EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF MUSTARD (SAU SHARISHA-1)

A Thesis

By

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CERTIFICATE

This is to certify that the thesis entitled, "*EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF MUSTARD (SAU SHARISHA-1)*" submitted to the *DEPARTMENT OF SOIL SCIENCE*, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE (M.S.)* in *SOIL SCIENCE* embodies the result of a piece of *bona fide* research work carried out by *MOHAMMED MOHIUDDIN* Registration No. *23963/00256* 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 by him.

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to determine the effect of different levels of nitrogen and sulphur on yield and yield contributing characters of mustard as well as the nutrient content and their uptake by mustard plants.

The experiment consisted of four levels of nitrogen i.e. 0 kg N/ha (N_0), 40 kg N/ha (N_1), 80 kg N/ha (N_2) and 120 kg N/ha (N_3); and four levels of sulphur i.e, 0 kg S/ha (S_0), 8 kg S/ha (S_1), 16 kg S/ha (S_2) and 24 kg S/ha (S_3). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications.

The plant height, the number of branches per plant, the number of siliqua per plant, seed and shoot yield increased with increasing N level upto 80 kg N/ha. Further increasing in N level i.e., 120 kg N/ha had a negative effect on seed yield. On the other hand, with increasing S levels from 0 to 24 kg S/ha, plant height, siliqua per plant, 1000 seed weight, siliqua per plant, 1000 seed weight increased significantly upto 16 S/ha. However the number of branches per plant and seed yield increased upto the highest dose of S (24 kg S/ha).

In general N and P content in seed yield increased significantly with increasing N levels upto 80 kg N/ha. However, N content and S content in seed increased with increasing S levels upto 16 kg S/ha and 24 kg S/ha, respectively. Uptake of N, P, K and S by plant increased significantly upto 80 kg N/ha (N_2) and 16 kg S/ha (S_2). The application of N fertilizers had a negative effect % on total N, available S, available P and available K content in soil while the application of S fertilizer upto 16 kg S/ha showed a significant positive effect on available S status of soil. Considering the combined effect of N and S, the treatment combination N_2S_3 produced the maximum seed yield (1738 kg/ha).

CONTENTS

CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter I
INTRODUCTION

Mustard (*Brassica* spp) is one of the most important oil seed crops through out the world after soybean and groundnut (FAO, 2004). 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).

In the year of 2003-04 it covered 1.79 lakhs hectare (ha) land and the production was 2.11 lakhs metric tonnes (Mt), whereas the total oilseed production was 4.07 lakhs Mt and total area covered by oilseed corps was 3.89 lakhs ha. In the year of 2004-05 it covered 3.95 lakhs ha land and the production was 3.79 lakhs Mt. (BBS, 2005).

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.

Mustard plant belongs to the genus *Brassica* under the family cruciferae. 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 subcontinust, *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-2-16-98. MM-34-7, MM-38-6-98, MM-49-3-98, Binasarisha-4 are high yielding mutants/varieties have been developed by the scientist of Bangladesh institute of nuclear agriculture (BINA). Very recently, a new variety of mustard named SAU-sharisha has been developed in the Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University.

Rape and 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 are very important for the cultivation of mustard in Bangladesh.

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).

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).

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 (Dijshorn *et al*., 1960).

In addition, the fertilizer requirement for maximum growth and yield of newly developed mustard variety SAU-Sharisha is not much investigated. With a view to determine the nitrogen and sulphur requirement of this new variety a field study was conducted with the fallowing objectives:

- to study the growth, yield performance of SAU mustard variety by using different doses of nitrogen and sulphur.
- to evaluate the economic productivity of mustard.
- to recommend the optimum dose of nitrogen (N) and sulphur (S) for better growth and yield of SAU mustard variety under deep red brown terrace soil.
- to study the N, P, K, S content in plant and their uptake by mustard as influenced by different nitrogen and sulphur doses.

Chapter II
REVIEW OF LITERATURE

2.1. Effect of Nitrogen (N) on Mustard/Rapeseed:

2.1.1 Effect of N on yield and yield contributing characters

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

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

Singh *et al*. (2004) reported that nitrogen application did not affect the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application increased the seed yield of mustard.

Nitrogen and sulphur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N/ha over its preceding rates. The increased nitrogen and sulphur content enhanced the total uptake of nitrogen and sulphur.

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

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

Field experiments were conducted by Abdin *et al*. (2003) 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 rapeseed-mustard can be optimized with the split application of 40 kg S/ha and 100 kg N/ha during the appropriate phenological stages of crop growth and development.

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

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

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

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

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

Singh (2002) found that application of N and P increased the length of siliqua, number of siliquae per plant, 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 and 30, 45 and 60 kg P/ha treatments. The maximum seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was not significant.

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

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). The proper placement of N is also important. Seeds in touch with nitrogen bonding may decrease seedling emergence (Koofoed and Larsen, 1971).

2.1.2 Effect of N on uptake of N by mustard

Nitrogen should be applied in two equal splits; first with phosphorus and potassium and second after 3 weeks of sowing. Rapeseed and mustard have high requirements of nitrogen to give higher seed yield. A spring rape seed crop accumulates 50-60 kg nitrogen for every tonne of seed produced (Geisler and Kullman, 1991; Grant and Bailey, 1993). The equivalent for winter rapeseed is about 70 kg nitrogen. One tonne of harvested seed with 42% oil and 38% protein in the meal, contains 35 kg nitrogen. So, for high yields, rapeseed needs a lot of nitrogen (150-210 kg nitrogen for 3 tonnes ha^{-1}).

Each tonne of seed removes about 32 kg nitrogen (13.75% of protein, whole-seed basis) and 210 kg nitrogen produces 7 tonns of grain ha^{-1}. It is very difficult to determine the appropriate fertilizer rate for rapeseed because of poor relationship between nitrogen utilization and seed yield. Crop requirements are provided by the addition of fertilizer and subsequent mineralization of soil nitrogen. Nitrogen is most immediately available to plants when applied in the form of nitrate although it has been showed that rapeseed can utilize the ammoniacal form too. Rapid availability of nitrogen is important at the end of winter when climatic condition do not favour soil mineralization.

Greath and Schweiger (1991) have shown that cultivars of mustard may differ in nitrogen uptake and translocation. They classified cultivars into three types: type I- 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 the 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; Bhatty, 1964 and Gupta *et al*., 1961).

2.2 Effect of Sulphur on mustard or Rapeseed

Sulphur has been recognized for over 100 years as one of the essential elements required for the growth of plants. Global reports of sulphur deficiency and consequent crop responses are quite ostensible (Singh and Rathi, 1984).

Sulphur is required by crops in about the same amounts as phosphorus and is therefore recognized by many agriculturists as the fourth important nutrient (BARC, 1986). Sulphur plays an important role in the synthesis of protein and the essential sulphur containing amino acids, methionine and cysteine, vitamins and chlorophyll. It is essential for the activation of certain enzymes and is a vital constituent of ferrodoxin which participate in the photosynthesis process. As sulphur is involved in photosynthesis, deficiency decreases chlorophyll content

and young leaves turn yellow showing interveinal chlorosis. Growth is stunted and the flowers have smaller petals which are pale yellow.

Sulphur has vital influence on growth and yield of mustard. When deficiency symptoms of sulphur noticeable rapeseed becomes severely lacking in sulphur. Pods form slowly, are small and poorly filled with shriveled seeds.

An experiment was conducted during 1987-88 and 1988-89 to study the effect of levels and modes of sulphur application on biochemical ehanges in leaves of mustard (*Brassica juncea*). Chlorophyll content (a, b and total) and peroxides activity in fresh head at 50% flowering increased significantly, but leaf-sap pH decreased significantly due to S application. Total chlorophyll content and peroxidase activity increased significantly up to 150 kg N ha^{-1} in pooled results (Khampara, *et al*., 1993).

Sulphur starved rape produced very low quality of oil (Rahman, 1977). 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}.

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.

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}.

Chapter III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during November 2006 to February 2007 to examine the effect of nitrogen (N) and sulphur (S) on the growth and yield of mustard SAU-Sharisha-1.

3.1 Experimental site and soil

The experimental site was located at $23^0 77'$ N latitude and $90^0 3'$ E longitude with an elevation of 1.0 meter from sea level (Fig. 1). The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ - 28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are shown in Table 1 & 2.

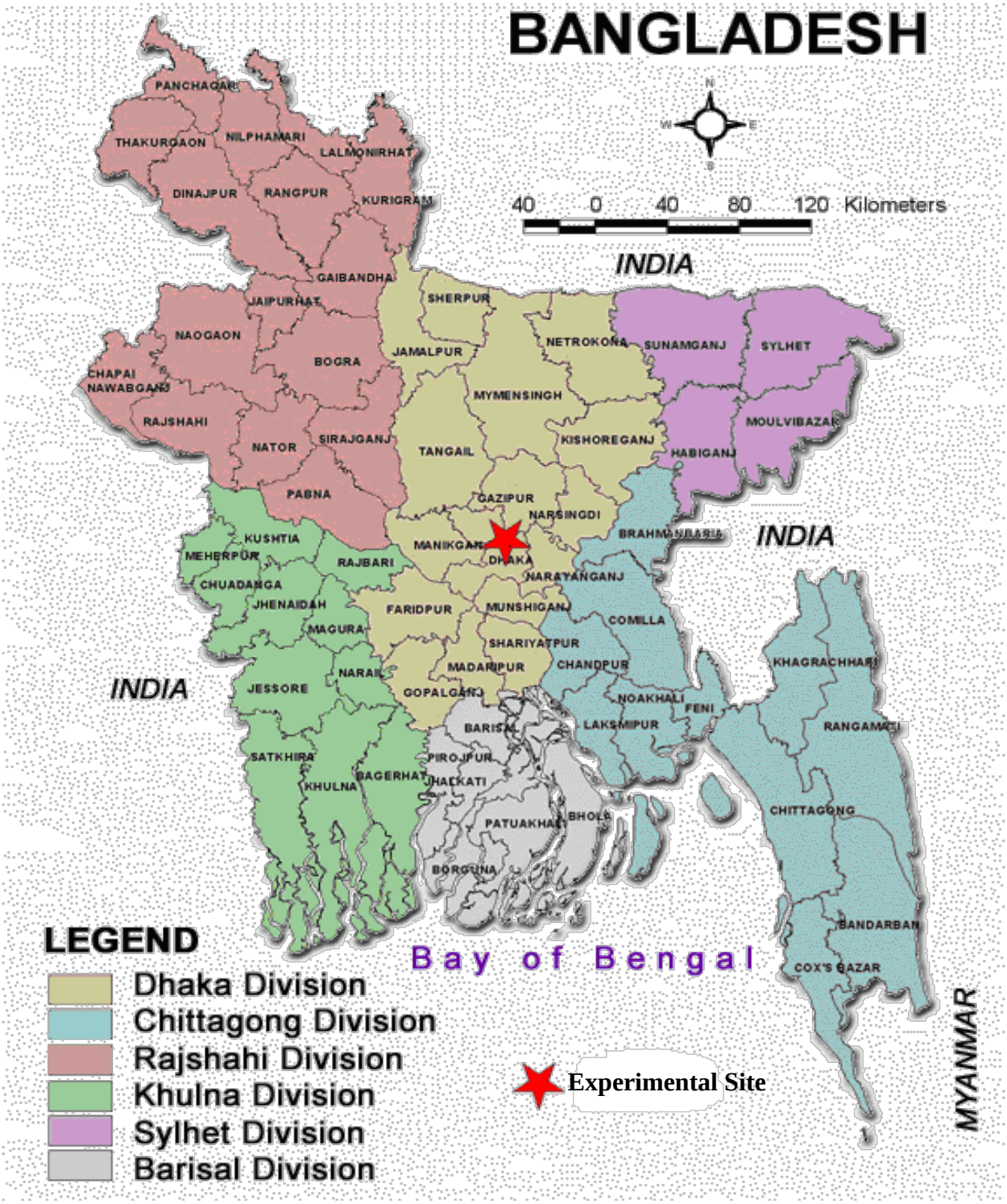

Fig.1. Map showing the experimental site under study

Table 1. Morphological Characteristics of experimental field

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

Table 2. Physical and chemical properties of the experimental soil

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

3.2 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm, the average maximum temperature is 30.3^0C and average minimum temperature is 21^0C. The average mean temperature is 25.8^0C. The experiment was carried out during rabi season, 2006-07. Temperature during the cropping period ranged from 20^0C to 29.2^0 C. The humidity varied from 61.72% to 70.45%. The day length was reduced to 10.5-11.0 hours only and there was no rainfall from the beginning of the experiment to harvesting. The monthly average temperature, humidity and rainfall of the site during the experimental work are enclosed in appendix Figures-5 to 7.

