EFFECT OF MAGNESIUM ON GROWTH AND YIELD OF MUSTARD (*Brassica napus*)

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his is to certify that thesis entitled, **"EFFECT OF MAGNESIUM ON 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 **Md. Fariduzzaman,** Registration **No.18-09096** 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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SAU, Dhaka **The Author**

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ABSTRACT

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during November 2019 to February 2020 to evaluate the performance of different doses of Mg fertilizer on growth and yield of mustard (BARI Sharisa-18) in respect of growth and yield performance. Single factors Randomized Complete Block Design was followed with seven treatments having unit plot size of 3m x 1.5m (4.5 m^2) and replicated thrice. The treatments were T_0= Control, T_1= 02 kg (Mg) ha^{-1}, T_2 = 04 kg (Mg) ha^{-1}, T_3 = 06 kg (Mg) ha^{-1}, T_4 = 08 kg (Mg) ha^{-1}, T_5= 09 kg (Mg) ha^{-1} and T_6= 10 kg (Mg) ha^{-1}. Magnesium showed positive effect on the different plant characteristics. The tallest plant (92.67cm) was found in T_6 treatment, which was higher over control (T_0) treatment (74.67cm). Number of siliqua per plant was found maximum (65) in T_6 treatment and minimum (37.33) in T_0 treatment. Number of branches per plant insignificantly varied with different characters (highest 8.671 in T_6 treatment and lowest T_0 treatment). Number of leaves per plant, seed per siliqua, length of siliqua, weight of thousand seed, seed yield, Stover yield (t/ha), biological yield (t/ha) and harvest index (%) were highest in T_6 (14), T_6 (50.33), T_6 (25), T_6 (7.67 cm), T_6 (4.03g), T_6 (1.457 t/ha), T_6 (2.609 t/ha), T_6 (4.066 t/ha) and T_6 (35.83%) respectively and the lowest was recorded in T_0 (4.67), T_0 (39), T_0 (14.33), T_0 (4.33 cm), T_0 (2.167 g), T_0 (0.861 t/ha), T_0 (1.845), T_0 (2.706 t/ha) and (31.83%) respectively. Based on the results it can be concluded that, 10 kg (Mg) ha^{-1} showed comparatively high yield for the production 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
^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 napus*) belongs to the Brassicaceae family which is also known as Cruciferae. There are about 100 species of Brassica (Baily, 1949) of which *Brassica campestris*, *B. juncea*, *B. napus*, *B. nigra* and *B. alba* are commercially important (Thakur, 1979). However, Brassica napus is a high yielding one (BINA, 2004). It is one of the most important oil seed crops throughout the world after soybean and groundnut (FAO, 2014). It is originated in Southern Europe from where it was introduced into Asia and Africa (Downey Roblelen, 1989). In Bangladesh, oil seed mustard is the number one edible oil crop, covering about 80% of the total oil crops area and contributing to more than 71% of the total oil crop production (BBS, 2019).

Mustard covers about 61.2% of the total acreage under oil seed and 52.6% of the total oil seed production in Bangladesh (BBS, 2019). Edible oil is an essential integral part of the daily diet of the people in Bangladesh. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. More energy is supplied by plant products than by animal products. For example, oil extracted from coconut, groundnut or mustard supplies 900 kilocalories (energy) as against butter and fist which provide 729 and 273 kilocalories respectively. It is evident that vegetable oil which may be obtained from plant sources by cultivation of oil crops is no less important than animal fat for energy.

Mustard seeds contain 40-45 % oil and 20-25 % protein. It also serves as 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 compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. Bangladesh is suffering from acute shortage of edible oil in terms of domestic production. About two thirds of the total edible oil consumed in the country is imported. Although the domestic production has considerably increased the deficiency has not reduced due to increased requirement of edible oil.

Edible oil is an essential integral part of the daily diet of the people in Bangladesh. Fats and oils are available from different sources like animal and plant. Animal fats are derived from milk, ghee, butter, etc. but compared to the oil obtained from various oil crops these are very costly. Oil from plants is easily digestible and its nutrition quality is better than that of animal fats. More energy is supplied by plant products than by animal products. For example, oil extracted from coconut, groundnut or mustard supplies 900 kilocalories (energy) as against butter and fist which provide 729 and 273 kilocalories respectively.

It is evident that vegetable oil which may be obtained from plant sources by cultivation of oil crops is no less important than animal fat for energy. Bangladesh is suffering from acute shortage of edible oil in terms of domestic production. About two thirds of the total edible oil consumed in the country is imported. Although the domestic production has considerably increased the deficiency has not reduced due to increased requirement of edible oil.

Bangladesh is facing a huge deficit of edible oil. In view of the importance of this crop, attention has to be given to increase its production in order to meet the huge shortage of cooking oil in the country. According to the National Nutrition Council (NNC) of Bangladesh the recommended dietary allowance (RDA) is estimated to be 6gm oil capita/day for a diet with 2700 Kcal (NNC, 1984). On this RDA basis, Bangladesh requires 0.29 million tons of oil equivalent to 0.8 million tons of oil seeds for nourishing her people. The soils of Bangladesh have recently been found to be deficient in secondary macro nutrient elements due to the use of non-judicious chemical fertilizers, such as Urea, TSP, MP, higher cropping intensity, without

proper replenishment of nutrients. For this reason, Mg, S, B and Zn deficiencies are being observed in many parts of the country (Islam and hossain, 1993).

Mustard shows a high efficiency in the magnesium uptake because of a high influx-rate through the root hairs (Föhseand Claasen, 1991; Delland Huang, 1977). It is obvious that mustard needs a low Mg-supply to build up a high content of high energy containing oil (Orlovius and Kirkby, 2013).

Although magnesium is one of the most important nutrients; involved in many enzyme activities and the structural stabilization of tissues; Its importance as a macronutrient ion has been overlooked in recent decades by botanists and agriculturists; who did not regard Mg deficiency in plants as a severe health problem. (Russel and Appleyapd, 1915), 149 affect seed germination, cell wall division, flowering, fruiting, synthesis of fat, starch and in fact most biochemical activities (Singh and Singh, 2012). Magnesium fertilization is of prime importance for normal growth and development of plants due to its vital role in chlorophyll synthesis and involvement in various physiological and metabolic processes of the plant (Mehta *et al.,* 2005). Magnesium has an important role in the process of photosynthesis of plants (Arnon, 1953).

The present study pertains to the effects of treatment to the seeds of one *Brassica juncea* L. variety BARI Sharisha 18 with Mg (MgO_2) and $MgSO_4$ in varying concentrations (i.e., 5.0 to 10mM). It is likely that the effect of Mg metabolism is stronger in oilseed crops. On the other hand, optimum population plays an important role in producing higher yield. Population density thus influences yield and yield contributing characters in mustard production. In addition, the fertilizer requirement with different population densities for maximum growth and yield of newly developed mustard variety BARI Sharisha 18 is not much investigated. With a view to determining the effect of Mg on growth and yield of this new variety, a field study was conducted with the following objectives:

1. To examine the effect of Mg on growth and development of BARI Sharisha-18 and;

2. To determine the suitable level of Magnesium for the maximum yield of BARI Sharisha-18.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the important oil crops in Bangladesh and also in many other countries of the world. Researches are going on in home and abroad to maximize the yield of mustard. However, a very few researches work related to growth, yield and development of mustard have been carried out in our country. Variety and nutrient management play an important role in improving mustard yield. But research works related to variety and source of nutrients as a management practices especially use of Mg on mustard are limited in Bangladesh context. However, some of the important and informative works and research findings related to the variety and Mg so far been done at home and abroad have been reviewed in this chapter under the following headings;

2.1. Effect of Macro nutrient on Mustard

2.1.1 Plant height (cm)

An experiment was conducted by Barman *et al.* (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety 5 on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on plant height and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted 186.56 cm plant height.

Mamun *et al.* (2014) evaluated the effect of variety (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and different plant densities on

growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and observed that BARI Sarisha-13 performed well in terms of plant height.

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30 and 60 kg N ha-1 under irrigated or non-irrigated condition in a field experiment. They observed that plant height increased with increasing rate of nitrogen and were higher under irrigated than nonirrigated condition. Singh *et al.* (2002) also reported that mustard plant height increased significantly with successive increase in nitrogen up to 120 kg ha-1.

BARI (1999) conducted a trial in two different regions of Bangladesh, at Joydebpur & Ishwardi to justify the effect of N on yield of mustard. The experiment conducted with 3 levels of nitrogen (0, 120, 160 k ha-1) and plant height (cm) was found 87.78, 113.94, 106.46 at Joydebpur and 90.79, 118.46, 113.69 cm at Ishwardi respectively. The highest plant height was found in both the location at 120 Kg N ha-1. Islam and Mondal (1997) showed that application of nitrogen at the rate of 0, 100, 200, 300 kg ha-1, the maximum plant height of rapeseed was found 93.6 cm at 300 kg N ha-1.

Chaubey *et al.* (2000) and Dubey *et al.* (1997) worked on groundnut and linseed respectively and stated that the increase in plant height as observed in the experiment may be due to the favorable effects of magnesium on N-metabolism and consequently on the vegetative growth of soybean plant.

Majnoun-Hosseini *et al.* (2006) and Mobasser *et al.* (2006) suggested that with decrease in planting space and use of nitrogen fertilizer the plant height would be increased.

