INFLUENCE OF NITROGEN AND SULPHUR LEVEL WITH POPULATION DENSITY ON GROWTH AND YIELD OF MUSTARD (SAU Sharisha-3)

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Dedicated to

My Beloved Parents

CERTIFICATE

*This is to certify that thesis entitled, **"Influence Of Nitrogen And Sulphur Level With Population Density On Growth And Yield Of Mustard (SAU Sharisha-3)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science in Agronomy**, embodies the result of a piece of bona fide research work carried out by **Md. JulfikerHaider**, **reg.o.: 09-03471** 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 been duly acknowledged.

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. A. K. M. Ruhul Amin
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ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2015 to February 2016 to determine the effect of nitrogen and sulphur levels with different population densities on growth and yield of mustard (SAU Sharisha-3). The experiment consists of two factors. Factor A: nitrogen + sulphur (5 levels) i.e. F_0 = Control, F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}, F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}, F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}, F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}; Factor B: Population density (4 levels) i.e. P_1 = 200000 plants ha^{-1}(20 plants m^{-2}), P_2 = 400000 plants ha^{-1} (40 plants m^{-2}), P_3= 600000 plants ha^{-1}(60 plants m^{-2}), P_4 = 800000 plants ha^{-1} (80 plants m^{-2}) were in this experiment. Significant variation was found in all parameters at different growth stages of mustard (SAU Sarisha-3). Data showed that F_3P_4 gave the tallest plant (90.73 cm) but F_4P_1 gave the highest no. of branches $plant^{-1}$ (8.20).Maximum value of 1000 seed weight (3.80 g), siliqua $plant^{-1}$ (137.61) and seeds $siliqua^{-1}$ (29.30) were found from F_3P_1. Again the maximum stover yield (4055 kg ha^{-1}) and biological yield (6093 kg ha^{-1}) were found from F_3P_4. Considering individual effect, F_4(130 kg nitrogen + 30 kg sulphur ha^{-1}) gave the highest seed yield (1862.5 kg ha^{-1}), biological yield (5458.4 kg ha^{-1}), harvest index (34%) and P_3 (60 plants m^{-2}) gave the maximum seed yield (1733.9 kg ha^{-1}) and harvest index (36.15%). But the maximum seed yield (2081 kg ha^{-1}) was found with the treatment combination of F_3P_3.

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SOME COMMONLY USED ABBREVIATION

FULL WORD	ABBREVIATION
And others	*et al.*
Bangladesh Bureau of Statistics	BBS
Bangladesh Agricultural Research Institution	BARI
Cultivar	cv.
Degree Celcius	^{o}C
edest (means That is)	i.e.
Figure	Fig.
Gram	g
Micro gram	µg
Micro mol	µM
Milligram/litre	mgL^{-1}
Namely	Viz.
Parts/million	ppm
Percentage	%
Species (plural number)	spp.
Variety	var.

CHAPTER I

INTRODUCTION

Mustard (*Brassica spp*) is one of the most important oil seed crops throughout the world after soybean and groundnut (FAO, 2003). It has a remarkable demand for edible oil in Bangladesh. Mustard tops the list among the oil seed crops grown in this country in respect of both production and acreage (BBS, 2004).

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.

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. Until recently, mustard varieties such as Tori-7, sampad (both are *B.campesties*) and Doulat *B. juncea* were mainly grown in this country. Recently, MM-2^{-1}6-98. MM-34-7, MM-38-6-98, MM-49-3-98, Binasarisha-4 are high yielding mutants/varieties have been developed by the scientist of Bangladesh Institute of Nuclear Agriculture (BINA). Very recently, a new variety of mustard named SAU-sharisha-3 has been developed in the Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University. 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).

However, the production of mustard is hampered due to many reasons of which suitable varieties, inadequate use of fertilizers such as nitrogen and sulphur fertilizer,inadequate population density etc. are very important for the cultivation of mustard in Bangladesh. Nitrogen is the most spectacular of all essential nutrients in its effect on plant growth and yield of this crop. The literature shows that nitrogen has significant effect on plant height, branches plant^{-1}, pods plant^{-1} and other growth factors and yield of mustard (Mondal and Gaffer, 1983; Allen and Morgan, 1972). Nitrogen increases the vegetative growth and delayed maturity of plants. Excessive use of this element may produce too much of vegetative growth, thus fruit production may be impaired (Sheppard and Bates, 1980; Singh *et al*., 1972). The importance of NPK in increasing production is well recognized but sulphur which is ranking third or fourth in the mineral composition of plants and is essential for the synthesis of proteins, vitamins and sulphur containing amino acid has been ignored (Kanwar, 1984). Oilseeds not only respond to applied S, but their requirement for S is also the highest among other crops, thereby attributing a role for the nutrient in oil biosynthesis. Moreover, nitrogen and sulphur are closely related with one another because both of these elements are required for protein synthesis and their amount in plant tissue always maintained at constant ratio with different population densities (Dijshorn *et al*., 1960). It is, therefore, likely that the effect of N and S 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 SAU Sharisha 3 is not much investigated. With a view to determining the effect of nitrogen and sulphur with different population densities on growth and yield of this new variety a field study was conducted with the following objectives:

1. to study the growth and yield performance of SAU Sharisha-3 by using different doses of nitrogen and sulphur,
2. to evaluate the effects of nitrogen and sulphur with different population densities on the agronomic characteristics of SAU Sharisha-3, and
3. to determine the optimum dose of nitrogen and sulphur along with population densities for better growth and yield of SAU Sharisha-3.

CHAPTER II

REVIEW OF LITERATURE

2.1. Effect of N and S on growth parameters of mustard

2.1.1 Plant height (cm)

Ali *et al*. (1990) reported that different levels of nitrogen significantly increased plant height of mustard. Gaffer and Razzaque (1983), and Asaduzzaman and Shamsuddin (1986) also worked on mustard and reported on the same on plant height of mustard.

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

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 sulphur 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}.

Mondal and Gaffer (1983) stated that nitrogen is the most spectacular of all essential nutrients in its effect on plant growth and yield of this crop. The literature shows that nitrogen has significant effect on plant height, branches plant^{-1}, pods plant^{-1}and other growth factors and yield of mustard. Nitrogen increases the vegetative growth and delayed maturity of plants. Sheppard and Bates (1980) and Singh *et al*. (1972) revealed that excessive use of this element may produce too much of vegetative growth, thus fruit production may be impaired.

Rana and Pachauri, (2001) conducted an experiment on sensitivity of zero erucic acid genotypes of *Oleiferous Brassica* to plant population and planting geometry and concluded that both the plant densities and nitrogen levels had significant effect on mustard plant height at maturity.

2.1.2 Branches plant^{-1} .

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 branches 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. 19 901 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}.

2.2. Effect of population density on growth parameters of mustard

2.2.1 Plant height

Chauhan *et al*. (1993) reported no significant effect of row spacing on the plant height of toria. They evaluated three row spacing viz 20, 30, and 40 cm. The maximum plant height was found at 20 cm row spacing which was similar to the plant height found at 30 cm row spacing and lowest at 40 cm row spacing. It ha-1showed that plant height decreased with the increase of row spacing.

Meitei *et al*. (2001) conducted two years experiment to determine the effect of (23000, 40000, 50000, 62000, 83000, 100000, 166000 plants ha^{-1}) spacing on the yield and yield components of *B. juncea* var. Rugosa cultivars (*Hanggam Amubi*, *Hanggam Angoubi* and *Hanggam Anganbi*). They observed that *Hanggam Angoubi* gave the highest plant height (52.25 and 48.29 cm) and 23000 plants ha^{-1} population density resulted on the tallest plants (55.00 and 48.38 cm).

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that plant height was higher in 340000 plants ha^{-1} population (166cm) as compared to 149000 plants ha^{-1}.

2.2.2 Branches plant^{-1}

Ali *et al.* (1996) reported that low density resulted in an increased number of branches per plant.

Gupta (1988) conducted a field experiment to determine the effects of spacing on rapeseed on using (330000 plants ha^{-1} , 400000 plants ha^{-1}, 200000 plants ha^{-1}, 250000 plants ha^{-1}, 166000 plants ha^{-1}, 266000 plants ha^{-1}) the mean population density and he found that wider spacing increased the number of branches plant^{-1} .

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and reported that primary and secondary branches plant^{-1} recorded significantly higher with 30× 15 cm row spacing (6.72 and 21.57 branches plant^{-1}) as compared to 45 × 15cm (5.80 and 16.76 branches plant^{-1}) .

Leach *et al.* (1999) also reported that plants grown at high density had fewer pod-bearing branches per plant but produced more branches.

Momoh and Zhou (2001) stated that the number of effective branches and pods per branch decreased with increasing plant density.

Rana and Pachauri (2001) also observed that the number of secondary branches plant^{-1} recorded higher in 340000 plants ha^{-1} density (7.6 branches plant^{-1}).

Shrief *et al*. (1990) maintained population density of 30, 60 and 90 plants m^{-2} for raising rapeseed and claimed positive response of all yield contributing characters.They found that number of branches plant^{-1} was significantly superior in the plant density of 30 plants m^{-2} compared to those from 60 and 90 plants m^{-2}.

Tomar and Namedo (1989) conducted a study on *Brassica campestris* var. Toria and found that when population density was maintained at 22.2 plants m^{-2} that increased the number of branches plant^{-1} when seed rate of rapeseed was maintained 5 kg ha^{-1}. *B. campestris* var. Toria, when population density was maintained 22.2 plants m^{-2} there was increment in the number of primary and secondary branches.

2.3. Effect of nitrogen and sulphur on yield contributing parameters of mustard

2.3.1 Siliqua length

Singh (2002) found that application of N and P increased the length of siliqua, number of siliqua plant^{-1}, seeds per siliqua, 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^{-1}and 30, 45 and 60 kg P ha^{-1} treatments. The

maximum seed yield was recorded from application of 45 kg P ha^{-1} (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N ha^{-1} (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.

2.3.2 Siliqua plant^{-1}

Chauhan *et al.* (1995) and Cheema *et al.* (2001). The number of seeds siliqua^{-1} and TSW were significantly increased with increasing levels of nitrogen fertilizer application.

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.

2.3.3 Seeds siliqua^{-1}

Qayyum *et al.* (1998) and Cheema *et al.* (2001) reported that an increase in number of seeds per siliqua with the application of N up to 120 and 135 kg N ha^{-1} respectively.

Reddy and Sinha (1989) showed that seed yield has increased linearly by increasing nitrogen consumption; comparing with no nitrogen consumption, the amounts of 40 and 80 Kg N ha^{-1} increased the seed yield to 49.5%, 96.5%, respectively.

Sharawat *et al.* (2002) observed that the yield and oil content generally increased with the increase in N and S rate. N at 120 kg ha^{-1} resulted in the highest number of siliqua plant^{-1} (397.25), weight of siliqua plant^{-1} (33.32 g), number of seeds per siliqua (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%).

2.3.4 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.

