha^{-1}. The maximum number of siliquae per plant (112.31), number of seed per pod (19.87) and thousand seed weight (3.4033g) was obtained from P_2, 35 kg P ha^{-1}. The highest yield of seed (1.55 t/ha) was obtained from P_2, 35kg P ha^{-1} while P_0 gave the lowest (0.92 t ha^{-1}), yield. For all parameters treatment P_1 gives nearest result with treatment P_2.

The combinations of N and P had significant effect on almost all parameter. The tallest plant (99.33 cm) was found in T_6 (100 kg N ha^{-1} and 35 kg P ha^{-1}). The maximum number of leaves per plant (33.57), number of primary branches per plant (7.07 and 7.73 at 45 DAS and 60 DAS respectively), number of secondary branches (3.20) per plant and length of siliquae (5.15 cm) was found in the same treatment. The maximum number of siliquae per plant (115.30), number of seed per siliquae (21.0), thousand seed weight (3.54 g) was also found in T_6 (100 kg N ha^{-1} with 35 kg P ha^{-1}). Moreover the highest yield of seed per hectare (1.59 tones) was obtained from T_6 (100 kg N ha^{-1} and 35 kg P ha^{-1}). The lowest yield of seed per hectare (0.8467 tones) was obtained from T_1 (control condition). For all parameters T_9 (combination of 120 kg N ha^{-1} and 35 kg P ha^{-1}) gives almost similar result with treatment T_6. Significance difference between T_6 and T_9 is very low. But cost of production of T_9 is higher than T_6. Therefore T_6 (combination of 120 kg N ha^{-1} and 35 kg P ha^{-1}) is expected to be more profitable.

Considering the above results, it may be summarized that growth and seed yield contributing parameters of mustard are influenced significantly with N and P application. Therefore, the present experimental results suggest that the combined use of 100 kg N ha^{-1} and 35 kg P ha^{-1} along with recommended doses of other fertilizer would be beneficial to increase the seed yield of mustard variety BARI sarisha-15 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

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

1. Similar type of study is needed to conduct in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. The results are required to substantiate further with different varieties of rapeseed and mustard.

3. The mustard crop should be included in the rice based cropping system to increase the production in order to minimize the huge deficit of edible oil in the country.

