RESPONSE OF NITROGEN AND SULPHUR ON THE YIELD OF RAPESEED (*Brassica campestris*) LINE SAU-C-F_7

BY

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CERTIFICATE

This is to certify that the thesis entitled, "Response of nitrogen and sulphur on the yield of rapeseed (*Brassica campestris*) line SAU-C-F_7" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of bonafide research work carried out by **Md. Shofikul Islam,** Registration No. 23880/00146 under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: 31/12/2005
Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)
Supervisor

Dedicated to

My

Beloved Parents

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RESPONSE OF NITROGEN AND SULPHUR ON THE YIELD OF RAPESEED (*Brassica campestris*) LINE SAU-C-F_7

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University Farm during the Rabi season 2004-2005 (October to February) to examine the response of nitrogen and sulphur on the growth, yield attributes and yield of newly developed rapeseed (*Brassica campestris*) line SAU-C-F_7. The experiment was laid out in split plot design with 3 replications. There were four different levels of nitrogen viz. 0, 40, 80 and 120 kg/ha and four levels of sulphur viz. 0, 30, 60 and 90 kg/ha. Nitrogen and sulphur significantly influenced the growth, yield and yield attributers of rapeseed. Plant height, dry matter, crop growth rate, branches per plant, length of main inflorescence, number of siliquae in the main inflorescence, siliquae per plant, seed yield, stover yield, harvest index and oil yield were significantly influenced by both nitrogen and sulphur. Oil content was only influenced by S application. The results revealed that nitrogen at the rate of 120 kg/ha showed the best performance in all respect. The highest seed yield (2.37 t/ha) was obtained with 120 kg N/ha while control treatment gave the lowest yield (0.66 t/ha). It was also observed that sulphur application at the rate of 30 kg/ha gave the best results while control treatments showed the lowest results. Application of sulphur at the rate of 30 kg/ha produced the maximum seed yield (1.66 t/ha). The interaction effect of nitrogen and sulphur revealed that 120 kg N in combination with 30 kg S/ha showed the best performance in most of the cases whereas, the combination affect of control treatments showed the worst performance.

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ACRONYMS

AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
FAO	=	Food and Agricultural Organization
CGR	=	Crop Growth Rate
RGR	=	Relative Growth Rate
N	=	Nitrogen
S	=	Sulphur
P_2O_5	=	Phosphorus Penta Oxide
K_2O	=	Potassium Oxide
DAS	=	Days After Sowing
SAU	=	Sher-e- Bangla Agricultural University
HI	=	Harvest Index
%	=	Percent
g	=	gram (s)
kg	=	kilogram (s)
TDM	=	Total Dry Matter
cv.	=	Cultivar (s)
t/ha	=	Tonnes per hectare
CV %	=	Percentage of Coefficient of Variance
hr	=	hour(s)
ppm	=	Parts per million
PK	=	Phosphorus, Potassium
CEC	=	Cation Exchange Capacity
mm	=	millimeter
^0C	=	Degree Celsius
DMRT	=	Duncan's Multiple Range Test
m^2	=	meter square
NS	=	Non significant
cm	=	Centi-meter
LYV	=	Low yielding varieties
L_n	=	Natural Logarithum
No	=	Number
SA	=	Surface area
RDA	=	Recommended Dietary Allowance
var.	=	Variety
et al.	=	And others
etc.	=	Etcetera

Chapter 1

Introduction

Chapter 1

INTRODUCTION

Oilseed crops play a vital role in human nutrition. It is not only rich source of energy (about 9 Kcal/g) but also rich in soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6g of oil for a diet with 2700 Kcal. On RDA basis, the edible oil need for 150 millions people are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). In 2004-2005, Bangladesh produced only 0.41 million tons of oil seed (BBS, 2005).

In Bangladesh, sources of edible oil are rapeseed-mustard, sesame, groundnut, soybean, niger, linseed, sunflower and safflower. But rapeseed-mustard is one of the important oilseed crops of the world after soybean and palm (FAO, 2004). Rapeseed belongs to the genus *Brassica* of the family Cruciferae. Rapeseed-mustard is the principal oilseed crop of Bangladesh. In Bangladesh, it covers an area of 0.28 million hactares with a production of 0.21 million tons (BBS, 2005). Rapeseed oil is widely used as cooking oil and medicinal ingredient and supplies fat in our daily diet. Rapeseed oil cake is used as feed for cattle and fish and good manure for crops. The average yield of rapeseed in Bangladesh is very low (0.765 t/ha) that is less than 50% of the world average (FAO, 2004).

Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% area of total cropped area in Bangladesh (BBS, 2002). The annual oil seed production of 0.41 million tons of which the share of rapeseed-mustard was 0.21 million tons, which comes about 52 % of the total edible oil seed production (BBS, 2005). It is top of the list in respect of area and production compare to among the oilseed crops grown in Bangladesh.

Bangladesh is running with acute shortage of about 70% edible oil. Annually producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons and to meet up the demand, the country has to import oil and oilseeds to the tune of about 160 million US $ every year (Wahhab *et al.*, 2002).

The cultivation of rapeseed has to compete with other food grain crops. Due to this reason, oilseed crops have been shifted to marginal land. Rapeseed productivity is very low due to poor fertilization, traditional cultivation practices, local varieties and scarcity of HYV seed etc.

The yield of rapeseed can be augmented with the use of high yielding varieties and appropriate agronomic management. Fertilizer is the depending source of nutrient that can be used to boost up growth and yield of mustard (Sinha *et al.*, 2003; Meena *et al.*, 2002; Shukla *et al.*, 2002a and Zhao *et al.*, 1997). High yielding varieties of rapeseed are very responsive to fertilizers especially nitrogen and sulphur (Patel *et al.*, 2004; Sharawat *et al.*, 2002 Ali and Rahman, 1986 and Gupta *et al.*, 1972). Application of 100 kg N and 30 kg S/ha promoted most of the growth parameters and yield attributes of musturd (Islam *et al.*, 2004).

Rapeseed is highly sensitive to nitrogen and this element has tremendous influence on plant height, dry matter accumulation and all the yield attributes (Tripathi and

Tripathi, 2003; Saikia *et al.*, 2002; Shukla *et al.*, 2002b; Singh *et al.*, 2002c and Srinivas and Raju, 1997). Excessive use of this element may produce too much of vegetative growth and thus fruit production may be impaired (Sheppard and Bates, 1980). An efficient method and time of application is very much important for proper utilization of nitrogen by plants (Ibrahim *et al.*, 1989).

Among the fertilizer elements S plays a key role in augmenting the production of oilseed. Sulphur fertilizers have been reported to increase the seed yield by improving yield components including the oil content of mustard (Birbal *et al.*, 2004; Singh *et al.*, 2004; Bharati and Prasad, 2003; Singh and Meena, 2003 and Prakash *et al.*, 2002). Sulphur also plays an essential role in the synthesis of amino acids, certain volatile compounds and secondary metabolites. The oilseed crops need comparatively higher amount of S for proper growth and higher yield and also S has been found to increase the uptake of nitrogen, phosphorus and potassium by mustard crop (Singh *et al.*, 1988). Response of rapeseed to S in addition to major nutrient has been high reported by many workers (Singh and Singh, 1984; Paul and Sarker, 1989 & Pathak and Tripathi, 1979). Sulphur is positively essential in order to obtain high yield from improved varieties of rapeseed. A yield response of 7-8 kg grain per kg S commonly been reported that were found in field condition (Aulakh and Pasrichar, 1988 & Gupta and Saini, 1988).

In Bangladesh, about 97% soils are deficit in S and this deficit is becoming acute day by day due to intensive cropping and less use of S free fertilizer (Mazid, 1986). An intensive cropping system removes 30-70 kg S/ha/year from soil in Bangladesh (Hussain, 1990). The removal of sulphur increased when oilseeds are included in the rotation of a cropping system (Joshi *et al.*, 1973). Rapeseed and mustard removed 17.27 kg sulphur reported by Jain, (1984). The effect of S on the protein and oil synthesis of rapeseed and mustard was reported by Finlayson *et al.* (1970). Sulphur deficiency is also known to affect nitrogen metabolism in plant, when S is limiting in plant, protein synthesis decreases, hereby N is not fully utilized resulting in accumulation of non-protein N in plants (Dev *et al.*, 1981).

Proper fertilization is an essential need to maximize rapeseed production in Bangladesh soil. The high yielding varieties of rapeseed introduced into intensive cropping system need through investigation on their requirements of N and S for their growth and development to obtain maximum yield. Although N and S fertilizer play a vital role in enhancing the production of rapeseed and thereby reducing the oil deficit in the country, very little studies have been documented. In view of the limited information on the problems mentioned above, the present piece of work was under taken on a newly developed rapeseed (*Brassica campestris*) line SAU-C-F_7 with the following objectives:

1. Determine the optimum dose of nitrogen and sulphur on yield.
2. Find out the relation between nitrogen and sulphur and their interaction on yield.
3. Determine the relation between nitrogen and sulphur and their interaction on oil yield.

Chapter 2
Review of literature

Chapter 2

REVIEW OF LITERATURE

Among the oil seed crops, rapeseed and mustard occupies topmost position in Bangladesh. SAU-C-F_7 (*Brassica campestris*) is a newly developed line which belonging to the group of rapeseed. The proper fertilizer management accelerates its growth and influenced its yield as well as oil content. The literature on the work done pertaining on the effect of nitrogen and sulphur nutrients on the yield and yield attributes of the crops belonging to the group rapeseed and mustard. Therefore, available findings of the direct effect of nitrogen and sulphur and combined effect relevant to the present study have also been briefly reviewed under the following heads:

2.1 Effect of nitrogen

2.1.1 Plant height

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

BARI (1999) conducted trial in two different regions of Bangladesh, at Joydebpur & Ishwardi to justify the effect of N on yield of mustard. The experiment conducted with 3 levels of nitrogen 0, 120, 160 k/ha and plant height was found 87.78, 113.94, 106.46 cm, respectively at Joydebpur and 90.79, 118.46, 113.69 cm at Ishwardi. The highest plant height was found in both the location at 120 Kg N/ha.

Islam and Mondal (1997) showed that application of nitrogen at the rate of 0,100,200,300 kg/ha, the maximum plant height was found 93.6 cm at 300 kg N/ha.

Ali and Ullah (1995) reported that with the application of different doses of nitrogen and maximum plant height was obtained from 120 kg N/ha.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased plant height.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation, observed that plant height increased progressively with increasing levels of nitrogen but was not significantly differed with the application of different levels of nitrogen. Nitrogen at the rate of 120 kg/ha gave the highest plant height.

Mondal and Gaffar (1983) observed highest plant height of the variety 'Sampad' by the treatment 140 kg N/ha, which was identical with the treatment 105 kg N/ha.

Bhan and Singh (1976) reported that when *Brassica juncea* was provided with 120 kg N/ha, remarkably increased the plant height.

2.1.2 Dry matter

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N/ha under irrigated or non-irrigated condition. They observed that dry matter accumulation increased with increasing rate of nitrogen.

Saikia *et al.* (2002) estimated that the total dry matter significantly responsed with the increasing levels of nitrogen (0, 30, 90, 120 and 150 kg/ha).

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They found highest total dry matter at harvest with the application of 120 kg N/ha.

Singh *et al.* (2002c) also concluded that dry matter accumulation/plant increased significantly with successive increased in nitrogen up to 120 kg/ha.

Vyas *et al.* (1995) observed the effect of nitrogen on the dry mater production of Indian mustard. They reported that an increase in N rate increased the DM production.

Patra *et al.* (1994) conducted field trial on mustard (*Brassica juncea*) cv. Sarama. The crop was given 20 or 40 kg N/ha. They found maximum dry matter accumulation after 90 days in mustard with 40 kg N/ha.

2.1.3 Crop growth rate (CGR)

Ali *et al.* (1996) reported that crop growth rate (CGR) significantly increased by levels of N and plant density up to 55 to 77 DAS and declined at later stage. Nitrogen at 120 kg/ha increased CGR values progressively at all growth stages as compared to control and 180 kg N/ha.

Allen and Morgan (1972) observed a gradual increase of CGR up to 42 days of plantation and, thereafter, showed a diminishing response up to 56 to 63 days after seeding (DAS) and increased sharply at 63 to 70 DAS and after that showed a negative response of CGR. Allen and Morgan (1971) also revealed that higher N rates of 211 kg/ha showed maximum CGR value of 400 g/m^2/week 70 DAS and thereafter, reduced sharply.

2.1.4 Relative growth rate (RGR)

Ali *et al.* (1996) studied with 4 levels of nitrogen to see the response of rapeseed to RGR and noticed that nitrogen application influenced RGR significantly up to 45-55 DAS. RGR was maximized at early growth stages and gradually declined with the advancement of crop growth.

2.1.5 Number of branches per plant

Tripathi and Tripathi (2003) performed an experiment to investigate the effect of N levels (80, 120, 160 and 200 kg/ha) on the branches number of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that the number of primary branches per plant increased up to 200 kg N/ha.

Singh *et al.* (2003) reported the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg/ha) and basis of N application (row and even application) on the performance of indian mustard cv. Basanti. They observed that N at 120 kg/ha produced higher number of branches per plant compared to 60 kg N/ha. The N level higher than 120 kg/ha did not increase the number of branches per plant.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) in a cropping system and observed that 80 kg N/ha resulted the highest number of branches (24.4) per plant.

Singh *et al.* (2002c) reported that primary and secondary branches per plant increased significantly with successive increase in nitrogen rate up to 120 kg/ha.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They found that the highest number of branches per plant was obtained with the application of 120 kg N /ha.

Tarafder and Mondal (1990) reported from an experiment conducting for determining the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sarisha) and found that the number of branches per plant increased with increasing levels of nitrogen. The combination of nitrogen and sulphur fertilizers significantly increased the number of primary branches per plant.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation and observed that nitrogen at the rate of 120 kg/ha gave highest number of primary branches per plant (5.03).

2.1.6 Number of siliquae per plant

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N/ha). He observed that adequate N fertilization is important in increasing pod number per plant and observed highest pod number per plant of summer oilseed rape at the rate of 160 kg N/ha.

Singh *et al.* (2003) conducted an experiment and determined the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg/ha) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg/ha produced higher number of siliquae per plant (48.03), siliqua weight (2.09) compared to 60 kg N/ha. The N level higher than 120 kg/ha did not increase the number of siliqua significantly.

Sharma and Jain (2002) studied with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) followed by the cropping system that the application of 80 kg N/ha resulted in the highest number of siliquae per plant (260.9). Singh *et al.* (2002) also reported that siliquae per plant increased significantly with successive increase in nitrogen up to 120 kg/ha.

Shukla *et al.* (2002b) performed an experiment to observe the integrated nutrient management for Indian mustard (*B. juncea*). They found that maximum number of siliquae per plant was obtained with the application of 120 kg N/ha.

Abadi *et al.* (2001) indicated that N had significant effect to increase the number of silique per plant of rapeseed.

BARI (1999) investigated in a field trial application with 0, 80, 120, 140 N kg/ha and siliquae per plant were found 22.7, 42.0, 45.6, 48.0, respectively.

