EFFECT OF NITROGEN AND BORON ON GROWTH AND YIELD OF MUSTARD (*Brassica campestris* cv. Tori-7)

By

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CERTIFICATE

This is to certify that thesis entitled, "***EFFECT OF NITROGEN AND BORON ON GROWTH AND YIELD OF MUSTARD***" Submitted to the ***DEPARTMENT OF SOIL SCIENCE***, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE (M.S.)*** in ***SOIL SCIENCE*** embodies the result of a piece of *bona fide* research work carried out by ***RASAMAY MONDAL*** Registration No. *25209/00335* under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated To My

Beloved Parents

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Thesis Abstract

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the rabi season of 2005-06 to study the effects of nitrogen (N) and boron (B) on growth, yield and yield attributes of mustard cv. Tori-7. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 (three) replications of each treatment. There were 16 treatments. The treatments consisted of 4 (four) levels of N (0, 50, 100 and 150 kg ha^{-1}) designated as N_0, N_{50}, N_{100}, and N_{150}, respectively and 4 (four) levels of B (0, 1, 2 and 3 kg ha^{-1}) designated as B_0, B_1, B_2, and B_3, respectively. There was a positive impact of each nutrient and their interaction on growth, yield and yield attributes of mustard. All the plant parameters were increased with increasing level of N except number of branch per plant, weight of 1000 seeds and seed yield. The highest seed yield (1.62 t/ha) was obtained with application of N @100 kg/ha and the minimum was recorded in N_0 (control) treatment. Similarly, application of B @ 2 kg/ha produced the highest yield of 0.97 t/ha, which was 31% higher over control (0.74 t/ha). The combined effect of N and B had positive impact on growth, yield, nutrient uptake and yield attributes of mustard. The tallest plant height (73.28 cm), maximum numbers of siliquae (169.7/plant) and root weight (0.37 t/ha) were observed in $N_{150}B_3$ treatment. The highest seed yield (1.96 t/ha), stover yield (5.54 t/ha), biological yield (7.5 t/ha), number of seeds (16.3/ siliqua) and number of branches (5/plant) were obtained from $N_{150}B_2$ treatment. The highest N, B, K and S uptake by seeds was found in $N_{150}B_2$ treatment, but the highest P uptake was found in $N_{150}B_3$ treatment. From the present findings it can be inferred that application of N @ 150 kg/ha and B @ 2 kg/ha is the most suitable combination to achieve the highest seed yield (1.96 t/ha) of mustard which was 165.0% higher over control treatment (0.74 t/ha).

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Introduction

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INTRODUCTION

Mustard (*Brassica spp.*) is one of the most important oilseed crops throughout the world after soyabean and groundnut (FAO, 2004). It has a remarkable demand for edible oil in Bangladesh. It occupies first position of the list in respect of area and production among the oilseed crops grown in this country (BBS, 2004). In the year of 2003-04 it covered 1.79 lakhs hectare (ha) land and the production was 2.11 lakhs metric ton (Mt), where as the total oilseed production was 4.07 lakhs Mt and total area covered by oilseed crops was 3.89 lakhs ha. In the year of 2004-05 it covered 3.95 lakhs ha land and the production was 3.79 lakhs Mt. (BBS, 2005).

Mustard seeds contain 40-45% oil and 20-25% protein (Mondal and Wahhab, 2001). Using local ghani average 33% oil may be extracted. Oil cake is a nutritious food item for cattle and fish. Oil cake is also used as a good organic fertilizer. Dry mustard plants may be used as fuel.

Mustard plant belongs to the genus *Brassica* under the family Cruciferae. The *Brassica* has three species that produce edible oil, *B. napus, B. campestris* and *B. juncea*. Of these, *B. napus* and *B. campestris* have the greatest importance in the world's oilseed trade. In this subcontinent, *B. juncea* is also an important oilseed crop. Until recently, mustard varieties such as Tori-7, Sampad (both are *B. campestris*) and Doulat (*B. juncea*) were mainly grown in this country. Recently, MM-2-16-98. MM- 34-7, MM-38-6-98, MM-49-3-98, Binasarisha-4 are high yielding mutants/Varieties have been developed by the scientists of Bangladesh Institute of Nuclear Agriculture (BINA).

Mustard is a cold loving crop and grows during Rabi season (October-February) usually under rainfed and low input condition in this country can be attributed to several factors, the nutritional deficiency, among others is highly important. There is very little scope of expansion for mustard and other oilseed acreage in the country, due to competition from more profitable alternative crops. The cultivation of mustard has to compete with other food grain crops have shifted to marginal lands of poor productivity. With increasing growth rate of population, the demand of edible oil is increasing day by day. It is, therefore, highly accepted that the production of edible oil should be increased considerably to fulfill the demand of the country. But the production of mustard is hampered due to many reasons of which suitable varieties, inadequate use of fertilizers such as nitrogen (N), phosphorus (P), boron (B), sulphur (S) and potash (K) fertilizers, negligible irrigation facilities and so on (Sheppard and Baten, 1980).

Although mustard is the principal oil crop in Bangladesh but its cultivation is very neglected. Moreover the yield of mustard is low in Bangladesh as compared to other countries of the world. There is great possibility to increase its production by applying adequate fertilizers, selecting high yielding varieties and adopting proper management practices. One of the common constraints to higher yield is lack of balanced fertilization.

Nitrogen has an important role in seed protein and physiological functions of the plant. It is possible to increase the yield per unite area by adopting improved cultural practices. The use of high yielding varieties coupled with application of balanced fertilizers might be a good means to enhance mustard yield. The practice of intensive cropping with modern varieties cause a marked depletion of inherent nutrient reserves in soils of Bangladesh. Consequently, in addition to N, P and K deficiencies, other nutrients such as S, Zn and B are also observed in some soils (Islam, 1988; Ali *et al.*, 1988 and Jahiruddin *et al.*, 1992).

Of all these, nitrogen and boron fertilizers are very important for the cultivation of mustard in Bangladesh. Mustard is highly sensitive to nitrogen and this element has great influence on the growth and yield of this crop. The literature shows that nitrogen has significant effect on plant height, branches plant^{-1}, siliquae plant^{-1} and other growth factors and yield of mustard (Mondal and Gaffer, 1983; Allen and Morgan, 1972). Nitrogen increases the vegetative growth and delayed maturity of plants. Excessive use of this element may produce too much of vegetative growth, thus fruit production may be impaired (Maini *et al.*, 1959; Singh *et al.*, 1972). Nitrogen (N) deficiency is widespread in Bangladesh.

Crops differ in their sensitivity to boron deficiency. *Brassica* crops in general have a high boron requirement (Mengel and Kirkby, 1987). Seed set failure is a major reason for lower yield of rabi crops and this problem can be attributed to boron deficiency, as reported in mustard (Rahman *et al.*, 1993; Islam *et al.*, 1997). Boron deficiency May cause sterility i,e. less pods and less seeds pod^{-1} attributing lower yield (Islam and Anwar, 1994). Deficiency of B causes restriction of water absorption and carbohydrate metabolism which ultimate affects seed and pod formation and thus reduces yield. Mehrotra *et al.* (1977) reported that seed yield of mustard increased by 15.5-68.5% due to boron application (Chatterjee *et al.*, 1985). In fertilizer schedule, an inclusion of B often decides the success and failure of the crops (Dwivedi *et al.*, 1990). It is reported that the ranges between deficiency and toxicity of B are quite narrow and that an application of B can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al.*, 1985). This emphasizes the need for a judicial use of B fertilizer. Information in our country to that end is practically meager.

In Bangladesh, there is limited information on the effect of nitrogen and boron on growth and yield of oil producing *Brassica spp.* In view of these limitations, a field experiment containing the treatments of nitrogen and boron was conducted with the following objectives:

- to know the growth and yield performance of mustard by using different doses of nitrogen and boron fertilizers.
- to know the interaction effect of nitrogen and boron on nutrient content and uptake by seeds of mustard.
- to identify the suitable doses of nitrogen and boron fertilizer for better yield of mustard.

Chapter 2
Review of Literature

Chapter 2

REVIEW OF LITERATURE

Among the oilseed crops, Mustard occupies the topmost position in Bangladesh. The proper fertilizer management essentially influences it's growth and yield performance. Experimental evidences showed that there is a profound influence of nitrogen (N) and boron (B) fertilizers on this crop. A brief of the relevant works performed in the past are presented in this Chapter

2.1 Effect of nitrogen (N) on Mustard:

Nitrogen is an essential macronutrient. High yielding mutants/varieties of mustard are very responsive to nitrogen (Ali and Rahman, 1986 and Gupta *et al*., 1985). Nitrogen is essential for cell division and expansion, chloroplast development, chlorophyll concentration and enzyme activity (Gardner *et al*., 1985).

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

A field experiment was conducted by Sinsinwar *et al*.(2004) during the 1999/2000 and 2000/01 rabi seasons in Bharatpur, Rajasthan, India, to determine the best cropping sequence and N fertilizer application rate (0, 30, 60 and 90 kg/ha) of Indian mustard cv. RH-30 under brackish water situation. The cropping sequences comprised: pearl millet + black gram followed by Indian mustard: pearl millet + pigeon pea followed by Indian mustard; black gram followed by Indian mustard; cluster bean followed by Indian mustard; and fallow followed by Indian mustard. The cropping sequences did not affect the growth, yield and yield components (i.e. plant height, number of primary and secondary branches per plant, number of siliquae per plant), 1000-seed weight and seed yield in both years. The seed yield of Indian mustard significantly increased with each increment of N fertilizer up to 60 kg/ha, beyond which the increase was marginal. On an average, the increase in seed yield compared to the control was 33.3 and 83.8% with 30 and 60 kg N/ha, respectively. The Indian mustard seed equivalent yield was significantly highest in pearl millet + black gram followed by Indian mustard (3190 kg/ha) cropping sequence during 1999/2000. In 2000/01, the Indian mustard equivalent yield of pearl millet + black gram followed by Indian mustard was highest (2435 kg/ha).

Singh *et al.* (2004) reported that nitrogen application did not affect the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application increased the seed yield of mustard. Nitrogen and sulfur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N/ha over its preceding rates. The increased nitrogen and sulfur content enhanced the total uptake of nitrogen and sulfur.

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

An experiment was conducted by Tripathi (2003) in Uttar Pradesh, India in 1994-95 and 1995-96 to investigate the effects of N levels (80, 120, 160 and 200 kg/ha) on the growth, yield and quality of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and at 60 days after sowing.

Results showed that all the yield characters except number of branches increased with increasing N levels up to 160 kg N/ha, The number of branches per plant increased up to 200 kg N/ha. Net returns were maximum (Rs. 19 901/ha) at 160 kg N/h because seed yield was also maximum at this N rate. The benefit : cost ratio increased up to 160 kg N/ha, with a maximum of Rs. 209 earned per rupee investment.

Field experiments were conducted by Abdin *et al.* (2003) in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (V1) and rape cv. Pusa Gold (V2). The treatments comprised: T1 (S0:N50 + 50); T2 (S40:N50 + 50 for V1 and S40:N50 + 25 + 25 for V2); and T3 (S20 + 20:N50 + 50 for V1 and S20 + 10 + 10:N50 + 25 + 25 for V2). Split application of S and N (T3) resulted in a significant increase in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t/ha for V1 and 3.06 t/ha for V2 under T3. The average oil yield under T3 was 1.71 t/ha for V1 and 1.42 t/ha in V2. The oil and protein contents in the seeds of V1 and V2 also increased with the split application of S and N. It may be concluded from these results that the yield and quality of rapeseed-mustard can be optimized with the split application of 40 kg S/ha and 100 kg N/ha during the appropriate phenological stages of crop growth and development.

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

Singh and Prasad, (2003) stated that among the N rates, 120 kg/ha gave the highest seed yield (20.24 quintal/ha), straw yield (12.22 quintal/ha), stick yield (43.52 quintal/ha), and net profit (12 975 rupees/ha). The highest cost benefit ratio (0.85) was obtained with 180 kg N/ha. [1 quintal=100 kg].

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

Babu and Sarkar, (2002) reported that mustard cultivars responded to N application up to 80 kg ha-1. Dry matter yield, N content, N uptake and per cent Ndff by mustard cultivars significantly increased with an increase in the level of fertilizer N. Per cent Ndff significantly increased from 12 at 40 kg N ha^{-1} to 22 at 80 kg N ha^{-1} in mustard seed while in stover the corresponding values ranged from 11 to 20%. Successive levels of N also increased significantly the uptake of soil N by mustard cultivars clearly establishing the 'priming' or 'added nitrogen interaction effect' of applied nitrogen.

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

Budzynski and Jankowski, (2001) stated that the effects of pre-sowing application of NPK (161 kg/ha)+S (30 kg/ha) or Mg (5 kg/ha) and top dressing of N (0, 30, 25+5 and 60 kg/ha) on the yield, yield components and morphological features of white mustard [*Sinapis alba*] and Indian mustard seeds were evaluated in an experiment conducted in Poland. N top dressing (30, 25+5 and 60 kg/ha) increased the height, diameter of stem base and branching of Indian mustard and white mustard stems. Both crops, however, exhibited lodging. The effects of NPKS and NPKMg on the yield potential of white mustard were not dependent on weather conditions. N applied at 30 kg/ha at the start of the flowering period gave the best results among the methods of white mustard top dressing. Splitting this rate to 25 kg N/ha as a solid fertilizer and 5 kg N/ha in a solution gave results similar to that of the whole rate of 30 kg N/ha as a solid fertilizer. N at 60 kg/ha appeared to be less productive. N applied as a solid fertilizer at a rate of up to 60 kg/ha increased the seed yield. Splitting the N rate to 25 kg/ha (solid fertilizer) and 4 kg/ha (solution) gave yield-enhancing effects similar to that of the whole 30 kg N/ha rate.

Singh, (2002) found that application of N and P increased the length of siliqua, number of siliquae per plant, seeds per siliqua, seed yield and 1000-seed weight of mustard. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha treatments. The maximum seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was not significant.

Kader *et al.*, (2003) observed that the effects of row spacing (30, 45 or 60 cm) and N rate (60, 120 or 180 kg/ha) on the yield of Indian mustard cv. Basanti were studied. N was applied at sowing (50%) and after the initial irrigation (50%). They found among the N rates, 120 kg/ha gave the highest seed yield (20.24 quintal/ha), straw yield (12.22 quintal/ha), stick yield (43.52 quintal/ha), and net profit (12975 rupees/ha). The highest cost benefit ratio (0.85) was obtained with 180 kg N/ha. [1 quintal=100 kg].

