EFFECT OF NITROGEN AND ZINC ON THE GROWTH AND YIELD OF MUSTARD

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EFFECT OF NITROGEN AND ZINC ON THE GROWTH AND YIELD OF MUSTARD

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF NITROGEN AND ZINC ON THE GROWTH AND YIELD OF MUSTARD"** 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 bonafide research work carried out by **MD. RUMMAN SHAHRIA, Registration No.18-09040** 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:
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DEDICATED TO

MY

BELOVED PARENTS

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The Author

Effect of Nitrogen and Zinc on the growth and yield of Mustard

ABSTRACT

The field experiment was conducted during rabi season, November 2018 to February 2019 in the experimental field of Sher-e-Bangla Agricultural university, Dhaka to determine effects of nitrogen and zinc on growth and yield of mustard (*Brassica campestris*) variety BARI Sarisha-15. The treatments of the experiment was consisted of three levels of nitrogen i.e., 0 kg N/ha (N_0), 80 kg N/ha (N_1) and 120 kg N/ha (N_2); three levels of zinc i.e., 0 kg Zn/ha (Zn_0), 2 kg Zn/ha (Zn_1), 3 kg Zn/ha (Zn_2). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Results of this experiment showed a significant variation among the treatments in respect of the majority of the observed parameters. The 120 kg N/ha (N_2) gave the highest plant height, number of branches per plant, number of seeds per siliquae, number of siliquae per plant, length of siliquae and 1000 seed weight. Again, N_2 resulted the maximum seed yield (1.70 t/ha), stover yield, biological yield and harvest index. In addition, except siliquae length and harvest index, 3 kg Zn/ha (Zn_2) resulted highest values in all parameters while the lowest values were found in Zn_0 treatment. The interaction between nitrogen and zinc had significant effect on all the growth and yield parameters. Except the harvest index, the N_2Zn_2 treatment combination or 120 kg N/ha with 3 kg Zn/ha gave maximum values on all parameters including seed yield (1.82 t/ha). Based on these results, it can be suggested that 120 kg N/ha with the combination of 3 kg Zn/ha increased the growth and yield 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 Agricultural Organization
N	=	Nitrogen
Zn	=	Zinc
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muirate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	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 (*Brassica* spp) is one of the most important oil seed crops throughout the world after soybean and groundnut (FAO, 2004). It has a huge demand for edible oil in Bangladesh. Mustard stands at the top of the list among the oilseed crops grown in this country in respect of both production and acreage (BBS, 2015).

In the year of 2017-18 it covered 7.59 lakhs acre land and the production was 3.51 lakhs metric tons (Mt), whereas the total oilseed production was 4.53 lakhs Mt and total area covered by oilseed corps was 9.46 lakhs acre. In the year of 2018-19 mustard covered 6.67 lakhs acre land and the production was 3.11 lakhs Mt. (BBS, 2019).

Mustard seeds contain 40-45 % oil and 20-25 % protein (Mondal and Wahab, 2001). It is also an important raw material for industrial use such as in soaps, paints, varnishes, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but these are very costly compared to the oil obtained crops. Oil from oil obtained crops is easily digestible and its nutrition quality is better compared to the animal fats.

Bangladesh is suffering from acute shortage of edible oil in terms of domestic production. 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).

Mustard plant belongs to the genus Brassica under the family brassicaceae. The brassica has three species that produce edible oil, *B. napus, B. campestris, B. juncea*. Of these *B. napus* and *B. campestries* have the greatest importance in the world's oilseed trade. In this subcontinent, *B. juncea* is also an important oilseed crop. Mustard is the most important oilseed crop among other oilseed crops like groundnut, sesame, coconut, castor and linseed of Bangladesh. Moreover, it is very well known to the farmers. Mustard oil is being used as a medium of cooking from time immemorial (Khaleque, 1985).

Mustard is a cold loving crop and grows during Rabi season (October-February) usually under rainfed and low input condition in this country can be attributed to several factors, the nutritional deficiency, among others is highly important. There is very little scope expansion for mustard and other oilseed acreage in the country, due to competition from more profitable alternative crops. Although mustard is the principal oil crop in Bangladesh but its cultivation is neglected. Moreover the yield of mustard is low in Bangladesh as compared to other countries of the world. There is great possibility to increase its production by applying adequate fertilizers, selecting high yielding varieties and adopting proper management practices. One of the common constraints to higher yield is lack of balanced fertilization.

Many previous researches showed that fertilization can be used to boost up growth and yield of crops (Sinha et al. 2003, Shukla et al. 2002, Meena *et al.* 2002 and Zhao *et al*. 1997). Nitrogen is the vital element for plant growth and yield of this crop. Nitrogen increases yield by influencing a number of growth parameters such as number of branches and siliquae plant^{-1}, seeds siliqua^{-1} and 1000-seed weight by producing more vigorous growth and development

(Taylor *et al.,* 1991; Qayyum *et al.,* 1998). Again, nitrogen has impacts on seed protein and physiological functions and supports the plant with rapid growth, increasing seed and oil seed yield (Allen and Morgan 2009). Excessive use of nitrogen may reduce seed yield and quality appreciably (Cheema *et al.,* 2001; Laaniste *et al.,* 2004).

Zinc is one of the first micronutrients recognized as essential for plants that transported to plant root surface through diffusion (Maqsood *et al.,* 2009). Zn is a micronutrient and in case of its severe deficiency the symptoms may last throughout the entire crop season (Asad and Rafique, 2000). Zn deficient plant also appears to be stunted (Torun *et al.,* 2001) as a result approximately 2 billion people suffer from Zn deficiency all over the world (Asad and Rafique, 2002). The grain yield can be improved by addition of Zn fertilization (Maqsood *et al.,* 2009). Bora and Hazarika, (1997) reported highest stover yield (2770 kg ha^{-1}) with Zn and almost the same trend of seed yield. The seed yield can be improved by addition of Zn fertilization. Chen and Aviad, (1990) found that application of Zn along with other micronutrients improved soil organic matter and resulted in increasing mustard yields. Kutuk *et al.,* (2000) also suggested that the application of Zn has become necessary for improved crop yields.

Application of proper amount of both macro and micro nutrients is essential to maximize crop production. Nitrogen and Zinc fertilizer play an important role to increase the mustard production. Zhu et al. (1996) stated that Zn increased the yield of mustard seed 18% over NPK alone. In addition, the fertilizer requirement for maximum growth and yield of newly developed mustard variety BARI Sarisha-15 is not much investigated. With a view to determine the nitrogen and zinc requirement of this new variety a field study was conducted with the fallowing objectives:

- to study the growth and yield performance of mustard by using different doses of nitrogen and zinc fertilizer.
- to find out suitable combination of N and Zn fertilizer for better growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the common and most important oil crops not only in Bangladesh but also in many countries of the world. In Bangladesh the average mustard production is comparatively low in comparison to the developed countries. Many studies have been carried out in many countries of the world. A brief of the relevant, important and informative works and researches performed in the past are presented in this chapter.

2.1 Effect of Nitrogen on growth and yield of mustard :

A field experiment was conducted by Ma and Herath (2016) for 3 years in Ontario, Canada to assess the impact of different rates and timing of application of N fertilizer on canola yield. Significant improvements were resulted in seed yield due to side-dressed N application. Maximum seed yield (2700 kg ha^{-1} in 2011 and 3500 kg ha^{-1} in 2013) was produced by the treatments including side-dressing: 50 + 50 kg N ha^{-1} or 50 + 100 kg N ha^{-1} (preplant + side-dressing).

Mehmet *et al.* (2016) investigated that branch number, siliquae number $plant^{-1}$, seed number $siliquae^{-1}$, seed yield $plant^{-1}$, 1000-seed weight and seed yield increased as N doses increased.

Al-Solaimani *et al.* (2015) conducted an experiment to assess the effect of different rates of N fertilizer (0, 60, 120 and 180 kg N ha^{-1}) on crop growth, seed yield, yield components and seed quality. Statistical analysis of the obtained data showed that N 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. An overall improvement of 59 % in plant height, 112% in number of branches, 111

% in number of siliquae plant^{-1}, 87 % in 1000-seed weights were documented for 180 Kg N ha^{-1}.

Samir *et al*. (2015) observed 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 of canola. Nitrogen was applied in three equal splits, 2 weeks, 4 weeks and 8 weeks after planting during each crop season. Statistical analysis of the obtained data showed 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 resulted by moving from 120 Kg N ha^{-1} to 180 Kg N ha^{-1}. Current findings suggested that N at a rate of 180 Kg h^{-1} can be adopted as best level of nitrogen fertilizer for cultivation.

Keivanrad and Zandi (2014) assessed the agronomical and qualitative features of Indian mustard in a semi-arid region from Iran. All of the growth and yield parameters (plant height, number of seeds siliquae^{-1},the number of siliquae plant^{-1}, seed yield, biological yield, 1000-seed weight and harvest index) of mustard plant were significantly affected by N fertilization. Maximum seed yield (2961 kg ha^{-1}) was resulted for the crop utilized with 200 kg N ha^{-1}.

A field experiment was conducted by Mozaffari *et al.* (2012) to assess the effect of different levels of nitrogen (N_0, N_{75}, N_{150} and N_{225} kg ha^{-1}) on yield and some of the agronomical characteristics in mustard. The findings showed that increased amount of N up to 225 kg N ha^{-1} had a positive and significant impact on seed yield of mustard. However, increased levels of nitrogen had a significant effect on harvest index but showed no consistent trend. The highest and lowest point of harvest index was recorded in the treatments N_{225} and N_{75}

kg ha^{-1}. Moreover the results point out that the interaction effect of N on all of the parameters being studied was significant ($p<0.01$).

Ozturk (2010) stated that the winter rapeseed (*Brassica napus* L.) had potential to become an alternate oilseed crop both for edible oil production and energy agriculture (biofuel production) for Turkey. Three N sources, ammonium sulfate, ammonium nitrate and urea, were applied as hand broadcast on the soil surface at five doses (0, 50, 100, 150, and 200 kg N ha^{-1}). The traits investigated were plant height, number of branches and pods plant^{-1}, number of seed pod^{-1}, thousand seed weight, seed yield, oil and protein content. There were significantly effects on seed yield, oil and protein content, and other yield components due to N sources and rates. In general, ammonium sulfate and urea gave higher seed yield than ammonium nitrate. 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.

Kardgar *et al*. (2010) conducted an experiment to investigate the effects of different levels of N fertilization and plant density on the growth and yield of field mustard (*Brassica campestris*) cv. Goldrush, a study was carried out in Qazvin, Iran in 2009-2010 as a split-plot experiment based on a randomized complete block design with three replications. The main plot was pure N from urea source at four levels of 0, 50, 100 and 150 kg ha^{-1} and the sub-plot was plant density at four levels of 60, 80, 100 and 120 plants m^{-2}. Data analysis showed that different levels of plant density and N have significant impacts on the number of siliquae plant^{-1}, the number of seeds siliquae^{-1}, 1000-seed weight, seed yield, oil yield, biological yield and harvest index. The increase in N level increased all these traits at all treatments. Also, higher densities up to 100 plants m^{-2} followed to higher values of all traits. The density of 120 plants m^{-2} resulted in the lowest value of all characters at all treatments. In total, the densities of 80 and 100 plants m^{-2} and the application of 100 kg N ha^{-1} were considerably the best and produced the highest seed yield (3491 kg ha^{-1}) and oil yield (1084 kg ha^{-1}). Furthermore, maximum seed oil content (37.97%) was resulted at the density of 100 plants ha^{-1} treated with 150 kg N ha^{-1}.