Jensen (1990) observed that when nitrogen fertilizer was applied @ 0, 50, 100, 200 kg/ha; pod/m^2 was found 1974.0, 2936.6, 3315.1 & 5023.8 respectively.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased the number of siliquae per plant.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation and observed that N at the rate of 120 kg/ha significantly increased the number of siliquae per plant.

2.1.7 Length of siliqua

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the length of siliqua. However, the significant increase in length of siliqua was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management in Indian mustard (*B. juncea*). They observed maximum siliqua length with the application of 120 kg N/ha. Singh *et al.* (2002) also reported that growth characters and length of siliqua increased significantly with successive increase in nitrogen up to 120 kg/ha.

2.1.8 Number of seeds per siliqua

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and five levels of P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the number of seeds per siliqua. However, the significant increase in seed per siliqua was recorded at 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha.

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management in Indian mustard (*B. juncea*). They obtained maximum number of seeds per siliqua when nitrogen was applied at 120 kg/ha.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) followed by the cropping system that the application of 80 kg N/ha resulted in the highest number seeds per siliqua (15.3).

Tarafder and Mondal (1990) reported from an experiment conducting for determining the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sharisa) and found that the combine effect of nitrogen and sulphur fertilizers increased the number of seeds per siliqua.

2.1.9 Weight of 1000 seeds

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N/ha). He observed that adequate N fertilization is important in increasing 1000- seed weight in summer oilseed rape and suggested that the rate of 160 kg N/ha will be adequate for the crop to meet its N requirements. 1000-seed weight differs with nitrogen levels that enhanced yield.

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased 1000-seed weight. However, the significant increase in 1000 seed weight was recorded in 120 kg N/ha.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) followed by the cropping system that the application of 80 kg N/ha increased 1000-seed weight (3.55 g).

Shukla *et al.* (2002b) conducted an experiment to study the integrated nutrient management for Indian mustard (*B. juncea*). They obtained maximum 1000-seed weight with the application of 120 kg N/ha.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased 1000-seed weight.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation and observed that 1000-seed weight increased progressively with the successive increase of N rate up to 120 kg/ha.

2.1.10 Seed yield

Sinsinwar *et al.* (2004) observed the increased seed yield of Indian mustard with each increment of N fertilizer up to 60 kg/ha, beyond this 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 (2004) conducted a field experiment using blue green algae (BGA) and *Azolla* in integration with graded levels of N fertilizer in rice followed by rapeseed. *Azolla* were found better in seed yield with regard to the effect on subsequent crop of rapeseed and the highest yield was recorded with higher dose of N (80 kg N/ha) in integration with *Azolla*.

Singh *et al.* (2003) reported from an experiment conducting for determining the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg/ha) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg/ha produced higher seed yield (2.55 q/ha) compared to 60 kg N/ha. The N level higher than 120 kg/ha did not increase the yield significantly.

Tripathi and Tripathi (2003) performed an experiment to inspect the effect of N levels (80, 120, 160 and 200 kg/ha) on the yield of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that seed yield increased with increasing N levels up to 160 kg N/ha.

Singh and Prasad (2003) reported that 120 kg N/ha gave the highest seed yield (20.24 q/ha). But the highest cost benefit ratio (0.85) was obtained with 180 kg N/ha.

Kumar and Singh (2003) reported significant increase in seed yield (1617 kg/ha) with nitrogen at 150 kg/ha. Addition of 50 kg N/ha resulted in producing 8.62 kg of seed per kg of N applied. The maximum yield (24.51 q/ha) was obtained from 20-25 October sown crops with 40 cm row spacing and supplied with 150 kg N/ha.

Khan *et al.* (2003) studied the interactive effect of nitrogen (0, 40, 60 and 80 kg/ha) and plant growth regulators (cycocel and ethrel both at 200 or 400 ppm) on the photosynthetic biomass production and partitioning in response of seed yield of indian mustard cv. Alankar and found that 80 kg N/ha and ethrel at 200 ppm increased the seed yield.

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

Singh (2002) conducted a study with variety Varuna of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the seed yield. However, the significant increase in seed yield was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha. The maximum seed yield (12.98 and 13.83 q/ha) were obtained with the application of nitrogen at 120 kg/ha.

Shukla *et al.* (2002b) investigated study the integrated nutrient management for Indian mustard (*B. juncea*). They observed maximum seed yield per hectare with the application of 120 kg N/ha.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) followed by the cropping system that the application of 80 kg N/ha resulted in the highest seed yield (1649.22 kg/ha). The highest values of seed yield and yield attributes were recorded for *S. canabiba* – Indian mustard receiving 80 kg N/ha. Shukla *et al.* (2002a) also conducted an experiment to investigate the effect of S (0 or 40 kg/ha) and N (60, 90 or 120 kg/ha) on the yield and yield attributes of rape cultivars. Sulphur did not significantly affect the seed yield and yield attributes. But N at 120 kg/ha produced higher seed yield than N at 60 and 90 kg/ha.

Ghosh *et al.* (2001) conducted an experiment to study the response of 3 levels of K (0, 12.5 and 25 kg/ha), 3 levels of N (0, 40 and 80 kg/ha) and biofertilizers (*Azotibacter, Azospirillum*) under irrigated condition. Interaction between K and biofertilizer and between biofertilizer and N were found significant in increasing the yield of rapeseed. They observed that maximum yield of rapeseed was obtained followed by the yield obtained with 80 kg N/ha along with 12.5 kg K/ha.

Sidlauskas (2000) found that the yield of rapeseed was increased with the increasing rate of nitrogen levels up to 120 kg/ha. Further increase of nitrogen level did not affect the seed yield. Zekaite (1999) also reported that, the seed yield of rapeseed (0.88 ton/ha) was obtained at a nitrogen fertilization of 90 kg/ha. Fertilization of nitrogen at 120 kg/ha significantly increased the seed yield.

BARI (1999) investigated with 4 levels of nitrogen (0, 80,120,140 kg/ha) on different varieties of mustard and yields were found 493.3, 833.3, 940.0, 993.7 kg/ha, respectively.

Patel (1998) conducted an experiment study the response of mustard (*Brassica juncea*) cv. Varuna to 3 levels of irrigation and 4 levels of nitrogen (0, 20, 40 and 80 kg/ha). He obtained seed yield averaged 0.43, 0.73, 0.95 and 1.21 t/ha with 0, 20, 40 and 60 kg N/ha, respectively.

Singh *et al.* (1998) reported that seed and oil yields as well oil component values were increased with increasing nitrogen rates (0, 40, and 80 kg N/ha). Dobariya and Mehta (1995) also reported that increasing nitrogen rate from 25 to 75 kg/ha increased seed yield from 2.07 - 2.41 t/ha.

Shukla and Kumar (1997) reported that six varieties of Indian mustard were grown to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content. They found that N application at 120 kg/ha significantly influenced the seed yield.

Gurjar and Chauhan (1997) observed that Pusa Bold and Kranti were grown in winter seasons at 5 N + P levels and at row spacing of 30 cm or 45 cm. They found that seed yield did not differ between cultivars, was greater at 30 cm spacing (1.68 vs. 1.12 t/ha) and increased up to 75 kg N + 50 kg P_2O_5/ha.

Islam and Mondal (1997) in a field trial showed that application of four levels of nitrogen 0, 100, 200, 300 kg/ha yielded 0.69, 1.29, 1.45, 1.21 t/ha seeds, respectively. They observed increased seed yield up to 200 kg N/ha.

Hossain and Gaffer (1997) conducted a trial with 5 levels of nitrogen at 0, 100, 150, 200, 250 kg/ha on rapeseed and maximum yield was found 1.73 t/ha with 250 kg N/ha. Letu *et al.* (1994) also reported that application of 3 levels of N at 0, 120, 160 kg/ha produced the seed yield of 1.3, 1.4 and 1.5 t/ha, respectively.

Mondal *et al.* (1996) reported that the highest seed yield of rapeseed (1.40 t/ha) was obtained from fertilizer levels of 150:90:100:30:4:1 kg/ha of N, P_2O5, K_2O, S, Zn and B with 6 tones of cowdung. This level of fertilizer was the most profitable among the 5 levels of fertilizers.

Arthamwar *et al.* (1996) conducted an experiment with mustard variety (Pusa Bold and T-59) having 3 levels of N (0, 50 and 100 kg) and P_2O_5 (0, 40 and 80 kg/ha). Result showed that highest seed yield obtained with N at of 100 kg/ha (1.20 t/ha) and 80 kg P_2O_5/ha (1.25 t/ha).

Thakuria and Gogoi (1996) conducted an experiment on *Brassica juncea* cv, TM 2, TM 4 and Varuna to evaluate the effect of 2 row spacing with 4 levels of nitrogen fertilizer (0, 40, 80 and 120 kg N/ha). Seed yield and yield components significantly increased with increasing N application up to 80 kg/ha.

Tuteja *et al.* (1996) investigated the effect of nitrogen at 60, 90 and 120 kg/ha on the yield of *Brassica juncea* cv. Varuna. Seed yield was highest (1.12 t/ha) with 120 kg N/ha.

Tarafder and Mondal (1990) set an experiment to evaluate the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sarisha) and found that seed yield increased with increasing levels of nitrogen or both nitrogen and sulphur. The results suggested that the nitrogen at the rate of 120 kg/ha did produce the economic seed yield in mustard in the grey terrace soil of Joydebpur.

Perniona *et al.* (1989) studied the effect of nitrogen (50, 100 and 150 kg/ha) on winter rape and found that average seed yield increased with the increased rate of nitrogen at 150 kg/ha.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased the seed yield. This dose gave seed yields of 1.20 t/ha compared to 0.89 t/ha without nitrogen. A further increase in yield with 90 kg/ha was not significant.

Shamsuddin *et al.* (1987) working with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation and observed that different levels of nitrogen did not significantly differed the seed yield. Nitrogen at the rate of 120 kg/ha gave seed yield of 830 kg/ha.

Mondal and Gaffer (1983) conducted experiment with Sampad variety of mustard having 5 levels of N (0, 35, 70, 105 and 140 kg/ha) and four levels of P_2O_5 (0, 35, 70 and 105 kg/ha). The highest seed yield (1280.95 kg/ha) was obtained from N treatment of 140 kg/ha, which was found identical with that of 105 kg/ha.

2.1.11 Stover yield

Prasad *et al.* (2003) reported the effect of N, S and Zn fertilizers on the nutrient uptake, quality and yield of Indian mustard cv. Vaibhav. The treatments consisted of 60 kg N/ha singly or in combination with 30 kg P, 20 kg S, 5 kg Zn; 30 kg P + 20 kg S; 30 kg P + 5 kg Zn; 20 kg S + 5 kg Zn; or 30 kg P + 20 kg S + 5 kg Zn/ha. N, P, S and Zn were applied through urea, diammonium phosphate, gypsum and zinc oxide, respectively. The application of 60 kg N + 30 kg P + 20 kg S + 5 kg Zn and 60 kg N + 30 kg P + 20 kg S gave the highest stover yield (33.08 q/ha).

Singh and Prasad (2003) also mentioned that 120 kg N/ha gave the highest stover yield (12.22 q/ha)

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that the application of 60 kg N/ha registered significantly higher stover yield of mustard over control. Singh *et al.* (2002) also reported that stover yield increased significantly with successive increase in nitrogen up to 120 kg/ha.

2.1.12 Harvest index

Shukla and Kumar (1997) grew six varieties of Indian mustard to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content. They found that N application at the rate of 120 kg/ha significantly influenced harvest index.

2.1.13 Oil content

Patel *et al.* (2004) conducted experiment to investigate the effect 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. They reported that oil contents decreased with increasing nitrogen levels. Saha *et al.* (2003) also reported the highest oil content at 30 kg N/ha.

Singh *et al.* (2004) conducted an experiment to study the response of Indian mustard cv. T-59 to nitrogen and sulfur rates. Different levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) application did not differed the oil content in mustard

Prasad *et al.* (2003) reported the effects of N, S and Zn fertilizers on nutrient uptake, quality and yield of Indian mustard (cv. Vaibhav).The application of 60 kg N/ha gave the highest oil content (39.98 %).

Singh and Meena (2003) conducted a field experiment to determine the effect of N fertilizers (20, 40, 60, 80 and 100 kg N/ha) on the oil and protein yield of Indian mustard cv. Varuna. Pooled analysis of data showed that 40 kg N/ha gave the highest oil content (39.61%). The most profitable rate of N was found at 80 kg/ha.

Meena and Sumeriya (2003) carried out a study to evaluate the effect of nitrogen (0, 30, 60 and 90 kg/ha) on oil content of mustard *Brassica juncea.* Application of 60 kg N/ha gave the maximum oil (37.04%) content, compared to no nitrogen application. Abadi *et al.* (2001) also indicated that N had a significant effect on oil content of rapeseed and mustard.

Shukla and Kumar (1997) investigated six varieties of Indian mustard (Krishna, Varuna, Vardan, Kranti, Rohini and Pusa Bold) to assess the effect of nitrogen fertilization on seed yield and oil content. A decreasing trend of oil content was observed with the increase in N fertilization.

Dubey *et al.* (1994) carried out an experiment on *B. juncea* cv. Varuna and was given 0, 30, 60 or 90 kg N/ha under irrigated condition. Seed oil content decreased by N application.

2.1.14 Oil yield

Ali *et al.* (1996) found that application of 120 kg N/ha favourably influenced the oil yield of rapeseed. Singh and Rathi (1987) also obtained maximum oil yields of Brassica species with N at 120 kg/ha.

Gawai *et al.* (1994) conducted an experiment to assess the impact of 0-100 kg N/ha on the performance of mustard (*Brassica juncea*) cv. TM-17 and concluded that oil yield increased with N rate, reaching a plateau at 75 kg/ha.

2.2 Effect of sulphur

2.2.1 Plant height

Birbal *et al.* (2004) conducted an experiment with the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on the yield and yield components of Indian mustard cv. Pusa Bold. They found that P at 75 kg and with 60 kg S/ha gave the maximum plant height.

Raut *et al.* (2003) stated from an experiment with the effect of 5 levels of irrigation and 4 levels of S (0, 20, 40 and 60 kg/ha) on the growth and yield attributes of indian mustard cv. Pusa Bold. They observed higher plant height at 20 kg S/ha resulted in higher compared to the other treatment combination.

Chaubey *et al.* (2001) conducted an experiment to evaluate the response of mustard to phosphorus (0, 40 and 60 kg P_2O_5/ha) and sulphur (0, 15, 30, 45 and 60 kg S/ha) fertilization. Plant height increased significantly with the increasing S up to 60 kg and P_2O_5 up to 30 kg/ha respectively.

Sudhakar *et al.* (2002) investigated the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna. Applied sulphur as ammonium sulfate, which significantly improved the plant height. The increase in plant height was observed up to 60 kg S/ha.

2.2.2 Dry matter

Bharati and Prasad (2003) reported the effect of sulphur rate on the performance of Indian mustard. The highest dry matter production and S uptake were recorded for 15 and 30 kg S/ha. Raut *et al.* (1999) also conducted an experiment with the different S rates (0, 20 40 and 60 kg/ha) on dry matter production and yield of Indian mustard cv. Pusa Bold. Sulphur application at 40 kg/ha resulted in the highest dry matter production of mustard at all growth stages (1.22, 31.86, 72.55 and 100.7 g/plant at 30, 60, 90 DAS and at harvest).