2.4. Effect of population density on yield contributing parameters of mustard

2.4.1 Siliqua length

Gangasaran *et al*. (1981) reported the regression analysis revealed that siliqua weight significantly influenced the seed yield whereas; siliqua length and siliqua diameter had a marginal effect.

2.4.2 Siliquae plant^{-1}

Al-Barzinjy *et al*. (1999) investigated the effects of different plant densities ranging from 20 to 130 plants m^{-2} in rapeseed. They concluded that pods per plant, seed weights and dry matter per plant decreased as plant density increased.

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and observed that number of siliquae plant^{-1}recorded higher with 30 cm × 15 cm row spacing (444) as compared to 45 cm × 15 cm row spacing (356).

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the number of siliquae plant^{-1} (272) recorded higher with 340000 plants ha^{-1}as compared to 148000 plants ha^{-1} population density.

Sharma (1992) conducted a field experiment at College of Agriculture, Gwalior (Madhya Pradesh) and concluded that a row spacing of 30 cm recorded higher number of siliquae plant^{-1} (233.4) as compared to 45 cm row spacing (228.4).

2.4.3 Seeds siliquae^{-1}

Mishra and Rana (1992) also reported that a row spacing of 60 cm recorded higher number of seeds siliquae^{-1} as compared to 30 cm or 45 cm row spacing.

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the number of seeds siliquae^{-1}recorded significantly higher under 220000 plants ha^{-1}as compared to 500000 plants ha^{-1}.

Sharma (1992) conducted a field experiment at College of Agriculture, Gwalior (Madhya Pradesh) and reported that row spacing of 45 cm recorded more number of seeds siliqua^{-1} as compared to 30 cm row spacing.

2.4.4 1000 seed weight

It is also an important character which reflects the seed size. It varies from genotype to genotype and is influenced by some production factors. A good number research works have been conducted on this character.

Chauhan *et al*. (1993) reported a positive relation between row spacing and 1000-seed weight. They found a significant effect of row spacing (20, 30 and 40 cm) on 1000-seeds weight of Toria. Among the row spacing 40 cm row spacing gave highest weight of 1000-seeds while 20 cm row spacing gave lowest weight.

Sharma (1992) found a significant increasing rate of 1000-seeds weight with the increase of row spacing in different mustard varieties. He conducted an experiment with four row spacing viz. 30.0, 33.5, 37.5 and 45.0 cm. Among all row spacing maximum seed weight was found from 45 cm which was significantly higher from others. Lowest seed weight was found from 33.5 cm row spacing.

Singh and Singh (1987) in an experiment with 3 row spacing (30, 45 and 60cm) in mustard found that no significant effect of row spacing on 1000-seed weight of mustard. However, the weight increased with the increase of row spacing and the highest seed weight was found from 60 cm row spacing and 30 cm row spacing gave the lowest weight of 1000-seeds.

Tomar and Namedo (1989) conducted a study on *Brassica campestris* var. Toria when population density was maintained 22.2 plants m^{-2} there was increment in 1000 seeds weight conditions. It was observed that interaction effect of variety and plant populations were found significant on pooled seed yield.

2.5. Effect of nitrogen and sulphur on yield parameters of mustard

2.5.1 Seed yield

Abdin *et al*. (2003) conducted a field experiments in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (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 increase in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t/ha 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. It may be concluded from these results that the yield and quality of mustard can be optimized with the split application of 40 kg S/ha and 100 kg N ha^{-1}during the appropriate phenological stages of crop growth and development.

Allen and Morgan (1972) Nitrogen increases yield by influencing different growth parameters and by producing more vigorous grow than development as reflected via increasing plant height, number of flowering branches, total plant weight, leaf are a index and number and weight of siliquae and seeds per plant.

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

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

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

An application of 135 kg N ha^{-1} has produced maximum seed yield under irrigated condition in Bangladesh. A highly economic response for crop yield was obtained by applying 134 kg N ha^{-1}in fallow land than non-fallow land to give satisfactory yield. Nitrogen application upto 50 kg N ha^{-1}increases dry matter, N content and uptake of N and P. The use of nitrogen alone in excess may cause lodging, delayed maturity and decreased oil content and increased crude protein in mustard (Rahman, 1977 and Gupta *et al.*, 1961).

Holmes and Ainsley, (1977) nitrogen fertilizer's requirements can differ very much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc.

Narwal *et al.* (1991) conducted pot experiment in a greenhouse with *Brassica juncea* CV. RH-30 was given 0, 30, 60, 90 or 120 μg S soil as superphosphate, gypsum, pressmud (filter cake) or pyrites. Grain and stem yields, total S uptake and oil yield increased with increasing S application rate. The highest seed and oil yields and S uptake were obtained with 120 μg S g^{-1} S as gypsum and the lowest with pyrites.

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

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

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.

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

Rahman (1977) concluded that sulphur starved rape produced very low quality of oil. In fact rapeseed and mustard required large amounts of sulphur to give a high seed yields. Sarker *et al*. (1992) carried out an experiment at the Bangladesh Agricultural University, Mymensingh with four high yielding varieties of mustard BAU-M/12 (Sampad), BAU-M/248 (Sambol), M-257 and SS-75 (Sonali Sarisha) to investigate their response to five levels of sulphur viz. 0, 10, 20, 30 and 40 kg S ha^{-1}. The seed yield was maximum in BAU-M/248 (Sambol) when-fertilized with sulphur at the rate of 40 kg S ha^{-1} in comparison to other varieties and rate of sulphur. The variety 'Sampad' followed 'Sambol' in respect of seed yield at this level of sulphur fertilizer. The seed yield of M/257 and SS-75 (Sonali Sarisha) were found to be maximum at 30 kg S ha^{-1}.

Roy *et al*. (1981) the recorded highest seed yield (1957 kg ha^{-1}) of mustard with the application of 240 kg N ha^{-1}. Beyond this level, seed yield decreased. The most economic rate of N application was 164 kg N ha^{-1}. In another experiment the effect of N was found to be significant at 90 kg N ha^{-1}. At 120 kg N ha^{-1} the response on the seed yield contributing characters was highest, but not significantly superior to that of 90 kg N ha^{-1} (Rahman *et al*., 1982). It was also reported that non-application of nitrogen resulted in poor seed weight. Yields were significantly inferior to that of any other higher rates (Ali *et al*., 1977).

Siadat *et al*. (2010) reported that nitrogen fertilizers gave substantial seed yield increase, even in diverse and contradicting conditions.

Singh and Rathi(1985) reported that increase in nitrogen significantly increased the crop yield; they observed the highest yield with 160 kg N ha^{-1}

Singh *et al.* (1999) and Biswas *et al.* (1995) stated that sulphur has been reported to influence productivity of oil seed and application of S fertilizer increased the seed yield of mustard.

Singh *et al*. (2002) conducted an experiment with three Indian mustard cultivars (Varuna, Vardan and Narendra Rai-1) subjected to various sulphur 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 sulphur 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 sulphur content enhanced the total uptake of nitrogen and sulphur.

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.

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

Wright *et al.* (1988) stated that Higher rate of nitrogen application at sowing leads to more rapid leaf area development, prolong the life of leaves, improves leaf area duration after flowering and increases overall crop assimilation thus contributing to increased seed yield.

2.5.2 Stover yield

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

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.

2.6 Effect of population density on yield parameters of mustard

2.6.1 Seed yield

Sharif *et al*. (1990) studied that the highest crop yield is gained from the lowest population density of 30 plants m^{-2} as compared to other treatments (60 and 90 plants m^{-2}).

Rana and Pachauri (2001) conducted a field experiment in New Delhi, and reported that the higher seed yield (1670 kg ha^{-1}) recorded higher with 333000 plants ha^{-1} as compared to 148000 plants ha^{-1} (1280 kg ha^{-1}).

2.6.2 Harvest index

Rana and Pachauri (2001) conducted a field experiment in New Delhi and reported that the harvest index recorded higher with 330000 plants ha^{-1} (24.8%) as compared to 148000 plants ha^{-1} (20.4%).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. This experiment was conducted on rapeseed with 5 doses of nitrogen (N) and sulfur (S) along with four population densities in the rabi season of November 2015 to February 2016 to evaluate the performance of different doses of nitrogen and sulphur fertilizer along with population density on growth and yield of mustard in respect of growth and yield performance.

3.1 Experimental site

The experimental site was located at 23°41′N latitude and 90°22′E longitude with an elevation of 8.6 meter above sea level (Fig. 1). The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ -28).

3.2 Soil

The soil of the experimental site belongs to the agro-ecological region of "Madhupur Tract" (AEZ No.28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The top soil is clay loam in texture. Organic matter content was very low (0.78%) and soil pH was 5.6. The physical and chemical characteristics of the soil have been presented in Appendix I and II.

