EFFECT OF NITROGEN AND BORON ON THE GROWTH AND YIELD OF SESAME

MD. SHAMSUZZOHA

DEPARTMENT OF SOIL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2015

EFFECT OF NITROGEN AND BORON ON THE GROWTH AND YIELD OF SESAME

BY

MD. SHAMSUZZOHA

REG. NO. : 09-03285

A Thesis
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 (MS)
IN
SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2015

Approved by:

Prof. Mst. Afrose Jahan
Department of Soil Science
Supervisor

Prof. Dr. Md. Asaduzzaman Khan
Department of Soil Science
Co-Supervisor

Mohammad Mosharraf Hossain
Chairman
Examination Committee
Department of Soil Science

DEPARTMENT OF SOIL SCIENCE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'Effect of Nitrogen and Boron on the Growth and Yield of Sesame'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Soil Science**, embodies the result of a piece of *bona fide* research work carried out by **Md. Shamsuzzoha**, Registration number: **09-03285** 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 duly been acknowledged.

Dated:
Dhaka, Bangladesh

Prof. Mst. Afrose Jahan
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENT

All praises to Almightly and Kindfull faith on to "Omnipotent Allah" for His never-ending blessing. The author deems it a great pleasure to express his profound gratefulness to his respected parents, who entiled much hardship inspiring for prosecuting his studies, receiving proper education.

The author likes to express his deepest sense of gratitude to his respected supervisor Mst. Afrose Jahan, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka, for her scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author also expresses his gratefulness to his respected Co-Supervisor Dr. Md. Asaduzzaman Khan,, Professor, Department of Soil Science, SAU, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author expresses his sincere gratitude towards the sincerity of the Chairman, Mohammad Mosharraf Hossain, Associate Professor, Department of Soil Science, SAU, Dhaka for his valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Soil Science, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses his sincere appreciation to his brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

EFFECT OF NITROGEN AND BORON ON THE GROWTH AND YIELD OF SESAME

ABSTRACT

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from February to May, 2015 to find out the effect of nitrogen and boron on the growth and yield of sesame. The experiment considered of two factors. Factor A: Levels of nitrogen (4 levels)- N_0: 0 kg N/ha (control), N_1: 50 kg N/ha, N_2: 60 kg N/ha and N_3: 70 kg N/ha; and Factor B: Levels of boron (3 levels)- B_0: 0 kg B/ha (control), B_1: 2 kg B/ha and B_2: 3 kg B/ha. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. For different level of nitrogen, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.49, 54.79, 78.07, 94.58 and 111.89 cm, respectively) was observed from N_2, while the shortest plant (29.87, 48.61, 68.16, 84.62 and 103.46 cm, respectively) from N_0. The highest seed yield (1.51 t/ha) was observed from N_2, while the lowest seed yield (1.09 t/ha) from N_0. The highest stover yield (2.91 t/ha) was recorded from N_2, while the lowest stover yield (2.01 t/ha) from N_0. The maximum concentration in seed for N (0.55%), P (0.32%), K (0.55%), S (0.21%) and B (0.014%) was observed from N_2, whereas the minimum concentration in seed for N (0.39%), P (0.26%), K (0.43%), S (0.17%) and B (0.011%) was found from N_0. For different level of boron, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.15, 54.54, 77.68, 92.46 and 110.93 cm, respectively) was recorded from B_2, whereas the shortest plant (30.61, 48.90, 68.54, 87.74 and 106.04 cm, respectively) from B_0. The highest seed yield (1.40 t/ah) was recorded from B_2, whereas the lowest seed yield (1.30 t/ha) from B_0. The maximum concentration in seeds for N (0.56%), P (0.31%), K (0.51%), S (0.20%) and B (0.014%) was recorded from B_2 and the minimum concentration for N (0.39%), P (0.27%), K (0.46%), S (0.18%) and B (0.009%) was found from B_0. For interaction effect, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (34.51, 58.26, 83.75, 97.05 and 116.43 cm, respectively) was observed from N_2B_2 and the shortest plant (25.24, 44.54, 62.37, 80.61 and 100.64 cm, respectively) from N_0B_0. The highest seed yield (1.59 t/ha) was observed from N_2B_2 and the lowest seed yield (1.03 t/ha) from N_0B_0. The maximum concentration in seeds for N (0.61%), P (0.34%), K (0.58%), S (0.22%) and B (0.017%) was observed from N_2B_2, while the minimum concentration in seeds for N (0.30%), P (0.24%), K (0.39%), S (0.16%) and B (0.007%) was recorded from N_0B_0. Combination of 60 kg N/ha and 3.0 kg B/ha can be more beneficial for the farmers to get better yield and economic return from the cultivation of sesame.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Sesame (*Sesamum indicum L.*) belongs to the family Pedaliaceae is one of the important oil crops, which was 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 contains 42-45% oil, 20% protein and 14-20% carbohydrate (BARI, 2012). In 2012-2013, the crop covered an area of 78.50 thousand hectares in Bangladesh with the production of 51,000 tons (BBS, 2014). The climate and edaphic conditions of Bangladesh are quite suitable for sesame cultivation.

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 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. 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 suitable production and quality yield for any crop it is necessary to apply proper management with ensuring the availability of essential nutrient in proper doses. Generally, a considerable amount of fertilizer is required for the growth and development of sesame (Opena *et al*., 1988).

Nitrogen is a structural component of chlorophyll and protein therefore adequate supply of nitrogen is beneficial for both carbohydrates and protein metabolism as it promotes cell division and cell enlargement, resulting in more leaf area and thus ensuring good seed and dry matter yield (Ibrahim *et al.*, 2014). 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).

Boron is one of the essential micronutrients required for plant growth and productivity. It plays an important role in cell wall synthesis, RNA metabolism, and root elongation as well as phenol metabolism. Also, boron involved in pollen and tube growth (Marschner, 1995; Srivastava and Gupta, 1996). Mary *et al.* (1990) observed that foliar application of boron resulted increase in the number of pods/branches, increased the number of seeds/plant and seed yield/plant. Kalyani *et al*. (1993) observed that boron applied as boric acid increased the plant height, relative growth rate, net assimilation rate and leaf area index. Born is a micronutrient essential for normal growth of pollen grains, sugar translocation and movement of growth regulators within the plant (Hamasa and Putaiah, 2012). Photosynthetic activity and metabolic activity enhanced with application of boron (Lalit Bhott *et al.*, 2004, Sathya *et al.*, 2009). Boron's involvement in hormone synthesis and translocation, carbohydrate metabolisms and DNA synthesis probably contributed to additional growth and yield (Ratna Kalyani *et al*., 1993). Deficiency of B causes severe reductions in crop yield, due to severe disturbances in B-involving metabolic processes, such as metabolism of nucleic acid, carbohydrate, protein and indole acetic acid, cell wall synthesis, membrane integrity and function, and phenol metabolism (Dell and Huang, 1997; Tanaka and Fujiwar, 2008).

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objectives:

- To find out the optimum dose of nitrogen and boron for maximizing the yield contributing characters and yield of sesame.
- To document the nutrient concentration in seeds and stover of sesame due to the application of nitrogen and boron.
- To observe the nutrient status of post harvest soil due to the application of nitrogen and boron in sesame field.

CHAPTER II

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 boron fertilizers play an important role in improving sesame yield. But research works related to nitrogen and boron fertilizer on sesame are limited in Bangladesh. However, some of the important and informative research findings related to the nitrogen and boron on sesame have been reviewed in this chapter under the following headings:

2.1 Effect of nitrogen on sesame

The experiment entitled effect of nitrogen and phosphorus on yield and yield components of sesame were conducted by Ibrahim *et al*. (2014) at New Developmental Farm of the University of Agriculture Peshawar with Nitrogen and phosphorus levels (0, 30, 60, 90 kg ha^{-1}) each were applied. The highest number of pods $plant^{-1}$ (67), number of seeds $pods^{-1}$ (54), grain yield (520 kg ha^{-1}), biological yield (2539 kg ha^{-1}), thousand seeds weight (3.91 g) and harvest index (24%) were recorded when higher dose of N i.e. 90 kg ha^{-1} were used. Similarly the lowest number of pods $plant^{-1}$ (55), number of seeds $pods^{-1}$ (50), grain yield (442 kg ha^{-1}), biological yield (1570 kg ha^{-1}), thousand seed weight (2.94 g), and harvest index (20%) were recorded in control plots.

Shilpi *et al*. (2012) carried out an experiment in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh to determine the effect of nitrogen and sulfur on growth and yield of sesame. The experiment consisted of two factors. 4 levels of nitrogen as N_0: 0 kg N ha^{-1} (control); N_1: 40 kg N ha^{-1}; N_2: 60 kg N ha^{-1} and N_3: 100 kg N ha^{-1}; and 4 levels of sulfur. Plant height, number of branches $plant^{-1}$, number of leaves $plant^{-1}$, seed yield, stover yield were increased significantly with increasing N level upto 60 kg N ha^{-1}. Interaction effects of nitrogen(60 kg N ha^{-1}) and sulphur (40 kg S ha^{-1}) gave the highest number of capsules $plant^{-1}$ (70.40), length of capsule (3.99 cm), diameter of capsule (2.77 cm), seeds $capsule^{-1}$ (50.63) and thousand seed weight (12.25 g). The combined application of 60 kg nitrogen and 40 kg sulphur may be considered to be optimum for getting higher yield of sesame.

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). Nitrogen 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 q/ha and 366.39 kg/ha, respectively) were obtained with the application of 80 kg N/ha.

A study was conducted by Malik *et al*. (2003) in Faisalabad, Pakistan in 2001 to investigate the effects of different nitrogen 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). Nitrogen 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 nitrogen levels (0, 15, 30 and 45 kg/ha) on the growth and yield of sesame (*S. indicum*). Nitrogen 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). Nitrogen 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 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 levels of nitrogen (20 and 40 kg N/ha) and 3 levels of potassium (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. Nitrogen 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, stover 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 nitrogen rate uoto 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.

A field experiment was conducted by Singaravel and Govindasamy (1998) 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 (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 days 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 stover 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 of sesame were grown at Joydevpur, Gazipur by Roy *et al*. (1995) in the early summer seasons of 1991-92 and found seed yield of 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 boron on sesame

To know the impact of S and B in the production phenology of sesame, the present study has been carried out by Jeena *et al*. (2013) in Onattukara sandy soil of Kerala. The experiment was laid out in factorial randomized block design with four levels each of sulphur and boron. The sulphur levels were 0, 7.5, 15 and 30 kg ha^{-1} where as in the case of boron, the levels were 0, 2.5, 5 and 7.5 kg ha^{-1}. It has been observed that sulphur and boron play a synergistic role in improving the grain yield and yield attributes of sesame. Application of sulphur @ 30 kg ha^{-1} and B @ 2.5 kg ha^{-1} along with the recommended dose of N, P and K resulted in better grain yield (1460 kg ha^{-1}) and other yield attributes such as number of capsules per plant, dry weight of capsules, shelling per cent and thousand seed weight and finally the highest net returns estimated in terms of B:C ratio. As the level of applied sulphur and boron is increased the availability of soil nutrients including S and B were also increased.

The effects of N, B (0 and 1 kg/ha) and S on the growth and productivity of sesame cv. B-67 were investigated by Sarkar and Anita (2005) during the summer seasons 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. Level of boron at 1 kg/ha resulted in 30.4% higher seed yield, respectively, compared to the control.

Liu *et al.* (2003) studied the effects of Mo and B, alone or in combination, on seed quality of pot growth soybean cultivars Zhechum 3, Zhechun 2, and 3811. Application of Mo and/or B increased the content of protein, in dispensable amino acids, total amino-acids (excluding proline), N, P, K and decrease the content of Ca and oil.

Deasarker *et al.* (2001) conducted an experiment with soybean, was given 2, 4 and 6 kg B ha^{-1}. Application of 2 kg B ha^{-1} was the best among the boron treatment for increasing row seed yield.

Hemantaranjan *et al*. (2000) conducted a field experiment on soybean. Plant height, root length, chlorophyll-B content, total dry matter production and seed yield of soybean were higher at 50 than 100 ppm B. However, chlorophyll-A content was higher at 100 ppm B. The combined application of S and Fe significantly increased shoot height, root length, number of leaves per plant, leaf area per plant, total dry matter production and seed oil content, with 80 + 20 mg per kg soil giving the best results.

Hua and Yan (1998) observed that the addition of B promoted elongation of epicotyle and hypocotyle of mungbean and increased seedling height and dry weight in the Al treated plant. Boron is essential for growth of new cells. Without adequate supply of boron, the number and retention of flowers reduces, and pollen tube growth is less; consequently less fruits are developed (Miller and Donahue, 1997*).*

Talashilkar and Chavan (1996) observed that pod production of groundnut was enhanced significantly with the addition of B by 44 percent. The maximum pod and haulm yields were recorded in the treatment receiving B through boronated super phosphate along with application of FYM, N and P.

Srivastava *et al.* (1996) in a field study with B deficient soil growing chickpea cv. Kaliaka and applying no fertilizer, complete fertilizer (P, K, S, B, Zn, Mo, Cu, Mn and Fe) or the complete fertilizer minus each of the trace elements observed that flower abortion was highest.

Ramirez and Linares (1995) reported sesame was exposed to 6.25-7.50 μg B litre^{-1}. Dry matter production of leaves, stems and roots were severely decreased when B in the leaf tissue was below 21 μg g^{-1}.

Sakal *et al.* (1994) evaluated the direct and residual effect of varying levels of B (0, 8, 16, 32 and 64 kg B ha^{-1} and FYM (0.25 and 5.0 t ha^{-1}) alone and in combinations on crops in maize-lentil cropping system. Increasing levels of B up to 16 kg B ha^{-1} significantly increased and higher levels decreased the yield of first crop. Application of 16 kg B ha^{-1} in conjunction with 5 t FYM ha^{-1} was an ideal combination which appreciably enhanced the cumulative grain yield response and sustained the productivity of four crops in this cropping system.

Sindoni *et al.* (1994) grew *Sesamum inclicum* in Hoagland No. 2 nutrient solution supplemented with 0.05 mg B $liter^{-1}$ or throughout the growth or until 20-30 or 40-day-old when B was either reduced to 0.25 mg B $liter^{1}$ or eliminated completely. Elimination of B at all ages reduced root and shoot dry weight but reduction of B supplementation significantly reduced dry weight only at 30 day. Reduction of B concentration significantly decreased seed production and concentration of B in leaves stems and pods. Seed weight was linearly and significantly correlated with concentration of' B in pods.

Singh and Singh (1994) noted that green pod yield of french beans increased with increase in P application and with B application up to 1 kg B ha^{-1}. Application of more than 1 kg B ha^{-1} caused a toxic effect.

Posypanov *et al.* (1994) observed that applying 1 kg B ha^{-1} to peas and soybeans and treating seeds whit the equivalent of 50 g ammonium molybdate ha^{-1} increased nodule weight, atmospheric N_2 fixation and seed yield.

In the field experiments borax solution at 0.2% was sprayed at seedling and flowering growth stages. In the pot experiments boric acid at 0.7 ppm was given and in hydroponic experiments 0.01, 0.02, 0.2 and 2.0 ppm boric acid were applied. Average yield increases of 4.6-21.2%, 3.3-19.9% and 2.l -17.1% were obtained with B application for Zhongzhi 8, Golden Turkey and Qingma, respectively. Application of rates higher than 0.20 ppm in the hydroponic experiments was detrimental, depressing growth of or even causing death to the plant (Li *et al.*, 1992).

Roy *et al.* (1992) observed that soil application of 20kg borax ha^{-1} increased seed yield of lentil, while soil application of 3 kg sodium molybdate ha^{-1} gave only small (about 14%) increase.

Sinha *et al.* (1991) studied the response of five kharif crops, viz. onion, groundnut, maize, sweet potato and yard long bean as well as five *rabi* crops, viz. mustard, onion, lentil, maize and sunflower to boron application on boron deficient calcareous soils under field condition. Boron was applied as borax @ 0, 1.5 and 2.5 kg B ha^{-1}. All the crops responded to boron, but the magnitude of yield response differed from crop to crop. The optimum level of B for kharif as well as rabi crops was 1.5 kg ha^{-1}.

Mandal *et al.* (1991) noted that most of alluvial acidic soils responded to the application of B and Mo fertilizer and thereby increased the yield of pulse in the area.

Dwivedi *et al.* (1990) reported that B uptake $plant^{-1}$ had highly significant positive correlation with yield of lentil. Soybean and pea and was a reliable index for predicting crop response to B.

Buzctti *et al.* (1990) observed that soybean cv. Porana when treated with 0, 0.2, 0.4, 0.6 or 0.8 ppm B pot^{-1}, DM and seed yield pot^{-1} increased up to approx. 0.3 ppm B and decreased at higher B rates.