3.3 Seeds and variety

SAU Sharisha-1, a medium yielding and short duration variety of mustard (*Brassica campestris*) developed by Sher-e-Bangla Agricultural University (SAU), Dhaka was used as experiment crop. The seeds were collected from Dept. of Genetics and Plant Breeding of SAU, Dhaka.

3.4 Design and layout of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Fertilizer treatments consisted of 4 levels of N (0, 40, 80 and 120 kg N/ha designated as N_0, N_1, N_2 and N_3 respectively) and 4 levels of S (0, 8, 16 and 24 kg S/ha designated as S_0, S_1, S_2 and S_3 respectively). There were 16 treatment combinations. The treatment combinations were as follows:

N_0S_0 = Control (without N and S application)

N_0S_1 = 0 kg N/ha+8 kg S/ha

N_0S_2 = 0 kg N/ha+16 kg S/ha

N_0S_3= 0 kg N/ha+24 kg S/ha

N_1S_0= 40 kg N/ha+0 kg S/ha

N_1S_1= 40 kg N/ha+8 kg S/ha

N_1S_2= 40 kg N/ha+16 kg S/ha

N_1S_3= 40 kg N/ha+24 kg S/ha

N_2S_0 =80 kg N/ha+0 kg S/ha

N_2S_1 = 80 kg N/ha+8 kg S/ha

N_2S_2 = 80 kg N/ha+16 kg S/ha

N_2S_3 = 80 kg N/ha+24 kg S/ha

N_3S_0 = 120 kg N/ha+0 kg S/ha

N_3S_1 = 120 kg N/ha+8 kg S/ha

N_3S_2 = 120 kg N/ha+16 kg S/ha

N_3S_3 =120 kg N/ha+24 kg S/ha

Fertilizer treatments were randomly distributed in each block. Each block consisted of 16 plots and individual plot was 2.5m × 2m i.e 5 sq. m in size. The row-to-row and seed to seed distance were 30 and 5 cm respectively accommodating 250 plants in each plot. The adjacent block and neighboring plots were separated by 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Fig. 2.

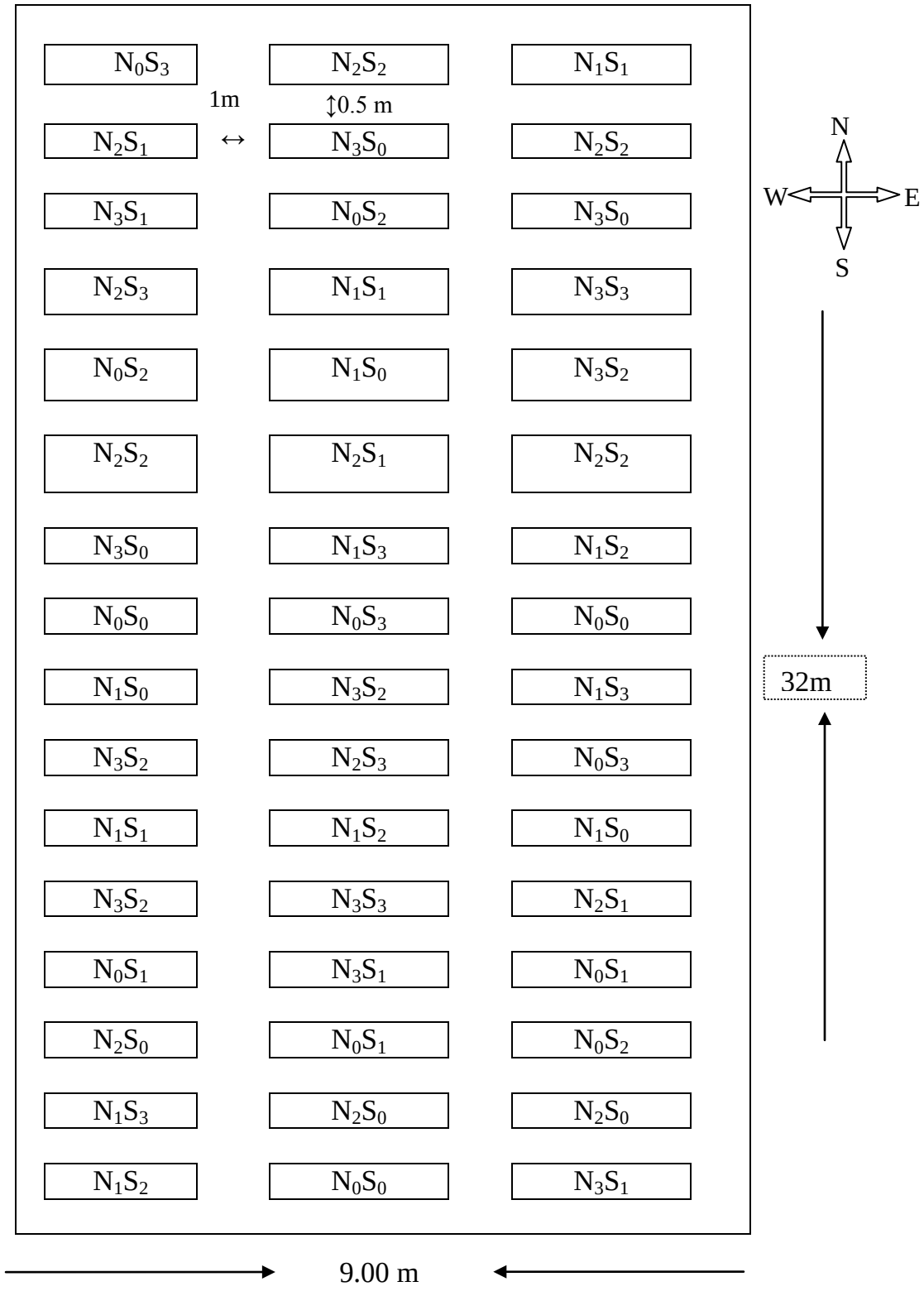

Fig. 2 Layout of the experiment

3.5 Collection and processing of soil sample

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

3.6 Land preparation

The land was first ploughed with a tractor drawn disc plough on 30 October 2006. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land operation was completed on 7 November 2006. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Application of fertilizers

The P K and Zn fertilizer were applied at the rate of 20, 50 and 2 kg/ha according to Fertilizer Recommendation Guide (BARC, 1997) through Triple super phosphate (TSP), Muriate of potash (MP) and Zinc oxide, respectively. 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.

3.8 Seed sowing

Seeds were sown continuously @ 7 kg /ha on 8 November 2006 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept about 200 per plot. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 26 November 2006. At the same time first thinning was done. The final weeding and thinning were done after 25 days of sowing, on 4 December 2006. Care was taken to maintain constant plant population per plot.

3.10 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 4 December 2006 at 25 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (35DAS), on 25 December 2006. The final irrigation was given at the stage of seed formation (50 DAS), on 30 December 2006.

3.11 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2ml /L water. The insecticide was sprayed thrice, the first on 28 November 2006; the second on 22 December 2006 and the last on 12 January, 2007. The crop was kept under constant observations from sowing to harvesting.

3.12 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 08 February 2007. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and

expressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.13 Collection of experimental data

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

1) Plant height (cm)
2) Number of primary branch per plant
3) Number of siliquae per plant
4) Number of seeds per siliqua
5) Weight of 1000-seeds (g)
6) Seed yield (t /ha)
7) Total shoot yield (t /ha)
8) Biological yield (t /ha)
9) N, P, K, S content in seeds (%) and plant (%)
10) N, P, K, S uptake by seeds (kg/ha) and shoot (Kg/ha).

3.14 Methods for Soil Analysis

3.14.1 Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method. The textural class was determined using Marshell's Triangular co-ordinate as designated by USDA.

3.14.2 Organic carbon (%)

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

3.14.3 C/N ratio

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

3.14.4 Soil organic matter

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

% organic matter = % organic carbon × 1.724

3.14.5 Soil pH

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

3.14.6 Total nitrogen (%)

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

3.14.7 Available sulphur (ppm)

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

3.14.8 Available Phosphorus (ppm)

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

3.14.9 Exchangeable Potassium (meq/100 g soil)

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

3.15 Methods for Seed Analysis

For determination of N, P, K and S content in seed the sample were first digested with acid and determination of elements in the digest was performed either by titration (for N), or by colorimetric method. For N, digestion was done with conc. H_2SO_4 and digest was distilled over following the procedure outlined under Soil Analysis section (3.14). The amount of these elements in the digest was estimated following the procedure described under Soil Analysis section (3.14).

3.16 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The test of significance of all parameters was done. The Duncan`s Multiple Range Test (DMRT) with Least Significant Difference value was determined with appropriate levels of significance and the means were tabulated. The mean comparison was carried out by DMRT technique (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different levels of nitrogen and sulphur on yield and yield contributing characters of mustard as well as the nutrient content and their uptake by mustard plants. The analyses of variance (ANOVA) of the data on different components are given in Appendix I-IV. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Yield and yield contributing character of mustard

Yield contributing characters such as plant height, branches per plant, Siliqua per plant, Seed per siliqua, 1000 seed weight, seed yield, shoot yield were recorded in every plot of the trial.

4.1.1 Plant height

Effect of nitrogen showed a statistically significant variation for plant height of mustard under the present trial (Appendix I). The tallest plant (88.0 cm) was recorded from N_2 treatment comprising of 80 kg N/ha which was statistically similar (85.7 cm) with the treatment N_3 as 120 kg N/ha (Table 3). The plant height increased significantly with increasing levels of N upto 80 kg N/ha (N_2). Probably 80 kg N/ha ensured the other nutrients and favorable condition for growth of mustard plant and the ultimate results is the tallest plant. Ali *et al*. (1990), Mondal and Gaffer (1983), Gaffer and Razzaque (1983), Asaduzzaman and Shamsuddin (1986) also reported the similar results from their experiment. They reported that different levels of nitrogen significantly increased plant height of mustard.

Table 3. Main effect of nitrogen on yield contributing characters of mustard

Nitrogen	Plant height (cm)	Branches per plant (No.)	Siliqua per plant (No.)
N_0	73.5 c	5.08 c	77.7 c
N_1	79.0 b	6.75 b	108 b
N_2	88.0 a	7.05 a	150 a
N_3	85.7 a	7.05 a	151 a
$LSD_{(0.05)}$	2.576	0.112	1.930

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 4. Main effect of sulphur on yield contributing characters of mustard

Sulphur	Plant height (cm)	Branches per plant (No.)	Siliqua per plant (No.)
S_0	79.6 b	5.93 d	109 c
S_1	80.4 b	6.29 c	125 b
S_2	82.2 ab	6.79 b	126 ab
S_3	83.9 a	6.93 a	127 a
$LSD_{(0.05)}$	2.576	0.112	1.930

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

Different level of sulphur exhibited statistically significant differences for plant height (Appendix I). With increasing the doses of S, the plant height increased significantly upto the highest dose 24 kg S/ha (S_3) and the maximum plant height was 83.9 cm. On the other hand the shortest plant height (79.6 cm) was recorded from S_0 treatment i.e. control condition under the present trial.

Significant interaction effect was also recorded between nitrogen and sulphur in consideration of plant height under the present experiment (Appendix I). The tallest plant (93.0 cm) was recorded from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha, while the shortest plant (72.0 cm) was recorded from N_0S_0 i.e. no nitrogen no sulphur (Table 5).

4.1.2 Branches per plant

A statistically significant variation for branches per plant of mustard was recorded for the effect of nitrogen (Appendix I). The number of branches per plant increased significantly with increasing N levels upto the treatment N_2 comprising of 80 kg N and the maximum number of branches per plant (7.05) was obtained with this treatment (Table 3). Probably 80 kg N/ha ensured the favorable condition for growth of mustard and the ultimate results is the maximum number of branches. Mondal and Gaffer (1983), Gaffer and Razzaque (1983) also reported the similar results from their experiment. They reported that different levels of nitrogen significantly increased branches per plant of mustard.

Number of branches per plant for different levels of sulphur also showed statistically significant variation (Appendix I). The highest significant increase in number of branches per plant (6.93) was recorded from S_3 treatment containing 24 kg S/ha. On the other hand the minimum number of branches per plant (5.93) was observed from the S_0 treatment.

Interaction effect between nitrogen and sulphur showed a significant difference for the number of branches per plant under the present experiment (Appendix I). The maximum number of branches per plant (8.10) was observed from the treatment combination N_2S_3 having 80 kg N/ha + 24 kg S/ha (Table 5).