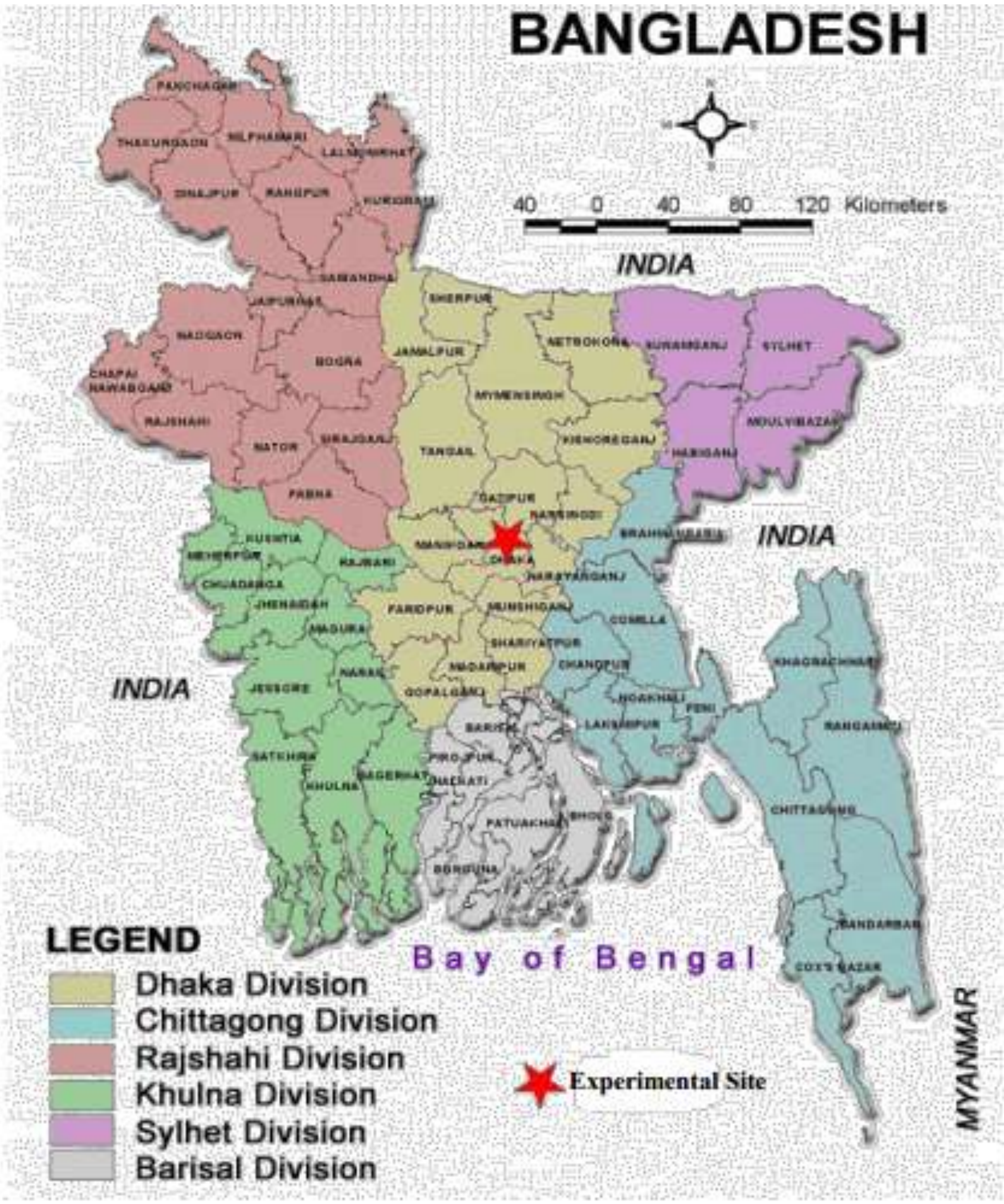


Figure 1. Map showing the experimental site under study

3.3 Climate and weather

The experimental area belongs to a sub-tropical climate where the kharif season starts with high temperature and it decreases when the season proceeds towards Rabi. The mean maximum temperature rises in the month of April, whereas in winter the mean maximum temperature downs in January. Usually scanty rainfalls in rabi season (October to March) and heavy rainfall during kharif season (April to September). The relative humidity increases from June to September (80% or above) and declined to a minimum in the winter. The monthly average rainfall, air temperature and relative humidity of the site during the experimental work have been shown in Appendix III.

3.4 Experimental materials

SAU Sharisha-3, a medium yielding and short duration variety of mustard (*Brassica rapa*) developed by Sher-e-Bangla Agricultural University (SAU), Dhaka was used as experiment crop. The seeds were collected from Department of Genetics and Plant Breeding of SAU, Dhaka.

The important characteristics of SAU Sarisha-3 mentioned below:

SAU Sarisha-3 is a high yielding variety of rapeseed. It is under yellow sarson group of *Brassica rapa*. Siliquae of this variety are medium. Plant height is about 80 cm. Seeds are dark grey in color. The crop matures within 110-115 days and its yield varies from 1.5-2 t ha^{-1}.

3.5 Experimental treatments

The treatments comprised of 5 different doses of Nitrogen and Sulphur fertilizer with four population densities.

3.5.1 Experimental factors

Factor-1: Nitrogen and sulphur level-5

i. F_0 = Control

ii. F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

iii. F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

iv. F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

v. F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

Factor-2: Population density-4

i. P1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

ii. P2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

iii. P3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

iv. P4 = 800000 plants ha^{-1}i.e. 80 plants m^{-2}

Note: All the fertilizers except N & S were applied as per their recommended doses.

3.5.2 Treatment combinations

There were altogether 20 treatments combinations. The experiment consisted of the following treatment combinations:

F_0 P_1	F_1 P_1	F_2 P_1	F_3 P_1	F_4 P_1
F_0 P_2	F_1 P_2	F_2 P_2	F_3 P_2	F_4 P_2
F_0 P_3	F_1 P_3	F_2 P_3	F_3 P_3	F_4 P_3
F_0 P_4	F_1 P_4	F_2 P_4	F_3 P_4	F_4 P_4

3.6 Experimental design and layout

The experiment was laid out in a Split plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. There were altogether 60 (20×3) unit plots, each plot measuring 3m × 2.0 m. Inter-block and Inter-plot spacing were 0.50 m and 0.75 m, respectively. The layout of the experiment was presented in Appendix IV.

3.7 Collection and processing of soil sample

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

3.8 Land preparation

The land was first ploughed with a tractor drawn disc plough on 27 October 2015. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. Weeds stubble and residues were cleaned from the soil and the land was made ready for layout. Finally, the plots were laid out and the decomposed organic manure were applied seven days before while the basal doses of inorganic fertilizer that applied one day before sowing and were spaded well following proper levelling to make the plots ready for sowing. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water. The land operation was completed on 6 November 2015.

3.9 Application of fertilizers

The P K and Zn fertilizer were applied at the rate of 20, 50 and 2 kg ha^{-1} according to Fertilizer Recommendation Guide (BARC, 2012) through Triple super phosphate (TSP), Muriate of potash (MP) and Zinc oxide, respectively. Sulphur and one third (1/3) of whole amount of Urea and full amount of MP, TSP and Zinc oxide were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after sowing (DAS) and 40 DAS, respectively.

3.10 Germination test

Germination test was performed before sowing the seeds in the laboratory. Filter paper was placed on petridishes and the papers were soaked with water. Seeds were distributed at random in petridish. Data on emergence were collected on percentage basis by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds set for germination}} \times 100$$

3.11 Seed sowing

Seeds were sown continuously @ 7 kg ha^{-1} on 6 November 2015 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. After sowing the seeds were covered with soil and slightly pressed by hand .Two times thinning operation was done at 20 and 30 days after sowing according to the treatment of population density.

3.12 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 21 November 2015. At the same time first thinning was done. The final weeding and thinning were done after 25 days of sowing, on 1 December 2016. Care was taken to maintain constant plant population per plot.

3.13 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 4 December 2015 at 25 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (35DAS), on 10 December 2015. The final irrigation was given at the stage of seed formation (50 DAS), on 25 December 2015.

3.14 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliquae filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2ml L^{-1} water. The insecticide was sprayed thrice, the first on 20 November 2015; the second on 20 December 2015 and the last on 10 January, 2016. The crop was kept under constant observations from sowing to harvesting.

3.15 General observations of experimental field

The plots under experiment were frequently observed to notice any change in plant growth and other characters were noted down immediately to make necessary measures.

3.16 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 10 February 2016. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise.

3.17 Collection of experimental data

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

3.18 Procedure for data collections after harvest

3.18.1 Plant height (cm)

Plant height was measured from the ground level to the apex of the leaf or siliquae in randomly selected 10 plants from specific rows of each plot at 20, 40, 60 DAS and at harvest and when from the mean plant height (cm) was recorded.

3.18.2 Branches plant^{-1} (no.)

The total number of branches plant^{-1}was counted from selected samples at the time of 20, 40, 60 DAS and harvest and was recorded. Mean number of branches plant^{-1} was expressed as number of branches plant^{-1}.

3.18.3 Siliqua plant^{-1} (no.)

Number of total siliqua of pre-selected ten plants from each unit plot was noted and the mean number was recorded. The number of siliqua of each plant was counted and the mean was recorded.

3.18.4 Siliqua length (cm)

The length of the siliqua was measured from the base to the tip of the 10 selected siliqua and then average then to have selequa length.

3.18.5 Seeds siliqua^{-1} (no.)

The number of seeds was counted from randomly taking 10 siliquae per treatment. The average value is calculated as the number of seeds siliquae^{-1}.

3.18.6 1000-seeds weight (g)

From the seed stock of each plot, 1000-seeeds were randomly collected and weighed by an electric balance. The 1000-seed weight was recorded in gram.

3.18.7 Seed yield (kg ha^{-1})

The mean weight were taken by threshing the plants of each sample area and then converted to kg ha^{-1} in dry weight basis.

3.18.8 Stover yield (kg ha^{-1})

The weight of the plants containing grain was taken by subtracting the grain weight from the total weight. The stover weights were calculated after threshing and separation of grain from the plants of harvested area and then expressed in kg ha^{-1} on dry weight basis.

3.18.9 Biological yield (kg ha^{-1})

The summation of seed yield and stover yield were considered as biological yield. Biological yield was calculated by using the following formula,

Biological yield = Seed yield + stover yield; (dry weight basis).

3.18.10 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. The following formula was used for calculating the harvest index-

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (t/ha)}}{\text{Biological yield (t/ha)}}) \times 100$$

3.19 Statistical analysis

The collected data were analyzed statistically by using analysis of variance (ANOVA) technique with the help of computer package MSTAT-C program. The mean differences among the treatments were tested by least significance difference at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

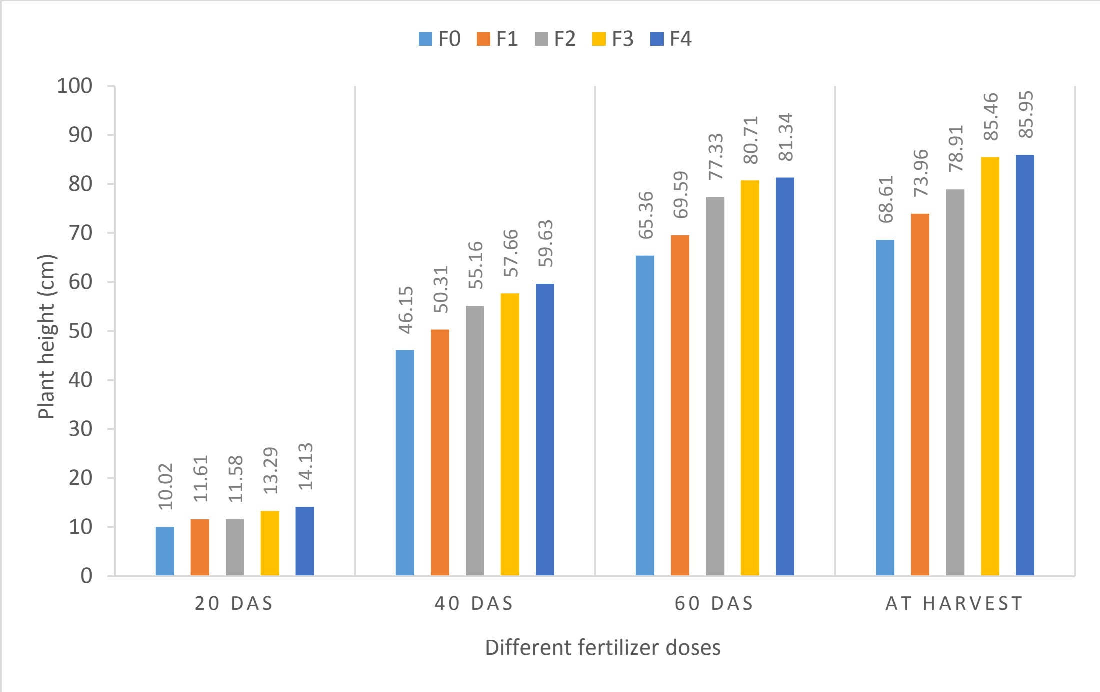
The present experiment was conducted to determine the effect of different levels of nitrogen and sulphur with population density on growth and yield of mustard. The analyses of variance (ANOVA) of the data on different components are given in Appendix V_A-V_D. The results have been presented and discussed, 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 nitrogen and sulphur level

Effect of different level of nitrogen and sulphur showed a statistically significant variation for plant height of mustard (Figure 2). With increasing the doses of nitrogen and sulphur the plant height increased significantly upto the highest dose comprising of F_4 (130 kg nitrogen + 30 kg sulphur) ha^{-1} at different stages 20 DAS (14.13 cm), 40 DAS(59.63 cm) 60 DAS (81.34 cm) and at harvest (85.95 cm) while the shortest plant was recorded from N_0S_0 i.e. no nitrogen no sulphur in every stages at (20DAS (10.02 cm), 40 DAS(46.15 cm) 60 DAS (65.36 cm) and at harvest (68.61 cm). (Table 1) .