Ram *et al.* (1999) investigated the effect of phosphorus, sulphur and phosphate solubilizing bacteria (PSB, *Pseudomonas radiate*) on growth and yield of mustard (*Brassica juncea*) cv. Bio 902. They concluded that application of 60 kg S/ha increased the dry matter accumulation per plant of mustard.

Mohan and Sharma (1992) conducted a study to evaluate the effect of nitrogen and sulphur on seed yield and oil content of Indian mustard. Sulphur at the rate of 50 kg/ha significantly increased the dry matter production.

2.2.3 Crop growth rate (CGR)

Ali *et al.* (1996) investigated that increasing levels of sulphur (30 kg/ha) progressively increased the CGR values (13.19) up to 55-70 DAS but they were not significantly different and concluded that irrespective of S levels CGR became negative at 85 DAS.

2.2.4 Relative growth rate (RGR)

Ali *et al.* (1996) carried out an experiment to observe the effect of S on RGR and concluded that S at 30 kg/ha gave maximum RGR values at initial stages, however RGR declined gradually at later stage and RGR became negative (-1.58) at 85 DAS.

2.2.5 Number of branches per plant

Birbal *et al.* (2004) conducted an experiment to evaluate the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on the yield and yield components of Indian mustard cv. Pusa Bold. They found that P at 75 kg/ha and 60 kg S/ha produced the maximum number of primary branches per plant.

Raut *et al.* (2003) stated the effect of 5 levels of irrigation and 4 levels of S (0, 20, 40 and 60 kg/ha) on the growth and yield attributes of indian mustard cv. Pusa Bold. They observed highest number of branches per plant sulphur at 20 kg/ha compared to the other treatment combination.

Sudhakar *et al.* (2002) studied the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna provided sulphur as ammonium sulfate was applied as basal. Sulphur significantly increased the number of primary and secondary branches per plant. The increase in primary and secondary branches per plant was observed up to 60 kg S/ha.

Chaubey *et al.* (2001) investigated the response of mustard to phosphorus (0, 40 and 60 kg P_2O_5/ha) and sulphur (0, 15, 30, 45 and 60 kg S/ha) fertilization. The number of branches per plant increased significantly with the increasing levels of P_2O_5 and S up to 60 and 30 kg /ha, respectively.

2.2.6 Number of siliquae per plant

Hidyatullah *et al.* (2004) conducted an experiment to evaluate the effect of 4 levels of sulphur (0, 7, 14 and 21 kg/ha) and 2 levels of NAA (0 and 50 ppm) on growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Application of sulphur produced a significant and consistent increase in number of siliquae per plant up to 14 kg/ha. Birbal *et al.* (2004) also investigated the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on the yield and yield components of Indian mustard cv. Pusa Bold. They found that P at 75 kg/ha and S at 60 kg/ha produced the maximum number of siliquae per plant.

Raut *et al.* (2003) observed the effect of 5 levels of irrigation and 4 levels of S (0, 20, 40 and 60 kg/ha) on the growth and yield attributes of indian mustard cv. Pusa Bold. They obtained the highest number siliquae per plant with 20 kg S/ha compared to the other treatment combination.

Verma *et al.* (2002) carried out a study an indian mustard, where 15, 30 and 45 kg S/ha and 20, 40 and 60 kg K_2O/ha were used. They observed increased the number of siliquae per plant only up to 30 kg S/ha.

Sudhakar *et al.* (2002) considered the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna provided sulphur as ammonium sulfate was applied as basal. Sulphur significantly improved number of siliquae per plant. The increase in number of siliquae per plant was observed up to 60 kg S/ha.

2.2.7 Length of siliqua

Verma *et al.* (2002) studied the response Indian mustard, where 15, 30 and 45 kg S/ha and 20, 40 and 60 kg K_2O/ha were applied and observed significant influence of sulphur to increase the length of siliqua only up to 30 kg S/ha.

Chaubey *et al.* (2001) stated the response of mustard (*Brassica juncea* L.) cv. Rohini to phosphorus (0, 40 and 60 kg P_2O_5/ha) and sulphur (0, 15, 30, 45 and 60 kg S/ha) fertilization. The length of siliqua increased significantly with the increasing S up to 30 kg/ha.

2.2.8 Number of seeds per siliqua

Hidyatullah *et al.* (2004) investigated the effect of 4 levels of sulphur (0, 7, 14 and 21 kg/ha) and 2 levels of NAA (0 and 50 ppm) on growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Number of seeds per siliqua showed significant improvement with sulphur application only up to 14 kg/ha. Birbal *et al.* (2004) also observed the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on yield and yield components of Indian mustard cv. Pusa Bold. They found that P at 75 kg/ha and 60 kg S/ha produced the maximum seeds per siliqua.

Verma *et al.* (2002) carried out a trial with Indian mustard, where 15, 30 and 45 kg S/ha and 20, 40 and 60 kg K_2O/ha were used and observed that S application significantly increased the number of seeds per siliqua only up to 30 kg/ha.

Sudhakar *et al.* (2002) studied the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna, given sulphur as ammonium sulfate as basal and obtained significant increase in number of seeds per siliqua. The increase in number of seeds per siliqua was observed up to 60 kg S/ha.

2.2.9 Weight of 1000 seeds

Hidyatullah *et al.* (2004) conducted an experiment to study the effect of 4 levels of sulphur (0, 7, 14 and 21 kg/ha) and 2 levels of NAA (0 and 50 ppm) on growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Thousand seed weight showed significant improvement with sulphur application only up to 14 kg/ha. Birbal *et al.* (2004) also investigated the effect of P (0, 25, 50 and 75 kg/ha) and S (20, 40 and 60 kg/ha) on yield and yield components of Indian mustard cv. Pusa Bold. They concluded that P at 75 kg/ha and 60 kg S/ha produced the maximum 1000 seed weight.

Verma *et al.* (2002) carried out an experiment with indian mustard, where 15, 30 and 45 kg S/ha and 20, 40 and 60 kg K_2O/ha were applied, resulted significant increase of 1000 seed weight only up to 30 kg S/ha.

Sudhakar *et al.* (2002) studied the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna applied sulphur as basal. Sulphur significantly improved 1000-seed weight. The increase in 1000-seed weight was observed up to 60 kg S/ha.

2.2.10 Seed yield

Hidyatullah *et al.* (2004) conducted an experiment to evaluate the effect of 4 levels of sulphur (0, 7, 14 and 21 kg/ha) and 2 levels of NAA (0 and 50 ppm) on growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Application of sulphur produced a significant and consistent increase in seed yield with the increasing levels of sulphur up to 21 kg/ha. Birbal *et al.* (2004) also investigated the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on yield and yield components of Indian mustard cv. Pusa Bold. They obtained maximum grain yield per hectare with the application of 75 kg P/ha in combination with 60 kg S/ha.

Raut *et al.* (2003) stated the effect of 5 levels of irrigation and 4 levels of S (0, 20, 40 and 60 kg/ha) on the growth and yield attributes of indian mustard cv. Pusa Bold. They observed that the highest number of siliquae per plant in higher seed yield per hectare (1787 kg/ha) S at 20 kg/ha compared to the other treatment combination.

Misra (2003) conducted an experiment on mustard cv. Varuna with 4 levels of sulphur (0, 20, 40 and 60 kg S/ha) and potassium (0, 30, 60 and 90 kg K_2O/ha) and found the increased seed yield in linear order up to 40 kg S and 60 kg K_2O/ha; and recorded the highest seed yield (2035 kg/ha) at 40 kg S/ha was 27.59% higher in comparison to the yield at control.

Praskash *et al.* (2002) conducted an experiment with the effect of sulphur rate (0, 20, 40 and 60 kg/ha) on three Indian mustard cultivars (Varuna, PNV-16, Rohini and Pusa Bahar), where sulphur used as gypsum into the soil one month before sowing. Pusa Bahar and Rohini recorded the highest seed yield when sulphur applied was at 40 kg/ha.

Singh *et al.* (2002b) investigated the performance of Indian mustard (*Brassica juncea*) genotypes Varuna (Type 54), PBM 16, Rohini and Pusa bahar in relation to S application (0, 20, 40 and 60 kg/ha). Sulphur application at 20 and 40 kg/ha improved the seed yield significantly indicating 46.7% and 63.4% over the control. Singh *et al.* (2002a) also conducted an experiment with 3 Indian mustard cultivars (Varuna, Vardan and Narendra Rai-1) subjected to various sources and levels of S (0, 20, 40 and 60 kg/ha). The application of 40 and 60 kg S/ha, which were at par, gave significantly higher yield than the application of 0 and 20 kg S/ha.

Chandel *et al.* (2002) stated the effect on growth and yield of rice and mustard, which was grown in sequence. They found that 40 kg S/ha significantly influence the seed yield.

Davaria *et al.* (2001) conducted an experiment on the effect of P_2O_5 (0, 25 and 50 kg/ha) and S (0, 25, 50 and 100 kg/ha) on the yield and biochemical composition of Indian mustard cv. Gujrat Mustard-1. They found that S had significant effect on seed yield, which was highest but identical at 50 and 100 kg/ha (13.28 and 14.12 q/ha, respectively).

Kumar *et al.* (2001) conducted an experiment on three Indian mustard cultivars with 4 levels of sulphur (0, 20, 40 and 60 kg/ha). The application of 40 and 60 kg S/ha being at par with each other gave significantly higher yield over 20 kg and no- sulphur application. Miah *et al.* (2001) also conducted a study on high yielding varieties of mustard (BINA Sarisha-1, BINA Sarisha-3, Sonali Sarisha and BARI Sarisha-6) with five doses of S (0, 14, 30, 45 and 60 kg/ha). Seed yield of all the test varieties increased significantly with the application of S up to 45 kg/ha.

Mondal (2000) conducted a study with *Brassica campestris* cv, Kos-1 and was given 0-40 kg S and 0-7.5 kg B/ha. Seed yield increased up to 5 kg boron and 20 kg S/ha. Singh *et al.* (2000) observed the effect of S levels (0, 15, 30 and 45 kg/ha) on 8 improved strains of *Brassica spp.*, application of S up to 45 kg/ha significantly increased the yield attributes, seed yield and oil content compared to its lower levels.

2.2.11 Stover yield

Birbal *et al.* (2004) conducted a study to evaluate the effect of P (0, 25, 50 and 75 kg/ha) and S (0, 20, 40 and 60 kg/ha) on yield and yield components of Indian mustard cv. Pusa Bold. They found that P at 75 kg/ha and 60 kg S/ha gave the maximum stover yield.

Misra (2003) conducted an experiment on mustard crop (cv. Varuna) with four levels of sulphur (0, 20, 40 and 60 kg S/ha) and potassium (0, 30, 60 and 90 kg K_2O/ha). They found that stover yield increased in the linear order up to 40 kg S/ha.

Chandel *et al.* (2002) studied the effect of sulphur applied to rice and mustard grown in sequence, showed that S application to mustard significantly improved straw yields in following season up to 40 kg/ha. Verma *et al.* (2002) also carried out an experiment on Indian mustard, where 15, 30 and 45 kg S/ha and 20, 40 and 60 kg K_2O/ha were used and observed that S application significantly increased the stover yield only up to 30 kg S/ha.

Sudhakar *et al.* (2002) studied the effect of S (20, 40 or 60 kg/ha) on the performance of Indian mustard cv. Varuna. Sulphur was applied as ammonium sulfate as basal and observed gradual increase of stover yields the increase of sulphur levels.

2.2.12 Harvest index

Chandel *et al.* (2002) conducted an experiment to study the effect of sulphur on rice and mustard grown in sequence and used 4 levels of S (0, 15, 30 and 45 kg/ha) applied during kharif (rice) season and 3 levels of S (0, 20 and 40 kg/ha) applied during rabi (mustard) season. Results showed that S application to mustard significantly improved harvest index as well as rice yield in the following season up to 40 kg/h.

2.2.13 Oil content

Hidyatullah *et al.* (2004) conducted an experiment to study the effect of 4 levels of sulphur (0, 7, 14 and 21 kg/ha) and 2 levels of NAA (0 and 50 ppm) on growth, yield and biochemical parameters of Indian mustard (*Brassica juncea*). Application of sulphur produced a significant and consistent increase in oil content of mustard with the increasing levels of sulphur up to 21 kg/ha.

Singh *et al.* (2004) carried out an experiment to study the response of Indian mustard cv. T-59 to nitrogen and sulfur rates. Sulphur application at 20 kg/ha increased oil content in mustard over the control.

Singh and Meena (2003) conducted a study to determine the effect of S fertilizers on the oil yield of Indian mustard cv. Varuna. Pooled analysis of data showed that 80 kg S/ha gave the highest oil content (39.48%). Bharati and Prasad (2003) also reported that, Indian mustard resulted the highest oil content (41.84%) with the application S at 45 kg/ha.

Praskash *et al.* (2002) conducted an experiment to evaluate the effect of sulphur rate (0, 20, 40 and 60 kg/ha) on three Indian mustard cultivars (Varuna, PNV-16, Rohini and Pusa Bahar), where sulphur used as gypsum into the soil one month before sowing. Pusa Bahar and Rohini recorded the highest oil contents, when fertilized with increased in sulphur rate up to 40 kg/ha only.

Singh *et al.* (2002b) carried out an experiment on Indian mustard (*Brassica juncea*) genotypes Varuna (Type 54), PBM 16, Rohini and Pusa bahar in relation to S application (0, 20, 40 and 60 kg/ha). Oil content and its production were also increased significantly with the application of 20 and 40 kg S/ ha over control.

Mondal (2000) carried out a field experiment on *Brassica campestris* cv, Kos-1 and was applied 0-40 kg S and 0-7.5 kg B/ha. Oil and protein contents increased by sulphur application and protein were also increased by boron.

Singh *et al.* (2000) observed the response of 8 improved strains of *Brassica spp.* to S levels (0, 15, 30 and 45 kg/ha) and concluded that application of S up to 45 kg/ha significantly increased the oil content compared to its lower levels.

Dubey *et al.* (1994) revealed a field experiment on irrigated *B. juncea* cv. Varuna was provided 0, 10, 20, 30, 40 or 50 kg S/ha. Seed oil content increased with the increasing rate of S application

2.2.14 Oil yield

Behera *et al.* (2003) conducted a field experiments to evaluate the response of cultivars (Sanjukta, Asceh and Varuna) to plant population levels (222 000, 148 000 and 111 000/ha) and sulfur levels (0, 10, 20 and 30 kg/ha) on yield, oil and protein content of rainfed Indian mustard. They observed significant increase of oil yield up to 20 kg S/ha.

Praskash *et al.* (2002) conducted an experiment to evaluate the effect of sulphur rate (0, 20, 40 and 60 kg/ha) on three Indian mustard cultivars, where sulphur used as gypsum into the soil one month before sowing. Pusa Bahar and Rohini recorded the highest oil yield, when fertilized with increased in sulphur rate up to 40 kg/ha only.

