# EFFECTS OF NITROGEN AND SULFUR ON THE GROWTH, YIELD AND OIL CONTENT OF SESAME

**BY**

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TO
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## CERTIFICATE

This is to certify that the thesis entitled **"Effects of Nitrogen and Sulfur on the Growth, Yield and Oil Content of Sesame"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Soil Science, embodies the result of a piece of bonafide research work carried out by **Sonia Shilpi**, Registration number: **04-1425** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
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## EFFECT OF NITROGEN AND SULFUR ON THE GROWTH, YIELD AND OIL CONTENT OF SESAME


## ABSTRACT

An experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from February to May, 2009 to determine the effect of nitrogen and sulfur on growth and yield of sesame. The experiment consisted of two factors. There were 4 levels each of nitrogen (0, 40, 60, 100 kg N $ha^{-1}$) and sulfur (0, 20, 40 and 60 kg S $ha^{-1}$). The experiment was laid out in Randomized Complete Block Design with three replications. Plant height, number of branches, number of leaves, seed yield, stover yield and oil content increased significantly with increasing N level upto 60 kg N/ha ($N_2$) whereas the concentration of N, P, K and S in plant increased upto 100 kg N/ha. The seed yield, stover yield and oil content at 60 kg N/ha were 1.31 t/ha, 3.05 t/ha and 42.80%, respectively. On the other hand, plant height, number of branches, number of leaves, seed yield and oil content were increased significantly with increasing S level upto 40 kg S/ha ($S_2$) whereas stover yield, N, P, K and S concentration in plant increased upto 60 kg S/ha. The maximum seed yield (1.21 t/ha) was obtained at 40 kg S/ha and the maximum stover yield (3.14 t/ha) and oil content (43.13%) were observed at 60 kg S/ha. In terms of seed yield, stover yield and oil content the combination $N_2S_2$ (60 kg N/ha and 40 kg S/ha) was found most suitable.

## LIST OF ABBREVIATED TERMS

| ABBREVIATION | FULL NAME |
|---|---|
| AEZ | Agro-Ecological Zone |
| *et al.* | and others |
| BBS | Bangladesh Bureau of Statistics |
| Cm | Centimeter |
| °C | Degree Celsius |
| DAS | Date After Seeding |
| etc | Etcetera |
| FAO | Food and Agriculture Organization |
| g | Gram |
| ha | Hectare |
| hr | Hour |
| kg | Kilogram |
| m | Meter |
| mm | Millimeter |
| Mo | Month |
| MP | Muriate of Potash |
| no. | Number |
| % | Percent |
| RCBD | Randomized Complete Block Design |
| $m^2$ | Square meter |
| TSP | Triple Super Phosphate |
| UNDP | United Nations Development Program |

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# Chapter I

# Introduction

# CHAPTER 1

# INTRODUCTION

Sesame (*Sesamum indicum L.*) belongs to the family Pedaliaceae is one of the important oil crops, which widely grown in different parts of the world. It is grown for seed and oil, both for human consumption and has been grown for thousand of years and today its major production areas are the tropics and the subtropics of Asia, Africa, East and Central America. In Bangladesh, it is locally known as til and is the second important edible oil crop (Mondal *et al.*, 1997). Sesame is a versatile crop having diversified usage and contain 42-45% oil, 20% protein and 14-20% carbohydrate (BARI, 2004).

Sesame oil is generally used mostly for edible purpose in confectionaries and for illumination. It is also used for some other purposes, such as in manufacture of margarine, soap, paint, perfumery products and drugs and as dispersing agent for different kinds of insecticide. Sesameolin, a constituent of the oil, is used for its synergistic effect in pyrethrumj, which increases the toxicity of insecticides (Chaubey *et al.*, 2003). The sesame oilcake is a very good cattle feed since it contains protein of high biological value and appreciable quantities of phosphorus and potassium. The cake is also used as manure (Malik *et al.*, 2003). Sesame seed may be eaten fried mixed with sugar or in the form of sweetmeats. The use of the seeds for decoration on the surface of breads and cookies is most familiar to the Americans.

The climate and edaphic conditions of Bangladesh are quite suitable for sesame cultivation. The crop is cultivated either as a pure stand or as a mixed crop with aus rice, jute, groundnut, millets and sugarcane. Among various oil crops grown in Bangladesh, sesame ranks next to mustard in respect of both cultivated area and production. Sesame is grown in almost all regions of Bangladesh. In 2007-2008, the crop covered an area of 78.50 thousand hectares in Bangladesh with the production of 51,000 tons (BBS, 2009). The crop is grown in both rabi and kharif seasons in Bangladesh but the Kharif season covers about two-third of the total sesame area. Khulna, Faridpur, Pabna, Barisal, Rajshahi, Jessore, Comilla, Dhaka, Patuakhali, Rangpur, Sylhet and Mymensingh districts are the leading sesame producing areas of Bangladesh (BARI, 2004).

Yield and quality of seeds of sesame are very low in Bangladesh. The low yield of sesame in Bangladesh however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper irrigation facilities. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). To attain considerable production and quality yield for any crop it is necessary to proper management ensuring the availability of essential nutrient in proper doses. Generally, a large amount of fertilizer is required for the growth and development of vegetable crops (Opena *et al.*, 1988).

Nitrogen plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most difficult element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anon., 1972). An adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa *et al*., 1981). On the other hand excessive application of nitrogen is not only uneconomical, but it can prolong the growing period and delay crop maturity. Excessive nitrogen application causes physiological disorder (Obreza and Vavrina, 1993). Sulfur plays a remarkable role in protein metabolism. It is required for the synthesis of proteins, vitamins and chlorophyl and also S containing amino acids such as cystine, cysteine and methionine which are essential components of proteins (Tisdale *et al*., 1999). Lack of S causes retardation of terminal growth and root development. S deficiency induces chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004).

Hence, considering the above facts the present study was undertaken to maximize the seed yield of sesame with nitrogen and sulfur fertilizer with the following objectives:

i. To find out the optimum dose of nitrogen and sulfur for maximizing the yield and oil content of sesame.

ii. To document the nutrient uptake by sesame.

iii. To observe the fertility status of post harvest soil.

# Chapter II

# Review of literature

## CHAPTER 2

## REVIEW OF LITERATURE

In Bangladesh and in many countries of the world sesame is an important oil crop. The crop has conventional less attention by the researchers on various aspects because normally it grows without care or management practices. Based on this very few research work related to growth, yield and development of sesame have been carried out in our country. Optimum nitrogen and sulfur fertilizers play an important role in improving sesame yield. But research works related to nitrogen and sulfur fertilizer on sesame are limited in Bangladesh. However, some of the important and informative research findings related to the nitrogen and sulfur on sesame have been reviewed in this chapter under the following headings-

### 2.1 Effect of nitrogen on sesame

Vegetable sesame (*Sesamum radiatum*) was fertilized with N applied as urea (46% N) at 0, 30, and 60 kg/ha and P applied as single super phosphate (SSP) (7.8% P) at 0, 15, and 30 kg/ha in a field experiment conducted by Auwalu *et al.* (2007) in the dry season of 1996 and wet season of 1997. Application of N significantly increased plant height, number of leaves per plant, leaf area index (LAI), leaf fresh and dry weight as well as total marketable yield in both seasons; shoot dry weight was not significantly increased by N application in the 1996 dry season.

The effect of nitrogen (N) rates (0, 60 and 90 kg/ha) and plant densities on the yield and yield components of sesame (*Sesamum indicum*) cultivars Zarghan local and Darab 14 was evaluated in Iran by Fard and Bahrani (2005). N rates exhibited significant effects on the number of branches per plant, number of capsules per plant, and seed and protein contents. Plant density also had significant effects on the seed yield, biological yield, harvest index, number of branches per plant and number of capsules per plant. Increasing N rates along with plant density increased the seed yield. Zarghan local recorded the highest yield (1724 kg/ha) and harvest index with the 90 kg N/ha rate and 25.0 plants/m$^2$ density. Application of 90 kg N/ha increased the protein accumulation by 25% compared to the control (no fertilizer). Seed oil percentage was a stable yield component and was not affected by either N rate or plant density.

A study was conducted by Abdel *et al.* (2003) in the sandy soil of Assiut, Egypt in 2001 and 2002 to investigate the effects of sowing dates, N fertilizer rate (60, 80 and 100 kg/ha) and plant population on the performance of sesame cv. Giza 32. Plants sown on 10 May showed the maximum height (178.99 cm), the height of the first branch and the number of branch per plant were the highest in plants sown on 25 May, while the height of the first capsule was the highest in plants sown on 10 June. The height of the first branch and first capsule, as well as the length of the fruiting zone were the highest at 60 kg N/ ha. The highest seed and oil yields (6.20 kg/ha and 366.39 kg/ha, respectively) were obtained at 80 kg N/ha.

A study was conducted by Malik *et al.* (2003) in Faisalabad, Pakistan in 2001 to investigate the effects of different N levels (0, 40 and 80 kg/ha) on the productivity of sesame cv. TS-3 under different plant geometries (flat sowing, paired row planting, ridge sowing and bed sowing). N at 80 kg/ha produced the highest yield (0.79 t/ha), 1000-seed weight (3.42 g) and seed oil content (45.88%). Among the plant geometry treatments, bed sowing (50/30 cm) produced the highest seed yield of 0.85 t/ha and seed oil contents (44.06%).

Pathak *et al.* (2002) carried out a field experiment during the kharif seasons of 1997 and 1998, in the Barak Valley Zone of Assam, India, to evaluate the effect of N levels (0, 15, 30 and 45 kg/ha) on the growth and yield of sesame (*S. indicum*). N at 45 kg/ha recorded the highest mean values for plant height (74.3 cm), number of branches per plant (4.50), number of capsules per plant (39.0) and 1000-grain weight (2.91 g). N at 45 kg/ha also recorded the highest seed yield (6.95 and 7.25 q/ha), net return (Rs. 4450 and 4700/ha) and benefit:cost ratio (1.78 and 1.84) during 1997 and 1998, respectively.

A field experiment was carried out by Singh *et al.* (2001) at Agra during rainy (kharif) seasons of 1995 and 1996 to assess the effect of nitrogen levels and different weed control techniques to *Sesamum indicum* on weed density, seed yield, nutrients depletion by weeds and net returns. Sixty kg N/ha registered the highest yield (979 kg/ha) and net returns (Rs. 10327/ha) in addition to higher N uptake by crop and N depletion by weeds. However, higher levels of N could not influence P and K removal by weeds significantly.

A field experiment was conducted by Ashfaq *et al.* (2001) during the summer seasons of 1996 and 1997, in Pakistan, to study the response of 2 sesame genotypes (92001 and TS3) to different rates of N and P (0, 40, 80 and 120 kg/ha). N at 120 kg/ha and P at 40 kg/ha significantly increased the seed and stalk yield of sesame, as well as the protein content of the oil. This response was higher in TS3 than in 92001.

Six combinations of 2 N (20 and 40 kg N/ha) and 3 K rates (0, 33 and 66 kg K/ha) were applied to soybean and sesame as sole crop or intercropped in a field experiment conducted by Mondal *et al.* (2001) in West Bengal, India during the rainy and summer seasons of 1994 and 1995. Oil yield of sesame and soybean as sole crops were higher compared to the oil yield of both crops as intercrops. Highest oil yield of soybean and sesame was observed with 66 kg K/ha + 40 kg N/ha application. Nutrient uptake by soybean as a sole crop and combined uptake of nutrients by both intercrops were higher during the rainy season than their respective nutrient uptake during summer. However, nutrient uptake of sesame as sole crop was higher in summer than during the rainy season. Maximum uptake of nutrients in both sesame and soyabean was observed with 66 kg K/ha + 40 kg N/ha application. Continuous N application resulted in higher N-status in soil. However, application of K with N resulted in a decreased total N status in soil after the fourth cropping.

The effects of N fertilizer application and weed control measures on sesame were investigated by Prakash *et al.* (2001) in Uttar Pradesh, India, during 1995 and 1996. Treatments consisted of 4 N levels (0, 30, 60 and 90 kg/ha) and weed control. N fertilizer rate did not significantly affect the weed population.

Application of 90 kg N/ha resulted in the highest number of capsules per plant, seeds per capsule, 1000-seed weight, seed yield, straw yield and harvest index in both the years.

Two field experiments were conducted by Fayed *et al.* (2000) in Egypt during 1997-98 to study the productivity and performance of sesame under drip irrigation as affected by sowing rate (3.6 kg/ha) and nitrogen fertilizer application (30, 60 and 90 kg/ha) in newly cultivated sandy soil. Increasing nitrogen rates up to 60 kg N/ha significantly increased the values of the yield and all the yield attributes of sesame. Further increase in N rates more than 60 kg/ha had no significant effects on seed yield and yield components except plant height.

A field experiment was conducted by Mitra and Pal (1999) in West Bengal, India, during the summer season (pre-kharif) of 1991 to study the effect of irrigation and nitrogen on growth, yield and water use of summer sesame (*Sesamum indicum*). A significant increase in seed yield of sesame was recorded up to three irrigations (0.784 t/ha). The increase in dry matter, number of capsules/plant, seed/capsule and seed yield of sesame was significant up to 100 kg N/ha. Further increase in nitrogen depressed the seed yield and yield attributing characters. For seed yield, the response to applied nitrogen was quadratic in nature and maximum response (0.90 kg seed/kg N) was observed at 100 kg N/ha level.

A field experiment was conducted by Parihar *et al.* (1999) during the summer seasons of 1995 and 1996 on a clay-loam soil at Bilaspur to study the response of summer sesame to irrigation and nitrogen levels. Irrigation scheduled at 0.6

IW/CPE was found to be the optimum, with little further increase in yield from irrigation at 0.8 IW/CPE. Yield increased with increasing N rate (0-80 kg/ha).

A field experiment was conducted by Singh and Singh (1999) in Uttar Pradesh, India, for 2 years (1991 and 1992) during the monsoon season to study the N requirement of the sesame + *V. mungo* intercropping system. The treatments included sole cropping and intercropping of sesame and *V. mungo*, and application of N at 3 rates (10, 20 and 40 kg/ha). Sole crop yields were higher than intercrop yields in both crops. Growth characters of both crops in the intercropping system improved with increasing N rates. The oil content and yield of sesame sole crops, and the grain and protein yields of *V. mungo* sole crops increased with increasing N rates. The best N treatment in intercropping systems was the application of 40 kg N/ha to sesame and 10 kg N/ha to *V. mungo*.

Subrahmaniyan and Arulmozhi (1999) conducted a field study during summer 1996 and 1997 at Vridhachalam, Tamil Nadu, India, sesame cv. VS 9104 and VRI 1 were grown at densities of 111000 or 166000 plants/ha and given 0, 35, 45 or 55 kg N/ha. VS 9104 had a higher number of branches and capsules/plant and higher dry matter production/plant, 1000-seed weight and yield than VRI 1. Yield and yield component values increased with increasing N rate.

In a field experiment conducted by Singaravel and Govindasamy (1998) in 1990 at Neyveli, Tamil Nadu, India, sesame cv. TMV 4 was given 35 kg N/ha and/or Azospirillum, together with 0, 10, 20 or 30 kg humic acid/ha. Seed yield and dry matter production were greatest with N fertilizer + 20 kg humic acid.

In a field experiment conducted by Thakur *et al.* (1998) at Raigarh, Madhya Pradesh during the 1994 and 1995 rainy seasons, sesame cv. Gujrat 1 was given 30, 45 or 60 kg N and 20, 30 or 40 kg $P_2O_5$/ha. Seed, oil and protein yields increased significantly with up to 45 kg N and 30 kg $P_2O_5$/ha.

A field experiment carried out by Bassiem and Anton (1998) in Ismailia, Egypt, during 1996 and 1997 to investigate the effects of N (at 30, 60 and 90 kg/ha) and K (at 24 and 48 kg $K_2O$/ha) and foliar spray with ascorbic acid (500 ppm) on yield and its components as well as seed contents of oil and protein of sesame cv. G.32. Seed yield increased significantly by increasing N upto 90 kg/ha, whereas yield attributes increased significantly by adding N upto 60 kg N/ha.

A field experiment was conducted by Dixit *et al.* (1997) during early rabi [winter] season of 1991-92 at Powarkheda, Madhya Pradesh to assess the productivity of sesame cv. TC-25 and Rauss-17 sown at 333 000, 444,000 or 666,000 plants/ha with application of 0-90 kg N/ha. Application of N upto 60 kg/ha increased the seed yield significantly and gave the highest net profit.

In a field experiment in 1990-91 at Tikamgarh, Madhya Pradesh, 4 sesame (*Sesamum indicum*) cultivars were sown at spacings of 30 × 10 or 15 cm and given 0-90 kg N/ha by Tiwari and Namdeo (1997). The application of 90 kg N produced the highest seed yield of 0.81 t/ha. Seed oil contents decreased and protein content increased with increasing N rate.

In field trials in 1993-94 at Cuttack, Orissa, India, sesame cv. Kalika, Kanak, OMT 10, Uma, Usha and Vinayak sown in rice fallows were compared by Moorthy *et al.* (1997). Seed yield was highest in cv. Kalika, whereas seed oil content was highest in cv. Uma. In a second trial in 1994-95 the same cultivars (except cv. OMT 10) were given 0-90 kg N/ha. Seed yield was not significantly different between cultivars and it increased with rate of N application. Seed oil content was highest in cv. Kalika and it increased with up to 60 kg N/ha.