F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

Figure 2. Effect of nitrogen and sulphur level on plant height at different days after sowing of mustard (LSD $_{0.05}$ = 0.61, 1.75, 0.28 and 0.61 at 20, 40, 60 DAS and at harvest, respectively).

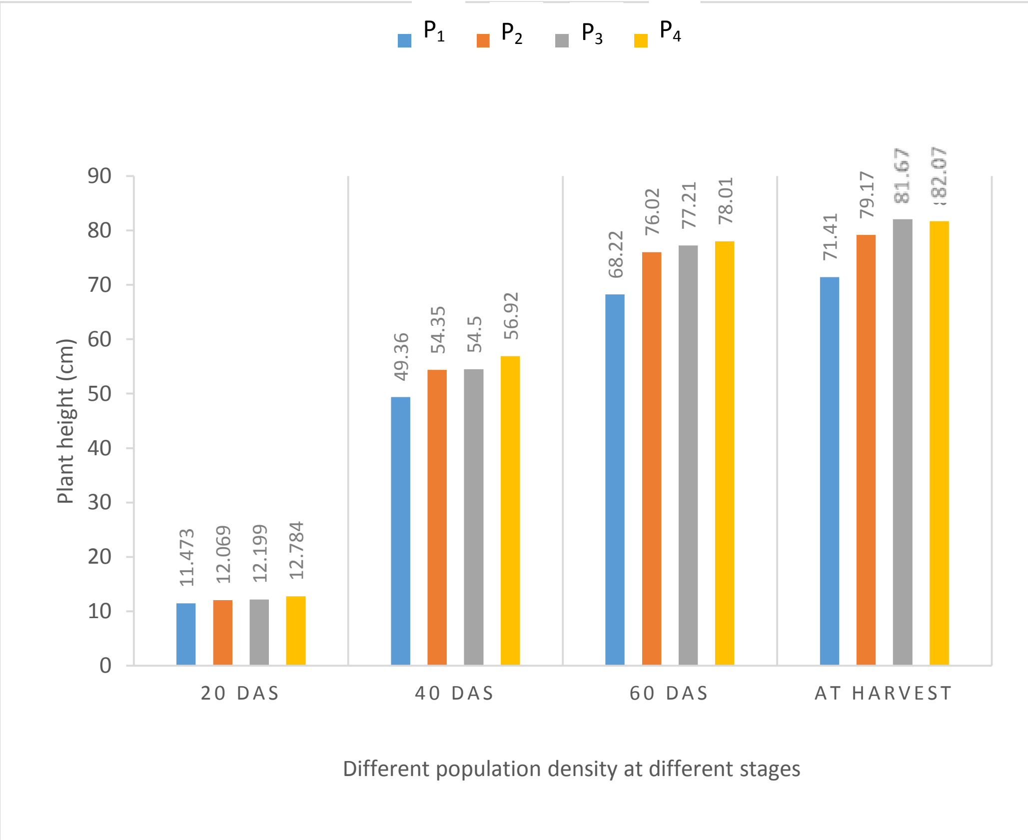
4.1.1.2 Effect of population density

Plant height was significantly affected by plant population density at different days after sowing (DAS) (Figure 3). This experiment revealed that at 20 DAS the tallest plant of 12.78 cm was recorded from P_4 (80 plants m^{-2}) density and also at 40 and 60 DAS produced the tallest plant of 56.92 cm and 78.01 cm, respectively at the same density. Again, at the time of harvest, P_4 (80 plants m^{-2}) gave the highest plant height of 82.07 cm followed by P_3 (60 plants m^{-2}). On the other hand, the lowest plant height was observed with P_1 (20 plants m^{-2}) in every stages 20, 40, 60 DAS and at harvest (11.47cm, 49.22cm, 68.22 and 71.41cm, respectively). The results obtained from the present study was conformity to the findings of Keivanradand and Zandi (2014) reported on the effect of population density on mustard with similar results from their experiment. They reported that population density has a significant effect on plant height of mustard.

4.1.1.3 Interaction effect of nitrogen and sulphur level and population density

The interaction effect of nitrogen and sulphur level and population density had a significant effect on the plant height (Table 1). Significant differences of plant heights were found in every stages of plant growth. Maximum plant height at 20 and 40 DAS of 14.69 cm and 65.05 cm, respectively was observed in the interaction of F_4S_4 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density). But at 60 DAS and at harvest F_3S_4 (110 kg ha^{-1}

nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density) gave the tallest plant of 86.73cm and 90.73 cm, respectively which was statistically similar with F_4S_3 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 80 plants m^{-2} plant density) at harvest. The lowest plant height was found from F_0S_1 at every stages of plant growth viz. 20 DAS, 40 DAS, 60DAS and as well as harvest (9.293 cm, 42.10 cm, 58.34 cm and 58.83 cm, respectively). Similar result was obtained by Meitei *et al*. (2001).



P1 = 200000 plants ha-1i.e. 20 plants m-2

P2 = 400000 plants ha-1i.e. 40 plants m-2

P3= 600000 plants ha-1i.e. 60 plants m-2

P4 = 800000 plants ha-1i.e. 80 plants m-2

Figure 3. Effect of population density on plant height at different days after sowing of mustard ($LSD_{0.05}$ = 0.594, 1.591, 1.070 and 1.837 at 20, 40, 60 DAS and at harvest, respectively).

Table 1. Interaction effect of nitrogen and sulphur level with population density on plant height (cm) at different stages of SAU Sarisha-3

Treatments	Plant Height			
	20 DAS	40 DAS	60 DAS	At Harvest
F_0P_1	9.293 k	42.10 m	58.34 r	58.83 m
F_0P_2	10.130 jk	51.73 ij	68.39 o	70.89 k
F_0P_3	10.167 i-k	46.733 k	68.35 o	72.85 ij
F_0P_4	10.513 h-j	44.067 lm	66.36 p	71.86 jk
F_1P_1	11.200 g-i	45.333 kl	60.342 q	64.34 l
F_1P_2	11.293 gh	50.400 j	72.344 m	77.82 g
F_1P_3	11.620 fg	52.733 h-j	74.340 l	79.34 ef
F_1P_4	12.333 d-f	52.800 h-j	71.340 n	74.34 h
F_2P_1	11.300 f-h	51.000 ij	72.357 m	73.66 hi
F_2P_2	11.233 gh	55.000 f-h	79.322 h	80.00 e
F_2P_3	11.667 fg	55.000 f-h	76.327 i	79.00 e-g
F_2P_4	12.133 fg	59.667 cd	81.332 e	83.00 c
F_3P_1	12.213 e-g	54.860 f-h	74.726 k	78.72 fg
F_3P_2	13.513 bc	56.293 e-g	79.705 g	83.70 c
F_3P_3	13.213 c-e	56.500 ef	81.709 d	88.70 b
F_3P_4	14.247 ab	63.000 ab	86.730 a	90.73 a
F_4P_1	13.360 b-d	53.540 g-i	75.377 j	81.48 d
F_4P_2	14.173 a-c	58.353 de	80.357 f	83.46 c
F_4P_3	14.330 ab	61.573 bc	85.336 b	90.44 a
F_4P_4	14.693 a	65.053 a	84.316 c	88.42 b
LSD(0.05)	**1.0152**	**2.7909**	**0.30**	**1.2212**
CV (%)	**5.02**	**2.81**	**5.10**	**4. 93**

F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

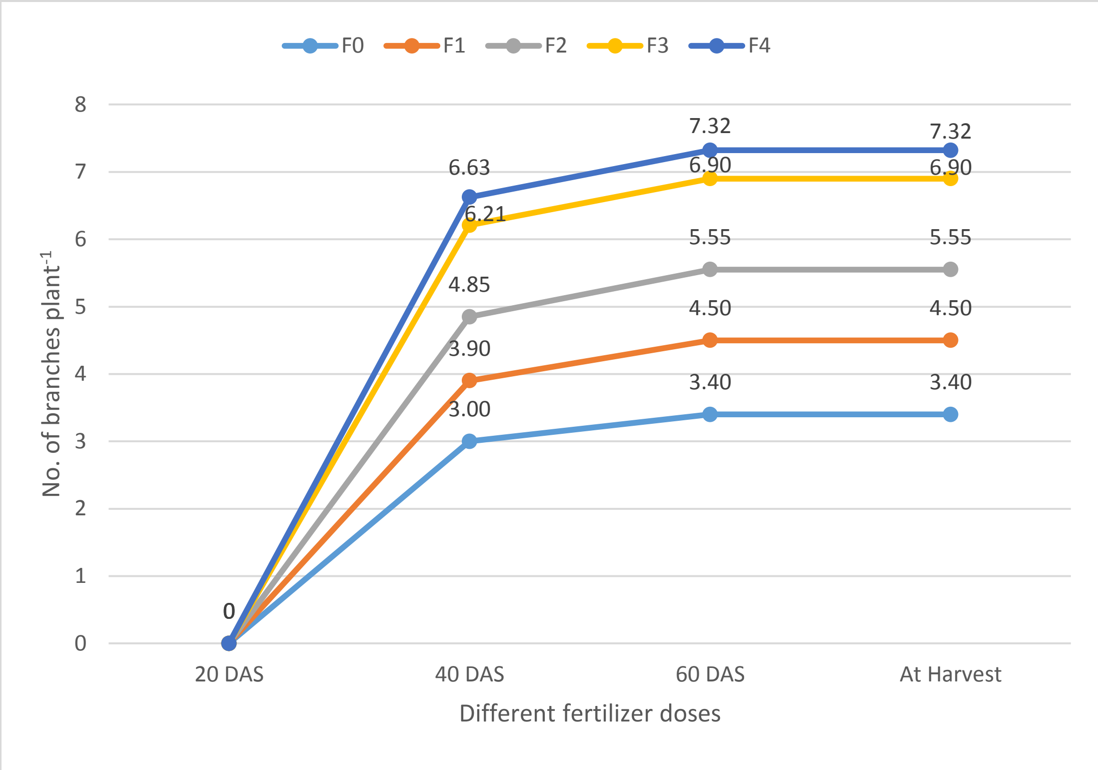
P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

P_4 = 800000 plants ha^{-1}i.e. 80 plants m^{-2}

4.1.2 Branches plant^{-1}

4.1.2.1 Effect of nitrogen and sulphur level

Effect of different levels of nitrogen and sulphur showed a statistically significant variation for branches per plant of mustard (Figure 4). The number of branches per plant increased significantly with increasing nitrogen and sulphur levels upto the treatment F_4 (130 kg ha^{-1} nitrogen + 30 kg ha^{-1} Sulphur) and the maximum number of branches per plant was obtained from every growth stages viz. 40 DAS, 60DAS as well as at harvest with this treatment (6.63, 7.32 and 7.32, respectively). Lowest number of branches per plant were also obtained from every growth stage viz. 40 DAS, 60DAS as well as at harvest with this treatment and these are 3.00, 3.40 and 3.40, respectively. Probably 130 kg ha^{-1} nitrogen + 30 kg ha^{-1} Sulphur ensured the favorable condition for growth of mustard and the ultimate results is the maximum number of branches. 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 S ha^{-1} application. Dubey *et al.* (1997) reported that S increased the number of primary branches per plant of linseed up to 40 kg S ha^{-1}.