Field experiments were conducted by Jamal *et al*., (2003) in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (V1) and rape cv. Pusa Gold (V2). The treatments comprised: T1 (S0:N50 + 50); T2 (S40:N50 + 50 for V1 and S40:N50 + 25 + 25 for V2); and T3 (S20 + 20:N50 + 50 for V1 and S20 + 10 + 10:N50 + 25 + 25 for V2). Split application of S and N (T3) resulted in a significant increase in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t/ha for V1 and 3.06 t/ha for V2 under T3. The average oil yield under T3 was 1.71 t/ha for V1 and 1.42 t/ha in V2. Harvest indices of both the genotypes increased significantly when S was applied in split rates. The oil and protein contents in the seeds of V1 and V2 also increased with the split application of S and N. It may be concluded from these results that the yield and quality of rapeseed-mustard can be optimized with the split application of 40 kg S/ha and 100 kg N/ha during the appropriate phenological stages of crop growth and development.

Sharawat *et al*., (2002) observed that the yield and oil content generally increased with the increase in N and S rate. N at 120 kg/ha resulted in the highest number of siliquae per plant (397.25), weight of siliquae per plant (33.32 g), number of seeds per siliqua (14.80), seed yield per plant (368.75 g), 1000-grain weight (17.33 g), seed yield per ha (17.33 quintal) and oil content (38.39%).

Saikia *et al*., (2002) stated that dry matter and seedyield affected by different level of N.

Sharma and Jain, (2002) reported that the application of 80 kg N/ha resulted in the highest number of branches (24.4) and siliquae (260.9) per plant, number of seeds per siliqua (15.3), 1000-seed weight (5.85 g), and seed yields (1649, 2217, and 1261 kg/ha).

Patil *et al*., (1997) cultivated *B. juncea* CV. pusa Bold and *B. campestris* CV. pusa kalayania under field conditions in New Delhi with 0, 40, 80 and 120 kg N ha^{-1} and observed changes in dry matter accumulation in various plant parts due to the influence of N. The application of N-fertilizer up to 120 kg ha^{-1} had effect on the increasing growth of leaves, stems and pods during the entire period of crop growth.

Tomer *et al*., (1996) reported the highest seed yield of cv. Varuna (2.86 t ha^{-1}) and Pusa (2.72 t ha^{-1}) with the highest dose of N 160 kg ha^{-1} over control.

Shahidullah *et al*., (1996) observed in a fertilizer trial with 0, 75, 100 and 150 kg ha^{-1} of N, the seed yield of the *B.Juncea* CV. Sonali sarisha, Daulat, Tori-5 were increased up to a dose of 100 kg N ha^{-1}. The highest yield was obtained from CV. Sonali sarisha.

Patil *et al*., (1996) reported that the effect on growth, yield components and seed yields of *B. juncea* that the branching pattern and number of pods produced on different order of branches, in the two species, were favorable modified by the increasing levels of N apply. Primary and secondary branches contributed to the seed yield to an extent of 80% of the total. Yield without any significant effect of N on 1000 seed weight. *B. juncea* exhibited significantly higher yield than *B. campestris*. Nitrogen supply up to 120 kg ha^{-1} linearly increased seed yield in both the species.

Kakati and Kalita (1996) found that most of the yield components (branches $plant^{-1}$, Siliqua $plant^{-1}$, seed and stover N content) increase with the increasing rate of N-fertilizer, while oil content of seed decreased, 1000 seed weight and number of seeds $siliqua^{-1}$ remained unchanged. The cv. Varuna was found to be highest yielding cultivar.

Khanpara *et al*., (1992) in a field experiment on clay loam soils with mustard (*B. juncea*) observed that the level of 60 kg N ha^{-1} was significantly superior to other levels for seed yield, plant height and primary and secondary branches $plant^{-1}$. Islam *et al*., (1992) from their field trail at Mymensingh found increased seed yield of mustard cv. Sambal from 0.73 to + 1.91 t ha^{-1} with 0-200 kg N ha^{-1} applied at the different stages of the growth.

Tomer and Mishra (1991) observed that N application increased seed yield of mustard (*B. Juncea*.) from 0-32 to 1.12 ton ha^{-1}. Singh and Chauhan (1991) found in a field trials that application of 60 kg N ha^{-1} as urea to mustard resulted in higher seed yield (1.53 t ha^{-1}) than that of 30 kg N applied as urea.

Rana *et al*., (1991) reported that nitrogen application at the rate of 0, 50, 100, 150 kg ha^{-1} increased yield gradually and it reached maximum by N application up to 100 kg ha^{-1}. Dubey and Khan (1991) observed that nitrogen at the rate of 90 kg N ha^{-1} significantly increased seed yield of mustard under irrigated condition.

Sharma and Kumar (1990) observed that application of 120 kg N ha^{-1} increased the seed yield of mustard but it is not significantly superior to that of 80 kg N ha^{-1}. With the application of 1 kg N, on and average, produced 11.48 kg seeds against the treatment of 120 kg N ha^{-1}. On the other hand, with the addition of 80 kg N ha^{-1}, 1 kg N produced 10.96 kg seeds.

Ali *et al*., (1990) obtained higher seed yield of rapeseed when 90 kg N ha^{-1} was applied under rainfed condition.

Sounda *et al*., (1989) reported from a two years trial under rainfed condition with mustard (*B. juncea*) that increasing rates (0-90 kg ha^{-1}) of nitrogen increased seed yield from 245 to 628 kg ha^{-1} in one year and also from 277 to 778 kg ha^{-1} in another year.

Murtaza and Paul (1989) in a pot culture studied three cultivars of rape seed Viz. Pola, Tori-7 and Sampad grown with four levels of N-Fertilizer (0, 5, 10, 20 g of urea) observed significant effect of nitrogen on the number of primary branches plant^{-1}, siliqua plant^{-1} seed siliqua^{-1} and weight and seed yield plant^{-1}. The cultivars showed significant differences in all the characters except the number of primary branches and siliqua plant^{-1}.

Srivastava *et al.*, (1988) observed in an experiment conducted with musrard (*Brassica juncea* cv. varuna) that the application of nitrogen at the rate of 90 kg /ha at the preflowering stage gave highest harvest index.

Singh and Singh (1987) stated that increasing rate of nitrogen from 75 kg /ha applied to mustard (*Brassica juncea*) increased the seed yield from 1.20-1.33 to 2.11-2.14 t/ha.

Shamsuddin *et al.*, (1987) working with mustard with five levels of nitrogen (0, 30, 60, 90 and 120 kg N /ha) and four levels of irrigation observed that plant height increased progressively with increasing levels of nitrogen application but was not significantly differed with the application of different levels of nitrogen. Nitrogen at the rate of 120 kg /ha gave taller plant, highest no. of primary branches of plant (5.30) and the highest seed yield (830 kg /ha) over control. Thousand seed weight also increased significantly due to application of nitrogen.

Singh and Saron (1987) set an experiment with *Brassica campestris* var. toria (*Brassica napus* var. toria) applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased plant height, number of pods/plant and 1000-seed weight. This dose gave seed yields of 1.20 t/ha compared to 0.89 t/ha without nitrogen. A further increase in yield with 90 kg N/ha was not significant.

Hasan and Rahman (1987) showed that application of nitrogen at the rate of 120 kg ha^{-1} increased the plant height, number of pod in the primary branches and in the main racemes and seed yield of mustard. *B. campestris* cv. Kalayania with nitrogen up to 120 kg ha^{-1} gave highest plant height, seed, stover and biological yield, while 60 kg N ha^{-1} resulted the highest number of primary branches, siliqua, seed weight $plant^{-1}$ and 1000-seed weight.

Narang and Singh (1985) fertilized Indian mustard with four levels of nitrogen (viz. 0, 50, 100 and 150 kg /ha). They have observed that nitrogen at the rate of 150 kg /ha gave highest seed yield (1.8 t /ha) over control.

Mondal and Gaffer (1983) working with mustard give five levels of nitrogen viz. 0, 35, 105 and 140 kg/ha observed that different levels of nitrogen had significant effects on the plant height, number of primary branches/plant, number of filled siliqua/plant, number of seeds/siliqua, weight of seed/plant, weight of total dry plant/plot and yield of seeds over control. They further, observed that plant height, number of primary branches/plant and number of filled siliqua/plant were increased with the increasing doses of nitrogen. Nitrogen at the rate of 140 kg/ha produced highest number of fertile seeds/siliqua and seed yield (1.3 t/ha).

Patel *et al.*, (1980) performed a field experiment with four levels of nitrogen (viz. 0, 25, 50 and 75 kg /ha). They reported that different levels of nitrogen gave different seed yields of mustard significantly. The highest seed yield was 0.73 t /ha achieved at the rate of 50 kg N /ha due to the formation of higher no. of secondary branches /plant, higher no. of siliquae /plant and higher harvest index.

2.2 Effect of Boron (B) on Mustard:

Boron is a micronutrient requiring for plant growth relatively to a smaller amount. The total B content of soils lies between 20 and 200 ppm with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 ppm (Gupta, 1979). Plants absorb B principally in the form of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$, $H_2BO_3^-$ and HBO_3^{2-}. The element plays a vital role in the physiological processes of plants such as cell nutrition, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, auxin and phenol metabolism. The function of boron is primarily extra cellular and related to lignification and xylem differentiation (Lewis, 1980), membrane stabilization (Pilbeam and Kirkby, 1983), and altered enzyme reactions (Dugger, 1983).

Boron has both direct and indirect effects on fertilization. Indirect effects are related to the increase in amount and change in sugar composition of the nectare, whereby the flowers of species that rely on pollinating insects become more attractive to insects (Smith and Johnson, 1969; Erikson, 1979). Direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*, 1981). Moreover, boron stimulates germination, particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants (Jakson and Chapman, 1975).

Gupta (1979) stated that some plant species have a low B requirement and may also be sensitive to elevated B level even only slightly above those needed for normal growth. Therefore, toxic effects of B are likely to arise due to excessive use of B fertilizers.

Juel (1980) reported from 17 trials that the application of boron at the rate of 2 kg/ha resulted in increased seed yield of mustard and oil content of seed.

Gerath *et al.* (1975) reported an increase in yield of winter rape through application of boron fertilizer and recommended an application of 1 to 2 kg B/ha for increased yield.

Islam and Sarker (1993) reported that the application of boron increased significantly the number of siliquae / plant, no. of seeds /siliqua and seed yield of mustard (cv. ss-75) at Rangpur Agricultural Research Station. From another study it was reported that application of boron on mustard (cv. ss-75) significantly increased the seed yield in farmer's field at Jamalpur.

Thomas (1985) reported that the highest yields were achieved on medium to heavy soil with 40 kg N and P, 80 kg K, 1 kg B and 30 kg S /ha applied before sowing, plus 180 kg to 220 kg N /ha applied as top dressing in two installments in late February to early March.

Chakravarty *et al.*, (1979) stated that boron concentration in all crops increased significantly with increasing level of applied boron.

Yadav and Manchandra, (1982); Dutta *et al.*, (1984) and Yang *et al.*, (1989) also reported that increased level of boron application in mustard (*B. campestris*) increased tissue B content.

Sharma and Ramchandra (1990) reported that boron deficiency in mustard (*B. campestris*) decreased dry matter yield. Boron deficient plant had low water potential, stomatal pore opening and transpiration, decreased chlorophyll concentration, hill reaction activity, inter-cellular concentration and photosynthesis but there was an increase in accumulation of soluble nitrogen, protein, sugar and starch.

Marschner, (1990) reported that the deficiency symptoms of some boron sensitive crops like legumes, *Brassica*, beets, celery, grapes and fruit trees are chlorosis and browning of young leaves, killed growing points, distorted blossom development, lesions in pith and roots, and plants, burning of the tips of the leaves and restricted root growth are the boron toxicity symptoms in most crops.

Application of boron significantly increased the yield of mustard and 1.5 kg B /ha appeared to be the optimum B level for mustard (Sinha *et al.*, 1991; Dixit and Shukla, 1984). Banuels *et al.* (1990) reported that the application of P, S, Zn, and B raised seed yield of mustard significantly. Combined application of N, K and B increased seed yield in rapeseed (Yang *et al.*, 1989).

Chatterjee *et al.*, (1985) reported that the application of sulphur at the rate of 20 kg/ha through gypsum in conjugation with borax (10 kg /ha) caused 42% increase in yield of mustard (*B. juncea*). The straw yield of mustard crop increased significantly by boron application (Sinha *et al.*, 1991). Application of B along with N and K promoted co_2 assimilation, nitrate reductase activity in leaves and dry matter accumulation. Seed glucosinolate and erucic acid content varies among cultivars and generally decreases with increasing K and B, while seed oil content increases (Yang *et al.*, 1989).

Sen and Farid (2005) reported that application of boron @ 1.5 kg/ha produced 37% higher yield over control.

Application of B (1 kg /ha) increased leaf area ratio (LAR), leaf area index (LIA), crop growth rate (CGR), no. of brunches /plant, no. of siliquae /plant, weight of seed /siliqua and a decrease in chlorophyll content and net assimilation rate (NAR), but the relative growth rate (RGR), total dry matter and seed yield and some of other growth attributes were unaffected (Dutta and Uddin, 1983; Dutta *et al.*, 1984).

Increasing rate of B application from 0 to 6 ppm had no effect on dry matter and seed yield of mustard (Yadav and Manchanda, 1982).

Sarkar *et al.*, (2004) conducted a field experiment to identify cultivars with tolerance to micronutrient stresses. Boron treatments were: 0, 2 and 5 kg borax (0, 0.221 and 0.553 kg B, respectively). Based on the grain yield and its component characters, 14 cultivars of rapeseed and mustard can be classified as highly boron-responsive, moderately-responsive and non-responsive with respect to response of the cultivars to boron, applied to the highly boron deficient soil. The genotypes included 10 cultivars of *Brassica juncea*, 2 of *Brassica campestris* var. sarson and 2 of toria *(B. campestris* var. toria). The cultivars RLM 619, NDR 8602, PBM 16, RK 9082 and C-3 were found to be highly boron responsive. The cultivar T-9 was boron non-responsive, while rest of the cultivars were found to be moderately boron-responsive.