Mondal *et al.* (1997) carried out a field trial at the University Farm, Kalyani, West Bengal, in summer 1992 in which sesame was not irrigated, irrigated at branching and seed setting growth stages or irrigated at branching, flowering and seed setting growth stages and given 0, 30, 60, 90 or 120 kg N/ha. Plant height, DM accumulation, number of capsules/plant, number of seeds/capsule, 1000-seed weight, seed yield and oil and protein yields were all increased as irrigation frequency and nitrogen fertilizer rate increased. Harvest index was not significantly affected by N application, but increased slightly with irrigation.

Ashok *et al.* (1996) conducted a field experiment in 1990-91 at Pusa, Bihar, where sesame was irrigated at irrigation water: cumulative pan evaporation (IW:CPE) ratios of 0.3, 0.5 or 0.7 or irrigated 30 and 60 d after sowing (DAS), and was given 0-90 kg N/ha. Irrigating at an IW:CPE ratio of 0.7 gave the highest mean seed yield of 0.81 t/ha. Irrigations at 30 and 60 DAS used the same quantity of water as irrigating at an IW:CPE ratio of 0.5, but the seed yield was significantly higher in the former treatment in 1990. Seed yield was highest with 90 kg N in

1990 (0.91 t/ha) and increased with up to 60 kg N in 1991 (0.92 t/ha). Total N uptake increased with increasing irrigation frequency and increasing N rate. Seed oil content was highest with 30 kg N.

In a field trial conducted by Balasubramaniyan (1996) at Vridhachalam, Tamil Nadu during the 1992-93 summer seasons on sandy-loam soil, 2 sesame genotypes were sown at 3.0, 4.5 or 6.0 x 105 plants/ha and given 0, 30, 60 or 90 kg N/ha. The pre-release genotype VS 350 yielded more (711 kg/ha) than cv. TMV 3 (636 kg/ha), and matured 10-12 days earlier. Yield was not significantly affected by plant density, but was increased by 30 kg N.

In a field trial conducted by Hooda *et al* (1996) in the rainy season of 1995 at Hisar, Haryana, Pennisetum glaucum cv. HHB 67 was intercropped with green gram and sesame cv. Haryana Til No. 1 and was given 0-40 kg N/ha. Grain and straw yields of *P. glaucum* were highest when grown alone with 40 kg N/ha. Gross and net returns were highest when *P. glaucum* was intercropped with green gram with application of 40 kg N/ha.

Seed yield of sesame grown at Joydebpur by Roy *et al.* (1995) in the early summer seasons of 1991-92 was 0.75 t/ha without N fertilizer and 0.91-0.97 t with 40-120 kg N/ha. Applied K also increased yield, with no significant difference between application rates of 33.2 and 66.4 kg K/ha.

A field experiment was conducted by Chandrakar *et al.* (1994) during the summer season of 1991 at Raipur, Madhya Pradesh. Sesame cv. Selection 5 irrigated at branching and podding stages, at an irrigation water:cumulative pan evaporation (IW:CPE) ratio of 0.5 upto the podding stage and 0.7 IW:CPE ratio after podding or at IW:CPE ratio of 0.7 throughout plant growth gave seed yields of 1.29, 1.45 and 1.58 t/ha, respectively. Seed yields increased with increasing N (0, 50, 100 or 150 kg/ha).

**2.2 Effect of Sulfur on sesame**

The sulfur (S) dynamics and its availability are less studied than other nutrients, even though S is an essential nutrient for crops production (Rheinheimer *et al.*, 2007). They carried out a study to evaluate the crop responses to $SO_4$ application in different soils and to study S recuperation by balancing it in soil and plants. The study composed of a greenhouse experiment with six successive crops (canola, soybean, black bean, sesame, clover and wheat) using four soils and four $SO_4$ levels (0, 5, 10 and 20 mg/kg) to evaluate immediate and residual effect of $SO_4$ application. Soil samples were taken from 0-10 cm layer before and after each crop and analysed for $SO_4$. The dry matter production and $SO_4$ absorbed by plants were evaluated. The increase of $SO_4$ availability with fertilizer application was greater in soils with more clay content.

The effects of sulfur in the form of Cochin Refinery sulfur material at 0, 20, 40, 60 and 80 kg/ha, applied alone or in combination with Thiobacillus inoculation and/or farmyard manure application on the seed and oil yield, as well as S uptake of sesame cv. Co1 were determined by Maragatham *et al.* (2006) in a field experiment conducted in Tamil Nadu, India during 2000. Application of Cochin sulfur material at 40 kg/ha resulted in the highest seed yield (0.82 t/ha) and oil yield (4.03 t/ha), as well as S uptake by the plants (5.88 kg/ha).

Amudha *et al.* (2005) carried out an experiment in Tamil Nadu, India, during the summer and kharif seasons in 2001 to study the effects of sulfur at varying rates 0, 15, 30 and 45 kg/ha and different organics (farmyard manure, poultry manure and pressmud each applied at 10 t/ha) on the yield and sulfur use efficiency (SUE) of sesame (*Sesamum indicum* cv. TMV 3). The seed and stover yields progressively increased with increasing S levels. While the response ratio, apparent S recovery and agronomic efficiency, but not physiological efficiency, were decreased with increasing S levels. Treatment with 45 kg S/ha registered the maximum seed (870.2 and 898.1 kg/ha) and stover yields (2853.2 and 3155.7 kg/ha) for summer and kharif seasons, respectively, as well as the maximum SUE. Among the organics, poultry manure recorded the highest response ratio, apparent S recovery, agronomic efficiency, physiological efficiency, SUE and seed yield (777.4 and 801.8 kg/ha for summer and kharif seasons, respectively).

To evaluate the efficiency of S sources and optimum S requirement in sesame, studies were carried out by Duhoon *et al.* (2005) during kharif season under rainfed conditions at four locations in India, i.e. for four years during 1998-2001 at Amreli (Gujarat) on Vertisol, for three years during 1998-2000 at Jalgaon (Maharashtra) on Vertisol and Vriddhachalam (Tamil Nadu) on Alfisol, and for two years during 2000-01 at Tikamgarh (Madhya Pradesh) on Inceptisol. The treatments consisted of three sources (elemental S, gypsum and single superphosphate) and three levels of sulfur (15, 30 and 45 kg/ha) plus the untreated control. Application of 15 kg S/ha through gypsum or single superphosphate gave remarkably higher seed and oil yields with higher benefit:cost ratio on Vertisol of Amerli and Jalgaon, and Inceptisol of Tikamgarh. Sulfur had no significant effects on these parameters on Alfisol of Vriddhachalam.

Field experiments were conducted by Vaiyapuri *et al.* (2004) during the 2001 summer and kharif seasons in Tamil Nadu, India, to study the effect of S (0, 15, 30 and 45 kg/ha) and organic amendments (farmyard manure, poultry manure and sulfitation pressmud each at 10 t/ha) on the growth and yield of sesame cv. TMV 3. S at 45 kg/ha and poultry manure gave the maximum plant height, leaf area index at 60 days after sowing, number of branches per plant, total chlorophyll content at 60 days after sowing, number of capsules per plant, number of seeds per capsule, 1000-seed weight, seed yield and stover yield.

A study was conducted by Sharma and Gupta (2003) to determine the effect of sulfur (S) on the growth and yield of selected rainy season crops (cowpea, cluster bean, pearl millet, castor and sesame) in Rajasthan, India, during the rainy season of 1998. Treatments comprised: four S rates (0, 20, 40 and 60 kg/ha). Sulfur increased the height of all tested crops. Increasing S rates also increased the dry matter accumulation per plant. Supply of S also promoted floral primordial initiation, resulting in higher number of pods (or earheads) per plant and seed number per pod or (earhead), and ultimately enhanced seed yield. Application of S had positive effects on the yields of all crops. The yield increase as a result of

60 kg S/ha varied greatly, ranging from 27% (sesame) to 45% (cowpea). The average grain yield obtained upon treatment with 40 kg S/ha 13.8 q/ha vs. that obtained upon treatment with the control (10.8 q/ha).

A field experiment was conducted by Sarkar and Banik (2002) during spring of 1999 and 2000 to study the effects of planting geometry (30×30, 45×15, and 45×30 cm), row orientation (east-west and north-south), and sulfur rate (0, 25, and 50 kg/ha) on the growth and productivity of sesame cv. B 67. Sowing was conducted on 12 March 1999 and 14 March 2000 after winter rice. Sesame matured in 90 days and was harvested in the first fortnight of June. Despite reductions in yield attributes (capsules per plant, seeds per capsule, and 1000-seed weight), plants grown at 45x15 cm had the highest seed yield (873 kg/ha), mainly due to high plant density. Planting in north-south direction and applying 50 kg S/ha were more effective in improving leaf area index, crop growth rate, relative growth rate, net assimilation rate, yield attributes, and crop yield than planting in east-west direction and applying 25 kg S/ha.

A field experiment was conducted by Radhamani *et al.* (2001) in Tamil Nadu, India, during summer of 2000 to study the effect of 100 ppm salicylic acid (SA); 100 ppm mepiquat chloride (MC); 0.5% potassium chloride; 100 ppm SA or MC+0.5% potassium chloride; and 20 kg S (gypsum)/ha singly or in combination with 100 ppm SA or MC, 0.5% potassium chloride, and 100 ppm SA or MC+0.05% potassium chloride on sesame cv. TMV 3.. At 30 DAS, 20 kg S/ha singly gave the tallest plants (17.3 cm) and with 100 ppm SA, the highest dry matter production (41.9 kg/ha). At harvest, the tallest plants (108.5 cm) were recorded for 20 kg S+100 ppm SA+0.5% potassium chloride while the highest dry matter production was obtained with 20 kg S/ha singly (3.90 kg/ha) or in combination with 100 ppm SA (3.94 kg/ha) and 100 ppm SA+0.5% potassium chloride (3.87 kg/ha). Treatment with 20 kg S/ha+0.5% potassium chloride and 20 kg S/ha+100 ppm SA+0.5% potassium chloride gave the highest number of capsules per plant (88 and 92), number of seeds per capsule (42 and 47), seed yield (732 and 747 kg/ha), and oil content (44.3%).

Ghosh *et al.* (1997) carried out an experiment with sesame cv. Rama grown on the Gangetic alluvial plains in summer 1994 was given 0-60 kg S/ha and irrigated 1-3 times at different growth stages. Plant height, branch number/plant, dry matter content/plant, 100-seed weight, and seed and oil yield were highest with 40 kg S. Among irrigation treatments, seed yield was highest (0.76 t/ha) with 3 irrigations at branching, flowering and pod development (30, 50 and 70 days after sowing). The crop responded to higher S rates with 2-3 than with 1 irrigation.

In a greenhouse experiment conducted by Yadav *et al.* (1996) the response of sesame cv. Pratap to different sources of sulfur applied through ammonium sulfate, gypsum, pyrites and elemental sulfur was studied on an alkaline sandy loam soil. Seed and stalk yields, S uptake and oil content of sesame increased significantly with increasing levels of sulfur. Amongst the sources of S tested, ammonium sulfate and gypsum were the best followed by pyrites and elemental sulfur in respect of yield, oil content and S uptake.

In a field experiment conducted by Chaplot (1996) in kharif 1986 in Udaipur, Rajasthan, India, sesame was given 20, 40 or 60 kg $P_2O_5$/ha as DAP [diammonium phosphate] or SSP [single superphosphate] with or without 50 kg S/ha. Application of 40 or 60 kg $P_2O_5$/ha gave the best growth and yield. P source was not significant. The highest net return and benefit:cost ratio were obtained with the application of S in combination with 40 kg $P_2O_5$/ha as DAP.

**2.3 Effect of nitrogen and sulfur on sesame**

The effects of N (0, 30, 60 and 90 kg/ha), B (0 and 1 kg/ha) and S (0, 25 and 50 kg/ha) on the growth and productivity of sesame cv. B-67 were investigated by Sarkar and Anita (2005) during the summer seasons of 2001 and 2002 in West Bengal, India. N, S and B improved leaf area index, biomass production, crop growth rate, relative growth rate, net assimilation rate and yield attributes, which resulted in higher seed yield. N at 90 kg/ha, S at 50 kg/ha and B at 1 kg/ha resulted in 94.2, 30.4 and 10.4% higher seed yield, respectively, compared to the control. Increasing N and S levels increased the agronomic and physiological efficiency of the nutrient.

A field experiment was conducted by Naugraiya and Jhapatsingh (2004) in Chhattisgarh, India, during the rainy season to find out the response of oil seed crop, *Sesamum indicum* to nitrogen, sulfur and tree canopy of *Dalbergia sissoo* under agrisilviculture system. Tree canopy of *D. sissoo* had partially adverse effect on plant dry matter production, leaf area index, capsules/plant, length of capsule and seeds/capsule of intercropped sesame, resulting in 6.21% decrease in sesame yield as compared to the crop grown in open field. The role of nitrogen resulted significant increase in the growth and yield attributes, with highest values under N60. Application of sulfur (10 kg S/ha) enhanced the growth and yield attributes significantly than control.

A field experiment was conducted by Chaubey *et al.* (2003) in Uttar Pradesh, India during rainy (kharif) seasons of 1997 and 1998 to study the response of nitrogen and sulfur on growth, yield attributes and yield of sesame (*Sesamum indicum* cv. T-4). The growth, yield attributes and seed yield of sesame were significantly increased with the application of different levels of nitrogen (0, 15, 30, 45 and 60 kg/ha) and sulfur (0, 15, 30 and 45 kg/ha). Interaction of N and S was also significant for capsules/plant and seed yield up to 45 kg N and 30 kg S/ha during both the years. Further increase in the dose of N and S i.e. 60 and 45 kg/ha, did not bring significant increase in the seed yield and other attributes. Application of 45 kg N along with 30 kg S/ha was the optimum dose of N and S for getting the highest seed yield of sesame.

The effects of gypsum (0, 500, and 1000 kg/ha) and N (4 5, 60, and 75 kg/ha) rates, and spacing (10, 20 and 30 cm) on sesame cv. Giza 32 were studied by Allam *et al.* (2002) in Assiut, Egypt, in 2000 and 2001. Gypsum was applied during sowing and 55 days after sowing. N as ammonium nitrate was applied after thinning and 3 weeks thereafter. Increasing gypsum and N rates increased plant height, length of fruiting zone, number of branches and capsules per plant, seed yield per plant and per ha, oil percentage, and oil yield. Seed index and capsule length were highest with 60 and 75 kg N/ha.

A field experiment was conducted by Tiwari *et al.* (2000) during the kharif seasons of 1996 and 1997 in Madhya Pradesh, India. Seeds of sesame cultivars were sown on 21-22 July 1996 and 1997 at 5 kg/ha. In the main plot, N was applied at (15, 30 or 60 kg/ha) partly as diammonium phosphate (basal application at 30 kg $P_2O_5$/ha, supplying 12 kg N/ha). The remaining N was supplied by urea (50% basal and 50% at 30 days after sowing). Crops were harvested on 15-17 October of both years. Subplots were treated with 0, 15 or 30 kg sulfur/ha. Significant improvement in growth and yield (plant height; numbers of primary branches, leaves and capsules/plant; podding length on the stem; number of seeds/capsule; 1000-seed weight (OSW); and seed (SW) and straw weights) were observed for N at 60 kg/ha, compared with N at 15 kg/ha. S at 30 kg/ha resulted in a significant increase only in the numbers of capsules/plant, seeds/capsule, OSW and SW, compared with S at 0 and 15 kg/ha. SO decreased and SP increased significantly with increasing N, while S application enhanced both SO and SP.

In a field experiment conducted by Nageshwar *et al.* (1995) during the summer season of 1991 at Raipur, Madhya Pradesh, sesame cv. Selection 5 was given 40, 80 or 120 kg N, 0, 30, 60 or 90 kg $K_2O$ and 0 or 10 kg S/ha. Seed yield was the highest with 120 kg N (1.82 t/ha), 60 kg $K_2O$ (1.75 t) and S application (1.68 t). Seed oil content was not affected by fertilizer application. Uptake of P, K and S increased with increasing N rate while N uptake was not affected by N rate. P, K and S uptakes were highest with 90 kg $K_2O$. S application increased N and K uptakes.

Literature showed wide variations in the requirements of N (45 to 120 kg/ha) and S (10 to 50 kg/ha) for sesame might be due to variations in soil, agro-ecological factors, varieties and management aspects.

# Chapter III

# Materials and Methods

# CHAPTER 3

# MATERIALS AND METHODS

The experiment was conducted during the period from February to May, 2009 to find out the effect of nitrogen and sulfur on the growth, yield and oil content of sesame. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters under the following headings:

## 3.1 Location

The experiment was carried out in the research field of Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh. The location of the experimental site is $23^{0}74^{\prime}$N latitude and $90^{0}35^{\prime}$E longitude and an elevation of 8.2 m from sea level (Anon., 1989). The following map shows the specific location of the experimental site (Plate 1).

## 3.2 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for important physical and chemical parameters. The initial physical and chemical characteristics of soil are presented in Table 1.