Table 5. Interaction effect of nitrogen and sulphur on yield contributing characters of mustard

Nitrogen × Sulphur	Plant height (cm)	Branches per plant (No.)	Siliqua per plant (No.)
N_0S_0	72.0 h	4.77 h	71.3 l
N_0S_1	72.8 gh	4.80 h	72.0 l
N_0S_2	73.3 efg	5.22 g	77.3 k
N_0S_3	75.7 efgh	5.53 f	90.0 j
N_1S_0	78.0 defg	6.40 de	96.0 i
N_1S_1	78.7 def	6.60 d	119 g
N_1S_2	79.7 cde	7.00 c	110 h
N_1S_3	79.5 cde	7.00 c	107 h
N_2S_0	85.0 bc	6.27 e	125 f
N_2S_1	85.1 bc	6.34 e	152 c
N_2S_2	88.85 ab	7.50 b	158 b
N_2S_3	93.0 a	8.10 a	165 a
N_3S_0	83.2 bcd	6.27 e	142 e
N_3S_1	85.2 bc	7.40 b	157 b
N_3S_2	87.0 b	7.43 b	158 b
N_3S_3	87.3 b	7.10 c	146 d
$LSD_{(0.05)}$	5.152	0.224	3.861
CV(%)	6.79	8.05	6.91

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

4.1.3 Siliqua per plant

Siliqua per plant of mustard showed a statistically significant variation for different nitrogen level under the present trial (Appendix I). The number of siliquae per plant enhanced with increasing the doses of N and the greatest significant number was obtained with N_2 (80 kg N/ha). Further increase in N level, failed to increase the number significantly (Table 3). Mondal and Gaffer (1983), Gaffer and Razzaque (1983) also reported the similar findings from their experiment. They reported that different levels of nitrogen significantly increased siliqua per plant of mustard ensuring proper growth of plant. Sharawat *et al*. (2002) recorded maximum number of siliquae/plant with 120 kg N/ha. These results indicated that higher dose of nitrogen favored higher number of siliqua formation in mustard.

Different level of sulphur showed statistically significant differences for siliqua per plant (Appendix I). The maximum number of siliqua per plant (127) was observed from S_3 treatment comprising of 24 kg S/ha which was statistically identical (126) with S_2 treatment as 16 kg S/ha (Table 4). On the other hand the minimum number of siliqua per plant (109) was recorded from the S_0 treatment.

Nitrogen and sulphur showed a significant interaction effect for number of siliqua per plant (Appendix I). The maximum number of siliqua per plant (165) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha).

4.1.4 Seed per siliqua

Effect of nitrogen showed a statistically significant variation for seed per siliqua of mustard (Appendix I). The number of seed per siliqua increased with increasing N levels and maximum significant increase was found with the treatment N_2 (80kg N/ha, Table 6) Application of 80 kg N/ha ensured the congenial condition for growth of mustard and also produced healthy silliqua and the ultimate result is the maximum number of siliqua. Mondal and Gaffer (1983), Gaffer and Razzaque (1983) also reported the similar results from their experiment. They 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).

Statistically significant variation was recorded for different level of sulphur used in this experiment for seed per siliqua (Appendix I). The number of seed per siliqua increased with increasing levels of S and the maximum number of seed per siliqua (21.2) was recorded from S_3 treatment as application of 24 kg S/ha which was statistically similar (20.7) with treatment S_2 as of 16 kg S/ha (Table 7). These results are in conformity with those of Islam and Sarker (1993), Dutta and Uddin (1983) who have observed increased number of siliquae/plant of mustard by increasing rate of sulphur.

A significant interaction effect was also recorded between nitrogen and sulphur in consideration of number of seed per siliqua under the present experiment (Appendix I). The maximum number of seed per siliqua (24.7) was recorded from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha.

Table 6. Main effect of nitrogen on yield contributing characters and yield of mustard

Nitrogen	Seed per siliqua (No.)	1000 seeds weight (g)	Seed yield (kg/ha)	Shoot yield (kg/ha)
N_0	17.7 c	2.28 d	908 d	757d
N_1	20.3 b	2.55 c	1098 c	1097c
N_2	21.5 a	2.73 b	1535 a	1552a
N_3	21.9 a	2.76 a	1431 b	1394b
$LSD_{(0.05)}$	0.966	0.026	18.01	21.2

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 7. Main effect of sulphur on yield contributing characters and yield of mustard

Sulphur	Seed per siliqua (No.)	1000 seeds weight (g)	Seed yield (kg/ha)	Shoot yield (kg/ha)
S_0	19.83 b	2.46 c	1078 d	1168d
S_1	19.8 b	2.53 b	1161 c	1201c
S_2	20.7 ab	2.67 a	1340 b	1369b
S_3	21.2 a	2.65 a	1394 a	1236a
$LSD_{(0.05)}$	0.966	0.026	18.01	21.2

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.1.5 1000 seed weight

Nitrogen showed statistically significant differences for 1000 seed weight of mustard under the present trial (Appendix I). The weight of 1000 seed increased with increasing levels of N upto N_3 (120 kg N/ha) (Table-6). The highest weight of 1000 of seeds (2.76 g) was recorded from N_3 treatment. Mondal and Gaffer (1983), Gaffer and Razzaque (1983), Sharawat *et al*. (2002), Mudhokar and Ahlawat (1981) also reported the similar results from their experiment.

Different level of sulphur exhibited statistically significant variation for 1000 seed weight (Appendix I). It increased significantly with higher levels of S with the highest (2.67 g) at S_2 treatment comprising of 16 kg S/ha which was statistically similar (2.65 g) with treatment S_3 comprising of 24 kg S/ha (Table 7).

Interaction effect of nitrogen and sulphur showed a significant variation for 1000 seed weight under the present experiment (Appendix I). The highest weight of 1000 seed (2.86 g) was recorded from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (1.60 g) was recorded from N_0S_0 where no nitrogen and sulphur were applied (Table 8).

Table 8. Interaction effect of nitrogen and sulphur on yield contributing characters and yield of mustard

Nitrogen × Sulphur	Seed per siliqua (No.)	1000 seeds weight (g)	Seed yield (kg/ha)	Shoot yield (kg/ha)
N_0S_0	16.0 g	2.10 i	850 i	918i
N_0S_1	16.7 fg	2.25 h	882 i	903i
N_0S_2	18.1 ef	2.35 g	946 h	931h
N_0S_3	20.1 de	2.42 f	954 h	975h
N_1S_0	20.7 cd	2.45 f	1038 g	1016g
N_1S_1	20.7 cd	2.47 f	962 h	981h
N_1S_2	20.0 de	2.65 d	1238 e	1226e
N_1S_3	20.0 de	2.63 de	1154 f	1165f
N_2S_0	20.0 de	2.58 e	1262 e	1280e
N_2S_1	18.3 ef	2.68 cd	1500 c	1516c
N_2S_2	23.0 ab	2.80 b	1640 b	1663b
N_2S_3	24.7 a	2.86 a	1738 a	1748a
N_3S_0	22.7 abc	2.71 c	1161 f	1460f
N_3S_1	23.3 ab	2.71 c	1300 d	1404d
N_3S_2	21.7 bcd	2.88 a	1534 c	1656c
N_3S_3	20.0 de	2.72 c	1728 a	1055a
$LSD_{(0.05)}$	1.932	0.053	36.03	39.02
CV(%)	5.69	7.48	5.74	8.5

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

4.1.6 Seed yield

Application of nitrogen at different level showed a statistically significant variation for seed yield per hectare of mustard under the present trial (Appendix I). With increasing the levels of nitrogen, the seed yield increased significantly upto 80 kg N/ha. However, the seed yield decreased significantly with the application of 120 kg N/ha (N_3) compared to 80 kg N/ha. The highest seed yield (1535 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely followed (1431 kg/ha) with N_3 and the lowest seed yield (908 kg) was recorded from N_0 treatment (control). These results are in conformity with that of Tomer *et al*. (1996), Mondal and Gaffer (1983), Singh and Rathi (1984), Narang and Singh (1985) who have observed increased seed yield of mustard by increasing rate of nitrogen.

Application of sulphur at different level showed statistically significant differences for seed yield per hectare (Appendix I). The application of S favored the seed yield of mustard upto the highest level (24 kg S/ha). The highest seed yield (1394 kg/ha) was recorded from S_3 treatment comprising of 24 kg S/ha (Table 7). On the other hand the lowest seed yield (1078 kg/ha) was recorded from the S_0 treatment (control). Banueles *et al*. (1990) recorded significant differences for different level of sulphur application.

Significant interaction effect was also recorded between nitrogen and sulphur for seed yield per hectare under the present experiment (Appendix I). The highest yield (1738 kg/ha) was recorded from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (850 kg/ha) was recorded from N_0S_0 where no nitrogen and sulphur was applied (Table 8).

4.1.7. Shoot yield

Application of nitrogen at different level showed a statistically significant variation for shoot yield per hectare of mustard under the present trial (Appendix I). With increasing the levels of nitrogen, the shoot yield increased significantly up to 80 kg N/ha. However, the shoot yield decreased significantly with the application of 120 kg N/ha (N_3) compared to 80 kg N/ha. The highest shoot yield (1552 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely followed (1394 kg/ha) with N_3 and the lowest shoot yield (757 kg) was recorded from N_0 treatment (control). These results are in conformity with that of Tomer *et al*. (1996), Mondal and Gaffer (1983), Singh and Rathi (1984), Narang and Singh (1985) who have observed increased shoot yield of mustard by increasing rate of nitrogen.

Application of sulphur at different level showed statistically significant differences for shoot yield per hectare (Appendix I). The application of S favored the shoot yield of mustard up to the highest level (24 kg S/ha). The highest shoot yield (1369 kg/ha) was recorded from S_3 treatment comprising of 24 kg S/ha (Table 7). On the other hand the lowest shoot yield (1168 kg/ha) was recorded from the S_0 treatment (control). Banueles *et al*. (1990) recorded significant differences for different level of sulphur application.

Significant interaction effect was also recorded between nitrogen and sulphur for shoot yield per hectare under the present experiment (Appendix I). The highest shoot yield (1748/ha) was recorded from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (918 kg/ha) was recorded from N_0S_0 where no nitrogen and sulphur was applied (Table 8).

4.2 Nutrient content in seed

Nutrient such as nitrogen, sulphur, phosphorus and potassium content in seed was estimated for different level of nitrogen and sulphur application and also their different combination.

4.2.1 Nitrogen (N)

The effect of nitrogen showed a statistically significant variation for nitrogen content in seed of mustard under the present trial (Appendix II). The highest nitrogen content in seed (3.57%) was recorded from N_3 treatment comprising of 120 kg N/ha which was statistically identical with N_2 (3.55%) and the lowest (2.85%) nitrogen content was recorded from N_0 treatment i.e. control (Table 9). Highest application of nitrogen accelerated nitrogen uptake by plant resulting he highest nitrogen content in seed. Mahajan *et al*. (1994) also recorded the similar results from their experiment.

Different level of sulphur showed statistically significant differences for nitrogen content in seed (Appendix II). The highest nitrogen content of seed (3.49%) was recorded from S_2 treatment comprising of 16 kg S/ha which was statistically identical with treatment S_3 comprising of 24 kg S/ha (Table 10). On the other hand the lowest nitrogen content in seed (3.10%) was recorded from the S_0 treatment.

Significant interaction effect was also recorded between nitrogen and sulphur for nitrogen content in seed under the present trial (Appendix II). The highest nitrogen content in seed (3.90%) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha) and the lowest (2.75%) was recorded from N_0S_0 (no nitrogen no sulphur) (Table 11).

Table 9. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium content by seed of mustard

Nitrogen	Content in seed (%)			
	N	S	P	K
N_0	2.85 c	1.01 c	0.49 c	0.797 b
N_1	3.28 b	1.15 a	0.51 bc	0.809 a
N_2	3.55 a	1.14 a	0.63 a	0.809 a
N_3	3.57 a	1.08 b	0.53 b	0.812 a
$LSD_{(0.05)}$	0.069	0.046	0.026	0.008

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 10. Effect of sulphur on nitrogen, sulphur, phosphorus and potassium content by seed of mustard

Sulphur	Content in seed (%)			
	N	S	P	K
S_0	3.10 c	0.90 d	0.51 c	0.806 ab
S_1	3.23 b	1.06 c	0.53 bc	0.801 b
S_2	3.49 a	1.19 b	0.55 ab	0.808 ab
S_3	3.42 a	1.24 a	0.57 a	0.811 a
$LSD_{(0.05)}$	0.069	0.046	0.026	0.008

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.2.2 Sulphur (S)

Nitrogen at different level showed a statistically significant variation for sulphur content in seed of mustard (Appendix II). The highest sulphur content in seed (1.15%) was recorded from N_1 treatment as 40 kg N/ha which was statistically identical (1.14%) with N_2 and the lowest (1.01%) sulphur content was recorded from N_0 treatment i.e. control condition (Table 9). The sulphur content was reduced significantly with the highest dose of N (120 kg N/ha). This may be due to proper utilization of S for the formation of protein leading to enhanced growth of plant.

Different level of sulphur showed statistically significant variation for sulphur content in mustard seed (Appendix II). The S content in seed increased with increasing S levels and the highest sulphur content of seed (1.24%) was recorded from S_3 treatment comprising of 24 kg S/ha (Table 10). On the other hand the lowest (0.90%) sulphur content in seed was recorded from the S_0 treatment.