A field experiment was conducted by Malewar, (2001) on a Typic Haplustert in Maharashtra, India to investigate the effects of four levels of zinc sulfate (0, 10, 20 and 30 kg/ha) and three levels of borax (0, 5 and 10 kg/ha) on yield, nutrient uptake and seed quality of mustard (*Brassica juncea* cv. Pusa Bold). Stover and seed yield significantly increased with each levels of either zinc or boron, which was attributed to the positive interaction of the two. Highest total mustard uptake of Zn and B was at 30 kg $ZnSO_4$ and 10 kg borax/ha, respectively. Zn and B interaction was also reflected in terms of improved seed quality of mustard. Oil and protein content was significantly increased with 30 kg $ZnSO_4$ x 10 kg borax/ha treatment.

Sinha *et al.*, (2000) stated that mustard (*Brassica campestris*) cv. T9 was grown in refined sand at three levels of boron (B): deficient (0.0033 ppm), normal (0.33 ppm), and excess (3.3 ppm), each at three levels of zinc (Zn): low (0.00065 ppm), adequate (0.065 ppm), and high (6.5ppm). The B deficiency effects were accentuated by low zinc, viz. the decreased biomass, B and Zn concentrations in leaves and seeds and the activity of carbonic anhydrase [carbonate dehydratase] and accumulation of reducing sugars and stimulated activities of peroxidase, ribonuclease, and acid phosphatase in B deficient leaves were aggravated further. Synergism was also observed between the two nutrients when both B and Zn were in excess together, as excess B accelerated the effects of high Zn by lowering further the reduced biomass, economic yield, and carbonic anhydrase activity and raised further the increased concentration of B and Zn in leaves and seeds, reducing sugars and activity of peroxidase obtained in excess Zn. High Zn levels lowered the high content of non-reducing sugars given by B deficiency.

Gupta *et al.*, (1996) reported that mustard [*Brassica juncea*] cv. GSL-1, Pusa Bold and RS-1359 grown in the rabi [winter] seasons of 1992/93 and 1993/94 were given recommended NPK fertilizers plus 10 or 20 kg Zn/ha, foliar application of 0.5% Zn, 25 or 50 kg S/ha, or 10 or 20 kg B/ha. Seed yield was highest in cv. GSL-1, and was increased more by S and B than by Zn.

In field trials on a sandy loam in West Bengal in rabi [winter] 1989/90, application of 20 kg S and 1 kg B/ha to rape-seed mustard [*Brassica juncea*] significantly increased plant height, leaf area index at flowering and crop growth rate, oil content and seed yield (Pradhan and Sarkar, 1993).

A pot experiment was conducted by Rashid and Rafique, (1992). They reported that *B. juncea* cv. Westar was grown in soil and given 0, 0.5, 1, 2, 4 and 8 mg B as H_3BO_3/kg soil. DM yield after 4 and 8 weeks growth increased with up to 1 mg B; application rates > 2 mg B were toxic. The critical B concentration in whole shoots was 57 mg B/kg for 4-week-old plants and 28 mg for 8-week-old plants.

In field trials in 1987-88 with 6 cultivars each of sesame and mustard [*Brassica juncea*] grown with applied NPK + Zn on a B-deficient soil, av. sesame seed yields increased from 502 to 569 kg/ha and mustard seed yields increased from 1.14 to 1.35 t/ha when 1.5 kg B/ha was applied; yields were decreased to 518 kg and 1.30 t, resp., with 2.5 kg B/ha. Sesame cv. OMT-11-6-3 and RT-54 and mustard cv. Pusa Bold were more tolerant of B deficiency than other cultivars, as they removed more B from the soil given no B. They also showed a lower yield response to applied B than more susceptible cultivars. There was a positive correlation between seed B content and uptake. Yield was positively correlated with seed B uptake (Sakal *et al.*, 1991).

Saini *et al.,* (1985) observed that seed yield *of B. juncea* were increased by increasing N rates from 0 to 120 kg and 1 kg B/ha. The response to S, Zn and B increased with increase in N rates. Oil content decreased slightly with increasing N rates and increased slightly with S, Zn and B.

From the above information it may be inferred that the optimum level of boron has a positive effect on seed yield but the growth and yield is depressed due to deficient or toxic level of boron.

Chapter 3

Materials and Methods

Chapter 3

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during November 2005 to February 2006 to examine the effect of nitrogen (N) and boron (B) on the growth and yield of mustard cv. Tori-7.

3.1 Experimental site and soil

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

Fig.1. Map showing the experimental site under study

Table 1. Morphological Characteristics of experimental field

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

Table 2. Physical and chemical properties of the experimental soil

Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	29.04
% Silt	41.80
% Clay	29.16
2. Soil texture	Clay loam
B. Chemical properties	
1. Soil pH	5.8
2. Organic carbon (%)	0.78
3. Organic matter (%)	1.35
4. Total N (%)	0.08
5. C : N ratio	9.75 : 1
6. Available P (ppm)	35
7. Exchangeable K (me/100g soil)	0.18
8. Available S (ppm)	40
9. Available B (ppm)	0.34

3.2 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm, the average maximum temperature is 30.34^0C and average minimum temperature is 21.21^0C. The average mean temperature is 25.17^0C. The experiment was carried out during rabi season, 2005-06. Temperature during the cropping period ranged from 0^0C to 29.2^0 C. The humidity varies from 61.72% to 70.45%. The day length was reduced to 10.5-11.0 hours only and there was no rainfall from the beginning of the experiment to harvesting. The monthly average temperature, humidity and rainfall of the site during the experimental work are enclosed in appendix Figures-5 to 7.

3.3 Seeds and variety

Tori-7, a medium yielding and short duration variety of mustard (*Brassica campestris*) developed by Bangladesh Agricultural Research Institute (BARI), Gazipur. The seeds were collected from Bangladesh Agricultural Development Corporation (BADC), Dhaka.

3.4 Design and layout of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each fertilizer treatment combinations. Fertilizer treatments consisted of 4 levels of N (0, 50, 100 and 150 kg N/ha designated as N_0, N_{50}, N_{100} and N_{150}, respectively) and 4 levels of B (0, 1, 2 and 3 kg B/ha designated as B_0, B_1, B_2 and B_3 respectively). There were 16 treatment combinations. The treatment combinations were as follows:

N_0B_0 = Control (without N and B application)

N_0B_1 = 0 kg N/ha+1 kg B/ha

N_0B_2 = 0 kg N/ha+2 kg B/ha

N_0B_3 = 0 kg N/ha+3 kg B/ha

$N_{50}B_0$ = 50 kg N/ha+0 kg B/ha

$N_{50}B_1$ = 50 kg N/ha+1 kg B/ha

$N_{50}B_2$ = 50 kg N/ha+2 kg B/ha

$N_{50}B_3$ = 50 kg N/ha+3 kg B/ha

$N_{100}B_0$ =100 kg N/ha+0 kg B/ha

$N_{100}B_1$ = 100 kg N/ha+1 kg B/ha

$N_{100}B_2$ = 100 kg N/ha+2 kg B/ha

$N_{100}B_3$ = 100 kg N/ha+3 kg B/ha

$N_{150}B_0$ = 150 kg N/ha+0 kg B/ha

$N_{150}B_1$ = 150 kg N/ha+1 kg B/ha

$N_{150}B_2$ = 150 kg N/ha+2 kg B/ha

$N_{150}B_3$ =15 0 kg N/ha+3 kg B/ha

Fertilizer treatments were randomly distributed in each block. Each block consisted of 16 plots and individual plot was 2m × 1.5m i.e 3 sq. m in size. The row-to-row and seed to seed distance were 30 and 5 cm respectively accommodating 200 plants in each plot. The adjacent block and neighboring plots were separated by 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Fig. 2.

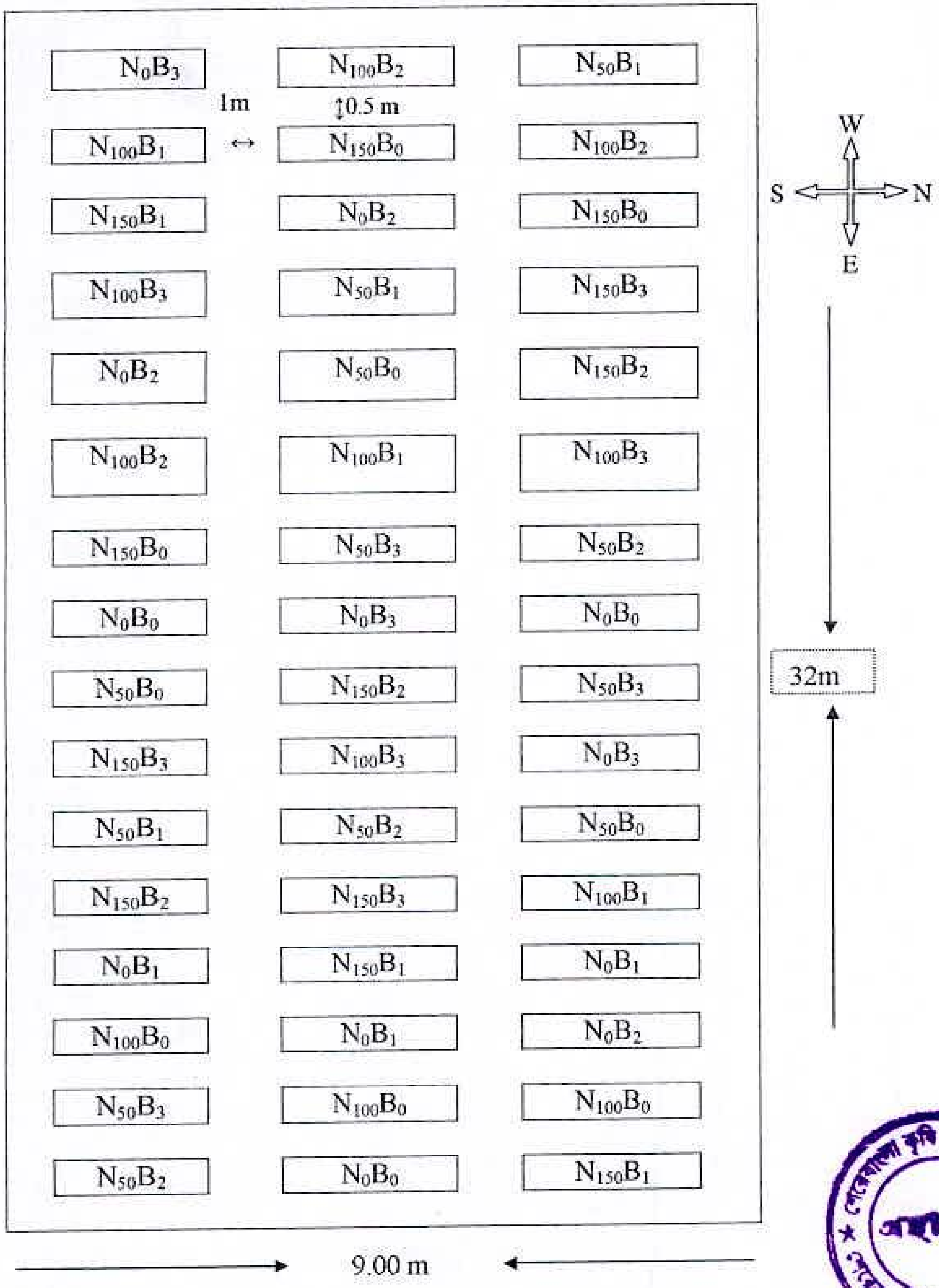

Fig. 2 Layout of the experiment

3.5 Collection and processing of soil sample

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

3.6 Land preparation

The land was first ploughed with a tractor drawn disc plough on 13 November 2005. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land operation was completed on 19 November 2005. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Application of fertilizers

The P, K, S and Zn fertilizer were applied according to Fertilizer Recommendation Guide (BARC, 1997) through Triple super phosphate (TSP), Muriate of potash (MP), Gypsum and Zinc oxide, respectively. One third (1/3) of whole amount of Urea and full amount of MP, TSP, Gypsum, Zinc oxide and Boric acid were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after sowing (DAS) and 40 DAS respectively.

3.8 Seed sowing

Seeds were sown continuously @ 7 kg /ha on 20 November 2005 by hand as uniform as possible in the 30cm apart lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept 200 per plot. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Weeding and thinning

Weeds of different types were controlled manually for the first time and removed from the field on 07 December 2005. At the same time fist thinning was done. The final weeding and thinning were done after 25 days of sowing, on 15 December 2005. Care was taken to maintain constant plant population per plot.

3.10 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 15 December 2005 at 25 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (35DAS), on 25 December 2005. The final irrigation was given at the stage of seed formation (50DAS), on 09 January 2006.

3.11 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Syphanon 57 EC @ 2ml /L water. The insecticide was sprayed thrice, the first on 27 December 2005; the second on 06 January 2006 and the last on 13 January, 2006. The crop was kept under constant observations from sowing to harvesting.

3.12 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 07 February 2006. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.13 Collection of experimental data

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Some data were collected from sowing to harvesting with 15 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1) Plant height (cm)

2) Number of primary branch per plant

3) Number of siliquae per plant

4) Number of seeds per siliqua

5) Weight of 1000-seeds (g)

6) Dry root weight (t/ha)

7) Seed yield (t /ha)

8) Stover yield (t /ha)

9) Biological yield (t /ha)

10) Harvest index (HI)

11) N, B, P, K, S content in seeds (%)

12) Protein content in seeds (%)

13) N, B, P, K, uptake by seeds (kg/ha)

3.14 Methods for Soil Analysis

1) Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method (Bouyoucos, 1927). The textural class was determined using Marshell's Triangular co-ordinate as designated by USDA (1951).

2) Organic carbon (%)

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

3) C/N ratio

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

4) Soil organic matter

Soil organic matter content was calculated by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724 as described by Piper (1942).

% organic matter = % organic carbon × 1.724

5) Soil P^H

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

6) Total nitrogen (%)

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

7) Available boron (ppm)

Available boron (B) content in the soil samples was determined by the method described by Hunter (1984). The extracting agent used was monocalcium phosphate [$CaH_4(Po_4)_2$. H_2O] solution and colour was developed by curcumin solution. The absorbance was read on spectrophotometer at 555 nm wavelengths.

8) Available Phosphorus (ppm)

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

9) Exchangeable Potassium (meq/100 g soil)

Exchangeable potassium (K) content of the soil sample was determined by flame photometer on the NH_4Oac extract (Black, 1965).