Ali *et al.* (1996) reported that oil yield of rapeseed significantly influenced with sulphur doses. They applied 4 levels of sulphur viz. 0, 10, 20 and 30 kg /ha and obtained maximum oil yield (510.31 kg/ha) with the application 30 kg S/ha.

Deekshitulu *et al.* (1998) observed that oil yield of mustard was increased with the increasing rates of S up to 50 kg/ha.

Chapter 3

Materials and Methods

Chapter 3

MATERIALS AND METHODS

The experiment was undertaken to examine the response of nitrogen and sulphur on yield attributes and yield of newly developed rapeseed line (SAU-C-F_7).

3.1 Location

The experiment was carried out during rabi season (October to February) of 2004-05, at Agronomy field laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2 Site selection

The experimental field was located at $90^0 22'$ E longitude and $23^0 41'$ N latitude at an altitude of 8.6 meters above the sea level. The land was in Agro-ecological region of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The soil was sandy loam in texture having pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix i.

3.3 Climate

Cold temperature and minimum rainfall is the main feature of the rabi season. The monthly total rainfall, average sunshine hour, temperature during the study period (October to February) are shown in Appendix ii.

3.4 Variety

SAU-C-F_7 (a newly developed high yielding improved line of rapeseed, developed by the Sher-e-Bangla Agricultural University; Dhaka-1207; not yet released) was used in the experiment as a planting material. The seed was collected from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207. Before sowing, germination test was carried out in the laboratory and percentage of germination was over 95%.

3.5 Lay out of the experiment

The experiment was laid out in a split plot design with three replications. Nitrogen treatments applied in main plot and sulphur treatments applied in sub plot. There were 16 fertilizer treatments for SAU-C-F_7 line of rapeseed and total numbers of experimental units were 16×3=48. The size of each plot was 3m×4m=12 m^2. The replications were separated from one another by 1 m. The distance between plots was 0.5m.

3.6 Fertilizer treatments

There were 16 fertilizer treatments in the experiment for SAU-C-F_7. The standard rate of P_2O_5 @ 82 kg/ha, K_2O @ 51 kg/ha and zinc oxide 5 kg/ha for other rapeseed varieties were applied to all the plots (Mondal and Wahhab, 2001). There were four levels of each N (0, 40, 80 and 120 kg/ha) and S (0, 30, 60 and 90 kg/ha).

Treatments:

Factor A: Levels of nitrogen (N kg/ha): 4

N_1 = 0 (control)

N_2 = 40

N_3 = 80

N_4 = 120

Factor B: Levels of sulphur (S kg/ha): 4

S_1 = 0 (control)

S_2 = 30

S_3 = 60

S_4 = 90

3.7 Details of the field operations

The particulars of cultural operations carried out during the experimentation are presented below.

3.7.1 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought into desirable fine tilth and leveled by four of ploughing operations followed by repeated laddering. The land was fallow, so the weeds of fallow land were cleaned properly. The final ploughing and land preparation were done on October 25, 2004. The plots were laid out in the field on October 28, 2004.

3.7.2 Application of fertilizer

The amounts of fertilizer in the forms of urea, triple super phosphate, muriate of potash, gypsum and zinc oxide required per plot were calculated from fertilizer doses. Half of urea and gypsum as per treatment were top dressed after 30 days of sowing and rest of half dose of urea and gypsum and entire quantity of TSP, MP and Zinc oxide were applied during final land preparation.

3.7.3 Sowing and seed rate

Sowing was done in rows 30 cm apart and in row seeds were sown continuously. Seeds at the rate of 9 kg/ha were used and sown on good tilth condition of soil to conserve moisture, which ensured satisfactory germination of seeds. After sowing; the seeds were covered with the soil and slightly pressed by hand. Plant populations were kept 60 per square meter through maintaining plant to plant distance 5 cm in rows.

3.7.4 Thinning and weeding

The optimum plant population was maintained by thinning 15 days after sowing. At final thinning plant spacing within rows was as kept 5 cm. Thinning was done in the entire plots with special care as to maintain a constant plant population in the entire plot. One weeding with khurpi was given 25 days after sowing.

3.7.5 Irrigation

Two irrigations were given as per requirements. First irrigation was given immediate after topdressing and second irrigation were applied 60 days after sowing. After irrigation all the plots were spaded uniformly and carefully to conserve the moisture.

3.7.6 Pest management and plant protection

As a precaution of the attack of aphid, Malathion 57 EC @ 2 ml per litre of water was applied once at 50 DAS.

3.7.7 Harvesting and threshing

When 80% of the siliquae in terminal raceme turned golden yellow in colour, crops were harvested. The crop maturity varied with fertilizer treatments. Samples were collected from different places of each plot leaving undisturbed one meter square in the centre. After collecting sample plants, harvesting was started on February 10 and completed on February 20, 2005. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.7.8 Drying and weighing

The seeds thus collected were dried into 6-8 % moisture contents. Dried seeds and stovers (Oven dry basis) of each plot was weighed and subsequently converted into yield t/ha.

3.8 Collection of experimental data

For the convenient of collecting data, ten plants per plot were randomly selected and tagged for recording various yield contributing characters and yield. But for estimation of total dry matter, five plants per plot for each time were selected at different growth stages of plant.

3.8.1 Plant height (cm)

At different stages of crop growth for all treatments the height of five randomly selected plants were measured from the base to the tip of the plant and mean plant height was determined. The plant height was measured at 30, 45, 60, 75 DAS and at harvest.

3.8.2 Dry matter (g/plant)

Dry matter at 30, 45, 60 and 75 days after sowing and at harvest observed and average was recorded.

3.8.3 Crop growth rate (CGR)

The dry matter accumulation of the crop per unit land area in unit of time is referred to crop growth rate (CGR), expressed as $g/m^2/day$. The mean CGR values for the crop during the sampling intervals have been computed by using the formula of Brown, (1984).

$$CGR = \frac{W_2 - W_1}{SA(t_2 - t_1)} \; g/m^2/day$$

where,

SA= Ground area occupied by the plant at each sampling. W_1 and W_2 are the total dry matter production in grams at the time t_1 and t_2 respectively. CGR values were calculated for the periods of 30-45, 45-60, 60-75 and 75 DAS to harvest (crop duration).

3.8.4 Relative growth rate (RGR)

The relative growth rate at which a plant incorporates new material into its sink is measured by Relative Growth Rate of dry matter accumulation and is expressed in g/g/day. Relative growth rate was worked out by following the formula of Radford (1967).

$$RGR = \frac{L_nW_2 - L_nW_1}{T_2 - T_1} \; g/g/day$$

where,

W_1 and W_2 is initial and final dry matter weight at the time T_1 and T_2 respectively. L_n refers to Natural Logarithm.

3.8.5 Number of primary branches per plant

The primary branches were counted from the ten tagged plants in each plot at harvest and average was taken.

3.8.6 Number of secondary branches per plant

The ten tagged plants in each plot were also used for counting the number of secondary branches at harvest. The secondary branches which borned at least one siliqua, were termed productive secondary branches and these were counted at harvest and expressed on per plant basis.

3.8.7 Length of main inflorescence (cm)

The ten tagged plant in each plot were also used for measure the length of main inflorescence. The main axis length represents the section of plant from point of initiation of first siliqua of most branches is termed as main inflorescence. These lengths were measured at harvest and expressed on main inflorescence basis.

3.8.8 Number of siliquae in the main inflorescence

Numbers of siliquae for each main inflorescence of ten tagged plants were counted at harvest.

3.8.9 Number of siliquae per plant

The number of siliquae from ten tagged plants were counted after the harvest and expressed on per plant basis.

3.8.10 Length of siliqua (cm)

Length of ten siliquae were randomly collected from the ten tagged plants and average length per siliqua was calculated.

3.8.11 Number of seeds per siliqua

At the time of counting the number of siliquae, all the siliquae of ten plants were thoroughly mixed and twenty siliquae were taken from this lot for counting the seeds and was made average to find out the number of seeds per siliqua.

3.8.12 Weight of 1000 seeds (g)

A composite sample was taken from the yield of ten tagged plants. 1000 seeds of each plot were counted and weighed with a digital electric balance. The 1000 seed weight was recorded in g.

3.8.13 Seed yield (t/ha)

$1m \times 1m = 1m^2$ areas were selected in middle points of each plot for recording seed yield per hectare. The total produce from the net area of each plot was cleaned and weighted and computed the seed yield in ton per hectare.

3.8.14 Stover yield (t/ha)

Before threshing, the total biological yield from the net area was recorded. Later, the stover per net area of each plot was obtained by deducting the seed yield per plot from the biological yield (seed+stover) per plot and used to compute the stover yield in t/ha.

3.8.15 Harvest index (%)

Harvest index was calculated by dividing the economic (seed) yield from the net plot by the total biological yield (seed+stover) from the same area (Donald, 1963) and multiplying by 100.

$$\text{Harvest index} = \frac{\text{Seed yield (t/ha)}}{\text{Biological yield (t/ha)}} \times 100$$

3.8.16 Oil content (%)

The oil content of seed was determined by Soxhlet method (Hughes, 1965) in percentage (%). This was done in Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701.

3.8.17 Oil yield (t/ha)

Yield of oil was calculated from the percent oil in the seed samples multiplied by seed yield (t/ha) and expressed in t/ha.

3.9 Soil sampling

Three composite soil samples were collected within 15 cm depth of soil profile, taking one from each block at first ploughing. Each composite sample was a mixture of 10 samples obtained from ten different spots in each block. Collected samples were air dried and ground to pass a 10-mesh sieve and stored in polythene bags for laboratory analysis. Soil analysis was done at Soil Resources and Development Institute (SRDI).

3.10 Data analysis

The collected data were complied and analyzed by split plot design to find out the statistical significance of experimental results. The collected data were analyzed by MSTAT software (Russell, 1986). The means for all recorded data were calculated and the analyses of variance for all characters were performed. The mean differences were evaluated also by least significant difference test.

Chapter 4
Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. Experimental results pertaining to the effects of different treatments viz. nitrogen and sulphur levels on SAU-C-F_7 rapeseed line are presented here. The yield and yield component included plant height (cm), total dry matter per plant, crop growth rate (CGR), relative growth rate (RGR), number of primary branches per plant, number of secondary branches per plant, length of main inflorescence, number of siliquae in main inflorescence, number of siliquae per plant, siliqua length, number of seeds per siliqua, 1000 seed weight, seed yield per plant, seed yield/ha, stover yield and harvest index have been presented in different tables and figures. The analyses of variance in respect of all the characters under studied have been presented in Appendix iii-vi. The detailed experimental findings have been explained and discussed below.

4.1 Plant height (cm)

4.1.1 Effect of nitrogen

Each successive increase of nitrogen increased the plant height significantly. It was observed from Table 1 that plant height varies due to variation of nitrogen at different growth stages. Application of 80 kg N/ha produced the tallest plant height (18.94 cm, 66.39 cm, 94.02 cm, 90.16 cm and 91.87 cm at 30, 40, 60, 75 DAS and at harvest, respectively) that was statistically similar with 120 kg/ha (19.73 cm, 63.44 cm, 95.76 cm, 100.25 cm and 94.62 cm at 30, 45, 60, 75 DAS and at harvest respectively) followed by 40 kg N/ha and the shortest plant height were produced (14.55 cm, 47.13 cm, 74.14 cm, 77.33 cm and 80.66 cm at 30, 45, 60, 75 DAS and at harvest, respectively) due to control treatment. These findings are an agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003), Singh *et al.* (2002c), Tarafder and Mondal (1990) obtained tallest plant height of mustard with the of application N at 120 kg/ha. Patel (1998), Shamsuddin *et al.* (1987), Gurjar and Chauhan (1997), Thakuria and Gogoi (1996) revealed taller plant height at 140 kg N/ha which was identical with that of 105 kg N/ha. Maximum plant height recorded at 100 kg N/ha reported by Patel *et al.* (2004).

Table 1 Plant height (cm) of rapeseed at different DAS as affected by different nitrogen doses

Treatments	Days after sowing (DAS)				
	30	45	60	75	At harvest
N_1	14.55	47.13	74.14	77.33	80.66
N_2	16.44	59.31	87.47	90.24	87.84
N_3	18.94	66.39	94.02	90.16	91.87
N_4	19.73	63.44	95.76	100.25	94.62
LSD (0.05)	1.80	2.02	3.44	1.77	5.60
CV %	6.05	4.64	4.61	4.35	4.65

4.1.2 Effect of sulphur

Application of sulphur had no significant effect on plant height at all growth stages except 45 and 75 days after sowing. It was revealed from Table 2 that the effect was perceptible up to 30 kg S/ha only. Application of 60 and 90 kg S/ha did not significantly increase plant height over control. Some cases plant height increased at 45 and 75 DAS with 60 and 90 kg S/ha of sulphur. At 30, 60, and at harvest plant height did not differ significantly due to application of S doses. But plant height was higher at 45 and 75 days after sowing. These results suggested that sulphur rate at 30 kg/ha performed better for plant height of rapeseed, above and below this level did not affect properly for this character. These findings were supported by Raut *et al.* (2003), Chandel *et al.* (2002), Chaubey *et al.* (2001), Sarkar *et al.* (1993), Pradhan and Sarkar (1993), Kanpara *et al.* (1992), Saran and Giri (1990) who obtained significantly highest plant height of mustard with the application of 30 kg S/ha. But Birbal *et al.* (2004), Jat and Khangarot (2003), Singh *et al.* (1998), Patel and Shelke (1998), Mohan and Sharma (1992) obtained tallest plant height at the sulphur application rate of 60 and 90 kg/ha.

Table 2 Plant height (cm) of rapeseed at different DAS as affected by different sulphur doses

Treatments	Days after sowing (DAS)				
	30	45	60	75	At harvest
S_1	16.88	55.53	86.71	87.85	89.21
S_2	17.49	61.91	88.27	94.09	88.72
S_3	17.42	59.76	83.30	92.42	91.87
S_4	17.87	59.07	87.11	89.56	94.62
LSD (0.05)	NS	1.31	NS	1.03	NS
CV (%)	6.05	4.64	4.61	4.35	4.65

4.1.3 Interaction effect of nitrogen and sulphur

It was found from Fig. 1 that the interaction of 120 kg N/ha with 30 kg S/ha gave the tallest plant height viz. 21.73 cm, 66.07 cm, 99.49 cm, 104.0 cm and 100.28 cm at 30, 45, 60, 75 DAS and at harvest respectively except 80 kg N/ha in combination with 30 kg S/ha gave the plant height (69.74 cm) only at 45 days after sowing. Plant growth rate was higher during 45 and 60 days after sowing. Control treatment of N and S gave the shortest plant height (13.80 cm, 45.75 cm, 68.85 cm, 74.27 cm and 74.49 cm at 30, 45, 60, 75 DAS and at harvest respectively). All the interaction treatments showed more or less similar values with each other. Plant height was significantly affected by the interaction between N and S with the rate of 120 kg N/ha and 30 kg S/ha. Ahmed *et al.* (1998), Abdin *et al.* (2003), Singh *et al.* (1996) obtained significantly taller plant height by applying N rates up to 120 kg/ha and S rates up to 30 kg/ha.