Significant interaction effect was also observed between nitrogen and sulphur in terms of sulphur content in seed under the present trial (Appendix II). The highest sulphur content in mustard seed (1.50%) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha) and the lowest (0.78%) was recorded from N_0S_0 (no nitrogen no sulphur) (Table 11).

4.2.3 Phosphorus (P)

Application of nitrogen at different level showed a statistically significant variation for phosphorus content in seed of mustard under the present trial (Appendix II). The highest phosphorus content in seed (0.63%) was recorded from N_2 treatment comprising of 80 kg N/ha and the lowest phosphorus content (0.49%) was recorded from N_0 treatment i.e. control condition (Table 9). Mahajan *et al*. (1994) reported that sulphur increased phosphorus content in seed.

Table 11. Interaction effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium content by seed of mustard

Nitrogen × Sulphur	Content in seed (%)			
	N	S	P	K
N_0S_0	2.75 i	0.78 h	0.41 g	0.785 cd
N_0S_1	2.87 hi	0.98 g	0.43 g	0.772 d
N_0S_2	2.88 hi	1.09 ef	0.53 ef	0.810 ab
N_0S_3	2.90 hi	1.20 bcd	0.58 bcde	0.822 a
N_1S_0	2.95 gh	0.99 g	0.48 f	0.807 ab
N_1S_1	3.06 g	1.15 cde	0.49 f	0.807 ab
N_1S_2	3.50 de	1.20 bcd	0.50 f	0.806 ab
N_1S_3	3.60 cd	1.25 bc	0.57 cde	0.815 ab
N_2S_0	3.25 f	0.90 g	0.60 abcd	0.812 ab
N_2S_1	3.30 f	1.00 fg	0.65 a	0.808 ab
N_2S_2	3.75 b	1.18 bcde	0.62 abc	0.808 ab
N_2S_3	3.90 a	1.50 a	0.63 ab	0.808 ab
N_3S_0	3.45 e	0.92 g	0.56 de	0.820 a
N_3S_1	3.70 bc	1.10 de	0.54 ef	0.818 a
N_3S_2	3.82 ab	1.28 b	0.53 ef	0.810 ab
N_3S_3	3.30 f	1.00 fg	0.50 f	0.798 bc
$LSD_{(0.05)}$	0.140	0.091	0.053	0.017
CV(%)	7.55	5.05	6.58	5.51

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

Sulphur at different level showed statistically significant variation for phosphorus content in mustard seed (Appendix II). The highest phosphorus content of seed

(0.57%) was recorded from S_3 treatment comprising of 24 kg S/ha which was statistically identical (0.55%) with treatment S_2 comprising of 16 kg S/ha (Table 10). On the other hand the lowest phosphorus content in seed (0.51%) was recorded from the S_0 treatment which was statistically similar (0.53%) with S_1 treatment.

Interaction effect was also significant between nitrogen and sulphur for phosphorus content in seed under the present trial (Appendix II). The highest phosphorus content in mustard seed (0.65%) was recorded from the treatment combination N_2S_1 as 80 kg N/ha + 8 kg S/ha and the lowest phosphorus content in seed (0.41%) was recorded from N_0S_0 i.e. no nitrogen no sulphur (Table 11).

4.2.4 Potassium (K)

Effect of nitrogen showed a statistically significant variation for potassium content in seed of mustard under the present trial (Appendix II). The K content in seed increased significantly with increasing N levels upto 40 kg N/ha. Further increase in N levels had no significant effect on K content. The highest potassium content in seed (0.812%) was recorded from N_3 treatment comprising of 120 kg N/ha which was statistically identical (0.809%) with N_1 and N_2 and the lowest potassium content (0.797%) was recorded from N_0 treatment i.e. control condition (Table 9).

Different level of sulphur showed statistically significant variation for potassium content in mustard seed (Appendix II). The highest potassium content of seed (0.811%)was recorded from S_3 treatment comprising of 24 kg S/ha which was statistically identical (0.808%) with treatment S_2 comprising of 16 kg S/ha (Table 10). On the other hand the lowest potassium content in seed (0.801%) was recorded from the S_1 treatment which statistically similar (0.806%) with S_0.

Under the present trial nitrogen and sulphur for potassium content in seed showed a significant interaction effect (Appendix II). The highest potassium content in mustard seed (0.820%) was recorded from the treatment combination N_3S_0 as 120 kg N/ha + 0 kg S/ha and the lowest potassium content in seed (0.772%) was recorded from N_0S_1 treatment (Table 11).

4.3 Nutrients uptake by seed

Nutrient such as nitrogen, sulphur, phosphorus and potassium uptake by mustard seed was estimated for different level of nitrogen and sulphur application and also their different combination in the present experiment.

4.3.1 Nitrogen (N)

Effect of nitrogen showed a statistically significant difference for nitrogen uptake by seed of mustard (Appendix II). The maximum nitrogen uptake by seed (55.0 kg/ha) was recorded from N_2 treatment (80 kg N/ha) which was significantly higher than that obtained from N_3 treatment (51.63) and the minimum nitrogen uptake by seed (26.3 kg/ha) was recorded from N_0 treatment (Table 12).

Different level of sulphur performed significant variation for nitrogen uptake in mustard seed (Appendix II). The maximum nitrogen uptake by seed (48.9 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was significantly greater than that obtained with the treatment S_3 comprising of 24 kg S/ha (43.3) (Table 13). On the other hand the minimum nitrogen uptake by seed (37.0 kg/ha) was recorded from the S_0 treatment. Mahajan *et al*. (1994) reported that sulphur increased nitrogen uptake in mustard seed.

A significant interaction effect was observed between nitrogen and sulphur for nitrogen uptake by seed (Appendix II). The maximum nitrogen uptake by mustard seed (68.2 kg/ha) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha) and the minimum nitrogen uptake by seed (24.4 kg/ha) was recorded from N_0S_0 (Table 14).

Table 12. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium uptake by seed of mustard

Nitrogen	Uptake by seed (kg/ha)			
	N	S	P	K
N_0	26.3 d	9.67 d	4.58 d	7.26 d
N_1	36.2 c	12.9 c	5.60 c	8.95 c
N_2	55.0 a	18.5 a	9.79 a	12.7 a
N_3	51.6 b	15.8 b	7.74 b	11.5 b
$LSD_{(0.05)}$	1.438	0.554	0.312	0.348

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 13. Effect of sulphur on nitrogen, sulphur, phosphorus and potassium uptake by seed of mustard

Sulphur	Uptake by seed (kg/ha)			
	N	S	P	K
S_0	37.0 d	10.7 d	6.04 d	9.39 c
S_1	40.0 c	13.2 c	6.64 c	9.92 b
S_2	48.9 a	16.8 a	7.74 a	11.2 a
S_3	43.3 b	16.1 b	7.30 b	9.93 b
$LSD_{(0.05)}$	1.438	0.554	0.312	0.348

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.3.2 Sulphur (S)

Application of nitrogen showed a statistically significant variation for sulphur uptake by seed of mustard under the present trial (Appendix II). The application of N increased S uptake by seed upto 80 kg N/ha. Further increase in N level had a negative effect on S uptake by seed. The maximum sulphur uptake by seed (18.5 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely followed by N_3 (15.8 kg/ha) and the minimum sulphur uptake by seed (9.67 kg/ha) was recorded from N_0 treatment (Table 12).

Application of S also resulted in a statistically significant variation for sulphur uptake in mustard seed (Appendix II). The maximum sulphur uptake by seed (16.8 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was closely (16.1 kg/ha) followed by treatment S_3 comprising of 24 kg S/ha (Table 13). On the other hand the minimum sulphur uptake by seed (10.7 kg/ha) was recorded from the S_0 treatment.

Interaction between N and S for the uptake of S by seed was significant under the present trial (Appendix II). The maximum sulphur uptake by mustard seed (27.0 kg/ha) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha) and the minimum sulphur uptake by seed (7.13 kg/ha) was recorded from N_0S_0 treatment (Table 14).

4.3.3 Phosphorus (P)

Effect of nitrogen showed a statistically significant variation for phosphorus uptake by seed of mustard under the present trial (Appendix II). The greatest significant P-uptake by seed was obtained with N_2 (80 kg N/ha) and there was a significant decline in P- uptake by seed with the next higher dose of N (120 kg N/ha). The maximum phosphorus uptake by seed (9.79 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha and the minimum phosphorus uptake by seed (4.58 kg/ha) was recorded from N_0 treatment (Table 12).

Table 14. Interaction effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium uptake by seed of mustard

Nitrogen × Sulphur	Uptake by seed (kg/ha)			
	N	S	P	K
N_0S_0	24.4 j	7.13 i	3.41 j	6.79 j
N_0S_1	25.6 ij	9.13 h	3.68 j	6.83 j
N_0S_2	27.4 ij	10.9 g	5.30 gh	7.80 hi
N_0S_3	27.7 i	11.6 g	5.93 fg	7.61 i
N_1S_0	31.3 h	10.7 g	5.03 hi	8.60 g
N_1S_1	28.1 i	11.5 g	4.60 i	7.75 hi
N_1S_2	43.2 f	14.6 ef	6.30 f	9.98 ef
N_1S_3	42.1 f	15.0 e	6.46 f	9.47 f
N_2S_0	41.2 f	11.5 g	7.60 e	10.5 e
N_2S_1	45.0 e	15.4 e	9.58 c	12.4 c
N_2S_2	60.8 c	20.1 c	10.7 b	13.5 b
N_2S_3	68.2 a	27.0 a	11.3 a	14.2 a
N_3S_0	50.8 e	13.7 f	8.13 de	11.6 d
N_3S_1	56.4 d	17.0 d	8.67 d	12.7 c
N_3S_2	64.1 b	21.7 b	8.66 d	13.4 b
N_3S_3	35.2 g	10.9 g	5.48 gh	8.42 gh
$LSD_{(0.05)}$	2.877	1.107	0.624	0.696
CV(%)	4.08	4.67	5.39	4.12

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

Different levels of sulphur showed statistically significant differences for phosphorus uptake in mustard seed (Appendix II). The uptake by P by seed increased significantly with increasing S levels upto 16 kg S/ha. The maximum

phosphorus uptake by seed (7.74 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was statistically identical (7.30 kg/ha) with treatment S_3 comprising of 24 kg S/ha (Table 13). On the other hand the minimum phosphorus uptake by seed (6.04 kg/ha) was recorded from the S_0 treatment which was closely (6.64 kg/ha) followed by S_1 treatment under the present trial.

Significant interaction effect was also recorded between nitrogen and sulphur in for phosphorus uptake by seed under the present trial (Appendix II). The maximum (11.3 kg/ha) phosphorus uptake by mustard seed was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum (3.41 kg/ha) phosphorus uptake by seed was recorded from N_0S_0 treatment (Table 14).

4.3.4 Potassium (K)

Effect of nitrogen showed a statistically significant variation for potassium uptake by seed of mustard under the present trial (Appendix II). With increasing N levels, K-uptake by seed enhanced significantly upto the dose 80 kg N/ha. The maximum potassium uptake by seed (12.7 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely by N_3 (11.5 kg/ha) and the minimum potassium uptake by seed (7.26 kg/ha) was recorded from N_0 treatment (Table 12).

Different level of sulphur showed statistically significant differences for potassium uptake in mustard seed (Appendix II). The maximum significant K uptake by seed was obtained with the treatment S_2 (16 kg S/ha). The maximum potassium uptake by seed (11.2 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha (Table 11). On the other hand the minimum potassium uptake by seed (9.39 kg/ha) was recorded from the S_0 treatment.

Interaction effect of nitrogen and sulphur for potassium uptake by seed showed a significant difference under the present trial (Appendix II). The maximum potassium uptake by mustard seed (14.2 kg/ha) was recorded from the treatment

combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum potassium uptake by seed (6.79 kg/ha) was recorded from N_0S_0 treatment (Table 14).

4.4 Nutrient content in shoot

Nitrogen, sulphur, phosphorus and potassium content in shoot was estimated for different level of nitrogen and sulphur application and also their different combination.

4.4.1 Nitrogen (N)

Application of nitrogen showed a statistically significant difference for nitrogen content in shoot of mustard under the present trial (Appendix III). The highest nitrogen content in shoot (2.14%) was recorded from N_3 treatment comprising of 120 kg N/ha which was closely followed (1.75%) by N_2 and the lowest nitrogen content (1.15%) was recorded from N_0 treatment i.e. control condition which was closely (1.57%) followed by N_1 (Table 15). The highest application of nitrogen accelerated nitrogen uptake by plant and finally produced the highest amount of nitrogen content in shoot.