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

2.1.2 Branches plant^{-1}

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 10.84 branches plant^{-1}, while variety Early Mustard resulted 9.25 branches plant^{-1}. Similarly, Mamun *et al.* (2014) reported that BARI Sarisha-13 performed well in terms of branches plant^{-1} (6.14) when evaluated the mustard varieties BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3 in different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

An experiment was conducted by Barman *et al.* (2016) at the Agronomy Field Laboratory and Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on number of branches plant^{-1} and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

A field experiment was conducted by Singh *et al.* (2017) at Faizabad, Uttar Pradesh, India, to assess the response of different mustard varieties (Vardan, Narendra Rai-1 and Narendra Ageti Rai-4 to different nutrient combinations under late sown condition during winter (rabi) season. Results revealed that among the different varieties, Narendra Rai-1 being at par with Vardan recorded significantly higher primary branching over Narendra Ageti Rai- 4.

Tripathi (2003) conducted an experiment in Uttar Pradesh, India in 1994-95 and 1995-96 to investigate the effects of N levels (80, 120, 160 and 200 kg ha^{-1}) 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 branch increased with increasing N

levels up to 160 kg N ha^{-1}, The number of branches per plant increased up to 200 kg N ha^{-1}. Net returns were maximum (Rs. 19000 ha^{-1}) at 160 kg N ha^{-1}because seed yield was also maximum at this N rate. The benefit: cost ratio increased up to 160 kg N ha^{-1}.

2.1.3 Days to flowering

Karim *et al.* (2000) stated that mustard varieties showed significant influence in terms of days to flowering and they found maximum days to flowering in J-3023 variety.

BARI (2001) concluded that there was significant variation days to flowering of mustard found in different varieties and highest days to flowering (32 days) was found in Jamalpur-1 variety and lowest in BARI Sarisha-10.

Mamun *et al.* (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 produced early flower than the others.

An experiment was conducted by Barman *et al.* (2016) at the Agronomy Field Laboratory and Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on days to flowering.

2.1.4 Number of siliquae $plant^{-1}$

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1^{st} with 581.11 pods $plant^{-1}$, while variety

Early Mustard resulted 484.67 pods plant^{-1}. On the other hand Mamun *et al.* (2014) reported that BARI Sarisha-13 performed well in terms of siliqua plant^{-1} (126.90) when they evaluated four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. were applied during the course of study.

An experiment was conducted by Barman *et al.* (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on number of siliqua plant^{-1} and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

Khan *et al.* (2003) observed that cycocel at 400 ppm + 60 kg N ha^{-1} and ethrel at 200 ppm + 80 kg N ha^{-1} 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.

2.1.5 Siliqua length

Hussain *et al.* (2008) conducted an experiment to show the effect of boron application on yield and yield attributes of different mustard varieties. The experiment involved five boron levels and three mustard varieties viz. BARI sharisha-8, BARI sharisha-9 and BARI sharisha-11. BARI sharisha-11 and BARI sharisha-8 performed better in terms of siliqua length.

An experiment was conducted by Barman *et al.* (2016) at the Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of

four fertilizer treatments. Results revealed that variety had significant effect on siliqua length (cm) and the best result of the above character was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

Mostafa *et al.* (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 showed highly significant and positive correlation in seed yield with siliqua plant^{-1}.

2.1.6 Number of seeds siliqua^{-1}

Laxminarayana and Pooranchand (2000) found no significant variations in seeds siliqua^{-1} among the cultivars. Das *et al.* (1999) reported that MM 7 (Mutant) produced the highest number of seeds siliqua^{-1} (29.2) followed by MM 20 (Mutant) (28.0) and Bina sarisha-4 (27.8) at Dinajpur.

Mamun *et al.* (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of seeds siliqua^{-1} (25.36).

An experiment was conducted by Barman *et al.* (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and

three varieties viz. BINA Sarisha-5, BINA Sarisha-8, Tori-7. Results revealed that variety had significant effect on number of seeds siliqua^{-1}, and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

2.1.7 Thousand seed weight

Bani Saeedi (2001) stated that nitrogen, by reducing flower abscission and consequently affecting thousand-seed weight (TSW), increasing the number of siliqua per unit area and decreasing the number of seeds siliqua^{-1}, caused more seed yield per hectare.

Chauhan, *et al.* (1995) and Cheema *et al.* (2001) both stated that the number of seeds per siliquae and thousand-seed weight (TSW) were significantly increased with increasing levels of nitrogen fertilizer application.

BARI (2001) concluded that there was significant variation in 1000-seed weight of mustard found in different varieties and highest weigh of 1000-seed was found in Jamalpur-1 variety and lowest in BARI Sarisha-10.

Karim *et al.* (2000) stated that cultivars showed significant influence in weight of thousand seeds. They found higher weight of 1000-seed in J-3023 (3.43 g), J-3018 (3.42 g) and J-4008 (3.50 g).

Mamun *et al.* (2014) evaluated the effect of variety and different plant densities on growth and yield of rapeseed mustard under rainfed conditions at Sher-e Bangla Agricultural University, Dhaka, Bangladesh. Four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that BARI Sarisha-13 performed well in terms of 1000 seed weight (4.00) considering the other variety.

Mostafa *et al.* (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties

(Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results recorded results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 showed highly significant and positive correlation in seed yield with 1000 seed weight of mustard.

An experiment was conducted by Barman *et al.* (2016) at Bangladesh Agricultural University, Mymensingh to find out the appropriate fertilizer dose and best variety on the yield and oil content of mustard. The experiment consisted of four fertilizer treatments viz., 0 fertilizer dose (control), 50% of recommended fertilizer dose, 100% recommended fertilizer dose and 150% of recommended fertilizer dose and three varieties viz. BINA Sarisha-5, BINA Sarisha-8 and Tori-7. Results revealed that variety had significant effect on 1000 seed weight and the best result of the above characters was recorded in 100% recommended fertilizer dose in combination with BINA Sarisha-8.

2.1.8 Seed yield

Pooran *et al.* (2000) studied 6 cultivars of mustard and observed that among the mustard cultivars, GM-1 gave the highest seed yield (1050 kg ha^{-1}) followed by Kranti and Pusa Bold (790 and 760 kg ha^{-1}, respectively) and Varuna and Sita produced comparable yields (680 and 610 kg ha^{-1}, respectively).

Behera *et al.* (2002) conducted a field experiment to study the effect of plant population and sulfur levels on yield of mustard (*B. juncea*) and found interaction effects of variety and plant population significant on pooled seed yield and recorded the maximum seed yield at the intermediate population level of 14.8 plants m^{-2}.

BARI (2001) showed that seed yield and other yield contributing characters significantly varied among the varieties. Rahman (2002) stated that yield variation existed among varieties and the highest seed yield was observed in BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha11 (2.00-2.50 t ha^{-1}) and lowest yield in variety Tori-7 (0.95-1.10 t ha^{-1}).

Prasad *et al.* (2003) stated that N at 30 kg ha^{-1} + P at 20 kg ha^{-1} + Zn at 5 kg ha^{-1}, and at 60 kg ha^{-1} + P at 30 kg ha^{-1} + S at 20 kg ha^{-1} produced the highest growth, yield and productivity, and also good cost**:** benefit ratio.

Singh *et al.* (2002) conducted an experiment with three Indian mustard cultivars (Varuna, Vardan and Narendra Rai-1) subjected to various magnesium sources and levels (0, 20, 40 and 60 kg ha^{-1}) were evaluated in Kumaraganj, Faizabad, Uttar Pradesh, India, during the winter season of 1996-97 and 1997-98 The application of 40 and 60 kg S ha^{-1}, which were at par, gave 6 significantly higher yield and quality than the application of 0 and 20 kg S ha^{-1} during the respective years.

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^{-1}over the control. Nitrogen application increased the seed yield of mustard. Nitrogen and magnesium content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N ha^{-1} over its preceding rates. The increased nitrogen and magnesium content enhanced the total uptake of nitrogen and magnesium.

Singh *et al.* (2008) conducted fertilizer trial experiment using S @ 0, 15, 45 and 60 kg ha^{-1}. They reported that Seed yield, total S-uptake, oil yield increased with successive increase in S-application up to 45 kg ha^{-1} in comparison to that of the control. Mean increase of seed yield and oil content to S was 159 kg ha^{-1} and 3.7% respectively.

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

Afroz *et al.* (2011) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date and three seed rates and higher seed yield was obtained by the variety BARI Sarisha-9.

Mamun *et al.* (2014) evaluated the effect of four varieties (BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU Sarisha-3) and four plant densities were applied during the course of study and reported that maximum seed yield (1.60 t ha^{-1}) was recorded for BARI Sarisha-13.

Hakim *et al.* (2014) evaluated two varieties (Early Mustard and S-9) were against six Zn levels and reported that S-9 ranked 1st with 1960.30 seed yield kg ha^{-1}, while variety Early Mustard resulted 1677.90 seed yield kg ha^{-1}.

The experiment was conducted by Sharif *et al.* (2016) at the field laboratory of the Patuakhali Science and Technology University, Patuakhali, Bangladesh under the tidal Floodplain region to find out optimum sowing time for the selected three cultivars (BARI Sharisha-15, BINA Sharisha-5 and BARI Sharisha-9). Results showed that the highest grain yield (1.73 t ha^{-1}) was obtained from the first sowing (30 November) with BINA Sharisha-5 and it was significantly different from the yields of all other combination.

Singh and Singh (2017) carried out an experiment with four dates of sowing and two varieties viz. Pusa Bold and Pusa Jaikisan (Bio-902). Highest yield was produced by mustard cv. Pusa Bold among the two varieties tested. The analysis of variance showed that the difference in seed yield were statistically significant for both the varieties.

2.1.9 Stover yield

Meena *et al.* (2002) reported that the application of 60 kg N ha^{-1} registered significantly higher seed and stover yield of mustard over control and 30 kg N ha^{-1} and found statistically at par with 90 kg N ha^{-1}. Tomar *et al.* (1995) who observed that straw yields of mustard increased with increasing S application rates.