Sakal *et al.* (1990) observed that seed yield of chickpea increased from 1.4 t ha^{-1} with no B to 1.49 t ha^{-1} with 3 kg B ha^{-1}. The yield response of B application was greater on low B soils. It was concluded that on soils containing <0.35 ppm B. 3 kg B ha^{-1} was optimum and on soils containing >0.35 rpm B, 2 kg B ha^{-1} was optimum.

Rerkasem *et al.* (1989) reported that wheat growing in the low boron soils exhibited symptoms of male sterility, which included poorly developed anthers and nonviable pollen grains. Grain set failure lower seed yield and male sterility symptoms were associated with low boron concentration in the flag leaf Failure in grain set up to 100% of florets was frequently observed. They also reported that poor grain set in wheat depressed seed yield by 4050% on Tropaqualf soils having low boron content (0.08-0.12 mg kg^{-1}).

Galrao (1989) reported that yield of soybean was 2.38 t ha^{-1} for using B, whereas yield was 2.24 t ha^{-1} without B. Sakal *et al.* (1988) reported on a coarse textured calcareous soil that application of 2.0 and 2.5 kg B ha^{-1} increased grain yields of black gram and chickpea by 63 and 38%, respectively.

Boron plays a vital role in the physiological processes of plants such as cell maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, acid and phenol metabolisms. The functions of B are primarily extra-cellular and related to lignification and xylem differentiation (Lewis, 1980), membrane stabilization and alteration of enzymatic reactions (Pilbeam and Kirkby, 1983).

From the foregoing review, it was evident that plant height, number of branches $plant^{-1}$, number of capsules $plant^{-1}$ and seed yield were influenced by different levels of nitrogen and boron application. Seed yield of sesame showed differential behavior due to different levels of applied nitrogen and boron in different parts of the world. It is, therefore, more researches on this aspect are necessary to arrive at a definite conclusion.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from February to May, 2015 to find out the effect of nitrogen and boron on the growth and yield 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 of the experiment

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 $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and an elevation of 8.2 m from sea level (Anon., 1989). The map shows the specific location of the experimental site (Appendix I).

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 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 in the Table 1 and 2.

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 II.

Table 1. Morphological characteristics of the experimental field

Morphology	Characteristics
Locality	SAU farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(UNDP and FAO, 1988)

Table 2. Initial physical and chemical characteristics of the soil (0-15 cm depth)

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	18.60
% Silt (0.02-0.002 mm)	45.40
% Clay (<0.002 mm)	36.00
Textural class	Silty Loam
Consistency	Granular and friable when dry
pH (1: 2.5 soil- water)	5.8
Organic Matter (%)	1.187
Total N (%)	0.06
Exchangeable K (mmol kg^{-1})	0.12
Available P (mg kg^{-1})	19.85
Available S (mg kg^{-1})	14.40
Available B (mg kg^{-1})	6.25

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, 2012). 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: 50 kg N/ha
iii. N_2: 60 kg N/ha
iv. N_3: 70 kg N/ha

Factor B: Levels of boron (3 levels)

i. B_0: 0 kg B/ha (control)
ii. B_1: 2 kg B/ha
iii. B_2: 3 kg B/ha

There were 12 (4 × 3) treatment combinations such as N_0B_0, N_0B_1, N_0B_2, N_1B_0, N_1B_1, N_1B_2, N_2B_0, N_2B_1, N_2B_2, N_3B_0, N_3B_1 and N_3B_2.

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 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots altogether in the experiment. The size of the plot was 2.5 m × 1.5 m. The distance between two blocks and two plots was 50 cm each.

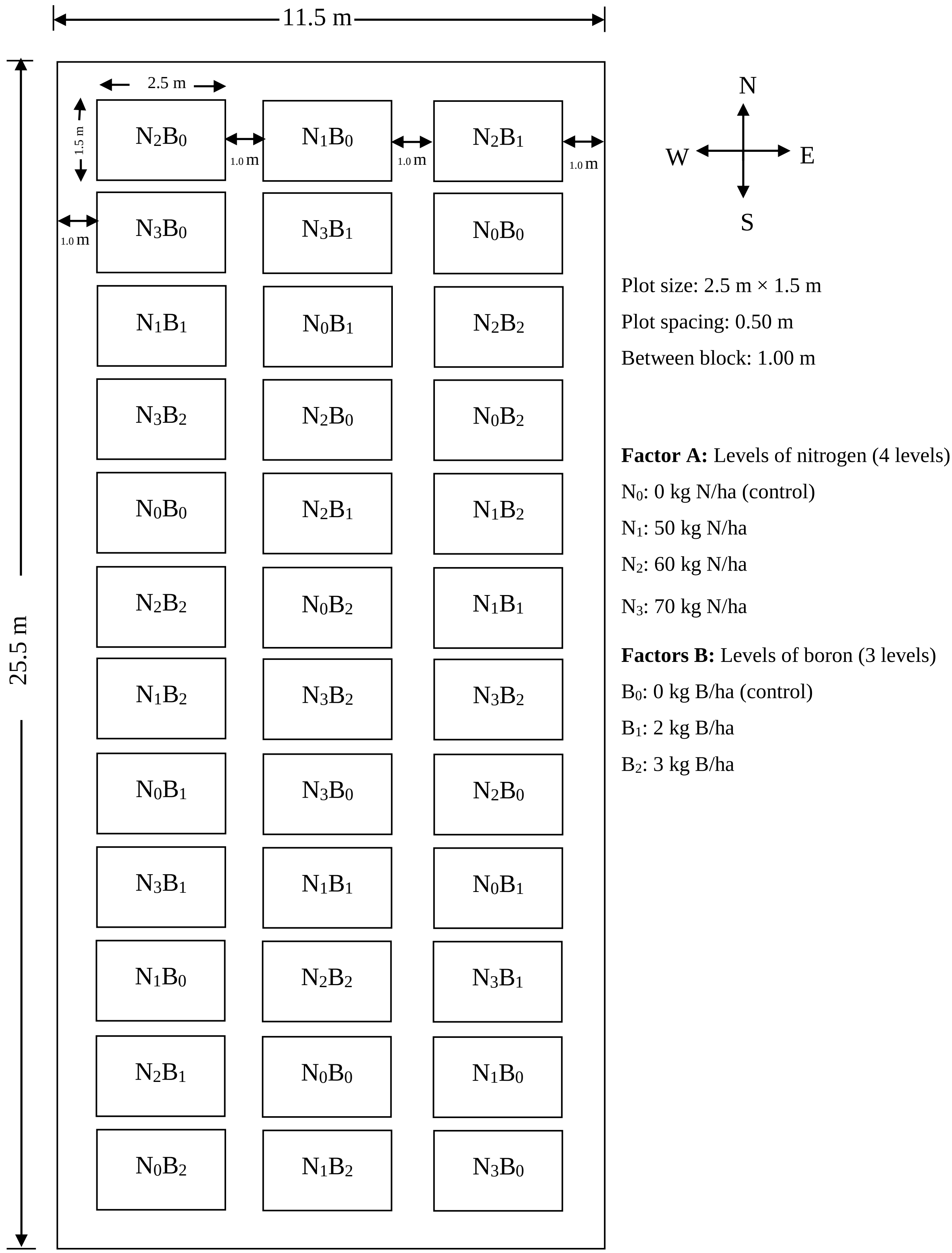

Figure 1. Layout of the experimental plot

3.7 Land preparation

The experimental field was first opened on February 05, 2015 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 3. The total amount of cowdung, TSP, half of MoP, total zinc and sulfur was applied as basal dose at the time of land preparation. The rest amount of MoP and total amount of urea (as per treatment) was applied in two installments at 15 and 30 day after seed sowing.

Table 3. Dose and method of application of fertilizers in sesame field

Fertilizers and Manures	Dose/ha	Application (%)		
		Basal	15 DAS	30 DAS
Cowdung	10 tonnes	100	--	--
Urea	As per treatment	--	50	50
TSP	150 kg	100	--	--
MoP	50 kg	50	25	25
Zinc Sulphate	5 kg	100	--	--
Sulfur	10 kg	100	--	--
Boron	As per treatment	100	--	--

Source: BARI, 2012

3.9 Sowing of seeds

The seeds of BARI Til-3 were sown on 17 February 2015 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. 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 plants and it was done manually after 22 days of sowing, on March 11, 2015. 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 Days required from sowing to harvest

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

3.12.4 Length of capsule (cm)

The capsules from each randomly selected plant were measured using centimeter scale and the mean value was calculated and was expressed in centimeter.

3.12.5 Number of capsule per plant

From 10 randomly selected plants from each unit plot numbers of capsule were counted and their mean values were recorded.

3.12.6 Seeds per capsule

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

3.12.7 Weight of 1000 seeds (g)

As per treatment combination, 1000 seeds were counted and weight was taken by a digital weighing machine accordingly and expressed in gram.

3.12.8 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).

3.12.9 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).

3.13 Chemical analysis of seed and stover samples

3.13.1 Collection of samples

Seeds and stover samples were collected after threshing 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, S and B.

3.13.2 Preparation of samples

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

3.13.3 Digestion of samples with sulphuric acid for N

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 in the ratio of 100: 10: 1), and 5 ml conc. H_2SO_4 were added. The flasks were heating at 120^0C and added 2.5 ml 30% H_2O_2 then heated was continued at 180^0C 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 samples with nitric-perchloric acid for P, K, S and B

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 at a temperature slowly raised to 200^0C. Heating were 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, S, Zn and B were determined from this digest.

3.13.5 Determination of P, K, S and B from samples

3.13.5.1 Phosphorus

Phosphorus was digested from the plant sample (seeds and stover) 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 grain sample and 2 ml for stover 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).

3.13.5.2 Potassium

Five milli-liter of digest sample for the grain and 10 ml for the stover were taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbance was measured by atomic absorption flame photometer.

3.13.5.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and stover) 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).

3.13.5.4 Boron

For B, the extractant of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H_2SO_4 and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the soil extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.14 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was 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.

3.15 Soil analysis

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

3.15.1 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 as described by Page *et al.*, 1982.

3.15.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N

$K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain 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).

3.15.3 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 gm 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 200^0C and added 3 ml H_2O_2 and then heating at 360^0C 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 is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions 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 distillates were 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:

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

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

3.15.4 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 with the standard P curve (Page *et al*., 1982).

3.15.5 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*., 1982).

3.15.6 Available Boron

For available B, the extractant composed of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H_2SO_4 and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the soil extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.16 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different levels of nitrogen and boron. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Abdel *et al*. (2003)

Anon., 1989

Ashfaq *et al*. (2001)

Ashok *et al*. (1996)

Auwalu *et al*. (2007)

Balasubramaniyan (1996)

BARI, 2004

BARI, 2012

Bassiem and Anton (1998)

BBS, 2014

Buzctti *et al.* (1990)

Chandrakar *et al*. (1994)

Chaubey *et al*., 2003

Deasarker *et al.* (2001)

Dell and Huang, 1997;

Dixit *et al*. (1997)

Dwivedi *et al.* (1990)

Edris *et al.*, 1979

Fard and Bahrani (2005)

Fayed *et al*. (2000)

Galrao (1989)

Gomez and Gomez, 1984

Hamasa and Putaiah, 2012

Hemantaranjan *et al*. (2000)

Hooda *et al* (1996)

Hua and Yan (1998)

Hunter, 1984

Ibrahim *et al*., 2014

Islam and Noor, 1982

Jeena *et al*. (2013)

Kalyani *et al*. (1993)

Lalit Bhott *et al.*, 2004,

Lewis, 1980

Li *et al.,* 1992

Liu *et al.* (2003)

Malik *et al*., 2003

Mandal *et al.* (1991)

Marschner, 1995;

Mary *et al.* (1990)

Mitra and Pal (1999)

Mondal *et al*. (2001)

Mondal *et al*., 1997

Moorthy *et al*. (1997)

Obreza and Vavrina, 1993

Olsen *et al.*, 1954

Opena *et al*., 1988

Page *et al*., 1982

Parihar *et al*. (1999)

Pathak *et al*. (2002)

Pilbeam and Kirkby, 1983

Posypanov *et al.* (1994)

Prakash *et al*. (2001)

Ramirez and Linares (1995)

Ratna Kalyani *et al*., 1993

Rerkasem *et al.* (1989)

Roy *et al.* (1992)

Roy *et al*. (1995)

Sakal *et al.* (1988)

Sakal *et al.* (1990)

Sakal *et al.* (1994)

Sarkar and Anita (2005)

Sathya *et al.*, 2009

Shilpi *et al*. (2012)

Sindoni *et al.* (1994)

Singaravel and Govindasamy (1998)

Singh and Singh (1994)

Singh and Singh (1999)

Singh *et al*. (2001)

Sinha *et al.* (1991)

Srivastava and Gupta, 1996

Srivastava *et al.* (1996)

Subrahmaniyan and Arulmozhi (1999)

Talashilkar and Chavan (1996)

Tanaka and Fujiwar, 2008

Thakur *et al*. (1998)

Tiwari and Namdeo (1997)

UNDP and FAO, 1988

Yoshizawa *et al*., 1981

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of nitrogen and boron application on growth and yield of sesame. Data on different growth parameter, yield, nutrient concentration in seeds and stover and characteristics of post harvest soil was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-VIII. The findings of the experiment have been presented and discusses with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Yield contributing characters and yield of sesame

4.1.1 Plant height

Plant height of sesame showed statistically significant differences due to different levels of nitrogen at 30, 40, 50, 60 days after sowing (DAS) and at harvest (Appendix III). At 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.49, 54.79, 78.07, 94.58 and 111.89 cm, respectively) were observed from N_2 (60 kg N/ha), which were statistically similar (32.87, 53.07, 74.23, 91.27 and 109.59 cm, respectively) to N_3 (70 kg N/ha) and closely followed (32.48, 52.29, 74.78, 90.82 and 109.05 cm, respectively) by N_1 (50 kg N/ha), while the shortest plant (29.87, 48.61, 68.16, 84.62 and 103.46 cm, respectively) were observed from N_0 (0 kg N/ha) (Figure 2). It was revealed from the observed data that plant height showed increasing trend with the increase of application of nitrogen nutrients upto a certain level then decreases. Nitrogen created a favorable condition for the growth of sesame with optimum vegetative growth and the ultimate results was the tallest plant. Nitrogen is a structural component of chlorophyll and protein therefore adequate supply of nitrogen is beneficial for both carbohydrates and protein metabolism as it promotes cell division and cell enlargement, resulting in longest plant (Ibrahim *et al*., 2014). Auwalu *et al*. (2007) reported that application of N significantly increased plant height.

Different levels of boron varied significantly in terms of plant height of sesame at 30, 40, 50, 60 DAS and at harvest (Appendix III). At 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.15, 54.54, 77.68, 92.46 and 110.93 cm, respectively) were recorded from B_2 (3.0 kg B/ha) which were statistically similar (32.77, 53.14, 75.23, 90.76 and 108.52 cm, respectively) to B_1 (2.0 kg B/ha), whereas the shortest plant (30.61, 48.90, 68.54, 87.74 and 106.04 cm, respectively) from B_0 (0 kg B/ha) (Figure 3). It was revealed that with the increase of boron fertilizer, plant height increased upto the highest level. Deasarker *et al.* (2001) conducted an experiment with soybean, was given 2, 4 and 6 kg B ha^{-1}. 2 kg B ha^{-1} was the best among the boron treatment for increasing plant height.

Statistically significant variation was recorded for the interaction effect of nitrogen and boron on plant height of sesame at 30, 40, 50, 60 DAS and at harvest under the present trial (Appendix III). At 30, 40, 50, 60 DAS and at harvest, the tallest plant (34.51, 58.26, 83.75, 97.05 and 116.43 cm, respectively) were observed from N_2B_2 (60 kg N/ha and 3.0 kg B/ha) and the shortest plant (25.24, 44.54, 62.37, 80.61 and 100.64 cm, respectively) were found from N_0B_0 (0 kg N/ha and 0 kg B/ha) treatment combination (Table 4).

4.1.2 Number of branches per plant

Number of branches per plant of sesame showed statistically significant differences due to different levels of nitrogen at 30, 40, 50, 60 DAS and at harvest (Appendix IV). At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.64, 4.58, 6.76, 8.47 and 8.80, respectively) were observed from N_2, which were statistically similar (2.60, 4.16, 6.40, 8.04 and 8.27, respectively) to N_3 and closely followed (2.47, 4.22, 6.58, 7.93 and 8.18, respectively) by N_1, while the minimum number (2.22, 3.44, 5.91, 7.36 and 7.91, respectively) were observed from N_0 (Figure 4). Auwalu *et al.* (2007) reported that application of N significantly increased number of leaves per plant.