F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

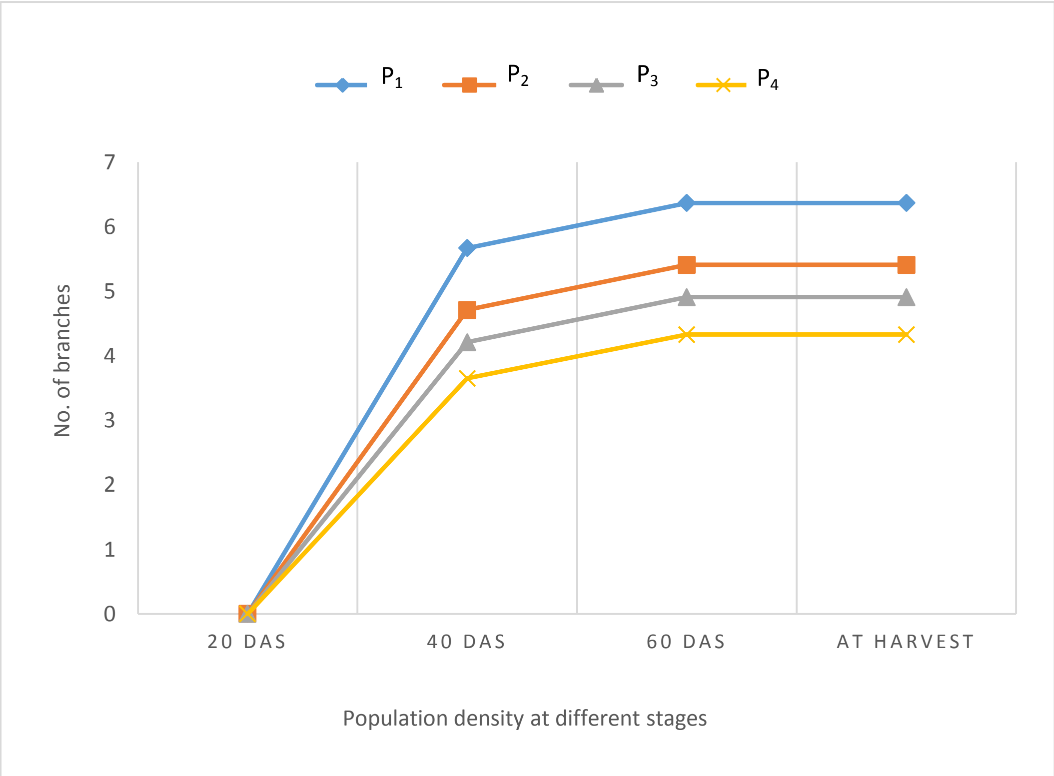
Figure 4. Effect of nitrogen and sulphur level on branches plant^{-1} at different days after sowing of rapeseed mustard ($LSD_{0.05}$ = 0.39, 0.38 and 0.38 at 40, 60 DAS and at harvest, respectively).

4.1.2.2 Effect of population density

Population density exerted significant influence on the number of branches plant^{-1} (Figure 5). Results indicated that higher population density produced lower number of branches plant^{-1}. Maximum number of branches per plant was obtained from P_1 (20 plants m^{-2}) in every growth stages viz. 40 DAS, 60DAS as well as at harvest with this treatment and these are 5.67, 6.37and 6.37, respectively. Lowest number of branches per plant were also obtained from P_4 for every growth stages viz. 40 DAS, 60 DAS as well as at harvest with this treatment and these 3.65, 4.33 and 4.33, respectively. Branch number was also increased with the increase of plant spacing. Similar findings were reported by Shrief *et al*. (1990), Chauhan *et al*. (1993) and Gupta (1988) that increased population density reduced the number of branches plant^{-1}.

4.1.2.3 Interaction effect of nitrogen and sulphur level and population density

Numbers of branches plant^{-1} were significantly influenced by the interaction effect of nitrogen and sulphur level and population density (Table 2). The maximum number of branches plant^{-1} of 8.20 was found from the interactions of F_3S_4 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density) which was statistically similar with F_3S_1 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 20 plants m^{-2} plant density). The lowest number of branches plant^{-1}was found from F_0S_4 at every stage of plant growth viz. 40 DAS, 60DAS and at harvest (3.05 and 3.75, respectively). Number of branches plant^{-1} was statistically similar to the number of branches plant^{-1} at 60 DAS and at harvest. The result obtained from the present study corroborated with the findings of Tomar and Namedo (1989) and Kumar and Gangwar (1985).



P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

P_4 = 800000 plants ha^{-1}i.e. 80 plants

Figure 5. Effect of population density on branches plant^{-1} at different days after sowing of mustard. ($LSD_{0.05}$ = 0.231, 0.873, 0.339 and 0.284 at 20, 40, 60 DAS and at harvest respectively)

Table 2. Interaction effect of nitrogen and sulphur level with population density on branches plant^{-1} at different stages of SAU Sarisha-3

Treatment	Branch per plant (no.)		
	40 DAS	**60 DAS**	**At Harvest**
F_0P_1	3.05 jk	3.75 jk	3.75 jk
F_0P_2	1.75 l	2.45 l	2.45 l
F_0P_3	1.35 lm	2.05 lm	2.05 lm
F_0P_4	1.10 m	1.75 m	1.75 m
F_1P_1	4.55 h	5.25 h	5.25 h
F_1P_2	3.25 j	3.95 j	3.95 j
F_1P_3	2.85 jk	3.55 jk	3.55 jk
F_1P_4	2.55 k	3.25 k	3.25 k
F_2P_1	5.95 e	6.65 e	6.65 e
F_2P_2	4.95 gh	5.65 gh	5.65 gh
F_2P_3	4.55 h	5.25 h	5.25 h
F_2P_4	3.95 i	4.65 i	4.65 i
F_3P_1	7.30 ab	8.00 ab	8.00 ab
F_3P_2	6.60 cd	7.30 cd	7.30 cd
F_3P_3	5.83 e	6.53 e	6.53 e
F_3P_4	5.10 fg	5.80 fg	5.80 fg
F_4P_1	7.50 a	8.20 a	8.20 a
F_4P_2	7.00 bc	7.70 bc	7.70 bc
F_4P_3	6.50 d	7.20 d	7.20 d
F_4P_4	5.50 ef	6.20 ef	6.20 ef
LSD(0.05)	**0.54**	**0.53**	**0.53**
CV (%)	**5.66**	**5.00**	**5.00**

F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

P_4 = 800000 plants ha^{-1}i.e. 80 plants m^{-2}

4.2 Yield contributing characters

4.2.1 Length of siliqua (cm)

4.2.1.1 Effect of nitrogen and sulphur level

Length of siliqua varied significantly with the different nitrogen and sulphur level (Table 3). The result revealed that the highest length of siliqua of 6.51 cm was obtained from the treatment F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) followed by F_3 (110 kg ha^{-1} nitrogen + 25 kg ha^{-1} Sulphur). Again, the lowest length of siliqua of 5.62 cm was found in F_0 (control) which was also significantly different from all other treatment. The result obtained from the present study was similar with the findings of Hussain *et al*. (1996) and Gangasaran *et al*. (1981).

4.2.1.2 Effect of population density

Population density exerted significant influence on the length of siliqua (Table 4). It was observed that the highest length of siliqua of 6.93 cm was found from P_1 (20 plants m^{-2}) which is closely followed by P_2 (40 plants m^{-2}) where the lowest length of siliqua 5.69 cm was found from P_4 (80 plants m^{-2}).

4.2.1.3 Interaction effect of nitrogen and sulphur level and population density

Length of siliqua was significantly influenced by the interaction effect of N and S level and population density (Table 5). The maximum length of siliqua of

7.33 cm was found from the interactions of F_1P_1 (70 kg ha^{-1} nitrogen+15 kg ha^{-1} sulphur with 20 plants m^{-2} plant density) which was closely followed by F_3P_1 (70 kg ha^{-1} nitrogen+15 kg ha^{-1} sulphur with 20 plants m^{-2} plant density). On the other hand, the lowest length of siliqua of 4.47 cm was found from the treatment combination of F_0P_4 (0 kg ha^{-1} nitrogen+ 0 kg ha^{-1} sulphur with 80 plants m^{-2} plant density).

4.2.2 Siliqua plant^{-1}

4.2.2.1 Effect of nitrogen and sulphur level

Siliqua plant^{-1} of mustard showed a statistically significant variation for different nitrogen and sulphur levels under this experiment (Table 3). The number of siliqua plant^{-1} enhanced with increasing the doses of nitrogen and sulphur and the highest and significant number 103.86 was obtained with F_3 (110 kg ha^{-1} nitrogen + 25 kg ha^{-1} sulphur). So Further increase in nitrogen and sulphur level from F_3 to F_4, failed to increase the number (103.54) significantly but statistically similar to F_4 (130 kg ha^{-1} nitrogen + 30 kg ha^{-1} sulphur) (Table 3) whereas lowest siliqua plant^{-1} was 45.52 and was found in F_0 (control). Mondal and Gaffer (1983) and Gaffer and Razzaque (1983) also reported the similar findings on nitrogen from their experiment. They reported that different levels of nitrogen significantly increased siliqua plant^{-1}of mustard ensuring proper growth of plant. Sharawat *et al*. (2002) recorded maximum number of siliquae plant^{-1} with 120 kg N ha^{-1}. These results indicated that higher dose of nitrogen favored higher number of siliqua formation in mustard.