BARI (2001) reported that in case of poor management Isd-local gave the highest straw yield (3779 kg ha^{-1}) and lowest yield (1295 kg ha^{-1}) was found from Nap-281 In case of medium management, highest weight (6223.3 kg ha^{-1}) was recorded from the same variety and lowest (3702.3 kg ha^{-1}) from PT-303 under high management

practices. The highest straw yield, 6400 kg was obtained from the variety Rai-5 and lowest 4413.3 kg ha^{-1} was obtained from variety Tori-7.

Mostafa *et al.* (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, the variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 and their growth parameters were also highly significant.

CHAPTER III

MATERIALS AND METHODS

This experiment was conducted on rapeseed with six doses of Magnesium (Mg) in the rabi season of November 2019 to February 2020 to evaluate the performance of different doses of Mg fertilizer on growth and yield of mustard in respect of growth and yield performance.

3.1 Description of the experimental site

3.1.1 Experimental period

The field experiment was conducted during the period of October 2019 to February 2020.

3.1.2 Experimental location

The present study was conducted in the Experimental Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. A map of the experimental location presented in Appendix I.

3.1.3 Soil characteristics

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter 5.9 and 0.78%, respectively and the the soil composed of 26% sand, 43% silt, 31% clay (Appendix II).

3.1.4 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest of the year. During the experimental period the maximum temperature (31.7^0C) was recorded in the month of March 2020, whereas the minimum temperature (25^0C) in December 2019. The highest humidity (69%) was recorded in the month of December, 2019, while the highest rainfall (47 mm) was recorded in February 2020. The monthly average temperature, humidity, rainfall and sunshine hour during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III.

3.2 Experimental details

The treatments comprised of 6 different doses of Magnesium (Mg) fertilizer.

3.2.1 Experimental factors

1. T_0= Control
2. T_1= 2 kg Mg ha^{-1}
3. T_2 = 4 kg (Mg) ha^{-1}
4. T_3 = 6 kg (Mg) ha^{-1}
5. T_4 = 8 kg (Mg) ha^{-1}
6. T_5= 9 kg (Mg) ha^{-1}
7. T_6= 10 kg (Mg) ha^{-1}

3.2.2 Experimental design and layout

The one factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block contained 21 plots altogether in the experiment. The size of each plot was 2.50 m × 1.25 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sharisha 18, a medium yielding and short duration variety of mustard (*Brassica rapa*) developed by BARI, Dhaka was used as experiment crop. The seeds were collected from BARI, Gazipur, Dhaka.

3.3.2 Soil Collection

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

3.3.3 Land preparation

The experimental plot was opened on 20 October 2019, with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed for three times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil. Finally, land was prepared on 4 November 2019.

3.3.4 Application of manure and fertilizers

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses (BARC, 2018) and as per treatment of the experiment.

Table 1. Dose and method of application of fertilizers in mustard field

Fertilizers	Dose ha^{-1}	Basal	Application (%)		
			20 DAS	30 DAS	40 DAS
Urea	220 kg	--	33.33	33.33	33.33
TSP (Triple Super Phosphate)	170 kg	100	--	--	--
MoP (Muriate of potash)	85 kg	100	--	--	--
Zinc sulphate	5 kg	100	--	--	--
Gypsum	150 kg		--	--	--
Magnesium Sulphate	As per treatment				

DAS: Days after sowing (source: BARC, 2018)

3.3.5 Seed sowing

The seeds of mustard variety were sown on 14 November, 2019 in rows in the furrows having a depth of 2-3 cm.

3.3.6 Intercultural operations

3.3.6.1 Thinning

Seeds germination started at 17 November, 2019. Thinning was done two times; first thinning was done at 8 DAS and second was done at 20 DAS to maintain optimum plant population in each plot as per the treatment of plant density.

3.3.6.2 Irrigation and weeding

Irrigation was provided for two times after seed sowing and before flowering to all experimental plots equally. The crop field was weeded before providing irrigation.

3.3.6.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plants. Ripcord 10 EC was sprayed at the rate of 1 ml with 1 liter water for two times at 15 days

interval after seedlings germination to control the insects.

3.4 Crop sampling and data collection

Five plants from each treatment and each replication were randomly selected and marked with sample card. Plant height, branches plant^{-1} and total dry matter content was recorded from selected plants at an interval of 15 days started from 30 DAS to 60 DAS and other parameters were recorded during harvest and as post-harvest operations.

3.5 Harvest and post-harvest operations

Harvesting was done at 03 March 2020 when 90% of the siliqua became brown in color which was estimated by eye observation**.** The matured plant was harvested manually.

3.6 Data collection

The following data were recorded

1. Plant height (cm)
2. Number of branches plant^{-1}
3. Number of leaves plant^{-1}
4. Number of siliqua plant^{-1}
5. Length of siliqua (cm)
6. Number of seeds siliqua^{-1}
7. Weight of 1000 seeds (g)
8. Seed yield hectare^{-1} (t)
9. Stover yield hectare^{-1} (t)
10. Biological yield hectare^{-1} (t)
11. Harvest Index (%)

3.7 Procedure of data collection

3.7.1 Plant height (cm)

The plant height was measured at 30, 45 and 60 DAS with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.7.2 Number of branches plant^{-1}

The number of branches plant^{-1} was counted at 30, 45 and 60 DAS from selected plants. The average number of branches plant^{-1} was determined and recorded.

3.7.3 Number of leaves plant^{-1}

The number of leaves plant^{-1} was counted at 30, 45 and 60 DAS from selected plants. The average number of leaves plant^{-1} was determined and recorded.

3.7.4 Number of siliqua plant^{-1}

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.7.5 Length of siliqua (cm)

Length of siliqua was taken from randomly selected ten siliqua and the mean length was expressed on siliqua^{-1} basis.

3.7.6 Number of seeds siliqua^{-1}

The number of seeds siliqua^{-1} was recorded from randomly selected 10 siliqua at the time of harvest. Data were recorded as the average and express in seeds siliqua^{-1}.

3.7.7 Weight of 1000 seeds (g)

One thousand cleaned, dried seeds of mustard were counted from each harvest sample and weighed by using a digital electronic balance and weight was expressed in gram 4.05 (g).

3.7.8 Seed yield hectare^{-1} (t)

The seeds collected from 2.25 (1.8 m × 1.25 m) square meter area of each plot were sun dried properly, weighted and data were recorded. The seeds yield of each plot were converted into yield hectare^{-1} and express in seed yield of t ha^{-1}.

3.7.9 Stover yield hectare^{-1} (t)

The stover collected from 2.25 (1.8 m × 1.25 m) square meter area of each plot was sun dried properly, weighted and data were recorded. The stover yield of each plot were converted into yield hectare^{-1} and express in stover yield of t ha^{-1}.

3.7.10 Biological yield

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

3.7.11 Harvest index (%)

The harvest index was calculated from the ratio of seed yield to biological yield (seed yield + stover yield) and expressed in terms of percentage.

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed the morphology and yield of mustard as influenced by Mg. The mean values of all the recorded parameters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).



Plate 1: Image of the experimental site.