Table 4. Interaction effect of nitrogen and boron on plant height at different days after sowing (DAS) and harvest of sesame

Treatments	Plant height (cm) at				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
N_0B_0	25.24 b	44.54 d	62.37 d	80.61 d	100.64 d
N_0B_1	30.87 a	48.50 cd	68.42 cd	81.37 d	100.87 cd
N_0B_2	33.49 a	52.79 abc	73.70 bc	91.87 bc	108.88 abc
N_1B_0	32.49 a	50.60 bc	71.21 bc	90.87 bc	107.27 abcd
N_1B_1	31.82 a	51.36 bc	74.08 bc	89.06 c	108.71 ab
N_1B_2	33.14 a	54.90 ab	79.07 ab	92.53 abc	112.79 bcd
N_2B_0	31.70 a	48.23 cd	67.39 cd	90.94 bc	105.77 ab
N_2B_1	34.27 a	57.88 a	83.07 a	95.74 ab	113.47 a
N_2B_2	34.51 a	58.26 a	83.75 a	97.05 a	116.43 ab
N_3B_0	33.03 a	52.21 bc	73.17 bc	88.56 c	110.49 ab
N_3B_1	34.11 a	54.80 ab	75.34 bc	96.85 a	111.02 ab
N_3B_2	31.48 a	52.19 bc	74.18 bc	88.41 c	105.63 bcd
$LSD_{(0.05)}$	4.054	5.056	7.006	4.578	7.264
Significance level	0.05	0.05	0.05	0.01	0.05
CV(%)	7.44	5.72	5.61	4.99	3.95

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

Different levels of boron varied significantly in terms of number of branches per plant of sesame at 30, 40, 50, 60 DAS and at harvest (Appendix IV). At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.68, 4.28, 6.75, 8.47 and 8.72, respectively) were recorded from B_2 which were statistically similar (2.57, 4.22, 6.58, 8.35 and 8.65, respectively) to B_1, whereas the minimum number (2.20, 3.80, 5.90, 7.03 and 7.50, respectively) from B_0 (Figure 5).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on plant height of sesame at 30, 40, 50, 60 DAS and at harvest (Appendix IV). At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.93, 4.93, 7.33, 9.13 and 9.47, respectively) were observed from N_2B_2 and the minimum number (1.80, 3.07, 5.47, 6.20 and 7.27, respectively) were found from N_0B_0 treatment combination (Table 5).

4.1.3 Days required from sowing to harvest

Days required from sowing to harvest of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The minimum number of days required from sowing to harvest (93.78) were observed from N_2, which were statistically similar (96.00) to N_3 and N_1, while the maximum number of days (97.78) were observed from N_0 (Table 6).

Different levels of boron varied significantly in terms of number of days required from sowing to harvest (Appendix V). The minimum number of days required from sowing to harvest (94.33) were recorded from B_2 which were statistically similar (96.08) to B_1, whereas the maximum number of days (97.25) from B_0 (Table 6).

Interaction effect of nitrogen and boron differed significantly on days required from sowing to harvest (Appendix V). The minimum number of days required from sowing to harvest (92.67) were observed from N_2B_2 and the maximum number of days (99.00) were found from N_0B_0 (Table 7).

Table 5. Interaction effect of nitrogen and boron on number of branches/plant at different days after sowing (DAS) and harvest of sesame

Treatments	Number of branches per plant at				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
N_0B_0	1.80 f	3.07 c	5.47 f	6.20 h	7.27 f
N_0B_1	2.20 e	3.33 c	6.07 cdef	7.80 ef	8.07 de
N_0B_2	2.67 abcd	3.93 b	6.20 cde	8.07 de	8.40 cd
N_1B_0	2.33 de	4.20 b	6.33 cde	7.20 g	7.40 f
N_1B_1	2.40 cde	4.33 b	6.67 abcd	8.07 de	8.40 cd
N_1B_2	2.67 abcd	4.13 b	6.73 abc	8.53 bcd	8.73 bc
N_2B_0	2.13 ef	3.93 b	5.80 ef	7.40 fg	7.67 ef
N_2B_1	2.87 ab	4.87 a	7.13 ab	8.87 ab	9.27 ab
N_2B_2	2.93 a	4.93 a	7.33 a	9.13 a	9.47 a
N_3B_0	2.53 abcde	4.00 b	6.00 def	7.33 fg	7.67 ef
N_3B_1	2.80 abc	4.33 b	6.47 bcde	8.67 abc	8.87 abc
N_3B_2	2.47 bcde	4.13 b	6.73 abc	8.13 cde	8.27 cde
$LSD_{(0.05)}$	0.363	0.527	0.613	0.533	0.594
Significance level	0.01	0.05	0.05	0.05	0.05
CV(%)	8.64	7.61	5.64	3.97	4.23

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

N_0: 0 kg N/ha (control)
N_1: 50 kg N/ha
N_2: 60 kg N/ha
N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)
B_1: 2.0 kg B/ha
B_2: 3.0 kg B/ha

Table 6. Effect of nitrogen and boron on yield contributing characters and yield of sesame

Treatments	Days from sowing to harvest	Length of capsule (cm)	Number of capsule per plant	Number of seeds per capsule	1000 seeds weight (g)	Seed yield (t/ha)	Stover yield (t/ha)
Levels of nitrogen							
N_0	97.78 a	3.06 b	57.78 b	50.00 b	11.25 b	1.09 c	2.01 c
N_1	96.00 ab	3.28 a	63.40 a	55.78 a	11.74 ab	1.42 b	2.67 b
N_2	93.78 b	3.46 a	65.16 a	57.11 a	12.12 a	1.51 a	2.91 a
N_3	96.00 ab	3.33 a	63.78 a	54.56 a	11.86 ab	1.39 b	2.77 b
$LSD_{(0.05)}$	2.149	0.183	2.593	3.448	0.581	0.076	0.142
Significance level	0.01	0.01	0.01	0.01	0.05	0.01	0.01
Levels of boron							
B_0	97.25 a	3.06 b	58.68 b	52.25 b	10.96 b	1.30 b	2.42 b
B_1	96.08 ab	3.33 a	63.40 a	54.58 ab	12.08 a	1.37 a	2.66 a
B_2	94.33 b	3.45 a	65.50 a	56.25 a	12.19 a	1.40 a	2.69 a
$LSD_{(0.05)}$	1.861	0.158	2.246	2.986	0.503	0.066	0.123
Significance level	0.01	0.01	0.01	0.05	0.01	0.01	0.01
CV(%)	5.29	5.66	4.24	6.49	5.06	5.79	5.56

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

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

Treatments	Days from sowing to harvest	Length of capsule (cm)	Number of capsule per plant	Number of seeds per capsule	1000 seeds weight (g)	Seed yield (t/ha)	Stover yield (t/ha)
N_0B_0	99.00 a	2.83 e	53.73 f	48.33 cd	10.27 e	1.03 g	1.83 e
N_0B_1	98.67 ab	3.08 de	56.33 ef	46.00 d	11.39 bcd	1.06 fg	1.97 e
N_0B_2	95.67 abcd	3.27 bcd	63.27 bc	55.67 ab	12.09 abc	1.18 ef	2.23 d
N_1B_0	97.67 abc	2.97 de	60.40 cde	53.00 abc	11.00 cde	1.40 bcd	2.63 c
N_1B_1	95.67 abcd	3.21 cd	64.40 abc	56.67 ab	12.01 abc	1.38 bcd	2.63 c
N_1B_2	94.67 bcd	3.67 a	65.40 abc	57.67 ab	12.22 a	1.48 abc	2.75 bc
N_2B_0	93.33 d	3.15 cde	58.20 def	53.33 abc	10.76 de	1.45 abc	2.53 c
N_2B_1	95.33 abcd	3.45 abc	67.93 ab	58.67 ab	12.67 a	1.50 ab	3.07 a
N_2B_2	92.67 d	3.77 a	69.33 a	59.33 a	12.93 a	1.59 a	3.13 a
N_3B_0	99.00 a	3.29 bcd	62.40 cd	54.33 abc	11.82 abcd	1.30 de	2.70 c
N_3B_1	94.67 bcd	3.59 ab	64.93 abc	57.00 ab	12.24 ab	1.52 ab	2.97 ab
N_3B_2	94.33 cd	3.11 cde	64.00 bc	52.33 bc	11.51 bcd	1.34 cd	2.63 c
$LSD_{(0.05)}$	3.722	0.317	4.492	5.972	1.006	0.131	0.245
Significance level	0.05	0.01	0.05	0.05	0.05	0.05	0.01
CV(%)	5.29	5.66	4.24	6.49	5.06	5.79	5.56

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

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

4.1.4 Length of capsule

Length of capsule of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The longest length of capsule (3.46 cm) were observed from N_2, which were statistically similar (3.33 cm and 3.28 cm) to N_3 and N_1, while the shortest length of capsule (3.06 cm) from N_0 (Table 6).

Different levels of boron varied significantly in terms of length of capsule (Appendix V). The longest length of capsule (3.45 cm) were recorded from B_2 which were statistically similar (3.33 cm) to B_1, whereas the shortest length of capsule (3.06 cm) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on length of capsule (Appendix V). The longest length of capsule (3.77 cm) were observed from N_2B_2 and the shortest length of capsule (2.83 cm) were found from N_0B_0 treatment combination (Table 7).

4.1.5 Number of capsule per plant

Number of capsule per plant of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The maximum number of capsule per plant (65.16) were observed from N_2, which were statistically similar (63.78 and 63.40) to N_3 and N_1, while the minimum number (57.78) were observed from N_0 (Table 6). Prakash *et al*. (2001) reported that application of 90 kg N/ha resulted in the highest number of capsules per plant.

Different levels of boron varied significantly in terms of number of capsule per plant (Appendix V). The maximum number of capsule per plant (65.50) were recorded from B_2 which were statistically similar (63.40) to B_1, whereas the minimum number (58.68) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on number of capsule per plant (Appendix V). The maximum number of capsule per plant (69.33) were observed from N_2B_2 and the minimum number (53.73) were found from N_0B_0 treatment combination (Table 7).

4.1.6 Number of seeds per capsule

Number of seeds per capsule of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The maximum number of seeds per capsule (57.11) were observed from N_2, which were statistically similar (54.56 and 55.78) to N_3 and N_1, while the minimum number (50.00) were observed from N_0 (Table 6). Prakash *et al.* (2001) reported that application of 90 kg N/ha resulted in the highest number of seeds per capsule.

Different levels of boron varied significantly in terms of number of seeds per capsule (Appendix V). The maximum number of seeds per capsule (56.25) were recorded from B_2 which were statistically similar (54.58) to B_1, whereas the minimum number (52.25) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on number of seeds per capsule (Appendix V). The maximum number of seeds per capsule (59.33) were observed from N_2B_2 and the minimum number (48.33) were found from N_0B_0 treatment combination (Table 7).

4.1.7 Weight of 1000 seeds

Weight of 1000 seeds of sesame showed significant differences due to different levels of nitrogen (Appendix V). The highest weight of 1000 seeds (12.12 g) was observed from N_2, which were statistically similar (11.86 g and 11.74 g) to N_3, while the lowest weight (11.25 g) from N_0 (Table 6). Prakash *et al.* (2001) reported that application of 90 kg N/ha resulted in the highest 1000-seed weight.

Different levels of boron varied significantly in terms of weight of 1000 seeds (Appendix V). The highest weight of 1000 seeds (12.19 g) were recorded from B_2 which were statistically similar (12.08 g) to B_1, whereas the lowest weight of 1000 seeds (10.96 g) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on weight of 1000 seeds (Appendix V). The highest weight 1000 seeds (12.93 g) were observed from N_2B_2 and the lowest weight of 1000 seeds (10.27 g) was found from N_0B_0 treatment combination (Table 7).

4.1.8 Seed yield

Seed yield of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The highest seed yield (1.51 t/ha) were observed from N_2, which was closely followed (1.42 t/ha and 1.39 t/ha) by N_3 and N_1 and they were statistically similar, while the lowest seed yield (1.09 t/ha) were observed from N_0 (Table 6). Shilpi *et al.* (2012) reported that application of 60 kg nitrogen may be considered to be optimum for getting higher yield of sesame.

Different levels of boron varied significantly in terms of seed yield (Appendix V). The highest seed yield (1.40 t/ah) were recorded from B_2 which were statistically similar (1.37 t/ha) to B_1, whereas the lowest (1.30 t/ha) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on seed yield (Appendix V). The highest seed yield (1.59 t/ha) were observed from N_2B_2 and the lowest seed yield (1.03 t/ha) were found from N_0B_0 treatment combination (Table 7).

4.1.9 Stover yield

Stover yield of sesame showed statistically significant differences due to different levels of nitrogen (Appendix V). The highest stover yield weight (2.91 t/ha) were observed from N_2, which was closely followed (2.77 t/ha and 2.67 t/ha) by N_3 and N_1 and they were statistically similar, while the lowest stover yield (2.01 t/ha) were observed from N_0 (Table 6). Prakash *et al.* (2001) reported that application of 90 kg N/ha resulted in the highest stover yield.

Different levels of boron varied significantly for stover yield (Appendix V). The highest stover yield (2.69 t/ha) were recorded from B_2 which were statistically similar (2.66 t/ha) to B_1, whereas the lowest (1.42 t/ha) from B_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on stover yield (Appendix V). The highest stover yield (3.13 t/ha) were observed from N_2B_2 and the lowest stover yield (1.83 t/ha) were found from N_0B_0 treatment combination (Table 7).

4.2 N, P, K, S and B concentration in seed and stover of sesame

4.2.1 N, P, K, S and B concentration in seeds

Statistically significant variation was recorded for N, P, K, S and B concentration in seeds due different levels of nitrogen (Appendix VI). The maximum concentration in seed for N (0.55%), P (0.32%), K (0.55%), S (0.21%) and B (0.014%) were observed from N_2, whereas the minimum concentration in seed for N (0.39%), P (0.26%), K (0.43%), S (0.17%) and B (0.011%) were found from N_0 (Table 8).

N, P, K, S and B concentration in seeds showed statistically significant variation due to different levels of boron (Appendix VI). The maximum concentration in seeds for N (0.56%), P (0.31%), K (0.51%), S (0.20%) and B (0.014%) were recorded from B_2 and the minimum concentration in seeds for N (0.39%), P (0.27%), K (0.46%), S (0.18%) and B (0.009%) from B_0 (Table 8).

Interaction effect of nitrogen and boron showed statistically significant variation in terms of N, P, K, S and B concentration in seeds (Appendix VI). The maximum concentration in seeds for N (0.61%), P (0.34%), K (0.58%), S (0.22%) and B (0.017%) were observed from N_2B_2, while the minimum concentration in seeds for N (0.30%), P (0.24%), K (0.39%), S (0.16%) and B (0.007%) were found from N_0B_0 treatment combination (Table 9).

Table 8. Effect of nitrogen and boron on N, P, K, S and B concentrations in seeds of sesame

Treatments	Concentration (%) in seeds				
	N	P	K	S	B
Levels of nitrogen					
N_0	0.39 c	0.26 c	0.43 c	0.17 c	0.011 b
N_1	0.51 b	0.29 b	0.48 b	0.19 b	0.012 ab
N_2	0.55 a	0.32 a	0.55 a	0.21 a	0.014 a
N_3	0.51 b	0.31 a	0.48 b	0.19 b	0.012 ab
$LSD_{(0.05)}$	0.031	0.010	0.031	0.010	0.003
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of boron					
B_0	0.39 c	0.27 c	0.46 b	0.18 b	0.009 b
B_1	0.52 b	0.30 b	0.49 a	0.19 a	0.014 a
B_2	0.56 a	0.31 a	0.51 a	0.20 a	0.014 a
$LSD_{(0.05)}$	0.027	0.009	0.027	0.009	0.003
Significance level	0.01	0.01	0.01	0.01	0.01
CV(%)	7.19	4.14	6.20	6.19	7.35

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

N_0: 0 kg N/ha (control)
N_1: 50 kg N/ha
N_2: 60 kg N/ha
N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)
B_1: 2.0 kg B/ha
B_2: 3.0 kg B/ha

Table 9. Interaction effect of nitrogen and boron on N, P, K, S and B concentrations in seeds of sesame

Treatments	Concentration (%) in seeds				
	N	P	K	S	B
N_0B_0	0.30 e	0.24 g	0.39 f	0.16 f	0.007 c
N_0B_1	0.38 d	0.26 f	0.41 ef	0.17 ef	0.012 abc
N_0B_2	0.49 c	0.28 de	0.49 cd	0.19 cd	0.014 ab
N_1B_0	0.38 d	0.27 ef	0.47 cde	0.18 cde	0.010 bc
N_1B_1	0.56 ab	0.30 bc	0.47 cde	0.18 cde	0.013 abc
N_1B_2	0.59 ab	0.29 cd	0.49 cd	0.20 bcd	0.013 abc
N_2B_0	0.44 c	0.28 de	0.51 bcd	0.20 bcd	0.010 bc
N_2B_1	0.60 ab	0.31 b	0.56 ab	0.21 ab	0.016 ab
N_2B_2	0.61 a	0.34 a	0.58 a	0.22 a	0.017 a
N_3B_0	0.44 c	0.30 bcd	0.47 cde	0.18 cde	0.009 bc
N_3B_1	0.55 b	0.31 bc	0.52 bc	0.20 bc	0.014 ab
N_3B_2	0.55 b	0.31 b	0.45 de	0.18 de	0.013 abc
$LSD_{(0.05)}$	0.054	0.017	0.054	0.017	0.005
Significance level	0.05	0.05	0.01	0.05	0.01
CV(%)	7.19	4.14	6.20	6.19	7.35

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

N_0: 0 kg N/ha (control)
N_1: 50 kg N/ha
N_2: 60 kg N/ha
N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)
B_1: 2.0 kg B/ha
B_2: 3.0 kg B/ha

4.2.2 N, P, K, S and B concentration in stover

Statistically significant variation was recorded for N, P, K, S and B concentration in stover due different levels of nitrogen (Appendix VII). The maximum concentration in stover for N (0.51%), P (0.26%), K (1.55%), S (0.22%) and B (0.012%) were observed from N_2, whereas the minimum concentration in stover for N (0.27%), P (0.19%), K (1.28%), S (0.15%) and B (0.008%) were found from N_0 (Table 10).