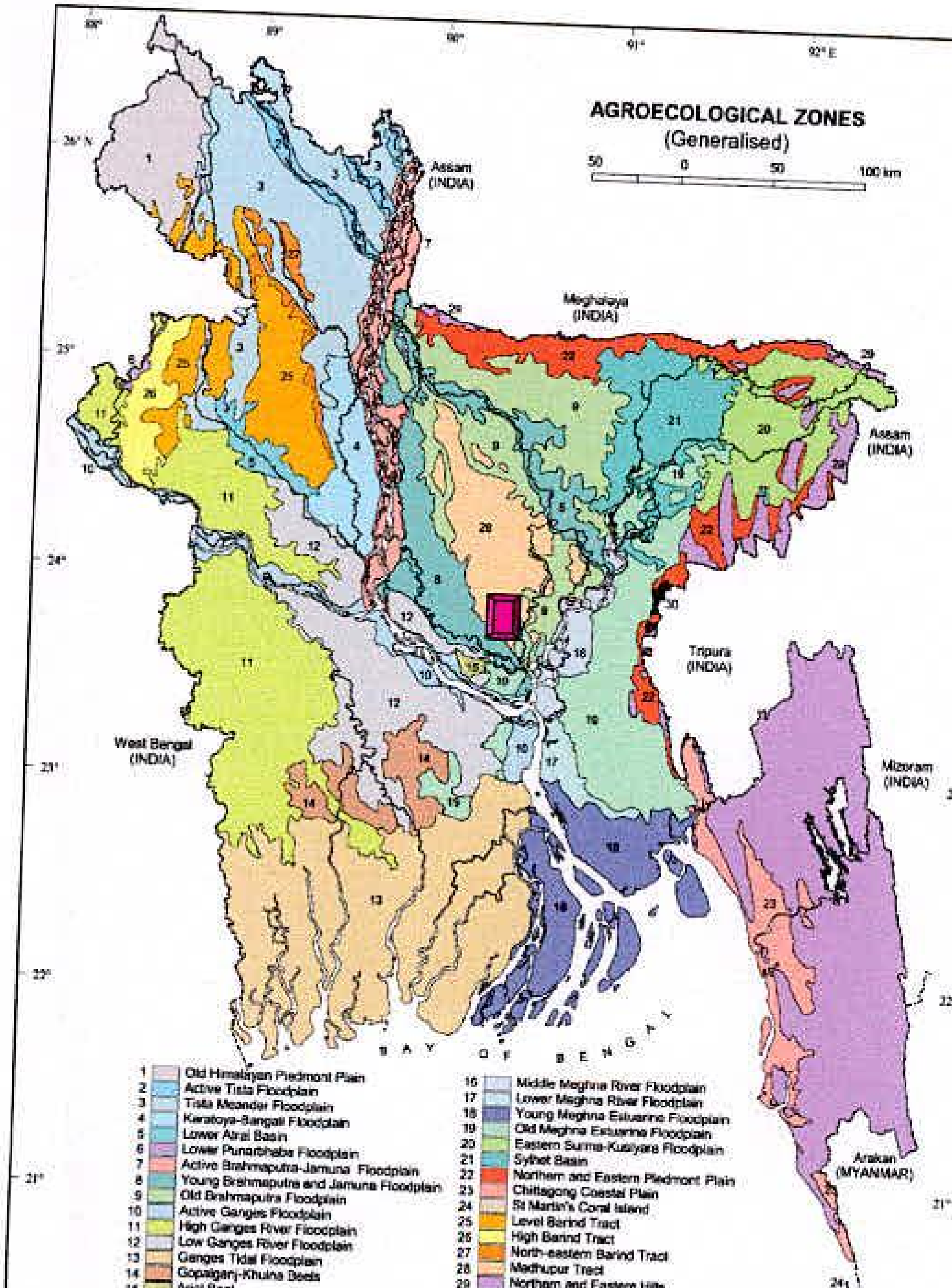



Plate 1. Map showing the experimental site under study

**Table 1. Initial characteristics of the soil in experimental field**

| Characters | | Value |
|---|---|---|
| 1. pH | | 6.07 |
| 2. Particle-size analysis of soil | Sand | 29.04 |
| | Silt | 41.80 |
| | Clay | 29.16 |
| 3. Textural Class | | Silty Clay Loam |
| 4. Organic carbon (%) | | 0.98 |
| 5. Total N (%) | | 0.078 |
| 6. Phosphorous (µg/g) | | 20.14 |
| 7. Potassium (meq/100 g) | | 0.185 |
| 8. Sulfur (µg/g) | | 10.87 |

### 3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix I.

### 3.4 Planting material

Seeds of BARI Til-3 used as a test crop for the study and those were collected from Bangladesh Agricultural Research Institute, Gazipur. This variety was developed by BARI and exposed for cultivation in the year of 2001 (BARI, 2008). It is a non-hairy medium sized plant with primary and secondary branches with high potential plant.

### 3.5 Treatment of the experiment

The experiment considered of two factors. Details of the treatments are presented below:

Factor A: Levels of nitrogen (4 levels)

i. $N_0$: 0 kg N/ha (control)

ii. $N_1$: 40 kg N/ha

iii. $N_2$: 60 kg N/ha

iv. $N_3$: 100 kg N/ha

Factor B: Levels of sulfur (4 levels)

i. $S_0$: 0 kg S/ha (control)

ii. $S_1$: 20 kg S/ha

iii. $S_2$: 40 kg S/ha

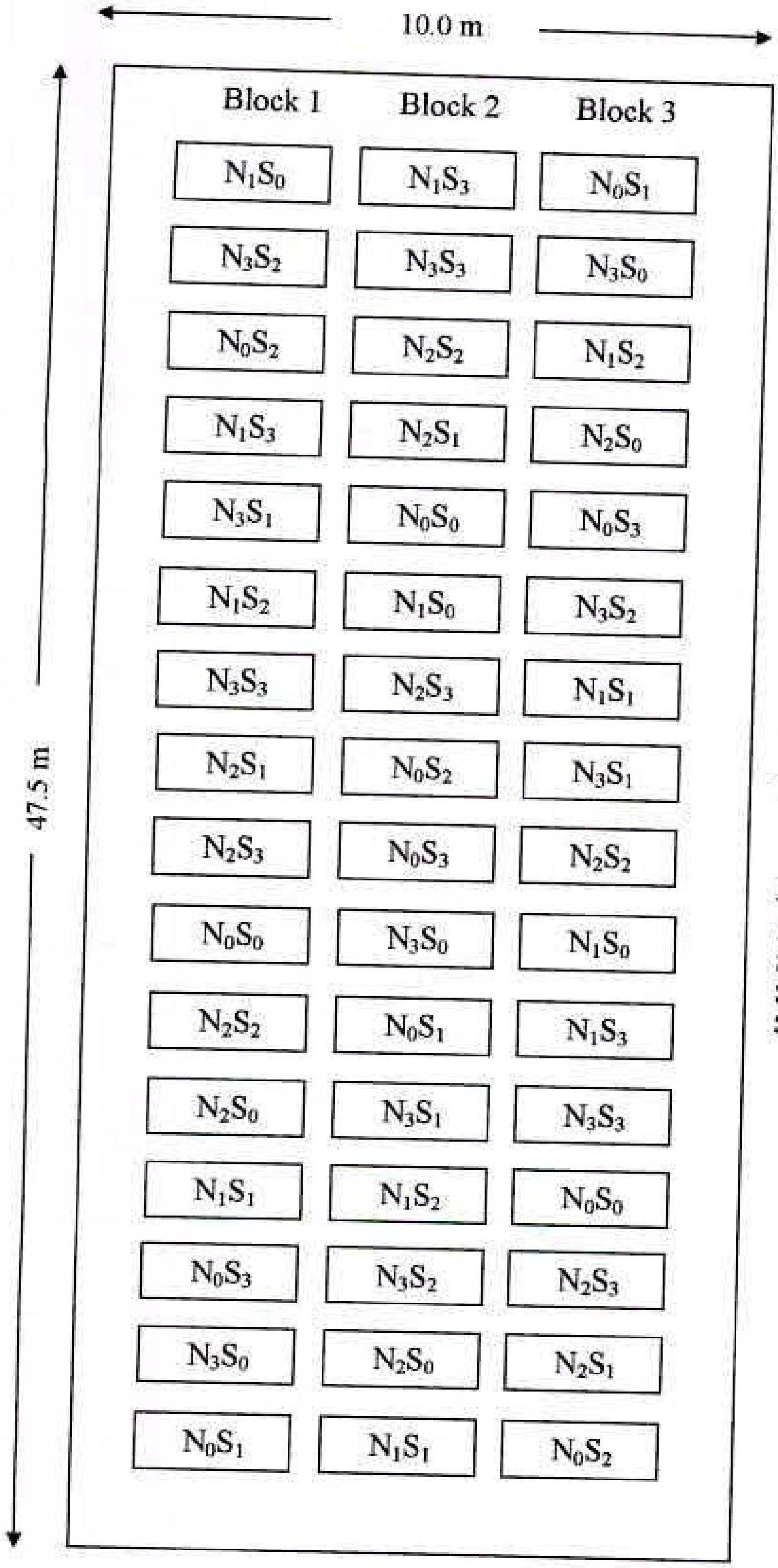
iv. $S_3$: 60 kg S/ha

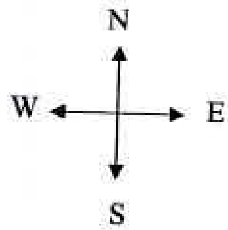
There were 16 (4 × 4) treatment combinations such as $N_0S_0$, $N_0S_1$, $N_0S_2$, $N_0S_3$, $N_1S_0$, $N_1S_1$, $N_1S_2$, $N_1S_3$, $N_2S_0$, $N_2S_1$, $N_2S_2$, $N_2S_3$, $N_3S_0$, $N_3S_1$, $N_3S_2$ and $N_3S_3$.



### 3.6 Layout of the experiment

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatments in each plot of each block. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. The size of the plot was 2.5 m × 2.0 m. The distance between two blocks and two plots was 50 cm each.




Plot size = 2.5 m ×2.0 m

Plot to plot: 0.5 m

Replication to replication: 1.0 m

**Factor A: Level of nitrogen**

$N_0$: 0 kg N/ha

$N_1$: 40 kg N/ha

$N_2$: 60 kg N/ha

$N_3$: 100 kg N/ha

**Factor B: Level of sulfur**

$S_0$: 0 kg S/ha

$S_1$: 20 kg S/ha

$S_2$: 40 kg S/ha

$S_3$: 60 kg S/ha

Figure 1. Field layout of factorial experiment in the Randomized Complete Block Design (RCBD)

## 3.7 Land preparation

The experimental field was first opened on February 05, 2009 with the help of a power tiller and prepared by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally leveled with the help of wooden plank.

## 3.8 Fertilizer application

Manures and fertilizers that were applied to the experimental plot presented in Table 2. The total amount of TSP, half of MP, total zinc oxide, boric acid and sulfur was applied as basal dose at the time of land preparation. The rest amount of MP and total amount of urea (as per treatment) was applied in two installments at 15 and 30 day after seed sowing.

**Table 2. Dose and method of application of fertilizers in sesame field**

| Fertilizers and Manures | Dose/ha | Application (%) | | |
|---|---|---|---|---|
| | | Basal | 15 DAS | 30 DAS |
| Urea | As per treatment | -- | 50 | 50 |
| TSP | 150 kg | 100 | -- | -- |
| MP | 50 kg | 50 | 25 | 25 |
| Zinc Oxide | 2 kg | 100 | -- | -- |
| Sulfur (Gypsum) | As per treatment | 100 | -- | -- |
| Boric Acid | 1 kg | 100 | -- | -- |

Source: BARI, 2008

### 3.9 Sowing of seeds

The seeds of BARI Til-3 were sown on 17 February 2009 in rows in broadcasting.

### 3.10 After care

#### 3.10.1 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after germination of seedlings. Irrigation also provided at 10 and 25 days after seed sowing.

#### 3.10.2 Thinning

Thinning was done carefully for better growth of the germinated palnts and it was done manually after 22 days of sowing, on March 11, 2009. Care was taken to maintain constant plant population per plot.

#### 3.10.3 Gap Filling

Dead, injured and week seedlings were replaced by healthy one from the stock kept on the border line of the experimental plot. Those seedlings were re-transplanted with a big mass of soil with roots to minimize transplanting shock. Replacement was done with healthy seedling having balls of earth those were also sown at same date on border line. The transplanted seedlings were provided shading and watering for 03 days for the establishment of seedlings.

#### 3.10.4 Weeding

Weeding was done two times at 10 and, 25 days after seed sowing followed by irrigation.

### 3.10.5 Plant Protection

The crop was protected from the attack of insect-pest by spraying Malathion. The insecticide application were made fortnightly as a matter of routine work from seedling emergence to the end of harvest.

## 3.11 Harvesting

The pod was harvested depending upon the attaining good sized and the harvesting was done manually. Enough care was taken during harvesting.

## 3.12 Data collection

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot, 10 plants were selected at random for data collection. Data were collected in respect of the plant growth characters and yield of sesame. Data were recorded on the following parameters-

### 3.12.1 Plant height

The height of plant was recorded at 30, 40, 50, 60 DAS and at harvest by using a meter scale. The height was measured from the ground level to the tip of the plant of an individual plant. Mean value of ten selected plants was calculated for each unit plot and expressed in centimeter (cm).

### 3.12.2 Number of branches per plant

Number of branches per plant was counted and the data were recorded from randomly selected 10 plants at 30, 40, 50, 60 DAS and harvest and mean value was counted and recorded.

### 3.12.3 Number of leaves per plant

Number of leaves per plant was counted and the data were recorded from randomly selected 10 plants at 30, 40, 50, 60 DAS and at harvest and mean value was counted and recorded.

### 3.12.4 Days to first flowering

The number of days from sowing to first flower opening was recorded from 10 randomly selected plants.

### 3.12.5 Number of capsule per plant

Numbers of capsule were counted from 10 randomly selected plants as harvested from each unit plot.

### 3.12.6 Length of capsule (cm)

Length of capsule was measured from 10 randomly selected plants as harvested from each unit plot.

### 3.12.7 Diameter of capsule (mm)

Diameter of capsule was measured from 10 randomly selected plants as harvested from each unit plot.

### 3.12.8 Seeds per capsule

Seeds per capsule were counted from 10 randomly selected capsules as harvested from each unit plot.

### 3.12.9 Weight of 1000 seeds (g)

As per treatment, 1000 seeds were counted and weighted accordingly expressing in gram.

### 3.12.10 Seed yield per hectare

Mature capsule pod were harvested from each plot and seeds were separated from capsule their weight was recorded. The seed yield per plot was finally converted to yield per hectare and expressed in ton (t).

### 3.12.11 Stover yield per hectare

Mature sesame plants were harvested from each plot and seeds and stover were separated and weight of stover was recorded. The stover yield per plot was finally converted to stover yield per hectare and expressed in ton (t).

### 3.12.12 Oil content

The oil content of sesame seed was determined by Folch method (Folch, *et al.*, 1957). One gram sesame seed was taken in a mortar. The seeds were completely ground with a pestle. Thirty milliliter Folch reagent (chloroform: methanol = 2: 1) was added to it. After through mixing, the melt was filtered through Whatman No. 42 filter paper and the filtrate taken in a beaker. The filtrate was allowed to stand for about six hours for air drying and then dried in an oven for about half an hour to determine total oil. Proper care was taken so that chloroform and methanol mixture completely had dried out. Oil content was calculated by the following formula:

$$\text{Oil content (\%)} = \frac{\text{Weight of extract (g)}}{\text{Sample weight (g)}} \times 100$$

### 3.13 Chemical analysis of plant sample

#### 3.13.1 Collection of samples

Plant samples (stover and seeds) were collected, dried and finely ground by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S.

#### 3.13.2 Preparation of samples

The plant samples were dried in an oven at $70^0$C for 72 hours and then ground by a grinding machine to pass through a 20-mesh sieve and analyzed for determination of N, P, K and S. The methods of analysis were as follows:

#### 3.13.3 Digestion of plant samples with sulphuric acid for Nitrogen

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture ($K_2SO_4$:$CuSO_4.5H_2O$: Se at the ratio of 100: 10: 1), and 5 ml conc. $H_2SO_4$ were added. The flasks were heated at $120^0$C and added 2.5 ml 30% $H_2O_2$ then heating was continued at 180 $^0$C until the digests became clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in $H_3BO_3$ indicator solution with 0.01N $H_2SO_4$.

#### 3.13.4 Digestion of plant samples with nitric-perchloric acid for P, K and S

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid ($HNO_3$: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated slowly and the temperature was raised to $200^0C$. Heating was stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest.

### 3.13.5 Determination of N, P, K and S from plant

#### 3.13.5.1 Nitrogen

Plant samples were digested with 30% $H_2O_2$, conc. $H_2SO_4$ and a catalyst mixture ($K_2SO_4$: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in $H_3BO_3$ with 0.01N $H_2SO_4$ (Jackson, 1973).

#### 3.13.5.2 Phosphorus

Phosphorus was digested from the plant sample with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

#### 3.13.5.3 Potassium

Five milli-liter of digest sample for the plant were taken and diluted to 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbances were measured by flame photometer.

#### 3.13.5.4 Sulphur

Sulphur content was determined from the digest of the plant samples with $CaCl_2$ (0.15%) solution as described by (Page *et al.*, 1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as $K_2SO_4$ in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

### 3.14 Nutrient Uptake

After chemical analysis of plant the nutrient contents and nutrient uptakes were also calculated by following formula:

$$\text{Nutrient uptake (kg/ha)} = \text{Nutrient content (\%)} \times \text{Yield (kg/ha)}$$

### 3.15 Post harvest soil sampling

After harvest of crop, soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

### 3.16 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P, K, and S contents. The soil samples were analyzed by the following standard methods as follows:

### 3.16.1 Soil pH

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

### 3.16.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. $H_2SO_4$ and conc. $H_3PO_4$ and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. The content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

### 3.16.3 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 g catalyst mixture ($K_2SO_4$: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 6 ml $H_2SO_4$ were added. The flasks were swirled and heated to $200^0$C and 3 ml $H_2O_2$ was added. The heating at $360^0$C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).