Cheema *et al*. (2010) carried out an experiment on canola crop which is substituting the indigenous rape and mustard crops because of its high quality edible oil and its ability to grow well on rain and canal irrigated areas. Nitrogen is one of the most important elements for growth and development. A two-years field study (Nov. 2001-April 2003) was carried out to assess optimum N level and stage of its application for canola crop under irrigated conditions of Faisalabad, Pakistan. Five N levels (0, 30, 60, 90 and 120 kg ha^{-1}) were maintained at different times i.e., full N at sowing, ½ N at sowing +½ N at branching, ½ N at sowing + ½ N at flowering and ½ N at branching + ½ N at flowering. The total dry matter (TDM), crop growth rate (CGR), leaf area duration (LAD), seed yield, oil yield and protein content were significantly affected by different nitrogen rates. The highest N level (120 kg ha^{-1}) produced the highest values for all these traits as compared to minimum in control during both years of study. Nitrogen application timing did not significantly affect TDM, CGR, protein and oil contents however, split application of nitrogen (½ at sowing + ½ at branching or flowering) produced significantly higher seed and oil yield than full nitrogen at sowing or its split application as ½ at branching + ½ at flowering.

Allen and Morgan (2009) conducted an experiment to determine the effect of nitrogen on the growth of oilseed rape. The results of the second experiment, when 0, 105·5 and 211·0 kg N ha-^{1} were compared, presented and discussed. Nitrogen application increased the yields of seed and oil, principally through increased production of seeds by a larger number of pods. However, the nitrogen application had little impacts on average pod weight or average seed weight. Crop growth rates were amplified by the application of nitrogen and reached their top levels during pod development period when the leaf areas had declined to very low levels. The order of effects of nitrogen ($N_2 > N_1 > N_0$) was similar for LAI, number of pods per plant and number of seeds per pod.

Singh *et al*. (2004) found that nitrogen application had no impacts on the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application enhanced the seed yield of mustard. In seed and straw, N and S and total N and S uptake promoted due to application of 90 kg N/ha over its preceding rates.

Prasad *et al.* (2003) found in an research that N at 30 kg/ha + P at 20 kg/ha + Zn at 5 kg/ha, and N at 60 kg/ha + P at 30 kg/ha + S at 20 kg/ha produced maximum growth, yield and productivity, and also good cost: benefit ratio.

Tripathi (2003) conducted an experiment in Uttar Pradesh, India in 1994- 95 and 1995-96 to determine 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. Findings showed that all the yield and growth parameters 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 the maximum (Rs. 19 901/ha) at 160 kg N/h because seed yield was also maximum at this N rate. The benefit: cost ratio increased up to 160 kg N/ha.

Abdin *et al*. (2003) carried out field experiments in Rajasthan, Haryana and Uttar Pradesh, India to determine the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (V1) and rape cv. Pusa Gold (V2). The treatments comprised: T1 [(S0:N (50 + 50)]; T2 [S40:N (50 + 50)] for V1 and [S40:N(50 + 25 + 25) for V2]; and T3 [(S20 + 20):N(50 + 50) for V1] and S(20 + 10 + 10):N(50 + 25 + 25) for V2]. Split application of S and N (T3) resulted in a significant improvement in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t/ha for V1 and 3.06 t/ha for V2 under T3. The average oil yield under T3 was 1.71 t/ha for V1 and 1.42 t/ha in V2. The oil and protein contents in the seeds of V1 and V2 also increased with the split application of S and N. From these findings it can be optimize that the yield and quality of rapeseed-mustard can be considerably the best with the split application of 40 kg S/ha and 100 kg N/ha during the appropriate phenological stages of crop growth and development. Nitrogen plays a key role for the growth and development in rapeseed-mustard.

Khan *et al*. (2003) stated 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. Maximum stem, pod and plant dry mass were resulted 120 days after sowing. At maturity, pod number and seed yield increased.

Singh *et al*. (2003) found in an experiment that N at 120 kg/ha produced 4.51 times higher number of branches, 48.03 times higher siliquae number, 2.09 g siliquae 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.

Singh (2002) investigated that the application of N and P increased the length of siliquae, number of siliquae per plant, seeds per siliquae, seed yield and 1000-seed weight of mustard. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha treatments. The highest seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was not significant.

Sharawat *et al*., (2002) found that 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%).

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

Meena *et al*. (2002) observed in an experiment that the application of 60 kg N/ha enrolled 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 NPKMg 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.

2.2 Effect of Zinc on the growth and yield of mustard :

An experiment was carried out by Meena *et al*(2018)in rabi season of 2013-2014 and investigated that the best yield attributes characters was in treatment T8 (@NPK$_{100}$ + @ Zinc Sulphate$_{100}$) in respect to different levels intervals i.e. 30,60,90 days after sowing (DAS). Number of leaves per plant were 14.06, 19.10 and 20.10 and no. of branches per plant were 6.30, 11.40 and 12.20 found to be significant at 30 DAS, 60 DAS, 90 DAS but, Plant height was 29.10 cm, 99.53 cm and 107.16 cm was significant at 30 DAS and 60 DAS and interaction effect of NPK and Zinc Sulphate was non-significant at 90 DAS. In the same treatment T_8, combination of the Zinc Sulphate and N P K on an average test weight, fresh weight, dry weight and oil content (%) found significant and effect of NPK on test weight found significant and effect of Zinc Sulphate was non-significant. Adequate plant nutrient supply maintains the key for developing the food seed production food security.

S. Singh and V. Singh (2017) carried out a field experiment in two consecutive rabi seasons of 2012-13 and 2013-14 at Panwari village, Agra (Uttar Pradesh) in India to determine the effect of rate and source of zinc on productivity, quality and uptake of nutrients in Indian mustard (*Brassica juncea* (L.) Czern and Cosson). The experiment was conducted in randomized block design with two sources (zinc oxide and zinc sulphate) and five levels of zinc (0, 2, 4, 6 and 8 kg Zn/ha) with three replications. The results showed that significantly taller plants and higher number of siliquae/plant, seed and stover yields were found in zinc sulphate as compared to zinc oxide. The plant height, yield attributes, i.e. siliquae/plant, seeds/ siliquae and test weight, seed and stover yields of mustard were significantly improved with the increase in the levels of zinc and the highest seed (19.22 q/ha) and stover (55.77 q/ha) yields were found with 6 kg Zn/ha. Application of 6 kg Zn/ ha resulted in 22.2% higher seed and 24.7% stover yield than the yield obtained in the control (16.86 q/ ha seed and 48.60

q/ha stover). The content and yields of protein and oil remained unaffected by sources of zinc but increased significantly with increasing Zn doses, thus mustard fertilized with 6 kg Zn/ha, which was found the maximum yield of protein (384.0 kg/ha) and oil (39.3%, 754.7 kg/ha). The highest value of protein content (21.0%) was recorded with 8 kg Zn/ha. The uptake values of N, P, K and S by mustard seed and straw were not affected by different levels of zinc but uptake of zinc increased significantly with zinc sulphate over zinc oxide. The uptake of nutrients in mustard crop increased significantly up to 6 kg Zn/ha followed by reductions at 8 kg Zn/ha. Nutrient status in postharvest soil was not affected with different levels of zinc but improved significantly with different Zn levels. The availability of N and Zn improved significantly up to 8 kg/ha, on the other hand P, K and S contents increased up to 4 kg Zn/ha.

An experiment was conducted by Sahito HA. *et al.* (2014) to investigate the effects of Zinc on mustard. Two varieties (Early Mustard and S-9) were evaluated against six Zn levels (0, 2, 4, 6, 8 and 10 kg Zn ha -1). Significant improvements in the plant growth, seed yield and oil contents were found with increasing Zn levels. The results showed that there was a significant improvement in the growth, seed yield and oil content with increasing levels of Zinc, irrespectively. The highest Zn level of 10 kg/ha resulted 216 cm plant height, 10.86 branches/plant , took 55.66 days to initiate flowering, 574.50 pods/plant , 17.61 g weight of seeds /plant , 3.63 g seed index, 2037.20 seed yield kg /ha and 36.80 percent oil as the highest output. In case of varieties, S-9 ranked 1 st with 216.50 cm plant height, 10.84 branches per plant , took 56.33 days to initiate flowering, 581.11 pods per plant , 17.82 g weight of seeds per plant , 3.66 g seed index, 1960.30 seed yield kg /ha and 36.80 percent oil content; while variety Early Mustard resulted 186.56 cm plant height, 9.25 branches /plant , took 52.72 days to initiate flowering, 484.67 pods /plant , 14.50 g weight of seeds /plant , 2.90 g seed index, 1677.90 seed yield kg /ha and 35.13 percent oil content. It suggests that to achieve economically higher seed yields in mustard, the Zinc application to mustard may be done at the rate of 8 kg /ha.

S. K. Dubey *et al.* (2013) carried out an experiment at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Faizabad (Uttar Pradesh), during the rabi season of 2008- 09 in RBD and replicated three times. The sowing was done on November 20, 2008. The treatments comprised four levels of sulphur (0, 20, 40 and 60 kg S /ha) and four levels of zinc (0, 5, 7.5 and 10 kg Zn /ha). The mustard variety "Varuna" was used as test crop. Application of 60 kg S /ha and 10 kg Zn /ha, produced significantly higher plant, primary and secondary branches per plant, number of leaves per plant, days taken to flowering, days taken to maturity, number of siliquae per plant, length of siliquae, and number of seeds per siliquae, harvest index and oil content. However, dry matter accumulation per plant, 1000-grain weight (g), biological yield, seed yield, stover yield and protein content significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg /ha.

Azam M.G. *et al.* (2013) conducted an experiment in the farmer's field at the MLT site Tularampur, Narail (AEZ 11) during the rabi season of 2011-12 to investigate the performance of newly released mustard varieties to Zn fertilization. Three levels of Zinc sulphate- 2, 3, 4 kg/ha was used in Bari Sarisha- 14. It is found that application of Zinc can affect the growth, yield and plant characters of mustard. The supplement of Zinc is important micronutrient to control Zn deficiency in high and medium lands in Jassore region. The seed yield of mustard (cv. BARI Sarisha – 14) increased markedly for the application of Zn in soil, showing 11-25% yield increases over control. In there the yield of BARI Sarisha -14 was the highest in T_2 treatments i.e. application of 3 kg zinc/ha. So, it is suggested that the rate of 3 kg Zn/ha was found optimum for higher seed yield of mustard.

An experiment was carried out by Singh B. *et al*. (2012) to determine the effect of sulphur and zinc application on growth, yield attributes, seed yield and quality of mustard at Agronomy Research Farm, College of Agriculture, S. K. Rajasthan Agricultural University, Bikaner (Rajasthan) in India during rabi season of 2006-2007 and 2007-2008. Here, treatments consisted of five levels of sulphur (0, 20, 40, 60 and 80 kg/ha) and four levels of zinc (0, 3, 6 and 9 kg/ha). The findings showed that application of 40 kg S/ha and 6 kg Zn/ha improved growth parameters like plant height, number of branches per plant and yield components viz., number of siliquae per plant, seed per siliqua, seed yield and stover yield as compared to other treatments. Protein content significantly increased up to 40 kg S/ha and 6 kg Zn/ha.