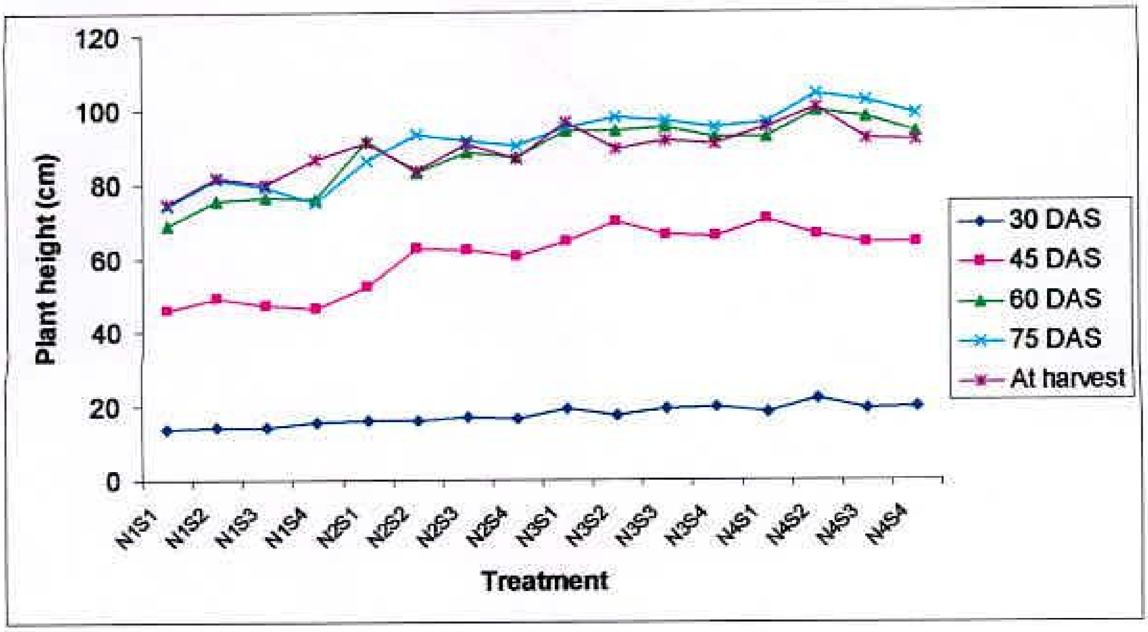

Fig. 1 Plant height of rapeseed at different DAS as affected by interaction between nitrogen and sulphur

4.2 Total dry matter (g/plant)

4.2.1 Effect of nitrogen

The dry matter per plant at 30, 45, 60, 75 DAS and at harvest was higher due to nitrogen application. Each level of nitrogen significantly increased dry matter over preceding level (Table 3). Nitrogen at 120 kg/ha produced the highest dry matter per plant (0.97 g, 3.94 g, 9.87 g, 11.30 g and 11.75 g at 30, 45, 60, 75 DAS and at harvest respectively) than 40 and 80 kg/ha nitrogen application and also control. Bharati and Prasad (2003),Vyas *et al.* (1995), Singh *et al.* (2002c), Shukla *et al.* (2002b), Murtaza and Paul (1989), Mondal and Gaffer (1983) also obtained similar respond at the rate of 120 kg N/ha on dry matter production.

Table 3 Dry matter (g/plant) of rapeseed at DAS as affected by different nitrogen doses

Treatments	Days after sowing (DAS)				
	30	45	60	75	At harvest
N_1	0.35	1.36	3.58	4.69	5.67
N_2	0.54	2.59	6.10	7.82	7.45
N_3	0.76	3.27	8.70	10.67	9.53
N_4	0.97	3.94	9.87	11.30	11.75
LSD (0.05)	0.04	0.10	0.46	0.14	0.66
CV (%)	6.49	6.28	6.31	4.37	6.06

4.2.2 Effect of sulphur

Sulphur fertilization exhibited significant difference on dry matter production per plant at 30, 45, 60, 75 DAS. However, there was no significant effect on dry matter production of rapeseed at harvest. Application of 30 kg S/ha recorded significantly higher dry matter production per plant (0.77 g, 3.12 g, 7.23 g, and 9.57 g per plant at 30, 45, 60, 75 DAS respectively) over control (Table 4). At harvest, application of S levels did not differ significantly the dry matter production per plant. Raut *et al.* (1999), Khan *et al.* (1999) were also observed same results. But, Ram *et al.* (1999), Patel and Shelke (1998) obtained highest dry matter production per plant at the rate of S application up to 60 kg/ha.

Table 4 Dry matter of rapeseed at different DAS as affected by different sulphur doses

Treatments	Days after sowing (DAS)				
	30	45	60	75	At harvest
S_1	0.55	2.52	6.64	7.53	8.77
S_2	0.77	3.12	7.23	9.57	8.50
S_3	0.68	2.85	7.26	8.95	8.41
S_4	0.62	2.66	7.12	8.44	8.72
LSD (0.05)	0.03	0.14	0.37	0.31	NS
CV (%)	6.49	6.28	6.31	4.37	6.06

4.2.3 Interaction effect of nitrogen and sulphur

It was revealed from Fig. 3 that the combined effect of 120 kg N/ha with 30 kg S/ha gave significantly the highest dry matter per plant at all growth stages (1.23, 4.56, 11.91 g per plant at 30, 45, 60, 75 and at harvest, respectively). Control treatment of nitrogen and sulphur gave the lowest dry matter production (0.31, 1.27, 2.81, 4.13 and 4.25 g per plant at 30, 45, 60 and 75 and at harvest). The result is in confirm attain with that of Tomar *et al.* (1996), Kachroo and Kumar (1999), Abdin *et al.* (2003) who had observed that N at the rate of 120 kg/ha and S at the rate of 30 kg/ha increased the dry matter production per plant.

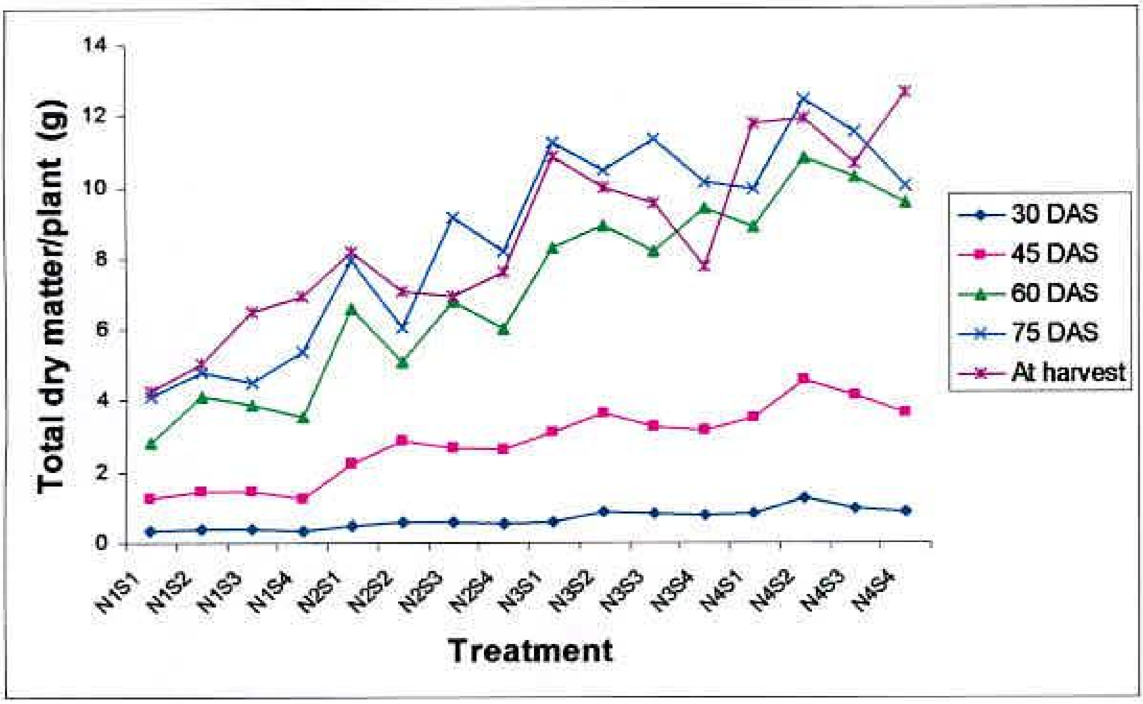

Fig. 2 Total dry matter per plant of rapeseed at different DAS as affected by different combination of nitrogen and sulphur doses

4.3 Crop growth rate (CGR)

4.3.1 Effect of nitrogen

Crop growth rate significantly affected by the levels of nitrogen up to 45 to 60 DAS and declined at later stages. At early stage, successive increase in the rate of nitrogen up to

120 kg/ha progressively increased CGR values (7.907 and 15.810 g/m^2/day at 30-45 and 45-60 DAS) of growth as compared to control (Table 5). But 80 kg N/ha had significant effect on CGR values at 60-75 DAS. Crop growth rate was maximum in the beginning, increased with the advancement of crop growth, and became negative at 75 DAS to harvest irrespective to nitrogen treatments. Ali *et al.* (1996) reported that CGR values significantly increased at 120 kg N/ha up 55-77 DAS and decline at later stage.

Table 5 Crop growth rate (CGR) of rapeseed at different DAS as affected by different nitrogen doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
N_1	2.660	5.947	2.947	2.617
N_2	5.748	9.372	4.572	-0.990
N_3	6.702	14.460	5.573	-3.365
N_4	7.907	15.810	2.967	2.102
LSD (0.05)	0.009	0.009	0.009	0.113
CV (%)	0.14	0.11	0.29	142.62

4.3.2 Effect of sulphur

Application of sulphur progressively increased the CGR values up to 45 to 60 DAS. Higher CGR values observed at 45 to 60 days after sowing (10.98, 10.96, 11.76 and 11.89 g/m^2/day at 0, 30, 60 and 90 kg/ha). Irrespective of S treatment CGR become negative at 75 DAS (Table 6). Ali *et al.* (1996) also reported that sulphur progressively increased the CGR values up to 45 to 60 DAS and concluded that irrespective of S levels CGR gave become negative at 75 DAS.

Table 6 Crop growth rate (CGR) of rapeseed at different DAS as affected by different sulphur doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
S_1	5.529	10.98	4.445	1.221
S_2	6.257	10.96	3.185	0.200
S_3	5.799	11.76	4.940	-1.907
S_4	5.434	11.89	3.490	0.850
LSD (0.05)	0.008	0.008	0.008	0.109
CV (%)	0.14	0.11	0.29	142.62

4.3.3 Interaction effect of Nitrogen and sulphur

All the combination of nitrogen and sulphur showed significant differences on CGR values at all growth stages. Interactive effect of nitrogen and sulphur were different at all growth stages. Higher CGR values found at 45 to 60 DAS due to 80 kg N/ha in combination with 90 kg S/ha (Table 7).

Table 7 Crop growth rate (CGR) of rapeseed at different DAS as affected by interaction between nitrogen and sulphur doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
N_1S_1	2.53	4.11	3.53	0.30
N_1S_2	2.82	7.13	1.74	0.61
N_1S_3	2.88	6.41	1.66	5.42
N_1S_4	2.39	6.14	4.86	4.14
N_2S_1	5.81	11.61	3.56	0.68
N_2S_2	6.02	5.90	2.58	2.78
N_2S_3	5.57	10.98	6.29	-5.84
N_2S_4	5.59	9.00	5.86	-1.58
N_3S_1	6.69	13.79	7.85	-0.98
N_3S_2	7.31	14.19	4.02	-1.18
N_3S_3	6.44	13.21	8.45	-4.86
N_3S_4	6.37	16.67	1.97	-6.44
N_4S_1	7.08	14.42	2.84	4.88
N_4S_2	8.87	16.63	4.40	-1.41
N_4S_3	8.30	16.44	3.36	-2.35
N_4S_4	7.38	15.76	1.27	7.28
LSD (0.05)	0.016	0.016	0.010	0.219
CV (%)	0.14 %	0.11 %	0.29 %	142.62 %

4.4 Relative growth rate (RGR)

4.4.1 Effect of nitrogen

Nitrogen application influenced RGR significantly at 30- 45, 60-75 DAS and 75 to harvest and showed no significant response at 45-60 DAS (Table 8). At early stage of growth, RGR was maximum and gradually declined with the advancement of crop age and became negative at later stage. At respective growth stages, RGR values became negative at 75 days after sowing. Kasa and Kondra (1986) reported higher RGR value at flowering, which resulted higher seed yield of *Brassica* species.

Table 8 Relative growth rate (RGR) of rapeseed at different DAS as affected by different nitrogen doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
N_1	0.0885	0.0642	0.0175	0.0107
N_2	0.1032	0.0567	0.0220	-0.0027
N_3	0.0975	0.0645	0.0140	-0.0082
N_4	0.0930	0.0610	0.0065	-0.0010
LSD (0.05)	0.009	0.009	0.009	0.009
CV (%)	1.00	1.64	76.44	-322.21

4.4.2 Effect of sulphur

Application of sulphur showed significant response on RGR values at 45-60 DAS. However, there was no significant difference on RGR values at 30-45, 60-75 and 75 to harvest. RGR declined gradually and became negative at 75 days after sowing (Table 9). Ali *et al.* (1996) also observed maximum RGR value at early stage of growth. However, RGR decline gradually at later stages.

Table 9 Relative growth rate (RGR) of rapeseed at different DAS as affected by different sulphur doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
S_1	0.0992	0.0630	0.0160	-0.0024
S_2	0.0927	0.0560	0.0164	0.0021
S_3	0.0947	0.0622	0.0140	-0.0027
S_4	0.0955	0.0652	0.0137	0.0017
LSD (0.05)	0.008	0.008	0.008	0.008
CV (%)	1.00	1.64	76.44	-322.21

4.4.3 Interaction effect of nitrogen and sulphur

It was also observed that treatment combination of nitrogen and sulphur had significant effect on RGR values at all stages of growth. Interactive effect of N and S were almost more or less similar in RGR values (Table 10).

Table 10 Relative growth rate (RGR) of rapeseed at different DAS as affected by interaction between nitrogen and sulphur doses

Treatments	Days after sowing (DAS)			
	30 to 45	45 to 60	60 to 75	75 to harvest
N_1S_1	0.091	0.053	0.025	0.001
N_1S_2	0.086	0.069	0.009	0.003
N_1S_3	0.091	0.065	0.009	0.023
N_1S_4	0.086	0.070	0.027	0.016
N_2S_1	0.100	0.072	0.012	0.002
N_2S_2	0.104	0.038	0.037	0.010
N_2S_3	0.103	0.062	0.018	-0.018
N_2S_4	0.106	0.055	0.020	-0.005
N_3S_1	0.110	0.065	0.020	-0.002
N_3S_2	0.095	0.060	0.010	-0.002
N_3S_3	0.091	0.061	0.021	-0.011
N_3S_4	0.094	0.072	0.005	-0.018
N_4S_1	0.096	0.062	0.007	-0.010
N_4S_2	0.086	0.057	0.009	-0.002
N_4S_3	0.094	0.061	0.007	-0.005
N_4S_4	0.096	0.064	0.003	0.014
LSD (0.05)	0.016	0.016	0.016	0.016
CV (%)	1.00	1.64	76.44	-322.21

4.5 Number of primary branches per plant

4.5.1 Effect of nitrogen

Nitrogen fertilizer had significant effect on primary branches per plant. The levels of nitrogen (80 and 120 kg/ha) produced higher number of primary branches over control (Fig. 3). Increasing rates of nitrogen increased the number of primary branches per plant and successive treatment differences were also significant. This findings were supported by Tripathi and Tripathi (2003), Ozer (2003), Singh *et al.* (2003), Sharma and Jain (2002), Singh *et al.* (2002c), Shukla *et al.* (2002b), Patel (1998), Tarafder and Mondal (1990), Shamsuddin *et al.* (1987), Mondal and Gaffer (1983) who obtained significantly higher number of primary branches per plant by applying nitrogen up to 120 kg/ha.