4.2.2.2 Effect of plant population density

Plant population density had significant influence on the number of siliquae plant^{-1} (Table 4). The maximum number of siliqua plant^{-1} of 108.29 was found from P_1 (20 plants m^{-2}). On the other hand, the lowest number of siliquae plant^{-1} of 61.08 was found from P_4 (80 plants m^{-2}). The maximum increases of 58.64% of siliqua plant^{-1} was observed with P_1 (20 plants m^{-2}) compared lowest performance of producing siliqua plant^{-1} (80 plants m^{-2}). Siliqua plant^{-1} was also increased with the increase of plant population. The result obtained from the present study was similar with the findings of Singh *et al*. (1986) and Mustapic *et al*. (1987).

4.2.2.3 Interaction effect of nitrogen and sulphur level and population density

Number of siliqua plant^{-1} was significantly increased by the interaction effect of N and S level and population density (Table 5). The maximum number of siliqua plant^{-1} of 137.61 was found from the interactions of F_3P_1 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 20 plants m^{-2} plant density) which was statistically different from all other treatment combinations. The combination F_2P_1 and F_4P_1 showed second highest number of siliqua plant^{-1}. On the other hand, the lowest number of siliqua plant^{-1} of 24.67 was found from the treatment combination of F_0P_3 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) which was statistically similar with F_0P_4 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 60 plants m^{-2} plant density). Similar results have been observed by Keivanrad and Zandi (2014) on rapeseed in south of Iran.

4.2.3 Seeds siliqua^{-1}

4.2.3.1 Effect of nitrogen and sulphur level

Effect of nitrogen and sulphur showed a statistically significant variation for seeds siliqua^{-1} of mustard (Table 3). The number of seeds siliqua^{-1} increased with increasing nitrogen and sulphur levels and maximum increase (22.34) was found with the treatment F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) followed by F_3 (110 kg ha^{-1} nitrogen + 25 kg ha^{-1} sulphur) and F_2 (100 kg ha^{-1} nitrogen+20 kg ha^{-1} sulphur). Application of 90-130 kg N ha^{-1} and 20-30 kg ha^{-1} ensured the congenial condition for growth of mustard and also produced healthy siliqua and the ultimate result is the maximum number of siliqua. On the other hand the lowest number of seeds siliqua^{-1} was 14.06 and found in F_0 (control). Mondal and Gaffer (1983) and Gaffer and Razzaque (1983) reported that different levels of nitrogen 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).

4.2.3.2 Effect of population density

Population density exerted significant influence on the number of seeds siliquae^{-1} (Table 4). It was observed that the highest number of seeds siliqua^{-1}

(24.49) was found from P_1 (20 plants m^{-2}) where the lowest number of seeds siliqua^{-1} (17.01) was found from P_4 (80 plants m^{-2}) which was statistically similar to P_3 (60 plants m^{-2}). The result obtained from the present study was similar with the findings of Singh and Singh (1987) and they reported that the number of seeds siliqua^{-1} increased as the population density decreased.

4.2.3.3 Interaction effect of nitrogen and sulphur level and population density

Number of seeds siliqua^{-1} was significantly varied by the interaction effect of nitrogen and sulphur level and population density (Table 5). The maximum number of seeds siliqua^{-1} (29.30) was found from the interaction of F_3P_1 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 20 plants m^{-2} plant density) and closely followed by F_4P_1 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 20 plants m^{-2} plant density). On the other hand, the lowest number of seeds siliqua^{-1} of 13.00 was found from the treatment combination of F_0P_2 (0 kg ha^{-1} nitrogen + 0 kg ha^{-1} sulphur with 40 plants m^{-2} plant density) which was statistically similar with F_0P_3 (0 kg ha^{-1} nitrogen + 0 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) and F_0P_4 (0 kg ha^{-1} nitrogen + 0 kg ha^{-1} sulphur with 80 plants m^{-2} plant density).

4.2.4 1000 seeds weight

4.2.4.1 Effect of nitrogen and sulphur level

Nitrogen and sulphur showed significant differences for 1000 seed weight of mustard under the present trial (Table 3). The weight of 1000 seed increased with increasing levels of nitrogen and sulphur level and the highest increase (3.54 g) was recorded from F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) treatment which was stastically similar to F_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur). Vineet *et al.* (2011) reported the similar result of nitrogen and sulphur effect on musturd. Mondal and Gaffer (1983), Gaffer and Razzaque (1983), Sharawat *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 N & S fertilizer to a certain extent.

4.2.4.2 Effect of population density

Different levels of population density had significant effect on 1000 seed weight (Table 4). The results showed that the highest 1000 seed weight of 3.62 gm was obtained with P_1 (20 plants m^{-2}) where the lowest of 3.22 was with P_4 (80 plants m^{-2}). The result obtained from the present study was similar with the findings of Chauhan *et al*. (1993), Sharma (1992) and Patel *et al*. (1980) and they observed that wider spacing gave higher 1000 seeds weight.

4.2.4.3 Interaction Effect of nitrogen and sulphur level and population density

Weight of 1000 seeds varied non-significantly with the interaction effect of nitrogen and sulphur level with population density (Table 5). Numerically the highest 1000 seed weight of 3.80 g was found from the interactions of F_3P_1 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 20 plants m^{-2} plant density) which was followed by F_4P_1 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 20 plants m^{-2} plant density) and F_4P_1 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 40 plants m^{-2} plant density). On the other hand, the lowest 1000 seed weight of 2.76 was found from the treatment combination of F_0P_4 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 80 plants m^{-2} plant density).

Table 3. Effect of nitrogen and sulphur level on yield contributing characters of SAU Sarisha-3

Treatments	Siliqua length (cm)	Siliqua Plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	1000 seed weight (g)
F_0	5.62 c	45.52 d	14.60 d	3.05 c
F_1	6.11 b	75.92 c	19.22 c	3.35 b
F_2	6.34 ab	95.37 b	20.24 b	3.42 ab
F_3	6.48 a	103.86 a	22.20 a	3.53 a
F_4	6.51 a	103.54 a	22.34 a	3.54 a
LSD(0.05)	0.18	2.82	0.33	0.1773
CV (%)	3.03	3.53	1.73	5.57

F_0 = Control
F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}
F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}
F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}
F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

Table 4. Effect of population density on yield contributing characters of SAU Sarisha-3

Treatments	Siliqua length (cm)	Siliqua Plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	1000 seed weight (g)
P_1	6.9307 a	108.29 a	24.49 a	3.62 a
P_2	6.5173 ab	89.95 b	20.03 b	3.41 b
P_3	5.7147 b	72.87 c	17.38 c	3.25 c
P_4	5.6964 c	68.26 d	17.01 c	3.22 c
LSD(0.05)	0.11	1.6509	0.7961	0.1034
CV (%)	2.00	3.36	11.11	3.59

P_1 = 200000 plants ha^{-1} i.e. 20 plants m^{-2}
P_2 = 400000 plants ha^{-1} i.e. 40 plants m^{-2}
p_3=600000 plants ha^{-1} i.e.60 plants m^{-2}
P_4= 800000 plants ha^{-1} i.e.80 plants m^{-2}

Table 5. Interaction effect nitrogen and sulphur level with population density on yield contributing characters of SAU Sarisha-3

Treatments	Siliqua length (cm)	Siliqua Plant^{-1} (no.)	Seeds siliquae^{-1} (no.)	1000 seed weight (g)
F_0P_1	7.01 b	53.00 n	18.133 g-i	3.53
F_0P_2	6.23 f	73.67 jk	14.033j	2.93
F_0P_3	4.80 i	28.40 o	13.000j	3.00
F_0P_4	4.47 j	27.00 o	13.233j	2.76
F_1P_1	7.33 a	109.33 c	23.80 cd	3.53
F_1P_2	6.92 bc	70.33 k	17.39 hi	3.50
F_1P_3	4.95 hi	65.33 l	17.87 g-i	3.13
F_1P_4	5.09 h	58.67 m	17.80 g-i	3.20
F_2P_1	6.88 b-d	122.23 b	25.30bc	3.54
F_2P_2	6.65 de	103.02 d	21.96 e	3.44
F_2P_3	5.82 g	81.57 i	17.12 hi	3.38
F_2P_4	6.04 fg	74.67 j	16.80 i	3.34
F_3P_1	7.02 b	137.61 a	29.30 a	3.80
F_3P_2	6.59 e	98.06 e	22.73 de	3.56
F_3P_3	6.13 f	92.21 g	18.63 gh	3.26
F_3P_4	6.19 f	87.58 h	18.13 g-i	3.46
F_4P_1	6.27 f	119.25 b	25.93 b	3.70
F_4P_2	6.20 f	104.65 d	24.03 cd	3.62
F_4P_3	6.87 b-d	96.85 ef	20.30 f	3.45
F_4P_4	6.70 c-e	93.40 fg	19.10 fg	3.35
LSD(0.05)	0.27	4.26	1.57	0.27
CV (%)	2.23	2.61	5.41	4.10

F_0 = Control
F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}
F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}
F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}
F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}
P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}
P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}
P_4 = 800000 plants ha^{-1}i.e. 80 plants

4.3 Yield parameters

4.3.1 Seed yield

4.3.1.1 Effect of nitrogen and sulphur level

Application of nitrogen and sulphur at different level showed a statistically significant variation for seed yield per hectare of mustard under the present trial (Table 6). With increasing the levels of nitrogen, the seed yield increased significantly upto the highest level of nitrogen and sulphur in this experiment. The highest seed yield (1862.5 kg ha^{-1}) was recorded from F_4 (130 kg ha^{-1} nitrogen +30 kg ha^{-1} sulphur) which was closely followed by F_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur) and the lowest seed yield (882.5 kg) was recorded from F_0 treatment (control). These results are in conformity with that of Mondal and Gaffer (1983), Singh and Rathi (1984), Narang and Singh (1985), Singh and Rathi (1985), Reddy and Sinha (1989) and Mankotish and Sharma (1997) who have observed increased seed yield of mustard by increasing rate of nitrogen,Banueles *et al*. (1990) recorded significant differences for different level of sulphur application.

4.3.1.2 Effect of population density

Population density had significant influence on the seed yield of mustard (Table 7). The maximum seed yield of 1733.9 kg ha^{-1} was found from P_3 (60 plants m^{-2}). Moreover, in this level of density by creating more suitable green canopy in the unit area with the least inter competition, solar radiation was used effectively for producing economic yield (Sharif *et al*., 1990; Saeed-

Shariati, 1996). On the other hand, the lowest seed yield of 1140.8 kg ha^{-1} was found from P_1 (20 plants m^{-2}). The maximum increases of 47.17% of seed yield was observed with P_3 (60 plants m^{-2}) compared to lowest performance of producing seed yield P_1 (20 plants m^{-2}). Here, it can be mentioned that lower plant spacing i.e. higher plant population increase seed yield to a certain level but excess plant population is a cause of decreased seed yield (1679.0 kg ha^{-1} seed yield was found in P_4). The result obtained from the present study was similar with the findings of Angadi *et al*. (2003).