N, P, K, S and B concentration in stover showed statistically significant variation due to different levels of boron (Appendix VII). The maximum concentration in stover for N (0.43%), P (0.25%), K (1.56%), S (0.20%) and B (0.012%) were recorded from B_2 and the minimum concentration in stover for N (0.39%), P (0.19%), K (1.35%), S (0.18%) and B (0.009%) from B_0 (Table 10).

Interaction effect of nitrogen and boron showed statistically significant variation in terms of N, P, K, S and B concentration in stover (Appendix VII). The maximum concentration in stover for N (0.54%), P (0.30%), K (1.67%), S (0.26%) and B (0.013%) were observed from N_2B_2, while the minimum concentration in stover for N (0.25%), P (0.15%), K (1.17%), S (0.13%) and B (0.006%) were found from N_0B_0 treatment combination (Table 11).

4.3 pH, organic matter, Total N, available P, exchangeable K and available B in post harvest soil

4.3.1 pH

pH of post harvest soil showed statistically non significant differences due to different levels of nitrogen (Appendix VIII). The highest pH (6.00) were observed from N_2, while the lowest pH of post harvest soil (5.67) were observed from N_0 (Table 12).

Different levels of boron varied non significantly in terms of pH of post harvest soil (Appendix VIII). The highest pH of post harvest soil (5.92) were recorded from B_2, whereas the lowest pH of post harvest soil (5.86) from B_0 (Table 12).

Table 10. Effect of nitrogen and boron on N, P, K, S and B concentrations in stover of sesame

Treatments	Concentration (%) in stover				
	N	P	K	S	B
Levels of nitrogen					
N_0	0.27 c	0.19 c	1.28 c	0.15 c	0.008 b
N_1	0.43 b	0.22 bc	1.48 b	0.19 b	0.011 ab
N_2	0.51 a	0.26 a	1.55 a	0.22 a	0.012 a
N_3	0.45 b	0.23 ab	1.52 ab	0.20 b	0.011 ab
$LSD_{(0.05)}$	0.031	0.031	0.069	0.010	0.003
Significance level	0.01	0.01	0.01	0.01	0.01
Levels of boron					
B_0	0.39 b	0.19 b	1.35 c	0.18 b	0.009 a
B_1	0.42 a	0.24 a	1.46 b	0.20 a	0.011 b
B_2	0.43 a	0.25 a	1.56 a	0.20 a	0.012 b
$LSD_{(0.05)}$	0.027	0.027	0.060	0.009	0.00
Significance level	0.05	0.01	0.01	0.05	0.001
CV(%)	7.42	9.87	4.64	10.86	4.98

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

Table 11. Interaction effect of nitrogen and boron on N, P, K, S and B concentrations in stover of sesame

Treatments	Concentration (%) in stover				
	N	P	K	S	B
N_0B_0	0.25 d	0.15 c	1.17 e	0.13 h	0.006 b
N_0B_1	0.26 d	0.22 b	1.26 de	0.16 fg	0.008 ab
N_0B_2	0.30 d	0.22 b	1.41 c	0.15 g	0.010 ab
N_1B_0	0.42 c	0.21 bc	1.41 c	0.20 cd	0.010 ab
N_1B_1	0.42 bc	0.22 b	1.40 c	0.20 cd	0.010 ab
N_1B_2	0.45 bc	0.23 b	1.61 a	0.18 de	0.012 ab
N_2B_0	0.46 bc	0.19 bc	1.35 cd	0.18 ef	0.011 ab
N_2B_1	0.52 a	0.29 a	1.64 a	0.24 b	0.012 ab
N_2B_2	0.54 a	0.30 a	1.67 a	0.26 a	0.013 a
N_3B_0	0.44 bc	0.21 b	1.46 bc	0.20 cd	0.010 ab
N_3B_1	0.48 ab	0.24 ab	1.54 ab	0.20 cde	0.011 ab
N_3B_2	0.41 c	0.25 ab	1.55 ab	0.21 c	0.012 ab
$LSD_{(0.05)}$	0.054	0.054	0.120	0.017	0.005
Significance level	0.05	0.05	0.01	0.05	0.01
CV(%)	7.42	9.87	4.64	10.86	4.98

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

N_0: 0 kg N/ha (control)
N_1: 50 kg N/ha
N_2: 60 kg N/ha
N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)
B_1: 2.0 kg B/ha
B_2: 3.0 kg B/ha

Statistically non significant variation was recorded due to the interaction effect of nitrogen and boron on pH of post harvest soil (Appendix VIII). The highest pH of post harvest soil (6.10) were observed from N_2B_2 and the lowest pH of post harvest soil (5.59) were found from N_0B_0 treatment combination (Table 13).

4.3.2 Organic matter

Organic matter of post harvest soil showed statistically non significant differences due to different levels of nitrogen (Appendix VIII). The highest organic matter (1.29%) were observed from N_2, while the lowest organic matter of post harvest soil (1.20%) were observed from N_0 (Table 12).

Different levels of boron varied non significantly in terms of organic matter of post harvest soil (Appendix VIII). The highest organic matter of post harvest soil (1.28%) were recorded from B_2, whereas the lowest organic matter of post harvest soil (1.21%) from B_0 (Table 12).

Statistically non significant variation was recorded due to the interaction effect of nitrogen and boron on organic matter of post harvest soil (Appendix VIII). The highest pH of post harvest soil (1.24%) were observed from N_2B_2 and the lowest organic matter of post harvest soil (1.15%) were found from N_0B_0 treatment combination (Table 13).

4.3.3 Total N

Total N of post harvest soil showed statistically significant differences due to different levels of nitrogen (Appendix VIII). The highest total N of post harvest (0.073%) were observed from N_2, which were statistically similar (0.069% and 0.066%) to N_1 and N_3, while the lowest total N of post harvest (0.050%) were observed from N_0 (Figure 6).

Different levels of boron varied significantly in terms of total N of post harvest soil (Appendix VIII). The highest total N of post harvest soil (0.070%) were recorded from B_2 which were statistically similar (0.065%) to B_1, whereas the lowest total N of post harvest soil (0.058%) from B_0 (Figure 7).

Table 12. Effect of nitrogen and boron on pH, organic matter, available P, exchangeable K and available of post harvest soil of sesame

Treatments	pH	Organic matter (%)	Available P (ppm)	Exchangeable K (me %)	Available B (ppm)
Levels of nitrogen					
N_0	5.67	1.20	27.25 c	0.129 b	0.244 c
N_1	5.97	1.24	31.68 b	0.138 ab	0.263 b
N_2	6.00	1.29	34.98 a	0.144 a	0.277 a
N_3	5.87	1.27	32.64 ab	0.139 ab	0.265 b
$LSD_{(0.05)}$	--	--	2.35	0.010	0.010
Significance level	NS	NS	0.01	0.01	0.01
Levels of boron					
B_0	5.86	1.21	29.47 b	0.130 b	0.185 b
B_1	5.92	1.26	32.93 a	0.140 a	0.298 a
B_2	5.84	1.28	32.51 a	0.143 a	0.303 a
$LSD_{(0.05)}$	--	--	2.035	0.009	0.009
Significance level	NS	NS	0.01	0.01	0.01
CV(%)	5.09	7.59	7.60	4.47	3.20

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

Table 13. Interaction effect of nitrogen and boron on pH, organic matter, available P, exchangeable K and available of post harvest soil of sesame

Treatments	pH	Organic matter (%)	Available P (ppm)	Exchangeable K (me %)	Available B (ppm)
N_0B_0	5.59	1.15	24.43 d	0.120 c	0.163 f
N_0B_1	5.98	1.16	29.60 bc	0.129 bc	0.268 d
N_0B_2	5.64	1.27	27.72 cd	0.138 abc	0.300 bc
N_1B_0	5.96	1.28	26.67 cd	0.134 abc	0.194 e
N_1B_1	5.94	1.21	32.41 ab	0.136 abc	0.292 c
N_1B_2	6.00	1.24	35.96 a	0.144 ab	0.304 abc
N_2B_0	5.92	1.19	33.37 ab	0.128 bc	0.196 e
N_2B_1	5.98	1.33	35.03 a	0.150 a	0.315 ab
N_2B_2	6.10	1.34	36.53 a	0.152 a	0.320 a
N_3B_0	5.98	1.23	33.42 ab	0.137 abc	0.189 e
N_3B_1	6.00	1.33	34.67 a	0.143 ab	0.317 ab
N_3B_2	5.61	1.27	29.83 bc	0.138 abc	0.290 c
$LSD_{(0.05)}$	--	--	4.070	0.017	0.017
Significance level	NS	NS	0.01	0.05	0.01
CV(%)	5.09	7.59	7.60	4.47	3.20

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

N_0: 0 kg N/ha (control)

N_1: 50 kg N/ha

N_2: 60 kg N/ha

N_3: 70 kg N/ha

B_0: 0 kg B/ha (control)

B_1: 2.0 kg B/ha

B_2: 3.0 kg B/ha

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on total N of post harvest soil (Appendix VIII). The highest total N of post harvest soil (0.078%) were observed from N_2B_2 and the lowest total N of post harvest soil (0.041%) were found from N_0B_0 treatment combination (Figure 8).

4.3.4 Available P

Available P of post harvest soil showed statistically significant differences due to different levels of nitrogen (Appendix VIII). The highest available P of post harvest (34.98 ppm) were observed from N_2, which were statistically similar (32.64 ppm and 31.68 ppm) to N_3 and N_1, while the lowest available P of post harvest (27.25 ppm) were observed from N_0 (Table 12).

Different levels of boron varied significantly in terms of available P of post harvest soil (Appendix VIII). The highest available P of post harvest soil (32.51 ppm) were recorded from B_2 which were statistically similar (32.93 ppm) to B_1, whereas the lowest available P of post harvest soil (29.47 ppm) from B_0 (Table 12).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on available P of post harvest soil (Appendix VIII). The highest available P of post harvest soil (36.53 ppm) were observed from N_2B_2 and the lowest available P of post harvest soil (24.43 ppm) were found from N_0B_0 treatment combination (Table 13).

4.3.5 Exchangeable K

Exchangeable K of post harvest soil showed statistically significant differences due to different levels of nitrogen (Appendix VIII). The highest exchangeable K of post harvest (0.144 me%) were observed from N_2, which were statistically similar (0.139 me% and 0.138 me%) to N_3 and N_1, while the lowest exchangeable K of post harvest (0.129 me%) were observed from N_0 (Table 12).

Different levels of boron varied significantly in terms of exchangeable K of post harvest soil (Appendix VIII). The highest exchangeable K of post harvest soil

(0.143 me%) were recorded from B_2 which were statistically similar (0.140 me%) to B_1, whereas the lowest exchangeable K of post harvest soil (0.130 me%) from B_0 (Table 12).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on exchangeable K of post harvest soil (Appendix VIII). The highest exchangeable K of post harvest soil (0.152 me%) were observed from N_2B_2 and the lowest exchangeable K of post harvest soil (0.120 me%) were found from N_0B_0 treatment combination (Table 13).

4.3.6 Available B

Available B of post harvest soil showed statistically significant differences due to different levels of nitrogen (Appendix VIII). The highest available B of post harvest (0.277 ppm) were observed from N_2, which was closely followed (0.265 ppm and 0.263 ppm) by N_3 and N_1 and they were statistically similar, while the lowest available B of post harvest (0.244 ppm) were observed from N_0 (Table 12).

Different levels of boron varied significantly in terms of available B of post harvest soil (Appendix VIII). The highest available B of post harvest soil (0.303 ppm) were recorded from B_2 which were statistically similar (0.298 ppm) to B_1, whereas the lowest available B of post harvest soil (0.185 ppm) from B_0 (Table 12).

Statistically significant variation was recorded due to the interaction effect of nitrogen and boron on available B of post harvest soil (Appendix VIII). The highest available P of post harvest soil (0.320 ppm) were observed from N_2B_2 and the lowest available B of post harvest soil (0.163 ppm) were found from N_0B_0 treatment combination (Table 13).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from February to May, 2015 to find out the effect of nitrogen and boron on the growth and yield of sesame. The experiment considered of two factors. Factor A: Levels of nitrogen (4 levels)- N_0: 0 kg N/ha (control), N_1: 50 kg N/ha, N_2: 60 kg N/ha and N_3: 70 kg N/ha; and Factor B: Levels of boron (3 levels)- B_0: 0 kg B/ha (control), B_1: 2 kg B/ha and B_2: 3 kg B/ha. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameter, yield, nutrient concentration in seeds and stover and characteristics of post harvest soil was recorded and statistically significant variation was recorded for different treatment.

For different level of nitrogen, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.49, 54.79, 78.07, 94.58 and 111.89 cm, respectively) were observed from N_2, while the shortest plant (29.87, 48.61, 68.16, 84.62 and 103.46 cm, respectively) were observed from N_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.64, 4.58, 6.76, 8.47 and 8.80, respectively) were observed from N_2, while the minimum number (2.22, 3.44, 5.91, 7.36 and 7.91, respectively) were observed from N_0. The minimum number of days required from sowing to harvest (93.78) were observed from N_2, while the maximum number of days (97.78) were observed from N_0. The longest length of capsule (3.46 cm) were observed from N_2, while the shortest length of capsule (3.06 cm) were observed from N_0. The maximum number of capsule per plant (65.16) were observed from N_2, while the minimum number (57.78) were observed from N_0. The maximum number of seeds per capsule (57.11) were observed from N_2, while the minimum number (50.00) were observed from N_0. The highest 1000 seeds weight (12.12 g) were observed from N_2, while the lowest weight (11.25 g) were observed from N_0. The highest seed yield weight (1.51 t/ha) were observed from N_2, while the lowest seed yield (1.09 t/ha) were observed from N_0. The highest stover yield weight (2.91 t/ha) were observed from N_2, while the lowest stover yield (2.01 t/ha) were observed from N_0.

The maximum concentration in seed for N (0.55%), P (0.32%), K (0.55%), S (0.21%) and B (0.014%) were observed from N_2, whereas the minimum concentration in seed for N (0.39%), P (0.26%), K (0.43%), S (0.17%) and B (0.011%) were found from N_0. The maximum concentration in stover for N (0.51%), P (0.26%), K (1.55%), S (0.22%) and B (0.012%) were observed from N_2, whereas the minimum concentration in stover for N (0.27%), P (0.19%), K (1.28%), S (0.15%) and B (0.008%) were found from N_0.

The highest pH (6.00) were observed from N_2, while the lowest pH of post harvest soil (5.67) were observed from N_0. The highest organic matter (1.29%) were observed from N_2, while the lowest organic matter of post harvest soil (1.20%) were observed from N_0. The highest total N of post harvest (0.073%) were observed from N_2, while the lowest total N of post harvest (0.050%) were observed from N_0. The highest available P of post harvest (34.98 ppm) were observed from N_2, while the lowest available P of post harvest (27.25 ppm) were observed from N_0. The highest available B of post harvest (0.277 ppm) were observed from N_2, while the lowest available B of post harvest (0.244 ppm) were observed from N_0.