Different level of sulphur showed statistically significant differences for nitrogen content in shoot (Appendix III). The highest nitrogen content of shoot (1.84%) was recorded from S_2 treatment comprising of 16 kg S/ha which was statistically identical (1.83%) with treatment S_3 comprising of 24 kg S/ha (Table 16). On the other hand the lowest nitrogen content in shoot (1.44%) was recorded from the S_0 treatment which was statistically similar (1.51%) with S_1 treatment under the present trial.

Interaction effect of nitrogen and sulphur for nitrogen content in shoot also varied significantly under the present trial (Appendix III). The highest nitrogen content in shoot (2.35%) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the lowest was recorded from N_0S_0 (1.10%) (Table 17).

Table 15. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium content by shoot of mustard

Nitrogen	Content in shoot (%)			
	N	S	P	K
N_0	1.15 d	0.28 c	0.085 c	2.90 b
N_1	1.57 c	0.36 b	0.080 c	2.96 ab
N_2	1.75 b	0.46 a	0.117 b	3.11 a
N_3	2.14 a	0.45 a	0.136 a	3.08 a
$LSD_{(0.05)}$	0.0791	0.0264	0.0083	0.169

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 16. Effect of sulphur on nitrogen, sulphur, phosphorus and potassium content by shoot of mustard

Sulphur	Content in shoot (%)			
	N	S	P	K
S_0	1.44 b	0.25 d	0.092 b	2.87 b
S_1	1.51 b	0.32 c	0.099 b	2.96 b
S_2	1.84 a	0.46 b	0.094 b	3.05 ab
S_3	1.83 a	0.52 a	0.134 a	3.17 a
$LSD_{(0.05)}$	0.0791	0.0264	0.0083	0.169

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.4.2 Sulphur (S)

Effect of nitrogen showed a statistically significant difference for sulphur content in shoot of mustard under the present trial (Appendix III). The highest sulphur content in shoot (0.46%) was recorded from N_2 treatment comprising of 80 kg N/ha which was statistically identical (0.45%) with N_3 treatment and the lowest sulphur content (0.28%) was recorded from N_0 treatment i.e. control condition which was closely (0.36%) followed by N_1 (Table 15).

Application of different levels of sulphur in soil showed statistically significant differences for sulphur content in mustard shoot (Appendix III). The highest sulphur content of shoot (0.52%) was recorded from S_3 treatment comprising of 24 kg S/ha which was closely (0.46%) followed by treatment S_2 comprising of 16 kg S/ha (Table 16). On the other hand the lowest sulphur content in shoot (0.25%) was recorded from the S_0 treatment which closely (0.32%) followed with S_1 treatment under the present trial.

Significant interaction effect was also recorded between nitrogen and sulphur for sulphur content in shoot under the present trial (Appendix III). The highest sulphur content in mustard shoot (0.65%) was recorded from the treatment combination N_2S_2 as 80 kg N/ha + 16 kg S/ha and the lowest (0.15%) was recorded from N_0S_0 i.e. no nitrogen no sulphur (Table 17).

4.4.3 Phosphorus (P)

Effect of nitrogen showed a statistically significant variation for phosphorus content in shoot of mustard under the present trial (Appendix III). The highest phosphorus content in shoot (0.136%) was recorded from N_3 treatment comprising of 120 kg N/ha which was closely followed (0.117%) by N_2 and the lowest phosphorus content (0.080%) was recorded from N_1 treatment which was statistically identical (0.085%) with N_0 treatment (Table 15).

Table 17. Interaction effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium content by shoot of mustard

Nitrogen × Sulphur	Content in shoot (%)			
	N	S	P	K
N_0S_0	1.10 f	0.15 h	0.076 g	2.82 d
N_0S_1	1.14 f	0.25 fg	0.086 fg	2.90 cd
N_0S_2	1.16 f	0.35 de	0.088 fg	2.92 bcd
N_0S_3	1.20 f	0.38 d	0.090 efg	2.95 bcd
N_1S_0	1.25 f	0.20 gh	0.081 fg	2.87 cd
N_1S_1	1.60 e	0.30 ef	0.082 fg	2.86 cd
N_1S_2	1.68 e	0.35 de	0.076 g	2.88 cd
N_1S_3	1.75 e	0.60 a	0.080 g	3.25 abc
N_2S_0	1.25 f	0.28 f	0.078 g	2.85 cd
N_2S_1	1.20 f	0.30 ef	0.107 cde	2.90 cd
N_2S_2	2.20 abc	0.65 a	0.100 def	3.50 a
N_2S_3	2.35 a	0.60 a	0.182 a	3.20 abcd
N_3S_0	2.15 bcd	0.35 de	0.132 b	2.95 bcd
N_3S_1	2.10 cd	0.45 c	0.119 bc	3.20 abcd
N_3S_2	2.30 ab	0.48 bc	0.110 cd	2.89 cd
N_3S_3	2.00 d	0.52 b	0.184 a	3.30 ab
$LSD_{(0.05)}$	0.158	0.0527	0.0167	0.338
CV(%)	5.84	8.40	5.17	6.68

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

Different level of sulphur showed statistically significant differences for phosphorus content in mustard shoot (Appendix III). The highest phosphorus content of shoot (0.134%) was recorded from S_3 treatment comprising of 24 kg S/ha which was closely followed (0.099%) with treatment S_1 comprising of 8 kg S/ha (Table 14). On the other hand the lowest phosphorus content in shoot (0.092%) was recorded from the S_0 treatment which statistically similar (0.0.94%) with S_2 treatment under the present trial.

Significant interaction effect was also recorded between nitrogen and sulphur for phosphorus content in shoot under the present trial (Appendix III). The highest phosphorus content in mustard shoot (0.182%) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the lowest phosphorus content in shoot (0.076%) was recorded from N_0S_0 i.e. no nitrogen no sulphur (Table 17).

4.4.4 Potassium (K)

Application of different level of nitrogen had a statistically significant variation for potassium content in shoot of mustard under the present trial (Appendix III). The highest potassium content in shoot (3.11%) was recorded from N_3 treatment comprising of 120 kg N/ha which was statistically identical (3.08%) with N_3, while the lowest potassium content (2.90%) was recorded from N_0 treatment i.e. control condition (Table 15).

Different levels of sulphur showed statistically significant differences for potassium content in mustard shoot (Appendix III). The highest potassium content of shoot (3.17%) was recorded from S_3 treatment comprising of 24 kg S/ha (Table 16). On the other hand the lowest potassium content in shoot (2.87%) was recorded from the S_0 treatment

Interaction effect was also significant between nitrogen and sulphur for potassium content in shoot under the present trial (Appendix III). The highest potassium content in mustard shoot (3.50%) was recorded from the treatment combination N_2S_2 as 80 kg N/ha + 16 kg S/ha and the lowest potassium content in shoot (2.82%) was recorded from N_0S_0 treatment (Table 17).

4.5 Nutrients uptake by shoot

Nutrient such as nitrogen, sulphur, phosphorus and potassium uptake by shoot of mustard plant was estimated for different level of nitrogen and sulphur application and also their different combination in the present experiment.

4.5.1 Nitrogen (N)

Different level of nitrogen showed a statistically significant variation for nitrogen uptake by shoot of mustard under the present trial (Appendix III). The maximum nitrogen uptake by shoot (30.7 kg/ha) was recorded from N_3 treatment comprising of 120 kg N/ha which was closely followed (28.0 kg/ha) by N_2 and the minimum nitrogen uptake by shoot (10.7 kg/ha) was recorded from N_0 treatment which was closely (17.3 kg/ha) followed by N_1 treatment (Table 18).

Sulphur at different level showed statistically significant variation for nitrogen uptake in mustard shoot (Appendix III). The maximum nitrogen uptake by shoot (26.5 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was closely followed (23.6 kg/ha) by treatment S_3 comprising of 24 kg S/ha (Table 19). On the other hand the minimum nitrogen uptake by shoot (17.5 kg/ha) was recorded from the S_0 treatment which was closely (19.1 kg/ha) followed by S_1 treatment under the present trial.

Nitrogen and sulphur at different level showed a significant interaction effect for nitrogen uptake by shoot under the present trial (Appendix III). The maximum nitrogen uptake by mustard shoot (41.1 kg/ha) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum nitrogen uptake by shoot (10.1 kg/ha) was recorded from N_0S_0 treatment (Table 20).

Table 18. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium uptake by shoot of mustard

Nitrogen	Uptake by shoot (kg/ha)			
	N	S	P	K
N_0	10.7 d	2.65 d	0.795 d	26.3 d
N_1	17.3 c	4.16 c	0.857 c	32.6 c
N_2	28.0 b	7.75 a	1.81 b	48.4 a
N_3	30.7 a	6.29 b	1.90 a	45.1 b
$LSD_{(0.05)}$	0.764	0.594	0.0457	1.144

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 19. Effect of sulphur on nitrogen, sulphur, phosphorus and potassium uptake by shoot of mustard

Sulphur	Uptake by shoot (kg/ha)			
	N	S	P	K
S_0	17.5 d	3.16 c	1.06 c	33.4 d
S_1	19.1 c	4.54 b	1.26 b	36.6 c
S_2	26.5 a	6.47 a	1.31 b	43.3 a
S_3	23.6 b	6.68 a	1.73 a	39.0 b
$LSD_{(0.05)}$				

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.5.2 Sulphur (S)

Effect of nitrogen showed a statistically significant variation for sulphur uptake by shoot of mustard under the present trial (Appendix III). The maximum sulphur uptake by shoot (7.75 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha and the minimum sulphur uptake by shoot (2.65 kg/ha) was recorded from N_0 treatment (Table 18).

Application of sulphur showed statistically significant differences for sulphur uptake in mustard shoot (Appendix III). The maximum sulphur uptake by shoot (6.68 kg/ha) was recorded from S_3 treatment comprising of 24 kg S/ha which was closely (6.47 kg/ha) followed by treatment S_2 comprising of 16 kg S/ha (Table 19). On the other hand the minimum sulphur uptake by shoot (3.16 kg/ha) was recorded from the S_0 treatment which was closely (4.54 kg/ha) followed by S_1 treatment under the present trial.

Significant interaction effect was also recorded between nitrogen and sulphur for sulphur uptake by shoot under the present trial (Appendix III). The maximum sulphur uptake by mustard shoot (10.6 kg/ha) was recorded from the treatment combination N_2S_2 as 80 kg N/ha + 16 kg S/ha and the minimum sulphur uptake by shoot (1.30 kg/ha) was recorded from N_0S_0 treatment (Table 20).

4.5.3 Phosphorus (P)

Effect of nitrogen showed a statistically significant variation for phosphorus uptake by shoot of mustard under the present trial (Appendix III). The maximum phosphorus uptake by shoot (1.90 kg/ha) was recorded from N_3 treatment comprising of 120 kg N/ha and the minimum phosphorus uptake by shoot (0.795 kg/ha) was recorded from N_0 treatment (Table 18).

Sulphur at different level showed statistically significant variation for phosphorus uptake in mustard shoot (Appendix III). The maximum phosphorus uptake by shoot (1.73 kg/ha) was recorded from S_3 treatment comprising of 24 kg S/ha (Table 19). On the other hand the minimum phosphorus uptake by shoot (1.06 kg/ha) was recorded from the S_0 treatment.

Interaction effect was also significant between nitrogen and sulphur in for phosphorus uptake by shoot under the present trial (Appendix III). The maximum phosphorus uptake by mustard shoot (3.14 kg/ha) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum phosphorus uptake by shoot (0.651 kg/ha) was recorded from N_0S_0 treatment (Table 20).

4.5.4 Potassium (K)

Nitrogen at different level showed a statistically significant variation for potassium uptake by shoot of mustard under the present trial (Appendix III). The maximum potassium uptake by shoot (48.3 kg/ha) as recorded from N_2 treatment as 80 kg N/ha and the minimum potassium uptake by shoot (26.3 kg/ha) was recorded from N_0 treatment (Table 18).

Different level of sulphur showed statistically significant differences for potassium uptake in mustard shoot (Appendix III). The maximum potassium uptake by shoot (43.3 kg/ha)was recorded from S_2 treatment comprising of 16 kg S/ha (Table 19). On the other hand the minimum potassium uptake by shoot (33.4 kg/ha) was recorded from the S_0 treatment.

Significant interaction effect was also recorded between nitrogen and sulphur for potassium uptake by shoot under the present trial (Appendix III). The maximum potassium uptake by mustard shoot (57.5 kg/ha) was recorded from the treatment combination N_2S_2 as 80 kg N/ha + 16 kg S/ha and the minimum potassium uptake by shoot (24.0 kg/ha) was recorded from N_0S_0 treatment (Table 20).