2.3 Combined effect of Nitrogen and zinc on the growth and yield of mustard :

Kumar Vineet *et al.* (2016) conducted a thrice replicated field trial in rabi season 2009-10 to evaluate 5 nitrogen rates and 2 zinc fertilizer rates on growth, yield and quality of Indian mustard. The experimental results showed that application of 100 kg N/ha increased significantly maximum growth attributes viz. plant height(cm), number of total (primary + secondary) branches per plant, total dry matter accumulation at 60, 90 DAS and harvest stage, dry matter g/plant husk, stem as well as total and seed, straw as well as total, yield attributes (number of siliquae per plant, length of siliquae per plant, number of seed per siliquae, seed weight per siliquae, 1000 seed weight, seed weight per plant) and yield such as grain yield (1804 kg/ha), biological yield (8406 kg/ha) and harvest index (21.6%), besides achieved better protein content and, protein and oil yield. But the highest oil (42.3%) content was found in a plot where N was absent. Moreover, like as above, application of 20 kg/ha zinc recorded the highest growth, yield and quality of Indian mustard over control plot. Thus, the interaction between Nitrogen @100 kg/ha and zinc

@5 kg/ha appeared to be more promising to increase the productivity *B. juncea* on one hand and to improve its quality on the other hand.

Rimi *et al.* (2015) carried out an experiment in the field of Sher-e-Bangla Agricultural University, Dhaka during the rabi season from November 2011 to February 2012 to determine the role of nitrogen (N) and zinc (Zn) on seed yield contributing characters and seed quality of rapeseed (*Brassica campestris L.).* The experiment was factorial with two factors, factor A consisted of four different levels of N viz. 0, 60, 120, 180 (kg/ha) and factor B consisted of three different Zn levels viz. 0, 1, 2 (kg/ha). Randomized Complete Block Design (RCBD) with three replications was used in this experiment. Nitrogen significantly increased number of siliquae per plant, thousand seed weight and oil content percent up to 120 kg N/ha but the highest dose 180 kg N/ha failed to produce better results as other doses. The number of siliquae per plant and oil content percent was increased significantly with the increment of Zinc up to 2 kg/ha. Interestingly, seed weight of 100 siliquae, 1000 seed weight did not show any statistical differences with the increment of Zn. The combination of N and Zn significantly increased seed weight per plant, seed weight of 100 siliquae, 1000 seed weight and oil content of seed. The highest value of seed yield contributing characters and oil content of rapeseed was studied with the combined dose of 120 kg N/ha and 2 Kg Zn/ha whereas the lowest values were found from control. The highest oil content (43.29%) was found in 120 kg N/ha with 2 Kg Zn/ha treatment combination. Separately, the combined use of N and Zn did not show any significant differences on regulation germination rate of rapeseed. Based on the present results, it is suggested that the combined doses of 120 kg N/ha with 2 kg Zn/ha is appropriate for higher yield and quality seed production of rapeseed using cv. BARI Sarisha 15.

A field experiment was conducted at Bichpuri in India by SP Singh and V Singh (2005) to determine the response of indian mustard [*Brassica juncea (L.*) Czenz & Cosson] to different levels of Nitrogen, Sulphur and Zinc. The research is done during winter season of 2000-2002. The seed yield of mustard significantly increased with increasing levels of applied N, S & Zn. Nitrogen application increased the mean seed yield by 36.2%, while decreased the oil content by 0.5% form the control. Sulphur application increased the mean seed yield and oil content by 35.6% and 6.3%. Zn application increased 12% & 0.7%, respectively over the control. Nitrogen, Sulphur and Zinc application increased significantly the protein contents in seed.

CHAPTER III

Materials and Methods

The experiment was conducted during rabi season at research farm, Sher e Bangla Agricultural University to determine the effect of nitrogen and zinc on the growth and yield of mustard variety BARI Sarisha-15 (*Brassica campestris).*

3.1 Experimental Site

The field experiment was located at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to February 2019. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract , which falls into Deep Red Brown Terrace Soils. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

The soil of the experimental field is slightly acidic in reaction with low organic matter content. Top soil was sandy loam in texture. Soil p^H was 5.47-5.63 and has organic carbon 0.89%. The research field was flat having available irrigation and drainage system and above flood levels. The selected plot was medium high land.

3.3 Climate

The experimental area is situated under the sub-tropical climate and 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. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Bangladesh Meterological Department (Appendix VI).

3.4 Plant material

BARI Sarisha-15 (*Brassica campestries*) developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was used as planting material in this experiment. The seed was collected from the BARI. Before sowing germination test of seeds were done in the laboratory and percentage of germination was found over 95%.

3.5 Experimental treatments

The experiment consisted of two treatment factors as mentioned below:

Factor A: Nitrogen levels designated as:

N_0 = 0 kg N ha^{-1} (control)
N_1 = 80 kg N ha^{-1}
N_2 = 120 kg N ha^{-1}

Factor B: Zinc levels designated as:

Zn_0 = 0 kg Zn ha^{-1} (control)
Zn_1 = 2 kg Zn ha^{-1}
Zn_2 = 3 kg Zn ha^{-1}

Treatment combinations:

T_1=N_0Zn_0	T_2= N_0Zn_1	T_3= N_0Zn_2
T_4= N_1Zn_0	T_5= N_1Zn_1	T_6= N_1Zn_2
T_7 = N_2Zn_0	T_8= N_2Zn_1	T_9= N_2Zn_2

3.6 Design and layout

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 2 m × 1.5 m = 3 m^2 and total numbers of plots were 27. There were 9 treatment combinations. Layout of the experiment was done on November 04, 2018 with inter plot spacing of 0.75 m and inter block spacing of 0.75 m. Plant spacing was maintained with 30 cm and 5 cm, as of line to line and plant to plant distance, respectively. The layout has been shown in Appendix V.

3.7 Land preparation

The land of the research field was first opened on November 5, 2018 with a power tiller. Then it was exposed to the sun for 7 days prior to the next ploughing. Then, the land was ploughed and cross-ploughed to have a good tilth. Laddering was done for breaking the soil clods into small pieces after each ploughing. All the weeds and stubbles were removed from the research field. The land operation was completed on 13 November 2018. According to the layout of the experiment, the entire experimental area was divided into blocks and subdivided into plots for the sowing of mustard. Irrigation and drainage channels were also made around the plots.

3.8 Fertilizer application

In this experiment fertilizers were used according to BARI and under as follows:

Fertilizers	Rate of application per ha
Urea	As per treatment
TSP	36 kg
MoP	80 kg
Gypsum	20 kg
$ZnSO_4$	As per treatment
Boric Acid	1.5 kg

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid required per plot were calculated. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil during final land preparation. Rest of the urea was top dressed after 30 days after sowing (DAS).

3.9 Seed Sowing

Sowing was done on 14th November, 2018 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 8 kg ha^{-1}. After sowing, the seeds were covered with the soil and slightly pressed by hand. Plant population was kept constant through maintaining plant to plant distant 5 cm in row.

3.10 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.10.1 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 27 November 2018. At the same time first thinning was done. The final weeding and thinning were done after 25 days of sowing, on 10 December 2018. Care was taken to maintain constant plant population per plot.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given on the post sowing. The second irrigation was given at 15 DAS on 29^{th} November, 2018. The final irrigation was given at the stage of seed formation (50 DAS), on 4^{th} January, 2019.

3.10.3 Crop protection

The crop was sprayed with Malathion 57 EC@ 2ml L^{-1} of water at siliquae formation stage to control aphids. The crop was kept under constant observations from sowing to harvesting.

3.11 General observations of the experimental field

Constant observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.12 Sampling

Ten sample plants were collected randomly from each plot. These 10 plants were used for taking data for yield attributes.

3.13 Harvest and post-harvest operation

Previous randomly selected ten plants, those were considered for the growth analysis was collected from each plot to study the yield and yield contributing parameters. Rest of the crops was harvested when 80% of the siliquae in terminal raceme turned golden yellow in colour. After collecting sample plants, harvesting was done on February 20. To avoid shattering, harvesting was done in the morning. The harvested crops from each plot were tied into bundles separately and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.14 Drying and weighing

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

3.15 Data Collection

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Some data were collected from sowing to harvesting with 20 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 taken from selected plants which were marked by tag. Final field data were collected at harvesting stage.

Data were collected on the following parameters:

1. Plant height (cm)

2. Number of branches per plant

3. Number of siliquae per plant

4. Number of seed per siliquae

5. Length of siliquae (cm)

6. Thousand seed weight (g)

7. Seed yield (t/ha)

8. Stover Yield (t/ha)

9. Biological Yield (t/ha)

10. Harvest Index (%)

3.16 Methods of recording data

3.16.1 Plant height (cm)

The height of the mustard plants was recorded at harvest. The height of 10 preselected sample plants were taken from the ground level to the tip of the shoot. Then the mean of the data were taken and expressed in cm.

3.16.2 Number of branches per plant

Total number of branches was taken at harvest. All the branches present on randomly selected plants were counted and average number of branches per plant was taken.

3.16.3 Number of siliquae per plant

Number of siliquae was counted from randomly selected ten plants after harvest and averaged them to have number of siliquae per plant.

3.16.4 Number of seeds per siliquae

Number of total seeds of 10 randomly preselected sample plants from each plot was recorded and the average number was expressed per siliquae basis.

3.16.5 Length of siliquae (cm)

Number of siliquae was recorded from randomly selected 10 sample plants after harvest and mean number was expressed in cm.

3.16.6 Thousand seed weight (g)

One thousand sun dried and cleaned seeds were counted randomly from the seed stock and weighed of seeds. Then the weight of 1000 seeds were recorded by means of a digital electrical balance and expressed in gram.

3.16.7 Seed yield (t/ha)

Seeds obtained from harvested area of each unit plot were dried in the sun and weighed. The seed weight was expressed in t/ha.

3.16.8 Stover yield (t/ha)

The Stover obtained from the harvested area of each unit plot was dried separately and weight was recorded. These values were expressed in t/ha.

3.16.9 Biological yield (t/ha)

Biological yield was calculated by using the following formula:

Biological yield= Seed yield + Stover yield

3.16.10 Harvest index (%)

Harvest index is the ratio of seed yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

Harvest index = (Seed yield / Biological yield) × 100

3.17 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:

3.17.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was estimated by plotting the values of % sand, % silt and % clay to the Marshall's textural triangular co-ordinate following the USDA system.

3.17.2 Soil pH

pH of soil was estimated with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1973).

3.17.3 Organic carbon

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

3.17.4 Organic matter

Soil organic matter content was determined by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724.

% organic matter = % organic carbon × 1.724

3.17.5 Total nitrogen

Total nitrogen content in soil was estimated 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:

$$\% \, N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4
B = Blank titration (ml) value of standard H_2SO_4
N = Strength of H_2SO_4
S = Sample weight in gram

3.17.6 Available Phosphorus (ppm)

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ solution, p^H 8.5 (Olsen et al., 1954). Phosphorus in the extract was measured spectrophotometrically after development of blue colour (Black, 1965).

3.17.7 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).

3.17.8 Available Zinc

Available Zinc content was estimated by extracting the soil with Zncl2 solution as described by Page et al. 1982. The digested Zn was determined by developing turbidity by adding Zncl2 solution. The intensity of turbidity was measured by spectrophotometer at 420 mm wavelengths (Hunter, 1984).