For different level of boron, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (33.15, 54.54, 77.68, 92.46 and 110.93 cm, respectively) were recorded from B_2, whereas the shortest plant (30.61, 48.90, 68.54, 87.74 and 106.04 cm, respectively) from B_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.68, 4.28, 6.75, 8.47 and 8.72, respectively) were recorded from B_2, whereas the minimum number (2.20, 3.80, 5.90, 7.03 and 7.50, respectively) from B_0. The minimum number of days required from sowing to harvest (94.33) were recorded from B_2, whereas the maximum number of days (97.25) from B_0. The longest length of capsule (3.45 cm) were recorded from B_2, whereas the shortest length of capsule (3.06 cm) from B_0. The maximum number of capsule per plant

(65.50) were recorded from B_2, whereas the minimum number (58.68) from B_0. The maximum number of seeds per capsule (56.25) were recorded from B_2, whereas the minimum number (52.25) from B_0. The highest 1000 seeds weight (12.19 g) were recorded from B_2, whereas the lowest 1000 seeds weight (10.96 g) from B_0. The highest seed yield (1.40 t/ah) were recorded from B_2, whereas the lowest seed yield (1.30 t/ha) from B_0. The highest stover yield (2.69 t/ha) were recorded from B_2, whereas the lowest stover yield (1.42 t/ha) from B_0.

The maximum concentration in seeds for N (0.56%), P (0.31%), K (0.51%), S (0.20%) and B (0.014%) were recorded from B_2 and the minimum concentration in seeds for N (0.39%), P (0.27%), K (0.46%), S (0.18%) and B (0.009%) from B_0. The maximum concentration in stover for N (0.43%), P (0.25%), K (1.56%), S (0.20%) and B (0.012%) were recorded from B_2 and the minimum concentration for N (0.39%), P (0.19%), K (1.35%), S (0.18%) and B (0.009%) from B_0.

The highest pH of post harvest soil (5.92) was recorded from B_2, whereas the lowest pH of post harvest soil (5.86) from B_0. The highest organic matter of post harvest soil (1.28%) was recorded from B_2, whereas the lowest organic matter of post harvest soil (1.21%) from B_0. The highest total N of post harvest soil (0.070%) were recorded from B_2, whereas the lowest total N of post harvest soil (0.058%) from B_0. The highest available P of post harvest soil (32.51 ppm) were recorded from B_2, whereas the lowest available P of post harvest soil (29.47 ppm) from B_0. The highest available B of post harvest soil (0.303 ppm) were recorded from B_2, whereas the lowest available B of post harvest soil (0.185 ppm) from B_0.

For interaction effect, at 30, 40, 50, 60 DAS and at harvest, the tallest plant (34.51, 58.26, 83.75, 97.05 and 116.43 cm, respectively) were observed from N_2B_2 and the shortest plant (25.24, 44.54, 62.37, 80.61 and 100.64 cm, respectively) were found from N_0B_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches per plant (2.93, 4.93, 7.33, 9.13 and 9.47, respectively) were observed from N_2B_2 and the minimum number (1.80, 3.07, 5.47, 6.20 and 7.27, respectively) were found from N_0B_0 treatment combination. The minimum number of days required from sowing to harvest (92.67) were observed from N_2B_2 and the maximum number of days (99.00) were found from N_0B_0 treatment combination. The longest length of capsule (3.77 cm) were observed from N_2B_2 and the shortest length of capsule (2.83 cm) were found from N_0B_0 treatment combination. The maximum number of capsule per plant (69.33) were observed from N_2B_2 and the minimum number (53.73) were found from N_0B_0 treatment combination. The maximum number of seeds per capsule (59.33) were observed from N_2B_2 and the minimum number (48.33) were found from N_0B_0 treatment combination. The highest 1000 seeds weight (12.93 g) were observed from N_2B_2 and the lowest 1000 seeds weight (10.27 g) were found from N_0B_0 treatment combination. The highest seed yield (1.59 t/ha) were observed from N_2B_2 and the lowest seed yield (1.03 t/ha) were found from N_0B_0 treatment combination. The highest stover yield (3.13 t/ha) were observed from N_2B_2 and the lowest stover yield (1.83 t/ha) were found from N_0B_0 treatment combination.

The maximum concentration in seeds for N (0.61%), P (0.34%), K (0.58%), S (0.22%) and B (0.017%) were observed from N_2B_2, while the minimum concentration in seeds for N (0.30%), P (0.24%), K (0.39%), S (0.16%) and B (0.007%) were found from N_0B_0 treatment combination. The maximum concentration in stover for N (0.54%), P (0.30%), K (1.67%), S (0.26%) and B (0.013%) were observed from N_2B_2, while the minimum concentration in stover for N (0.25%), P (0.15%), K (1.17%), S (0.13%) and B (0.006%) were found from N_0B_0 treatment combination.

The highest pH of post harvest soil (6.10) were observed from N_2B_2 and the lowest pH of post harvest soil (5.59) were found from N_0B_0 treatment combination. The highest pH of post harvest soil (1.24%) were observed from N_2B_2 and the lowest organic matter of post harvest soil (1.15%) were found from N_0B_0 treatment combination. The highest total N of post harvest soil (0.078%) were observed from N_2B_2 and the lowest total N of post harvest soil (0.041%) were found from N_0B_0 treatment combination. The highest available P of post harvest soil (36.53 ppm) were observed from N_2B_2 and the lowest available P of post harvest soil (24.43

ppm) were found from N_0B_0 treatment combination. The highest exchangeable K of post harvest soil (0.152 me%) were observed from N_2B_2 and the lowest (0.120 me%) were found from N_0B_0 treatment combination. The highest available P of post harvest soil (0.320 ppm) were observed from N_2B_2 and the lowest available B of post harvest soil (0.163 ppm) were found from N_0B_0 treatment combination.

Conclusion

From the findings it was found that application of 60 kg N/ha and 3.0 kg B/ha produced highest yield. So, it can be concluded that combination of 60 kg N/ha and 3.0 kg B/ha can be more beneficial for the farmers to get better yield and economic return from the cultivation of sesame.

Considering the above results of this experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

2. More experiments may be carried out with other organic and inorganic nutrients and also other management practices.

REFERENCES

Abdel-Rahman, K.A., Allam, A.Y., Galal, A.H. and Bakry, B.A. 2003. Response of sesame to sowing dates, nitrogen fertilization and plant populations in sandy soil. *Assiut J. Agril. Sci.,* **34**(3): 1-13.

Anonymous. 1989. Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Ashfaq, A., Abid, H., Mahboob, A. and Ehsanullah, M.M. 2001. Yield and quality of two sesame varieties as affected by different rates of nitrogen and phosphorus. *Pakistan J. Agril. Sci.,* **38**(1/2): 4-7.

Ashok, K., Prasad, T.N. and Prasad, U.K. 1996. Effect of irrigation and nitrogen on growth yield, oil content, nitrogen uptake and water-use of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(1): 111-115.

Auwalu, B.M., Babatunde, F.E., Oseni, T.O. and Muhammad, Y.M. 2007. Productivity of vegetable sesame (*Sesamum radiatum*) as influenced by nitrogen, phosphorus and seasons. *Adv. Hort. Sci.,* **21**(1): 9-13.

Balasubramaniyan, P. 1996. Influence of plant population and nitrogen on yield and nutrient response of sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(3): 448-450.

BARI (Bangladesh Agricultural Research Institute). 2004. Annual Report for 2003. BARI. p. 28.

BARI (Bangladesh Agricultural Research Institute). 2012. BARI Til-3. Oil seeds Research Centre. p. 16.

Bassiem, M.M. and Anton, N.A. 1998. Effect of nitrogen and potassium fertilizers and foliar spray with ascorbic acid on sesame plant in sandy soil. *Annls. Agril. Sci.,* **36**(1): 95-103.

BBS (Bangladesh Bureau of Statistics). 2014. Yearly Statistical Book. Bangladesh Bureau of Statistics, Dhaka Bangladesh. p. 153.

Buzetti, S., Muraoka, T. and Sa, M.E. 1990. Boron rates in soybean under different soil acidity conditions. Dry matter and grain yields and critical level in soil. *Field Crop Abst*., **46**(2): 233.

Chandrakar, B.L., Sekhar, N., Tuteja, S.S. and Tripathi, R.S. 1994. Effect of irrigation and nitrogen on growth and yield of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **39**(4): 701-702.

Chaubey, A.K., Kaushik, M.K. and Singh, S.B. 2003. Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured entisol. *New Agriculturist*. **14**(1/2): 61-64.

Deasarker, D.B. Patinge, S.P. Bhosalo, A.M. and Deshmukh, S.B. 2001. Effect of micronutrients on seed yield of soybean. *Ann. Plant Physiol*. **15**(2): 163-166.

Dell, B. and Huang, L. 1997. Physiological responses of plants to boron. *Plant Soil*. **193**: 103-120.

Dixit, J.P., Rao, V.S.N., Ambabatiya, G.R. and Khan, R.A. 1997. Productivity of sesame cultivars sown as semi-rabi under various plant densities and nitrogen levels. *Crop Res. Hisar*., **13**(1): 27-31.

Dwivedi, G.K. Dwivedi, M. and Pal, S. S. 1990. Models of application of micronutrients in acid soil in soybean-wheat crop sequence. *J. Indian Soc. Soil Sci*., **38**(3): 458-463.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey and Govt. People's Republic of Bangladesh. 118 p.

Fard, A.P.M. and Bahrani, M.J. 2005. Effect of nitrogen fertilizer rates and plant density on some agronomic characteristics, seed yield, oil and protein percentage in two sesame cultivars. *Indian J. Agril. Sci.*, **36**(1): 129-135.

Fayed, E.H.M., Hassan, A.A. and Hussain, S.M.A. 2000. Sesame performance as affected by seeding rate and nitrogen levels under drip irrigation system in newly cultivated sandy soil. I. Yield and yield attributes. *Annals of Agril. Sci.*, **38**(1): 65-73.

Galrao, E.Z. 1989. Effect of micronutrients and cobalt on soybean yield on cerrado soil. *Crop Abst*., **45**(3): 436.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hamasa, A. and Putaiah, E.T. 2012. Residual effect of zinc and boron on growth and yield of sesame. *Intl. J. Env. Sci*., **3**(1): 167-172.

Hemantaranjan, A., Trivedi, A.K. and Mariram, 2000. Effect of foliar applied boron and soil applied iron and sulphur on growth and yield of soybean *(Glycine max L.* Merr.). *Indian J. Plant Physiol*., **5**(2): 142-144.

Hooda, R.S., Verma, O.P.S. and Anil, K. 1996. Intercropping of green gram and sesame in pearl millet under different nitrogen fertilization. *Crop Res. Hisar*., **12**(2): 213-215.

Hua, P. and Yan, K. 1998. Boron amelioration of aluminum toxicity in mungbean seedlings. *J. Plant Nutr*., **21**(5): 1045-1054.

Hunter, A.H. 1984. Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Ibrahim, M., Hussain, M., Khan, A., Jamal, Y., Ali, M. and Malik, M.F.A. 2014. Effect of nitrogen and phosphorus on yield and yield components of Sesame. *Intl. J. Sci. Basic & Appl. Res*., **18**(1): 95-101.

Islam, J.K. and Noor, S.P. 1982. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh. *Pakistan J. Sci. Res*., **34**(3-4): 113-119.

Jeena, M., Sumam, G. and Indira, M. 2013. Effect of sulphur and boron on the performance of sesame (*Sesamum indicum* L.) in onattukara sandy soil of Kerala, India. *Indian J. Agril. Res.*, **47**(3): 214-219.

Kalyani, R.R., Sree Devi, V., Satyanarayana, N.R. and Rao, M.K. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant. Phyto*., **4**: 223-226.

Lalit Bhatt, Srivastava, B.K. and Singh, M.P.M. 2004. Studies on the effect of foliar application of micronutrients on growth, yield and economics of sesame. *Prog. Hort*., **2**: 331-334.

Lewis, D.H. 1980. Boron. Are there inter-relations between the metabolic role of boron, synthesis of phenolic phytoalexins and the germination of pollen. *New Phytol*., **84**: 264-270.

Li, Z.Y., Guo, Q.Y., Tu, X.W., Chen, H.X. and Ding, G.Y. 1992. Boron nutrition of sesame and B fertilizer application II. Effects of the plants of different varieties. Oil Crops of China. *Crop Res. Inst., China*. **4**: 45-48.

Liu, P., Yang, Y. and Yang, Y.A. 2003. Effect of molybdenum and boron on quality of soybean. *Sci. Agril. Sci.*, **36**(2): 184-189.

Malik, M.A., Saleem, M.F., Cheema, M.A. and Shamim, A. 2003. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *Intl. J. Agric. Bio*., **5**(4): 490-492.

Mandal, A.K., Pal, S., Mandal, B. and Mandal, L.N. 1991. Available boron and molybdenum content in some alluvial acidic soils of north Bengal. *Indian J. Agric. Sci*., **67**(7): 502-504.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd edition. Academic Press, London, UK. p. 78.

Mary, K.S., Galal, A.H. and Dale, G.B. 1990. Foliar boron applications increase the final number of branches and pods on branches of field-grown sesame. *Plant Physol.*, **3**: 602- 607.

Miller, W.R. and Donahue, L.R. 1997. Soils in Our Environment. Prentice Hall of India Pvt. Ltd., New Delhi, India. 7 Edn. p. 302-315.

Mitra, S. and Pal, A.K. 1999. Water use and productivity of summer sesame as influenced by irrigation and nitrogen. *J. Indian Soc. Soil Sci.,* **47**(3): 400-404.

Mondal, D.K., Sounda, G., Panda, P.K., Ghosh, P., Maitra, S. and Roy, D.K. 1997. Effect of different irrigation levels and nitrogen doses on growth and yield of sesame (*Sesamum indicum* L.). *Indian Agriculturist*. **41**(1): 15-21.

Mondal, S.S., Pramanik, C.K. and Das, J. 2001. Effect of nitrogen and potassium on oil yield, nutrient uptake and soil fertility in soybean (*Glycine max*) - sesame (*Sesamum indicum*) intercropping system. *Indian J. Agril. Sci.,* **71**(1): 44-46.

Moorthy, B.T.S., Das, T.K. and Nanda, B.B. 1997. Studies on varietal evaluation, nitrogen and spacing requirement of sesame in rice fallows in summer season. *Annals of Agril. Res.,* **18**(3): 408-410.

Obreza, T.A. and Vavrina, C.S. 1993. Production of chinese cabbage in relation to nitrogen source, rate and leaf nutrient concentration. *Soil Sci. Plant Analysis*. **24**: 13-14.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Opena, R.T., Kuo, C.C. and Yoon, J.Y. 1988. Breeding and Seed Production of Root crops in the Tropics and Subtropics. *Tech. Bul*., 17, AVRDC. p. 97.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. p. 403-430.

Parihar, S.S., Pandey, D. and Shukla, R.K. 1999. Response of summer sesame (*Sesamum indicum*) to irrigation schedule and nitrogen level in clay-loam soil. *Interl. J. Trop. Agric.,* **17**(1/4): 189-193.

Pathak, K., Barman, U., Kalita, M.K. and Hazarika, B.N. 2002. Effect of nitrogen levels on growth and yield of sesamum (*Sesamum indicum*) in Barak Valley Zone of Assam. *Adv. Pl. Sci.,* **15**(1): 341-343.

Pilbeam, D.J. and Kirkby, E.A. 1983. The physiological role of boron in plants. *J. Plant Nutri*., **6**: 563-582.

Posypanov, G.S., Kashukoev, M.Y. and Zherukov, B.K.H. 1994. Basic parameters for optimal supply of water, phosphorus, boron and molybdenum to peas and soybeans for active symbiotic nitrogen fixation. *Intl. Agril. Sci*., **2**: 33-42.

Prakash, O., Singh, B.P. and Singh, P.K. 2001. Effect of weed-control measures and nitrogen fertilization on yield and yield attributes of sesame (*Sesamum indicum*) under rainfed condition. *Indian J. Agril. Sci.,* **71**(9): 610-612.

Ramirez, R. and Linares, J.C. 1995. Boron deficiency symptoms and dry matter production of sesame under green house conditions. *Comm. Soil Sci.; Plant Anal. Maracay, Venezuela*. **26**(17/18): 3043-3049.

Ratna Kalyani, R., Sree Devi, V., Satyanarayana, N.V. and Madhana Rao, K.V. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant Physio*., **4**: 223-226.

Rerkasem, B., Saunders, D.A. and Jamjod, S. 1989. Correcting boron deficiency induced ear sterility in wheat and barley. *Thailand J. Soils Fert*., **11**: 200-209.

Roy, A.K.S., Maiti, S. and Bhattacharyya, K.K. 1992. Effect of phosphatic fertilizers micronutrients on limited and its influence on rice in lentil rice sequence. *Environ. Ecol*., **10**(4): 837-841.

Roy, S.K., Rahaman, S.M.L. and; Salahuddin, A.B.M. 1995. Effect of nitrogen and potassium on growth and seed yield of sesame (*Sesamum indicum*). *Indian J. Agril. Sci.,* **65**(7): 509-511.

Sakal, R., Sin R.B. and Singh, A.P. 1994. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*., **37**(5): 31-32.

Sakal, R., Singh. R.B. and Singh. A.P. 1988. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*. **33**(2): 27-30.