Table 20. Interaction effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium uptake by shoot of mustard

Nitrogen × Sulphur	Uptake by shoot (kg/ha)			
	N	S	P	K
N_0S_0	10.1 i	1.30 j	0.651 h	24.0 j
N_0S_1	10.3 i	2.27 ij	0.770 g	25.7 ij
N_0S_2	10.8 i	3.39 ghi	0.803 fg	27.1 hi
N_0S_3	11.7 hi	3.64 gh	0.955 d	28.4 gh
N_1S_0	12.7 h	2.19 ij	0.824 efg	30.2 g
N_1S_1	15.7 g	3.00 hi	0.790 g	27.1 hi
N_1S_2	20.6 e	4.34 fg	0.914 de	35.8 ef
N_1S_3	20.4 e	7.11 bc	0.902 def	37.5 e
N_2S_0	16.0 g	3.75 gh	0.843 efg	36.2 ef
N_2S_1	18.2 f	6.21 cde	1.61 c	43.8 d
N_2S_2	36.6 c	10.6 a	1.64 c	57.5 a
N_2S_3	41.1 a	10.5 a	3.14 a	55.6 a
N_3S_0	31.4 d	5.38 ef	1.91 b	43.2 d
N_3S_1	32.3 d	6.69 bcd	1.89 b	49.8 c
N_3S_2	38.1 b	7.58 b	1.87 b	52.8 b
N_3S_3	21.1 e	5.51 def	1.92 b	34.5 f
$LSD_{(0.05)}$	1.527	1.187	0.091	2.289
CV(%)	4.22	13.66	4.35	3.61

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

4.6 Nutrients uptake by plant

Nutrient such as nitrogen, sulphur, phosphorus and potassium total by mustard plant including seed and shoot was estimated for different level of nitrogen and sulphur application and also their different combination in the present experiment.

4.6.1 Nitrogen (N)

Application of nitrogen at different level showed a statistically significant difference for nitrogen uptake by plant of mustard under the present trial (Appendix IV). The maximum nitrogen uptake by plant (83.0 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha and the minimum nitrogen uptake by plant (37.0 kg/ha) was recorded from N_0 treatment (Table 21). Asaduzzaman and Shamsuddin (1986) also reported the similar results from their experiment.

Different level of sulphur showed statistically significant differences for nitrogen uptake in mustard plant (Appendix IV). The maximum nitrogen uptake by plant (75.4 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was closely followed (66.9 kg/ha) by the treatment S_3 comprising of 24 kg S/ha (Table 22). On the other hand the minimum nitrogen uptake by plant (54.5 kg/ha) was recorded from the S_0 treatment which was closely (59.1 kg/ha) followed by S_1 treatment under the present trial.

Nitrogen and sulphur in showed significant interaction effect for nitrogen uptake by plant (Appendix IV). The maximum nitrogen uptake by mustard plant (109 kg/ha) was recorded from the treatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha) and the minimum nitrogen uptake by plant (34.6 kg/ha) was recorded from N_0S_0 treatment (Table 23).

4.6.2 Sulphur (S)

Effect of nitrogen showed a statistically significant variation for sulphur uptake by plant under the present trial (Appendix IV). The maximum sulphur uptake by plant (26.2 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha and the minimum sulphur uptake by plant (12.3 kg/ha) was recorded from N_0 treatment (Table 21). Gaffer and Razzaque (1983), Asaduzzaman and Shamsuddin (1986) also reported the similar results from their experiments.

Different level of sulphur showed statistically significant differences for sulphur uptake in mustard plant (Appendix IV). The maximum sulphur uptake by plant (23.3 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha (Table 22). On the other hand the minimum sulphur uptake by plant (13.9 kg/ha) was recorded from the S_0 treatment.

A statistically significant interaction effect was also recorded between nitrogen and sulphur for sulphur uptake by plant (Appendix IV). The maximum sulphur uptake by mustard plant (37.4 kg/ha) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum sulphur uptake by plant (8.43 kg/ha) was recorded from N_0S_0 treatment (Table 23).

Table 21. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium total uptake by plant

Nitrogen	Total uptake by plant (kg/ha)			
	N	S	P	K
N_0	37.0 b	12.3 d	5.38 d	33.5 d
N_1	53.5 b	17.1 c	6.45 c	41.6 c
N_2	83.0 a	26.2 a	11.6 a	61.0 a
N_3	82.3 a	22.1 b	9.63 b	56.6 b
$LSD_{(0.05)}$	4.513	2.451	1.024	3.105

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 22. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium total uptake by plant

Sulphur	Total uptake by plant (kg/ha)			
	N	S	P	K
S_0	54.5 d	13.9 d	7.10 b	42.8 d
S_1	59.1 c	17.8 c	7.90 b	46.5 c
S_2	75.4 a	23.3 a	9.04 a	54.5 a
S_3	66.9 b	22.8 b	9.03 a	48.9 b
$LSD_{(0.05)}$	4.513	2.451	1.024	3.105

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha

4.6.3 Phosphorus (P)

Effect of nitrogen showed a statistically significant variation for phosphorus uptake by plant of mustard under the present trial (Appendix IV). The maximum phosphorus uptake by plant (11.6 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely (9.63 kg/ha) followed by N_2 and the minimum phosphorus uptake by plant (5.38 kg/ha) was recorded from N_0 treatment which was closely (6.45 kg/ha) followed by N_1 treatment (Table 21).

Application of different level of sulphur showed statistically significant variation for phosphorus uptake in mustard plant (Appendix IV). The maximum phosphorus uptake by plant (9.04 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha which was statistically similar (9.03 kg/ha) with treatment S_3 comprising of 24 kg S/ha (Table 22). On the other hand the minimum phosphorus uptake by plant (7.10 kg/ha) was recorded from the S_0 treatment.

Interaction effect was also significant between nitrogen and sulphur in for phosphorus uptake by plant under the present trial (Appendix IV). The maximum phosphorus uptake by mustard plant (14.5 kg/ha) was recorded from the treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha and the minimum phosphorus uptake by plant (4.06 kg/ha) was recorded from N_0S_0 treatment (Table 23).

Table 23. Effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium total uptake by plant

Nitrogen × Sulphur	Total uptake by plant (kg/ha)			
	N	S	P	K
N_0S_0	34.6 k	8.43 i	4.06 i	30.8 i
N_0S_1	35.9 ik	11.4 h	4.45 i	32.5 i
N_0S_2	38.3 i	14.3 gh	6.11 gh	34.9 h
N_0S_3	39.4 i	15.2 gh	6.88 gh	36.0 h
N_1S_0	44.1 i	12.9 h	5.85 h	38.8 h
N_1S_1	43.8 i	14.5 g	5.39 h	34.9 h
N_1S_2	63.8 g	18.9 ef	7.22 fg	45.8 fg
N_1S_3	62.5 g	22.1 cd	7.36 fg	46.9 ef
N_2S_0	57.2 h	15.2	8.44 ef	46.7 ef
N_2S_1	68.2 f	21.6 de	11.2 c	56.3 d
N_2S_2	97.3 c	30.7 b	12.3 b	71.0 a
N_2S_3	109 a	37.4 a	14.5 a	69.8 a
N_3S_0	82.2 e	19.1 ef	10.0 d	54.8 d
N_3S_1	88.7 d	23.7 cd	10.6 d	62.5 c
N_3S_2	102 b	29.2 b	10.5 d	66.2 b
N_3S_3	56.3	16.4 f	7.40	42.9 gh
$LSD_{(0.05)}$	4.983	2.789	1.695	3.156
CV(%)	8.45	7.69	9.31	3.98

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_0: 0 kg S/ha
S_0: 8 kg S/ha
S_2: 16 kg S/ha
S_3: 24 kg S/ha

4.6.4 Potassium (K)

Effect of nitrogen showed a statistically significant variation for potassium uptake under the present trial (Appendix IV). The maximum potassium uptake by plant (61.0 kg/ha) was recorded from N_2 treatment comprising of 80 kg N/ha which was closely (56.6 kg/ha) followed by N_3 and the minimum potassium uptake by plant (33.5 kg/ha) was recorded from N_0 treatment (Table 21).

Different levels of sulphur showed significant differences for potassium uptake in mustard plant (Appendix IV). The maximum potassium uptake by plant (54.5 kg/ha) was recorded from S_2 treatment comprising of 16 kg S/ha (Table 22). On the other hand the minimum potassium uptake by plant (42.8 kg/ha) was recorded from the S_0 treatment.

Significant interaction effect was also recorded between nitrogen and sulphur for potassium uptake by plant under the present trial (Appendix IV). The maximum potassium uptake by mustard plant (71.0 kg/ha) was recorded from the treatment combination N_2S_2 as 80 kg N/ha + 16 kg S/ha and the minimum potassium uptake by plant (30.8 kg/ha) was recorded from N_0S_0 treatment (Table 23).

Table 24. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium available in soil

Nitrogen	Available in soil			
	Total N (%)	Available S (µg/g soil)	Available P (µg/g soil)	Available K (me/100 g soil)
N_0	0.090 a	34.0 a	83.9 a	0.35 a
N_1	0.079 b	29.0 b	78.6 b	0.27 b
N_2	0.075 b	22.3 d	71.5 c	0.19 c
N_3	0.071 a	26.2 c	80.4 b	0.27 b
$LSD_{(0.05)}$	0.008	1.353	2.261	0.0264

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

N_0: 0 kg N/ha N_1: 40 kg N/ha
N_2: 80 kg N/ha N_3: 120 kg N/ha

Table 25. Effect of nitrogen on nitrogen, sulphur, phosphorus and potassium available in soil

Sulphur	Available in soil			
	Total N (%)	Available S (µg/g soil)	Available P (µg/g soil)	Available K (me/100 g soil)
S_0	0.080	26.8 b	80.4 a	0.29 a
S_1	0.080	27.4 b	78.6 ab	0.27 ab
S_2	0.080	28.0 ab	76.7 b	0.25 b
S_3	0.075	29.1 a	78.6 ab	0.26 b
$LSD_{(0.05)}$	NS	1.353	2.261	0.0264

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

S_0: 0 kg S/ha S_0: 8 kg S/ha
S_2: 16 kg S/ha S_3: 24 kg S/ha
NS: Non Significant

4.7 Nutrients available in soil

Available nutrients such as nitrogen, sulphur, phosphorus and potassium in soil were estimated for different level of nitrogen and sulphur treatments and their different combinations in the present experiment.

4.7.1 Nitrogen (N)

Different level of nitrogen showed a significant variation for total nitrogen in soil under the present trial (Appendix IV). The maximum total nitrogen (0.090%) was recorded from N_0 treatment comprising of 0 kg N/ha and the minimum total nitrogen (0.075%) in soil was recorded from N_2 treatment (Table 24). Ali *et al*. (1990), Mondal and Gaffer (1983), Gaffer and Razzaque (1983), Asaduzzaman and Shamsuddin (1986) also reported the similar results from their experiment.

Application of different level of sulphur showed no statistically significant differences for total nitrogen in soil (Appendix IV). The maximum total nitrogen (0.80%) in soil was recorded from S_0, S_1 and S_2 treatment, while the minimum total nitrogen (0.075%) in soil was recorded from the S_3 treatment under the present trial.

Significant interaction effect was also observed between nitrogen and sulphur for total nitrogen in soil under the present trial (Appendix IV). The maximum total nitrogen (0.095%) in soil was recorded from the treatment combination N_0S_0 and the minimum total soil nitrogen (0.068%) was recorded from N_3S_3 treatment (Table 26).

4.7.2 Sulphur (S)

Effect of nitrogen showed a statistically significant variation for available sulphur in soil (Appendix IV). The maximum available sulphur (34.0 μg/g soil) in soil was recorded from N_0 treatment and the minimum available sulphur (22.3 μg/g soil) was recorded from N_0 treatment (Table 24). Ali *et al*. (1990), Mondal and Gaffer (1983), Gaffer and Razzaque (1983) also reported the similar results from their experiments.

Sulphur at different level showed statistically significant variation for available sulphur in soil (Appendix IV). The maximum available sulphur (29.1 μg/g soil) in soil was recorded from S_3 treatment comprising of 24 kg S/ha (Table 25). On the other hand the minimum available sulphur (26.8 μg/g soil) in soil was recorded from the S_0 treatment.

A statistically significant interaction effect was also observed between nitrogen and sulphur for available sulphur in soil under the present trial (Appendix IV). The maximum available sulphur (36.4 μg/g soil) in soil was recorded from the treatment combination N_0S_3 as 0 kg N/ha + 24 kg S/ha and the minimum available sulphur (19.8 μg/g soil) in soil was recorded from N_3S_0 treatment (Table 26).

4.7.3 Phosphorus (P)

Application of nitrogen at different level showed a statistically significant variation for available phosphorus in soil under the present trial (Appendix IV). The maximum available phosphorus (83.9 μg/g soil) in soil was recorded from N_0 treatment comprising of 0 kg N/ha and the minimum available phosphorus (71.49 μg/g soil) in soil was recorded from N_2 treatment (Table 24). Ali *et al*. (1990), Gaffer and Razzaque (1983) also reported the similar results from their experiment.