10) Available sulphur (ppm)

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

3.15 Methods for Seed Analysis

For determination of N, P, K and B content in seed the sample were first digested with acid and determination of elements in the digest was performed either by titration (for N) or by colorimetric methods (for B). For N, digestion was done with conc. H_2SO_4 and digest was distilled over following the procedure outlined under Soil Analysis section (3.14). While for B, digestion was performed by diacid mixture of HNO_3 and $HclO_4$ in the ratio of 2:1. The amount of these elements in the digest was estimated following the procedure described under Soil Analysis section (3.14).

3.15.1 Protein content in seeds

Protein content in seeds was estimated by multiplying N (%) in seeds with 6.25.

$$\text{Total protein (\%)} = \text{Total N (\%)} \times 6.25.$$

3.16 Statistical Analysis

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

Chapter 4
Results and Discussion

Chapter 4

RESULTS AND DISCUSSIONS

This Chapter includes the experimental results along with discussions. Effects of N and B on plant height, number of branches per plant, number of siliquae per plant, number of seeds per siliqua, weight of 1000-seeds, root dry weight, seed yield, stover yield, biological yield, harvest index, nutrient content and its uptake by seeds, protein content in seeds of mustard are shown in the Tables 3-15. Nutrient status in post harvest soil also presented in Table 16.The results presented in tables are discussed characterwise under the following heads.

4.1 Effect of N and B on growth and yield of mustard

4.1.1 Plant height

Plant height of mustard was significantly increased by different levels of nitrogen (Table 3). The tallest plant (72.23 cm) was produced with 150 kg N/ha which was statistically similar with that of 100 kg N/ha followed by 50 kg N/ha and shortest plant (63.50 cm) was found in control treatment. The increment of plant height due to N application @ 150 kg/ha was 17.3% higher over control plots (N_0). It was observed that plant height increased gradually with the increment of nitrogen doses. This might be due to higher availability of N and their uptake that progressively enhanced the vegetative growth of the plant. These are an agreement with those of Ali *et al.* (1990), Mondal and Gaffer (1983), Gaffer and Razzaque (1983), who have reported that different levels of nitrogen significantly increased plant height. Asaduzzaman and Shamsuddin (1986) have also obtained the similar results.

There was no significant difference among the different levels of boron in respect of plant height (Table 4). But plant height increased with increasing levels of boron up to higher level. The tallest plant (67.07 cm) was produced with 3 kg B/ha and shortest plant (63.50 cm) was found control treatment.

The treatment combinations of nitrogen and boron had significant effect on plant height (Table 5). The tallest plant (73.28 cm) was found in $N_{150}B_3$ treatment. The shortest plant (63.50 cm) was observed in the control treatment. These results revealed that higher dose of nitrogen and boron were influential nutrients for increasing the plant height.

4.1.2 Number of branches per plant

The effect of N on number of primary branches per plant was influenced significantly (Table 3). The highest number of branches per plant (4.33) was recorded from the treatment of 100 kg N /ha, which was significantly different from others treatment except the highest treatment of 150 kg N /ha. Plants in control plots (N_0) produced the lowest number of primary branches /plant (2.33). It is evident from the results that the application of N up to 100 kg/ha increased number of branches per plant. Gaffer and Razzaque (1983) also observed the similar results in mustard.

Boron fertilizer had no significant effect on number of branches /plant (Table 4). But number of branches per plant increased with increasing level of B up to 2 kg B/ha. Further addition of B decreased the number of branches per plant. The highest number of branches per plant (3.33) was recorded from the treatment of 2 kg B /ha and the minimum number of branches per plant (2.33) was produced by 1 kg B/ha and in control treatment.

Interaction effect of N and B on the number of primary branches per plant was found positive (Table 5). Treatment $N_{150}B_2$ produced the maximum number of primary branches per plant (5.00), which was not statistically different from

$N_{100}B_3$, $N_{100}B_0$, and $N_{50}B_3$. The lowest number of branches per plant was obtained from N_0B_1, which was similar with N_0B_0 (Table 5). It was further observed that the treatment $N_{150}B_3$ was identical with $N_{50}B_3$, $N_{100}B_0$, and $N_{100}B_3$.

4.1.3 Number of siliquae per plant

Number of siliquae per plant progressively increased with increasing level of N (Table 3). The highest number of siliquae per plant (139.30) was produced by 150 kg N/ha, which was 99% higher over control (70/plant). Sharawat *et al.*(2002) found maximum no. of siliquae per plant with 120 kg N/ha. Grewal and Kolar (1990) recorded maximum number of siliquae per plant when N was applied at 100 kg /ha which promoted higher seed yield of *Brassica juncea*. These results indicated that higher dose of nitrogen favoured for higher number of siliquae formation.

Number of siliquae per plant was significantly influenced by the application of B up to certain level (Table 4). The highest number of siliquae per plant (73.33) was produced by 2 kg B/ha, which was not statistically different from other treatment except control treatment. The lowest number (68.33) was produced B control treatment. These results are in conformity with those of Islam and Sarker (1993), Dutta and Uddin (1983) and Dutta *et al.* (1984), who have observed increased number of siliquae per plant of mustard by increasing rate of boron.

Interaction effect of N and B on the number of siliquae per plant was significant (Table 5). The the highest number of siliquae per plant (169.7) was found in $N_{150}B_3$ treatment, which was not statistically different from $N_{150}B_2$ and $N_{150}B_1$ treatment. The treatment combination N_0B_0 gave the lowest number of siliquae per plant (68.3), which was statistically similar with the treatment combination N_0B_1, N_0B_2 and N_0B_3. These results revealed that higher higher dose of nitrogen is influential nutrient for producing number of siliquae per plant and boron had no such influence for this character.

Table 3. Effect of N on growth and yield attributes of mustard

Nitrogen levels (kg/ha)	Plant height (cm)	Branches $Plant^{-1}$ (no.)	Siliquae $Plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Root Weight (t/ha)
0 (N_0)	63.50 c	2.33 c	70.00 c	11.00 c	0.17 d
50 (N_{50})	68.17 b	3.33 b	121.30 b	12.33 bc	0.28 c
100 (N_{100})	69.30 ab	4.33 a	130.00 ab	13.67 ab	0.30 b
150 (N_{150})	72.23 a	4.00 a	139.30 a	15.00 a	0.33 a
CV (%)	2.57	8.25	4.32	7.58	7.11
$LSD_{(0.01)}$	3.508*	0.576	10.01	1.97*	0.020

Figure in column, having same letter(s) do not differ significantly at 1% level of significance. *= Significant at 5% level of significance

Table 4. Effect of B on growth and yield attributes of mustard

Boron levels (kg/ha)	Plant height (cm)	Branches $Plant^{-1}$ (no.)	Siliquae $Plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Root weight (t/ha)
0 (B_0)	63.50	2.33	68.3 b	11.0 b	0.17 c
1 (B_1)	63.63	2.33	70.0 ab	12.0 ab	0.18 bc
2 (B_2)	66.53	3.33	73.3 a	13.0 a	0.20 b
3 (B_3)	67.07	2.66	72.3 ab	12.3 ab	0.23 a
CV (%)	4.37	17.21	3.07	5.34	8.84
$LSD_{0.05}$	NS	NS	4.354	1.29	0.020

Figure in column, having same letter(s) do not differ significantly at 5% level of significance. NS = Non significant

4.1.4 Number of seeds per siliqua

There were significant differences among the different levels of N (Table 3). Number of seeds per siliqua gradually increased with increasing levels of nitrogen. The highest number of seeds per siliqua (15) was obtained with the application of 150 kg N/ha, which was not significantly different from the second highest N dose (100 kg N/ha) but was significantly different from other two treatments. The lowest number of seeds per siliqua (11) was produced by control treatment. Mondal and Gaffer (1983) observed that different levels of N had significant effect on number of seeds per siliqua and highest number of seeds per siliqua was produced by 140 kg N/ha. Similar result was also obtained by Sharawat *et al.* (2002), Sen *et al.* (1977) and Allen and Morgan (1972).

The effect of boron on the number of seeds per siliqua was found positive but not significant except control treatment (Table 4). Number of seeds per siliqua gradually increased with increasing level of B up to 2 kg/ha. The highest number of seeds/siliqua (13.00) was obtained with the application of 2 kg B/ha, which was not statistically different from other two treatments except control treatment. The lowest number of seeds/siliqua (11.00) was found in control treatment. Islam and Sarker (1993) also observed that number of seeds per siliqua increased with increasing rate of boron.

The treatment combinations of nitrogen and boron on number of seeds per siliqua were significant (Table 5). The highest no. of seeds /siliqua (16.33) was obtained in $N_{150}B_2$, which was not statistically different from the treatment of $N_{150}B_0$, $N_{150}B_1$, $N_{50}B_1$, $N_{150}B_3$ and $N_{100}B_2$ and the lowest number of seeds per siliqua (11.00) was produced by the control treatment, which was not statistically different from the treatment of N_0B_1, N_0B_2, N_0B_3, $N_{50}B_0$, $N_{50}B_2$ and $N_{100}B_1$.

4.1.5 Root dry weight

Root dry weight of mustard was significantly affected by different levels of N (Table 3). The highest root weight (0.33 t/ha) was produced by 150 kg N/ha, which was significantly different from others. Root dry weight progressively increased with increasing level of N up to higher level. This might be due to better growth character of the plant for higher nitrogen. The minimum root dry weight (0.17 t/ha) was found in control treatment.

The effect of boron on root dry weight was found positive (Table 4). Root dry weight gradually increased with increasing level of B up to higher level. The highest root dry weight (0.23 t/ha) was obtained with the application of 3 kg B /ha, which was significantly different from other treatments. The lowest root dry weight (0.17 t/ha) was found in control treatment. This results also indicate that root dry weight 94% increased due application of B @3 kg/ha over control.

The treatment combination of nitrogen and boron had significant effect on plant root dry weight of mustard (Table 5). The highest root dry weight (0.37 t/ha) was produced by $N_{150}B_3$, which was not statistically different with $N_{150}B_2$, $N_{150}B_1$, $N_{150}B_0$, $N_{100}B_3$ and $N_{100}B_1$. Control treatment N_0B_0 gave the lowest root weight (0.17 t/ha), which was statistically similar with N_0B_1 and N_0B_2. It was observed that the treatment combination of $N_{150}B_0$ was identical with $N_{100}B_1$. It was further observed that interaction of $N_{100}B_2$ was identical with $N_{50}B_3$.

Table 5. Interaction effect of N and B on growth and yield attributes of mustard

Treatment	Plant Height (cm)	Branches Plant^{-1} (No.)	Siliquae Plant^{-1} (No.)	Seeds siliqua^{-1} (No.)	Root weight (t/ha)
N_0B_0	63. 50 e	2.33 e	68.3 g	11.0 e	0.17 h
N_0B_1	63.63 e	2.33 e	70.0 g	12.0 de	0.18 gh
N_0B_2	66.53 d	3.33 cd	73.3 g	13.0 b-e	0.20 gh
N_0B_3	67.07 cd	2.67 de	72.3 g	12.3 cde	0.23 fg
$N_{50}B_0$	68.17 cd	3.67 bc	121.3 de	12.3 cde	0.28 def
$N_{50}B_1$	68.30 cd	3.67 bc	97.3 f	14.0 a-d	0.29 cde
$N_{50}B_2$	68.49 cd	3.33 cd	106.3 ef	12.0 de	0.26 ef
$N_{50}B_3$	68.28 cd	4.33 ab	125.3 de	13.7 bcd	0.30 b-e
$N_{100}B_0$	69.30 bcd	4.33 ab	130.0 cd	13.7 bcd	0.30 b-e
$N_{100}B_1$	69.90 bc	3.67 bc	139.3 cd	13.0 b-e	0.33 a-d
$N_{100}B_2$	68.89 bc	4.00 bc	139.0 cd	14.7 abc	0.30 b-e
$N_{100}B_3$	69.14 bc	4.33 ab	148.3 bc	13.7 bcd	0.35 ab
$N_{150}B_0$	72.23 ab	4.00 bc	139.3 cd	15.0 ab	0.33 a-d
$N_{150}B_1$	72.15 ab	4.00 bc	164.0 ab	14.3 a-d	0.32 a-e
$N_{150}B_2$	72.32 ab	5.00 a	167.0 ab	16.3 a	0.34 abc
$N_{150}B_3$	73.28 a	4.00 bc	169.7 a	14.7 abc	0.37 a
CV (%)	2.43	13.06	9.51	11.25	9.15
$LSD_{0.01}$	2.795	0.803	19.14	2.528*	0.053

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

*= Significant at 5% level of significance

4.1.6. Thousand (1000) seeds Weight

Thousand (1000) seeds weight of mustard was significantly affected by different levels of nitrogen (Table 6). Plant receiving N at the rate of 100 kg/ha produced significantly higher weight of 1000 seeds, which was 7.9% higher over control treatment. Further increment of N, did not affect the seed weight. The lowest weight of 1000 seeds was recorded in N control treatment. Sharawat *et al.* (2002), Mudholkar and Ahlawat (1981) observed such insignificant response of N application on 1000-seeds weight of rapeseed.

Thousand (1000) seeds weight of rapeseed was not significantly affected by different levels of boron (Table 7). In absence of B (B_0) gave the lowest 1000-seeds weight (1.70 g).

The combined effect of N and b on thousand (1000) seeds weight of mustard was significant (Table 8). The treatment combination $N_{100}B_3$ gave the highest 1000-seeds weight (2.33 g), which was statistically similar with $N_{100}B_0$ and $N_{50}B_2$ followed by $N_{100}B_2$. The lowest 1000-seeds weight (1.70 g) was obtained from the N_0B_1 treatment combination, which was not statistically different from N_0B_1 and N_0B_2.