3.18 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The data obtained from the experiment on various parameters were statistically analyzed in MSTAT-C computer program (Russel, 1986). 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 present experiment was carried out to study the effect of different levels of nitrogen and zinc on growth and yield parameters of mustard plants. The analyses of variance (ANOVA) of the data on different components are given in Appendix II and III. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Plant height:

4.1.1 Effect of nitrogen levels:

The results of this study showed that mustard plant height (Fig. 1) was significantly affected by nitrogen (N) levels. Here, the tallest plant (76.69 cm) was recorded with $N_{2,}$ 120 kg N ha^{-1}. In contrast, the shortest plants were recorded from control, N_0 and it was 62.20 cm. The requirement of nitrogen fertilizer can differ much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc. These results are in agreement with those of Singh *et al*. (2003), Tripathi and Tripathi (2003), Singh (2002). Similar results were observed by Tomar *et al.* (1996), FAO (1999), Ali and Ullah (1995), Shamsuddin *et al.* (1987), Ali and Rahman (1986) and Hasan and Rahman (1987). Above all, these findings suggest that higher doses of N increase plant height of mustard.

4.1.2 Effect of zinc levels:

Again, the results showed that Zinc (Zn) levels showed significant effect on mustard plant height. It can be observed from the figure (Fig. 2) that Zn_2 , 3 kg Zn ha^{-1} showed the tallest plant (73.10 cm) and the control, 0 kg Zn ha^{-1} produced the shortest plant (69.94 cm) .

4.1.3 Combined effect of nitrogen and zinc levels:

Interaction between N and Zn (Table 4.1) had significant effect on mustard plant height. The tallest plant (78.37 cm) was resulted in N_2Zn_2 treatment combination, 120 kg N/ha with 3 kg Zn/ha whereas the shortest plant (59.97 cm) was observed in the control treatment combination. Singh (2002) observed that plant height increased significantly with successive increase in nitrogen up to 120 kg/ha. These results showed that mustard plant height increases with combined use of nitrogen and zinc.

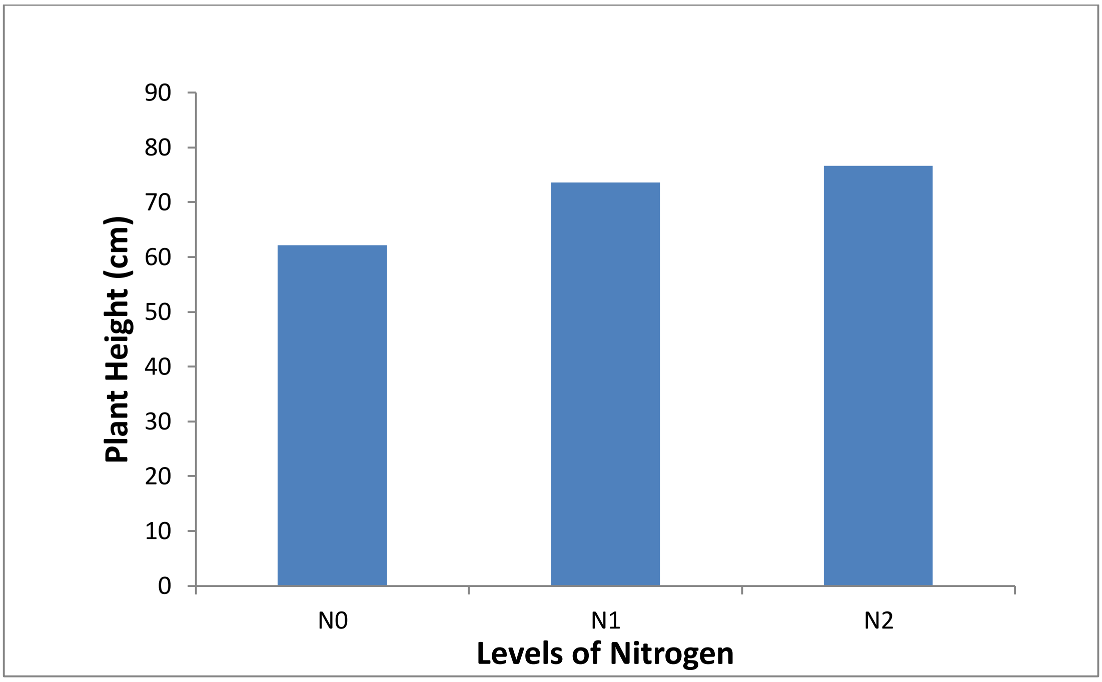

Fig 1: Effect of different levels of nitrogen on plant height (cm) of mustard at harvest

Fig 2: Effect of different levels of zinc on plant height (cm) of mustard at harvest

4.2 Number of branches per plant:

4.2.2 Effect of nitrogen levels:

The significant result was found in branches per plant of mustard by the different levels of nitrogen application. The figure (Fig. 3) indicated that $N_{2,}$ 120 kg N ha^{-1} produced the maximum number branches per plant (5.18) whereas N_0 , the control produced the minimum number of branches per plant (3.99). Khan *et al.* (2002) and Uddin *et al.* (1992) suggested that number of branches $plant^{-1}$ increased significantly with increasing nitrogen levels up to 120 and 150 kg N ha^{-1}, respectively.

4.2.2 Effect of zinc levels:

A statistically significant variation was found in number of branches per plant by different levels of Zinc application. The maximum number of branches per plant (4.81) was recorded by $Zn_{2,}$ 3 kg Zn ha^{-1}. On the other hand minimum number of branches per plant (4.36) was recorded by $Zn_{0,}$ the control (Fig. 4).

4.2.3 Combined effect of nitrogen and zinc levels:

The combined effect of nitrogen and zinc was found significant in number of branches per plant (Table 4.1). The highest number of branches per plant (5.99) was resulted in N_2Zn_2 treatment combination, 120 kg N/ha and 3 kg Zn/ha whereas lowest number of branches per plant (3.66) was resulted in N_0Zn_0, control treatment. The result of this study suggested that combined use of nitrogen and zinc increases mustard yield.

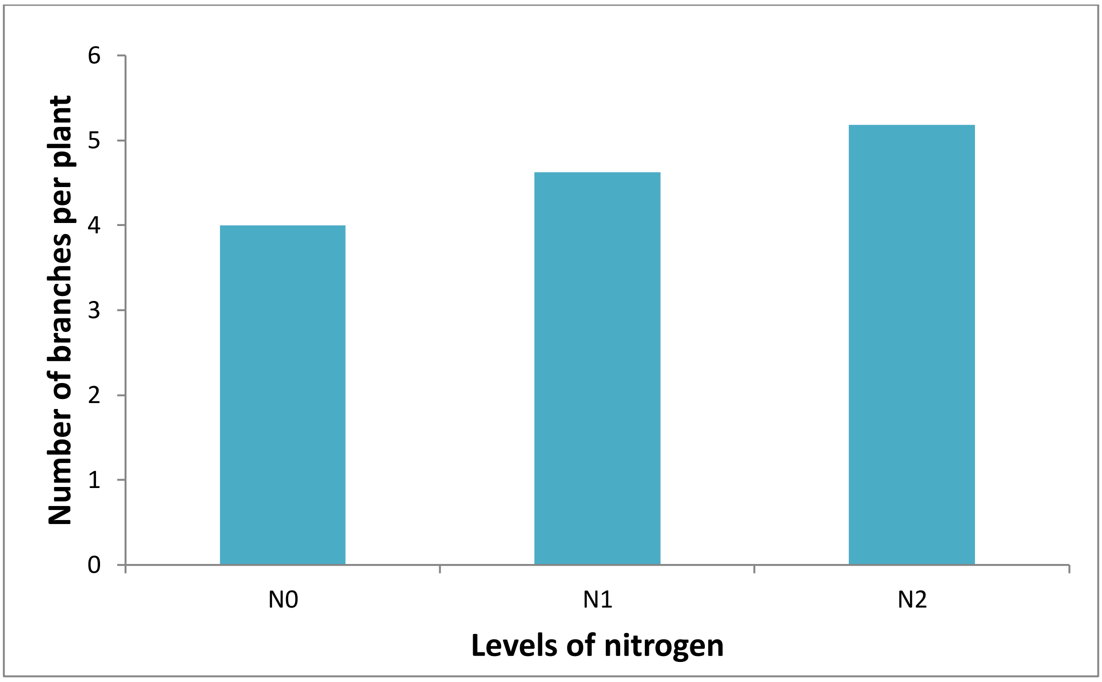

Fig 3: Effect of different levels of nitrogen on number of branches per plant of mustard

Fig 4: Effect of different levels of zinc on number of branches per plant of mustard

Table 4.1: Combined effect of different levels of nitrogen and zinc on plant height (cm), Number of branches per plant of mustard

Treatment	Plant height (cm)	Number of branches per plant
$T_1(N_0Zn_0)$	59.97 h	3.66 d
$T_2(N_0Zn_1)$	62.35 g	4.11 cd
$T_3(N_0Zn_2)$	63.40 f	4.22 c
$T_4(N_1Zn_0)$	69.68 e	4.33 c
$T_5(N_1Zn_1)$	77.50 b	5.33 b
$T_6(N_1Zn_2)$	73.65 d	4.22 c
$T_7(N_2Zn_0)$	77.17 b	5.11 b
$T_8(N_2Zn_1)$	74.53 c	4.44 c
$T_9(N_2Zn_2)$	78.37 a	5.99 a
$LSD_{0.05}$	0.3677	0.46
CV (%)	0.31%	5.98%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0: 0 kg N/ha (control) N_1: 80 kg N/ha N_2: 120 kg N/ha

Zn_0: 0 kg Zn/ha (control) Zn_1: 2 kg Zn/ha Zn_2: 3 kg Zn/ha

4.3 Number of siliquae per plant:

4.3.1 Effect of nitrogen levels:

The number of siliquae per plant was not found significant by different levels of nitrogen application (Table 4.2). N_2, 120 kg N/ha produced the maximum number of siliquae per plant (48.89). On the other hand, control treatment, N_0 produced the minimum number of siliquae per plant (41.00), that are correlate with the findings of Shukla et al.(2002) different levels of nitrogen increased siliquae per plant of mustard ensuring proper growth of plant. Sharawat *et al*. (2002) recorded maximum number of siliquae/plant with 120 kg N/ha.

4.3.2 Effect of zinc levels:

Different levels of zinc had no significant differences for siliquae per plant (Table 4.3). The highest number of siliquae per plant (47.52) was produced by Zn_2, 3 kg Zn/ha whereas lowest number of siliquae per plant (43.81) was resulted by the Zn_1, 2 kg Zn/ha.

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4.3.3 Combined effect of nitrogen and zinc levels:

Interaction between nitrogen and zinc had significant effect on number of siliquae per plant (Table 4.4). The highest number of siliquae per plant (57.00) was resulted in N_2Zn_2, 120 kg N/ha with 3 kg Zn/ha, whereas the lowest number of siliquae per plant (39.33) was found in N_0Zn_0, the control in where no nitrogen and zinc applied.

4.4 Number of seeds per siliquae:

4.4.1 Effect of nitrogen levels:

The results of this study showed that number of seeds per siliquae was significantly affected by different N levels (Table 4.2). Here, the highest number of siliquae per plant (23.56) was found in N_2, 120 kg N/ha. In contrast, the lowest number of siliquae per plant (20.92) was obtained from control, N_0, 0 kg N/ha combination. The results are in full agreement with findings of Singh (2002), Tarafder and Mondal (1990).