Different level of sulphur showed significant variation for available phosphorus in soil (Appendix IV). The maximum phosphorus (80.41 µg/g soil) in soil was recorded from S_0 treatment comprising of 0 kg S/ha (Table 25). On the other hand the minimum available phosphorus (76.7 µg/g soil) in soil was recorded from the S_2 treatment.

Table 26. Effect of nitrogen and sulphur on nitrogen, sulphur, phosphorus and potassium available in soil

Nitrogen × Sulphur	Available in soil			
	Total N (%)	Available S (µg/g soil)	Available P (µg/g soil)	Available K (me/100 g soil)
N_0S_0	0.095 a	30.5 cd	89.1 a	0.40 a
N_0S_1	0.090 ab	35.1 a	85.3 ab	0.38 ab
N_0S_2	0.089 abc	34.0 ab	82.0 bcd	0.35 abc
N_0S_3	0.085 abcd	36.4 a	79.0 cde	0.29 def
N_1S_0	0.075 bcd	32.1 bc	79.5 cde	0.33 bcd
N_1S_1	0.083 abcd	28.0 de	78.5 cde	0.25 efg
N_1S_2	0.080 abcd	30.1 cd	76.9 def	0.23 fghi
N_1S_3	0.077 abcd	25.7 efg	79.5 cde	0.26 efg
N_2S_0	0.077 abcd	25.0 efg	75.5 ef	0.21 ghij
N_2S_1	0.075 bcd	23.8 gh	69.9 gh	0.18 ij
N_2S_2	0.079 abcd	20.2 i	67.2 h	0.17 j
N_2S_3	0.070 cd	20.0 i	73.5 fg	0.19 hij
N_3S_0	0.072 bcd	19.8 i	77.6 cdef	0.24 efgh
N_3S_1	0.073 bcd	22.7 hi	80.6 bcde	0.27 efg
N_3S_2	0.070 cd	27.6 def	80.8 bcd	0.26 efg
N_3S_3	0.068 d	34.5 ab	82.5 bc	0.30 cde
$LSD_{(0.05)}$	0.0167	2.707	4.521	0.053
CV(%)	4.50	5.83	3.45	8.83

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

N_0: 0 kg N/ha
N_1: 40 kg N/ha
S_0: 0 kg S/ha
S_0: 8 kg S/ha

N_2: 80 kg N/ha
N_3: 120 kg N/ha

S_2: 16 kg S/ha
S_3: 24 kg S/ha

Significant interaction effect was also observed between nitrogen and sulphur for phosphorus uptake by plant under the present trial (Appendix IV). The maximum available phosphorus (89.1 μg/g soil) in soil was recorded from the treatment combination N_0S_0 and the minimum available phosphorus (67.2 μg/g soil) in soil was recorded from N_2S_2 treatment (Table 26).

4.7.4 Potassium (K)

Nitrogen at different level showed a statistically significant variation for available potassium in soil under the present trial (Appendix IV). The maximum available potassium (0.35 me/100 g soil) in soil was recorded from N_0 treatment and the minimum available potassium (0.19 me/100 g soil) in soil was recorded from N_2 treatment (Table 24). Mondal and Gaffer (1983), Asaduzzaman and Shamsuddin (1986) also reported the similar results from their experiment.

Application of different level of sulphur showed statistically significant differences for available potassium in soil (Appendix IV). The maximum available potassium (0.29 me/100 g soil) in soil was recorded from S_0 treatment which was statistically similar (0.27 me/100 g soil) with treatment S_1 comprising of 8 kg S/ha (Table 25). On the other hand the minimum available potassium (0.25 me/100 g soil) in soil was recorded from the S_2 treatment which was statistically similar (0.26 me/100 g soil) followed by S_3 treatment under the present trial.

Interaction effect between nitrogen and sulphur for available potassium in soil also varied significantly (Appendix IV). The maximum available potassium (0.40 me/100 g soil) in soil was recorded from the treatment combination N_0S_0 and the minimum available potassium (0.17 me/100 g soil) in soil was recorded from N_2S_2 treatment (Table 26).

Chapter V

SUMMARY AND CONCLUSION

An experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2006 to February 2007 to determine the effect of different levels of nitrogen and sulphur on yield and yield contributing characters of mustard as well as the nutrient content and their uptake by mustard plants. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) i.e. 0 kg N/ha (N_0), 40 kg N/ha (N_1), 80 kg N/ha (N_2) and 120 kg N/ha (N_3); Factor B: Sulphur (4 levels) i.e. 0 kg S/ha (S_0), 8 kg S/ha (S_1), 16 kg S/ha (S_2), 24 kg S/ha (S_3). There were 16 treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. After emergence of mustard seedlings, various intercultural operations were accomplished for better growth. Data were collected in respect of the plant growth characters and content and uptake by seed, shoot and plant and available nutrients in soil for different levels of nitrogen and sulphur. The data obtained for different characters were statistically analyzed to find out the significance of the nitrogen and sulphur.

In general the plant height, branches per plant, siliqua per plant, seed and shoot yield increased with increasing the N doses upto 80 kg N/ha (N_2). The tallest plant height (88.0 cm) and the maximum number of branches per plant (7.05) were observed from N_2 treatment whereas the maximum number of siliqua per plant (151), the maximum number of seed per siliqua (21.9) and the highest weight of 1000 of seeds (2.76 g) were recorded from N_3 treatment. Minimum values of these parameters were obtained from N_0(control). However, the highest seed yield (1535 kg/ha) was recorded from N_2 and the lowest seed yield (908 kg) was recorded from control condition. The highest nitrogen content (3.57%) and potassium content (0.802) were recorded from N_3 treatment. The highest sulphur content in

seed (1.15%) was recorded from N_1 treatment the highest phosphorus content in seed (0.63%) was recorded from N_2 treatment. All the nutrient contents in seed were the lowest in the control. The maximum nitrogen uptake by plant (83.0 kg/ha) and the maximum sulphur uptake by plant (26.2 kg/ha) were observed from N_2 treatment. The maximum available total nitrogen (0.090%) available sulphur (34.0 μg/g soil) in soil and available phosphorus (83.7 μg/g soil) in soil an the maximum available potassium (0.35 me/100 g soil) in soil were recorded from N_0 treatment. Application of higher doses of N decreased the status of these nutrients in soil.

The tallest plant height (83.8 cm) the maximum number of branches per plant (6.93), the maximum number of siliqua per plant (127) was observed from S_3 treatment and the maximum number of seed per siliqua (21.2) were recorded from S_3 treatment and the minimum values of these parameters were recorded from the S_1 treatment. On the other hand, the highest weight of 1000 seeds (2.67 g) was recorded from S_2 treatment and the lowest (2.46 g) was recorded from the S_0 treatment. The highest nitrogen content of seed (3.49%) was recorded from S_2 treatment. The highest sulphur (1.24%), phosphorus (0.57%), and potassium (0.811%) content of seed were recorded from S_3 treatment comprising of 24 kg S/ha. The maximum nitrogen uptake by plant (75.4 kg/ha) and sulphur uptake (23.3 kg/ha) by plant were recorded from S_2 treatment comprising of 16 kg S/ha. The maximum available sulphur (29.1 μg/g soil) in soil was recorded from S_3 treatment. The maximum available phosphorus (80.4 μg/g soil) and available potassium (0.29 me/100 g soil) in soil were recorded from S_0 treatment and the minimum (0.25 me/100 g soil) was recorded from the S_2 treatment.

The treatment combination N_2S_3 as 80 kg N/ha + 24 kg S/ha gave the maximum considerable value, while the minimum was found from N_0S_0. 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 sulphur may be included in the further study;
3. Another fertilizer may also included in the program for future study.

Chapter VI
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APPENDICES

Appendix I. Analysis of variance of the data on yield contributing characters and yield of mustard as influenced by nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm)	Branches per plant (No.)	Siliqua per plant (No.)	Seed per siliqua (No.)	1000 seeds weight (g)	Seed yield (kg/ha)
Replication	2	11.168	0.007	0.583	0.303	0.0001	2256.25
Nitrogen (A)	3	521.598**	10.751**	15057.47**	42.842**	0.575**	1015056.19**
Sulphur (B)	3	44.036**	2.583**	917.361**	5.804**	0.127**	263976.19**
Interaction (A×B)	9	6.389	0.464**	230.602**	11.793**	0.011**	35107.521**
Error	30	9.545	0.018	5.361	1.342	0.001	466.783

** : Significant at 0.01 level of probability;

Appendix II. Analysis of variance of the data on nitrogen, sulphur, phosphorus and potassium content and uptake by seed of mustard as influenced by nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square							
		Content in seed (%)				Uptake by seed (kg/ha)			
		N	S	P	K	N	S	P	K
Replication	2	0.006	0.0001	0.0001	0.0001	1.623	0.904	0.004	0.094
Nitrogen (A)	3	1346**	0.050**	0.044**	0.0001**	2170.02**	171.093**	64.572**	72.182**
Sulphur (B)	3	0.379**	0.277**	0.007**	0.0001**	312.740**	93.075**	6.637**	6.818**
Interaction (A×B)	9	0.141**	0.046**	0.007**	0.001**	246.813**	43.523**	5.131**	6.367**
Error	30	0.007	0.092	0.001	0.0001	2.976	0.441	0.140	0.174

** : Significant at 0.01 level of probability;

Appendix III. Analysis of variance of the data on nitrogen, sulphur, phosphorus and potassium content and uptake by shoot of mustard as influenced by nitrogen and sulphur

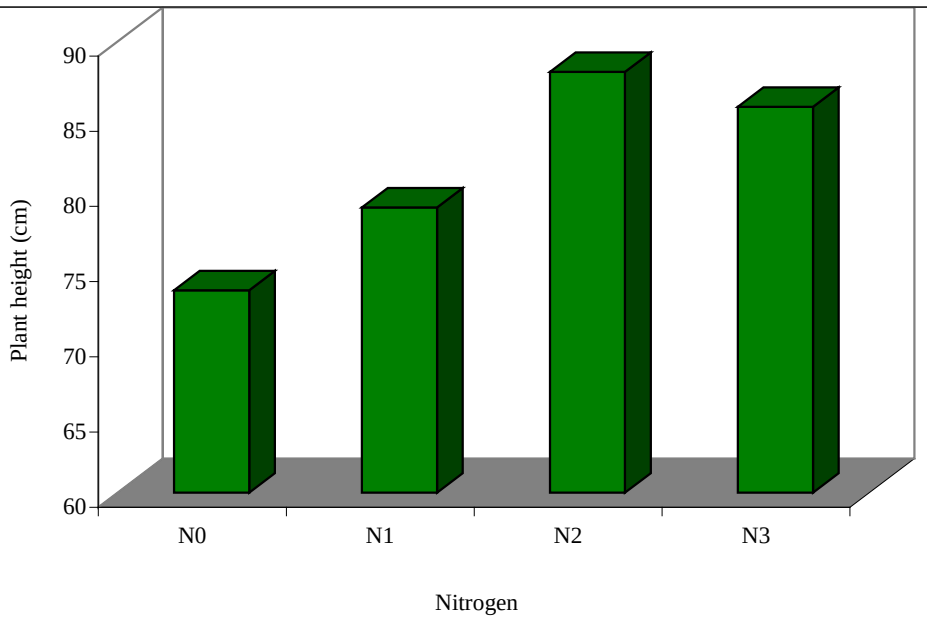
Source of variation	Degrees of freedom	Mean square							
		Content in shoot (%)				Uptake by shoot (kg/ha)			
		N	S	P	K	N	S	P	K
Replication	2	0.001	0.0001	0.0001	0.042	0.918	0.284	0.005	1.349
Nitrogen (A)	3	2.016**	0.082**	0.009**	0.123*	1037.39**	61.089**	4.237**	1286.59**
Sulphur (B)	3	0.518**	0.192**	0.005**	0.197**	202.748**	33.662**	0.961**	210.063**
Interaction (A×B)	9	0.266**	0.019**	0.002**	0.103*	159.037**	6.899**	0.626**	124.554**
Error	30	0.009	0.001	0.0001	0.041	0.839	0.507	0.003	1.884