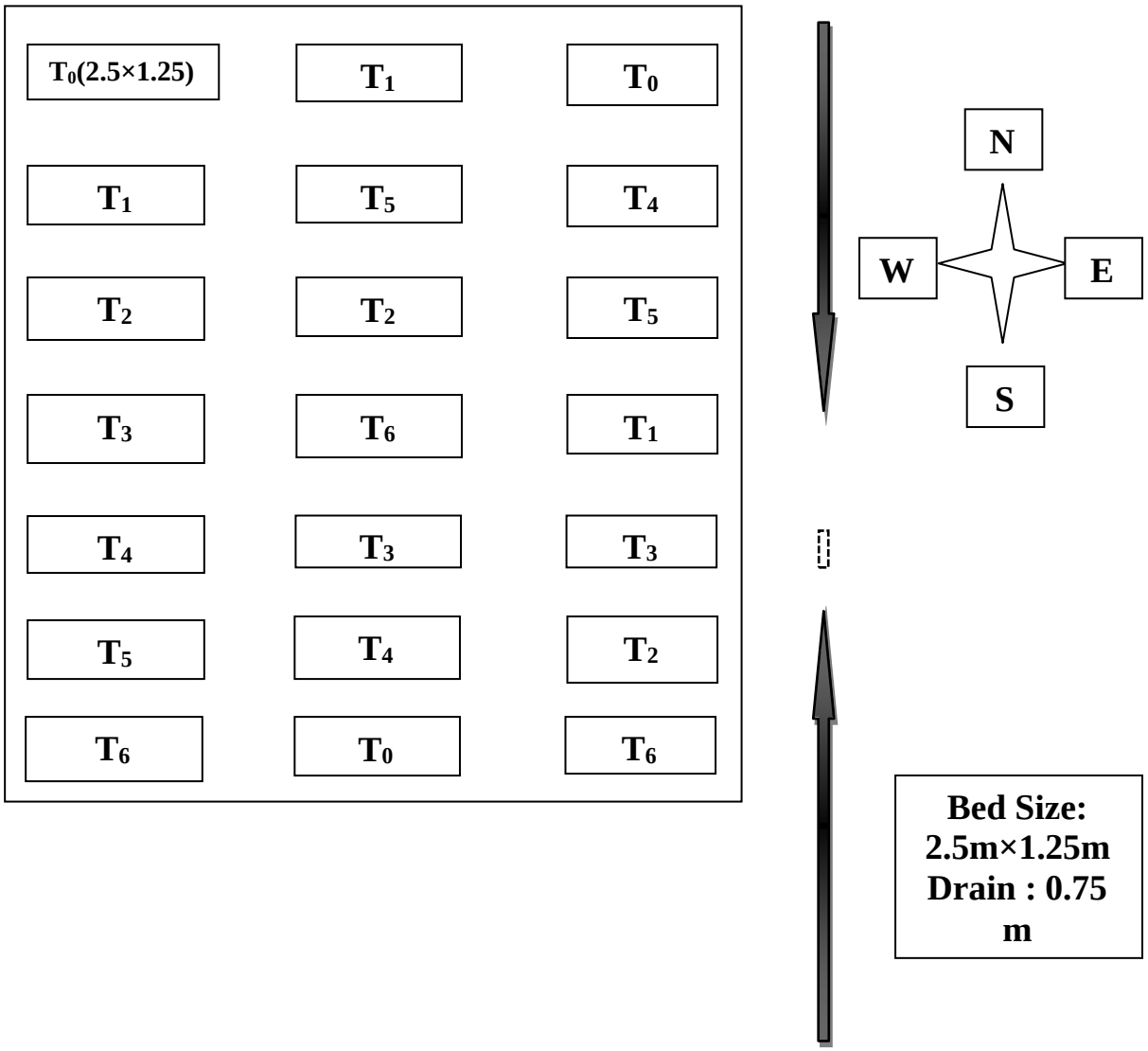


Plate 2: layout of the experimental site

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different levels of Magnesium (Mg) with population density on growth and yield of mustard (BARI Sharisha-18). The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of Magnesium (Mg) on the plant height (cm) of mustard

Differences in plant height at all the stages of growth were significant due to different doses of Magnesium (Table 2) (Appendix IV). Plant height increased with increasing doses of Magnesium at all the stages of growth. At 60 DAS among the different doses of Magnesium, T_6 @ 10 kg (Mg) ha^{-1} showed the highest plant height (92.67cm), on the other hand, the lowest plant height (74.67 cm) was observed in the T_0 treatment where no magnesium was applied. Laxminarayana and Pooranchand (2000) found no significant variations in terms of plant height among the cultivars that they studied earlier. But in another experiment Mamun *et al.* (2014) reported that BARI Sarisha-13 performed well in terms of plant height compared to other varieties that they studied. Hakim *et al.* (2014) evaluated two varieties and reported that S-9 ranked 1st with 216.50 cm plant height, while variety Early Mustard resulted 186.56 cm plant height. Altogether therefore these results indicate that different varieties of mustard produced different size of plant height.

Table 2: Effect of different doses of Mg on plant height at different days after sowing (DAS) of mustard.

Treatments	Plant height (cm)		
	30 DAS	45 DAS	60 DAS
T_0	10.33 e	44.33 f	74.67 f
T_1	11.33 e	50.00 e	79.33 e
T_2	13.33 d	52.67 d	83.67 d
T_3	16.00 c	54.67 c	86.33 c
T_4	19.33 b	56.00 b	90.00 b
T_5	20.67 ab	59.67 a	92.33 a
T_6	21.00 a	60.33 a	92.67 a
LSD (0.05)	1.54	1.07	1.55
CV%	5.43	8.12	9.08

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1},

T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1},

T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and

T_6= 10 kg Magnesium (Mg) ha^{-1}

4.1.2 Number of branches $plant^{-1}$

Different treatments of magnesium fertilizer showed insignificant variations in respect of number of primary branches $plant^{-1}$ (Table 3) (Appendix V). At 60 DAS among the different doses of magnesium, 10 kg (Mg) ha^{-1} showed the highest number of primary branches plant (8.67). On the contrary, the lowest number of primary branches $plant^{-1}$ (3.67) was recorded in the T_0 treatment. The decrease number of branches/plant may be due to negative effects of magnesium on the vegetative growth and accumulation of materials that helped proper growth and development of the mustard plant. The results obtained from the present study was conformity to the findings of Fahmina *et al.* (2013). Mohanti *et al.* (2004) reported similar observations with 30 kg Mg ha^{-1} application. Dubey *et al.* (1997) reported that Mg increased the number of primary branches per plant of linseed up to 40 kg Mg ha^{-1}.

Table 3: Effect of different doses of Mg on Number of branches plant^{-1} at different days after sowing (DAS) of mustard.

Treatments	Number of branches plant^{-1}		
	30 DAS	45 DAS	60 DAS
T_0	2.00 e	2.67 c	3.67 d
T_1	2.33 de	4.00 b	5.00 c
T_2	3.00 cd	4.33 b	5.67 c
T_3	3.33 bc	4.67 b	6.67 b
T_4	4.00 ab	5.67 a	7.33 b
T_5	4.33 a	6.00 a	8.33 a
T_6	4.67 a	6.33 a	8.67 a
LSD (0.05)	0.82	0.69	0.71
CV%	13.69	8.07	6.15

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1}, T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1}, T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and T_6= 10 kg Magnesium (Mg) ha^{-1}

4.1.3 Number of leaves plant^{-1}

Different treatments of magnesium fertilizer showed insignificant variations in respect of number of leaves plant^{-1} (Table 4). At 60 DAS among the different doses of magnesium, 10 kg (Mg) ha^{-1} showed the highest number of leaves plant^{-1} (14). On the contrary, the lowest number of leaves plant^{-1} (4.67) was recorded in the T_0 treatment.

Table 4: Effect of different doses of Mg on Number of leaves plant^{-1}at different days after sowing (DAS) of mustard.

Treatments	Number of leaves plant^{-1}		
	30 DAS	45 DAS	60 DAS
T_0	2.67 c	3.33 e	4.67 e
T_1	3.00 c	4.33 d	6.67 d
T_2	3.67 b	4.67 d	7.67 c
T_3	4.00 b	5.67 c	8.33 c
T_4	4.07 a	7.33 b	10.33 b
T_5	4.37 a	7.67 ab	13.67 a
T_6	4.67 a	8.00 a	14.00 a
LSD (0.05)	0.57	0.61	0.94
CV%	8.23	5.89	5.65

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1},

T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1},

T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and

T_6= 10 kg Magnesium (Mg) ha^{-1}

4.1.4 Number of siliqua plant^{-1}

Siliqua plant^{-1} of mustard showed a statistically significant variation for different magnesium levels under this experiment (Table 6) (Appendix VI). The number of siliqua plant^{-1} enhanced with increasing the doses of magnesium and the highest and significant number 65 was obtained with T_6 (10 kg ha^{-1} magnesium) whereas lowest siliqua plant^{-1} was 37.33 and was found in T_0 (control).

4.1.5 Length of siliqua (cm)

Length of siliqua of mustard showed a statistically significant variation for different magnesium levels under this experiment (Table 6) (Appendix VI). The length of siliqua enhanced with increasing the doses of magnesium and the highest and significant number 7.67cm was obtained with T_6 (10 kg ha^{-1} magnesium) whereas lowest length of siliqua was 4.33 cm and was found in T_0 (control). The result obtained from the present study was similar with the findings of Hussain et al. (1996) and Gangasaran et al. (1981).

4.1.6 Number of seeds siliqua^{-1}

Siliqua plant^{-1} of mustard showed a statistically significant variation for different magnesium levels under this experiment (Table 6) (Appendix VI). The number of seeds siliqua^{-1} enhanced with increasing the doses of magnesium and the highest and significant number 25 was obtained with T_6 (10 kg ha^{-1} magnesium) whereas lowest number of seeds siliqua^{-1} was 14.33 and was found in T_0 (control). Mondal and Gaffer (1983) and Gaffer and Razzaque (1983) reported that different levels of magnesium significantly increased seed per siliqua of mustard. Similar result was also reported by Sharawat *et al.* (2002), Sen *et al.* (1977) and Allen and Morgan (1972). These results are in conformity with those of Islam and Sarker (1993).

Table 5: Effect of different doses of Mg on Number of siliqua plant^{-1}, Length of siliqua (cm) and Number of seeds siliqua^{-1} of mustard

Treatments	Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}
T_0	37.33 e	4.33 d	14.33 d
T_1	40.67 d	5.33 c	20.33 c
T_2	56.33 c	5.67 c	21.33 bc
T_3	57.00 c	6.33 b	23.00 ab
T_4	58.33 c	6.67 b	23.67 a
T_5	62.33 b	7.33 a	24.33 a
T_6	65.00 a	7.67 a	25.00 a
LSD (0.05)	2.19	0.55	2.21
CV%	8.40	4.99	5.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1},

T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1},

T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and

T_6= 10 kg Magnesium (Mg) ha^{-1}

4.2 Yield and yield contributing parameters

4.2.1 Weight of 1000 seeds (gm)

Different level of magnesium exhibited statistically significant variation for 1000 seed weight (Appendix VIII). It increased significantly with higher levels of Mg with the highest (4.03 g) at T_6 treatment comprising of 10 kg Mg/ha whereas lowest (2.167) T_0 treatment (Table 7). Harawat *et al.* (2002) and Mudhokar and Ahlawat (1981) reported the similar results from their experiment and they concluded that the 100 seed weight was increased due to increasing doses of Mg fertilizer to a certain extent.

4.2.2 Seed yield hectare^{-1} (t)

Different level of magnesium exhibited statistically significant variation for seed yield hectare^{-1} (Appendix VIII). It increased significantly with higher levels of Mg with the highest (1.457 t ha-1) at T_6 treatment comprising of 10 kg Mg/ha whereas lowest (0.861 t ha-1) T_0 treatment (Table 7). The result obtained from the present study was similar with the findings of Angadi *et al.* (2003). Afroz *et al.* (2011) was obtained higher seed yield from variety BARI Sarisha-9. Mamun *et al.* (2014) reported that maximum seed yield (1.60 t ha-1) for BARI Sarisha-13.