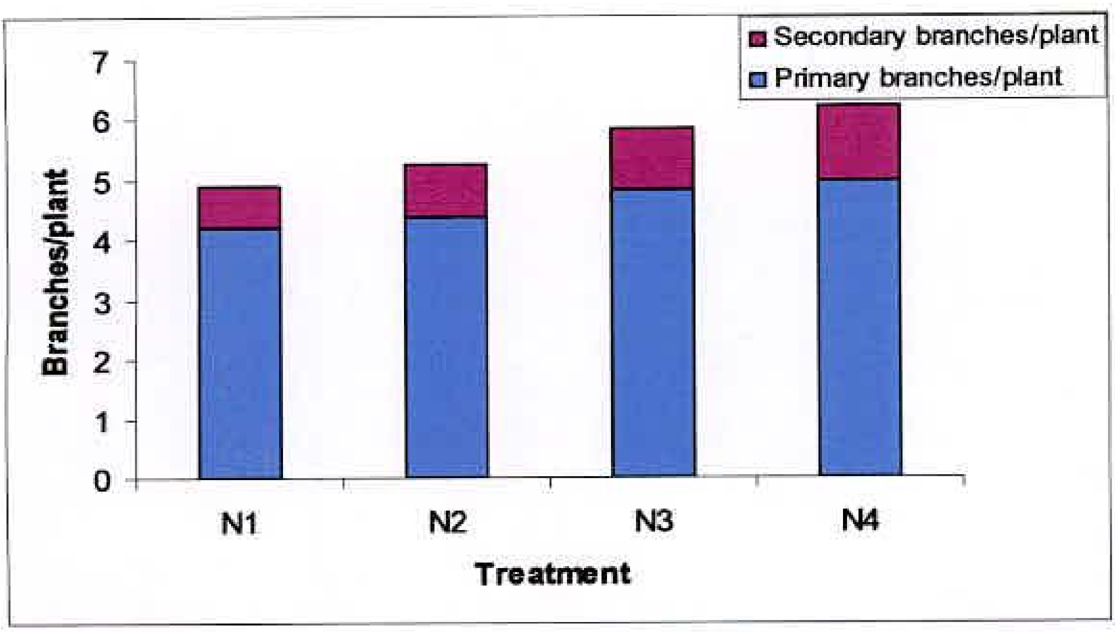

Fig. 3 Number of primary and secondary branches per plant at harvest as affected by different nitrogen doses

4.5.2 Effect of sulphur

From Fig. 4, it was observed that the differences in the number of primary branches per plant due to 90 kg S/ha was significant. Jat and Khangarot (2003), Singh *et al.* (1998) obtained significantly higher number of primary branches per plant by applying sulphur rates up to 90 kg/ha. But Saran and Giri (1990), Birbal *et al.* (2004), Mahapatra *et al.* (1999), Ram *et al.* (1999) and Singh *et al.* (2002c) reported higher number of primary branches by applying sulphur up to 60 kg/ha.

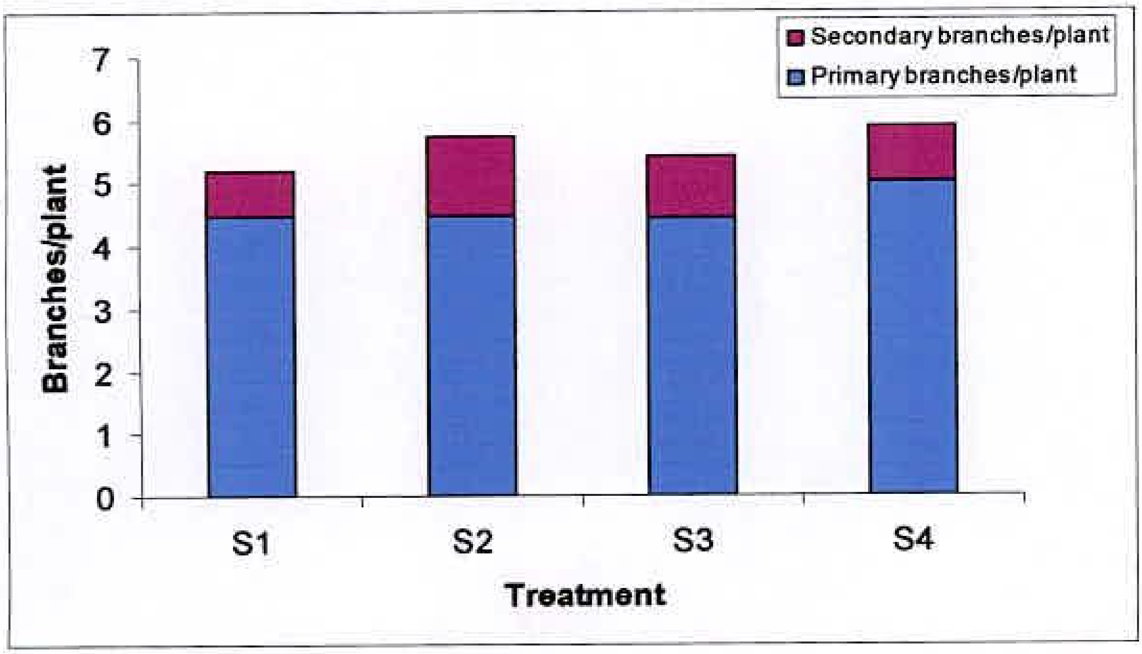

Fig. 4 Number of primary and secondary branches per plant at harvest as affected by different sulphur doses

4.5.3 Interaction effect of nitrogen and sulphur

It was observed that combined effect of nitrogen and sulphur did not show any significant difference to produce primary branches per plant. All the effect is similar to produce primary branches per plant. The application rate of N 80 kg/ha and S 90 kg/ha produced higher number of primary branches/plant (5.33) (Fig. 5). Tomar *et al.* (1996) obtained similar results.

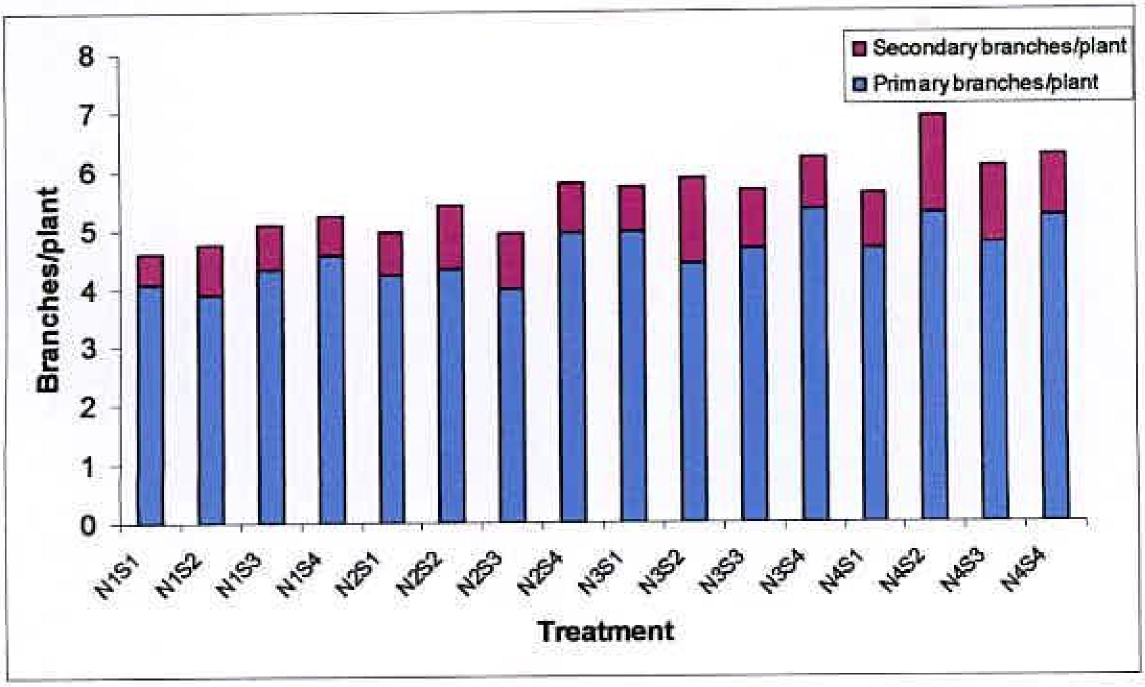

Fig. 5 Interaction effect of nitrogen and sulphur on the production of primary and secondary branches per plant

4.6 Number of secondary branches per plant

4.6.1 Effect of nitrogen

Nitrogen application favored to produce number of secondary branches per plant (Fig. 3). However, the significant increase was noted at the level of 120 kg N/ha compared to 40, 80 kg N/ha and control. Singh *et al.* (2003) and Singh *et al.* (2002c) obtained increased number of the secondary branches per plant with nitrogen at 120 kg/ha. But Sharma and Jain (2002) reported higher secondary branches per plant at the rate of 80 kg N/ha.

4.6.2 Effect of sulphur

The response of sulphur on the number of secondary branches was noted that sulphur level at 30 kg/ha produced significantly more number of secondary branches (1.25) than control (0.73) (Fig. 4). Above this S level did not show significant effect to produce secondary branches per plant. Raut *et al.* (2003) and Chandel *et al.* (2002) also obtained similar results that sulphur at the rate of 20 and 40 kg S/ha increased number of secondary branches per plant. But Ram *et al.* (1999) obtained higher number of secondary branches at the rate of sulphur 60 kg /ha.

4.6.3 Interaction effect of nitrogen and sulphur

The treatment combination of nitrogen and sulphur had significant effect on secondary branches per plant (Fig. 5). In the present work, it might be concluded that 120 kg N/ha and 30 kg S/ha produced maximum number of secondary branches per plant (1.63) and the lowest number of secondary branches/plant (0.53) were produced from the control treatment. Rathore and Monohar (1989) obtained significantly highest number of secondary branches per plant by applying nitrogen up to 120 kg/ha and sulphur up to 30 kg/ha.

4.7 Length of main inflorescence

4.7.1 Effect of nitrogen

Nitrogen fertilizer had significant effect on the length of main inflorescence. The rate of 80 kg and 120 kg N/ha showed significant effect on length of main inflorescence (37.17 cm 37.35 cm respectively) and control gave the lowest one (31.10 cm) (Table 11). However, the differences between 80 and 120 kg N/ha were not significant.

Table 11 Effect of nitrogen on yield attributes of rapeseed

Treatments (kg/ha)	Length of main inflorescence (cm)	No. of siliquae in main inflorescence	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	Weight of 1000 seeds (g)
N_1	31.10	21.23	48.44	4.99	20.06	2.54
N_2	35.13	26.02	67.43	5.06	19.85	2.60
N_3	37.17	27.89	83.27	5.17	21.14	2.88
N_4	37.35	29.86	91.50	5.08	20.57	2.65
LSD (0.05)	1.59	0.81	1.29	NS	NS	NS
CV %	3.38	4.32	4.57	4.10	5.24	5.18

4.7.2 Effect of sulphur

Table 12 reveals that sulphur fertilizer had significant effect on length of main inflorescence. The rate of sulphur at 30 kg/ha significantly increased the length of main inflorescence compared to 60 kg and 90 kg/ha and control. Sulphur at the rate of 30 kg/ha produced highest length of main inflorescence (37.18 cm) than control (32.77 cm) and 60 and 90 kg S/ha produced the main inflorescence of 35.74 and 35.05 cm respectively.

4.7.3 Interaction effect of nitrogen and sulphur

It was seen that the treatment combination of N and S at the rate 120 and 30 kg/ha produced the highest length of main inflorescence (39.68 cm) (Table 13) and it was also similar with the effect of 80 kg N and 30 kg S/ha. The control combination of N and S gave the lowest length (28.32 cm).

Table 12 Effect of sulphur on yield attributes of rapeseed

Treatment (kg/ha)	Length of main inflorescence (cm)	No. of siliquae in main inflorescence	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	Weight of 1000 seed (g)
S_1	32.77	24.74	65.11	5.04	20.45	2.67
S_2	37.18	27.59	82.39	5.09	20.33	2.64
S_3	35.74	26.80	74.19	5.04	20.08	2.66
S_4	35.05	25.87	68.95	5.11	20.75	2.71
LSD (0.05)	1.41	0.95	1.57	NS	NS	NS
CV %	3.38	4.32	4.57	4.10	5.24	5.18

4.8 Number of siliquae in main inflorescence

4.8.1 Effect of nitrogen

Application of N at 120 kg/ha significantly increased the number of siliquae in main inflorescence (29.86) over control (21.23) (Table 11). Application of 40 and 80 kg N/ha resulted to produce 26.02 and 27.89 siliquae, respectively in the main inflorescence.

4.8.2 Effect of sulphur

Application of 30 and 60 kg S/ha significantly increased the number of siliqua (27.59 and 26.80 siliqua respectively) over control (24.74). Above this level, S had no significance effect to increase the siliqua number in main inflorescence. However, the difference between 30 and 60 kg S/ha were not significant (Table 12).

Table 13 Interaction effect of nitrogen and sulphur on yield attributes of rapeseed

Treatments (interaction)	Length of main inflorescence (cm)	No. of siliquae in main inflorescence	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	Weight of 1000 seed(g)
N_1S_1	28.32	19.90	41.20	4.33	20.07	2.54
N_1S_2	32.86	22.60	55.87	4.14	21.07	2.48
N_1S_3	31.74	22.53	53.20	4.99	19.32	2.54
N_1S_4	31.46	19.90	43.50	4.88	19.80	2.62
N_2S_1	33.41	24.50	62.90	5.07	20.00	2.60
N_2S_2	36.60	27.70	70.73	4.99	18.98	2.58
N_2S_3	35.52	26.07	70.00	5.14	19.93	2.58
N_2S_4	34.97	25.80	66.07	5.02	20.48	2.62
N_3S_1	35.04	27.47	74.73	5.18	21.33	2.83
N_3S_2	39.58	28.67	99.60	5.04	20.30	2.66
N_3S_3	37.61	27.93	80.03	5.07	20.87	2.87
N_3S_4	36.45	27.50	78.70	5.39	22.05	2.88
N_4S_1	34.30	27.10	81.61	4.97	20.38	2.71
N_4S_2	39.68	31.40	103.40	5.21	20.98	2.66
N_4S_3	38.10	30.67	93.53	5.01	20.22	2.63
N_4S_4	37.30	30.27	87.53	5.15	20.69	2.63
LSD (0.05)	2.00	1.91	3.14	NS	NS	NS
CV %	3.38	4.32	4.57	4.10	5.24	5.18

4.8.3 Interaction of nitrogen and sulphur

It was also observed that treatment combination of nitrogen and sulphur had significant effect on number of siliquae in the main inflorescence. Nitrogen at the rate 120 kg with 30 kg S/ha produced maximum number of siliquae in the main inflorescence (31.40). Nitrogen at 120 kg with 60 and 90 kg S/ha produced almost similar number of siliquae in main inflorescence (30.67 and 30.27 respectively). Minimum numbers of siliqua in main inflorescence (19.90) were produced by control treatment (Table 13).