** : Significant at 0.01 level of probability; ** : Significant at 0.01 level of probability

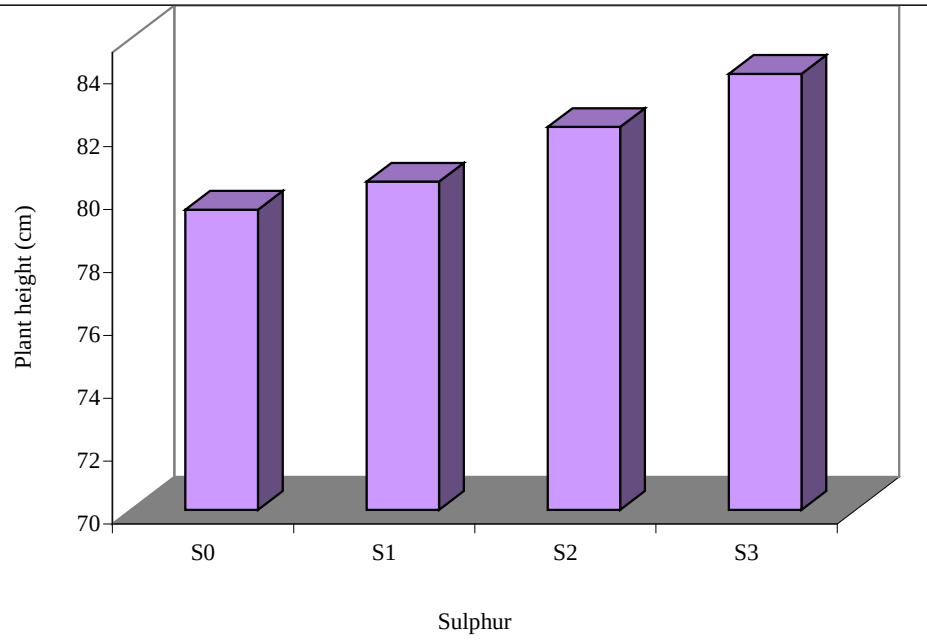
Appendix I V. Analysis of variance of the data on nitrogen, sulphur, phosphorus and potassium total uptake by plant and available in soil as influenced by nitrogen and sulphur

Source of variation	Degrees of freedom	Mean square							
		Total uptake by plant (kg/ha)				Available in soil			
		N	S	P	K	Total N (%)	Available S (µg/g soil)	Available P (µg/g soil)	Available K (me/100 g soil)
Replication	2	4.975	2.0212	0.012	0.897	0.0001	29.621	12.259	0.0001
Nitrogen (A)	3	6132.699**	435.830**	98.505**	1966.604**	0.001**	292.870**	325.373**	0.056**
Sulphur (B)	3	1009.731**	237.371**	10.731**	289.267**	0.0001**	11.630**	27.355*	0.004**
Interaction (A×B)	9	757.327**	75.506**	7.739**	183.009**	0.0001	57.826**	29.064**	0.004**
Error	30	3.277	0.903	0.138	1.444	0.0001	2.635	7.351	0.001

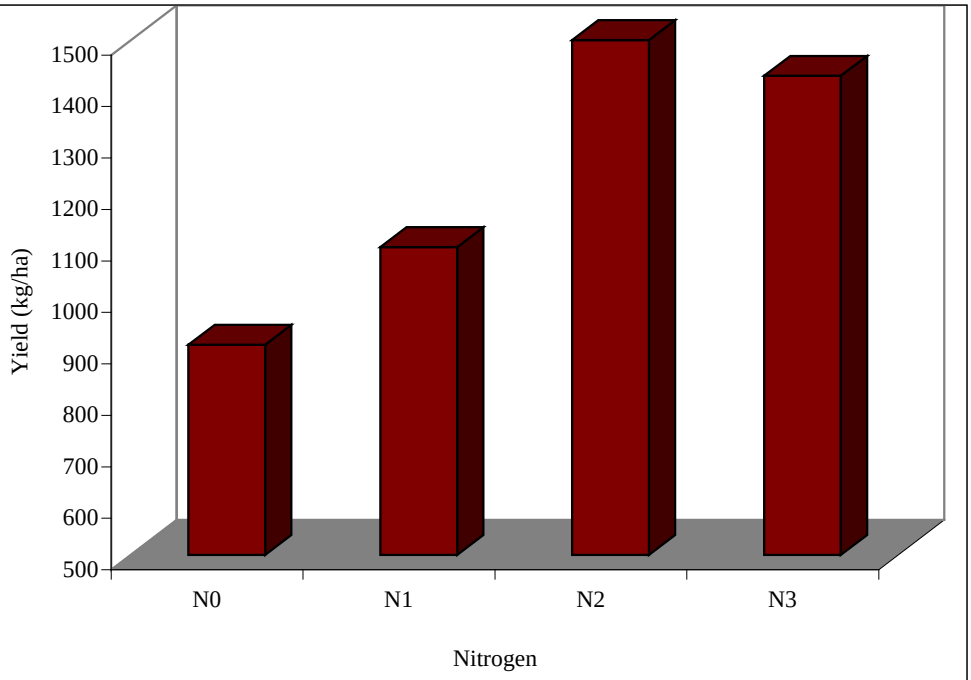
** : Significant at 0.01 level of probability; ** : Significant at 0.01 level of probability



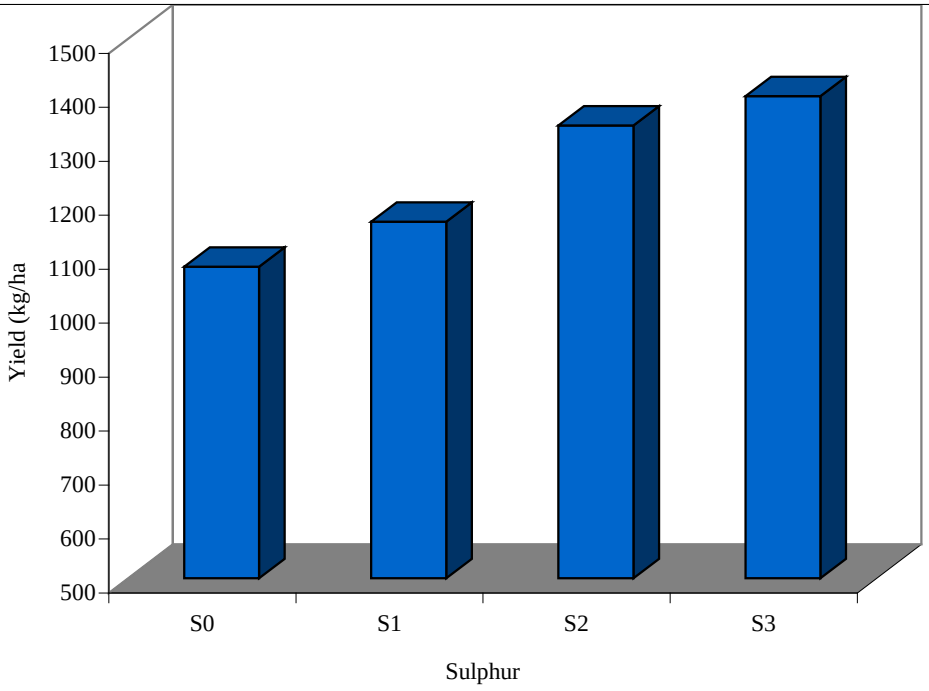
Appendix: V. Effect of nitrogen on plant height of mustard



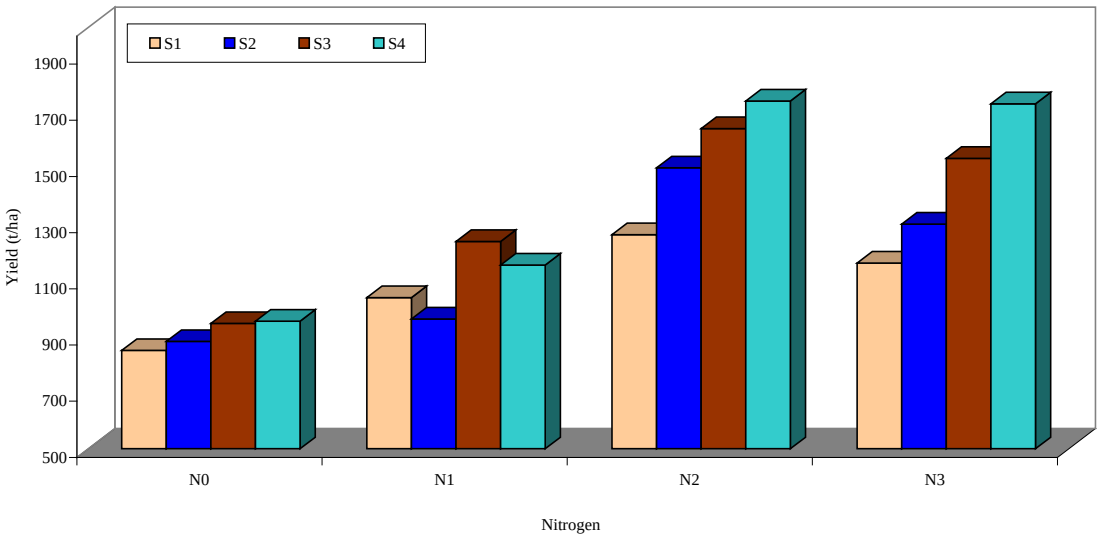
Appendix: VI. Effect of sulphur on plant height of mustard



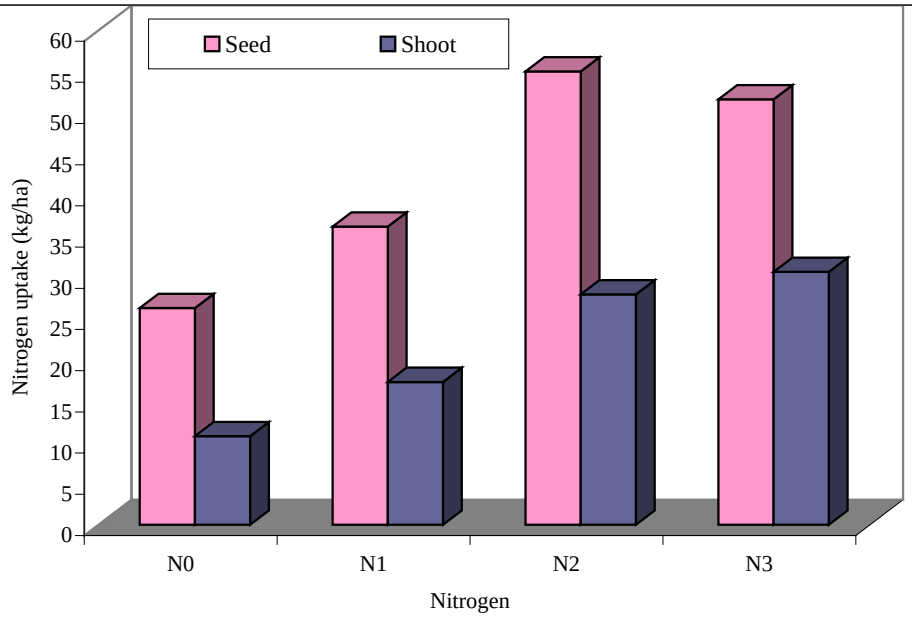
Appendix: VII. Effect of nitrogen on yield of mustard



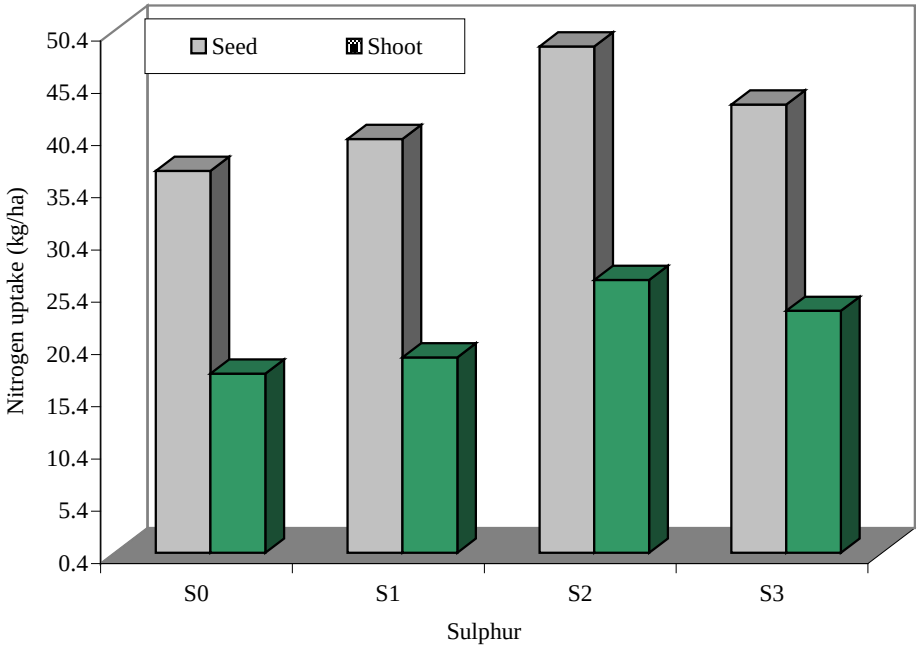
Appendix: VIII. Effect of sulphur on yield of mustard



Appendix: IX. Effect of nitrogen and sulphur on yield of mustard



Appendix: X. Effect of nitrogen on nitrogen uptake by seed and shoot of mustard



Appendix: XI. Effect of sulphur on nitrogen uptake by seed and shoot of mustard