4.2.3 Stover yield hectare^{-1} (t)

Different level of magnesium exhibited statistically significant variation for stover yield hectare^{-1} (Appendix VIII). It increased significantly with higher levels of Mg with the highest (2.609 t ha-1) at T_6 treatment comprising of 10 kg Mg/ha whereas lowest (1.845 t ha-1) T_0 treatment (Table 7). The result obtained from the present study had similarity with the findings of Ali *et al.* (1996).

Table 6: Effect of different doses of Mg on Weight of 1000 seeds (gm), Seed yield hectare^{-1} (t)and Stover yield hectare^{-1} (t) of mustard.

Treatments	Weight of 1000 seeds (gm)	Seed yield hectare^{-1} (t)	Stover yield hectare^{-1} (t)
T_0	2.17 f	0.86 f	1.85 g
T_1	2.77 e	0.90 e	1.89 f
T_2	3.06 d	1.09 d	2.19 e
T_3	3.17 cd	1.17 c	2.26 d
T_4	3.27 bc	1.31 b	2.43 c
T_5	3.36 ab	1.44 a	2.52 b
T_6	4.03 a	1.46 a	2.61 a
LSD (0.05)	0.13	0.02	0.01
CV%	12.44	9.86	10.45

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1},

T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1},

T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and

T_6= 10 kg Magnesium (Mg) ha^{-1}

4.2.4 Biological yield hectare^{-1} (t)

Magnesium had significant influence on the biological yield of mustard (Table 8). The highest biological yield of 4.066 t ha^{-1} was found from T_6 (10 kg/ha) On the other hand, the lowest biological yield of 2.706 t ha^{-1} was found from T_0 (control). The result obtained from the present study was similar with the findings of Singh *et al.* (1986).

4.2.5 Harvest Index (%)

Magnesium had significant influence on the biological yield of mustard (Table 8). The highest harvest index of 35.83 % was found from T_6 (10 kg/ha) On the other hand, the lowest harvest index of 31.83 %was found from T_0 (control). The result obtained from the present study was similar with the findings of Scarisbric *et al.* (1982) and Sharif *et al.* (1990).

Table 7: Effect of different doses of Mg on Biological yield hectare^{-1} (t) and Harvest Index (%) of mustard.

Treatments	Biological yield hectare^{-1} (t)	Harvest Index (%)
T_0	2.71 g	31.83 f
T_1	2.79 f	32.10 f
T_2	3.28 e	33.20 e
T_3	3.43 e	34.10 d
T_4	3.74 c	34.93 c
T_5	3.96 b	36.40 a
T_6	4.06 a	35.83 b
LSD (0.05)	0.03	3.27
CV%	10.46	8.54

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1},

T_2 = 04 kg Magnesium (Mg) ha^{-1} T_3 = 06 kg Magnesium (Mg) ha^{-1},

T_4 = 08 kg Magnesium (Mg) ha^{-1} T_5= 09 kg Magnesium (Mg) ha^{-1} and

T_6= 10 kg Magnesium (Mg) ha^{-1}

4.3 Post-harvest soil

4.3.1 Soil pH and Magnesium content

The study of soil pH is very important in agriculture due to the fact that soil pH regulates plant nutrient availability by controlling the chemical forms of the different nutrients and also influences their chemical reactions. The pH influences the availability of essential nutrients. Most crops grow satisfactorily in soils having a pH between 6 (slightly acid) and 7.5 (slightly alkaline).

Table 8: Showing data on soil pH and Mg content

Treatments	pH	Mg (meq/100g soil)
T_1	5.96	1.7
T_2	6.05	1.2
T_3	6.30	2.7
T_4	5.90	1.6
T_5	5.75	1.5
T_6	6.23	1.3

4.3.2 Other nutrients

Based on the nutrient availability on soil the treatments were selected. Organic matter (OM) 2–10% in most soil's mass has an important role in the physical, chemical and biological function of agricultural soils.

Table 9: Nutrient contents in soil

No.	Lab no	Name of nutrients			
		N (%)	**P** (ppm)	**K** (meq/100g soil)	**S** (ppm)
01	2873	0.10	12.87	0.26	24.51
02	2874	0.12	13.86	0.24	27.45
03	2875	0.06	15.18	0.21	30.68
04	2876	0.11	26.78	0.25	27.52
05	2877	0.07	16.78	0.33	24.55
06	2878	0.11	19.23	0.25	30.51
07	2879	0.09	14.77	0.25	25.24
08	2880	0.10	15.14	0.18	4.84
09	2881	0.11	15.68	0.21	14.79
10	2882	0.12	15.81	0.25	3.64
11	2883	0.12	15.79	0.26	3.64
12	2884	0.09	15.69	0.27	36.85

CHAPTER V

SUMMARY

This experiment was conducted on rapeseed with six doses of Magnesium (Mg) in the rabi season of November 2019 to February 2020 to evaluate the performance of different doses of Mg fertilizer on growth and yield of mustard (BARI Sharisa-18) in respect of growth and yield performance.

Single factors Randomized Complete Block Design was followed with 7 treatment having unit plot size of 3m x 1.5m (4.5 m^2) and replicated thrice. The treatments were T_0= Control, T_1= 02 kg Magnesium (Mg) ha^{-1}, T_2 = 04 kg Magnesium (Mg) ha-1, T_3 = 06 kg Magnesium (Mg) ha^{-1}, T_4 = 08 kg Magnesium (Mg) ha^{-1}, T_5= 09 kg Magnesium (Mg) $ha^{-1}$and T_6= 10 kg Magnesium (Mg) ha^{-1}.

Recommended doses of N, K, Zn and B (120 kg N from urea, 40 kg K from MOP, 3 kg Zn from ZnO and 1 kg B ha^{-1} from Boric acid, respectively) were applied. The whole required amounts of MOP, ZnO, Boric acid and half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 22 days of germination. The required amounts of P (from TSP) and S (from gypsum) were applied at a time as per treatment combination after land preparation were mixed properly through hand spading. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT.

Magnesium showed positive effect on the plant height, number of primary branches per plant, number of leaves per plant, number of siliqua per plant, length of siliqua, number of seeds per siliqua, thousand seed weight (g), seed yield (t ha^{-1}), stover yield(t/ha), biological yield(t/ha) and harvest index (%). All the plant characters increased with increasing levels of Mg up to certain level.

Plant height was significantly influenced by different levels of application Mg. Plant height increased with increasing levels of Mg up to certain level. The tallest plant (92.67cm) was found in T_6 treatment, which was higher over control (T_0) treatment (74.67cm). Number of siliqua per plant was found maximum (65) in T_6 treatment and minimum (37.33) in T_0 treatment. Number of branches per plant

insignificantly varied with different characters (highest 8.671 in T_6 treatment and lowest T_0 treatment). Number of leaves per plant, seed per siliqua, length of siliqua, weight of thousand seed, seed yield, Stover yield(t/ha), biological yield(t/ha) and harvest index(%) were highest in T_6 (14), T_6 (50.33), T_6 (25), T_6 (7.67 cm), T_6 (4.03g), T_6 (1.457 t/ha), T_6 (2.609 t/ha), T_6 (4.066 t/ha) and T_6 (35.83%) respectively and the lowest was recorded in T_0 (4.67), T_0 (39), T_0 (14.33), T_0 (4.33 cm), T_0 (2.167 g), T_0 (0.861 t/ha), T_0 (1.845), T_0 (2.706 t/ha) and (31.83%) respectively.

CHAPTER VI

CONCLUSION

Based on the results it can be concluded that, treatment 6 10 kg Magnesium (Mg) ha^{-1} showed comparatively high yield for the production of mustard.

However, this result has made a basis for further study that in different regions involving different factors of production of mustard to make a specific conclusion. Further research is, therefore, necessary to reach a conclusion.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh to investigate regional adaptability and other performances;
2. Another level of magnesium may be included in the further study;
3. Another fertilizer may also include in the program for future study.

REFERENCES

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

Afroz, M.M., Sarkar, M.A.R., Bhuiya, M.S.U. and Roy, A.K. (2011). Effect of sowing date and seed rate on yield performance of two mustard varieties. *J. Bangladesh Agril. Univ.*, 9(1): 5-8.

AIS (Agricultural Information Service). (2017). Krishi Diary (In Bangla). Agril. Inform. Ser. Khamarbari, Farmgate, Dhaka, Bangladesh. p.16.

Alam, M.M. and Rahman, M.M. (2006). Effect of row spacing on seed yield of five varieties of Rapeseed. *Bangladesh J. Crop Sci*., 17: 163-168.

Al-Barzinjy, M., Stolen, O., Christiansen, J. L. and Jensen, J. E. (1999). Relationship between plant density and yield for two spring cultivars of oilseed rape (*Brassica napus* L.). Acta Agr. Scand. Sect. B, *Soil Plant Sci*. 49: 129–133.

Ali, M.H., Karim, M.M. and Khaleque, M.A. (1977). Effect of irrigation and nitrogen on mustard. *Bangladesh J. Agric*. 1: 5-8.

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

Ali, M.H., Zaman, S.M.H., Hossain, S.M.A. (1996). Variation in yield, oil and protein content of rapeseed (Brassica campestris) in relation to levels of nitrogen, magnesium and plant density. *Indian J. Agron*. 41: 290–295.

Alien, E.J. and Morgan, D.G. (1972). A quantitative analysis of the effect of nitrogen on the growth, development and yield of oilseed rape. *J. Agri. Sci.* (Camb.) 78: 315-324.