4.9 Number of siliquae per plant

4.9.1 Effect of nitrogen

Nitrogen fertilizer had significant effect on number of siliquae per plant. The rate of 120 kg N/ha showed highest number of siliquae per plant (91.50) and control treatment gave the lowest one (48.44) (Table 11). Similar result also obtained by Shukla *et al.* (2002b), Singh *et al.* (2003), Singh *et al* (2002c), Tarafder and Mondal (1990) and Shamsuddin *et al.* (1987). On the other hand, higher number of siliquae per plant obtained at the 80 kg N/ha by Khan *et al.* (2003), Sharma and Jain (2002), Patel (1998).

4.9.2 Effect of sulphur

The rate of 30 kg S/ha significantly increased the number of siliquae per plant (82.39) and control treatment gave the lowest number of siliquae per plant (65.11) (Table 12). Similar result was also found by Verma *et al* (2002), Sharawat *et al.* (2002), Chaubey *et al.* (2001) at this same sulphur level.

4.9.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur showed significant effect on number of siliquae per plant. The highest number of siliquae per plant (103.4) was produced with the interaction of 120 kg N and 30 kg S/ha. Nitrogen at the rate of 120 kg with 60 kg and 90 kg S/ha did not show significant difference to produce the number of siliquae per plant. Lowest number of siliquae per plant (41.20) was given by the combination (without N or S) (Table 13). Sharawat *et al* (2002) also obtained highest number of siliquae per plant, produced with the interaction of 120 kg N and 30 kg S/ha. Increased number of siliquae per plant were also observed with the interaction of 100 kg N with 25 kg S/ha recorded by Deekshitulu and Subbaiah (1997).

4.10 Length of siliqua (cm)

4.10.1 Effect of nitrogen

The level of nitrogen had no significant effect on the siliqua length. It was observed that 80 kg N/ha gave highest siliqua length (5.17 cm) and control gave the lowest one (4.99 cm) (Table 11). Singh (2002), Shukla *et al.* (2002b), Singh *et al.* (2002c) who reported the highest length of siliqua at the rate of 120 kg N/ha.

4.10.2 Effect of sulphur

Sulphur had also no significant effect on the siliqua length. It was observed that 90 kg S/ha gave the highest siliqua length (5.11 cm) and control gave the lowest siliqua length (5.04 cm) (Table 12). However, Verma *et al.* (2002) who obtained highest length of siliqua only up to 30 kg S/ha. Chaubey *et al.* (2001) also obtained higher length of siliqua at the rate of 30 kg S/ha. But Kumar *et al.* (2002) obtained higher number of siliqua at the rate of 60 kg S/ha. Mohan and Sharma (1992) reported the highest length of siliqua at 75 kg S/ha.

4.10.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur interaction had no significant effect on siliqua length. The combination of nitrogen and sulphur at the rate of 80 and 90 kg/ha produced the highest siliqua length (5.39 cm) and control gave the shortest siliqua (4.33 cm) (Table 13). Abdin *et al.* (2003) who also obtained similar results.

4.11 Number of seeds per siliqua

4.11.1 Effect of nitrogen

Nitrogen rates did not significantly influence the number of seeds per siliqua. The results were also similar at all levels of nitrogen. Applying nitrogen at the rate of 80 kg/ha gave highest number of seeds per siliqua (21.14) (Table 11). Some results showed significant effect on number of seed per siliqua that were obtained by Singh (2002), Shukla *et al.* (2002b), Tarafder and Mondal (1990), Mondal and Gaffer (1983) showed significant effect on number of seeds per siliqua nitrogen at rate of nitrogen of 120 kg/ha. Sharma and Jain (2002) obtained higher number of seeds per siliqua at the rate of 80 kg N/ha. Patel (1998) also obtained similar response of nitrogen on number of seeds per siliqua.

4.11.2 Effect of sulphur

The number seeds per siliqua did not differ significantly due to different levels of sulphur. All levels of S showed similar performance. Highest rate of sulphur (90 kg/ha) produced maximum number of seeds per siliqua (20.75) (Table 12). Jat and Khangarot (2003) also obtained significant number of seeds per siliqua at the same sulphur rate. But Birbal *et al.* (2004), Kumar *et al.* (2002), Saran and Giri (1990) observed higher number seed per siliqua at the sulphur application rate up to 60 kg/ha. Verma *et al.* (2002), Chaubey *et al.* (2001) obtained higher number of seeds per siliqua at the sulphur application rate up to 30 kg/ha.

4.11.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur interaction did not show significant effect on number of seeds per siliqua. Highest numbers of seeds per siliqua (22.05) were produced with the interaction of 80 kg N and with 90 kg S/ha (Table 13). Deekshitulu and Subbaiah (1997) obtained higher number of seed per siliqua at 100 kg N/ha in combination with 50 kg S/ha.

x 4.12 Weight of 1000 seeds (g)

4.12.1 Effect of nitrogen

Application of nitrogen at 40, 80 and 120 kg/ha did not significantly increased the 1000 seed weight over no nitrogen. All levels of nitrogen produce similar trends in increase of 1000 seed weight (Table 11). At the rate 80 kg N/ha produced maximum seed weight (2.88 g) and control treatment gave the lowest one (2.54 g). Sharma and Jain (2002) also obtained highest 1000 seed weight at 80 kg N/ha. But, Ozer (2003), Singh *et al.* (2002), Shukla *et al.* (2002b) and Shamsuddin *et al.* (1987) obtained highest 1000-seed weight N at120 kg/ha.

4.12.2 Effect of sulphur

Sulphur rate did not significantly influence 1000 seed weight. Applying sulphur at the rate of 90 kg/ha, 1000 seed weight increased up to 2.714 g (Table 12). Increasing rates of sulphur increased 1000-seed weight gradually and successive difference of treatments were not significant. Jat and Khangarot (2003) showed that the application of 90 kg S/ha significantly enhanced 1000 seed weight. Mohan and Sharma (1992) reported that 1000-seed weight significantly increased at sulphur rate 75 kg/ha. Highest 1000 seed weight obtained by Birbal *et al.* (2004), Kumar *et al.* (2000) and Saran and Giri (1990) at the rate 60 kg S/ha. Chaubey *et al.* (2001) obtained maximum 1000 seed weight S at 30 kg/ha.

4.12.3 Interaction effect of nitrogen and sulphur

It was also observed that treatment combination of nitrogen and sulphur had no significant effect on 1000 seed weight (Table 13). The 1000 seed weight increased with the increasing levels of nitrogen and sulphur reported by Sharawat *et al.* (2002), Singh *et al.* (1996) and Deekshitulu and Subbaiah (1997).

4.13 Seed yield (t/ha)

4.13.1 Effect of nitrogen

The different rate of nitrogen significantly increased seed yield per hectare. The rate of nitrogen at 120 kg/ha significantly produced highest seed yield (2.37 t/ha) over 40 kg/ha (1.14 t/ha) and 80 kg N/ha (1.76) and control (0.64 t/ha) (Table 14). Seed yield decreased with the decreasing rates of nitrogen fertilizer. The higher seed yield/ha was also obtained with same nitrogen rate reported by Singh and Prasad (2003), Singh *et al.* (2003), Shukla *et al.* (2002b), Singh (2002), Shukla *et al.* (2002a), Singh *et al.* (2002c), Shukla and Kumar (1997), Tuteja *et al.* (1996), Shamsuddin *et al.* (1987). Some cases highest seed yield /ha obtained by Singh (2004), Sharma and Jain (2002), Ghosh *et al.* (2001), Khan *et al.* (2003), Singh *et al.* (1998), Thakuria and Gogoi (1996) at the rate of nitrogen application at 80 kg/ha.

Table 14 Effect of nitrogen on seed yield, stover yield, harvest index (%), oil content (%) and oil yield of rapeseed

Treatments	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Oil content (%)	Oil yield (t/ha)
N_1	0.64	1.82	25.10	41.95	0.27
N_2	1.14	2.81	29.95	41.86	0.48
N_3	1.76	3.32	35.47	41.86	0.73
N_4	2.37	4.09	38.72	41.81	0.99
LSD (0.05)	0.10	0.28	1.16	NS	0.009
CV %	3.85	6.66	3.15	0.64	0.46

4.13.2 Effect of sulphur

Application of sulphur at 30 kg/ha significantly increased the seed yield (1.66 t/ha) over all other doses and no sulphur application (Table 15) and above that level, sulphur did not differ seed yield significantly. Similar results were also observed by Verma *et al.* (2002), Patel and Shelke (1998), Sarkar *et al.* (1993), Dubey and Khan (1991), Saran and Giri (1990), Singh and Gangasaran (1987) at the same sulphur fertilization. Hidyatullah *et al.* (2004), Raut *et al* (2003), Singh *et al.* (2002b), Khan *et al.* (1999), Khurana *et al.* (1998), Pradhan and Sarkar (1993) were observed higher yield at 20 kg S/ha. Application of 40 and 60 kg S/ha gave significantly higher seed yield obtain by Birbal *et al.* (2004), Misra (2003), Prakash *et al.* (2002), Singh *et al.* (2002b), Chandel *et al.* (2002), Kumar *et al.* (2001), Miah *et al.* (2001), Singh *et al.* (2000), Kumar *et al.* (2002), Raut *et al.* (1999), Mahapatra *et al.* (1999), Jat and Khangarot (2003), Ram *et al.* (1999), Ahmed *et al.* (1998), Zhao *et al.* (1997), Jaggi and Sharma (1997).

Table 15 Effect of sulphur on seed yield, stover yield, harvest index (%), oil content (%) and oil yield of rapeseed

Treatments S kg/ha	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Oil content (%)	Oil yield (t/ha)
S_1	1.29	2.68	29.08	40.47	0.52
S_2	1.66	3.32	35.23	41.45	0.68
S_3	1.57	3.15	33.13	42.45	0.66
S_4	1.39	2.89	31.82	43.12	0.60
LSD (0.05)	0.04	0.21	0.95	0.21	0.008
CV %	3.85	6.66	3.15	0.64	0.46

Table 16 Interaction effect of nitrogen and sulphur on seed yield, stover yield, harvest index (%), oil content (%) and oil yield of rapeseed

Interaction	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Oil content (%)	Oil yield (t/ha)
N_1S_1	0.42	1.68	19.90	40.56	0.17
N_1S_2	0.83	1.93	28.51	41.60	0.34
N_1S_3	0.75	1.87	26.31	42.45	0.32
N_1S_4	0.56	1.82	25.67	43.19	0.24
N_2S_1	0.93	2.37	27.60	40.16	0.37
N_2S_2	1.32	3.22	33.10	41.31	0.54
N_2S_3	1.28	3.11	29.90	42.42	0.54
N_2S_4	1.05	2.53	29.20	43.24	0.45
N_3S_1	1.63	3.00	33.70	40.37	0.66
N_3S_2	1.91	3.60	37.70	41.34	0.78
N_3S_3	1.80	3.50	35.80	42.54	0.76
N_3S_4	1.70	3.17	34.70	43.18	0.73
N_4S_1	2.20	3.67	35.10	40.47	0.89
N_4S_2	2.56	4.52	41.60	41.55	1.06
N_4S_3	2.47	4.14	40.50	42.32	1.04
N_4S_4	2.26	4.05	37.70	42.88	0.97
LSD (0.05)	0.09	0.43	1.91	0.42	0.01
CV %	3.85	6.66	3.15	0.64	0.46

4.13.3 Interaction effect of nitrogen and sulphur

It was revealed that nitrogen and sulphur interaction influenced the seed yield per hectare and seed yield was significantly superior (2.56 t/ha) at 120 kg N with 30 kg S/ha. But control treatment gave the lowest yield (0.42 t/ha) (Table 16). Sharawat *et al.* (2002), Saini *et al.* (1985) observed significantly higher seed yield at 120 kg N/ha in combination with 30 kg S/ha. Tomar *et al.* (1996) reported that N application up to 90 kg/ha and S application up to 45 kg/ha significantly increased seed yield. Mondal *et al.* (1996) obtained highest seed yield of mustard at 80 kg N with 20 kg S/ha. The highest seed yield was realized at higher rate of nitrogen application (150 kg/ha) and sulphur (50 kg/ha) recorded by Deekshitulu and Subbaiah (1997).

4.14 Stover yield (t/ha)

4.14.1 Effect of nitrogen

The nitrogen application favorably influenced the stover yield and the difference among the consecutive levels was significant (Table 14). The application of 120 kg N/ha gave significantly highest stover yield (4.09 t/ha) over 40 and 80 kg N/ha (2.81 and 3.32 t/ha, respectively) and also control (1.82 t/ha). These findings were an agreement with that of Singh and Prasad (2003), Singh *et al.* (2002c). But, Meena *et al.* (2002) observed higher stover yield of mustard at the nitrogen rate of 60 kg/ha.

4.14.2 Effect of sulphur

Application of sulphur, 30 and 60 kg/ha significantly increased the stover yield (3.32 and 3.15 t/ha, respectively) over no sulphur application (2.68 t/ha). After these levels, 90 kg S/ha did not significantly increase the stover yield of rapeseed (Table 15). The stover yield from 30 and 60 kg S/ha was statistically similar. Birbal *et al.* (2004), Chandel *et al.* (2002), Misra (2003) observed the highest stover yield at 40 kg S/ha sulphur application.

Verma *et al.* (2002) obtained similar result at 30 kg S/ha and Ram *et al.* (1999) concluded that application of 60 kg S/ha increased stover yield compare to no S. Jat and Khangarot (2003) mentioned that stover yield significantly influenced with the application rate of S up to 90 kg/ha.

4.14.3 Interaction effect of nitrogen and sulphur

Nitrogen and sulphur interaction had significant effect on stover yield. Stover yield was highest (4.52 t/ha) when 120 kg N was applied with 30 kg S/ha. The rate of nitrogen at 120 kg/ha with 30, 60 and 90 kg S/ha showed significant results that were statistically identical (Table 16). The lowest stover yield (1.68 t/ha) observed by applying control treatment. Stover yield increased with the increased levels of nitrogen up to 60 kg/ha and sulphur up to 40 kg /ha reported by Singh *et al.* (1996).

4.15 Harvest index (%)

4.15.1 Effect of nitrogen

From Table 14 it revealed that the different nitrogen level, significant effect on harvest index. Application of nitrogen at 120 kg/ha significantly increased the harvest index (38.72%) followed by 40 and 80 kg/ha (29.95 and 35.47% respectively) and control (25.10%). Highest harvest index observed at 120 kg N/ha. Similar result was also observed by Shukla and Kumar (1997) at the same nitrogen level.