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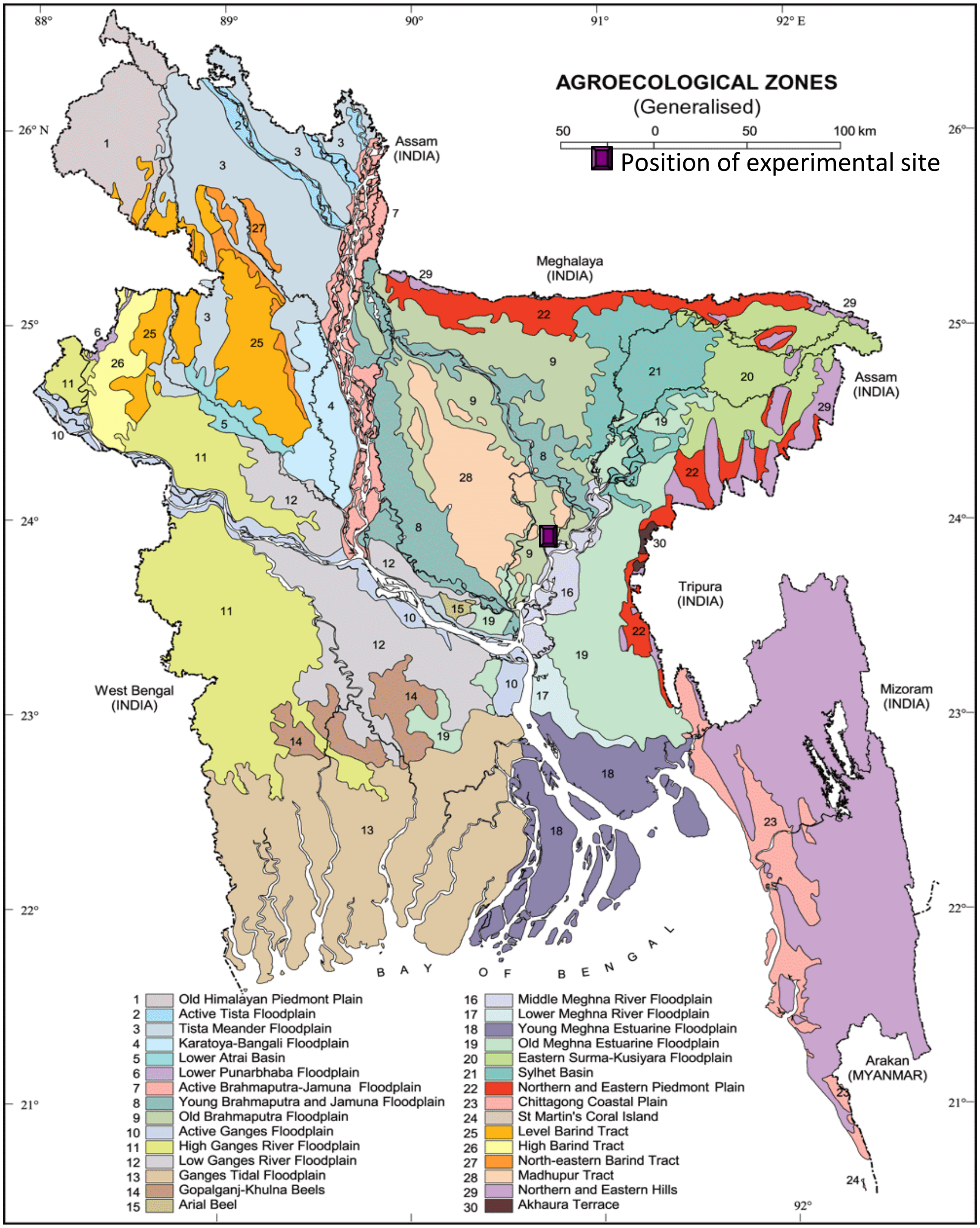
APPENDICES



Appendix I. Map showing the experimental site under study

Appendix II. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

Appendix III. Monthly average air temperature, relative humidity, total rainfall and sun shine hours of the experimental site during November'20-February'21