Then 20 ml digest solution was transferred into the distillation flask. Then 10 ml of $H_3BO_3$ indicator solution was taken into a 250 ml conical flask which was placed under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10 N-NaOH solution was in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillate was titrated with standard 0.01 N $H_2SO_4$ until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T\text{-}B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard $H_2SO_4$

B = Blank titration (ml) value of standard $H_2SO_4$

N = Strength of $H_2SO_4$

S = Sample weight in gram

### 3.16.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated by the standard P curve (Page *et al.*, 1982).

### 3.16.5 Exchangeable potassium

Exchangeable K was determined by 1 N $NH_4OAC$ (pH 7) extraction methods and reading was taken by flame photometer (Page *et al.*, 1982).

### 3.16.6 Available sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al.*, 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as $K_2SO_4$ in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

### 3.17 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference. The mean values of all the characters were evaluated and analysis of variance was done by the 'F' (variance ratio) test. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

# Chapter IV
# Results and Discussion

# CHAPTER IV

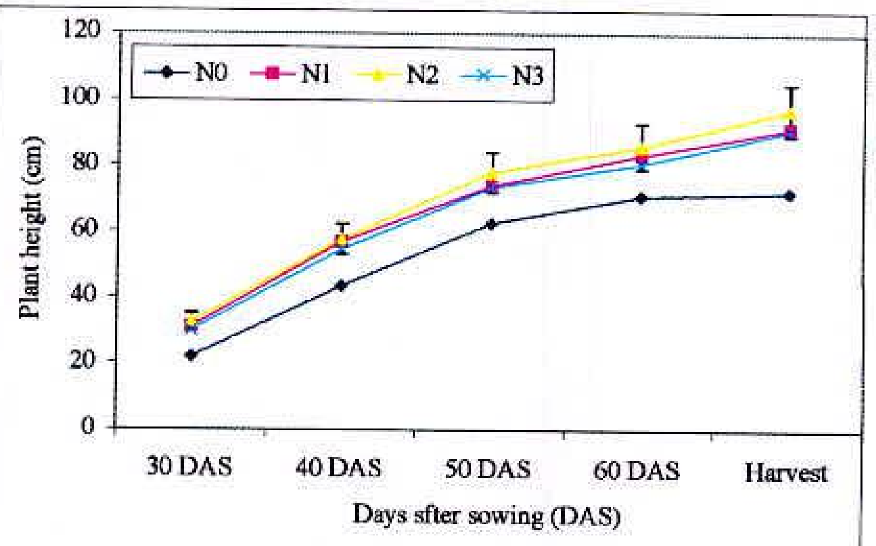
# RESULTS AND DISCUSSION

The study was conducted to determine the effect of nitrogen and sulfur on growth and yield of sesame. Data on different yield contributing characters and yield were recorded to find out the optimum level of nitrogen and sulfur for sesame cultivation. The analysis of variance (ANOVA) of the data on different yield contributing characters and yield are given in Appendix II-VIII. The results have been presented and discussed, and possible interpretations given under the following headings:

## 4.1 Yield contributing characters and yield of sesame

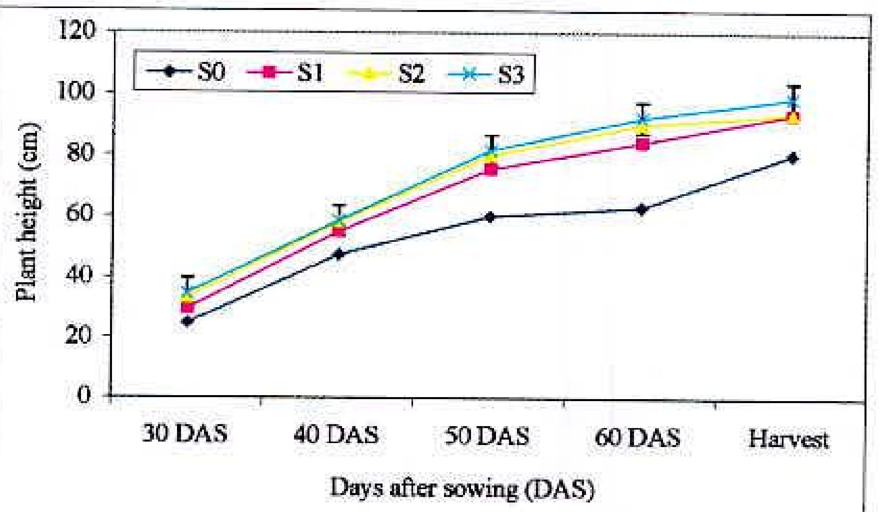
### 4.1.1 Plant height

Statistically significant variation was recorded for nitrogen on plant height of sesame at 30, 40, 50, 60 DAS and at harvest (Figure 2). The tallest plant (32.53 cm, 57.64 cm, 78.04 cm, 86.09 cm and 99.09 cm) was observed from $N_2$ (60 kg N/ha) which was followed (30.96 cm, 56.80 cm, 73.89 cm, 83.27 cm and 91.50 cm) by $N_1$ (40 kg N/ha), while the shortest plant (21.88 cm, 43.40 cm, 62.53 cm, 70.85 cm and 72.09 cm) was recorded from $N_0$ treated plots (control) at 30, 40, 50, 60 DAS and harvest, respectively. It was revealed that with the increase of nitrogen fertilizer plant height increased upto a certain level. Nitrogen ensured favorable condition for the growth of sesame plant with optimum vegetative growth and the ultimate results was the tallest plant. Fayed *et al.* (2000) and Pathak *et al.* (2002) also reported similar findings.




$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha

Figure 2. Effect of nitrogen on plant height of sesame




$S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 3. Effect of sulfur on plant height of sesame

Plant height of sesame varied significantly at 30, 40, 50, 60 DAS and harvest due to sulfur application (Figure 3). At 30, 40, 50, 60 DAS and harvest the tallest plant (34.68 cm, 58.59 cm, 81.69 cm, 92.40 cm and 98.83 cm) was recorded from $S_3$ (60 kg S/ha) which was statistically identical (33.28 cm, 58.19 cm, 80.05 cm, 90.16 cm and 98.83 cm) with $S_2$ (40 kg S/ha) and the shortest plant (24.74 cm, 47.47 cm, 60.05 cm, 63.10 cm and 80.43 cm) was obtained from $S_0$ treated plots (control), respectively for same days after sowing. It revealed that with the increase of sulfur application plant height showed slightly increasing trend.

Significant difference was recorded for the interaction effect of nitrogen and sulfur in terms of plant height at 30, 40, 50, 60 DAS and harvest (Table 3). The tallest plant (39.96 cm, 64.15 cm, 89.03 cm, 99.43 cm, 119.58 cm) was observed from $N_2S_3$ treatment combination (60 kg N/ha and 60 kg S/ha) and the shortest plant (17.81 cm, 35.90 cm, 48.61 cm, 54.35 cm and 63.68 cm) was recorded from $N_0S_0$ treatment combination (control).

**4.1.2 Number of branches per plant**

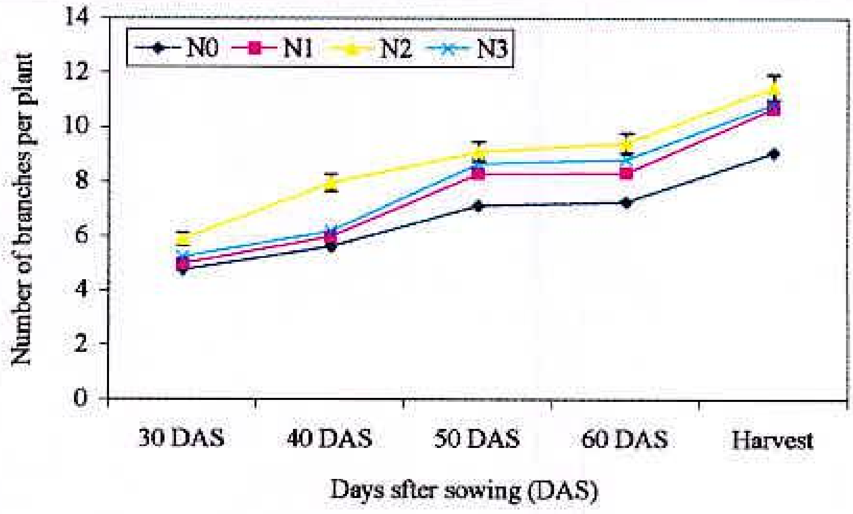
Number of branches per plant of sesame at 30, 40, 50, 60 DAS and at harvest showed statistically significant variation for nitrogen (Figure 4). The maximum number of branches per plant (5.89, 7.96, 9.10, 9.42, 11.47) was recorded from $N_2$ (60 kg N/ha) which was followed (5.24, 6.18, 8.66, 8.82 and 10.85) by $N_3$ (100 kg N/ha), again the minimum number (4.75, 5.62, 7.12, 7.26 and 9.06) was obtained from $N_0$ (control) at 30, 40, 50, 60 DAS and harvest, respectively. Mitra and Pal (1999) also reported similar findings.

**Table 3. Interaction effect of nitrogen and sulfur on plant height of sesame**

| Treatment | Plant height (cm) at | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| $N_0S_0$ | 17.81 ef | 35.90 fg | 48.61 fg | 54.35 d | 63.68 j |
| $N_0S_1$ | 20.92 de | 44.03 bcde | 64.40 cd | 74.17 bc | 74.22 i |
| $N_0S_2$ | 22.87 cde | 46.24 bcde | 66.96 bc | 75.19 bc | 75.72 hi |
| $N_0S_3$ | 26.66 bcd | 48.62 abcd | 70.44 abc | 79.96 ab | 74.75 i |
| $N_1S_0$ | 29.62 cde | 52.08 def | 61.21 efg | 65.06 d | 80.19 gh |
| $N_1S_1$ | 30.19 cde | 54.91 bcde | 77.17 bc | 88.11 abc | 93.16 f |
| $N_1S_2$ | 30.81 bcde | 55.45 bcde | 79.22 bc | 89.55 ab | 98.72 e |
| $N_1S_3$ | 34.27 abcd | 57.10 abcd | 79.18 abc | 91.83 ab | 93.93 f |
| $N_2S_0$ | 20.38 f | 42.91 g | 53.78 g | 54.43 e | 103.12 c |
| $N_2S_1$ | 32.72 bcd | 58.24 abcd | 80.24 abc | 90.92 ab | 115.41 a |
| $N_2S_2$ | 37.07 ab | 61.27 ab | 85.10 ab | 95.01 ab | 110.70 b |
| $N_2S_3$ | 39.96 a | 64.15 a | 89.03 a | 99.43 a | 119.58 a |
| $N_3S_0$ | 24.69 ef | 48.98 efg | 66.61 def | 70.55 d | 74.70 g |
| $N_3S_1$ | 27.90 de | 53.06 cdef | 70.46 cde | 76.03 cd | 91.88 de |
| $N_3S_2$ | 35.50 cbc | 60.17 abc | 78.42 bc | 87.23 abc | 101.29 c |
| $N_3S_3$ | 31.16 bcd | 55.67 bcde | 79.13 bc | 90.82 ab | 95.88 d |
| Level of significance | 0.01 | 0.05 | 0.05 | 0.01 | 0.01 |
| CV(%) | 11.17 | 7.26 | 5.22 | 8.13 | 8.18 |

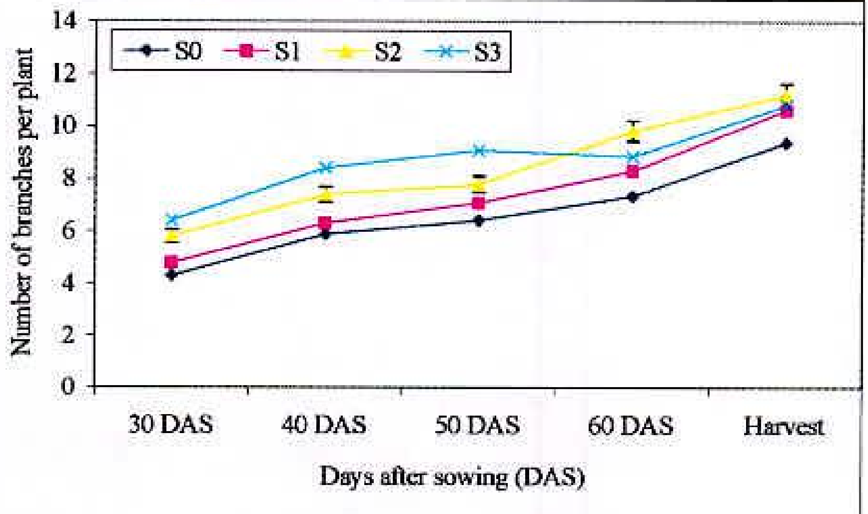
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability by DMRT

| | |
|---|---|
| $N_0$: 0 kg N/ha (control) | $S_0$: 0 kg S/ha (control) |
| $N_1$: 40 kg N/ha | $S_1$: 20 kg S/ha |
| $N_2$: 60 kg N/ha | $S_2$: 40 kg S/ha |
| $N_3$: 100 kg N/ha | $S_3$: 60 kg S/ha |




$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha

Figure 4. Effect of nitrogen on number of branches per plant of sesame




$S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 5. Effect of sulfur on number of branches per plant of sesame

Significant variation was recorded for number of branches per plant of sesame at 30, 40, 50, 60 DAS and harvest due to S application (Figure 5). At 30, 40, 50, 60 DAS and harvest the maximum number of branches per plant (6.41, 8.43, 9.10, 9.85 and 11.22) was recorded from $S_3$ (60 kg S/ha) which was followed (5.82, 7.42, 7.81, 8.87 and 10.82) by $S_2$ (40 kg S/ha), while the minimum number (4.31, 5.89, 6.42, 7.37 and 9.40) was observed from $S_0$ (control), respectively for same days after sowing.

Interaction effects of nitrogen and sulfur were only statistically significant in terms of number of branches per plant at 60 DAS and harvest (Table 4). The maximum number of branches per plant (9.63 and 12.25) was found from $N_2S_3$ (60 kg N/ha and 60 kg S/ha), whereas the minimum number (7.31 and 8.41) was recorded from $N_0S_0$ treatment combination (control).

**4.1.3 Number of leaves per plant**

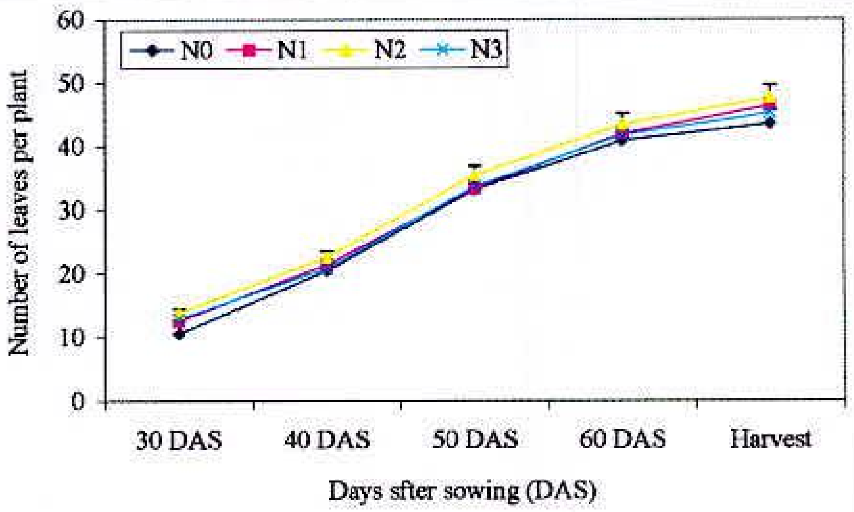
Significant differences were recorded for nitrogen on number of leaves per plant of sesame at 30, 40, 50, 60 DAS and at harvest (Figure 6). The maximum number of leaves per plant (13.91, 22.61, 35.49, 43.44 and 47.58) was obtained from $N_2$ (60 kg N/ha) which was followed by 12.89, 20.83, 33.67, 41.76 and 45.20 from $N_3$ (100 kg N/ha) and the minimum number (10.58, 20.46, 33.21, 40.86 and 43.52) was recorded from $N_0$ (control) at 30, 40, 50, 60 DAS and harvest, respectively. Pathak *et al.* (2002) also reported similar findings.