Table 6. Effect of N on yield and yield attributes of mustard

Nitrogen levels (kg/ha)	1000-seeds weight (gm)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
0 (N_0)	1.79 c	0.74 b	1.57 c	2.31 d	0.32 a
50 (N_{50})	1.90 bc	0.89 b	3.03 b	3.91 c	0.23 c
100 (N_{100})	2.30 a	1.62 a	3.34 b	4.96 b	0.33 a
150 (N_{150})	2.05 b	1.54 a	4.55 a	6.09 a	0.25 b
CV (%)	4.86	7.58	14.31	5.88	6.48
$LSD_{0.01}$	0.200	0.155	0.894	0.505	0.020

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

Table 7. Effect of B on yield and yield attributes of mustard

Boron levels (kg/ha)	1000-seeds weight (gm)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
0 (B_0)	1.70	0.74 b	1.57 b	2.31	0.32 b
1 (B_1)	1.90	0.75 b	1.61 b	2.36	0.33 b
2 (B_2)	1.80	0.97 a	1.68 b	2.65	0.37 a
3 (B_3)	1.86	0.85 ab	2.07 a	2.92	0.29 c
CV (%)	6.26	8.69	10.36	12.36	5.04
$LSD_{0.05}$	NS	0.141	0.357	NS	0.020

Figure in column, having same letter(s) do not differ significantly at 5% level of significance. NS = Non significant

4.1.7 Seed Yield (t /ha)

Seed yield was significantly affected by different levels of N (Table 6 and Fig. 3). Seed yield increased with increasing level of N up to 100 kg/ha. Further addition of N above 100 kg/ha decreased seed yield of mustard. The highest seed yield (1.62 t/ha) was obtained in N_{100} treatment, which was significantly 118% higher as compared to the lowest seed yield (0.74 t/ha) in N_0 treatment. The cause of yield increment might be due to higher nitrogen consumption and favorable effect of yield contributing characters of mustard/rapeseed. These results are in conformity with that of Tomer *et al.* (1996), Mondal and Gaffar (1983), Singh and Rathi (1984), Narang and Singh (1985) and Sharawat *et al.* (2002), who have observed increased seed yield of mustard by increasing rate of nitrogen. A similar result was obtained by Shahidullah *et al.* (1996).

Seed yield was significantly affected by different levels of B (Table 7 and Fig. 4). Application of B at the rate of 2 kg/ha produced higher seed yield (0.97 t/ha). Further addition of B beyond 2 kg/ha could not increase seed yield. The lowest seed yield (0.74 t/ha) was produced with control treatment. Sakal *et al.* (1991), Sinha *et al.* (1991), Banuels *et al.* (1990), Islam and Sarker (1993), Juel (1980), Gerath *et al.* (1975) obtained a similar result by applying 1 to 2 kg B/ha. Malewar (2001) found that seed yield significantly increased with each levels of boron.

Different treatment combinations of nitrogen (N) and boron had significant effect on Seed yield (Table 8). The highest seed yield (1.96 t/ha) was recorded in $N_{150}B_2$ treatment, which was 164.9% higher over control (N_0B_0) treatment. The lowest seed yield (0.74 t/ha) was found by the control treatment, which was statistically similar with N_0B_1, N_0B_3, $N_{50}B_0$ and N_0B_2. Without addition of B, the seed yield of mustard increased with every increment in rate of N application up to 100 kg/ha, beyond which at 150 kg/ha created a detrimental effect to reduce the yield by 10.86%. Similar trend was also noted in case of B, where the mustard yield in absence of B, in N_0B_0 treatment was as low as 0.74 t/ha, which increased gradually to 0.75 t/ha in N_0B_1 and 0.97 t/ha in N_0B_2 treatment. Finally the yield declined to 0.85 t/ha under the highest rate of B application in N_0B_3 treatment. Patra (1989) found higher seed yield in soybean due to application of B @2 kg/ha. This results supported the present findings. Thomas (1985) found the highest yield by applying 1 kg B/ha + 220 to 260 kg N/ha. Yang *et al.* (1989) and Saini *et al.* (1985) observed that combined application of N and B increased seed yield.

4.1.8 Stover Yield (t /ha)

Stover yield was significantly increased with increasing levels of N up to higher level (150 kg/ha). Application of 150 kg N/ha produced the highest stover yield (4.55 t/ha) which was significantly different from others treatment of nitrogen (Table 6). It was further observed that 100 kg N/ha produced the second highest stover yield (3.34 t/ha), which was not significantly different from 50 kg N/ha (3.03 t/ha). The lowest stover yield (1.57 t/ha) was obtained in control treatment (N_0). Roy *et al.* (1981) and Kumar and Gangwar (1985) found higher Dry matter and seed yields with 120 kg N/ha irrespective of two *spp.*(*B. juncea* and *B. Campestris*).

The effect of B on stover yield was found positive (Table 7). There was no significant difference among the treatments except B_3 treatment. But stover yield increased with increasing level of B. Application of 3 kg B/ha produced the highest stover yield (2.07 t/ha) which was significantly different from others treatment. It was further observed that 2 kg B/ha produced the second highest stover yield (1.68 t/ha) which was not significantly different from $B_1$and B_0 treatment. These are an agreement with those of Malewar (2001) and Sinha *et al.* (1991), who have reported that the stover yield of mustard increased significantly by boron application. The minimum stover yield (1.57 t/ha) was recorded in control treatment.

The combined effect of N and B on stover yield was significantly influenced (Table 8). The highest stover yield (5.54 t/ha) was produced by the $N_{150}B_2$ treatment, which was statistically similar with $N_{150}B_1$, $N_{150}B_3$ and $N_{100}B_3$. The lowest stover yield (1.57 t/ha) was obtained from control treatment, which was not statistically different from N_0B_1, N_0B_2, and N_0B_3. The combined effect of nitrogen and boron used as 150 kg N/ha and 2 kg B/ha gave the highest stover yield, which was 252.86% higher as compared to control treatment (N_0B_{10}). These results revealed that higher dose of nitrogen is influential nutrient for seed yield and boron had favorable effect for this character. Chatterjee *et al.* (1985) found that application of B along with N promoted dry matter accumulation.

4.1.9 Biological yield (t/ha)

The effect of N on biological yield was found positive (Table 6). Application of N at the rate of 150 kg/ha significantly produced higher biological yield (6.09 t/ha), which was 164% higher over control. The second highest biological yield (4.96 t/ha) was recorded by 100 kg N/ha which was significantly different from the nitrogen level 50 kg/ha and the lowest (2.31 t/ha) was observed in control treatment. It was clear from this study that higher nitrogen dose gave higher biological yield.

Biological yield was not significantly affected by different levels of boron (Table 7). Biological yield increased with increasing level of boron. Application of B at the rate of 3 kg/ha produced higher biological yield (2.92 t/ha) and lowest (2.31 t/ha) was in control treatment.

Biological yield was significantly influenced by combined effect of N and B (Table 8). Application of N (@ of 150 kg/ha) along with B (@ 2 kg/ha) gave the highest biological yield (7.37 t/ha), which was statistically similar with $N_{150}B_3$, $N_{150}B_1$ and $N_{100}B_3$. The lowest biological yield was recorded in control treatment, which was not statistically different from N_0B_1, N_0B_2 and N_0B_3.

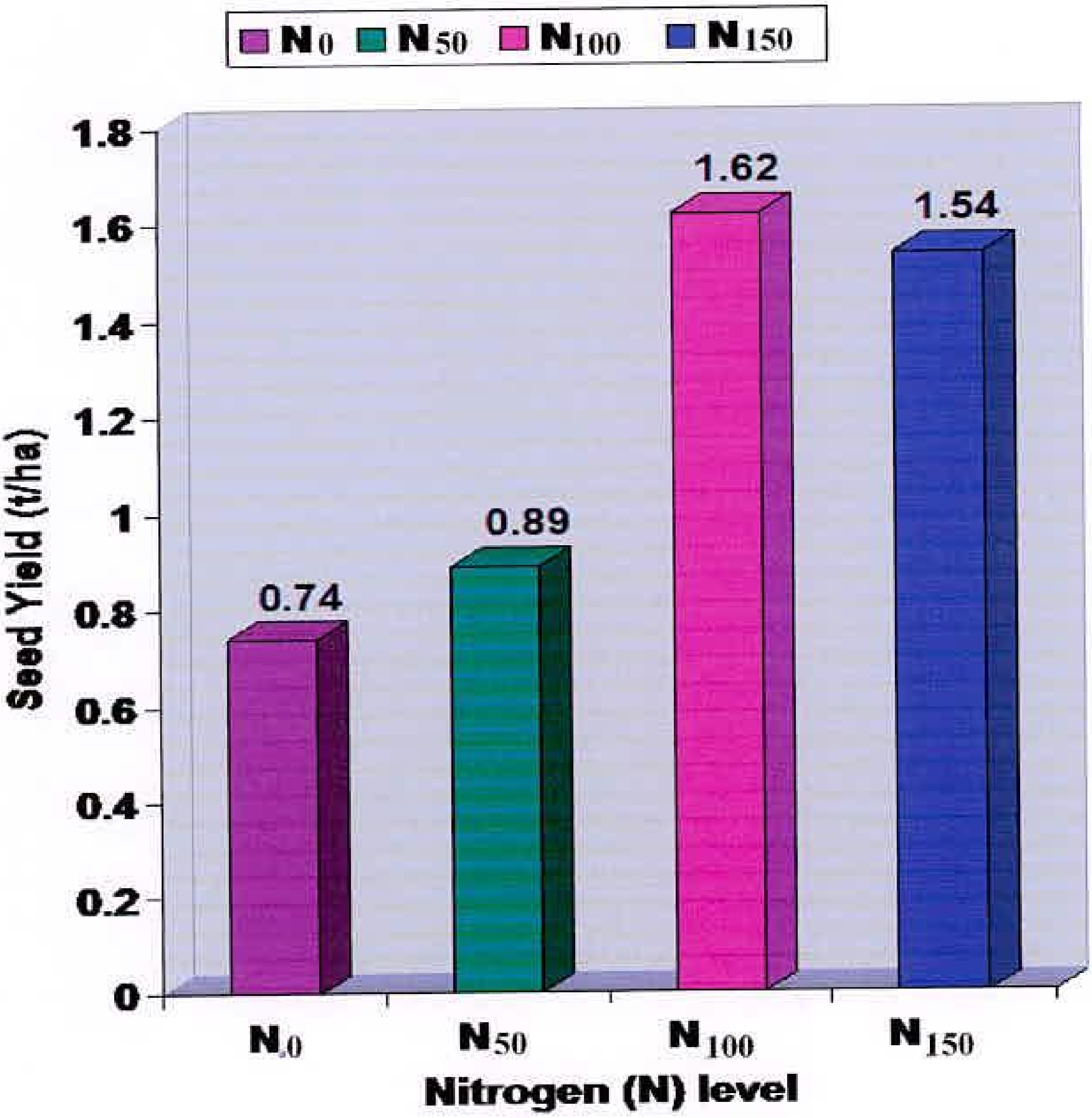

Figure 3. Response of Nitrogen (N) on seed yield of mustard

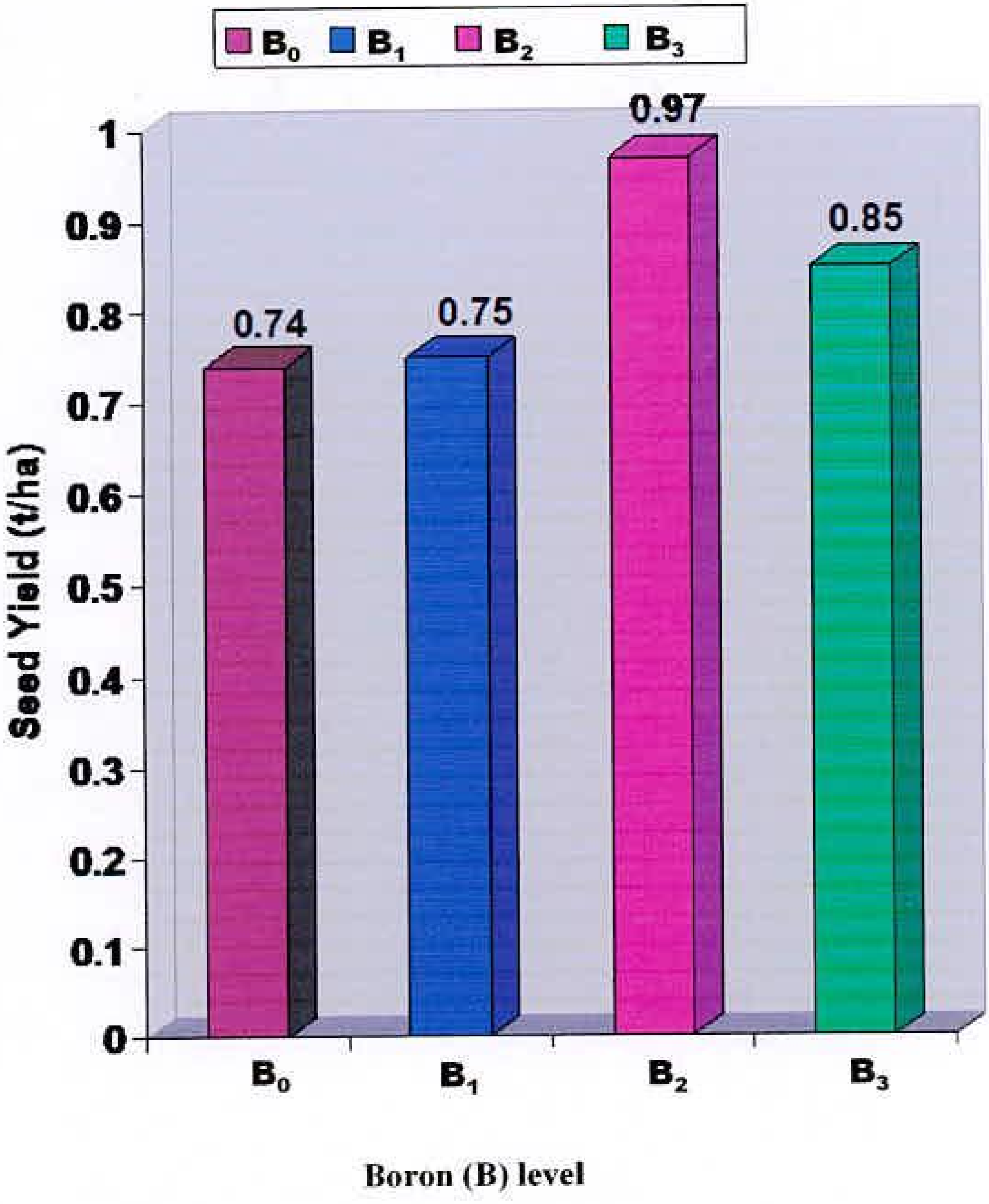

Figure 4. Response of Boron (B) on seed yield of mustard

Table 8. Interaction effect of N and B on yield and yield attributes of mustard

Treatment	1000-seeds weight (gm)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
N_0B_0	1.70 h	0.74 e	1.57 h	2.31 j	0.32 abc
N_0B_1	1.79 gh	0.75 ef	1.61 h	2.36 j	0.32 abc
$N_0 B_2$	1.80 fgh	0.97 e	1.68 h	2.65 j	0.37 a
$N_0 B_3$	1.87 efg	0.85 ef	2.07 gh	2.92 j	0.29 bcd
$N_{50} B_0$	1.90 efg	0.89 ef	3.03 ef	3.91 i	0.23 e
$N_{50}B_1$	1.93 def	1.25 d	2.83 fg	4.08 hi	0.31 bcd
$N_{50}B_2$	2.18 ab	1.44 cd	3.02 ef	4.46 ghi	0.32 ab
$N_{50}B_3$	1.91 efg	1.47 cd	3.71 de	5.18 efg	0.28 b-e
$N_{100}B_0$	2.30 a	1.62 bc	3.34 ef	4.96 fgh	0.33 ab
$N_{100}B_1$	2.05 bcd	1.54 c	4.19 cd	5.73 def	0.27 b-e
$N_{100}B_2$	2.13 b	1.46 cd	4.39 cd	5.85 c-f	0.25 de
$N_{100}B_3$	2.33 a	1.77 ab	4.71 abc	6.48 bcd	0.27 b-e
$N_{150}B_0$	2.05 bcd	1.54 c	4.55 bc	6.09 cde	0.25 de
$N_{150}B_1$	1.98 cde	1.78 ab	5.33 ab	7.11 ab	0.25 de
$N_{150} B_2$	2.07 bc	1.96 a	5.54 a	7.50 a	0.26 cde
$N_{150}B_3$	2.08 bc	1.80 ab	4.90 abc	6.70 abc	0.27 b-e
CV (%)	4.28	9.36	14.18	10.50	10.35
$LSD_{0.01}$	0.140	0.211	0.835	0.857	0.053