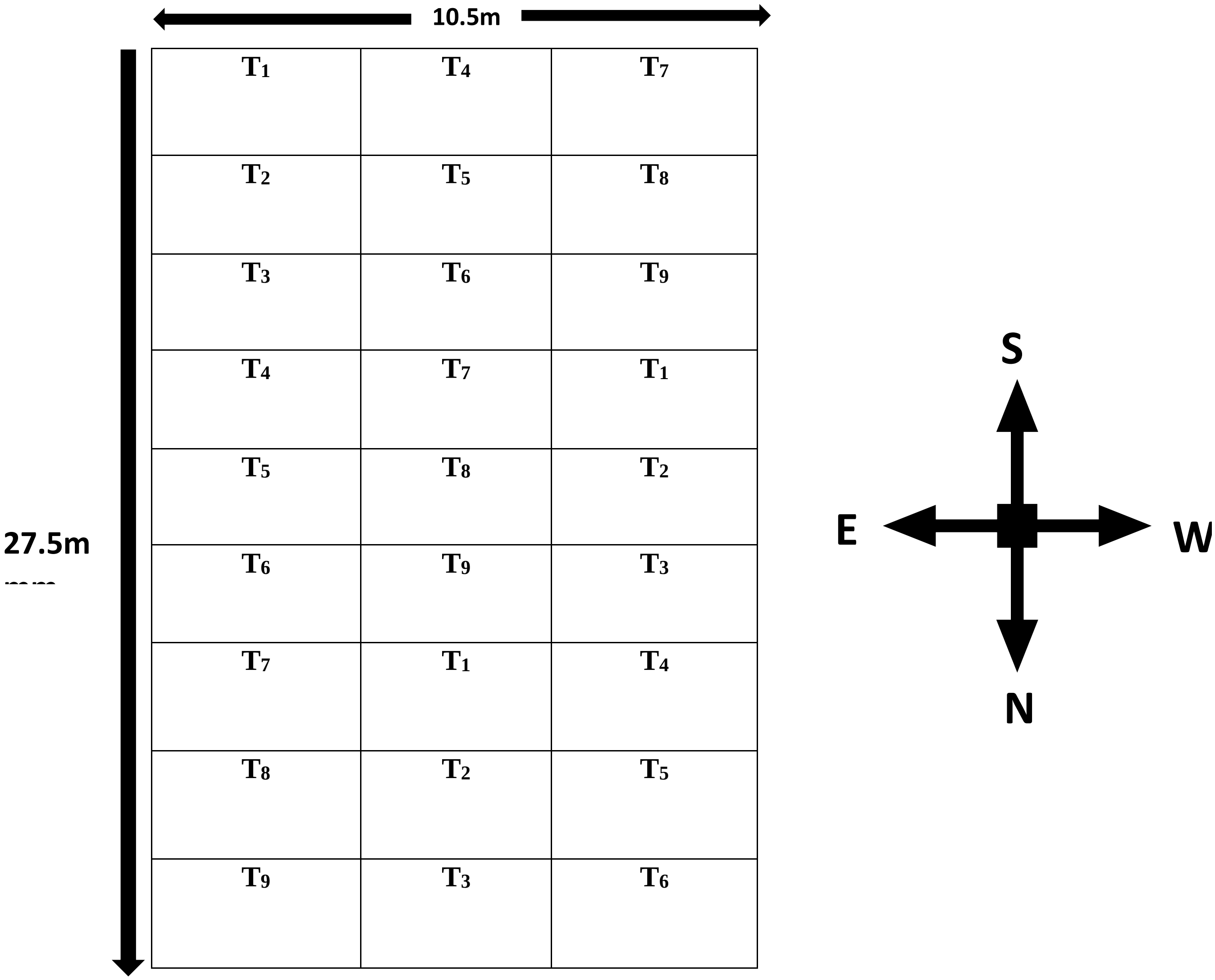
Year	Month	Air Temperature (^{0}C)			Relative Humidity (%)	Total Rainfall (mm)	Sun Shine (hr)
		Max.	Min.	Mean			
2020	Nov.	29.2	20.5	24.85	67.0	9	7.3
	Dec.	26.4	17	21.7	60.0	9	7.4
2021	Jan.	26	15.3	20.65	53.0	10	7.6
	Feb.	29.8	17.4	23.6	45.0	25	7.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka-1207

Appendix IV. Physiochemical characteristics of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	silty loam
pH	5.6
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Available P (µg/ g soil)	23.64
Exchangeable K (me/ 100 g soil)	0.60
Available S (µg/ g soil)	28.43
Available B (µg/ g soil)	0.05
Available Zn (µg/ g soil)	2.31

Source: Soil Resources Development Institute (SRDI), Dhaka-1207



Where: In vertical plot to plot space 1m and in horizontal plot to plot space 0.5m. Area of each plot 2.5m*2m = 5m^2

Appendix V: Field layout of the experimental plot

Appendix VI. Means square values for plant height (cm) of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)		
		25 DAS	45 DAS	60 DAS
Replication	2	9.94	158.81	75.18
Treatment	8	3.915*	102.31*	179.64*
Error	16	0.68	3.39	2.48

*Significant at 5% level

Appendix VII. Means square values for leaf no. of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)	
		45 DAS	60 DAS
Replication	2	0.8715	16.7937
Treatment	8	21.7298*	11.9851*
Error	16	1.1894	1.2225