Sakal, R., Sinha, R.B. and Singh, A.P. 1990. Response of chickpea to boron application in calcareous soils. *Intl. Chickpea News*. **1**(22): 28-29.

Sarkar, R.P. and Anita, R.D. 2005. Effects of N, B and S on the growth and productivity of sesame. *Indian J. Agril. Sci.,* **36**(1): 129-135.

Sathya, S., Pitchai, G.J. and Indirani, R. 2009. Boron nutrition of crops in relation to yield and quality review. *Agric. Rev*., **2**: 139-144.

Shilpi, S., Islam, M.N., Sutradhar, G.N.C., Husna, A. and Akter, F. 2012. Effect of Nitrogen and Sulfur on the Growth and Yield of Sesame. *Intl. J. of Bio-resource Stress Manag*., **3**(2): 177-182.

Sindoni, M., Zamora, J. and Ramirez, R. 1994. Symptoms of boron deficiency and dry matter production in sesame. *Agronomic Tropical (Maracay)*. **44**(1): 135-150.

Singaravel, R. and Govindasamy, R. 1998. Effect of humic acid, nitrogen and biofertilizer on the growth and yield of sesame. *J. Oilseeds Res.,* **15**(2): 366-367.

Singh, B.P. and Singh, B. 1994. Response of french bean to phosphorus and boron in acid Alfisols in Megbaiaya. *J. Indian Soc. Soil Sci*., **38**(4): 769-771.

Singh, P.K., Prakash, O. and Singh, B.P. 2001. Studies on the effect of N-fertilization and weed control techniques on weed suppression, yield and nutrients uptake in sesame (*Sesamum indicum*). *Indian J. Weed Sci.,* **33**(3/4): 139-142.

Singh, S.P. and Singh, R.A. 1999. Effect of nitrogen on growth, yield and quality of sesame (*Sesamum indicum* L.) and blackgram (*Vigna mungo* L.) in intercropping system. *J. Appl. Biol.,* **9**(2): 163-166.

Sinha, R.B., Sakal, F.L., Singh, A.P. and Bhogal, N.S. 1991. Response of some field crops to boron application in calcareous soil. *J. Indian Soc. Soil Sci*., **39**: 117-122.

Srivastava, P.C. and Gupta, U.C. 1996. Trace Elements in crop production. Science Pub. Inc. Lebanon, NHO3766 USA. p. 366.

Srivastava, S., Yandev, C.R., Rego, T.J., Johansen, C., Saxena, N. and Ramakrishna, A. 1996. Diagnosis of boron deficiency as a cause of flower abortion and failure of pod set in chickpea in Nepal. *Intl. Chickpea & Pigeonpea News*. **1**(3): 29-30.

Subrahmaniyan, K. and Arulmozhi, N. 1999. Response of sesame (*Sesamum indicum*) to plant population and nitrogen under irrigated condition. *Indian J. Agron.*, **44**(2): 413-415.

Talashilkar, S.C. and Chavan, A.S. 1996. Response of groundnut to calcium, sulphur and boron with and without FYM on Inceptisol. *J. Indian Soc. Soil Sci.*, **44**(2): 343-344.

Tanaka, M. and Fujiwar, T. 2008. Physiological roles and transport mechanisms of boron: perspectives from plants. *Plants Arch. European J. Physiol.*, **456**: 671-677.

Thakur, D.S., Patel, S.R. and Nageshwar, L. 1998. Yield and quality of sesame (*Sesamum indicum*) as influenced by nitrogen and phosphorus in light-textured inceptisols. *Indian J. Agron.*, **43**(2): 325-328.

Tiwari, K.P. and Namdeo, K.N. 1997. Response of sesame (*Sesamum indicum*) to planting geometry and nitrogen. *Indian J. Agron.*, **42**(2): 365-369.

UNDP (United Nations Development Program) and FAO (Food and Agricultural Organization). 1988. Land Resources Appraisal of Bangladesh for Agricultural Department. Report 2. Agro ecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization. p. 212-221.

Yoshizawa, T.C.H.M. and Roan, Y.C. 1981. Management of Summer Pulse in Taiwan. AVRDC, Shanhua, Taiwan. p. 125.

REFERENCES

Abdel-Rahman, K.A., Allam, A.Y., Galal, A.H. and Bakry, B.A. 2003. Response of sesame to sowing dates, nitrogen fertilization and plant populations in sandy soil. *Assiut J. Agril. Sci.,* **34**(3): 1-13.

Anonymous. 1989. Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Ashfaq, A., Abid, H., Mahboob, A. and Ehsanullah, M.M. 2001. Yield and quality of two sesame varieties as affected by different rates of nitrogen and phosphorus. *Pakistan J. Agril. Sci.,* **38**(1/2): 4-7.

Ashok, K., Prasad, T.N. and Prasad, U.K. 1996. Effect of irrigation and nitrogen on growth yield, oil content, nitrogen uptake and water-use of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(1): 111-115.

Auwalu, B.M., Babatunde, F.E., Oseni, T.O. and Muhammad, Y.M. 2007. Productivity of vegetable sesame (*Sesamum radiatum*) as influenced by nitrogen, phosphorus and seasons. *Adv. Hort. Sci.,* **21**(1): 9-13.

Balasubramaniyan, P. 1996. Influence of plant population and nitrogen on yield and nutrient response of sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(3): 448-450.

BARI (Bangladesh Agricultural Research Institute). 2004. Annual Report for 2003. BARI. p. 28.

BARI (Bangladesh Agricultural Research Institute). 2012. BARI Til-3. Oil seeds Research Centre. p. 16.

Bassiem, M.M. and Anton, N.A. 1998. Effect of nitrogen and potassium fertilizers and foliar spray with ascorbic acid on sesame plant in sandy soil. *Annls. Agril. Sci.,* **36**(1): 95-103.

BBS (Bangladesh Bureau of Statistics). 2014. Yearly Statistical Book. Bangladesh Bureau of Statistics, Dhaka Bangladesh. p. 153.

Buzetti, S., Muraoka, T. and Sa, M.E. 1990. Boron rates in soybean under different soil acidity conditions. Dry matter and grain yields and critical level in soil. *Field Crop Abst*., **46**(2): 233.

Chandrakar, B.L., Sekhar, N., Tuteja, S.S. and Tripathi, R.S. 1994. Effect of irrigation and nitrogen on growth and yield of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **39**(4): 701-702.

Chaubey, A.K., Kaushik, M.K. and Singh, S.B. 2003. Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured entisol. *New Agriculturist*. **14**(1/2): 61-64.

Deasarker, D.B. Patinge, S.P. Bhosalo, A.M. and Deshmukh, S.B. 2001. Effect of micronutrients on seed yield of soybean. *Ann. Plant Physiol*. **15**(2): 163-166.

Dell, B. and Huang, L. 1997. Physiological responses of plants to boron. *Plant Soil*. **193**: 103-120.

Dixit, J.P., Rao, V.S.N., Ambabatiya, G.R. and Khan, R.A. 1997. Productivity of sesame cultivars sown as semi-rabi under various plant densities and nitrogen levels. *Crop Res. Hisar*., **13**(1): 27-31.

Dwivedi, G.K. Dwivedi, M. and Pal, S. S. 1990. Models of application of micronutrients in acid soil in soybean-wheat crop sequence. *J. Indian Soc. Soil Sci*., **38**(3): 458-463.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey and Govt. People's Republic of Bangladesh. 118 p.

Fard, A.P.M. and Bahrani, M.J. 2005. Effect of nitrogen fertilizer rates and plant density on some agronomic characteristics, seed yield, oil and protein percentage in two sesame cultivars. *Indian J. Agril. Sci.*, **36**(1): 129-135.

Fayed, E.H.M., Hassan, A.A. and Hussain, S.M.A. 2000. Sesame performance as affected by seeding rate and nitrogen levels under drip irrigation system in newly cultivated sandy soil. I. Yield and yield attributes. *Annals of Agril. Sci.*, **38**(1): 65-73.

Galrao, E.Z. 1989. Effect of micronutrients and cobalt on soybean yield on cerrado soil. *Crop Abst*., **45**(3): 436.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hamasa, A. and Putaiah, E.T. 2012. Residual effect of zinc and boron on growth and yield of sesame. *Intl. J. Env. Sci*., **3**(1): 167-172.

Hemantaranjan, A., Trivedi, A.K. and Mariram, 2000. Effect of foliar applied boron and soil applied iron and sulphur on growth and yield of soybean *(Glycine max L.* Merr.). *Indian J. Plant Physiol*., **5**(2): 142-144.

Hooda, R.S., Verma, O.P.S. and Anil, K. 1996. Intercropping of green gram and sesame in pearl millet under different nitrogen fertilization. *Crop Res. Hisar*., **12**(2): 213-215.

Hua, P. and Yan, K. 1998. Boron amelioration of aluminum toxicity in mungbean seedlings. *J. Plant Nutr*., **21**(5): 1045-1054.

Hunter, A.H. 1984. Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Ibrahim, M., Hussain, M., Khan, A., Jamal, Y., Ali, M. and Malik, M.F.A. 2014. Effect of nitrogen and phosphorus on yield and yield components of Sesame. *Intl. J. Sci. Basic & Appl. Res*., **18**(1): 95-101.

Islam, J.K. and Noor, S.P. 1982. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh. *Pakistan J. Sci. Res.*, **34**(3-4): 113-119.

Jeena, M., Sumam, G. and Indira, M. 2013. Effect of sulphur and boron on the performance of sesame (*Sesamum indicum* L.) in onattukara sandy soil of Kerala, India. *Indian J. Agril. Res.*, **47**(3): 214-219.

Kalyani, R.R., Sree Devi, V., Satyanarayana, N.R. and Rao, M.K. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant. Phyto*., **4**: 223-226.

Lalit Bhatt, Srivastava, B.K. and Singh, M.P.M. 2004. Studies on the effect of foliar application of micronutrients on growth, yield and economics of sesame. *Prog. Hort*., **2**: 331-334.

Lewis, D.H. 1980. Boron. Are there inter-relations between the metabolic role of boron, synthesis of phenolic phytoalexins and the germination of pollen. *New Phytol*., **84**: 264-270.

Li, Z.Y., Guo, Q.Y., Tu, X.W., Chen, H.X. and Ding, G.Y. 1992. Boron nutrition of sesame and B fertilizer application II. Effects of the plants of different varieties. Oil Crops of China. *Crop Res. Inst., China*. **4**: 45-48.

Liu, P., Yang, Y. and Yang, Y.A. 2003. Effect of molybdenum and boron on quality of soybean. *Sci. Agril. Sci.*, **36**(2): 184-189.

Malik, M.A., Saleem, M.F., Cheema, M.A. and Shamim, A. 2003. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *Intl. J. Agric. Bio*., **5**(4): 490-492.

Mandal, A.K., Pal, S., Mandal, B. and Mandal, L.N. 1991. Available boron and molybdenum content in some alluvial acidic soils of north Bengal. *Indian J. Agric. Sci*., **67**(7): 502-504.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd edition. Academic Press, London, UK. p. 78.

Mary, K.S., Galal, A.H. and Dale, G.B. 1990. Foliar boron applications increase the final number of branches and pods on branches of field-grown sesame. *Plant Physol.*, **3**: 602- 607.

Miller, W.R. and Donahue, L.R. 1997. Soils in Our Environment. Prentice Hall of India Pvt. Ltd., New Delhi, India. 7 Edn. p. 302-315.

Mitra, S. and Pal, A.K. 1999. Water use and productivity of summer sesame as influenced by irrigation and nitrogen. *J. Indian Soc. Soil Sci.,* **47**(3): 400-404.

Mondal, D.K., Sounda, G., Panda, P.K., Ghosh, P., Maitra, S. and Roy, D.K. 1997. Effect of different irrigation levels and nitrogen doses on growth and yield of sesame (*Sesamum indicum* L.). *Indian Agriculturist*. **41**(1): 15-21.

Mondal, S.S., Pramanik, C.K. and Das, J. 2001. Effect of nitrogen and potassium on oil yield, nutrient uptake and soil fertility in soybean (*Glycine max*) - sesame (*Sesamum indicum*) intercropping system. *Indian J. Agril. Sci.,* **71**(1): 44-46.

Moorthy, B.T.S., Das, T.K. and Nanda, B.B. 1997. Studies on varietal evaluation, nitrogen and spacing requirement of sesame in rice fallows in summer season. *Annals of Agril. Res.*, **18**(3): 408-410.

Obreza, T.A. and Vavrina, C.S. 1993. Production of chinese cabbage in relation to nitrogen source, rate and leaf nutrient concentration. *Soil Sci. Plant Analysis*. **24**: 13-14.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Opena, R.T., Kuo, C.C. and Yoon, J.Y. 1988. Breeding and Seed Production of Root crops in the Tropics and Subtropics. *Tech. Bul*., 17, AVRDC. p. 97.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. p. 403-430.

Parihar, S.S., Pandey, D. and Shukla, R.K. 1999. Response of summer sesame (*Sesamum indicum*) to irrigation schedule and nitrogen level in clay-loam soil. *Interl. J. Trop. Agric.,* **17**(1/4): 189-193.

Pathak, K., Barman, U., Kalita, M.K. and Hazarika, B.N. 2002. Effect of nitrogen levels on growth and yield of sesamum (*Sesamum indicum*) in Barak Valley Zone of Assam. *Adv. Pl. Sci.,* **15**(1): 341-343.

Pilbeam, D.J. and Kirkby, E.A. 1983. The physiological role of boron in plants. *J. Plant Nutri*., **6**: 563-582.

Posypanov, G.S., Kashukoev, M.Y. and Zherukov, B.K.H. 1994. Basic parameters for optimal supply of water, phosphorus, boron and molybdenum to peas and soybeans for active symbiotic nitrogen fixation. *Intl. Agril. Sci*., **2**: 33-42.

Prakash, O., Singh, B.P. and Singh, P.K. 2001. Effect of weed-control measures and nitrogen fertilization on yield and yield attributes of sesame (*Sesamum indicum*) under rainfed condition. *Indian J. Agril. Sci.,* **71**(9): 610-612.

Ramirez, R. and Linares, J.C. 1995. Boron deficiency symptoms and dry matter production of sesame under green house conditions. *Comm. Soil Sci.; Plant Anal. Maracay, Venezuela*. **26**(17/18): 3043-3049.

Ratna Kalyani, R., Sree Devi, V., Satyanarayana, N.V. and Madhana Rao, K.V. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant Physio*., **4**: 223-226.

Rerkasem, B., Saunders, D.A. and Jamjod, S. 1989. Correcting boron deficiency induced ear sterility in wheat and barley. *Thailand J. Soils Fert*., **11**: 200-209.

Roy, A.K.S., Maiti, S. and Bhattacharyya, K.K. 1992. Effect of phosphatic fertilizers micronutrients on limited and its influence on rice in lentil rice sequence. *Environ. Ecol*., **10**(4): 837-841.

Roy, S.K., Rahaman, S.M.L. and; Salahuddin, A.B.M. 1995. Effect of nitrogen and potassium on growth and seed yield of sesame (*Sesamum indicum*). *Indian J. Agril. Sci.,* **65**(7): 509-511.

Sakal, R., Sin R.B. and Singh, A.P. 1994. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*., **37**(5): 31-32.

Sakal, R., Singh. R.B. and Singh. A.P. 1988. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*. **33**(2): 27-30.

Sakal, R., Sinha, R.B. and Singh, A.P. 1990. Response of chickpea to boron application in calcareous soils. *Intl. Chickpea News*. **1**(22): 28-29.

Sarkar, R.P. and Anita, R.D. 2005. Effects of N, B and S on the growth and productivity of sesame. *Indian J. Agril. Sci.,* **36**(1): 129-135.

Sathya, S., Pitchai, G.J. and Indirani, R. 2009. Boron nutrition of crops in relation to yield and quality review. *Agric. Rev*., **2**: 139-144.

Shilpi, S., Islam, M.N., Sutradhar, G.N.C., Husna, A. and Akter, F. 2012. Effect of Nitrogen and Sulfur on the Growth and Yield of Sesame. *Intl. J. of Bio-resource Stress Manag*., **3**(2): 177-182.

Sindoni, M., Zamora, J. and Ramirez, R. 1994. Symptoms of boron deficiency and dry matter production in sesame. *Agronomic Tropical (Maracay)*. **44**(1): 135-150.

Singaravel, R. and Govindasamy, R. 1998. Effect of humic acid, nitrogen and biofertilizer on the growth and yield of sesame. *J. Oilseeds Res.,* **15**(2): 366-367.

Singh, B.P. and Singh, B. 1994. Response of french bean to phosphorus and boron in acid Alfisols in Megbaiaya. *J. Indian Soc. Soil Sci*., **38**(4): 769-771.