Figure in column, having same letter(s) do not differ significantly at 1% level of significance

4.1.10 Harvest index (%)

It was found that nitrogen application had significant effect on harvest index (Table 6). The highest harvest index (.32) was observed from 100 kg N/ha which was not statistically different from the control treatment (N_0). The lowest harvest index (0.23) was found in 50 kg N/ha treated plot. Srivastava *et al.* (1988), Chauhan *et al* (1986) and Bhargava (1991) found a similar result in their experiment.

It was found that boron application had significant effect on harvest index (Table 7). The highest harvest index (0.37) was observed from 2 kg B/ha which was statistically significant from others. The lowest harvest index (29.00) was found in 3 kg B/ha. Mahajan *et al.* (1994) found higher harvest index due to B application.

It was found that interaction of nitrogen and boron had significant effect on harvest index (Table 8). The highest harvest index (0.37) was observed from N_0B_2, which was identical with $N_{100}B_0$, $N_{50}B_2$, N_0B_1 and control treatment. The lowest harvest index (0.23) was found with $N_{50}B_0$, which was statistically similar with most of the other treatment combinations.

4.2 Effects of N and B on nutrient content and it's uptake by mustard seeds

4.2.1 Nitrogen content in seeds

Data on N content in seeds was influenced by N fertilization. The effect of N on N content of seeds was found positive and significant (Table 9). The average N content in seed increased linearly from 2.92% observed in control to 3.60% in N_{150} treatment. The highest N was found in N_{150}, which was statistically similar with N_{100}. The lowest concentration of seed-N was in control treatment. The result revealed that nitrogen content in seed was increased with increasing rate of nitrogen.

Nitrogen content in seed was significantly increased with increasing level of B up to higher level (Table 10). The N content in seed ranged from 2.92% observed in control to 3.05% recorded in B_3 treatment. The highest concentration of N obtained with B_3 treatment, which was statistically similar with B_2 and B_1 treatments. The lowest concentration of seed-N was in control treatment. Mahajan *et al.* (1994) observed that application of B (0.5 kg/ha) increased N concentration over control.

The combined effect of N and B on N content in seed was significant (Table 11). The N content in seed ranged from 2.92% observed in control to 3.85% in $N_{150}B_2$ treatment. The highest concentration of N obtained with $N_{150}B_2$ treatment, which was statistically similar with $N_{150}B_3$ treatment. The minimum seed-N content was found in control, which was statistically identical with N_0B_1, N_0B_2 and N_0B_3 treatment.

4.2.2 Boron content in seeds

There was no significant difference among the different treatments of N in respect of B content in seed (Table 9). Maximum B content of 0.397% was found in N_{100} treatment. Further addition of N decreased B content in seed. Minimum B content in seed was recorded in N_0 treatment.

There was significant difference among the different treatments of B except control (Table 10). The B content in seed ranged from 0.0347% observed in control to 0.0417% in B_3. The highest B concentration (0.0417%) was observed in B_3, which was not significantly different from B_2 and B_1. The result showed that seed-B content was increased with increasing rate of boron. Chakravarty *et al.* (1979) found a similar result in his research. A same trend was found by Yadav and Manchandra (1982), Dutta *et al.* (1984) and Yang *et al.* (1989).

The combined effect of Nitrogen and boron on B content in seeds was significant (Table 11). Boron content in seed was ranged from 0.0347% to 0.0433%. The maximum boron content in seed was found in $N_{50}B_3$ treatment, which was significantly identical with N_0B_3, $N_{50}B_0$, $N_{50}B_1$, $N_{50}B_2$, $N_{100}B_0$, $N_{100}B_1$and $N_{100}B_2$ and the minimum B-content (0.0347%) was found in control.

Table 9. Effect of N on nutrient content in seeds of mustard

Nitrogen levels (kg/ha)	Nutrient content in seeds (%)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
0 (N_0)	2.92 c	0.0347	0.553 a	0.707 b	0.989 d
50 (N_{50})	3.18 b	0.0390	0.517 c	0.707 b	1.016 c
100 (N_{100})	3.54 a	0.0397	0.490 d	0.717 a	1.078 a
150 (N_{150})	3.60 a	0.0363	0.530 b	0.717 a	1.043 b
CV (%)	3.29	3.05	3.21	1.07	0.10
$LSD_{0.05}$	0.219	NS	0.006	0.006	0.006**

Figure in column, having same letter(s) do not differ significantly at 5% level of significance.

** = Significant at 1% level of significance, NS = Non significant

Table 10. Effect of B on nutrient content in seeds of mustard

Boron levels (kg/ha)	Nutrient content in seeds (%)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
0 (B_0)	2.92 c	0.0347 b	0.553	0.707 b	0.989 a
1 (B_1)	2.94 a	0.0357 ab	0.537	0.713 a	0.983 a
2 (B_2)	2.95 a	0.0367 ab	0.533	0.713 a	0.958 b
3 (B_3)	3.05 a	0.0417 a	0.523	0.710 ab	0.954 b
CV (%)	2.72	1.55	6.43	1.12	0.05
$LSD_{0.05}$	0.167	0.006**	NS	0.006	0.006

Figure in column, having same letter(s) do not differ significantly at 5% level of significance.

**= Significant at 1% level of significance, NS = Non significant

4.2.3 Phosphorus content in seeds

Phosphorus content in seed had no positive effect by different nitrogen level (Table 9). The highest p content in seed (0.553%) was found in control treatment, which was significantly different from all other treatment and lowest P-content (0.490%) was found with N_{100}. The second highest P-content was obtained from the nitrogen level N_{150}, significantly different from highest and lowest N-level.

Phosphorus content in seed was not significantly affected by different boron level (Table 10). The highest p content in seed (0.553%) was found in control treatment and lowest P-content (0.523%) was found with B_3. The second highest P-content was obtained from the boron level B_1. The result revealed that seed-P content was decreased with increasing rate of boron. Mahajan *et al.* (1994) reported that P content increased due to B (0.5 kg/ha) application.

The treatment combinations of nitrogen and boron significantly influenced the phosphorus content in seed (Table 11). The phosphorus content in seed was ranged from 0.43%, observed in $N_{150}B_2$ to 0.65% found in $N_{50}B_3$. The highest P content (0.65%) in seed was obtained from the treatment $N_{50}B_3$, which was significantly different from all other treatment combinations and the lowest one (0.043%) was obtained from $N_{150}B_2$, which was identical with $N_{150}B_1$, $N_{100}B_3$, $N_{100}B_2$ and $N_{100}B_1$. Individually, P-content was decreased with increasing rate of boron and nitrogen had same effect up to 100 kg N/ha.

Table 11. Interaction effect of N and B on nutrient content in seeds of mustard

	Nutrient content in seeds (%)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
N_0B_0	2.92 h	0.0347 c	0.55 b	0.707 b	0.99 de
N_0B_1	2.94 h	0.0357 bc	0.54 bc	0.713 b	0.98 e
N_0B_2	2.95 h	0.0367 bc	0.53 bc	0.713 b	0.96 f
N_0B_3	3.05 gh	0.0417 ab	0.52 bcd	0.710 b	0.95 f
$N_{50}B_0$	3.18 fg	0.0397 abc	0.52 bcd	0.707 b	1.02 c
$N_{50}B_1$	3.28 ef	0.0387 abc	0.48 cde	0.707 b	0.98 e
$N_{50}B_2$	3.45 cd	0.0400 abc	0.53 bcd	0.707 b	1.02 c
$N_{50}B_3$	3.48 cd	0.0433 a	0.65 a	0.707 b	1.01 c
$N_{100}B_0$	3.54 bcd	0.0390 abc	0.49 cde	0.717 b	1.08 a
$N_{100}B_1$	3.30 ef	0.0403 abc	0.45 e	0.713 b	1.02 c
$N_{100}B_2$	3.41 de	0.0377 abc	0.48 cde	0.707 b	0.99 de
$N_{100}B_3$	3.52 bcd	0.0363 bc	0.47 de	0.747 a	1.04 b
$N_{150}B_0$	3.60 bc	0.0363 bc	0.53 bcd	0.717 b	1.04 b
$N_{150}B_1$	3.66 b	0.0360 bc	0.47 de	0.717 b	1.09 a
$N_{150}B_2$	3.85 a	0.0367 bc	0.43 e	0.717 b	0.98 e
$N_{150}B_3$	3.83 a	0.0363 bc	0.54 bc	0.720 b	1.00 cd
CV (%)	2.47	2.68	5.70	1.09	0.17
$LSD_{0.01}$	0.140	0.005	0.053	0.017	0.017

Figure in column, having same letter(s) do not differ significantly at1% level of significance.

4.2.4 Potassium content in seeds

Potassium (K) content in seed was affected by different N treatments (Table 9). The highest K content in seed (0.717%) was found in N_{100} treatment, which was similar as N_{150} and the lowest seed-K content (0.707%) was found in N_{50} treatment, which was similar with control.

It was observed that K content in seed increased with increasing level of B up to 1 kg/ha (Table 10). The highest seed-K content (0.713%) was found in B_1, which was similar with B_2 and was identical with B_3. The lowest seed-K content (0.707%) was found in the control.

Potassium (K) content in seed was significantly affected by the combined effect of nitrogen and boron (Table 11). The treatment combination $N_{100}B_3$ gave the highest K content in seed (0.747%), which was significantly different from the others and the second highest K content (0.720%) was obtained from $N_{150}B_3$ treatment, which was identical with other treatment combinations. The lowest K content in seed (0.707%) was found in control.

4.2.5 Sulphur content in seeds

Data on S content in seed was influenced by N fertilizer (Table 9). S content in seed ranged from 0.989% observed in control to 1.078% recorded in N_{100} treatment. Sulphur content in seed increased with increasing level of N up to 100 kg/ha. Highest S content was found in N_{100} treatment, which was significantly different from other treatments. The lowest S content (0.989%) was found in control treatment.

Sulphur content in seed decreased with increasing level of B (Table 10). It was found that boron had significant effect on seed-S content. Sulphur content in seed ranged from 0.989% observed in control to 0.854% in B_3. The highest S-content was found in control, which was identical with B_1. The lowest S content (0.854%) was found in B_3, which was similar with B_2. The result showed that seed-S content was decreased with increasing rate of boron.

The Interaction effect of Nitrogen and boron on S content in seed was significantly influenced (Table 11). Sulphur content in seed was ranged from 0.095% to 1.090%. The maximum sulphur content (1.090%) in seed was found in $N_{150}B_1$ treatment, which was significantly similar with $N_{100}B_0$ treatment and the minimum sulphur content (0.095%) was observed in N_0B_3, which was identical with N_0B_2 treatment.

4.2.6 Nitrogen uptake by seeds

Data on N uptake by seeds was influenced by N fertilization. The effect of N on N uptake by seeds was found positive and significant (Table 12). The N uptake by seed ranged from 21.61 kg/ha observed in control treatment to 57.35 kg/ha recorded in N_{100}. The highest N uptake by seeds was found in N_{100} and lowest N uptake by seeds was observed in control treatment. The result revealed that nitrogen uptake by seeds was increased with increasing rate of nitrogen up to 100 kg/ha. Further addition of nitrogen decreased N uptake by seeds.

Nitrogen uptake by seeds was significantly increased with increasing level of B up to 2 kg/ha (Table 13). The N uptake by seeds ranged from 21.61 kg/ha observed in control to 28.62 kg/ha with the application of B @ 2 kg/ha. The highest N uptake obtained from 2 kg B/ha and lowest N uptake by seeds was found in control treatment. Addition of B above 2 kg/ha decreased N uptake by seeds.

The combined effect of N and B on N uptake by seeds was significant (Table 14). The N uptake by seeds ranged from 21.61 kg/ha observed in control to 75.46 kg/ah recorded in $N_{150}B_2$ treatment. The highest N obtained with $N_{150}B_2$ treatment, which was significantly different with other treatment combinations. The minimum N uptake by seeds was found in control, which was statistically identical with N_0B_1 treatment.

4.2.7 Boron uptake by seeds

There was significant difference among the different treatments of N in respect of B uptake by seeds (Table 12). Boron (B) uptake by seeds (0.632 kg/ha) was significantly increased with increasing level of B up to 1 kg/ha. Further addition of N decreased B uptake by seeds. Minimum B uptake by seeds (0.257 kg/ha) was recorded in N_0 treatment.

There was significant difference among the B treatments in respect of B uptake by seeds except control (Table 13). The B uptake by seeds ranged from 0.257 kg/ha to 0.356 kg/ha. Boron uptake significantly increased with increasing level of B. Application of B @ 3 kg/ha produced the highest B uptake by seeds (0.356 kg/ha), which was not significantly different from the application of B @ 2 kg/ha.