*Significant at 5% level

Appendix VIII. Means square values for branches of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square of primary branches		Means square of secondary branches
		45 DAS	60 DAS	
Replication	2	10.6893	10.8011	10.1359
Treatment	8	0.6279*	0.7292*	0.5084*
Error	16	0.1340	0.6070	0.3930

*Significant at 5% level

Appendix IX. Means square values for growth parameter and yield of mustard

Sources of variation	Degrees of Freedom	Mean Square				
		Number of siliquae plant^{-1}	Length of siliquae (cm)	Number of seed siliquae^{-1}	1000 seed weight(g)	Yield (t/Ha)
Replication	2	143.580	9.31176	16.4404	0.05271	0.09100
Treatment	8	575.238*	0.34412*	20.5770*	0.10857*	0.17315*
Error	16	2.253	0.4260	1.3791	0.2380	0.370

*Significant at 5% level

Appendix X. Means square values for stover yield, biological yield and harvest index of mustard

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)		
		Stover Yield(t/Ha)	Biological Yield(t/Ha)	Harvest Index(%)
Replication	2	0.09000	0.36000	36.0000
Treatment	8	0.07731*	0.55569*	35.7482*
Error	16	1.207	7.459	2.925

*Significant at 5% level

Some pictorial view of my thesis paper

Figure 1: seed sowing

Figure 2: seeding stage

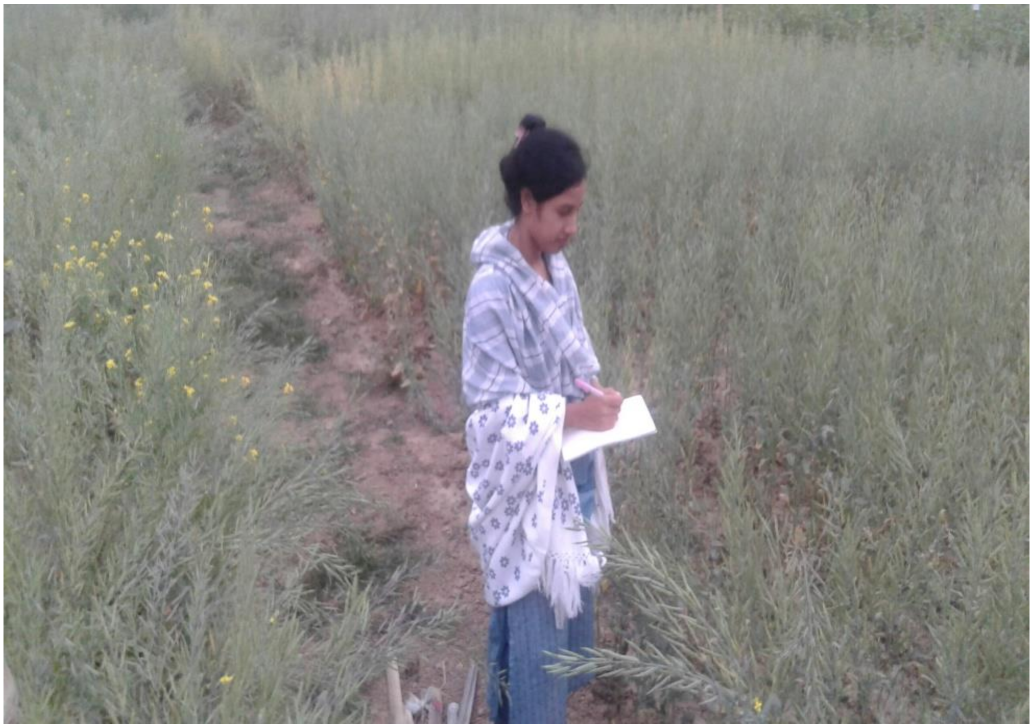


Figure 3: pod stage

Figure 4: harvesting stage