Angadi, S.V., Cutforth, B.G., McConkey, H.W. and Gan. Y. (2003). Yield Adjustment by Canola grown at different plant populations under Semiarid Conditions. *Crop Sci*. 43: 1358-1366.

Anonymous. (2012). Bangladesh Bureau of Statistics. Monthly Statistical Bulletin of Bangladesh. January, Statistics Div., Ministry of Planning, Govt. People's Repub. Bangladesh. p. 54.

Asaduzzaman, S.M. and Shamsuddin, A.M. (1986). Effect of nitrogen on yield and yield components of mustard (var. SS-75) under different levels of irrigation. Abstract of papers of Bangladesh Soc. of agron. Ann. Conf. Dhaka, BARI, Bangladesh. pp. 4-5.

Aziz, M.A., Chakma, R., Ahmed, M., Rahman, A.K.M.M. and Roy, K. (2011). Effect of sowing dates on the growth, development and yield of mustard in the hilly areas. *J. Expt. Biosci*., 2(1): 33-36.

Bani-Saeedi, A. (2001). Examination of different amount of nitrogen and density on growth, quantity and quality characters in canola, in Khozestan climate condition. M.Sc. Thesis, Dezfool University, Dezfool, Iran (In Persian).

Banuels, G.S., Meek, D.W. and Joffman, G.J. (1990). The influence of Selenium, salinity and boron on selenium uptake in wild mustard. *Plant and Soil.* 127(2): 201-206.

BARI (Bangladesh Agricultural Research Institute). (2001). Annual Report 2000-2001. Oilseed Research Centre. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. p. 115-118.

BARI (Bangladesh Agricultural Research Institute). (2014). Krishi Projucti, Handbook of Agro-technology. 3rd Edn., 2013-2014. Oilseed Research Centre. *Bangladesh Agril. Res. Inst*., Joydebpur, Gazipur.

Barman, K.K., Mahmud, S., Salim, M. and Chowdhury, B.L.D. (2016). Yield attributes and oil content of different mustard (*Brassica campestris* l.)

varieties effected by different levels of fertilizers. *Asian J. Med. Biol.* Res.,2(1): 143-147.

BBS (Bangladesh Bureau of Statistics). (2019). Monthly Statistical Bulletin. (August). Stat. Div., Minis. Planning, Govt. Peoples Repub. Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2019). Statistical Pocket Book of Bangladesh Bureau of Staistics. Statistics Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh p. 28.

Begum F., Hossain F. and Mondal M.R.I. (2012). Influence of Magnesium on morpho-physiological and yield parameters of rapeseed. *Bangladsh J. Agril. Res*., 37(4): 645-652.

Behera, B.H.W., Sharma, H.C. and Paula, P.K. (2002). Effect of plant population and magnesium levels on root growth, seed yield, and moisture use efficiency of mustard varieties under rain fed condition. *Indian J. Soil. Cons.* 3(2):161-165.

Biswas, D. , Ali, S. A. and Khera, M.S. (1995). Response of Ghobi sarson (*Brassica napus* L. ASN-706) to nitrogen and magnesium. *J. Indian Soc. Soil Sci.* 43: 220-225.

Chaubey, A.K., Singhand, S. B., Kaushik, M. K. (2000). Response of groundnut (Arachis hypogaea) to source and level of magnesium fertilizer in mid-western plains of Uttar Pradesh. *Indian. J. Agron* 45(1): 166- 169.

Chauhan, A.K., Singh, M. and Dadhwal, K. S. (1993). Effect of nitrogen level and row spacing on the performance of rapeseed (Brassica napus). *Indian. J. Agron*. 37(4): 851-853.

Chauhan, D.R., Paroda, S. and Singh, D.P. (1995). Effect of biofertilizers, gypsum and nitrogen on growth and yield of raya (*Brassica juncea*). *Indian J. Agron.* 40:639-642.

Cheema, M.A., Saleem, M. and Malik, M.A. (2001). Effect of row spacing and nitrogen management of agronomic traits and oil quality of canola (*Brassica napus* L.). *Pakistan. J. Agri. Sci*. 38: 15-18.

Day, K.S., Thornton, R., Kreeft, H., Ghabbour, E.A. and Davies, G. (2000). Humic acid products for improved phosphorus fertilizer management. Humic substances, versatile components of plants, soil and water. Proceedings of the Fourth Humic Substances Seminar held at Northeastern University, Boston, Massachusetts, USA, on 22-24 March. pp. 321-325.

Dijshorn, W. Larup, J.W.M. and Van Burg, U.E.J. (1960). A method of diagnosing the sulfur nutrition status of herbage, *Plant and Soil*. 13: 227-241.

Dubey, S.D., Shukla, P. and Tiwari, S.P. (1997). Effect of S fertilizer on growth and yield of linseed (*Linum usitatissium*). *Indian J. Agri. Sci*. 67(11), 539-540.

El-Agrodi, M.W.M., Zein, F.I., Labeeb, G. and Ramadan, M.S.A. (2016). Impact of EDTA, citric acid and humic acid on phytoremedation of metal contaminated soil by Indian mustard (*Brassica juncea*). *J. Soil Sci. and Agric. Eng*., Mansoura Univ., 7(10): 729-737.

FAO (Food and Agriculture Organization). (2003). FAO Production Year Book. Food Agriculture Organization of United Nations, Rome 00100, Italy.

FAO (Food and Agriculture Organization). (2004). FAO Production Year Book. Food and Agriculture Organization of the United Nations, Rome 00100, Italy. 56: 118.

FAO (Food and Agriculture Organization). (2012). Production Year Book. Food and Agriculture Organization of the United Nations, Rome. Italy.

FAO (Food and Agriculture Organization). (2014). FAO Production Year Book. Food and Agriculture Organization of the United Nations, Rome 00100, Italy. 65: 123.

Gaffer, M.A. and Razzaque, A.H.M. (1983). Response of mustard to different levels of N, P, K fertiizers under two methods of seeding. Bangladesh Association for the advancement of Science, Khaka. Proc. 8th Bangladesh Sci. Conf. BAAS, Dhaka, p. 20.

Gangasaran, Patil, R.R. and Prasad, M. (1981). Multiple regression studies on brown sarson. *Indian J. Agron*. 26: 220-224.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed. A. John Wiley Inter sci. Pub. p. 130-240.

Greath, N. and Schweiger, W. (1991). Improvement of the use of nutrients winter rape-a strategy of economically responsible fertilizing. In: McGregor. D. I. (ed), Proceedings of the Eighth. International Rapeseed Congress, Saskatoon, Canada. Organizing Committee, Saskatoon. Pp. 1197-1201.

Gupta, G.P., Mehta, R.P. and Khan, A.R. (1961). Effect of time of application of nitrogen on yield and quality of linseed. *Ind. Oilseed J.* 5(1): 63-68.

Gupta, S.K. (1988). Effect plant geometry on growth and yield of mustard. *Indian J. Agron.* 33(2): 208-209.

Gurjar, B.S. and Chauhan, D.V.S. (1997). Yield attributes and seed yield of Indian mustard (Brassica juncea) as influenced by varieties, fertility levels and spacing in Harsi command areas. *Indian J. Agron.* 42(1): 142-144.

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

Holmes, M.R.J., Ainsley, A.M. (1977). Fertiliser requirements of spring oilseed rape. *J. Sci. Food Agric*. 28(3): 301-311.

Hussain, M.F., Zakaria, A.K.M., and Jahan, M.H. (1996). Technical report on variety screening adaptive research on oilseeds. Rural Develoment Academy, Bogra, Bangladesh. pp. 6-34.

Hussain, M.J., Sarker, M.M.R., Sarker, M.H., Ali, M. and Salim, M.M.R. (2008). Effect of different levels of boron on the yield and yield attributes of mustard in Surma-Kushiara flood plain soil (AEZ 20). J. Soil. Nature. 2(3): 06-09.

Islam, M. B. and Sarker, M. A. Z. (1993). Effect of different level of boron on the yield of mustard. Research Report 1992-1993. OFRD, BARI, Rangpur.

Kanwar, J. S. (1984). Sulfur and food production in the tropical countries problems projections and policy implications. *Ind. Soc. Sci.* 32: 583-594.

Karim, M.R., Islam, F., Ahmed, F. and Islam, M.R. (2000). Performance of some B. juncea varieties under on-farm condition at Pabna. *Bangladesh J. Agril. Extn.*, 27(1): 157-158.

Keeling, A.A., McCallum, K.R. and Beckwith, C.P. (2003). Crop and Environment Research Centre, Harper Adams University College, Newport, Shropshire, UK, Bioresource Tech., 90(2): 127-137.

Keivanrad, S. and Zandi, P. (2014). Effect of nitrogen levels on growth, yield and oil quality of indian mustard Grown under different plant densities. Agronomical and qualitative features of indian mustard. XLVII: 1 (157)

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.

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.

Kjellstrom, C. (1993). Comparative growth analysis of Brassica napus and Brassica juncea under Swedish conditions. Canadian J. Plant Sci. 73: 795-801.

Kumar, A. and Gangwar, K.S. (1985). Analysis of growth, development and yield of Indian rape seed (Brassica campestris var. tori) in relation to N and plant densities. *Indian J. Agron*. 30(3): 358-363.

Laxminarayana, P. and Pooranchand, C. (2000). Response of mustard varieties to time of sowing in Northern Telangana. J. Hyderabad Agril. Univ., 28(1/2): 75-77.

Leach, J. E., Stevenson, H. J., Rainbow, A. J., Mullen, L. A. (1999). Effects of high plant populations on the growth and yield of winter oilseed rape (*Brassica napus*). *J. Agr. Sci*. 132: 173–180.