**Table 4. Interaction effect of effect of nitrogen and sulfur on number of branches per plant of sesame**

| Treatment | Number of branches per plant at | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| $N_0S_0$ | 4.53 | 5.77 | 6.77 | 7.31 b | 8.41 g |
| $N_0S_1$ | 4.77 | 5.96 | 7.11 | 7.79 ab | 9.18 f |
| $N_0S_2$ | 5.28 | 6.52 | 7.46 | 8.55 ab | 9.52 ef |
| $N_0S_3$ | 5.58 | 7.02 | 8.11 | 8.06 ab | 9.11 f |
| $N_1S_0$ | 4.65 | 5.93 | 7.35 | 7.74 ab | 9.47 ef |
| $N_1S_1$ | 4.89 | 6.14 | 7.69 | 8.22 ab | 10.62 d |
| $N_1S_2$ | 5.40 | 6.69 | 8.20 | 8.98 ab | 11.60 b |
| $N_1S_3$ | 5.70 | 7.20 | 8.69 | 8.49 ab | 11.11 c |
| $N_2S_0$ | 5.01 | 6.92 | 7.76 | 8.39 ab | 9.92 e |
| $N_2S_1$ | 5.34 | 7.13 | 8.10 | 8.87 ab | 11.72 b |
| $N_2S_2$ | 5.85 | 7.69 | 8.45 | 9.14 ab | 11.97 ab |
| $N_2S_3$ | 6.15 | 8.19 | 9.10 | 9.63 a | 12.25 a |
| $N_3S_0$ | 4.62 | 6.03 | 7.54 | 8.09 ab | 9.78 e |
| $N_3S_1$ | 5.01 | 6.24 | 7.88 | 8.57 ab | 11.04 cd |
| $N_3S_2$ | 5.53 | 6.80 | 8.23 | 9.33 ab | 11.50 bc |
| $N_3S_3$ | 5.69 | 7.30 | 8.88 | 8.84 ab | 11.09 cd |
| Level of significance | NS | NS | NS | 0.05 | 0.01 |
| CV(%) | 6.931 | 7.125 | 9.821 | 5.516 | 12.53 |

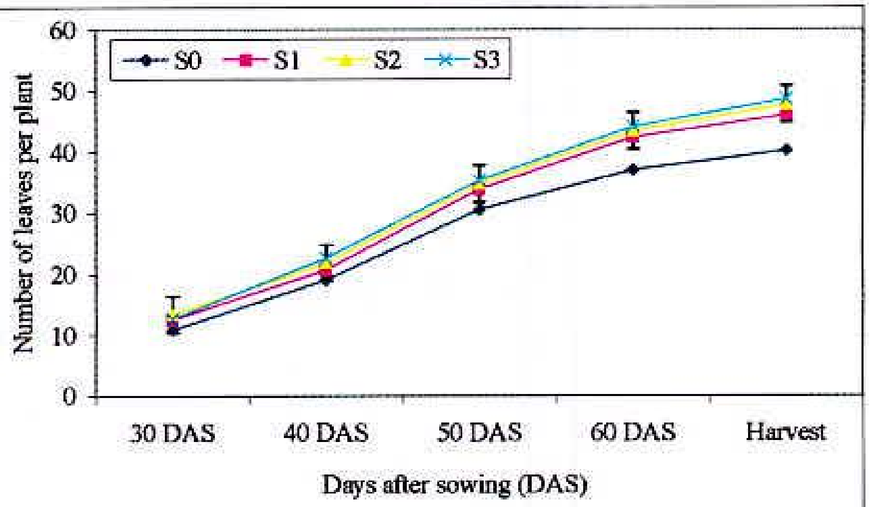
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability by DMRT

| | |
|---|---|
| $N_0$: 0 kg N/ha (control) | $S_0$: 0 kg S/ha (control) |
| $N_1$: 40 kg N/ha | $S_1$: 20 kg S/ha |
| $N_2$: 60 kg N/ha | $S_2$: 40 kg S/ha |
| $N_3$: 100 kg N/ha | $S_3$: 60 kg S/ha |




$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha

Figure 6. Effect of nitrogen on number of leaves per plant of sesame




$S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 7. Effect of sulfur on number of leaves per plant of sesame

Number of leaves per plant of sesame at 30, 40, 50, 60 DAS and harvest varied significantly due to the application of sulfur (Figure 7). At 30, 40, 50, 60 DAS and harvest the maximum number of leaves per plant (13.48, 22.68, 35.38, 44.12 and 48.65) was observed from $S_3$ (60 kg S/ha) which was followed (12.80, 21.84, 34.82, 43.42 and 47.76) by $S_2$ (40 kg S/ha), again the minimum number (11.00, 19.08, 30.57, 37.04 and 40.21) was obtained from $S_0$ (control), respectively for same days after sowing. Vaiyapuri *et al.* (2004) reported similar results by using S upto 45 kg/ha.

Significant variation was recorded for the interaction effect of nitrogen and sulfur in terms of number of leaves per plant at 30, 40, 50 DAS, 60 DAS and harvest (Table 5). The maximum number of leaves per plant (15.30, 24.35, 37.60, 45.98 and 50.57) was found from $N_2S_3$ (60 kg N/ha and 60 kg S/ha), whereas the minimum number (10.23, 19.15, 29.60, 35.45 and 39.35) was recorded from $N_0S_0$.

### 4.1.4 Days for 1st flowering

Days for 1st flowering of sesame showed statistically significant variation for nitrogen (Figure 8). The lowest days for 1st flowering (50.83 days) was obtained from $N_2$ (60 kg N/ha) which was followed by 51.75 days obtained from $N_1$ (40 kg N/ha) and $N_3$ (100 kg N/ha) but the highest days (53.67) from $N_0$ (control).

Different sulfur doses caused a significant variation in the days for 1st flowering of sesame (Figure 9). The lowest days for 1st flowering (50.25) was found from $S_2$ (40 kg S/ha) which was followed by 51.83 found from $S_3$ (60 kg S/ha), while the highest (53.92) from $S_0$ treatment.

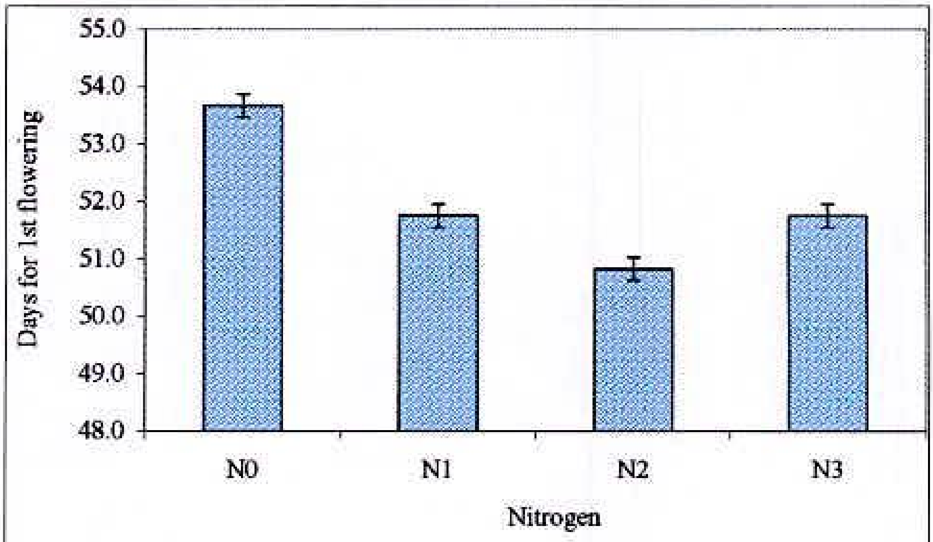
**Table 5. Interaction effect of nitrogen and sulfur on number of leaves per plant of sesame**

| Treatment | Number of leaves per plant at | | | | |
|---|---|---|---|---|---|
| | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| $N_0S_0$ | 10.23 i | 19.15 de | 29.60 ef | 35.45 f | 39.35 h |
| $N_0S_1$ | 10.80 hi | 21.44 cd | 33.99 bcd | 42.12 bcd | 46.06 cde |
| $N_0S_2$ | 10.80 hi | 20.57 bcd | 34.12 bcd | 42.45 abcd | 45.73 de |
| $N_0S_3$ | 10.50 i | 21.84 bc | 35.38 abcd | 43.43 abcd | 47.04 bcd |
| $N_1S_0$ | 10.87 hi | 20.69 bcd | 31.82 de | 37.97 ef | 40.50 gh |
| $N_1S_1$ | 12.36 f | 20.91 bcd | 33.26 bcd | 42.86 abcd | 47.29 bcd |
| $N_1S_2$ | 14.07 bc | 21.25 bcd | 33.71 bcd | 43.08 abcd | 49.13 abc |
| $N_1S_3$ | 13.00 ef | 22.80 ab | 34.71 abcd | 43.83 abcd | 48.99 abc |
| $N_2S_0$ | 11.57 g | 17.51 e | 28.38 f | 34.67 f | 38.61 h |
| $N_2S_1$ | 14.23 bc | 21.68 bc | 35.60 abc | 44.01 abc | 47.62 bcd |
| $N_2S_2$ | 14.53 b | 22.89 ab | 36.38 ab | 45.12 ab | 49.68 ab |
| $N_2S_3$ | 15.30 a | 24.35 a | 37.60 a | 45.98 a | 50.57 a |
| $N_3S_0$ | 11.33 gh | 18.98 de | 32.49 cde | 40.07 de | 42.36 fg |
| $N_3S_1$ | 13.30 de | 21.27 cd | 33.81 bcd | 40.70 cde | 43.56 ef |
| $N_3S_2$ | 13.77 cd | 22.64 ab | 35.27 abcd | 43.13 abcd | 46.58 cd |
| $N_3S_3$ | 13.17 de | 21.91 bc | 33.93 bcd | 43.52 abcd | 48.29 abcd |
| Level of significance | 0.01 | 0.01 | 0.05 | 0.05 | 0.01 |
| CV(%) | 9.14 | 5.84 | 7.43 | 9.64 | 12.44 |

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

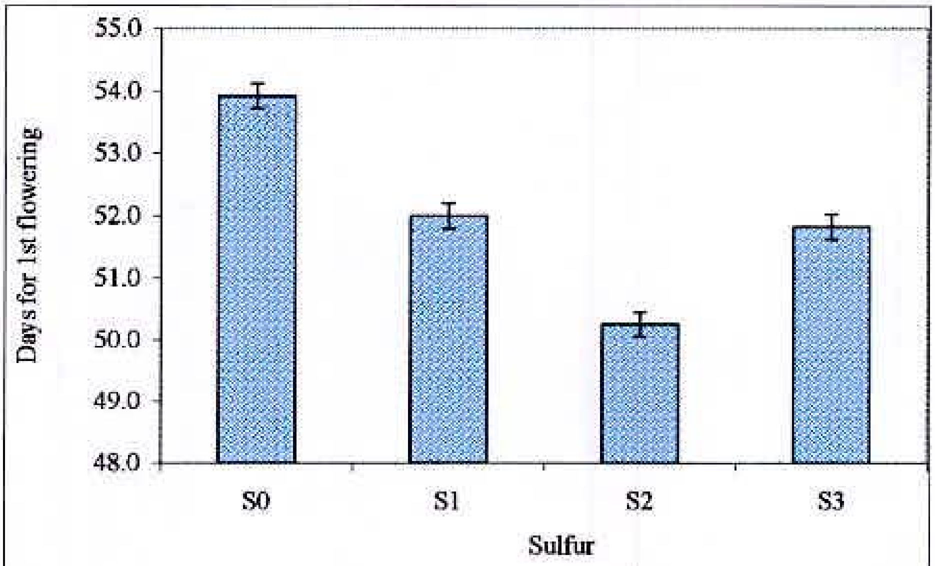
$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha




$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha

Figure 8. Effect of nitrogen on days for 1st flowering of sesame




$S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 9. Effect of sulfur on days to 1st flowering of sesame

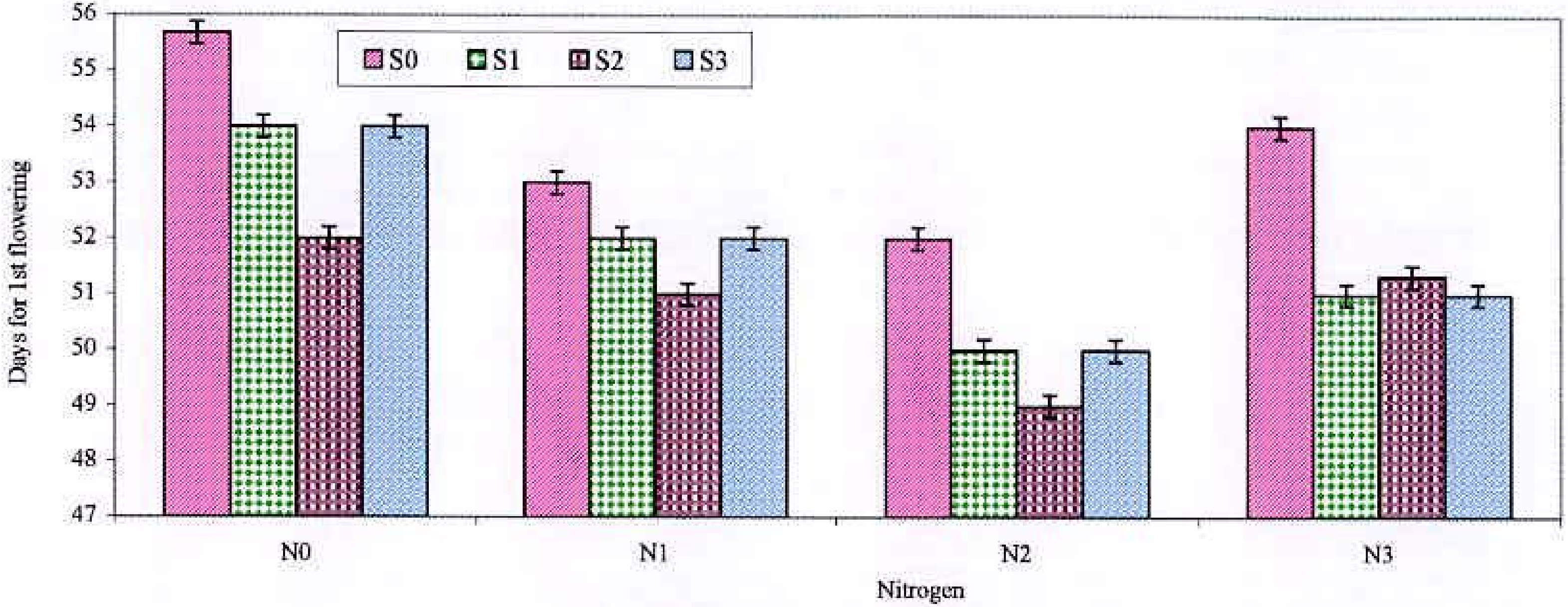
Interaction effect of nitrogen and sulfur showed statistically significant difference in terms of days for 1st flowering (Figure 10). The lowest days for 1st flowering (49.00) was recorded from $N_2S_2$ (60 kg N/ha and 40 kg S/ha) and the highest days (55.67) was observed from $N_0S_0$ (control).

### 4.1.5 Number of capsule per plant

Significant variation was recorded for nitrogen on the number of capsule per plant of sesame (Table 6). The number of capsule per plant increased significantly with increasing N level upto 60 kg N/ha, but decreased significantly with further increase of N level. The maximum number of capsule per plant was 64.29, while the minimum number (48.88) was found from $N_0$ treatment. Mondal *et al.* (2001) and Pathak *et al.* (2002) also reported similar findings.

Number of capsule per plant of sesame varied significantly for the application of sulfur (Table 6). The number of capsule per plant increased significantly with increasing S level upto 40 kg S/ha but decreased significantly with further increase in S level. The maximum number was 62.34 ($S_2$) and the minimum number (50.79) was obtained from $S_0$ treatment (control).

Number of capsule per plant showed significant difference for the interaction between nitrogen and sulfur (Table 7). The maximum number of capsule per plant (70.40) was found from $N_2S_2$ treatment combination (60 kg N/ha and 40 kg S/ha) and the minimum number (46.80) was obtained from $N_0S_0$ (control).




$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha
$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

Figure 10. Interaction effect of nitrogen and sulfur on days for 1st flowering of sesame

**Table 6. Main effect of nitrogen and sulfur on yield contributing characters and yield of sesame**

| Treatment(s) | Number of capsule per plant | Length of capsule (cm) | Diameter of capsule (cm) | Seeds per capsule | Weight of 1000 seeds (g) | Seed yield (t/ha) | Stover yield (t/ha) |
|---|---|---|---|---|---|---|---|
| **Nitrogen** | | | | | | | |
| $N_0$ | 48.88 c | 2.30 c | 1.31 d | 38.02 c | 9.06 c | 0.91 d | 2.52 c |
| $N_1$ | 58.22 b | 3.48 b | 1.77 c | 45.75 b | 10.70 b | 1.05 c | 2.96 b |
| $N_2$ | 64.29 a | 3.62 a | 2.58 a | 47.79 a | 11.47 a | 1.31 a | 3.05 ab |
| $N_3$ | 59.69 b | 3.44 b | 2.02 b | 46.09 b | 10.85 b | 1.22 b | 3.11 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Sulfur** | | | | | | | |
| $S_0$ | 50.79 c | 2.80 c | 1.66 c | 39.44 c | 9.40 c | 0.98 c | 2.74 c |
| $S_1$ | 58.69 b | 3.30 b | 1.97 b | 45.11 b | 10.64 b | 1.14 b | 2.87 b |
| $S_2$ | 62.34 a | 3.44 a | 2.09 a | 47.77 a | 11.22 a | 1.21 a | 2.88 b |
| $S_3$ | 59.26 b | 3.31 b | 1.97 b | 45.34 b | 10.82 b | 1.18 ab | 3.14 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 10.17 | 7.98 | 9.94 | 9.12 | 12.53 | 6.45 | 5.91 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

**Table 7. Interaction effect of effect of nitrogen and sulfur on yield contributing characters and yield of sesame**

| Treatment | Number of capsule per plant | Length of capsule (cm) | Diameter of capsule (cm) | Seeds per capsule | Weight of 1000 seeds (g) | Seed yield (t/ha) | Stover yield (t/ha) |
|---|---|---|---|---|---|---|---|
| $N_0S_0$ | 46.80 j | 2.11 g | 1.10 j | 32.47 j | 8.41 g | 0.77 g | 2.32 g |
| $N_0S_1$ | 50.04 hij | 2.37 f | 1.37 i | 38.24 i | 9.18 f | 0.95 ef | 2.50 fg |
| $N_0S_2$ | 50.08 hij | 2.40 f | 1.41 hi | 41.62 fg | 9.52 ef | 0.98 ef | 2.59 ef |
| $N_0S_3$ | 48.62 ij | 2.34 f | 1.38 hi | 39.76 hi | 9.11 f | 0.94 ef | 2.66 ef |
| $N_1S_0$ | 50.31 hi | 3.09 d | 1.51 gh | 40.43 gh | 9.47 ef | 0.90 f | 2.75 de |
| $N_1S_1$ | 57.26 f | 3.56 c | 1.82 f | 46.03 de | 10.62 d | 1.07 de | 3.01 c |
| $N_1S_2$ | 65.13 bc | 3.71 b | 1.93 ef | 49.77 ab | 11.60 b | 1.11 d | 2.98 c |
| $N_1S_3$ | 60.19 ef | 3.57 c | 1.82 f | 46.79 de | 11.11 c | 1.14 cd | 3.10 c |
| $N_2S_0$ | 53.56 g | 3.03 de | 2.39 bc | 42.78 f | 9.92 e | 1.27 ab | 3.00 c |
| $N_2S_1$ | 65.90 bc | 3.72 b | 2.64 a | 48.69 bc | 11.72 b | 1.29 ab | 3.00 c |
| $N_2S_2$ | 70.40 a | 3.99 a | 2.77 a | 50.63 a | 12.25 a | 1.40 a | 2.91 cd |
| $N_2S_3$ | 67.29 b | 3.75 b | 2.51 b | 49.07 abc | 11.97 ab | 1.29 ab | 3.30 b |
| $N_3S_0$ | 52.47 gh | 2.95 e | 1.63 g | 42.07 fg | 9.78 e | 0.96 ef | 2.91 cd |
| $N_3S_1$ | 61.58 de | 3.55 c | 2.04 de | 47.48 cd | 11.04 cd | 1.24 bc | 2.97 c |
| $N_3S_2$ | 63.74 cd | 3.69 b | 2.27 c | 49.07 abc | 11.50 bc | 1.35 ab | 3.05 c |
| $N_3S_3$ | 60.96 de | 3.56 c | 2.14 d | 45.75 e | 11.09 cd | 1.34 ab | 3.51 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 | 0.05 | 0.05 |
| CV(%) | 10.17 | 7.98 | 9.94 | 9.12 | 12.53 | 6.45 | 5.91 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

### 4.1.6 Length of capsule

Statistically significant variation was recorded for nitrogen on length of capsule of sesame (Table 6). The longest length of capsule (3.62 cm) was recorded from $N_2$ (60 kg N/ha), whereas the shortest length (2.30 cm) was observed from $N_0$ (control). However, it was reduced significantly at the highest dose of N. Mitra and Pal (1999) also reported similar findings earlier.