The combined effect of Nitrogen and boron was significant on B uptake by seeds (Table 14). Boron uptake by seeds was ranged from 0.257 kg/ha to 0.72 kg/ha. The maximum boron uptake by seeds was found in $N_{50}B_2$ treatment, which was significantly different with other treatments and the minimum B uptake by seeds (0.257 kg/ha) was found in control treatment. Both of the two nutrients individually and combinedly have favoured in significant increase N accumulation in seeds.

Table 12. Effect of N on nutrient uptake by seeds of mustard

Nitrogen levels (kg/ha)	Nutrient uptake by seeds (kg/ha)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
0 (N_0)	21.61 d	0.257 c	4.09 d	5.30 d	7.32 d
50 (N_{50})	28.30 c	0.320 c	4.60 c	6.29 c	9.04 c
100 (N_{100})	57.35 a	0.632 a	7.94 b	11.62 a	17.46 a
150 (N_{150})	55.44 b	0.559 b	8.16 a	11.04 b	15.79 b
CV (%)	1.57	5.99	1.13	1.21	2.32
$LSD_{0.01}$	1.280	0.063	0.141	0.210	0.576

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

Table 13. Effect of B on nutrient uptake by seeds of mustard

Boron levels (kg/ha)	Nutrient uptake by seeds (kg/ha)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
0 (B_0)	21.61 c	0.257 b	4.09 bc	5.30 c	7.32 c
1 (B_1)	22.05 c	0.268 b	4.03 c	5.35 c	7.37 c
2 (B_2)	28.62 a	0.354 a	5.17 a	6.92 a	9.29 a
3 (B_3)	25.93 b	0.356 a	4.45 b	6.04 b	8.11 b
CV (%)	1.47	2.14	4.29	2.79	2.68
$LSD_{0.01}$	0.721	0.020	0.379	0.328	0.429

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

4.2.8 Phosphorus uptake by seeds

Phosphorus uptake by seeds affected positively by different nitrogen level (Table 12). Phosphorus uptake by seeds increased with increasing level of N up to higher level. Application of N @ 150 kg/ha accumulates the higher P in seeds and the lowest uptake by seeds (4.09 kg/ha) was found in control treatment. The second highest P uptake by seeds was obtained from the application of nitrogen @ 100 kg/ha, which was significantly different from highest and lowest N-level.

Phosphorus uptake by seeds was significantly affected by different boron level (Table 13). The highest p uptake by seeds (5.17 kg/ha) was found in B_2 treatment (@ 2 kg B/ha) and lowest P uptake by seeds (4.03 kg/ha) was found with B_1 treatment (@1 kg B/ha). The second highest P uptake by seeds (4.45 kg/ha) was obtained from the boron level B_3 (@ 3 kg B/ha), which was identical with control treatment. Mahajan *et al.* (1994) observed that P uptake by ground nut significantly increased due to B (0.5 kg/ha) application.

The treatment combinations of nitrogen and boron significantly influenced the phosphorus uptake by seeds (Table 14). Phosphorus uptake by seeds was ranged from 4.03 kg/ha, observed in N_0B_1 to 9.72 kg/ha, found in $N_{150}B_3$. The highest P uptake by seeds (9.72 kg/ha) was obtained from the treatment $N_{150}B_3$, which was significantly different from all other treatment combinations and the lowest one (4.03 kg/ha) was obtained from N_0B_1, which was identical with $N_{50}B_0$, N_0B_3, N_0B_2 and control treatment.

Table 14. Interaction effect of N & B on nutrient uptake by seeds of mustard

Treatments	Nutrient uptake by seeds (kg/ha)				
	Nitrogen	Boron	Phosphorus	Potassium	Sulphur
N_0B_0	21.61 i	0.257 h	4.09 f	5.30 f	7.32 g
N_0B_1	22.05 i	0.268 gh	4.03 f	5.35 f	7.37 g
N_0B_2	28.62 h	0.354 f	5.17 ef	6.92 def	9.29 f
N_0B_3	25.93 h	0.356 f	4.45 f	6.04 f	8.11 fg
$N_{50}B_0$	28.30 h	0.353 fg	4.60 ef	6.29 ef	9.04 f
$N_{50}B_1$	41.00 g	0.480 e	6.00 de	8.84 c-f	12.25 f
$N_{50}B_2$	49.68 f	0.580 cd	7.60 c	10.18 bcd	14.69 d
$N_{50}B_3$	57.16 f	0.64 b	9.56 ab	10.39 bcd	14.85 e
$N_{100}B_0$	57.35 e	0.632 bc	7.94 c	11.62 abc	17.46 c
$N_{100}B_1$	50.82 f	0.620 bc	6.93 cd	10.98 abc	15.71 d
$N_{100}B_2$	49.79 f	0.550 d	7.01 cd	10.32 bcd	14.45 d
$N_{100}B_3$	62.30 d	0.640 b	8.32 abc	13.22 b-e	18.40 bc
$N_{150}B_0$	55.44 e	0.559 d	8.16 bc	11.04 abc	16.06 d
$N_{150}B_1$	65.15 c	0.640 b	8.37 abc	12.76 ab	19.20 ab
$N_{150}B_2$	75.46 a	0.720 a	8.43 abc	14.05 a	19.40 a
$N_{150}B_3$	68.95 b	0.650 b	9.72 a	12.96 ab	18.00 bc
CV (%)	3.46	6.12	11.79	19.92	6.20
$LSD_{0.01}$	2.715	0.053	1.357	3.167	1.437

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

4.2.9 Potassium uptake by seed

Effect of N on K uptake by seeds was significantly affected by N treatments (Table 12). Potassium uptake by seeds due to different level of N application ranged from 5.30 kg/ha to 11.62 kg/ha. Application of N @ 100 kg/ha accumulates 119% higher N in seeds over control treatment (without N fertilization).

Potassium uptake by seeds was also significantly influenced by different B level (Table 13). The highest K uptake by seeds (6.92 kg/ha) was found with the B @ 2 kg/ha application, which was significant with other treatments. The lowest K uptake by seeds (5.30 kg/ha) was found in control treatment, which was statistically similar with the application of B @ 1 kg/ha.

Potassium (K) uptake by seeds was significantly affected by the combined effect of nitrogen and boron (Table 14). The treatment combination $N_{150}B_2$ gave the highest K uptake by seeds (14.05 kg/ha), which was not significantly different from $N_{150}B_3$, $N_{150}B_1$, $N_{150}B_0$, $N_{100}B_1$ and $N_{100}B_0$ treatments. The lowest K uptake by seeds (5.30 kg/ha) was found in control treatment (N_0B_0).

4.2.10 Sulphur uptake by seeds

Data on S uptake by seeds was influenced by different level of N (Table 12). S uptake by seeds ranged from 7.32 kg/ha observed in control to 17.46 kg/ha recorded with the application of N @ 100 kg/ha. Sulphur uptake by seeds increased with increasing level of N up to 100 kg/ha. Further addition of N decreased S uptake by seeds. The lowest S uptake by seeds (7.32 kg/ha) was found in control treatment.

Sulphur uptake by seeds was also influenced by different levels of B (Table 13). Sulphur uptake by seeds ranged from 7.32 kg/ha to 9.29 kg/ha. The highest S uptake by seeds was found with the application of B @ 2 kg/ha, which was significant with other treatments. The lowest S uptake by seeds (7.32 kg/ha) was found in control treatment, which was similar with B_1 treatment (application of B @1 kg/ha).

Interaction effect of Nitrogen and boron on S uptake by seeds was significantly influenced (Table 14). Sulphur uptake by seeds was ranged from 7.32 kg/ha to 19.40 kg/ha. The maximum sulphur uptake by seeds (19.40 kg/ha) was found in $N_{150}B_2$ treatment, which was identical with $N_{150}B_1$ treatment and the minimum sulphur uptake by seeds (7.32 kg/ha) was observed in control, which was identical with N_0B_1 and N_0B_3 treatment

4.3 Effect of N and B on protein content in seeds of mustard

Protein content in seeds of mustard was significantly influenced by the effect of N and B (Table 15). The trend of variation in protein content was similar to that of N content because protein content was computed directly from the values of N content in seeds. As before the highest protein content of 24% was recorded in $N_{150}B_2$ being followed by $N_{150}B_3$ (23.9%) treatment having the lowest value of 18.25% in N_0B_0 treatment. Plant receiving N (@ 150 kg/ha) and B (@ 2 kg/ha) accumulated significantly 24.15% higher protein content in seeds as compared to control treatment (N_0B_0). Protein content reduced remarkably in absence of either of the two nutrients (N and B). Even with the minimum dose of any one of the nutrient has led to increased protein content and attained the highest range.

These information reflect that nitrogen and protein content in seeds of mustard may be raised to the satisfactory level by addition of even minimum dose of N and B. Mahajan *et al.* (1994) reported that protein content increased with increasing levels of B application.

Table 15. Effect of N and B on protein content in seeds of mustard

Treatments	Protein content in seeds (%)	% increase protein content (over control)
N_0B_0	18.25 f	–
N_0B_1	18.38 f	0.71
N_0B_2	18.44 f	1.03
N_0B_3	19.06 ef	4.25
$N_{50}B_0$	19.88 def	8.20
$N_{50}B_1$	20.50 c-f	10.98
$N_{50}B_2$	21.56 bcd	15.35
$N_{50}B_3$	21.75 a-d	16.09
$N_{100}B_0$	22.13 a-d	17.53
$N_{100}B_1$	20.63 c-f	11.54
$N_{100}B_2$	21.31 cde	14.36
$N_{100}B_3$	22.00 a-d	16.81
$N_{150}B_0$	22.50 abc	18.88
$N_{150}B_1$	22.88 abc	20.25
$N_{150}B_2$	24.00 a	24.15
$N_{150}B_3$	23.90 ab	23.75
CV (%)	6.02	–
$LSD_{0.01}$	2.117	–

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

4.4 Nutrient status of post harvest soil

Macro nutrients (N, P, K and S) content in post harvest soil as influenced by different treatments is presented in Table 16. Results showed a marked variation on the N, P, K and S content in the post harvest soil values due to addition of nutrients in soil and their uptake by crops.

Table 16. Effect of N and B on nutrient status of post harvest soil

Treatments	Total nitrogen (%)	Available Phosphorus (ppm)	Exchangeable Potassium (meq/100g soil)	Available Sulphur (ppm)
N_0B_0	0.0760 efg	53.33 a	0.307 a	16.00 a
N_0B_1	0.0753 efg	45.00 a-d	0.280 a-d	14.67 ab
N_0B_2	0.0737 fgh	48.33 a-d	0.283 abc	14.33 abc
N_0B_3	0.0683 hi	48.67 a-d	0.293 ab	14.00 a-d
$N_{50}B_0$	0.0800 cde	45.67 a-d	0.243 a-e	13.33 b-e
$N_{50}B_1$	0.0877 ab	52.33 a	0.277 a-e	14.00 a-d
$N_{50}B_2$	0.0773 d-g	51.67 ab	0.237 a-e	13.33 b-e
$N_{50}B_3$	0.0747 efg	46.33 a-d	0.273 a-e	12.67 b-e
$N_{100}B_0$	0.0640 i	39.33 d	0.210 b-e	12.67 b-e
$N_{100}B_1$	0.0797 c-f	48.00 a-d	0.250 a-e	14.00 a-d
$N_{100}B_2$	0.0887 a	49.67 abc	0.230 a-e	12.67 b-e
$N_{100}B_3$	0.0743 efg	42.00 bcd	0.200 cde	11.67 de
$N_{150}B_0$	0.0827 bcd	46.33 a-d	0.253 a-e	12.00 cde
$N_{150}B_1$	0.0730 gh	40.00 cd	0.190 e	11.00 e
$N_{150}B_2$	0.0843 abc	44.00 a-d	0.203 cde	11.33 e
$N_{150}B_3$	0.0803 cde	40.00 cd	0.193 de	11.67 de
CV (%)	8.30	11.18	17.30	9.55
$LSD_{0.01}$	0.005	8.631*	0.075*	2.085
Initial soil	**0.08**	**35.00**	**0.18**	**40.00**

Figure in column, having same letter(s) do not differ significantly at 1% level of significance.

* = Significant at 5% level of significance

The total N content of the post harvest soil varied from 0.0640% to 0.0887% (Table 16). The highest total N content (0.0887%) was observed in $N_{100}B_2$ treatment being closely followed by $N_{50}B_1$ (0.877%) and $N_{150}B_2$ (0.084%), which was statistically identical having the lowest value of 0.064% in N_0B_0.

The P content in post harvest soils ranged from 39.33 to 53.33 ppm (Table 16). The highest P content was recorded in N_0B_0 treatment (53.33ppm) and the lowest P content was found in the treatment $N_{100}B_0$. These results indicate that the absence of N and B, phosphorus uptake by plant may be decreased as well as lowest yield was found in N_0B_0 treatment.

The K content of post harvest soils varied from 0.190 to 0.307 meq/100g soil (Table 16).The highest K content (0.307 meq/100g soil) was observed in control treatment N_0B_0, which was not statistically identical to most of other treatments and the lowest K content was recorded in $N_{150}B_1$ treatment.

Available S content of post harvest soils influenced significantly due to different treatments (Table 16). The maximum S content (16.00 ppm) was observed in control treatment and the lowest S content (11.00 ppm) was observed in $N_{150}B_1$ treatment.

Chapter 5

Summary and Conclusion

Chapter 5
SUMMARY AND CONCLUSION

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2005 to February 2006 to study the effects of nitrogen and boron on growth and yield of mustard cv. Tori-7. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. The unit plot size was 3 m^2 (2.0 m x 1.5 m). There were 16 treatments combinations in the experiment comprising 4 levels of N (0, 50, 100 & 150 kg/ha designated as N_0, N_{50}, N_{100} & N_{150}, respectively) and 4 levels of B (0, 1, 2 &3 kg/ha designated as B_0, B_1, B_2 & B_3, respectively). The individual and combined effects of nitrogen (N) and boron (B) on growth, yield and nutrient uptake by seeds of mustard were studied.

Data on plant characters were recorded at harvesting stage. Nitrogen and Boron fertilization at different levels individually influenced plant characters. The individual and interaction effect of N and B on growth, yield and nutrient content was found positive.