Lotfi, R., Kalaji, H.M., Valizadeh, G.R., Khalilvand B.E., Hemati A., GharaviKochebagh, P. and Ghassemi, A. (2018). Effects of humic acid on photosynthetic efficiency of rapeseed plants growing under different watering conditions. Photosynthetica. 56(3): 962-970.

Mackowiak, C., Grossl, P. and Bugbee, B. (2001). Beneficial effects of humic acid on micronutrient availability to wheat. *Soil Sci. Soc. Am. J.*, 65(6): 1744-1750.

Majnoun-hosseini, N., Alizadeh, H. M. and Malekahmadi, H. (2006). Effects of plant density and nitrogen rates on the competitive ability of canola (*Brassica napus L*.) against weeds. *J. Agric. Sci. Technol*. 8: 281-291.

Mamun, F., Ali, M.H., Chowdhury, I.F., Hasanuzzaman, M. and Matin, M.A. (2014). Performance of Rapeseed and Mustard Varieties Grown Under Different Plant Density. *Sci. Agri*., 8(2): 70-75.

Mankotish, B.S. and Sharma, H.L. (1997). Yield attributes and yield of gobhi sarson (*Brassica napus* L.) and toria (Brassica rapa) under different levels of nitrogen, phosphorus and farm yard manure in mid-hills of north western Himalayas. *Indian J. Agri. Sci*. 67(3): 106-109.

Mauromicale, G., Angela, M.G.L. and Monaco, A.L. (2011). The effect of organic supplementation of solarized soil on the quality of tomato. Scientia Hort., 129(2): 189-196.

Meena, B.S., Shara, 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, H., Meena, P.K.P. and Kumhar, B.L. (2017). Studies on Response of Mustard Varieties to Different Sowing Dates under Humid Southern Plain Zone of Rajasthan. Intl. J. Pure App. Biosci., 5(3): 385-391.

Meitei, W.I., Anal, P.S.M. and Luikham, E. (2001). Rate and pattern of growth in physiological parameters as affected by spacing and varieties in broad leaf mustard (Brassica juncea var. rugoja Roxb., Tsen and Lee). *Indian J. Hill Farm*. 14(2): 44-47.

Mikkelsen, R.L. (2005). Humic materials for agriculture, Davis, California, USA. Better Crops with Plant Food. 89(3): 6-7.

Mir, M. R., M., Mobin, N. A., Khan, M. A., Bhat, N. A., Lone, K. A., Mirzashahi K., Salimpour, S., Daryashenas, A., Malakouti, M. J., Rezaie, H. (2000). Determination of the best rate and application method of nitrogen in rapeseed in Safiabad. Iranian J. Soil and Water Sci. (Special Issues: Canola) 12(12):7-11. (In Persian)

Mishra, B. K. and Rana, N. S. (1992). Response of yellow sarson (Brassica napus var. glaucal to row spacing and nitrogen fertilization under late sown condition. Indian. J. Agron. 37(4): 847-848.

Mohanti, A. K., Sunil, K., Jha, S. K., Sanjeev, M., Chandrakar, B. L. (2004). Effect of different level of magnesium and boron on morpho-physiological growth and economics of soybean (Glycine max). Plant Archives 4(2), 375-377.

Momoh, E. J. J. and Zhou, W. (2001). Growth and yield responses to plant density and stage of transplanting in winter oilseed rape (Brassica napus L). J. Agron. Crop Sci. 186: 253–259.

Mondal, M.R.I. and Gaffer, M.A. (1983). Effect of different levels of nitrogen and phosphorus on the yield and yield contributing characters of mustard. *Bangladesh J. Agril. Res.* 8 (1): 37-43.

Mondal, M.R. and Wahab, M.A. (2001). Production Technology of Oilseeds. Oilseed Res. Centre, BARI, Joydebpur, Gazipur. 6-24.

Mostofa, M.H.U., Islam, M.N., Kadir, M. and Miah, N.H. (2016). Performance of rapeseed and mustard (Brassica sp.) varieties/lines in north-east region (sylhet) of Bangladesh. Adv. Plants Agric. Res., 5(1): 457-462.

Mudholkar, N. H. and Ahlawat, I.P.S. (1981). Response of rapeseed to plant density and fertilizer. *Indian. J. Agron.* 26(2): 184-188.

Mustapic, Z., Gotlin, J. and Gasperov. (1987). Studies on sowing rate and stand density in winter rape cv. Belinda and Tmara in North Cooatia, Yugoslavia, Field Crop Abst. 41(10): 859.

Narang, R. S. and Singh, S. (1985). Nitrogen management in India mustard. *Indian J. Agron.* 30 (4): 477-482.

Nardi, S., Pizzeghello, D. and Pandalai, S.G. (2004). Rhizosphere: A communication between plant and soil. Recent Res. Development in Crop Sci., 1(2): 349-360.

Narwal, R. P., Gupta, A. P., Karwasra, S. P. S., Antil, R. S. (1991). Effect of carriers of magnesium on yield and uptake of magnesium by mustard. J. Indian Soc. Sci. 39(2): 327.

Nasiri, A., Samdaliri, M., Shirani-Rad, A., Mirkale, A.M. and Jabbari, H. (2017). Influence of humic acid, plant density on yield and fatty acid composition of some rapeseeds cultivars during two years. *Academic J. Agric. Res.*, 5(7): 155-161.

Patel, R.H., Sharma, V. and Usadadia, V.P. (2004). Influence of irrigation schedule, spacing and nitrogen on growth, yield and quality of mustard. Department of Agronomy, Gujarat Agricultural University. India. 5 (2-3): 290-293.

Patel. J.R., Parmar, M.T. and Patel, J.C. (1980). Effect of different sowing dates spacing and plant population on yield of mustard. *Indian J. Agron*. 25(3):526-527.

Peng, Z.P., Shi-Chuan, X., Zhi-Mei, S., Ming-Xin, M. and Huixin, Z. (2001). A study of the effect of humic acid compound fertilizer on the quality and physiological index of Brassica. J. Hebei Agric. Univ., 24(1): 24-27.

Pooran, C., Govardhan, M. and Sujatha, M. (2000). Effect of dates of sowing on performance of mustard varieties. Gaurav Society of Agril. Res. Infor. Cent. 1(2): 153-155.

Prakash5: 263-268.

Rahman, L. (1977). Breeding for oil content and composition in oleiferous Brassica. Breeding for oil content. *Bangladesh J. Agric*. 1(2): 127-134.

Rahman, M. L., Quddus, M. A. and Shae-Alam, M. (1982). Performance of two selected and two locally recommended varieties under different cultural conditions. Breeding, Bangladesh Agril. Univ. Mymensingh. Annual Report No. 2(77): 8-14.

Rahman, M., Karim, Z. and Khan, M. S. (1984). The response of mustard to irrigation at different levels of magnesium. *Bangladesh J. Soil. Sci*. 19: 75-82.

Rahman, M.M. (2002). Status of oil seeds and future prospects in Bangladesh, Paper Presented in Review Workshop on the Impact of Technology Transfer on Oil Crops, held at BARI on 29 April 2002.

Rajpar, M.B., Bhatti, Z.H., Shah, A.N. and Tunio, S.D. (2011). Humic acid improves growth, yield and oil content of Brassica compestris L. Pakistan J. Agri., *Agril. Engg. Vet. Sci*., 27(2): 125-133.

Rana, D. S. and Pachauri, D. K. (2001). Sensitivity of zero erucic acid genotypes of Oleiferous Brassica to plant population and planting geometry. *Ind. J. Agron.* 46(4): 736-740.

Rastghalam, Z.S., Hoodaji, M. and Javanmard, H. (2011). The Influence of Humic Acid and Nano-superabsorbent Application on the Growth of Brassica Napus L. in Lead-contaminated Soil. *Intl. Conf. on Env. & Agric*. Engin. Ipcbee, IACSIT Press, Singapore.

Reddy, B.N. and Sinha, M.N. (1989). Integrated fertilizer and water management to boost mustard production. Indian farming. 39(5):5-6. In: Field Crop Abst. 43(3): 272.

Roy, V., Maiti, S. and Chatterjee, B. N. (1981). Growth analysis and fertilizer response of varuna. Indian mustard. Indian J. Agric. Sci. 51(3): 173-180.

Saeed-Shariati S. (1996). Evaluation of plant density and time of topdressing on yield, yield components and phonologic stages of spring rapeseed in Mashhad. M.Sc. Thesis, Mashhad University, Mashhad, Iran.

Sarkar, M. A. R., Sarker, A.V., Das, P. K. and Chowdhury, A. K. M. S. H. (1992). Effect of magnesium fertilization on the yield componenets of mustard varieties. Bangladesh J. Agril. Sci. 20(2): 351-358.

Scarisbrick, D.H., Daniels, R.W and Rawi, N. (1982). Effect of varying seed rate on the yield components of oil seed rape (*Brassica napus*). *J. Agric. Sci. Cambridge*. 99: 561-568.

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

Sharif, M.A., Ahmad, M.S. and Khattak. R A. (2004). Effect of organic and inorganic fertilizers on the yield and yield components of maize. Pakistan J. Agric. Agril. Engg. Vet. Sci., 20(1): 11-16.

Sharif, M.A.R., Haque, M.Z., Howlader, M.H.K. and Hossain, M.J. (2016). Effect of sowing time on growth and yield attributes of three mustard cultivars grown in Tidal Floodplain of Bangladesh. *J. Bangladesh Agril. Univ*.,14(2): 155–160

Sharif, S.A., Shavana, R., Ibrahim, A.F. and Geisler, G. (1990). Variation in seed yield and quality characters of four spring oil rapeseed cultivars as influenced by population arrangements and densities. *J. Agron. And Crop Sci*. 165(2-3): 103-109.