4.3.1.3 Interaction effect of nitrogen and sulphur level with population density

Seed yield was increased significantly by the interaction effect of nitrogen and sulphur level with population density (Table 8). Results showed that the maximum seed yield (2134.0 kg ha^{-1}) was found from the interactions of F_4P_3 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) which was closely followed by F_3P_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) and F_3P_4 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density). On the other hand, the lowest seed yield of (463.7 kg ha^{-1}) was found from the treatment combination of F_0P_1 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 20 plants m^{-2} plant density). The results obtained from the present study was conformity to the findings of Keivanradand and Zandi (2012). The result obtained from the present study was also similar with the findings of Behera *et al*. (2002) and Surya *et al*. (1998).

4.3.2 Stover yield

4.3.2.1 Effect of nitrogen and sulphur level

Stover yield of rapeseed mustard was significantly different at different level of nitrogen and sulphur (Table 6). The results under the present study indicated that the treatment F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) produced the highest stover yield of 3595.9 kg ha^{-1}, which was statistically identical with the treatment F_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} Sulphur). The lowest stover yield of 1770.3 kg ha^{-1} was found in the treatment F_0 (control). The result obtained from the present study had similarity with the findings of Ali *et al*. (1996).

4.3.2.2 Effect of population density

Population density had significant influence on the stover yield of mustard (Table 7). It was observed that the highest stover yield of 3328.2 kg ha^{-1} was found from P_4 (80 plants m^{-2}). On the other hand, the lowest stover yield of 2403.8 kg ha^{-1} was found from P_1 (20 plants m^{-2}). The maximum increase (38.46%) of stover yield was observed with P_3 (60 plants m^{-2}) compared to lowest performance producing stover yield of P_1 (20 plants m^{-2}). Here, it can be concluded that lower plant spacing i.e. higher plant population increased stover yield to at a certain level.

4.3.2.3 Interaction effect of nitrogen and sulphur level with population density

Stover yield was significantly increased by the interaction effect of nitrogen and sulphur level and population density of mustard (Table 8). Results showed that the maximum stover yield of 4055.8 kg ha^{-1} was found from the interactions of F_3P_4 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density) which was statistically similar with F_3P_3, F_4P_2, F_4P_3, and F_4P_4. On the other hand, the lowest stover yield of 968.1 kg ha^{-1} was found from the treatment combination of F_0P_1 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 20 plants m^{-2} plant density).

4.3.3 Biological yield

4.3.3.1 Effect of nitrogen and sulphur level

Biological yield of mustard was significantly different at different level of nitrogen and sulphur (Table 6). The results under the present study indicated that the treatment F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) produced maximum biological yield of 5458.4 kg ha^{-1} followed by the treatment F_3 comprising (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur) of 5420.7 kg ha^{-1}. The lowest biological yield of 2652.9 kg ha^{-1} was found with the treatment F_0 (control).

4.3.3.2 Effect of population density

Population density had significant influence on the biological yield of mustard (Table 7). The highest biological yield of 5007.2 kg $ha^{-1}$was found from P_4 (80 plants m^{-2}) which was statistically similar with P_3 (60 plants m^{-2}). On the other hand, the lowest biological yield of 3544.5 kg ha^{-1} was found from P_1 (control=10 plants m^{-2}). The result obtained from the present study was similar with the findings of Singh *et al*. (1986).

4.3.3.3 Interaction effect of nitrogen and sulphur level with population density

Biological yield was significantly influenced by the interaction effect of nitrogen and sulphur level and population density (Table 8). Results showed that the maximum biological yield of 6093.2 kg ha^{-1} was found from the interactions of F_3P_4 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 80 plants m^{-2} plant density) which was statistically similar to F_3P_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) producing 5833.4 kg ha^{-1} and also followed by F_4P_2 and F_4P_3 and F_4P_4. On the other hand, the lowest biological yield of 1431.8 kg ha^{-1} was found from the treatment combination of F_0P_1 (0 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 20 plants m^{-2} plant density).

4.3.4 Harvest index

4.3.4.1 Effect of nitrogen and sulphur level

Harvest index (%) of mustard was significantly different at different level of nitrogen and sulphur. (Table 6). The table shows that the treatment F_4 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur) produced maximum harvest index of 34.00% followed by the treatment F_3 (110 kg ha^{-1} nitrogen+25 kg ha^{-1} sulphur) of 33.87%, F_2 (90 kg ha^{-1} nitrogen +20 kg ha^{-1} sulphur) producing 33.86% and F_1 (70 kg ha^{-1} nitrogen+20 kg ha^{-1} sulphur) of 33.22%. The lowest harvest index of 32.97% was found with the treatment F_0 (control).

4.3.4.2 Effect of population density

Population density had significant influence on the harvest index (Table 7). It was observed that the highest harvest index of 36.15% was found from P_3 (60 plants m^{-2}) followed by P_4. On the other hand, the lowest harvest index of 32.08% was found from P_1 (control). The result obtained from the present study was similar with the findings of Scarisbric *et al*. (1982) and Sharif *et al*. (1990).

4.3.4.3 Interaction effect of nitrogen and sulphur level and population density

Harvest index (%) was not significantly influenced by the interaction effect of nitrogen and sulphur level and population density (Table 8). Numerically the highest harvest index (%) of 36.81 was found from the interactions of F_4P_3 (130 kg ha^{-1} nitrogen+30 kg ha^{-1} sulphur with 60 plants m^{-2} plant density) which was statistically and closely followed by F_1P_3, F_2P_3 and F_3P_3. On the other hand, the lowest harvest index (%) of 31.15 was found from the treatment combination of F_2P_1 (90 kg ha^{-1} nitrogen+0 kg ha^{-1} sulphur with 20 plants m^{-2} plant density).

Table 6. Effect of nitrogen and sulphur level on yield parameters of SAU Sarisha-3

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
F_0	882.5 d	1770.3 c	2652.9 d	32.97 c
F_1	1332.7 c	2671.2 b	4003.9 c	33.22 b
F_2	1532.5 b	2985.6 b	4518.1 b	33.86 b
F_3	1832.5 a	3588.2 a	5420.7 a	33.87 b
F_4	1862.5 a	3595.9 a	5458.4 a	34.00 a
LSD(0.05)	**88.59**	**330.71**	**380.51**	**2.5**
CV (%)	**6.32**	**12.02**	**9.16**	**4.49**

F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

Table 7. Effect of population density on yield parameters of SAU Sarisha-3

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
P_1	1140.8 d	2403.8 c	3544.5 c	32.08 c
P_2	1400.5 c	2897.7 b	4298.2 b	32.54 bc
P_3	1733.9 a	3059.3 b	4793.2 a	36.15 a
P_4	1679.0 b	3328.2 a	5007.2 a	33.55 b
LSD(0.05)	**51.620**	**220.71**	**260.30**	**1.1237**
CV (%)	**4.07**	**8.79**	**7.08**	**4.21**

P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

P_4 = 800000 plants ha^{-1}i.e. 80 plants m^{-2}

Table 8. Interaction effect nitrogen and sulphur level with population density on yield parameters of SAU Sarisha-3

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
F_0P_1	463.7 j	968.1 j	1431.8 j	32.29
F_0P_2	830.4 i	1782.7 i	2613.1 i	31.63
F_0P_3	1046.9 h	1888.9 i	2935.8 i	35.56
F_0P_4	1189.0 g	2441.7 gh	3630.7 gh	32.74
F_1P_1	991.7 h	2143.0 hi	3134.7 hi	31.63
F_1P_2	1205.2 g	2453.3 gh	3658.4 gh	32.98
F_1P_3	1638.5 de	2877.3 fg	4515.8 ef	36.28
F_1P_4	1495.4 f	3211.2 d-f	4706.6 de	31.97
F_2P_1	1216.6 g	2687.2 fg	3903.8 fg	31.15
F_2P_2	1485.5 f	3025.6 ef	4511.1 ef	32.98
F_2P_3	1769.0 cd	3115.1 ef	4884.0 e-e	36.32
F_2P_4	1658.9 de	3114.5 ef	4773.5 de	35.00
F_3P_1	1530.8 ef	3000.1 f	4530.9 ef	33.87
F_3P_2	1680.7 cd	3544.5 b-e	5225.1 b-d	32.28
F_3P_3	2081.0 ab	3752.4 a-c	5833.4 a	35.80
F_3P_4	2037.4 ab	4055.8 a	6093.2 a	33.51
F_4P_1	1501.0 f	3220.4 c-f	4721.4 de	31.80
F_4P_2	1800.7 c	3682.4 a-d	5483.1 a-c	32.85
F_4P_3	2134.0 a	3662.8 a-d	5796.8 ab	36.81
F_4P_4	2014.3 b	3817.9 ab	5832.2 ab	34.57
LSD(0.05)	**133.33**	**539.50**	**630.53**	**3.30**
CV (%)	**4.65**	**10.13**	**7.91**	**4.49**

F_0 = Control

F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}

F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}

F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}

F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}

P_1 = 200000 plants ha^{-1}i.e. 20 plants m^{-2}

P_2 = 400000 plants ha^{-1}i.e. 40 plants m^{-2}

P_3= 600000 plants ha^{-1}i.e. 60 plants m^{-2}

P_4 = 800000 plants ha^{-1}i.e. 80 plants m^{-2}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the field of Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2015 to February 2016 to determine the effect of nitrogen and sulphur with different population density on growth and yield of mustard (SAU Sarisha-3).

The experiment consists of two factors. Factor A: nitrogen + sulphur (5 levels) i.e. F_0 = Control, F_1 = (70 kg nitrogen + 15 kg sulphur) ha^{-1}, F_2 = (90 kg nitrogen + 20 kg sulphur) ha^{-1}, F_3 = (110 kg nitrogen + 25 kg sulphur) ha^{-1}, F_4 = (130 kg nitrogen + 30 kg sulphur) ha^{-1}; Factor B: Population density (4 levels) i.e. P_1 = 200000 plants ha^{-1} (20 plants m^{-2}), P_2 = 400000 plants ha^{-1} (40 plants m^{-2}), P_3= 600000 plants ha^{-1} (60 plants m^{-2}), P_4 = 800000 plants ha^{-1} (80 plants m^{-2}) in this experiment. There were twenty treatment combinations under the present study. Data were collected from the experimental field and analyzed statically. The experiment was laid out in Split plot design with three replications. After emergence of mustard seedlings, various intercultural operations were accomplished for growth. The data obtained for different characters were statistically analyzed to find out the significance of the nitrogen and sulphur with different population density.

Data were collected on plant height (cm), branches $plant^{-1}$ (no.), siliqua $plant^{-1}$ (no.), seeds $siliqua^{-1}$, length of siliqua (cm), weight of 1000 seeds (g), seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%). Significant variation was found in all parameters at different growth stages of mustard. Different varieties showed significant variation at different stages.

At 20, 40, 60 DAS and at harvest F_4 (130 kg nitrogen + 30 kg sulphur ha^{-1}) gave highest plant height of 14.13, 59.63, 81.34 and 85.95 cm, respectively where F_0 (Control) showed the lowest plant height of 10.02, 46.15, 65.36 and 68.61 cm, respectively. In terms of number of branches $plant^{-1}$, F_4 (130 kg nitrogen + 30 kg sulphur) ha^{-1} showed the highest number of 6.63, 7.32 and 7.32 at 40, 60 DAS and at harvest, respectively where F_0 (Control) gave the lowest number of branches $plant^{-1}$ of 3.00, 3.40 and 3.40 at 40, 60 DAS and at harvest, respectively.