4.4.2 Effect of zinc levels:

A statistically significant variation was found in number of seeds per plant by different levels of Zinc application (Table 4.3). The highest number of branches per plant (22.91) was found in Zn_2, 3 kg Zn ha^{-1}. On the other hand lowest number of seed per siliquae (21.72) was found in Zn_0, the control plots where no zinc was applied.

4.4.3 Combined effect of nitrogen and zinc levels:

A significant variation indicated among the treatment combinations of N and Zn in number of seeds per siliquae (Table 4.4). The highest number of siliquae per plant (24.77) was recorded by N_2Zn_2, whereas the lowest number of seeds per siliquae (20.11) was recorded by the control plots, N_0Zn_0 treatment combination.

4.5 Length of Siliquae :

4.5.1 Effect of nitrogen levels:

Different levels of nitrogen showed significant effect on siliquae length of mustard (Table 4.2). The maximum length of siliquae (4.53 cm) was obtained from N_2Zn_2, 120 kg N/ha whereas the minimum (4.33 cm) length of siliquae was found from the control (0 kg N/ha) treatment. These results are in conformity with the finding by Shukla et al. (2002) and El-Kholy *et al.* (2007).

4.5.2 Effect of zinc levels:

The results of this study showed that mustard siliquae length was significantly affected by different levels of Zinc (Table 4.3). Here, the maximum length of siliquae (4.48 cm) was recorded with Zn_1, 2 kg Zn/ha. In contrast, the minimum siliquae length (4.37 cm) was obtained from control, Zn_0, 0 kg Zn/ha combination.

4.5.3 Combined effect of nitrogen and zinc levels:

Interaction of nitrogen and zinc application showed significant effect on length of siliquae of mustard (Table 4.4). The maximum length of siliquae (4.60 cm) was found in the N_2Zn_2 treatment combination, 120 kg N/ha and 3 kg Zn/ha whereas the minimum (4.30 cm) was obtained from control plots, N_0Zn_0 treatment combination.

4.6 Thousand Seed weight:

4.6.1 Effect of nitrogen levels:

Different nitrogen levels had significant effect on thousand seed weight of mustard (Table 4.2). The maximum thousand seed weight (2.88 g) was found in the N_2, 120 kg N ha^{-1} and the minimum (2.11 g) was obtained from the control treatment plots, N_0. Ozer (2003), Singh (2002) and Shamsuddin *et al.* (1987) also found highest 1000-seed weight with 120 kg N ha^{-1}.

4.6.2 Effect of zinc levels:

The application of zinc influenced significantly on the thousand seed weight (Table 4.3). The maximum thousand seed weight (2.72 g) was produced by Zn_2, and Zn_0 produced the minimum thousand seed weight (2.40 g).

4.6.3 Combined effect of nitrogen and zinc levels:

Combination of nitrogen and zinc application showed significant effect on thousand seed weight of mustard (Table 4.4). The highest thousand seed weight (3.14 g) was found in the N_2Zn_2 treatment combination, 120 kg N/ha and 3 kg Zn/ha whereas the lowest (1.92 g) was found from control plots, N_0Zn_0 treatment combination.

Table 4.2: Effect of different levels of nitrogen on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustard

N Dose	Number of seeds per siliquae	Number of siliquae per plant	Siliquae length (cm)	1000 seed weight (g)
N_0	20.92 c	41.00 a	4.33 c	2.11 c
N_1	22.33 b	47.44 a	4.44 b	2.74 b
N_2	23.56 a	48.89 a	4.53 a	2.88 a
$LSD_{0.05}$	0.11	8.50	0.07	0.07
CV (%)	0.53%	19.18%	1.80%	3.01%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0: 0 kg N/ha (control) N_1: 80 kg N/ha N_2: 120 kg N/ha

Table 4.3: Effect of different levels of zinc on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustard

Zn Dose	Number of seeds per siliquae	Number of siliquae per plant	Siliquae length (cm)	1000 seed weight (g)
Zn_0	21.72 c	46.00 a	4.37 b	2.40 c
Zn_1	22.19 b	43.81 a	4.48 a	2.60 b
Zn_2	22.91 a	47.52 a	4.45 ab	2.72 a
$LSD_{0.05}$	0.11	8.50	0.07	0.07
CV (%)	0.53%	19.18%	1.80%	3.01%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0: 0 kg Zn/ha (control) Zn_1: 2 kg Zn/ha Zn_2: 3 kg Zn/ha

Table 4.4: Combined effect of different levels of nitrogen and zinc on number of seeds per siliquae, number of siliquae per plant, siliquae length and 1000 seed weight of mustard

Treatment	Number of seeds per siliquae	Number of siliquae per plant	Siliquae length (cm)	1000 seed weight (g)
$T_1(N_0Zn_0)$	20.11 g	39.33 bc	4.30 d	1.92 g
$T_2(N_0Zn_1)$	20.54 f	41.44 abc	4.34 cd	2.13 f
$T_3(N_0Zn_2)$	22.12 c	42.22 abc	4.35 cd	2.27 e
$T_4(N_1Zn_0)$	21.38 e	43.44 abc	4.35 cd	2.49 d
$T_5(N_1Zn_1)$	23.78 b	55.55 ab	4.59 a	2.98 b
$T_6(N_1Zn_2)$	21.83 d	43.33 abc	4.40 bcd	2.75 c
$T_7(N_2Zn_0)$	23.67 b	55.22 ab	4.48 abc	2.79 c
$T_8(N_2Zn_1)$	22.24 c	34.44 c	4.53 ab	2.71 c
$T_9(N_2Zn_2)$	24.77 a	57.00 a	4.60 a	3.14 a
$LSD_{0.05}$	0.1986	14.73	0.13	0.13
CV(%)	0.53%	19.18%	1.80%	1.84%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0: 0 kg N/ha (control) N_1: 80 kg N/ha N_2: 120 kg N/ha

Zn: 0 kg Zn/ha (control) Zn_1: 2 kg Zn/ha Zn_2: 3 kg Zn/ha

4.7 Seed yield:

4.7.1 Effect of nitrogen levels:

Different levels of nitrogen exhibited statistically significant variation for seed yield (Table 4.5). The seed yield of mustard was converted into metric tons per hectare. The maximum seed yield (1.70 ton/ha) was obtained from the 120 kg N/ha and the minimum yield (1.03 ton/ha) was found from the control (0 kg N/ha) treatment. The increase in seed yield under all the doses of the nitrogen was significantly higher as compared to 0 kg of N/ha. The results are in full agreement with those findings of Seyedeh *et al.* (2012), Singh et al. (1998) and Tuteja et al. (1996). Moreover, Cheema *et al.* (2001) reported that the seed yield of *Brassica* increased with increased N application from 0 to 90 kg/ha, while at the highest N application (120 kg/ha), *Brassica* seed yield was significantly reduced.

4.7.2 Effect of zinc levels:

Application of zinc at different level had statistically significant differences for seed yield per hectare (Table 4.6). The highest seed yield (1.49 ton/ha) was recorded from Zn_2 treatment, 3 kg Zn/ha. On the other hand the lowest seed yield (1.31 ton/ha) was found in the Zn_0 treatment, the control.

4.7.3 Combined effect of nitrogen and zinc levels:

A significant variation indicated among the treatment combinations of N and Zn in seed yield (Table 4.7). The maximum seed yield (1.82 ton/ha) was found by N_2Zn_2, whereas the minimum seed yield (1.01 ton/ha) was obtained from the control plots, N_0Zn_0 treatment combination. Nitrogen increases crop yield by influencing growth parameters and by producing more vigorous growth and development through increasing plant height, leaf area index, total plant weight and seeds per plant (Allen and Morgan, 2009). So, the results indicate that the combined use of 120 kg N/ha and 3 kg Zn/ha produce the highest seed yield.

4.8 Stover Yield:

4.8.1 Effect of nitrogen levels:

Different doses of Nitrogen fertilizer had significant variation on the stover yield of mustard (Table 4.5). The maximum stover yield (2.79 t/ha) was recorded from the 120 kg N ha^{-1} and the minimum stover yield (2.06 t/ha) was found in the control (0 kg N/ha) treatment. This result is similiar with the findings of Mohiuddin *et al.* (2011). But, Meena *et al.* (2002) reported that higher stover yield at 60 kh N/ha.

4.8.2 Effect zinc levels:

Stover yield of mustard for different levels of zinc also showed statistically significant variation (Table 4.6). The highest significant increase in stover yield (2.60 t/ha) was obtained from Zn_2 treatment. On the other hand the lowest stover yield (2.37 t/ha) was obtained from the Zn_0 treatment, the control plots.

4.8.3 Combined effect of nitrogen and zinc levels:

Significant interaction effect was also obtained between nitrogen and zinc in consideration of stover yield under the present experiment. The maximum stover yield (2.91 t/ha) was obtained from the treatment combination N_2Zn_2 comprising of 120 kg N/ha and 3 kg Zn/ha, while the minimum stover yield (1.98 t/ha) was obtained from N_0Zn_0 i.e. no nitrogen no zinc (Table 4.7).

4.9 Biological Yield:

4.9.1 Effect of nitrogen levels:

A statistically significant variation was found in biological yield of mustard by different levels of nitrogen application (Table 4.5).The biological yield of mustard was converted into metric tons per hectare. The maximum biological yield (4.49 t/ha) was obtained by $N_{2,}$ 120 kg N/ha. On the other hand minimum biological yield (3.09 t/ha) was recorded by N_0, the control. These results are in consonance to result reported by Singh and Kumar (2014).

4.9.2 Effect of zinc levels:

Different levels of zinc exhibited statistically significant variation for biological yield (Table 4.6).The maximum biological yield (4.10 t /ha) was obtained from the 3 kg Zn/ha, Zn_2 and the minimum yield (3.69 t /ha) was found from the control (0 kg Zn/ha) treatment.

4.9.3 Combined effect of nitrogen and zinc levels:

Interaction between N and Zn (Table 4.7) had significant effect on mustard plant height. The maximum biological yield (4.74 t/ha) was found in N_2Zn_2 treatment combination, 120 kg N/ha with 3 kg Zn/ha while the minimum biological yield (2.99 t/ha) was observed in the control treatment combination, N_0Zn_0. From this study it suggests that proper combination of nitrogen and zinc increases biological yield.

4.10 Harvest Index:

4.10.1 Effect of nitrogen levels:

Harvest index is an important attribute in determining economic yield and represents an increased physiological capacity to mobilize photosynthates and translocate them to organs of economic value (Jamal *et al.,* 2006; Malhi *et al.,* 2007). Harvest index may be termed as the ratio of economic yield to biological yield. A statistically significant variation was found in harvest index by different levels of nitrogen application (Table 4.5). The maximum harvest index (37.87) was obtained by N_2 , 120 kg N ha^{-1} whereas the minimum harvest index (33.11) was recorded by N_0 , the control. This result is similar with the findings of Shukla and Kumar (1997).

4.10.2 Effect of zinc levels:

Harvest index of mustard for different levels of zinc also had statistically significant variation (Table 4.6). The maximum harvest index (36.27) was obtained from Zn_1 treatment. On the other hand the minimum harvest index (34.97) was obtained from the Zn_0 treatment, the control plots.

4.10.3 Combined effect of nitrogen and zinc levels:

Significant interaction effect was also obtained between nitrogen and zinc in consideration of harvest index under the present experiment (Table 4.7). The maximum harvest index (38.64) was recorded from the treatment combination N_2Zn_0, while the minimum stover yield (33.77) was recorded from N_0Zn_0 i.e. no nitrogen no zinc.