Sharma, M.L. (1992). Response of mustard (Brassica juncea) varieties to row spacing. Indian J. Agron. 27(3): 593-594.

Sheppeard, D.C. and Bates, T.E. (1980). Yield and chemical composition of rape in response to nitrogen, phosphorus and potassium. Canadian J. Soil. Sci. 60: 153-163.

Siadat, S.A., Sadeghipour, O. and Hashemi-dezfouli, A.H., (2010). Effect of nitrogen and plant density on yield and yield component of rapeseed. *J. Crop Prod. Res.*, (Environmental stresses in plant sciences) 2(1): 49- 62 (In Persian).

Singh, A.K., Singh, H., Rai, O.P., Singh, G., Singh, V.P., Singh, N.P. and Singh, R. (2017). Effect of sowing dates and varieties for higher productivity of Indian mustard. J. Appl. & Natural Sci., 9(2): 883-887.

Singh, B., Singh, J.A., Yadav, Y. P. and Singh, S. (1999). Response of Brassica to magnesium for yield. Indian J. Agric. Sci. 69: 427-43.

Singh, D., Jain, K. K. and Sharma, S. K. (2004). Quality and nutrient uptake in mustard as influenced by levels of nitrogen and magnesium. Department of Agronomy, College of Agriculture, Bikaner, India. Maharashtra J. Agric. Univ. 29 (1): 87-88.

Singh, K. and Singh, D. (1987). Response of mustard to nitrogen and spacing. Indian J. Agron. 32(1): 15-17.

Singh, K., Singh, B. P., Bhola, A. L. and Yadava, T. P. (1972). Effect of sowing time and nitrogen application in varieties of Indian mustard (Brassica juncea) under irrigated conditions in Haryana. *Indian. J. Agric. Sci*. 42 (7): 601-603.

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, P.L., Giri, G., Gangasaran and Tarkhede, B. B. (1986). Effect of spatial arrangement in mustard under rainfed conditions. *Indian J. Agron*. 31(4): 357-369.

Singh, R. A. and Rathi, K. S. (1984). Studies on nitrogen requirement of mustard

Singh, R. A. and Rathi, K. S. (1985). Studies on nitrogen requirements of mustard. Ind. J. Agron. 30: 257-259.

Singh, R.K. and Singh, C.V. (2017). Studies on response of mustard varieties to different sowing dates under alluvial soils of indo-gengetic plains. *Intl. J. Appl. & Natural Sci.,* 6(3): 9-14.

Singh, V., Lothi, M. and Verma, N. K. (2008). Effect of phosphorus and sulfur levels on growth and yield of mustard (*Brassica juncea* Coss) variety „Varuna". *Agric. Sci. Digest*. 28 (1): 59-60.

Sinsinwar, B. S., Kumar, A., Premi, O. P. and Singh, F. (2004). Production potential and nitrogen requirement of Indian mustard. National Research Centre on mustard, Sewar, Bharatpur, Rajasthan, India. 21(1): 175-177.

Surya, K., Singh, D., Rao, V. U. M., Singh, R. and Kant, S. (1998). Effect of sowing date, plant densities and varieties on yield and yield attributes of Indian mustard. Ann. Agro. Bio. Res. 3(1):105-107.

Tomar, R. K. S., Chaurasia, S. C. and Aghes, J. S., (1995). Effect of N and S on nitrogen concentration, yield and oil content of mustard on vertical irrigated condition. Advances in Agricultural Research in India 4: 153-160.

Tomar, S. S. and Namedo, K. N. (1989). Response of Indian mustard varieties to row spacing and nitrogen. Indian J. Agron. 34(4): 472-473.

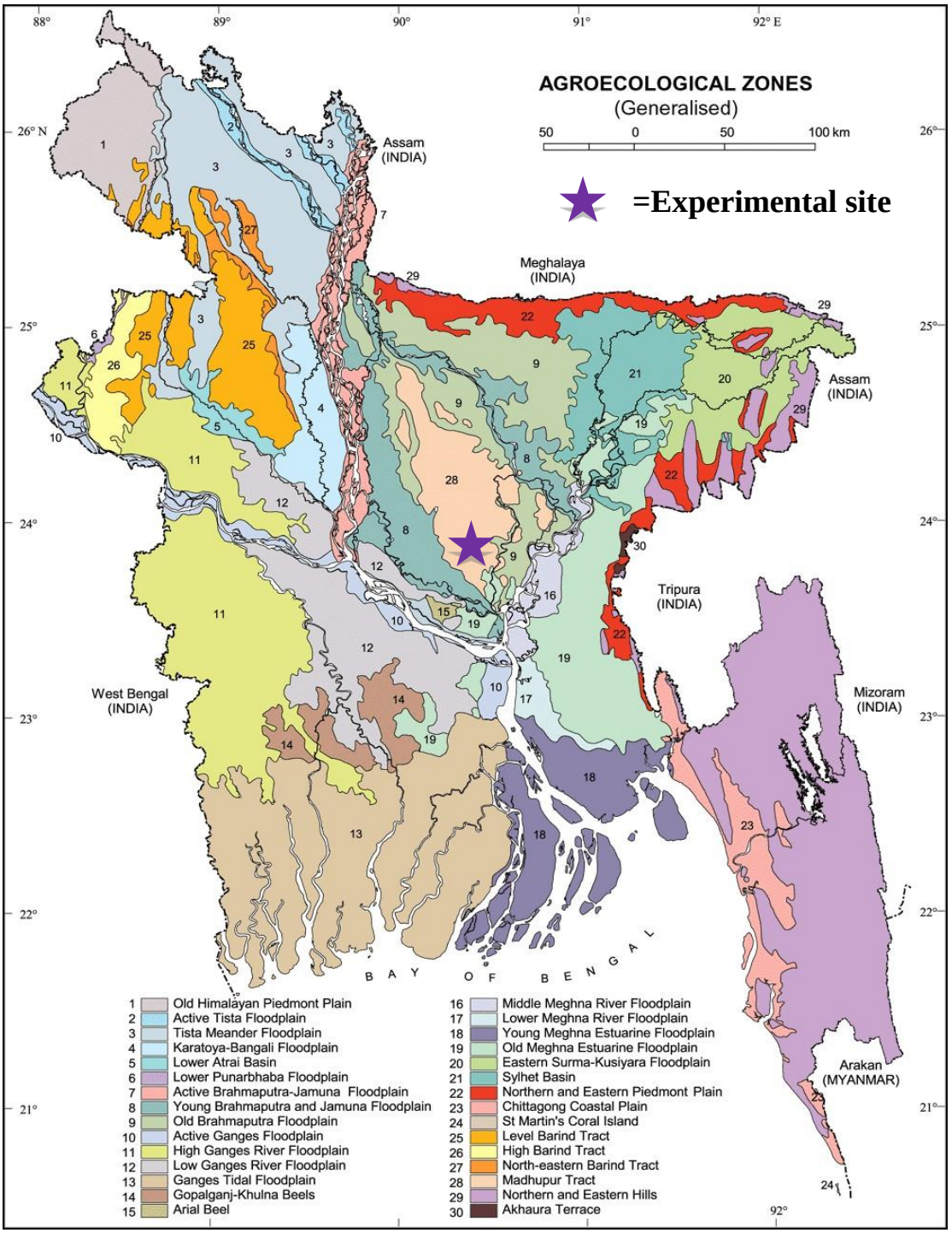
Tripathi, A. K. and Tripathi, H. N. (2003). Influence of nitrogen levels on growth, yield and quality of Indian mustard. Farm Sci J. C. S. Azad University of Agriculture and Technology, Kanpur, India. 12(1): 71-72.

Vetayasuporn, S. (2006). Effects of biological and chemical fertilizers on growth and yield of glutinous corn production. *J. Agron*., 5(1): 1-4.

Wright, G.C., Smith, C.J. and Woodroof, M.R. (1988). The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napus* L.) production in South Eastern Australia. I. Growth and seed yield. Irrig. Sci. 9: 1-13.

Appendices

Appendix I. Map showing the experimental site under study



Appendix II. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from October, 2020 to April, 2021

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2020	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	32.4	21.1	63	31

Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV: Analysis of variance (mean square) of the data for plant height.

Source of variation	df	Plant height		
		30 DAT	45 DAT	60 DAT
Replication	2	0.142	1.476	0.429
Treatment	6	59.444**	93.936**	138.857**
Error	12	0.754	0.365	0.762

Appendix V: Analysis of variance (mean square) of the data for Number of branches.

Source of variation	df	Number of branches		
		30 DAT	45 DAT	60 DAT
Replication	2	0.047	0.761	2.047
Treatment	6	3.047*	4.984**	9.873**
Error	12	0.214	0.150	0.158

Appendix VI: Analysis of variance (mean square) of the data for Number of siliqua plant^{-1}, Length of siliqua (cm) and Number of seeds siliqua^{-1} of mustard.

Source of variation	df	Number of siliqua plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}
Replication	2	3.571	1.761	7.428
Treatment	6	339.540**	4.094**	39.825**
Error	12	1.516	0.095	1.539

Appendix VII : Analysis of variance (mean square) of the data for Weight of 1000 seeds (g), Seed yield hectare^{-1} (t) and Stover yield hectare^{-1} (t) of mustard.

Source of variation	df	Weight of 1000 seeds	Seed yield hectare^{-1} (t)	Stover yield hectare^{-1} (t)
Replication	2	0.004	0.042	0.002
Treatment	6	0.583**	0.174**	0.262**
Error	12	0.005	0.001	0.002