4.15.2 Effect of sulphur

From Table 15 it would be seen that sulphur level at 30 kg/ha recorded significant harvest index (35.23%) over control (29.08%). Above this level, 60 and 90 kg S/ha did not show positive effect to enhance harvest index. Chandel *et al.* (2002) concluded that 40 kg S/ha to mustard also significantly increased harvest index. These are in agreement of Saran and Giri (1990) and Chowdhury *et al.* (1991).

4.15.3 Interaction effect of nitrogen and sulphur

It was observed that nitrogen and sulphur interaction had significant effect on harvest index. Harvest index was significantly higher when applied 120 kg N in combination with 30, 60 and 90 kg S/ha and produced higher harvest index 41.60%, 40.50% and 37.70% respectively (Table 16). The lowest harvest index (19.90%) was recorded from the control combination.

4.16 Oil content (%)

4.16.1 Effect of nitrogen

Nitrogen rates did not significantly influenced oil content of rapeseed. All level of nitrogen gave similar results in oil content. Oil content of rapeseed did not respond to nitrogen application (Table 14). Singh *et al.* (2004) also concluded that nitrogen application did not affect the oil content of rapeseed.

4.16.2 Effect of sulphur

The effect of sulphur on oil content of mustard significantly increased up to 90 kg S/ha, sulphur application at higher level indicates highest oil content (43.12%) and lowest level of S indicates lowest oil content (40.16%). All levels of S significantly differed in increasing oil content of rapeseed (Table 16). Singh and Meena (2003) also observed highest oil content at 80 kg S/ha. But Prakash *et al.* (2002) reported that oil content increased with the increase rate up to 40 kg S/ha.

4.16.3 Interaction effect of nitrogen and sulphur

Oil content had significant response to nitrogen along with sulphur fertilization. It was observed that 40kg N with 90 kg S/ha gave highest oil content (43.24%) and lowest oil content (40.16%) observed at no S application with 80 kg N/ha. All levels of N with 90 kg S/ha gave almost similar oil content (Table 16). Singh and Meena (2003) also obtained highest oil content with the increasing levels of nitrogen and sulphur and they found that nitrogen at 80 kg with 80 kg S/ha gave highest oil content.

4.17 Oil yield (t/ha)

4.17.1 Effect of nitrogen

The effect of nitrogen on oil yield of rapeseed significantly increased up to 120 kg N/ha. Nitrogen at 120 kg/ha produced maximum oil yield (0.99 t/ha) compare to 40 and 80 kg N/ha and lowest oil yield (0.27 t/ha) found at control. All levels of nitrogen significantly differed in increasing oil yield of rapeseed (Table 14). Ali and Ullah (1995) also observed higher oil yield (369 kg/ha) at the same nitrogen fertilization.

4.17.2 Effect of sulphur

From Table 15 it would be seen that sulphur at 30 kg/ha recorded significant oil yield (0.68 t/ha) over control (0.52 t/ha). Above this level, 60 and 90 kg/ha did not show significant effect on oil yield. Ali *et al.* (1996) reported that higher S rate at 30 kg/ha gave 20.19% higher oil yield over control and also concluded that sulphur at 30 kg/ha significantly increased oil yield , because of the higher oil content found in seed at the same S rate.

4.17.3 Interaction effect of nitrogen and sulphur

It was revealed from Table 16 that the treatment combination of nitrogen and sulphur had significant effect on oil yield of rapeseed. All combination of nitrogen and sulphur significantly differ on oil yield. Nitrogen at 120 kg/ha with 30 kg S/ha produced significant highest oil yield (1.06 t/ha). Lowest oil yield (0.17 t/ha) was observed at control combination. Ali *et al.* (1996) reported that higher oil yield of 683.75 kg/ha was obtained at 120 kg N along with 30 kg S/ha.

Chapter 5

Summary and conclusion

Chapter 5

SUMMARY AND CONCLUSION

An experiment entitled "Response of nitrogen and sulphur on the yield of rapeseed (*Brassica campestris*) line SAU-C-F_7" was conducted during Rabi season (October – February, 2004-2005), at Agronomy field laboratory, SAU, Dhaka-1207. The treatment comprised 4 levels of nitrogen and 4 levels of sulphur.

A progressive increase of plant height and length of main inflorescence were observed up to 80 kg N/ha. Sulphur had significant effect on length of main inflorescence at 30 kg S/ha. At initial stage, sulphur response was not significant on plant height. But a little response of sulphur observed on plant height after 45 and 75 days after sowing. Plant height and length of main inflorescence were significantly influenced by the interaction effect of nitrogen and sulphur on different growth stage and at harvest. Application of 80 kg N/ha along with 30 kg S/ha showed higher plant height and length of main inflorescence, but on the other hand, lower plant height and inflorescence length were observed at control combination treatments. In general, more than 90 percent of the plant height was attained at 60 DAS and the crop reached a maximum height at 75 DAS, there after, height remained more or less constant.

Dry matter accumulation increased significantly at all growth stages. At early growth stage maximum dry matter accumulation was observed at higher nitrogen levels but at later stages N at 120 kg/ha maintained higher dry matter. Application of 30 kg S/ha significantly increased by the interaction effect of 120 kg N/ha. Sulphur at 30 kg S/ha along with 120 kg N/ha produced higher dry matter at different growth stages and at harvest. Nitrogen rate at 120 kg/ha in combination with 30 kg S/ha produced maximum dry matter at 60 and 75 DAS.

Crop growth rate (CGR) progressively increased up to 45-60 DAS with different levels of nitrogen at initial growth stages and thereafter, CGR gradually declined and became negative at harvest. Similarly higher CGR values were obtained with 30 kg S/ha.

In general, relative growth rate (RGR) values declined gradually with increasing levels of nitrogen. RGR was not significantly affected by the sulphur application at 30-45, 60-75 and 75 to harvest. However, the significant effect on RGR found at 45-60 days after sowing and obtained the highest RGR at 90 kg/ha sulphur application.

The number of primary branches per plant, secondary branches per plant, siliquae in main inflorescence, siliquae per plant increased progressively with the increasing level of Nitrogen. The average number of primary, secondary branches per plant, number of siliquae in the main inflorescence, siliquae per plant were found at higher rate of 120 kg/ha nitrogen application. Application of 30 kg S/ha significantly increased number of secondary branches per plant, siliquae number in main inflorescence, siliquae per plant except primary branches per plant. The average number of siliquae in growing season were 65.11, 82.39, 74.19 and 68.95 under S_1, S_2, S_3 and S_4 kg/ha, respectively.

Interaction of N and S significantly influenced branch number, siliquae number in the main inflorescence and per plant. Application of 120 kg N/ha with 30 kg S/ha gave significantly higher number of secondary branches (1.63), siliqua number in the main inflorescence (31.40) and per plant (103.4).

The levels of nitrogen did not show significant effect on the siliqua length and seed per siliqua. The higher number siliqua (21.14) and siliqua length (5.17 cm) obtained at

80 kg N/ha. The 1000 seed weight was not influenced with application of nitrogen. But 80 kg N/ha produced highest 1000 seed weight (2.887 g). Similarly, S had no significant effect on siliqua length, seeds number per siliqua and 1000 seed weight. The highest levels of S gave highest 1000 seed weight (2.71 g), siliqua length (5.11 cm) and seed number per siliqua (20.75). Nitrogen along with S did not affect the seeds number per siliqua, siliqua length and 1000 seed weight. The highest siliqua length (5.39 cm) and seed per siliqua (22.05) obtained at 80 kg N/ha in combination with 90 kg S/ha. But highest 1000 seed weight (2.88 g) obtained at 120 kg N/ha along with no S application.

The seed and stover yield were increased significantly up to 120 kg N/ha. Nitrogen level at 120 kg/ha increased the seed yield up to 268.94, 107.51 and 34.54 percent over control, 40 and 80 kg N/ha, respectively. The average stover yields were 1.829, 2.812, 3.320 and 4.098 t/ha against the treatments of 0, 40, 80 and 120 kg N/ha, respectively. Higher seed yield of rapeseed obtained at 30 kg S/ha. The average seed and stover yield were 1.294, 1.661, 1.579 and 1.399; and 2.683, 3.323, 3.158 and 2.895 t/ha against the treatments of 0, 30, 60 and 90 kg S/ha, respectively.

Seed yield and stover yield were increased significantly by the interaction effect of N and S levels. Significant seed yields of 2.566 t/ha and stover yield of 4.527 t/ha were obtained at 120 kg N/ha along with 30 kg S/ha.

Higher harvest index (38.72 %) was obtained at 120 kg N/ha and lowest harvest index found at control. All levels of nitrogen significantly differ to increasing the harvest index. Application of 30 kg S/ha gave significantly highest harvest index (35.23%) compared to the 0, 60, and 90 kg S/ha. Higher HI of 41.60 was obtained at 120 kg N along with 30 kg S/ha.

Nitrogen had no significant effect on oil content of rapeseed but affected the oil yield, but sulphur showed significant differences in increasing oil content as well as oil yield. Highest levels of N gave the highest oil yield (0.99 t/ha) while control gave the lowest yield (0.27 t/ha). Sulphur application gave highest oil content (43.12%) as well as oil yield (0.69 t/ha) and control gave lowest oil content (40.47%) and oil yield (0.53 t/ha).

The conclusion drawn here are limited to the present experiment.

i) Nitrogen and sulphur significantly influenced plant height, inflorescence length, dry matter accumulation, CGR, RGR, siliquae per plant, HI, seed and stover yield, oil content. But nitrogen and sulphur did not show significant differences on siliqua length, number of seeds per siliqua and 1000 seed weight.

ii) Most of the characters including seed yield responded significantly up to an application of 120 kg N/ha. Hence, this level seems to be adequate for higher seed yield among the all treatments.

iii) The rapeseed line showed a positive response to sulphur application with respect to seed yield and oil yield.

iv) Most of the growth characters and seed yield significantly enhanced at 30 kg S/ha.

v) Increasing rate of S application increased oil content. But the highest oil yield observed at 30 kg S/ha.

vi) Oil content remained unaffected by nitrogen application. However, Sulphur improved oil content.

vii) N and S interacted significantly with each other in increasing the seed and oil yield.

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APPENDICES

Appendix i: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth)

A. Physical composition of the soil

Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

C. Chemical composition of the soil

Sl.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner & Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lancster, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner , 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt ,1965
8	Available S (ppm)	16.00	Hunter, 1984
9	PH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Appendix ii: Monthly average of Temperature, Relative humidity, Total Rainfall and sunshine hour of the experiment site during the period from November 2004 to February 2005

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2004	November	29.5	18.6	24.0	69.5	0.0	233.2
	December	26.9	16.2	21.5	70.6	0.0	210.5
2005	January	24.5	13.9	19.2	68.5	4.0	194.1
	February	28.9	18.0	23.4	61.0	3.0	221.5

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

Appendix iii: Source of variation, degrees of freedom and mean square for plant height and dry matter

Source of variation	d. f.	Mean square									
		Plant height					Dry matter				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
R	2	0.357	7.101	16.448	12.426	3.527	0.003	0.308	0.405	1.575	0.418
N	3	67.437**	861.945**	1154.689**	1195.377**	442.152**	0.864**	14.675**	94.353**	109.816**	82.594**
Error I	6	3.248	4.117	11.871	3.142	31.494	0.002	0.011	0.212	0.020	0.440
S	3	1.980NS	84.290**	16.548NS	94.461**	1.486NS	0.100**	0.810**	1.008**	8.917**	0.359NS
N×S	9	7.921*	9.018*	49.383*	4.097*	62.886**	0.018**	0.106**	1.601**	0.531**	4.186**
Error II	24	1.967	2.430	16.422	1.513	17.012	0.002	0.031	0.199	0.142	0.272
Total	47										

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means non significant, R =Replication
N= Nitrogen and S= sulphur

Appendix iv: Source of variation, degrees of freedom and mean square for CGR and RGR

Source of variation	d. f	Mean square							
		CGR				RGR			
		30-45 DAS	45-60 DAS	60 -75 DAS	75 to harvest	30-45 DAS	45-60 DAS	60 -75 DAS	75 to harvest
R	2	0.0001	0.0001	0.0001	0.021	0.0001	0.0001	0.0001	0.0001
N	3	60.428*	250.813*	19.895*	94.154*	0.0001*	0.0001NS	0.0010*	0.0010*
Error I	6	0.0001	0.0001	0.0001	0.015	0.0001	0.0001	0.0001	0.0001
S	3	1.634*	2.952*	8.020*	23.439*	0.0001NS	0.0001*	0.0001NS	0.0001NS
N×S	9	0.419*	10.609*	14.218*	41.965*	0.0001*	0.0001*	0.0001*	0.0001*
Error II	24	0.0001	0.0001	0.0001	0.017	0.0001	0.0001	0.0001	0.0001
Total	47								

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means non significant, R =Replication
N= Nitrogen and S= sulphur

Appendix v: Source of variation, degrees of freedom and mean square for yield attributes

Source of variation	d. f.	Mean square							
		No. of primary bracches/plant	No. of secondary bracches/plant	1000 seed weight(g)	Siliqua per plant	Siliqua length (cm)	Seeds per siliqua	Length of main inflorescence	No. of siliqua in main inflorescence
R	2	0.123	0.005	0.337	10.188	0.053	1.395	13.923	6.076
N	3	1.562^{**}	0.611^{**}	0.268^{NS}	4326.733^{**}	0.069^{NS}	3.950^{NS}	101.260^{**}	163.785^{**}
Error I	6	0.096	0.001	0.089	1.687	0.059	1.159	2.556	0.659
S	3	0.895^{**}	0.591^{**}	0.010^{NS}	671.085^{**}	0.013^{NS}	0.930^{NS}	40.575^{**}	18.095^{**}
N×S	9	0.203^{NS}	0.039^{NS}	0.006^{NS}	50.896^{**}	0.015^{NS}	1.290^{NS}	0.798^{*}	1.979^{*}
Error II	24	0.163	0.001	0.019	3.479	0.043	1.143	1.416	1.285
Total	47								

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means non significant, R =Replication N= Nitrogen and S= sulphur

Appendix vi: Source of variation, degrees of freedom and mean square for yield and harvest index and oil content

Source of variation	d. f.	Mean square					
		Seed yield (g/plant)	Seed yield (t/plant)	Stover yield (t/ha)	Oil yield (t/ha)	Harvest index (%)	Oil content (%)
R	2	0.537	0.023	0.090	0.0001	12.960	0.202
N	3	14.285^{**}	6.785^{**}	10.848^{**}	1.1840^{*}	435.037^{**}	0.044^{NS}
Error I	6	0.063	0.011	0.083	0.0001	1.365	0.103
S	3	0.865^{**}	0.335^{**}	0.959^{**}	0.0650^{*}	79.552^{**}	16.098^{*}
N×S	9	0.124^{**}	0.008^{*}	0.208^{*}	0.0010^{*}	3.777^{*}	0.048^{*}
Error II	24	0.043	0.003	0.068	0.0001	1.287	0.064
Total	47						

Note: Single and double asterisks indicate significant at 5% and 1% levels respectively. NS means non significant, R =Replication N= Nitrogen and S= sulphur