Table 4.5: Effect of different levels of nitrogen on Seed yield, Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

N Dose	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
N_0	1.03 c	2.06 c	3.09 c	33.11 c
N_1	1.52 b	2.65 b	4.18 b	36.48 b
N_2	1.70 a	2.79 a	4.49 a	37.87 a
$LSD_{0.05}$	0.03	0.04	0.05	0.50
CV (%)	1.84%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0: 0 kg N/ha (control), N_1: 80 kg N/ha N_2: 120 kg N/ha

Table 4.6: Effect of different levels of zinc on Seed yield (t/ha), Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

Zn Dose	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Zn_0	1.31 c	2.37 c	3.69 c	34.97 b
Zn_1	1.45 b	2.52 b	3.97 b	36.27 a
Zn_2	1.49 a	2.60 a	4.10 a	36.23 a
$LSD_{0.05}$	0.03	0.04	0.05	0.50
CV (%)	1.84%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Zn: 0 kg Zn/ha (control) Zn_1: 2 kg Zn/ha Zn_2: 3 kg Zn/ha

Table 4.7: Combined effect of different levels of nitrogen and zinc on Seed yield, Stover yield (t/ha), Biological yield (t/ha), Harvest index (%) of mustard

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
$T_1(N_0Zn_0)$	1.01 h	1.98 g	2.99 h	33.77 e
T_2 (N_0Zn_1)	1.04 g	2.04 f	3.08 g	33.80 d
T_3 (N_0Zn_2)	1.22 f	2.29 e	3.52 f	34.75 c
T_4 (N_1Zn_0)	1.36 e	2.50 d	3.86 e	35.47 c
T_5 (N_1Zn_1)	1.78 ab	2.84 ab	4.62 b	38.54 a
T_6 (N_1Zn_2)	1.44 d	2.61 c	4.04 d	35.41 c
T_7 (N_2Zn_0)	1.75 b	2.78 b	4.53 b	38.64 a
T_8 (N_2Zn_1)	1.53 c	2.67 c	4.21 c	36.47 b
T_9 (N_2Zn_2)	1.82 a	2.91 a	4.74 a	38.51 a
$LSD_{0.05}$	0.07	0.07	0.09	0.87
CV (%)	3.13%	1.59%	1.31%	1.45%

In a column means having similar letter(s) do not differ significantly as per LSD and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0: 0 kg N/ha (control) N_1: 80 kg N/ha N_2: 120 kg N/ha

Zn: 0 kg Zn/ha (control) Zn_1: 2 kg Zn/ha Zn_2: 3 kg Zn/ha

Chapter V

Summary and Conclusion

The experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during rabi season, from November 2018 to February 2019 to find the effect of different levels of nitrogen (N) and zinc (Zn) on growth and yield contributing characters of mustard. The experiment was formed by two factors. Factor A: Nitrogen (3 levels) i.e. 0 kg N/ha (N_0), 80 kg N/ha (N_1) and 120 kg N/ha (N_2); Factor B: zinc (3 levels) i.e. 0 kg Zn/ha (Zn_0), 2 kg Zn/ha (Zn_1), 3 kg Zn/ha (Zn_2). There were 9 treatments combinations. The total number of plots was 27. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications.

Data were collected in respect of the plant growth and yield characters for different levels of nitrogen and zinc. Plant height, Number of primary branches per plant, Number of siliquae per plant, Length of siliquae, Number of seed per siliquae, 1000 seed weight, Seed yield, Stover yield, Biological yield and Harvest index were recorded. The data obtained for these characters were statistically analyzed to find out the significance of the nitrogen and zinc. The mean differences among the treatments were compared by Least Significant Difference (LSD) test at 5% level of significance.

Nitrogen had significant effect almost on all parameters in mustard except number of siliquae per plant. The tallest plant height (76.69 cm) and the maximum number of branches per plant (5.182) were recorded from N_2 treatment. Again, the highest number of seed per siliquae (23.56), maximum length of siliquae (4.539 cm) and the maximum weight of thousand seeds (2.882 g) were obtained from N_2 treatment. Minimum values of these parameters were found in N_0 (control). Maximum number of siliquae per plant

(48.89) was also observed by N_2, 120 kg N/ha. The maximum seed yield (1.706 t/ha) was recorded from N_2 whereas the lowest seed yield (1.0 t/ha) was recorded from control condition, N_0. The highest stover yield (2.792 t/ha), highest biological yield (4.498 t/ha) and maximum harvest index (37.87%) were recorded from N_2, 120 kg N/ha. Lowest values of these parameters were also recorded from the control, N_0 treatment combination.

Number of siliquae per plant did not show any statistical difference for Zinc. The tallest plant height (73.10 cm), the highest number of branches per plant (4.812), the highest number of seeds per siliquae (22.91) were recorded from Zn_2 treatment combination, 3 kg Zn/ ha. Lowest values of these parameters obtained from the control, Zn_0. The highest number of siliquae per plant (47.52) was recorded from Zn_2 treatment whereas the lowest value (43.81) of this parameter was recorded from the Zn_1 treatment, 2 kg Zn/ ha. Again, the maximum 1000 seed weight (2.723 g), maximum length of siliquae (4.488 cm), maximum seed yield (1.497 t/ha) were obtained from Zn_1 treatment and the minimum (1.313 t/ha) was obtained from the Zn_0 treatment. Highest stover yield (2.609 t/ha) and highest biological yield (4.103 t/ha) were also recorded from Zn_2 treatment and minimum from Zn_0. However the maximum harvest index (36.27%) was obtained from Zn_1, 2 kg Zn /ha and the minimum was recorded from the control.

The combination of Nitrogen and Zinc showed significant effect on almost all parameter. The tallest plant height (78.37 cm), the highest number of branches (5.997), the highest number of siliquae per plant (57.00) and the highest number of seeds per siliquae (24.77) were recorded from N_2Zn_2 combination, 120 kg N/ha and 3 kg Zn/ha. Lowest values of these parameters recorded from the control plots where no nitrogen and no zinc were applied. The maximum siliquae length (4.60 cm), maximum 1000 seed weight (3.140 g) and highest seed yield (1.82 t/ha) were recorded from N_2Zn_2 combination. On the other hand minimum values of siliquae length (4.30 cm), minimum 1000 seed weight

(1.92 g) and seed yield (1.01 t/ha) were obtained from N_0Zn_0 treatment combination. The highest stover yield (2.91 t/ha) and highest biological yield (4.74 t/ha) were also obtained from N_2Zn_2 treatment combination. The lowest values of these parameters also obtained from the control. However, the maximum harvest index (38.64%) was recorded from N_2Zn_0 treatment combination whereas minimum value (33.77%) was obtained from N_0Zn_0, the control.

Considering the above results of this experiment, it may be summarized that growth and yield contributing parameters of mustard are positively correlated with N and Zn application. Therefore, the present experimental results suggest that the combined use of 120 kg N/ha and 3 kg Zn/ha fertilizer combination 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 and similar environment elsewhere in Bangladesh.

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

- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh to investigate regional adaptability and other performance.
- It needs to conduct more researches of nitrogen and zinc to investigate the growth and yield BARI Sarisha- 15.
- It needs to conduct more advanced and related experiments with other varieties of mustard and also in different climate and soil condition.

REFERENCE

Abdin, M. Z., Khan, N.I., Israr, M. and Jamal, A. (2003). Nitrogen and sulphur interaction in relation to yield and quality attributes of rapeseed-mustard. Centre for Biotechnology, Faculty of Science, Hamdard University, New Delhi, India. **5** (3/4): 35-41.

Al-Solaimani, S.G., Alghabari, F. and Ihsan, M. Z. (2015). Effect of different rates of nitrogen fertilizer on growth, seed yield, yield components and quality of canola (*Brassica napus* L.) under arid environment of Saudi Arabia. *Intl. J. Agron. Agril. Res.* **6**(4): 268-274.

Allen, E.J. and Morgan, D.G. (2009). A quantitative analysis of the effects of nitrogen on the growth, development and yield of oilseed rape. *J. Agril. Sci.*, **78**: 315-324 (1972).

Ali, M. H. and Ullah, M. J. (1995). Effect of different levels and methods of nitrogen application on growth and yield of rapeseed (*Brassica Campestris L.) Ann. Bangladesh Agric.* **5**(2): 115-120.

Ali, M. H., Rahman, A. M. M. D. and Ullah, M. J. (1990). Effect of plant population and nitrogen on yield and oil content of rapeseed (*Brassica campestris). Indian. J. Agril. Sci.* **60**(9): 627-630.

Ali, Hasan, A. A. and Rahman, A. (1987). Effect of various combinations of water supplies and nitrogen rates on growth and yield of mustard. *Thailand J. Agric. Sci.* **20**: 17-35.

Asad A. and Rafique R, 2000. Effect of Zinc, Copper, Iron, Manganese and Boron on the yield and yield components of wheat crop in Tehsil Peshawar. *Pakistan J. Biol. Sci*., **3** (10):1815- 1820.

Asad A. and Rafique R, 2002. Identification of micronutrient deficiency of wheat in the Peshawar valley, Pakistan. Communications in Soil Science and Plant Analysis, **33** (3/4): 349-364.

Azam, M.G., Mahmud, J.A., Ahammad, K.U., Gulandaz, M.A. and Islam, M. (2013). Efficiency of different dose of zinc on growth, productivity and economic returns of mustard in AEZ 11 of *Bangladesh. J. Environ. Sci. Nat. Resou.* **61**:37-40.

Babu, M. B.B.P. and Sarker, M.C. (2002). Nitrogen use efficiency of 15N-labelled urea applied to mustard. *Journal-of-the-Indian-Society-of-Soil-Science*. Indian Agricultural Research Institute, New Delhi, India. **50**.3, 248-253.

BARI (Bangladesh Agricultural Research Institute). 2008. Annual Report for 2007- 2008.Gazipur-1701, Bangladesh. pp. 1- 385.

BBS (Bangladesh Bureau of Statistics). (2019). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2015). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh. p. 172.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2007). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh.

Black, C.A. (1965). “Methods of Soil Analysis.” Part I and II. *American Society of Agrounomy Inc.* Wisconsin. USA. Pp. 320-360.

Bora PC, Hazarika V, 1997. (*Brassica campestrissub* sp. oleifera var. toria). *Indian J. Agron.*, **42**: 361-364.

Budzynski, W. and Jankowski, K. (2001). Effect of fertilization with sulphur, magnesium and nitrogen on the growth and yield of white and Indian mustard seeds. Rosliny-Oleiste. Uniwersytet Warminsko-Mazurski, Olszynie, Poland. **22**: 1, 45-58.

Chen Y, Aviad T, 1990. Use of humic acid for crop production. *J. Am Soc. of Agronomy*, **12** (3): 86-90.

Cheema M. A., Malik M. A., Hussain A., Shah S. H., Basra S. M. A. (2001). Effects of time and rate of nitrogen and phosphorus application on the growth and the seed and oil yields of canola (*Brassica napus* L.). *J. Agron. Crop Sci.* **186**: 103-110.

Cheema, M.A., Saleem, M.F, Muhammad, N, Wahid, M.A. and Baber, B.H. (2010). Impact of rate and timing of nitrogen application on yield and quality of canola (*Brassica napus* L.). *Pakistan J. Bot.*, **42**(3): 1723-1731.