Singh, P.K., Prakash, O. and Singh, B.P. 2001. Studies on the effect of N-fertilization and weed control techniques on weed suppression, yield and nutrients uptake in sesame (*Sesamum indicum*). *Indian J. Weed Sci.,* **33**(3/4): 139-142.

Singh, S.P. and Singh, R.A. 1999. Effect of nitrogen on growth, yield and quality of sesame (*Sesamum indicum* L.) and blackgram (*Vigna mungo* L.) in intercropping system. *J. Appl. Biol.,* **9**(2): 163-166.

Sinha, R.B., Sakal, F.L., Singh, A.P. and Bhogal, N.S. 1991. Response of some field crops to boron application in calcareous soil. *J. Indian Soc. Soil Sci*., **39**: 117-122.

Srivastava, P.C. and Gupta, U.C. 1996. Trace Elements in crop production. Science Pub. Inc. Lebanon, NHO3766 USA. p. 366.

Srivastava, S., Yandev, C.R., Rego, T.J., Johansen, C., Saxena, N. and Ramakrishna, A. 1996. Diagnosis of boron deficiency as a cause of flower abortion and failure of pod set in chickpea in Nepal. *Intl. Chickpea & Pigeonpea News*. **1**(3): 29-30.

Subrahmaniyan, K. and Arulmozhi, N. 1999. Response of sesame (*Sesamum indicum*) to plant population and nitrogen under irrigated condition. *Indian J. Agron.*, **44**(2): 413-415.

Talashilkar, S.C. and Chavan, A.S. 1996. Response of groundnut to calcium, sulphur and boron with and without FYM on Inceptisol. *J. Indian Soc. Soil Sci.*, **44**(2): 343-344.

Tanaka, M. and Fujiwar, T. 2008. Physiological roles and transport mechanisms of boron: perspectives from plants. *Plants Arch. European J. Physiol.*, **456**: 671-677.

Thakur, D.S., Patel, S.R. and Nageshwar, L. 1998. Yield and quality of sesame (*Sesamum indicum*) as influenced by nitrogen and phosphorus in light-textured inceptisols. *Indian J. Agron.*, **43**(2): 325-328.

Tiwari, K.P. and Namdeo, K.N. 1997. Response of sesame (*Sesamum indicum*) to planting geometry and nitrogen. *Indian J. Agron.*, **42**(2): 365-369.

UNDP (United Nations Development Program) and FAO (Food and Agricultural Organization). 1988. Land Resources Appraisal of Bangladesh for Agricultural Department. Report 2. Agro ecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization. p. 212-221.

Yoshizawa, T.C.H.M. and Roan, Y.C. 1981. Management of Summer Pulse in Taiwan. AVRDC, Shanhua, Taiwan. p. 125.

REFERENCES

Abdel-Rahman, K.A., Allam, A.Y., Galal, A.H. and Bakry, B.A. 2003. Response of sesame to sowing dates, nitrogen fertilization and plant populations in sandy soil. *Assiut J. Agril. Sci.,* **34**(3): 1-13.

Anonymous. 1989. Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Ashfaq, A., Abid, H., Mahboob, A. and Ehsanullah, M.M. 2001. Yield and quality of two sesame varieties as affected by different rates of nitrogen and phosphorus. *Pakistan J. Agril. Sci.,* **38**(1/2): 4-7.

Ashok, K., Prasad, T.N. and Prasad, U.K. 1996. Effect of irrigation and nitrogen on growth yield, oil content, nitrogen uptake and water-use of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(1): 111-115.

Auwalu, B.M., Babatunde, F.E., Oseni, T.O. and Muhammad, Y.M. 2007. Productivity of vegetable sesame (*Sesamum radiatum*) as influenced by nitrogen, phosphorus and seasons. *Adv. Hort. Sci.,* **21**(1): 9-13.

Balasubramaniyan, P. 1996. Influence of plant population and nitrogen on yield and nutrient response of sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(3): 448-450.

BARI (Bangladesh Agricultural Research Institute). 2004. Annual Report for 2003. BARI. p. 28.

BARI (Bangladesh Agricultural Research Institute). 2012. BARI Til-3. Oil seeds Research Centre. p. 16.

Bassiem, M.M. and Anton, N.A. 1998. Effect of nitrogen and potassium fertilizers and foliar spray with ascorbic acid on sesame plant in sandy soil. *Annls. Agril. Sci.,* **36**(1): 95-103.

BBS (Bangladesh Bureau of Statistics). 2014. Yearly Statistical Book. Bangladesh Bureau of Statistics, Dhaka Bangladesh. p. 153.

Buzetti, S., Muraoka, T. and Sa, M.E. 1990. Boron rates in soybean under different soil acidity conditions. Dry matter and grain yields and critical level in soil. *Field Crop Abst*., **46**(2): 233.

Chandrakar, B.L., Sekhar, N., Tuteja, S.S. and Tripathi, R.S. 1994. Effect of irrigation and nitrogen on growth and yield of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **39**(4): 701-702.

Chaubey, A.K., Kaushik, M.K. and Singh, S.B. 2003. Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured entisol. *New Agriculturist*. **14**(1/2): 61-64.

Deasarker, D.B. Patinge, S.P. Bhosalo, A.M. and Deshmukh, S.B. 2001. Effect of micronutrients on seed yield of soybean. *Ann. Plant Physiol*. **15**(2): 163-166.

Dell, B. and Huang, L. 1997. Physiological responses of plants to boron. *Plant Soil*. **193**: 103-120.

Dixit, J.P., Rao, V.S.N., Ambabatiya, G.R. and Khan, R.A. 1997. Productivity of sesame cultivars sown as semi-rabi under various plant densities and nitrogen levels. *Crop Res. Hisar*., **13**(1): 27-31.

Dwivedi, G.K. Dwivedi, M. and Pal, S. S. 1990. Models of application of micronutrients in acid soil in soybean-wheat crop sequence. *J. Indian Soc. Soil Sci*., **38**(3): 458-463.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey and Govt. People's Republic of Bangladesh. 118 p.

Fard, A.P.M. and Bahrani, M.J. 2005. Effect of nitrogen fertilizer rates and plant density on some agronomic characteristics, seed yield, oil and protein percentage in two sesame cultivars. *Indian J. Agril. Sci.*, **36**(1): 129-135.

Fayed, E.H.M., Hassan, A.A. and Hussain, S.M.A. 2000. Sesame performance as affected by seeding rate and nitrogen levels under drip irrigation system in newly cultivated sandy soil. I. Yield and yield attributes. *Annals of Agril. Sci.*, **38**(1): 65-73.

Galrao, E.Z. 1989. Effect of micronutrients and cobalt on soybean yield on cerrado soil. *Crop Abst*., **45**(3): 436.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hamasa, A. and Putaiah, E.T. 2012. Residual effect of zinc and boron on growth and yield of sesame. *Intl. J. Env. Sci*., **3**(1): 167-172.

Hemantaranjan, A., Trivedi, A.K. and Mariram, 2000. Effect of foliar applied boron and soil applied iron and sulphur on growth and yield of soybean *(Glycine max L.* Merr.). *Indian J. Plant Physiol*., **5**(2): 142-144.

Hooda, R.S., Verma, O.P.S. and Anil, K. 1996. Intercropping of green gram and sesame in pearl millet under different nitrogen fertilization. *Crop Res. Hisar*., **12**(2): 213-215.

Hua, P. and Yan, K. 1998. Boron amelioration of aluminum toxicity in mungbean seedlings. *J. Plant Nutr*., **21**(5): 1045-1054.

Hunter, A.H. 1984. Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Ibrahim, M., Hussain, M., Khan, A., Jamal, Y., Ali, M. and Malik, M.F.A. 2014. Effect of nitrogen and phosphorus on yield and yield components of Sesame. *Intl. J. Sci. Basic & Appl. Res*., **18**(1): 95-101.

Islam, J.K. and Noor, S.P. 1982. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh. *Pakistan J. Sci. Res*., **34**(3-4): 113-119.

Jeena, M., Sumam, G. and Indira, M. 2013. Effect of sulphur and boron on the performance of sesame (*Sesamum indicum* L.) in onattukara sandy soil of Kerala, India. *Indian J. Agril. Res.*, **47**(3): 214-219.

Kalyani, R.R., Sree Devi, V., Satyanarayana, N.R. and Rao, M.K. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant. Phyto*., **4**: 223-226.

Lalit Bhatt, Srivastava, B.K. and Singh, M.P.M. 2004. Studies on the effect of foliar application of micronutrients on growth, yield and economics of sesame. *Prog. Hort*., **2**: 331-334.

Lewis, D.H. 1980. Boron. Are there inter-relations between the metabolic role of boron, synthesis of phenolic phytoalexins and the germination of pollen. *New Phytol*., **84**: 264-270.

Li, Z.Y., Guo, Q.Y., Tu, X.W., Chen, H.X. and Ding, G.Y. 1992. Boron nutrition of sesame and B fertilizer application II. Effects of the plants of different varieties. Oil Crops of China. *Crop Res. Inst., China*. **4**: 45-48.

Liu, P., Yang, Y. and Yang, Y.A. 2003. Effect of molybdenum and boron on quality of soybean. *Sci. Agril. Sci.*, **36**(2): 184-189.

Malik, M.A., Saleem, M.F., Cheema, M.A. and Shamim, A. 2003. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *Intl. J. Agric. Bio*., **5**(4): 490-492.

Mandal, A.K., Pal, S., Mandal, B. and Mandal, L.N. 1991. Available boron and molybdenum content in some alluvial acidic soils of north Bengal. *Indian J. Agric. Sci*., **67**(7): 502-504.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd edition. Academic Press, London, UK. p. 78.

Mary, K.S., Galal, A.H. and Dale, G.B. 1990. Foliar boron applications increase the final number of branches and pods on branches of field-grown sesame. *Plant Physol.*, **3**: 602- 607.

Miller, W.R. and Donahue, L.R. 1997. Soils in Our Environment. Prentice Hall of India Pvt. Ltd., New Delhi, India. 7 Edn. p. 302-315.

Mitra, S. and Pal, A.K. 1999. Water use and productivity of summer sesame as influenced by irrigation and nitrogen. *J. Indian Soc. Soil Sci.,* **47**(3): 400-404.

Mondal, D.K., Sounda, G., Panda, P.K., Ghosh, P., Maitra, S. and Roy, D.K. 1997. Effect of different irrigation levels and nitrogen doses on growth and yield of sesame (*Sesamum indicum* L.). *Indian Agriculturist*. **41**(1): 15-21.

Mondal, S.S., Pramanik, C.K. and Das, J. 2001. Effect of nitrogen and potassium on oil yield, nutrient uptake and soil fertility in soybean (*Glycine max*) - sesame (*Sesamum indicum*) intercropping system. *Indian J. Agril. Sci.,* **71**(1): 44-46.

Moorthy, B.T.S., Das, T.K. and Nanda, B.B. 1997. Studies on varietal evaluation, nitrogen and spacing requirement of sesame in rice fallows in summer season. *Annals of Agril. Res.*, **18**(3): 408-410.

Obreza, T.A. and Vavrina, C.S. 1993. Production of chinese cabbage in relation to nitrogen source, rate and leaf nutrient concentration. *Soil Sci. Plant Analysis*. **24**: 13-14.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Opena, R.T., Kuo, C.C. and Yoon, J.Y. 1988. Breeding and Seed Production of Root crops in the Tropics and Subtropics. *Tech. Bul*., 17, AVRDC. p. 97.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. p. 403-430.

Parihar, S.S., Pandey, D. and Shukla, R.K. 1999. Response of summer sesame (*Sesamum indicum*) to irrigation schedule and nitrogen level in clay-loam soil. *Interl. J. Trop. Agric.,* **17**(1/4): 189-193.

Pathak, K., Barman, U., Kalita, M.K. and Hazarika, B.N. 2002. Effect of nitrogen levels on growth and yield of sesamum (*Sesamum indicum*) in Barak Valley Zone of Assam. *Adv. Pl. Sci.,* **15**(1): 341-343.

Pilbeam, D.J. and Kirkby, E.A. 1983. The physiological role of boron in plants. *J. Plant Nutri*., **6**: 563-582.

Posypanov, G.S., Kashukoev, M.Y. and Zherukov, B.K.H. 1994. Basic parameters for optimal supply of water, phosphorus, boron and molybdenum to peas and soybeans for active symbiotic nitrogen fixation. *Intl. Agril. Sci*., **2**: 33-42.

Prakash, O., Singh, B.P. and Singh, P.K. 2001. Effect of weed-control measures and nitrogen fertilization on yield and yield attributes of sesame (*Sesamum indicum*) under rainfed condition. *Indian J. Agril. Sci.,* **71**(9): 610-612.

Ramirez, R. and Linares, J.C. 1995. Boron deficiency symptoms and dry matter production of sesame under green house conditions. *Comm. Soil Sci.; Plant Anal. Maracay, Venezuela*. **26**(17/18): 3043-3049.

Ratna Kalyani, R., Sree Devi, V., Satyanarayana, N.V. and Madhana Rao, K.V. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant Physio*., **4**: 223-226.

Rerkasem, B., Saunders, D.A. and Jamjod, S. 1989. Correcting boron deficiency induced ear sterility in wheat and barley. *Thailand J. Soils Fert*., **11**: 200-209.

Roy, A.K.S., Maiti, S. and Bhattacharyya, K.K. 1992. Effect of phosphatic fertilizers micronutrients on limited and its influence on rice in lentil rice sequence. *Environ. Ecol*., **10**(4): 837-841.

Roy, S.K., Rahaman, S.M.L. and; Salahuddin, A.B.M. 1995. Effect of nitrogen and potassium on growth and seed yield of sesame (*Sesamum indicum*). *Indian J. Agril. Sci.,* **65**(7): 509-511.

Sakal, R., Sin R.B. and Singh, A.P. 1994. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*., **37**(5): 31-32.

Sakal, R., Singh. R.B. and Singh. A.P. 1988. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*. **33**(2): 27-30.

Sakal, R., Sinha, R.B. and Singh, A.P. 1990. Response of chickpea to boron application in calcareous soils. *Intl. Chickpea News*. **1**(22): 28-29.

Sarkar, R.P. and Anita, R.D. 2005. Effects of N, B and S on the growth and productivity of sesame. *Indian J. Agril. Sci.,* **36**(1): 129-135.

Sathya, S., Pitchai, G.J. and Indirani, R. 2009. Boron nutrition of crops in relation to yield and quality review. *Agric. Rev*., **2**: 139-144.

Shilpi, S., Islam, M.N., Sutradhar, G.N.C., Husna, A. and Akter, F. 2012. Effect of Nitrogen and Sulfur on the Growth and Yield of Sesame. *Intl. J. of Bio-resource Stress Manag*., **3**(2): 177-182.

Sindoni, M., Zamora, J. and Ramirez, R. 1994. Symptoms of boron deficiency and dry matter production in sesame. *Agronomic Tropical (Maracay)*. **44**(1): 135-150.

Singaravel, R. and Govindasamy, R. 1998. Effect of humic acid, nitrogen and biofertilizer on the growth and yield of sesame. *J. Oilseeds Res.,* **15**(2): 366-367.

Singh, B.P. and Singh, B. 1994. Response of french bean to phosphorus and boron in acid Alfisols in Megbaiaya. *J. Indian Soc. Soil Sci*., **38**(4): 769-771.

Singh, P.K., Prakash, O. and Singh, B.P. 2001. Studies on the effect of N-fertilization and weed control techniques on weed suppression, yield and nutrients uptake in sesame (*Sesamum indicum*). *Indian J. Weed Sci.,* **33**(3/4): 139-142.

Singh, S.P. and Singh, R.A. 1999. Effect of nitrogen on growth, yield and quality of sesame (*Sesamum indicum* L.) and blackgram (*Vigna mungo* L.) in intercropping system. *J. Appl. Biol.,* **9**(2): 163-166.

Sinha, R.B., Sakal, F.L., Singh, A.P. and Bhogal, N.S. 1991. Response of some field crops to boron application in calcareous soil. *J. Indian Soc. Soil Sci*., **39**: 117-122.

Srivastava, P.C. and Gupta, U.C. 1996. Trace Elements in crop production. Science Pub. Inc. Lebanon, NHO3766 USA. p. 366.

Srivastava, S., Yandev, C.R., Rego, T.J., Johansen, C., Saxena, N. and Ramakrishna, A. 1996. Diagnosis of boron deficiency as a cause of flower abortion and failure of pod set in chickpea in Nepal. *Intl. Chickpea & Pigeonpea News*. **1**(3): 29-30.

Subrahmaniyan, K. and Arulmozhi, N. 1999. Response of sesame (*Sesamum indicum*) to plant population and nitrogen under irrigated condition. *Indian J. Agron.*, **44**(2): 413-415.

Talashilkar, S.C. and Chavan, A.S. 1996. Response of groundnut to calcium, sulphur and boron with and without FYM on Inceptisol. *J. Indian Soc. Soil Sci.*, **44**(2): 343-344.