Different sulfur doses resulted in a significant variation for length of capsule of sesame (Table 6). The longest length of capsule (3.44 cm) was found from $S_2$ (40 kg S/ha) and the shortest length (2.80 cm) was attained from $S_0$ (control). However, it was decreased significantly at the highest dose of S.

Combined effect of nitrogen and sulfur varied significantly in terms of length of capsule (Table 7). The highest length of capsule (3.99 cm) was observed from $N_2S_2$ treatment combination (60 kg N/ha and 40 kg S/ha), while the shortest length (2.11 cm) was recorded from $N_0S_0$ treatment combination (control).

### 4.1.7 Diameter of capsule

Diameter of capsule of sesame showed statistically significant variation for nitrogen (Table 6). The longest diameter of capsule (2.58 mm) was observed from $N_2$ (60 kg N/ha) and the shortest diameter (1.31 mm) was recorded from $N_0$ (control).

Statistically significant variation was recorded for different sulfur in terms of diameter of capsule of sesame (Table 6). The longest diameter of capsule (2.09

mm) was found from $S_2$ (40 kg S/ha) and the shortest diameter (1.66 mm) was obtained from $S_0$ (control).

Diameter of capsule showed a statistically significant variation for the interaction effect of nitrogen and sulfur (Table 7). The highest diameter of capsule (2.77 mm) was obtained from $N_2S_2$ (60 kg N/ha and 40 kg S/ha), while the shortest diameter (1.10 mm) was recorded from $N_0S_0$ (control).

**4.1.8 Number of seeds per capsule**

Statistically significant variation was recorded for nitrogen on number of seeds per capsule of sesame (Table 6). The maximum number of seeds per capsule (47.79) was obtained from $N_2$ treatment (60 kg N/ha), whereas the minimum number (38.02 cm) was found from $N_0$ treatment (control). However, the highest dose of N reduced the number of seeds per capsule significantly. Pathak *et al.* (2002) also reported similar findings.

Different sulfur doses caused a significant variation for number of seeds per capsule of sesame (Table 6). The maximum number of seeds per capsule of sesame (47.77) was found from $S_2$ treatment (40 kg S/ha) and the minimum number (39.44) was recorded from $S_0$ (control). But increase of S from $S_2$ to $S_3$ treatment, reduced the number of seeds per capsule significantly.

Interaction effect of nitrogen and sulfur showed a statistically significant difference in terms of number of seeds per capsule of sesame (Table 7). The maximum number of seeds per capsule of sesame (50.63) was recorded from $N_2S_2$ (60 kg N/ha and 40 kg S/ha), whereas the minimum number (32.47) from $N_0S_0$ (control).

### 4.1.9 Weight of 1000 seeds

Statistically significant variation was recorded on the nitrogen for weight of 1000 seeds of sesame (Table 6). The highest weight of 1000 seeds (11.47 g) was observed from $N_2$ (60 kg N/ha) and the lowest weight (9.06 g) was found from $N_0$ (control).

Weight of 1000 seeds of sesame varied significantly for sulfur (Table 6). The highest weight of 1000 seeds (11.22 g) was recorded from $S_2$ (40 kg S/ha) and the lowest weight (9.40 g) was obtained from $S_0$ treatment (control).

Significant difference was recorded for the interaction effect of nitrogen and sulfur in terms of weight of 1000 seeds of sesame (Table 7). The highest weight of 1000 seeds (12.25 g) was recorded from $N_2S_2$ treatment combination (60 kg N/ha and 40 kg S/ha) and the lowest weight (8.41 g) was recorded from $N_0S_0$ (control).

### 4.1.10 Seed yield per hectare

Seed yield per hectare of sesame showed statistically significant differences for nitrogen (Table 6). The seed yield increased significantly with increasing N doses upto $N_2$ (60 kg N/ha). The yield for nitrogen varied from 0.91 to 1.31 t/ha where the highest result was observed from $N_2$ (60 kg N/ha) followed by $N_3$ (100 kg N/ha) and the lowest in $N_0$ (control). An adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa *et al.*, 1981). Abdel *et al.* (2003) recorded highest seed yield (0.62 t/ha) were obtained at 80 kg N/ha.

Sulfur had a significant effect on the seed yield of sesame (Table 6). The seed yield increased significantly with increasing S doses upto 40 kg/ha. The highest seed yield was 1.21 t/ha obtained from $S_2$, while the lowest seed yield (0.98 t/ha) was obtained from $S_0$ (control). Amudha *et al.* (2005) reported highest yield with the application of 45 kg S/ha.

Interaction effect of nitrogen and sulfur showed statistically significant difference on the seed yield (Table 7). The highest seed yield of sesame (1.40 t/ha) was recorded from $N_2S_2$ (60 kg N/ha and 40 kg S/ha), whereas and the lowest yield (0.77 t/ha) was recorded from $N_0S_0$ treatment combination (control).

### 4.1.11 Stover yield per hectare

Significant variation was recorded for stover yield per hectare of sesame for the application of nitrogen (Table 6). Stover yield increased significantly with increasing N doses upto $N_3$ (100 kg N/ha). The stover yield for nitrogen varied from 2.52 to 3.11 t/ha where the highest result was observed from $N_3$ (100 kg N/ha) followed by $N_2$ (60 kg N/ha) and the lowest in $N_0$ (control). An adequate supply of nitrogen is essential for vegetative growth and (Yoshizawa *et al.*, 1981).

Sulfur had a significant effect on stover yield per hectare of sesame (Table 6). The stover yield increased significantly with increasing S doses upto 60 kg/ha. The highest stover yield was 3.14 t/ha obtained from $S_3$ treatment, while the lowest yield (2.74 t/ha) was obtained from $S_0$ (control). Amudha *et al.* (2005) reported highest yield with the application of 45 kg S/ha.

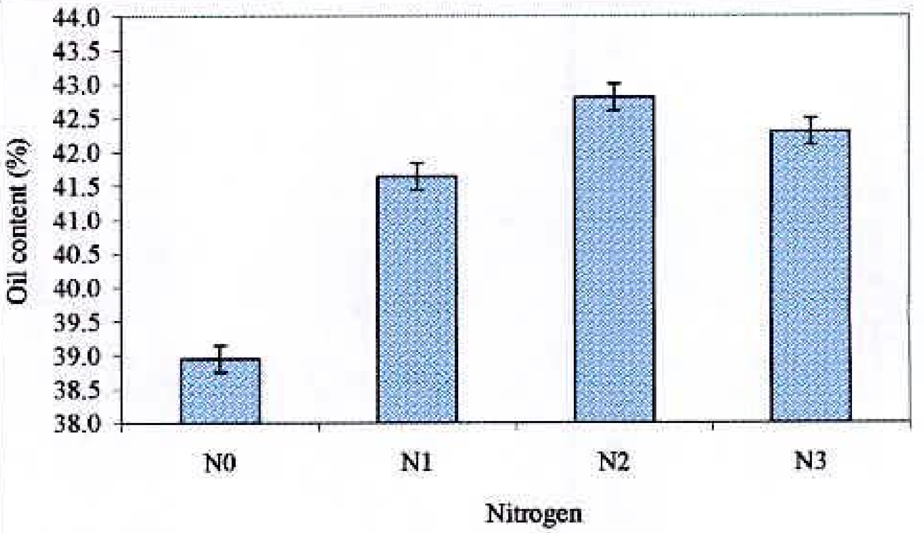
Interaction effect of nitrogen and sulfur showed statistically significant difference for stover yield (Table 7). The highest stover yield of sesame (3.51 t/ha) was recorded from $N_3S_3$ (100 kg N/ha and 60 kg S/ha), whereas and the lowest (2.32 t/ha) was recorded from $N_0S_0$ (control).

### 4.1.12 Oil content in seed

Statistically significant difference in oil content in seed was recorded for nitrogen (Figure 11). The maximum oil content in seed (42.80%) was observed from $N_2$ (60 kg N/ha) which was statistically identical (42.29% and 41.63%) with $N_3$ (100 kg N/ha) and $N_1$ (40 kg N/ha), while the minimum (38.94%) from $N_0$ (control). Abdel *et al.* (2003) recorded highest oil yields (36.39%) were obtained at 80 kg N/ha. But Fard and Bahrani (2005) earlier reported that seed oil percentage was a stable yield component and was not affected by either N rate.

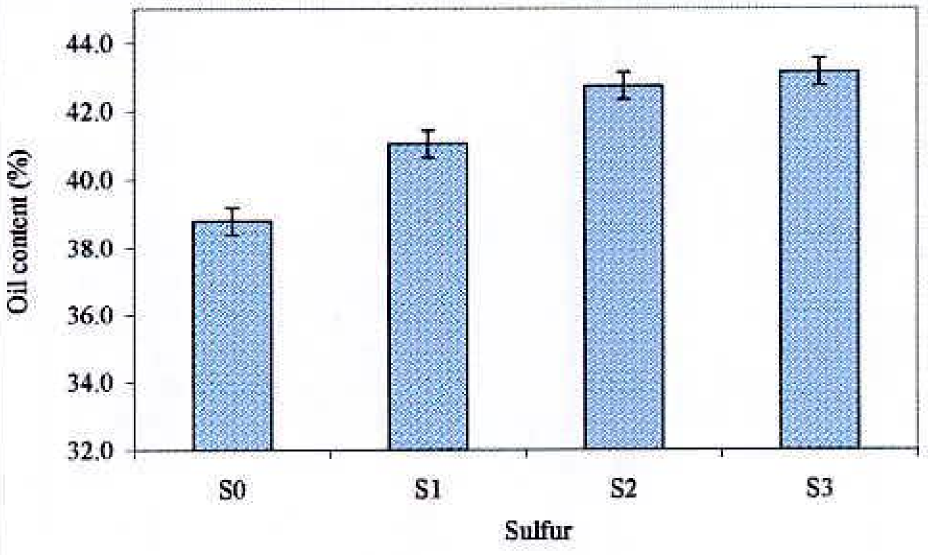
Oil content in seed of sesame varied significantly for sulfur (Figure 12). The highest oil content (43.13%) was recorded from $S_3$ (60 kg S/ha) which was statistically identical (42.73%) with $S_2$ (40 kg S/ha) and closely followed (41.03%) by and $S_1$ (20 kg S/ha) and the minimum oil content in seed (38.78%) was obtained from $S_0$ (control).

Significant difference was recorded for the interaction effect of nitrogen and sulfur in terms of oil content in seed of sesame (Figure 13). The maximum oil content of sesame (46.98%) was recorded from $N_2S_3$ (60 kg N/ha and 60 kg S/ha), while the minimum oil content (36.57%) was recorded from $N_0S_0$.



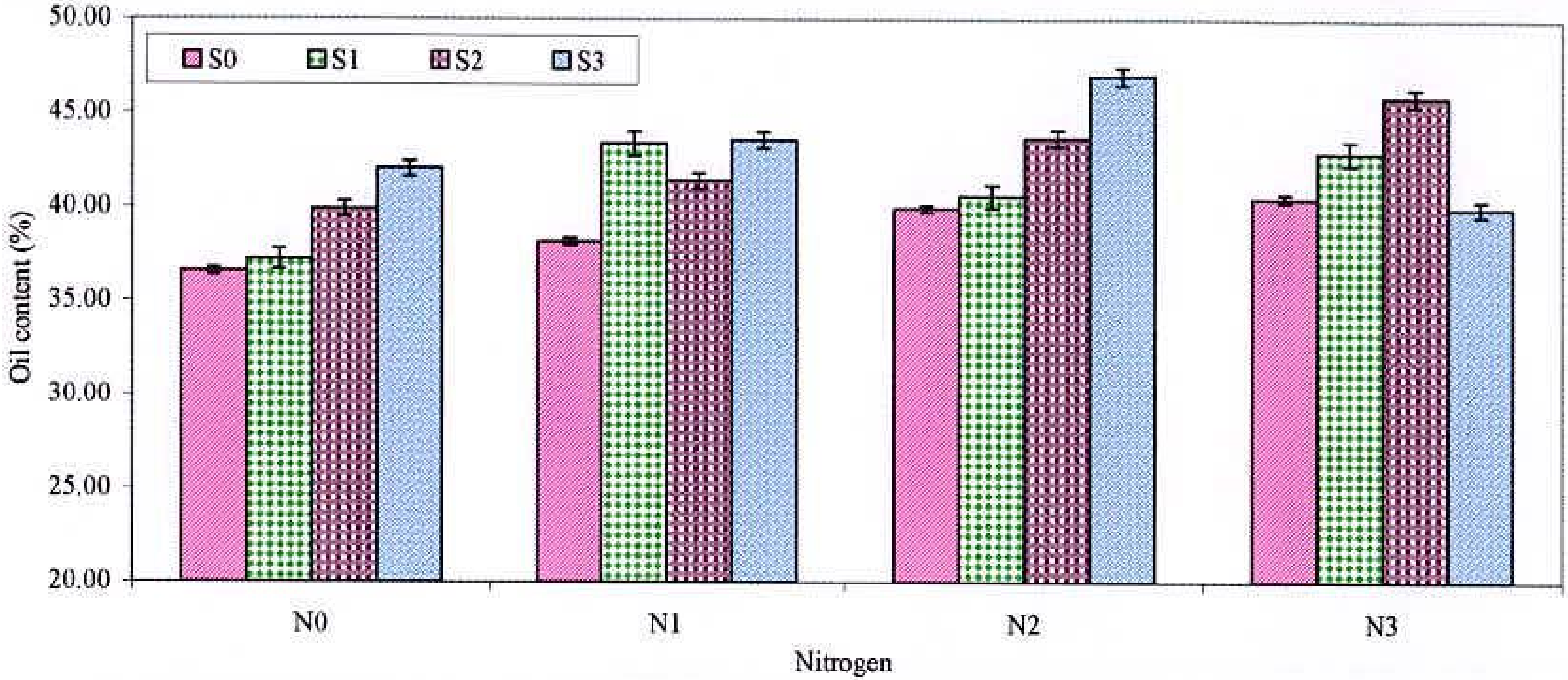

$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha

Figure 11. Effect of nitrogen on oil content of sesame




$S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 12. Effect of sulfur on oil content of sesame




$N_0$: 0 kg N/ha (control) $N_1$: 40 kg N/ha $S_0$: 0 kg S/ha (control) $S_1$: 20 kg S/ha

$N_2$: 60 kg N/ha $N_3$: 100 kg N/ha $S_2$: 40 kg S/ha $S_3$: 60 kg S/ha

Figure 13. Interaction effect of nitrogen and sulfur on oil content of sesame

**Relationship between level of nitrogen and sulfur on seed yield and oil content of sesame**

Relationship between level of nitrogen and sulfur on seed yield and oil content of sesame were presented in Figure 14 and 15.

**Relationship between seed yield and level of nitrogen**

The data on seed yield were regressed against level of nitrogen and a linear relationship was obtained between them. It was evident from the Figure 14 that the equation $y = 0.0035x + 0.9485$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.6627$) showed that, fitted regression line had significant regression co-efficient.

**Relationship between seed yield and level of sulfur**

Correlation study was done to establish a relationship between seed yield and level of sulfur. From the study it was revealed that significant correlations existed between the characters (Figure 14). The regression equation $y = 0.0034x + 1.027$ gave a good fit to the data and the value of the co-efficient of determination ($R^2 = 0.7131$).