Dubey, S.K., Tripathi, S.K. and Singh, B. (2013). Effect of sulphur and zinc levels on growth, yield and quality of mustard [*Brassica juncea* (L.) Czern and Coss.]. *A j. of Crop Sci. and Tech.* **2**(1): 2319-3395.

El-Kholy, M. H., Zeky, M., El., Saleh, S. Z. and Metwaly, S. G. (2007). Physical and chemical studies on some rapeseed varieties under different levels of nitrogen fertilization. Proceeding of the 12th International Rapeseed Congress 26-30 March, Sustainable Development in Cruciferous Oilseed crop Production, Wuhan, China, **3**: 217-222.

FAO, (1999). FAO production year book. Food and Agricultural Organization of the United Nations, Rome, Italy. **51**:25-27.

FAO, (2004). FAO Production Year Book. Food and Agricultural Organization of the United Nations, Rome 00100, Italy.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nded. John Wiley and Sons. New York. p. 64.

Jackson, M.L. (1973). Soil Chemical Analysis. Printice Hall Inc. Engiewood Cliffs. N. J. U.S.A.

Jamal, A., Fazili, I. S., Ahmad, S. and Abdin, M. Z. (2006). Interactive effect of nitrogen and sulfur on yield and quality of groundnut (*Arachis hypogea* L.). *Korean J. Crop Sci.* **51**: 519-522.

Kardgara, V., Delkhoshb, B., Noormohammadic, G. and Shiranirad. A.H. (2010). Effects of nitrogen and plant density on yield of field mustard (*Brassica campestris*). *Plant Ecophysiology* **2**:157-164.

Keivanrad, S. and Zandi, P. (2014). Effect of nitrogen levels on growth, yield and oil quality of Indian mustard grown under different plant densities. *Cercetari Agronomice Moldova.* **47**(1): 81-95.

Khan, N., Jan, Ihsanullah, A. Khan, I. A. and Khan, N. (2002). Response of canola to nitrogen and sulphur Nutrition. *Asian J. Plant Sci.* **1**(5): 516-518.

Khan, N., Singh, A., Khan, S. and Samiullah, M. (2003). Interactive effect of nitrogen and plant growth regulators on biomass partitioning and seed yield in mustard. Department of Botany, Aligarh Muslim University, Aligarh, India. **5** (3&8): 64.71.

Khaleque, M.A. (1985). A guide book on production of oilcrops in Bangladesh. Dept. of Agricultural extension. Ministry of Agriculture. Government of the peoples republick of Bangladesh and FAO/UNDP Project. pp. 17.29.

Kumar Vineet, et al. (2016). Effect of Nitrogen and Zinc fertilizer rates on growth, yield and quality of indian mustard (*Brassica juncea L.*). *Int. J. of Agric. Sci.* ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 8, Issue 6, pp.- 1031-1035.

Kutuk, C., Gökhan C, Abdullah B, Başkan O,(2000). Effect of Humic Acid on some soil properties. Bildiri Özetleri, Soil Science Department, Agricultural Faculty, Ankara University, 06110- Ankara Turkey.

Laaniste, P., Jaudu, J. and Eremeev, V. (2004). Oil content of spring oilseed rapeseeds according to fertilization. *Agron. Res.* **2**: 83-86.

Malhi, S. S., Gan, Y. and Raney, J. P. (2007). Yield, seed quality, and sulfur uptake of *Brassica* oilseed crops in response to sulfur fertilization. *Agron. J.* **99**(2): 570-577.

Ma, B. L. and Herath, A. W. (2016). Timing and rates of nitrogen fertilizer application on seed yield, quality and nitrogen-use efficiency of canola. *Crop Past. Sci.* **67**: 167-180.

Maqsood MA, Rahmatullah S, Kanwal T, Aziz, Ashraf M, (2009). Evaluation of Zn distribution among grain and straw of twelve indigenous wheat, *Triticum aestivum* L. genotypes. *Pak. J. Bot*., **41** (1): 225-231.

Meena, B.S., Shar,a, G.L. and Sharma, R.P. (2002). Effect of nitrogen, irrigation and interculture on yield attributes and yield of mustard. Research on Crops. Rajasthan College of Agriculture, Udaipur, India. **3**. 1, 37-39.

Meena, M., David, A.A. and Kumar, S., (2018). Effect of Different Levels of NPK and Zinc Sulphate on Yield and Oil Content in Mustard (*Brassica juncea L.*) Var. Jai Kisan, *Int. J. Pure App. Biosci*. **6**(6): 722-727.

Mehmet, O. Z., Hayrettin K. U. S. C. U. and Abdullah K. A. R. A. S. U. (2016). Nitrogen, yield and quality relationship in the rapeseed (*Brassica napus* ssp. oleifera L.). *Intl. J. Agric. Environ. Res.* **2**(5): 1122-1137.

Mohiuddin, M., Paul, A. K., Sutradhar, G. N. C., Bhuiyan, M. S. I. and Zubair, H.M. (2011). Response of nitrogen and sulphur fertilizers on yield, yield components and protein content of oilseed mustard (*Brassica sp*.). *Intl J. Bioresour. Stress Manag.* **2**(1): 93-99.

Mondal, M. R. I. and Wahhab, M. A. (2001). Production technology of oil crops. Oil seed Res. Centre, Bangladesh agricultural Research Institute, Joydebpur, Gazipur. Bangladesh. P. 4

Mozaffari, S. N., Delkhosh, B. and Rad, A. S. (2012). Effect of nitrogen and potassium levels on yield and some of the agronomical characteristics in Mustard (*Brassica juncea*). *Indian J. Sci. Technol.* **5**(2): 2051-2054.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. (1954). Estimation of Available phosphorus in soil by extraction with sodium bicarbonate. U. S. Dept. Agr. Circ. P. 939.

Ozer, H. (2003). Sowing date and nitrogen rates effect on growth, yield and yield components of two summer rapeseed cultivars. *European J. Agron*. **19**(3): 453-463.

Ozturk, O. (2010). Effects of Source and Rate of Nitrogen Fertilizer on Yield, Yield Components and Quality of Winter Rapeseed (*Brassica napus* L.). *Chilean J. Agril. Res*., **70**(1): 132-141.

Prasad, K., Chaudhary, H. P. and Uttam, S. (2003). Effect of nitrogen, phosphorus, sulphur and zinc on growth, yield attributes and yield of mustard under rainfed condition. *Bhartiya-Krishi-anusandhan-Patrika.* **18**(3/4): 124-129.

Qayyum, S. M., Kakar, A. A. and Naz, M. A. (1998). Influence of nitrogen levels on the growth and yield of rape (*Brassica napus* L.) *Sarhad J. Agric.* **15**: 263-268.

Rimi, T. A., Islam, M. M., Siddik, M. A., Islam, S., Shovon, S. C. and Parvin, S. (2015). Response of seed yield contributing characters and seed quality of rapeseed (*Brassica campestris* L.) to nitrogen and zinc. *Intl. J. Sci. Res. Publ.* **5**(11): 187-193.

Russell, O. F. (1986). MSTAT-C package programme. Crop and Soil Science Department.

Samir G. Al-Solaimani, Fahad Alghabari, Muhammad Zahid Ihsan. (2015). Effect of different rates of nitrogen fertilizer on growth, seed yield, yield components and quality of canola (*Brassica napus* L.) under arid environment of Saudi Arabia. *J. Agri. R.*, **8**(2): 01-07.

Sahito, H.A., Solangi, A.W., Lanjar, A.G., Solangi, A.H. and Khushro, S.A. (2014). Effect of micronutrient (Zinc) on growth and yield of mustard varieties. *Asian J. Agri. Biol.* **2**(2): 105-113.

Seyedeh, N. M., Babak, D. and Amirhossein, S. R. (2012). Effect of nitrogen and potassium levels on yield and some of the agronomical characteristics in Mustard (*Brassica juncea*). *Indian J. Sci. Technol.* **5**(2): 2051-2054.

Shamsuddin, A. M., Islam. M. A. and Asaduzzaman, S. M. (1987). Effect of nitrogen on yield and yield contributing characters of mustard at different levels. *Bangladesh J. Agric. Sci.***14**(2): 165-167.

Sharawat, S., Singh, T.P., Singh, J.P. and Sharawat, S. (2002). Effect of nitrogen and sulphur on the yield and oil content of Varuna mustard. Progressive Agriculture. C. C. S. University, Meerut, (U. P.), Indian. **2**: 2, 177.

Shukla, A. and Kumar, A. (1997). Seed yield and oil content of Indian mustard (*Brassica juncea L.*) varieties as influenced by N fertilization. *J. Res. Brisa Agril. Univ*. **9**(2): 107-111.

Shukla. R. K., Kumar, A., Mahapatra, B. S., Kandpal, B., Kumar, A. and Kandpal, B. (2002 a). Integrated nutrient management practices in relation to morphological and physiological determinants of seed yield in Indian mustard (*Brassica juncea). Indian J. Agril. Sci.* **72**(11): 670-672.

Sinha, S., Nayak, R. L. and Mitra, B. (2003). Effect of different levels of nitrogen on the growth of rapeseed under irrigated and rainfed conditions. *Env. Ecol.* **21**(4): 741-743.

Singh, R. P., Singh, Y. and Singh, Y. (1998). Performance of rainfed Indian mustard (*Brassica juncea*) varieties at varying levels of nitrogen. *Indian J. Agron*. **43**(4): 709-712.

Singh, P.C. (2002). Effect of different levels of nitrogen and phosphorus on yield, yield components and oil content of mustard. Journal-of-Living-World. S.D.J. Post Graduate College, Chandeshwar, Azamgarh (U. P.), India. **9**: (1) 1-4.

Singh, G.K.; Kedar and Prasad, K. (2003). Effect of row spacings, nitrogen levels and basis of N application on yield attributes and yield of mustard. Crop Research Hisar. C. S. Azad University of Agriculture & Technology, Kanpur, India. **25**:(3) pp 427-430.

Singh, D., Jain, K. K. and Sharma, S. K. (2004). Quality and nutrient uptake in mustard as influenced by levels of nitrogen and sulphur. *J. Maharashtra Agric. Univ.* **29**(1): 87-88.

Singh, S.P. and Singh, V. (2005). Effect of nitrogen, sulphur and zinc on Indian mustard (*Brassica juncea*). *Indian J. Agric. Sci.* **75**(12): 828-830.

Singh, B., Sharma, Y. and Rathore, B.S. (2012). Effect of Sulphur and zinc on growth, yield and quality of mustard [*Brassica juncea* (L). Czern and Coss.]. Research on Crops, **13**(3): 963-969.

Singh, M. and Kumar, M. (2014). Effect of nitrogen and sulphur levels on seed yield and some other characters in mustard [*Brassica juncea* (L.) Czern and Coss]. *Int. J. Agric. Sci.* **10**(1): 449-452.

Singh, S. and Singh, V. (2017). Effect of rate and source of Zinc on yield, quality and uptake of nutrients in Indian mustard (*Brassica juncea*) and soil fertility. *Indian j. of Agric. Sci.* **87**(12): 1701-1705.

Tarafder, M. G. S. and Mondal, M. H. (1990). Response on mustard (var. sonali sorisha) to nitrogen and sulphur fertilization. *Bangladesh J. Agril. Sci.* **15**(2): 125-132.

Taylor, A. J., Smith, C. J. and Wilson, I. B. (1991). Effect of irrigation and nitrogen fertilizer on yield, oil content, nitrogen accumulation and water use of canola (*Brassica napus* L.) *Fert. Res.* **29**: 249-260.