Tanaka, M. and Fujiwar, T. 2008. Physiological roles and transport mechanisms of boron: perspectives from plants. *Plants Arch. European J. Physiol.*, **456**: 671-677.

Thakur, D.S., Patel, S.R. and Nageshwar, L. 1998. Yield and quality of sesame (*Sesamum indicum*) as influenced by nitrogen and phosphorus in light-textured inceptisols. *Indian J. Agron.*, **43**(2): 325-328.

Tiwari, K.P. and Namdeo, K.N. 1997. Response of sesame (*Sesamum indicum*) to planting geometry and nitrogen. *Indian J. Agron.*, **42**(2): 365-369.

UNDP (United Nations Development Program) and FAO (Food and Agricultural Organization). 1988. Land Resources Appraisal of Bangladesh for Agricultural Department. Report 2. Agro ecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization. p. 212-221.

Yoshizawa, T.C.H.M. and Roan, Y.C. 1981. Management of Summer Pulse in Taiwan. AVRDC, Shanhua, Taiwan. p. 125.

REFERENCES

Abdel-Rahman, K.A., Allam, A.Y., Galal, A.H. and Bakry, B.A. 2003. Response of sesame to sowing dates, nitrogen fertilization and plant populations in sandy soil. *Assiut J. Agril. Sci.,* **34**(3): 1-13.

Anonymous. 1989. Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Ashfaq, A., Abid, H., Mahboob, A. and Ehsanullah, M.M. 2001. Yield and quality of two sesame varieties as affected by different rates of nitrogen and phosphorus. *Pakistan J. Agril. Sci.,* **38**(1/2): 4-7.

Ashok, K., Prasad, T.N. and Prasad, U.K. 1996. Effect of irrigation and nitrogen on growth yield, oil content, nitrogen uptake and water-use of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(1): 111-115.

Auwalu, B.M., Babatunde, F.E., Oseni, T.O. and Muhammad, Y.M. 2007. Productivity of vegetable sesame (*Sesamum radiatum*) as influenced by nitrogen, phosphorus and seasons. *Adv. Hort. Sci.,* **21**(1): 9-13.

Balasubramaniyan, P. 1996. Influence of plant population and nitrogen on yield and nutrient response of sesame (*Sesamum indicum*). *Indian J. Agron.,* **41**(3): 448-450.

BARI (Bangladesh Agricultural Research Institute). 2004. Annual Report for 2003. BARI. p. 28.

BARI (Bangladesh Agricultural Research Institute). 2012. BARI Til-3. Oil seeds Research Centre. p. 16.

Bassiem, M.M. and Anton, N.A. 1998. Effect of nitrogen and potassium fertilizers and foliar spray with ascorbic acid on sesame plant in sandy soil. *Annls. Agril. Sci.,* **36**(1): 95-103.

BBS (Bangladesh Bureau of Statistics). 2014. Yearly Statistical Book. Bangladesh Bureau of Statistics, Dhaka Bangladesh. p. 153.

Buzetti, S., Muraoka, T. and Sa, M.E. 1990. Boron rates in soybean under different soil acidity conditions. Dry matter and grain yields and critical level in soil. *Field Crop Abst*., **46**(2): 233.

Chandrakar, B.L., Sekhar, N., Tuteja, S.S. and Tripathi, R.S. 1994. Effect of irrigation and nitrogen on growth and yield of summer sesame (*Sesamum indicum*). *Indian J. Agron.,* **39**(4): 701-702.

Chaubey, A.K., Kaushik, M.K. and Singh, S.B. 2003. Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured entisol. *New Agriculturist*. **14**(1/2): 61-64.

Deasarker, D.B. Patinge, S.P. Bhosalo, A.M. and Deshmukh, S.B. 2001. Effect of micronutrients on seed yield of soybean. *Ann. Plant Physiol*. **15**(2): 163-166.

Dell, B. and Huang, L. 1997. Physiological responses of plants to boron. *Plant Soil*. **193**: 103-120.

Dixit, J.P., Rao, V.S.N., Ambabatiya, G.R. and Khan, R.A. 1997. Productivity of sesame cultivars sown as semi-rabi under various plant densities and nitrogen levels. *Crop Res. Hisar*., **13**(1): 27-31.

Dwivedi, G.K. Dwivedi, M. and Pal, S. S. 1990. Models of application of micronutrients in acid soil in soybean-wheat crop sequence. *J. Indian Soc. Soil Sci*., **38**(3): 458-463.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. 1979. Detailed Soil Survey of Bangladesh, Dept. Soil Survey and Govt. People's Republic of Bangladesh. 118 p.

Fard, A.P.M. and Bahrani, M.J. 2005. Effect of nitrogen fertilizer rates and plant density on some agronomic characteristics, seed yield, oil and protein percentage in two sesame cultivars. *Indian J. Agril. Sci.*, **36**(1): 129-135.

Fayed, E.H.M., Hassan, A.A. and Hussain, S.M.A. 2000. Sesame performance as affected by seeding rate and nitrogen levels under drip irrigation system in newly cultivated sandy soil. I. Yield and yield attributes. *Annals of Agril. Sci.*, **38**(1): 65-73.

Galrao, E.Z. 1989. Effect of micronutrients and cobalt on soybean yield on cerrado soil. *Crop Abst*., **45**(3): 436.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hamasa, A. and Putaiah, E.T. 2012. Residual effect of zinc and boron on growth and yield of sesame. *Intl. J. Env. Sci*., **3**(1): 167-172.

Hemantaranjan, A., Trivedi, A.K. and Mariram, 2000. Effect of foliar applied boron and soil applied iron and sulphur on growth and yield of soybean *(Glycine max L.* Merr.). *Indian J. Plant Physiol*., **5**(2): 142-144.

Hooda, R.S., Verma, O.P.S. and Anil, K. 1996. Intercropping of green gram and sesame in pearl millet under different nitrogen fertilization. *Crop Res. Hisar*., **12**(2): 213-215.

Hua, P. and Yan, K. 1998. Boron amelioration of aluminum toxicity in mungbean seedlings. *J. Plant Nutr*., **21**(5): 1045-1054.

Hunter, A.H. 1984. Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Ibrahim, M., Hussain, M., Khan, A., Jamal, Y., Ali, M. and Malik, M.F.A. 2014. Effect of nitrogen and phosphorus on yield and yield components of Sesame. *Intl. J. Sci. Basic & Appl. Res*., **18**(1): 95-101.

Islam, J.K. and Noor, S.P. 1982. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh. *Pakistan J. Sci. Res*., **34**(3-4): 113-119.

Jeena, M., Sumam, G. and Indira, M. 2013. Effect of sulphur and boron on the performance of sesame (*Sesamum indicum* L.) in onattukara sandy soil of Kerala, India. *Indian J. Agril. Res.,* **47**(3): 214-219.

Kalyani, R.R., Sree Devi, V., Satyanarayana, N.R. and Rao, M.K. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant. Phyto*., **4**: 223-226.

Lalit Bhatt, Srivastava, B.K. and Singh, M.P.M. 2004. Studies on the effect of foliar application of micronutrients on growth, yield and economics of sesame. *Prog. Hort*., **2**: 331-334.

Lewis, D.H. 1980. Boron. Are there inter-relations between the metabolic role of boron, synthesis of phenolic phytoalexins and the germination of pollen. *New Phytol*., **84**: 264-270.

Li, Z.Y., Guo, Q.Y., Tu, X.W., Chen, H.X. and Ding, G.Y. 1992. Boron nutrition of sesame and B fertilizer application II. Effects of the plants of different varieties. Oil Crops of China. *Crop Res. Inst., China*. **4**: 45-48.

Liu, P., Yang, Y. and Yang, Y.A. 2003. Effect of molybdenum and boron on quality of soybean. *Sci. Agril. Sci.*, **36**(2): 184-189.

Malik, M.A., Saleem, M.F., Cheema, M.A. and Shamim, A. 2003. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *Intl. J. Agric. Bio*., **5**(4): 490-492.

Mandal, A.K., Pal, S., Mandal, B. and Mandal, L.N. 1991. Available boron and molybdenum content in some alluvial acidic soils of north Bengal. *Indian J. Agric. Sci*., **67**(7): 502-504.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd edition. Academic Press, London, UK. p. 78.

Mary, K.S., Galal, A.H. and Dale, G.B. 1990. Foliar boron applications increase the final number of branches and pods on branches of field-grown sesame. *Plant Physol.*, **3**: 602- 607.

Miller, W.R. and Donahue, L.R. 1997. Soils in Our Environment. Prentice Hall of India Pvt. Ltd., New Delhi, India. 7 Edn. p. 302-315.

Mitra, S. and Pal, A.K. 1999. Water use and productivity of summer sesame as influenced by irrigation and nitrogen. *J. Indian Soc. Soil Sci.,* **47**(3): 400-404.

Mondal, D.K., Sounda, G., Panda, P.K., Ghosh, P., Maitra, S. and Roy, D.K. 1997. Effect of different irrigation levels and nitrogen doses on growth and yield of sesame (*Sesamum indicum* L.). *Indian Agriculturist*. **41**(1): 15-21.

Mondal, S.S., Pramanik, C.K. and Das, J. 2001. Effect of nitrogen and potassium on oil yield, nutrient uptake and soil fertility in soybean (*Glycine max*) - sesame (*Sesamum indicum*) intercropping system. *Indian J. Agril. Sci.,* **71**(1): 44-46.

Moorthy, B.T.S., Das, T.K. and Nanda, B.B. 1997. Studies on varietal evaluation, nitrogen and spacing requirement of sesame in rice fallows in summer season. *Annals of Agril. Res.,* **18**(3): 408-410.

Obreza, T.A. and Vavrina, C.S. 1993. Production of chinese cabbage in relation to nitrogen source, rate and leaf nutrient concentration. *Soil Sci. Plant Analysis*. **24**: 13-14.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Opena, R.T., Kuo, C.C. and Yoon, J.Y. 1988. Breeding and Seed Production of Root crops in the Tropics and Subtropics. *Tech. Bul*., 17, AVRDC. p. 97.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. p. 403-430.

Parihar, S.S., Pandey, D. and Shukla, R.K. 1999. Response of summer sesame (*Sesamum indicum*) to irrigation schedule and nitrogen level in clay-loam soil. *Interl. J. Trop. Agric.,* **17**(1/4): 189-193.

Pathak, K., Barman, U., Kalita, M.K. and Hazarika, B.N. 2002. Effect of nitrogen levels on growth and yield of sesamum (*Sesamum indicum*) in Barak Valley Zone of Assam. *Adv. Pl. Sci.,* **15**(1): 341-343.

Pilbeam, D.J. and Kirkby, E.A. 1983. The physiological role of boron in plants. *J. Plant Nutri*., **6**: 563-582.

Posypanov, G.S., Kashukoev, M.Y. and Zherukov, B.K.H. 1994. Basic parameters for optimal supply of water, phosphorus, boron and molybdenum to peas and soybeans for active symbiotic nitrogen fixation. *Intl. Agril. Sci*., **2**: 33-42.

Prakash, O., Singh, B.P. and Singh, P.K. 2001. Effect of weed-control measures and nitrogen fertilization on yield and yield attributes of sesame (*Sesamum indicum*) under rainfed condition. *Indian J. Agril. Sci.,* **71**(9): 610-612.

Ramirez, R. and Linares, J.C. 1995. Boron deficiency symptoms and dry matter production of sesame under green house conditions. *Comm. Soil Sci.; Plant Anal. Maracay, Venezuela*. **26**(17/18): 3043-3049.

Ratna Kalyani, R., Sree Devi, V., Satyanarayana, N.V. and Madhana Rao, K.V. 1993. Effect of foliar application of boron on crop growth and yield of sesame. *Indian J. Plant Physio*., **4**: 223-226.

Rerkasem, B., Saunders, D.A. and Jamjod, S. 1989. Correcting boron deficiency induced ear sterility in wheat and barley. *Thailand J. Soils Fert*., **11**: 200-209.

Roy, A.K.S., Maiti, S. and Bhattacharyya, K.K. 1992. Effect of phosphatic fertilizers micronutrients on limited and its influence on rice in lentil rice sequence. *Environ. Ecol*., **10**(4): 837-841.

Roy, S.K., Rahaman, S.M.L. and; Salahuddin, A.B.M. 1995. Effect of nitrogen and potassium on growth and seed yield of sesame (*Sesamum indicum*). *Indian J. Agril. Sci.,* **65**(7): 509-511.

Sakal, R., Sin R.B. and Singh, A.P. 1994. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*., **37**(5): 31-32.

Sakal, R., Singh. R.B. and Singh. A.P. 1988. Effect of boron application on black gram and chickpea production in calcareous soil. *Fert. News*. **33**(2): 27-30.

Sakal, R., Sinha, R.B. and Singh, A.P. 1990. Response of chickpea to boron application in calcareous soils. *Intl. Chickpea News*. **1**(22): 28-29.

Sarkar, R.P. and Anita, R.D. 2005. Effects of N, B and S on the growth and productivity of sesame. *Indian J. Agril. Sci.,* **36**(1): 129-135.

Sathya, S., Pitchai, G.J. and Indirani, R. 2009. Boron nutrition of crops in relation to yield and quality review. *Agric. Rev*., **2**: 139-144.

Shilpi, S., Islam, M.N., Sutradhar, G.N.C., Husna, A. and Akter, F. 2012. Effect of Nitrogen and Sulfur on the Growth and Yield of Sesame. *Intl. J. of Bio-resource Stress Manag*., **3**(2): 177-182.

Sindoni, M., Zamora, J. and Ramirez, R. 1994. Symptoms of boron deficiency and dry matter production in sesame. *Agronomic Tropical (Maracay)*. **44**(1): 135-150.

Singaravel, R. and Govindasamy, R. 1998. Effect of humic acid, nitrogen and biofertilizer on the growth and yield of sesame. *J. Oilseeds Res.,* **15**(2): 366-367.

Singh, B.P. and Singh, B. 1994. Response of french bean to phosphorus and boron in acid Alfisols in Megbaiaya. *J. Indian Soc. Soil Sci*., **38**(4): 769-771.

Singh, P.K., Prakash, O. and Singh, B.P. 2001. Studies on the effect of N-fertilization and weed control techniques on weed suppression, yield and nutrients uptake in sesame (*Sesamum indicum*). *Indian J. Weed Sci.,* **33**(3/4): 139-142.

Singh, S.P. and Singh, R.A. 1999. Effect of nitrogen on growth, yield and quality of sesame (*Sesamum indicum* L.) and blackgram (*Vigna mungo* L.) in intercropping system. *J. Appl. Biol.,* **9**(2): 163-166.

Sinha, R.B., Sakal, F.L., Singh, A.P. and Bhogal, N.S. 1991. Response of some field crops to boron application in calcareous soil. *J. Indian Soc. Soil Sci*., **39**: 117-122.

Srivastava, P.C. and Gupta, U.C. 1996. Trace Elements in crop production. Science Pub. Inc. Lebanon, NHO3766 USA. p. 366.

Srivastava, S., Yandev, C.R., Rego, T.J., Johansen, C., Saxena, N. and Ramakrishna, A. 1996. Diagnosis of boron deficiency as a cause of flower abortion and failure of pod set in chickpea in Nepal. *Intl. Chickpea & Pigeonpea News*. **1**(3): 29-30.

Subrahmaniyan, K. and Arulmozhi, N. 1999. Response of sesame (*Sesamum indicum*) to plant population and nitrogen under irrigated condition. *Indian J. Agron.*, **44**(2): 413-415.

Talashilkar, S.C. and Chavan, A.S. 1996. Response of groundnut to calcium, sulphur and boron with and without FYM on Inceptisol. *J. Indian Soc. Soil Sci.*, **44**(2): 343-344.

Tanaka, M. and Fujiwar, T. 2008. Physiological roles and transport mechanisms of boron: perspectives from plants. *Plants Arch. European J. Physiol.*, **456**: 671-677.

Thakur, D.S., Patel, S.R. and Nageshwar, L. 1998. Yield and quality of sesame (*Sesamum indicum*) as influenced by nitrogen and phosphorus in light-textured inceptisols. *Indian J. Agron.*, **43**(2): 325-328.

Tiwari, K.P. and Namdeo, K.N. 1997. Response of sesame (*Sesamum indicum*) to planting geometry and nitrogen. *Indian J. Agron.*, **42**(2): 365-369.

UNDP (United Nations Development Program) and FAO (Food and Agricultural Organization). 1988. Land Resources Appraisal of Bangladesh for Agricultural Department. Report 2. Agro ecological Regions of Bangladesh. United Nations Development Program and Food and Agricultural Organization. p. 212-221.

Yoshizawa, T.C.H.M. and Roan, Y.C. 1981. Management of Summer Pulse in Taiwan. AVRDC, Shanhua, Taiwan. p. 125.