**Relationship between oil content and level of nitrogen**

When the data on % oil content and level of nitrogen were regressed a positive relationship was obtained between these two characters. Here the equation $y = 0.0345x + 39.695$ gave a good fit to the data, and the value of the co-efficient of determination ($R^2 = 0.698$) showed that the fitted regression line had a significant regression coefficient (Figure 15).

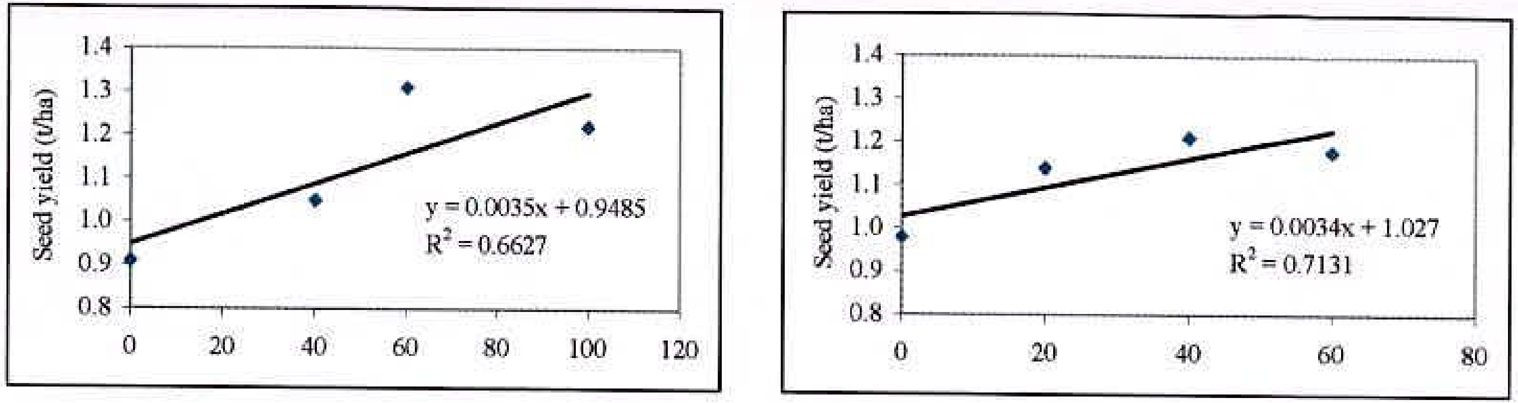



Figure 14. Relationship between level of nitrogen and sulfur with seed yield of sesame

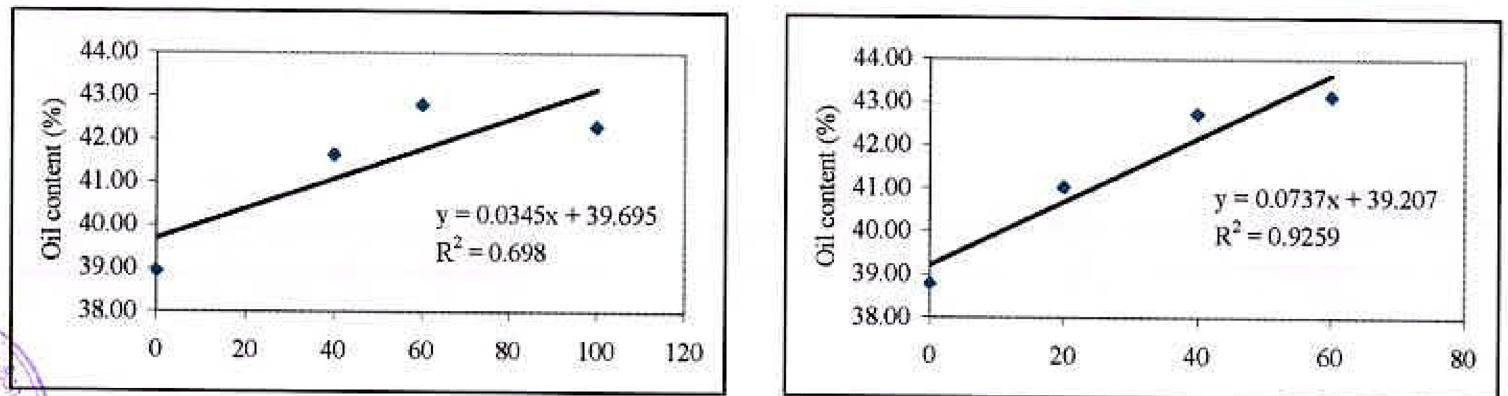



Figure 15. Relationship between level of nitrogen and sulfur with oil content of sesame

### Relationship between oil content and level of sulfur

The data on oil content were regressed against level of sulfur and a positive linear relationship was obtained between the characters. It was evident from the Figure 15 that the equation $y = 0.0737x + 39.207$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9259$) showed that, fitted regression line had a significant regression co-efficient.

## 4.2 NPKS concentrations in plant

Significant variations were recorded for NPKS concentrations in plant of sesame due to different level of nitrogen (Table 8). The maximum concentration of N (0.80%), P (0.67%), K (1.10%) and S (0.63%) in plant was recorded with $N_3$ (100 kg N/ha). On the other hand, the minimum concentrations of N (0.71%), P (0.48%), K (0.82%) and S (0.49%) in plant were observed from $N_0$ (control).

Different level of sulfur caused significant variation for NPKS concentrations in plant of sesame (Table 8). The maximum concentration of N (0.79%), P (0.66%), K (1.20%) and S (0.61%) in plant was recorded with $S_3$ (60 kg N/ha). On the other hand, the minimum concentrations of N (0.73%), P (0.55%), K (0.78%) and S (0.49%) in plant were observed from $S_0$ (control).

Interaction effect of nitrogen and sulfur showed significant variations for NPKS concentrations in plant of sesame (Table 9). The maximum concentration of N (0.82%), P (0.78%), K (1.31%) and S (0.71%) in plant was recorded with $N_3S_3$ (100 kg N and 60 kg N/ha), again, the minimum concentrations of N (0.65%), P (0.41%), K (0.73%) and S (0.37%) in plant were observed from $N_0S_0$ (control).

**Table 8. Main effect of nitrogen and sulfur on NPKS concentration in plant of sesame**

| Treatment(s) | Concentration in plant (%) | | | |
|---|---|---|---|---|
| | N | P | K | S |
| **Nitrogen** | | | | |
| $N_0$ | 0.71 b | 0.48 b | 0.81 c | 0.49 b |
| $N_1$ | 0.72 b | 0.66 a | 0.94 b | 0.51 b |
| $N_2$ | 0.78 a | 0.65 a | 1.04 a | 0.53 b |
| $N_3$ | 0.80 a | 0.67 a | 1.10 a | 0.63 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 |
| **Sulfur** | | | | |
| $S_0$ | 0.73 b | 0.55 c | 0.77 c | 0.49 c |
| $S_1$ | 0.75 b | 0.61 b | 0.95 b | 0.51 bc |
| $S_2$ | 0.75 b | 0.61 b | 0.97 b | 0.55 b |
| $S_3$ | 0.79 a | 0.66 a | 1.20 a | 0.61 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 6.73 | 5.71 | 110.98 | 8.05 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

**Table 9. Interaction effect of effect of nitrogen and sulfur on NPKS concentration in plant of sesame**

| Treatment | Concentration in plant (%) | | | |
|---|---|---|---|---|
| | N | P | K | S |
| $N_0S_0$ | 0.65 e | 0.41 g | 0.73 c | 0.37 f |
| $N_0S_1$ | 0.69 de | 0.51 f | 0.83 c | 0.47 de |
| $N_0S_2$ | 0.72 bcd | 0.51 f | 0.83 c | 0.53 bcd |
| $N_0S_3$ | 0.79 a | 0.48 f | 0.87 c | 0.58 bc |
| $N_1S_0$ | 0.71 bcd | 0.57 e | 0.77 c | 0.43 ef |
| $N_1S_1$ | 0.72 bcd | 0.69 bc | 0.87 c | 0.53 bcd |
| $N_1S_2$ | 0.70 cde | 0.68 bc | 0.87 c | 0.50 cde |
| $N_1S_3$ | 0.73 bcd | 0.69 bc | 1.23 b | 0.57 bc |
| $N_2S_0$ | 0.80 a | 0.62 de | 0.77 c | 0.53 bcd |
| $N_2S_1$ | 0.77 ab | 0.65 cd | 0.90 c | 0.44 ef |
| $N_2S_2$ | 0.76 abc | 0.61 de | 1.30 b | 0.56 bc |
| $N_2S_3$ | 0.80 a | 0.73 ab | 1.20 b | 0.57 bc |
| $N_3S_0$ | 0.76 abc | 0.61 de | 0.83 c | 0.61 b |
| $N_3S_1$ | 0.81 a | 0.60 de | 1.20 b | 0.60 b |
| $N_3S_2$ | 0.81 a | 0.64 cd | 0.87 c | 0.59 b |
| $N_3S_3$ | 0.82 a | 0.78 a | 1.31 a | 0.71 a |
| Level of significance | 0.05 | 0.01 | 0.01 | 0.01 |
| CV(%) | 6.73 | 5.71 | 11.98 | 8.05 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

### 4.3 NPKS uptake by plant

Significant variations were recorded in NPKS uptake by sesame due to different level of nitrogen (Table 10). The highest uptake of N (34.70 kg), P (28.81 kg), K (48.46 kg) and S (27.31 kg) by sesame was recorded with $N_3$ treatment (100 kg N/ha) and. On the other hand, the lowest uptake of N (24.54 kg), P (16.45 kg), K (28.09 kg) and S (16.92 kg) by sesame were observed from $N_0$.

Different level of sulfur contributed significant variation for NPKS uptake by sesame (Table 10). The highest uptake of N (33.99 kg), P (20.88 kg), K (29.72 kg) and S (26.40 kg) by sesame was recorded with $S_3$ (60 kg N/ha). Again, the lowest uptake of N (27.38 kg), P (30.57 kg), K (28.98 kg) and S (18.39 kg) by sesame were observed from $S_0$ treatment.

Interaction effect of nitrogen and sulfur showed significant variations for NPKS uptake by sesame (Table 11). The highest uptake of N (39.77 kg), P (38.18 kg), K (56.05 kg) and S (34.40 kg) by sesame was recorded with $N_3S_3$ treatment combination (100 kg N and 60 kg N/ha), while the lowest uptake of N (20.09 kg), P (12.67 kg), K (22.86 kg) and S (11.52 kg) by sesame were recorded from $N_0S_0$ treatment combination.

**Table 10. Main effect of nitrogen and sulfur on NPKS uptake by plant of sesame**

| Treatment(s) | Uptake by plant (kg/ha) | | | |
|---|---|---|---|---|
| | N | P | K | S |
| **Nitrogen** | | | | |
| $N_0$ | 24.54 c | 16.45 c | 28.09 c | 16.92 d |
| $N_1$ | 28.74 b | 26.72 b | 37.89 b | 20.49 c |
| $N_2$ | 34.15 a | 28.59 a | 45.63 a | 22.97 b |
| $N_3$ | 34.69 a | 28.81 a | 48.46 a | 27.31 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 |
| **Sulfur** | | | | |
| $S_0$ | 27.38 c | 20.88 c | 28.98 c | 18.39 d |
| $S_1$ | 30.06 b | 24.79 b | 38.31 b | 20.53 c |
| $S_2$ | 30.69 b | 25.17 b | 39.84 b | 22.37 b |
| $S_3$ | 33.99 a | 29.72 a | 52.95 a | 26.40 a |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 6.21 | 7.67 | 13.36 | 8.69 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

**Table 11. Interaction effect of effect of nitrogen and sulfur on NPKS uptake by plant of sesame**

| Treatment | Uptake by plant (kg/ha) | | | |
|---|---|---|---|---|
| | N | P | K | S |
| $N_0S_0$ | 20.09 i | 12.67 i | 22.86 e | 11.52 g |
| $N_0S_1$ | 23.83 h | 17.59 h | 28.63 cde | 16.29 f |
| $N_0S_2$ | 25.74 gh | 18.19 h | 29.57 cde | 18.95 ef |
| $N_0S_3$ | 28.48 fg | 17.33 h | 31.30 cde | 20.91 cde |
| $N_1S_0$ | 25.91 gh | 20.79 g | 28.08 de | 15.66 f |
| $N_1S_1$ | 29.42 ef | 28.44 cd | 35.59 cd | 21.66 cde |
| $N_1S_2$ | 28.64 fg | 28.09 cd | 35.59 cd | 20.47 de |
| $N_1S_3$ | 31.00 def | 29.57 c | 52.31 b | 24.17 bc |
| $N_2S_0$ | 34.14 bcd | 26.45 de | 32.84 cde | 22.75 bcd |
| $N_2S_1$ | 33.02 cd | 27.85 cde | 38.50 c | 18.88 ef |
| $N_2S_2$ | 32.74 cde | 26.26 de | 55.94 a | 24.11 bc |
| $N_2S_3$ | 36.72 ab | 33.81 b | 55.25 a | 26.13 b |
| $N_3S_0$ | 29.39 ef | 23.62 f | 32.12 cde | 23.62 bcd |
| $N_3S_1$ | 33.98 bcd | 25.28 ef | 50.54 b | 25.28 b |
| $N_3S_2$ | 35.64 bc | 28.16 cd | 38.28 cd | 25.96 b |
| $N_3S_3$ | 39.77 a | 38.18 a | 56.05 a | 34.40 a |
| Level of significance | 0.05 | 0.01 | 0.01 | 0.01 |
| CV(%) | 6.21 | 7.67 | 13.36 | 8.69 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

### 4.4 Nutrient status of post harvest soil

Significant variations was recorded for organic matter, total N, available P, exchangeable K and available S in post harvest soil for the application of different levels of nitrogen (Table 12). The highest organic matter (1.10%), total N (0.90%), available P (30.56 ppm), exchangeable K (0.35 me%), available S (33.49 ppm) were recorded from $N_2$ (60 kg N/ha). while the lowest pH (5.68), organic matter (0.98%), total N (0.071%), available P (27.21 ppm), exchangeable K (0.19 me%), available S (31.53 ppm) were observed from $N_0$ treatment.

Significant variations were recorded for pH, organic matter, total N, available P, exchangeable K and available S in post harvest soil due to the application of different levels of sulfur (Table 12). The highest pH (6.02), organic matter (1.07%), total N (0.82%), available P (29.95 ppm), exchangeable K (0.29 me%) and available S (35.52 ppm) were recorded from $S_3$ and the lowest pH (5.58), organic matter (1.02%), total N (0.0752%), available P (27.55 ppm), exchangeable K (0.25 me%) and available S (26.11 ppm) were observed from $S_0$ treatment.

Significant variations were recorded for total N, available P, exchangeable K and available S in post harvest soil due to the interaction effect of nitrogen and sulfur (Table 13). The highest total N (0.095%), available P (33.30 ppm), exchangeable K (0.40 me%) and available S (38.71 ppm) were recorded from $N_3S_3$ and the lowest pH (5.43), organic matter (0.91%), total N (0.068%), available P (24.19 ppm), exchangeable K (0.17 me%) and available S (23.38 ppm) were observed from $N_0S_0$ treatment combination.