Tomar, R. K. S., Chouraria, S. C., Raghu, J. S. and Sing, V. B. (1996). Growth, yield and net returns of mustard under different levels of nitrogen and sulphur application on clay loam soils. J. Oilseed Res. **10**(1): 13-17.

Tripathi, A. K. and Tripathi, H. N. (2003). Influence of nitrogen levels on growth, yield and quality of Indian mustard. *Farm Sci. J.* **12**(1): 71-72.

Tuteja, S. S., Lalpale, R. and Tripathi, R. S. (1996). Effect of date of sowing , nitrogen levels and nitrogen splitting on mustard (*Brassica juncea). Adv. Plant Sci*. **9**(1): 167-168.

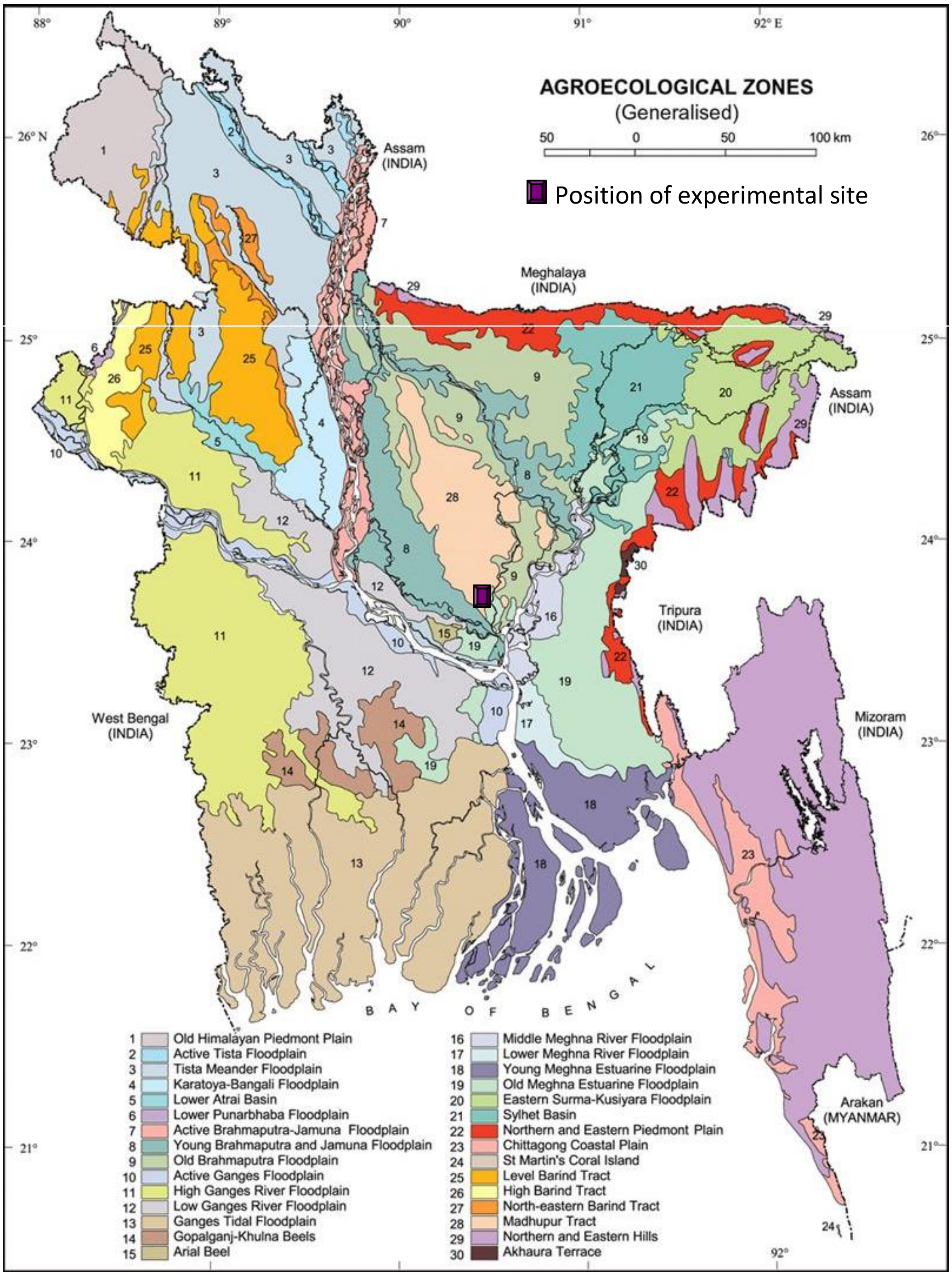
Uddin, M. K., Khan, M. N. H. Mahbub, A. S. M. and Hussain, M. M. (1992). Growth and yield of rapeseed as affected by nitrogen and seed rate. *Bangladesh J. Sci. Ind. Res.* **27**: 30-38.

Zhao, F. J.; Withers, P. J. A.; Evans, E. J.; Monaghan, S. E.; Shewry, P. R. and Mogarth, S. P. 1997. Nitrogen nutrition and important factor for the quality of wheat and rapeseed. *Soil Sci. Plant Nutri.* **43**: 1137-1142.

Zhu, H., Zhang, X. and Chunhi, s. (1996). Characteristics of micronutrient uptake by raps plants and the methods of B and Zn application. Oil Crops of China. **18**:59-61.

Appendices

Appendix I. Map showing the experimental site under study



Appendix II. Analysis of variance (mean square) of the data for Plant Height(cm), Number of branches/plant, Number of seeds/siliquae, Number of siliquae /plant, Length of Siliquae(cm).

Source of variation	Degrees of Freedom	Plant height	Number of branches/plant	Number of seeds per siliquae	Number of siliquae per plant	Siliquae length
Replication	2	0.231	0.127	0.014	64.186	0.001
Factor A	2	294.905	3.161	15.655	158.974	0.097
Factor B	2	27.884	0.448	3.217	31.212	0.028
Factor AB	4	22.761	1.382	4.928	297.708	0.016
Error	16	0.048	0.076	0.014	77.070	0.006

Appendix III. Analysis of variance (mean square) of the data for 1000 seed weight(g), Seed yield (t/ha) , Stover yield(t/ha), Biological yield, Harvest index(%) of Mustard.

Source of variation	Degrees of Freedom	Seed yield	1000 seed weight	Stover yield	Biological yield	Harvest index
Replication	2	0.001	0.006	0.003	0.005	0.003
Factor A	2	1.105	1.525	1.348	4.881	0.003
Factor B	2	0.083	0.237	0.121	0.398	4.915
Factor AB	4	0.128	0.097	0.081	0.413	11.002
Error	16	0.001	0.006	0.002	0.003	0.271

Appendix IV. Physical and chemical properties of the initial soil

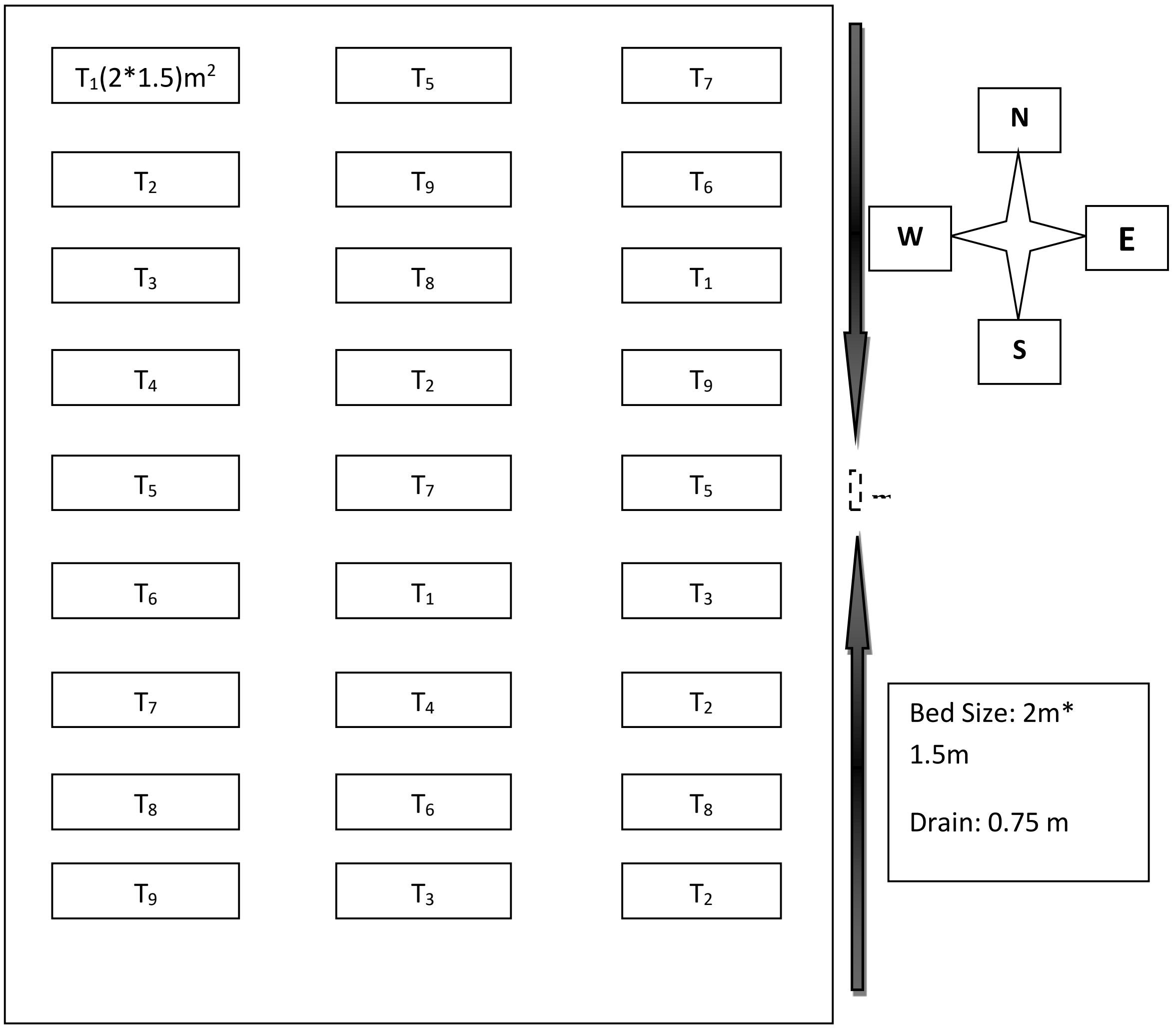
Physical composition of soil

Soil separates	Value
Sand (%)	**29.8**
Silt (%)	**39.1**
Clay (%)	**31.1**
Textural class	**Clay loam**

B. Chemical properties of soil

Chemical properties	Value
P^H	5.56
Organic carbon	0.75
Organic matter	1.29
Total Nitrogen (%)	0.08
Available P (ppm)	31.5
Exchangeable K (me/100g soil)	0.16
Available Zinc (mg/g soil)	4.78

Appendix V. Layout of the experimental site



Appendix VI. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to February 2019

Year	Month	Air Temperature (^0C)			Relative humidity (%)	Rainfall (mm)
		Max	**Min**	**Mean**		
2018	November	28.50	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.70	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	36.80	0.0

Source: Bangladesh Meterological Department (Climate division), Agargaon, Dhaka-1212