Considering yield contributing parameters, F_4 (130 kg nitrogen + 30 kg sulphur ha^{-1}) produced the highest 1000 seeds weight of 3.54 gm, length of siliqua of 6.51 cm, number of seeds $siliqua^{-1}$ of 22.34 but F_3 (110 kg nitrogen + 25 kg sulphur ha^{-1}) produced highest siliqua $plant^{-1}$ of 103.86 where F_0 (Control) gave the lowest number of siliqua $plant^{-1}$ of 45.52 and 1000 seed weight of 3.05 g, lowest length of siliqua of 5.62 cm and number of seeds $siliqua^{-1}$ of 14.60.

Considering yield parameters, it was observed that F_4 (130 kg nitrogen + 30 kg sulphur ha^{-1}) gave the highest seed yield of 1862.5 kg ha^{-1}, stover yield of 3595.9 kg ha^{-1} , biological yield of 5458.4 kg $ha^{-1}$and harvest index of 34 % where the lowest seed yield of 882.5 kg ha^{-1}, stover yield of 1770.3 kg ha^{-1}, biological yield of 2652.9 kg ha^{-1} and harvest index of 39.97% were found with F_0 (control).

Different population densities showed significant variation at different stages. Plant height at the time of harvest, P_4 (800000 plants ha^{-1} i.e. 80 plants m^{-2}) gave best result of 82.07 cm where lowest plant height was observed with P_1 (200000 plants ha^{-1} i.e. 20 plants m^{-2}) of 71.41 cm, respectively. Again, the highest number of branch per plant was achieved from P_1 (200000 plants ha^{-1} i.e. 20 plants m^{-2}) at 40, 60 DAS and at harvest of 5.67, 6.37 and 6.37 cm, respectively where P_4 (800000 plants ha^{-1} i.e. 80 plants m^{-2}) showed the lowest number of branch per plant of 5.67, 6.37 and 6.37 cm at 40, 60 DAS and at harvest, respectively.

Considering yield contributing parameters, P_4 (800000 plants ha^{-1} i.e. 80 plants m^{-2}) gave the highest value and P_1 (200000 plants ha^{-1} i.e. 20 plants m^{-2}) gave the lowest value of 1000 seeds weight, length of siliqua, number of seeds $siliqua^{-1}$ and siliqua $plant^{-1}$ respectively.

Considering yield parameters, P_3 (600000 plants ha^{-1} i.e. 60 plants m^{-2}) gave the maximum Seed yield of 1733.9 kg ha^{-1} , harvest index of 36.15% and P_4 (800000 plants ha^{-1} i.e. 80 plants m^{-2}) gave maximum stover yield of 3328.2 kg ha^{-1}, biological yield of 5007.2 kg ha^{-1} where the lowest Seed yield of 1140.8 kg ha^{-1}, stover yield of 2403.8 kg ha^{-1} , biological yield of 3544.5 kg ha^{-1} and harvest index of 32.08 % were found from P_1 (200000 plants ha^{-1} i.e. 20 plants m^{-2}).

In case of combined effect of fertilizer and population density, F_3P_4 gave the tallest plant of 86.73 and 90.73 cm at 60 DAS and at harvest respectively where the shortest plant height was found from F_0P_1 at harvest of 58.83 cm. In case of number of branches plant^{-1}, F_4P_1 gave the highest value and F_0P_4 gave the lowest value at 40, 60 DAS and at harvest, respectively.

Considering yield contributing parameters, the maximum value of 1000 seed weight of 3.80g, siliqua plant^{-1} of 137.61 and number of seeds siliqua^{-1} of 29.30 were found from F_3P_1 but the maximum length of siliqua of 7.33 cm. The lowest value of 1000 seed weight of 2.76g, number of siliqua plant^{-1} of 27 and length of siliqua of 4.47 cm were found from F_0P_4, the lowest number of seeds siliqua^{-1} of 13 were found from F_0P_3.

Considering yield parameters, the maximum seed yield of 2081 kg ha^{-1} was found from F_3P_3 but the maximum stover yield of 4055 kg ha^{-1} and the maximum biological yield of 6093 kg ha^{-1} were found from F_3P_4 where the lowest seed yield of 463.7 kg ha^{-1}, stover yield of 1645.5 kg ha^{-1} and biological yield of 2430.5 kg ha^{-1} were found from F_0P_1.

From the results of the present experiment, it may be concluded that with this treatment combination of F_3P_3 the yield was 2081 kg ha^{-1}. But the treatment combination of F_3P_4 showed very close yield of 2037.4 kg ha^{-1}. So, from economic point of view, F_3P_3 was the best treatment combination.

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.

CHAPTER VI

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APPENDICES

Appendix I. Morphological Characteristics of experimental field

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

Appendix II. Physical and chemical properties of the experimental soil

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

Appendix III. Monthly average of air temperature, Relative Humidity and Total rainfall of the experimental site during the period from November 2015 to February 2016.

Month	Air Temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2015	30.3	18	70	1
December, 2015	26.7	13	73	0
January, 2016	26.0	13.2	72	1
February, 2016	32.9	19.2	61	1

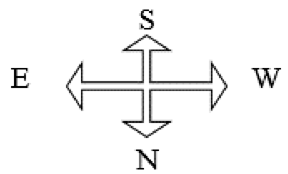
Source: Bangladesh Metrological Department (Climate division), Agargaon. Dhaka-1212.

Appendix IV: Lay-out of the experiment

$F_2 P_3$	$F_0 P_1$	$F_3 P_2$	$F_1 P_4$	$F_4 P_4$
$F_2 P_1$	$F_0 P_2$	$F_3 P_4$	$F_1 P_2$	$F_4 P_2$
$F_2 P_2$	$F_0 P_4$	$F_3 P_1$	$F_1 P_3$	$F_4 P_3$
$F_2 P_4$	$F_0 P_3$	$F_3 P_3$	$F_1 P_1$	$F_4 P_1$

$F_0 P_3$	$F_3 P_2$	$F_1 P_1$	$F_4 P_2$	$F_2 P_2$
$F_0 P_2$	$F_3 P_1$	$F_1 P_2$	$F_4 P_3$	$F_2 P_4$
$F_0 P_1$	$F_3 P_4$	$F_1 P_3$	$F_4 P_4$	$F_2 P_1$
$F_0 P_4$	$F_3 P_3$	$F_1 P_4$	$F_4 P_1$	$F_2 P_3$

$F_3 P_4$	$F_4 P_2$	$F_1 P_1$	$F_2 P_4$	$F_0 P_1$
$F_3 P_3$	$F_4 P_1$	$F_1 P_3$	$F_2 P_2$	$F_0 P_2$
$F_3 P_2$	$F_4 P_4$	$F_1 P_4$	$F_2 P_3$	$F_0 P_4$
$F_3 P_1$	$F_4 P_3$	$F_1 P_2$	$F_2 P_1$	$F_0 P_3$



Number of plots: 60

Plot size: 2m × 1.5m ($5m^2$) Block to block distance: 0.75m

Plot to plot distance: 0.5m

Factor-1: Nitrogen and Sulphur level

i. F_0 = Control

ii. F_1 = (70 kg Nitrogen + 15 kg Sulphur) ha^{-1}

iii. F_2 = (90 kg Nitrogen + 20 kg Sulphur) ha^{-1}

iv. F_3 = (110 kg Nitrogen + 25 kg Sulphur) ha^{-1}

v. F_4 = (130 kg Nitrogen + 30 kg Sulphur) ha^{-1}

Factor-2: Population density

i. P1 = 200000 plants ha^{-1} i.e. 20 plants m^{-2}

ii. P2 = 400000 plants ha^{-1} i.e. 40 plants m^{-2}

iii. P3= 600000 plants ha^{-1} i.e. 60 plants m^{-2}

iv. P4 = 800000 plants ha^{-1} i.e. 80 plants m^{-2}

Appendix VA: Effect of nitrogen and sulphur level with population density on plant height at different days after sowing of mustard

Source of variation	Degrees of freedom (df)	Mean square of plant height (cm) at different days after sowing			
		20 DAS	40 DAS	60 DAS	At harvest
Replication	2	0.54	193.29	295.80	306.99
Factor A (Nitrogen and sulphur level)	4	31.17**	363.93**	601.35**	667.98**
Error I	8	0.41	3.43	0.09	0.43
Factor B (Population density)	3	4.33**	150.91**	304.18**	367.47**
AB	12	0.21**	21.83**	16.03**	20.76**
Error II	30	0.37	2.28	0.005	0.53
Total	**59**				

.** indicates significant at 1% level of probability

Appendix VB: Effect of nitrogen and sulphur level with population density on branches plant^{-1} at different days after sowing of mustard

Source of variation	Degrees of freedom (df)	Mean square of branches plant^{-1} (no.) at different days after sowing			
		20 DAS	40 DAS	60 DAS	At harvest
Replication	2	0.00	0.77	0.80	0.80
Factor A (Nitrogen and sulphur level)	4	0.00	48.60**	48.81**	48.81**
Error I	8	0.00	0.17	0.16	0.16
Factor B (Population density)	3	0.00	11.09**	11.18**	11.18**
AB	12	0.00	0.13*	0.12*	0.12*
Error II	30	0.00	0.06	0.07	0.07
Total	**59**				

** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

Appendix VC: Effect of nitrogen and sulphur level with population density on yield contributing characters of mustard.

Source of variation	Degrees of freedom (df)	Mean square of on yield contributing characters			
		Siliquae plant^{-1} (no.)	Length of siliquae (cm)	Seeds siliquae^{-1} (no.)	1000 seed weight (g)
Replication	2	17.88	3.37	0.42	3.38
Factor A (Nitrogen and sulphur level)	4	7345.20**	1.59**	119.46**	0.45*
Error I	8	8.97	0.03	0.12	0.04
Factor B (Population density)	3	4969.12**	10.07**	178.33**	0.51**
AB	12	360.28**	1.29**	6.89**	0.05*
Error II	30	4.90	0.01	1.14	0.02
Total	**59**				

****** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

Appendix VD: Effect of variety and population density on seed yield, stover yield, biological yield and harvest index of mustard.

Source of variation	Degrees of freedom (df)	Mean square of on yield contributing characters			
		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest index (%)
Replication	2	845296	3134615	7235219	1.7409
Factor A (Nitrogen and sulphur level)	4	1954844**	6873621**	1.615^{7}**	2.5491*
Error I	8	8856	123404	163366	7.0324
Factor B (Population density)	3	1125869**	2265067**	163365**	49.7689**
AB	12	12181*	105902*	6325200*	2.4090 NS
Error II	30	4791	87591	165318	2.2704
Total	**59**				

****** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

'NS' indicates the values are not significant.