**Table 12. Main effect of nitrogen and sulfur on nutrient status of post harvest soil of sesame**

| Treatment(s) | pH | Organic matter (%) | Total N (%) | Available P (ppm) | Exchangeable K (me %) | Available S (ppm) |
|---|---|---|---|---|---|---|
| **Nitrogen** | | | | | | |
| $N_0$ | 5.68 | 0.98 c | 0.071 c | 27.21 c | 0.19 c | 31.53 b |
| $N_1$ | 5.80 | 1.04 b | 0.079 b | 28.61 b | 0.27 b | 31.91 b |
| $N_2$ | 5.81 | 1.10 a | 0.090 a | 30.56 a | 0.35 a | 33.49 a |
| $N_3$ | 5.69 | 1.04 b | 0.075 b | 29.38 ab | 0.27 b | 32.12 ab |
| Level of significance | NS | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Sulfur** | | | | | | |
| $S_0$ | 5.58 b | 1.02 | 0.075 | 27.55 b | 0.25 b | 26.11c |
| $S_1$ | 5.67 b | 1.03 | 0.080 | 28.56 ab | 0.27 ab | 32.83 b |
| $S_2$ | 5.70 b | 1.05 | 0.080 | 29.70 a | 0.26 b | 34.61 a |
| $S_3$ | 6.02 a | 1.07 | 0.082 | 29.95 a | 0.29 a | 35.52 a |
| Level of significance | 0.01 | NS | NS | 0.01 | 0.01 | 0.01 |
| CV(%) | 4.92 | 5.02 | 4.50 | 5.55 | 8.83 | 6.33 |

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

$N_0$: 0 kg N/ha (control)
$N_1$: 40 kg N/ha
$N_2$: 60 kg N/ha
$N_3$: 100 kg N/ha

$S_0$: 0 kg S/ha (control)
$S_1$: 20 kg S/ha
$S_2$: 40 kg S/ha
$S_3$: 60 kg S/ha

**Table 13. Interaction effect of nitrogen and sulfur on nutrient status of post harvest soil of sesame**

| Treatment | pH | Organic matter (%) | Total N (%) | Available P (µg/g) | Exchangeable K (me %) | Available S (ppm) |
|---|---|---|---|---|---|---|
| $N_0S_0$ | 5.43 | 0.91 | 0.068 d | 24.19 e | 0.17 j | 23.38 h |
| $N_0S_1$ | 5.63 | 0.99 | 0.090 ab | 28.26 bcd | 0.38 ab | 33.33 cd |
| $N_0S_2$ | 5.63 | 0.98 | 0.089 abc | 30.04 bc | 0.35 abc | 34.97 bc |
| $N_0S_3$ | 6.00 | 1.05 | 0.085 abcd | 26.36 de | 0.29 def | 25.48 gh |
| $N_1S_0$ | 5.97 | 1.03 | 0.075 bcd | 27.55 cd | 0.33 bcd | 30.63 de |
| $N_1S_1$ | 5.47 | 1.05 | 0.083 abcd | 31.03 ab | 0.25 efg | 34.10 bc |
| $N_1S_2$ | 5.87 | 1.03 | 0.080 abcd | 29.71 bc | 0.23 fghi | 33.96 bc |
| $N_1S_3$ | 5.90 | 1.06 | 0.077 abcd | 26.15 de | 0.26 efg | 28.96 ef |
| $N_2S_0$ | 5.67 | 1.09 | 0.077 abcd | 28.72 bcd | 0.21 ghij | 33.46 cd |
| $N_2S_1$ | 5.67 | 1.08 | 0.075 bcd | 29.16 bcd | 0.18 ij | 34.00 bc |
| $N_2S_2$ | 5.63 | 1.07 | 0.079 abcd | 31.23 ab | 0.30 cde | 34.42 bc |
| $N_2S_3$ | 5.80 | 1.09 | 0.070 cd | 28.42 bcd | 0.19 hij | 26.61 fg |
| $N_3S_0$ | 6.00 | 1.04 | 0.072 bcd | 29.75 bc | 0.24 efgh | 34.89 bc |
| $N_3S_1$ | 5.57 | 1.02 | 0.073 bcd | 31.36 ab | 0.27 efg | 37.00 ab |
| $N_3S_2$ | 5.53 | 1.03 | 0.070 cd | 27.81 cd | 0.26 efg | 32.35 cd |
| $N_3S_3$ | 6.10 | 1.14 | 0.095 a | 33.30 a | 0.40 a | 38.71 a |
| Level of significance | NS | NS | 0.05 | 0.01 | 0.01 | 0.01 |
| CV(%) | 4.92 | 5.02 | 4.50 | 5.55 | 8.83 | 6.33 |

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

| | |
|---|---|
| $N_0$: 0 kg N/ha (control) | $S_0$: 0 kg S/ha (control) |
| $N_1$: 40 kg N/ha | $S_1$: 20 kg S/ha |
| $N_2$: 60 kg N/ha | $S_2$: 40 kg S/ha |
| $N_3$: 100 kg N/ha | $S_3$: 60 kg S/ha |

# Chapter V

# Summary and Conclusion

## CHAPTER V

## SUMMARY AND CONCLUSION

An experiment was conducted in the research field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from February to May, 2009. The objectives if the study was to determine the effect of nitrogen and sulfur on growth and yield of sesame. Seeds of BARI Til-3 used as a test crop for the study. The experiment consisted of two factors. Factor A: Levels of nitrogen (4 levels): $N_0$: 0 kg N/ha (control); $N_1$: 40 kg N/ha; $N_2$: 60 kg N/ha and $N_3$: 100 kg N/ha; Factor B: Levels of sulfur (4 levels); $S_0$: 0 kg S/ha (control); $S_1$: 20 kg S/ha; $S_2$: 40 kg S/ha and $S_3$: 60 kg S/ha. The experiment was laid out in Randomized Complete Block Design with three replications.

In case of nitrogen the tallest plant (32.53 cm, 57.64 cm, 78.04 cm, 86.09 cm and 99.09 cm) was observed from $N_2$ treatment, while the shortest plant (21.88 cm, 43.40 cm, 62.53 cm, 70.85 cm and 72.09 cm) was recorded from $N_0$ treatment at 30, 40, 50, 60 DAS and harvest, respectively. The maximum number of branches per plant (5.89, 7.96, 9.10, 9.42 and 11.47) was recorded from $N_2$ treatment again the minimum number (4.75, 5.62, 7.12, 7.26 and 9.06) was found from $N_0$ treatment at 30, 40, 50, 60 DAS and harvest, respectively. The lowest days for 1$^{st}$ flowering (50.83) was obtained from $N_2$ treatment, again the highest days (53.67) were observed from $N_0$ treatment. The maximum number of capsule per plant (64.29) was observed from $N_2$ treatment and the minimum number (48.88) was found from $N_0$ treatment. The longest length of capsule (3.62 cm) was recorded from $N_2$ treatment, whereas the shortest length (2.30 cm) was observed from $N_0$

treatment. The maximum number of seeds per capsule (47.79) was obtained from $N_2$ treatment, whereas the minimum number (38.02 cm) from $N_0$ treatment. The highest weight of 1000 seeds (11.47 g) was observed from $N_2$ treatment again the lowest weight (9.06 g) from $N_0$ treatment. The highest seed yield (1.30 ton) was recorded from $N_2$ treatment and the lowest (0.91 t/ha) from $N_0$ treatment. The highest stover yield obtained from $N_2$ treatment was 3.11 t/ha the lowest yield (2.52 t/ha) was observed from $N_0$ treatment. The maximum oil content in seed (42.80%) was observed from $N_2$ treatment, while the minimum (38.94%) from $N_0$ treatment.

The maximum concentration of N (0.80%), P (0.67%), K (1.10%) and S (0.63%) in plant was recorded with $N_3$ treatment and, the minimum concentrations of N (0.71%), P (0.48%), K (0.82%) and S (0.49%) in plant were observed from $N_0$ treatment. The highest uptake of N (34.70 kg), P (28.81 kg), K (48.46 kg) and S (27.31 kg) by plant was recorded with $N_3$ treatment and S (7.69 kg) from $N_3$ treatment. On the other hand, the lowest uptake of N (24.54 kg), P (16.45 kg), K (28.09 kg) and S (16.92 kg) by plant were observed from $N_0$ treatment. The highest pH (5.81), organic matter (1.10%), total N (0.90%), available P (30.56 ppm), exchangeable K (0.35 me%), available S (33.49 ppm) were recorded from $N_2$ treatment. while the lowest pH (5.68), organic matter (0.98%), total N (0.071%), available P (27.21 ppm), exchangeable K (0.19 me%), available S (31.53 ppm) were observed from $N_0$ treatment.

In case of sulfur, the tallest plant (34.68 cm, 58.59 cm, 81.69 cm, 92.40 cm and 98.83 cm) was recorded from $S_3$ treatment and the shortest plant (24.74 cm, 47.47 cm, 60.05 cm, 63.10 cm and 80.43 cm) was obtained from $S_0$ treatment. At 30, 40, 50, 60 DAS and harvest the maximum number of branches per plant (6.41, 8.43, 9.10, 9.85 and 11.22) was recorded from $S_3$ treatment, while the minimum number (4.31, 5.89, 6.42, 7.37 and 9.40) was observed from $S_0$ treatment. The lowest days for 1st flowering (50.25) were found from $S_2$ treatment, while the highest days (53.92) were recorded from $S_0$ treatment. The maximum number of capsule per plant (62.34) was recorded from $S_2$ treatment and the minimum number (50.79) was obtained from $S_0$ treatment. The longest length of capsule (3.44 cm) was found from $S_2$ treatment, consequently the shortest length (2.80 cm) was attained from $S_0$ treatment. The maximum number of seeds per capsule of sesame (47.77) was found from $S_2$ treatment, again the minimum number (39.44) was recorded from $S_0$ treatment. The highest weight of 1000 seeds (11.22 g) was recorded from $S_2$ treatment and the lowest weight (9.40 g) was obtained from $S_0$ treatment. The highest seed yield (1.22 t/ha) was found from $S_2$ treatment, while the lowest seed yield (0.98 t/ha) was obtained from $S_0$ treatment. The highest stover yield was 3.14 t/ha obtained from $S_3$ treatment, while the lowest yield (2.74 t/ha) was obtained from $S_0$ treatment. The highest oil content (43.13%) was recorded from $S_3$ treatment and the minimum oil content in seed (38.78%) was obtained from $S_0$ treatment.

The maximum concentration of N (0.79%), P (0.66%), K (1.20%) and S (0.61%) in plant was recorded with $S_3$ treatment. On the other hand, the minimum concentrations of N (0.73%), P (0.55%), K (0.78%) and S (0.49%) in plant were observed from $S_0$ treatment. The highest uptake of N (33.99 kg), P (29.72 kg), K (52.95 kg) and S (26.40 kg) by plant was recorded with $S_3$ treatment, again the lowest uptake of N (27.38 kg), P (20.88 kg), K (28.98 kg) and S (18.39 kg) by plant was observed from $S_0$ treatment. The highest pH (6.02), organic matter (1.07%), total N (0.82%), available P (29.95 ppm), exchangeable K (0.29 me%) and available S (35.52 ppm) were recorded from $S_3$ treatment and the lowest pH (5.58), organic matter (1.02%), total N (0.0752%), available P (27.55 ppm), exchangeable K (0.25 me%) and available S (26.11 ppm) from $S_0$ treatment.

In case of interaction effect of nitrogen and sulfur, the tallest plant (39.96 cm, 64.15 cm, 89.03 cm, 99.43 cm and 119.58 cm) was observed from $N_2S_3$ treatment combination and the shortest plant (17.81 cm, 35.90 cm, 48.61 cm, 54.35 cm and 63.68 cm) was recorded from $N_0S_0$ treatment combination. The maximum number of branches per plant (6.15, 8.19, 9.10, 9.63 and 12.25) was found from $N_2S_3$ treatment combination, whereas the minimum number (4.53, 5.77, 6.77, 7.31 and 8.41) from $N_0S_0$ treatment combination. The lowest day for 1st flowering (49.00) was recorded from $N_2S_2$, consequently and the highest days (55.67) from $N_0S_0$ treatment combination. The maximum number of capsule per plant (70.40) was found from $N_2S_2$ treatment combination and the minimum number (46.80) from $N_0S_0$ treatment combination. The maximum number of seeds per capsule of sesame (50.63) was recorded from $N_2S_2$ treatment combination, whereas the minimum number (32.47) from $N_0S_0$ treatment combination. The highest weight of 1000 seeds of sesame (12.25 g) was recorded from $N_2S_2$ treatment combination and the lowest weight (8.41 g) was recorded from $N_0S_0$ treatment combination. The highest seed yield of sesame (1.40 t/ha) was recorded from $N_2S_2$ treatment combination and the lowest yield (0.77 t/ha) from $N_0S_0$ treatment combination. The highest stover yield of sesame (3.51 t/ha) was recorded from $N_3S_3$ treatment combination, whereas and the lowest (2.32 t/ha) was recorded from $N_0S_0$. The maximum oil content of sesame (46.98%) was recorded from $N_2S_3$ treatment combination, while the minimum oil content (36.57%) from $N_0S_0$ treatment combination.

The maximum concentration of N (0.82%), P (0.78%), K (1.31%) and S (0.71%) in plant was recorded with $N_3S_3$ treatment combination, again, the minimum concentrations of N (0.65%), P (0.41%), K (0.73%) and S (0.37%) in plant were observed from $N_0S_0$ treatment combination. The highest uptake of N (39.77 kg), P (38.18 kg), K (56.05 kg) and S (34.40 kg) by plant was recorded with $N_3S_3$ treatment combination, while the lowest uptake of N (20.09 kg), P (12.67 kg), K (22.86 kg) and S (11.52 kg) by plant was recorded from $N_0S_0$ treatment combination. The highest pH (6.10), organic matter (1.14%), total N (0.095%), available P (33.30 ppm), exchangeable K (0.40 me%) and available S (38.71 ppm) were recorded from $N_3S_3$ treatment combination and the lowest pH (5.43), organic matter (0.91%), total N (0.068%), available P (24.19 ppm), exchangeable K (0.17 me%) and available S (23.38 ppm) from $N_0S_0$ treatment combination.

From the above discussion it can be concluded that the combination of $N_2S_2$ treatment combination i.e. 60 kg N/ha and 40 kg S/ha is optimum for the best growth, yield and oil content of sesame. Considering the findings of the present experiment, further studies in the following areas may be suggested:

1. Such study should repeat in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;

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# Appendices

## APPENDICES

**Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from February to May 2009**

| Month (2009) | *Air temperature ($^0$c) | | *Relative humidity (%) | *Rain fall (mm) (total) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| February | 27.1 | 16.7 | 67 | 30 |
| March | 31.4 | 19.6 | 54 | 11 |
| April | 33.2 | 21.1 | 61 | 88 |
| May | 34.1 | 20.2 | 78 | 102 |

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

**Appendix II. Analysis of variance of the data on plant height of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square<br>Plant height at | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| Replication | 2 | 0.061 | 0.396 | 0.917 | 0.389 | 5.519 |
| Factor A (Nitrogen) | 3 | 5.808** | 2.847* | 31.402** | 58.715** | 77.472** |
| Factor B (Sulfur) | 3 | 2.615** | 13.288** | 50.926** | 100.476** | 119.389** |
| Interaction (A×B) | 9 | 0.549** | 2.349* | 4.198* | 15.433** | 18.341** |
| Error | 30 | 0.197 | 0.720 | 1.382 | 3.262 | 4.521 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix III. Analysis of variance of the data on number of branches per plant of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square<br>Number of branches per plant at | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| Replication | 2 | 0.044 | 0.234 | 0.154 | 0.661 | 0.461 |
| Factor A (Nitrogen) | 3 | 4.474** | 12.736** | 23.261** | 29.752** | 36.047** |
| Factor B (Sulfur) | 3 | 0.975** | 7.413** | 13.344** | 18.213** | 23.219** |
| Interaction (A×B) | 9 | 0.003 | 0.136 | 0.197 | 0.333* | 1.265** |
| Error | 30 | 0.004 | 0.071 | 0.153 | 0.146 | 0.181 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix IV. Analysis of variance of the data on number of leaves per plant of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Number of leaves per plant at | | | | |
| | | 30 DAS | 40 DAS | 50 DAS | 60 DAS | Harvest |
| Replication | 2 | 0.026 | 0.069 | 0.023 | 0.173 | 0.012 |
| Factor A (Nitrogen) | 3 | 18.803** | 0.297* | 0.329** | 8.665* | 0.397** |
| Factor B (Sulfur) | 3 | 139.196** | 2.090** | 1.885** | 0.847** | 7.090** |
| Interaction (A×B) | 9 | 8.889** | 0.365** | 0.244* | 31.824* | 0.816** |
| Error | 30 | 3.082 | 0.102 | 0.108 | 21.223 | 0.123 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix V. Analysis of variance of the data on yield contributing characters and yield of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to first flowering | Number of capsule per plant | Length of capsule (cm) | Diameter of capsule (cm) | Seeds per capsule | Weight of 1000 seeds (g) | Seed yield (t/ha) | Stover yield (t/ha) | Oil content (%) |
| Replication | 2 | 2.313 | 2.646 | 0.039 | 0.012 | 0.455 | 0.750 | 0.004 | 0.007 | 1.155 |
| Factor A (Nitrogen) | 3 | 17.056** | 101.278** | 11.878** | 3.725** | 8.001** | 8.358** | 0.383** | 0.860** | 5.339** |
| Factor B (Sulfur) | 3 | 27.056** | 35.667** | 7.711** | 0.518** | 10.070** | 13.331** | 0.131** | 0.340** | 32.492** |
| Interaction (A×B) | 9 | 17.926** | 35.722** | 0.111** | 0.022** | 5.810** | 6.551** | 0.014* | 0.036* | 4.354** |
| Error | 30 | 4.024 | 5.535 | 0.046 | 0.006 | 0.944 | 1.242 | 0.005 | 0.013 | 1.031 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix VI. Analysis of variance of the data on NPKS concentration in plant sample and uptake by plant of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concentration in plant (%) | | | | Uptake by plant (kg) | | | |
| | | N | P | K | S | N | P | K | S |
| Replication | 2 | 0.001 | 0.001 | 0.0001 | 0.001 | 1.856 | 0.366 | 0.727 | 1.730 |
| Factor A (Nitrogen) | 3 | 0.024** | 0.123** | 0.189** | 0.047** | 278.47** | 664.51** | 998.39** | 229.083** |
| Factor B (Sulfur) | 3 | 0.006** | 0.063** | 0.365** | 0.034** | 88.567** | 338.91** | 1167.83** | 138.782** |
| Interaction (A×B) | 9 | 0.004* | 0.013** | 0.083** | 0.007** | 9.179* | 53.186** | 191.171** | 15.622** |
| Error | 30 | 0.001 | 0.002 | 0.014 | 0.002 | 3.593 | 7.625 | 28.568 | 3.625 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix VII. Analysis of variance of the data on nutrient status of post harvest soil of sesame as influenced by nitrogen and sulfur**

| Source of variation | Degrees of freedom | Mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | pH | Organic matter (%) | Total N (%) | Available P (ppm) | Exchangeable K (me %) | Available S (ppm) |
| Replication | 2 | 0.0001 | 0.014 | 0.087 | 0.189 | 0.576 | 0.0001 |
| Factor A (Nitrogen) | 3 | 0.052 | 0.326** | 2.854** | 23.612** | 1.842** | 0.152** |
| Factor B (Sulfur) | 3 | 3.285** | 0.020 | 0.217 | 14.710** | 3.130** | 3.285** |
| Interaction (A×B) | 9 | 0.046 | 0.033 | 0.286** | 13.233** | 3.182** | 0.146** |
| Error | 30 | 0.034 | 0.023 | 0.188 | 2.581 | 0.246 | 0.034 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

## Field view of the experiment


Appendix Figure I. Field view of experimental plot at 80 DAS