Plant height was significantly affected by different level of N and B. The tallest plant (73.28 cm) was found in $N_{150}B_3$ treatment, which was 15.4% higher over control treatment (63.50 cm). This result indicate that higher dose of N and B produced the tallest plants. Plant height also increased with increasing level of N and B individually. The individual application of N @150 kg/ha produced the tallest plant (72.23 cm), whereas application of B @ 3 kg/ha produced the tallest plant of 67.07 cm height. Plant height increased 7.69% higher due to application of N @ 150 kg/ha over boron fertilization (@ 3 kg/ha).

The individual application of N and B had positive effect on the number of branches per plant, number of siliquae per plant, number of seeds per siliqua, root dry weight, weight of 1000 seeds, stover yield, seed yield and biological yield. All the plant characters increased with increasing level of N and B up to higher level except number of branches per plant, 1000 seeds weight, seed yield, number of siliquae per plant and number of seeds per siliqua, respectively. Application of N @ 150 kg/ha produced the highest number of siliqua (139.30/plant), number of seeds (15/siliqua), Root dry weight (0.33 t/ha), Stover yield (4.55 t/ha) and biological yield (6.09 t/ha). But the highest grain yield (1.62 t/ha), dry weight of 1000 seeds (2.3 g), number of branches (4.33/plant) was found with the application of N @ 100 kg/ha.

The highest number of branches (3.33/plant), number of siliqua (73.3/plant), number of seeds (13.0/siliqua) and seed yield was recorded with application of B @ 2 kg/ha. But at higher doses of boron @ 3 kg/ha produced the maximum root weight (0.23 t/ha), weight of 1000 seeds (1.86 g), stover yield (2.07 t/ha) and biological yield (2.92 t/ha). The combined effect N and B on growth and yield attributes of mustard was significant. The highest number of branches (5/plant), number of seeds (16.3/siliqua), stover yield (5.54 t/ha), biological yield (7.5 t/ha) and seed yield (1.96 t/ha) was recorded in $N_{150}B_2$ treatment and the lowest was recorded yield N_0B_0 treatment. The highest number of siliquae (169.7/plant), Root weight (0.37 t/ha), was observed in $N_{150}B_3$ treatment.

Nutrient contents (N, P, K and S) in seed were positively affected due to N and B fertilization. The interaction effect of N & B was also found remarkable. The N, B, P, K and S content in seeds varied from 2.92% was recorded in N_0B_0 treatment to 3.85% was recorded in $N_{150}B_2$ treatment, 0.0347% was recorded in N_0B_0 treatment to 0.0433% in $N_{50}B_3$ treatment, 0.43% was recorded in $N_{150}B_2$ treatment to 0.65% in $N_{50}B_3$ treatment, 0.707% was noted in N_0B_0 treatment to 0.747% in $N_{100}B_3$ and 0.95% in N_0B_3 to 1.08 in $N_{100}B_0$ treatment, respectively. Nitrogen (N), K, B and S content in seeds increased with increasing level of N up to certain level. The highest N content in seeds (3.6%) due to application of N at higher level (@ 150 kg/ha). Potassium (K) and B content in seeds significantly increased with increasing level of N up to 100 kg/ha and then decreased.

Nitrogen and B content in seed increased with increasing level of B up to 3 kg/ha. But S and P content decreased with increasing level of B. The highest S content in seeds (0.989%) was accumulated in control treatment. The combined effect of N and B on nutrients content in seeds was significant. The highest N, B, P, K and S were recorded $N_{150}B_2$, $N_{50}B_3$, $N_{50}B_3$, $N_{100}B_3$ and $N_{150}B_1$ treatments, respectively.

Nutrients uptake by seeds was also affected by N and B fertilization. Nutrients uptake by seeds increased with increasing level of N up to 100 kg/ha except P. Nutrients uptake by seeds increased with increasing level of B up to 2 kg/ha except B uptake. Boron uptake increased with increasing level of B up to higher level. The highest boron uptake by seeds (0.356 kg/ha) was recorded with the application of B @ 3 kg/ha, which was 38.5% higher as compared to control. The combined effect of N and B on nutrient uptake by seeds was significant. The maximum uptake of N (75.46 kg/ha), B (0.72 kg/ha), K (14.05 kg/ha) and S (19.41 kg/ha) was found in $N_{150}B_2$ treatment and P (9.72 kg/ha) in $N_{150}B_3$. The minimum nutrient (N, P, K, S and B) was recorded in N_0B_0 treatment. From findings it may be concluded that application of N and B accumulates higher amount of nutrient as compared to single application of N or B.

Nutrient content in post harvest soil was also influenced by different level of N and B application. The total N, available B, exchangeable K and available S of post harvest soil varied from 0.064 to 0.0887%, 39.33 to 53.33ppm, 0.19 to 0.307meq/100 g soil and 11to 16ppm, respectively due to combined application of N and B at different level. The addition of N and B not only increased the yield but also protect the soil from total exhaustion of nutrients and protein content in seeds of mustard was significantly increased due to application of N and B. The trend of variation in protein content was similar to that of N content because protein content was calculated directly from the values of N content in seeds. The range of protein content in seeds varied from 18.25% in N_0B_0 to 24.00% in $N_{150}B_2$ treatment. Application of N @ 150 kg/ha and B @ 2 kg/ha produced 31.8% higher protein content in seeds as compared to control treatment (N_0B_0).

Like all other plant characters, seed yield of mustard was influenced significantly due to application of N and B. Seed yield increased with increasing level of N and B up to certain level. The highest seed yield (1.62 t/ha) was found in plants receiving N @ 100 kg/ha and the lowest was recorded in N control treatment. The individual application of B @ 2 kg/ha produced the highest amount of seed yield (0.97 t/ha). Further addition of N or B has led to decrease the yield. The combined application of N and B had positive effect on seed yield of mustard. The highest seed yield of mustard was recorded in $N_{150}B_2$ treatment followed by $N_{150}B_3$, $N_{150}B_1$ and $N_{100}B_3$, which was statistically identical with each other. The lowest yield was recorded in N_0B_0 treatment. Application of N @ 150 kg/ha and B @ 2 kg/ha produced 165% higher seed yield as compared to control treatment significantly.

From the present study, the following conclusion may be drawn –

- Individual effect of N and B on growth and yield of mustard was found positive and significant.
- Protein content in seeds increased with increasing level of N and B up to certain level.
- The combined effect of N and B enhanced growth, yield and yield attributes of mustard.
- Application of N @ 150 kg/ha and B @ 2 kg/ha was the most suitable combination to give the highest yield of mustard in Deep Red Brown Terrace Soils under Tejgaon series of Bangladesh.

Further research works at different regions of the country are needed to be carried out for the confirmation of the present findings.

Chapter 6
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Chapter 6

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APPENDICES

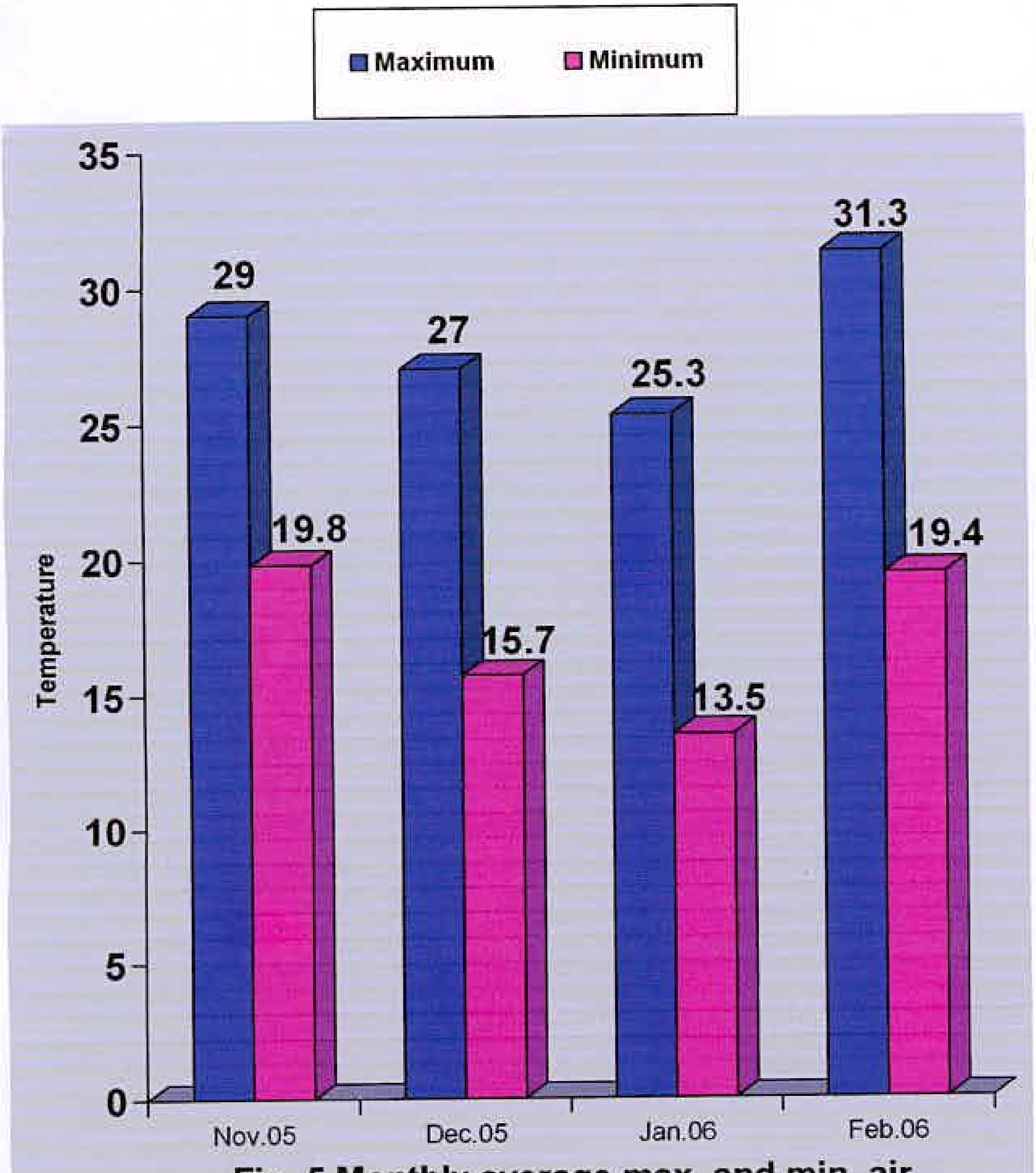

Fig. 5 Monthly average max. and min. air temperature. During Nov.05 to Feb.06.

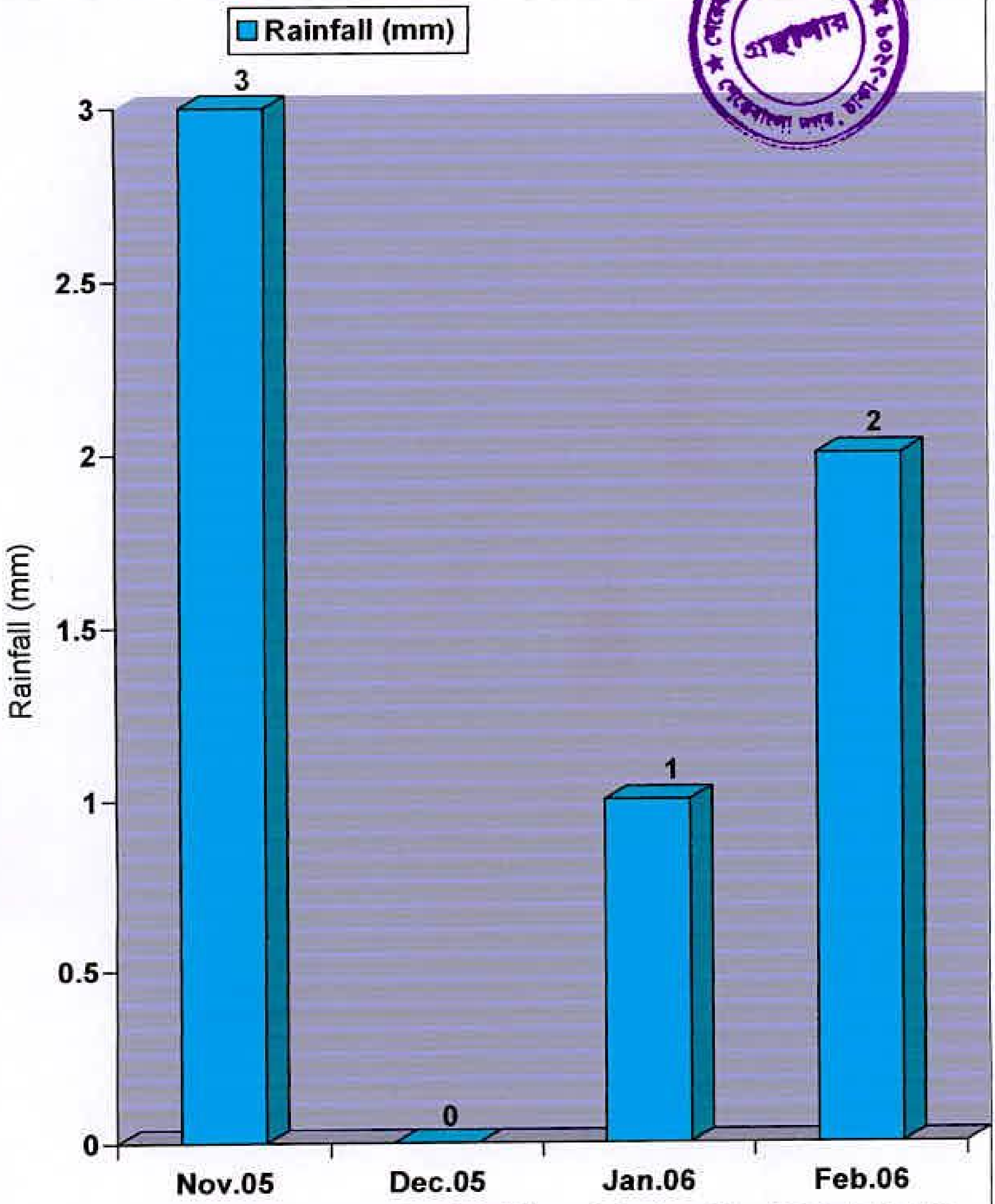

Fig. 6 Monthly total rainfall (mm) during Nov.05 to Feb.06

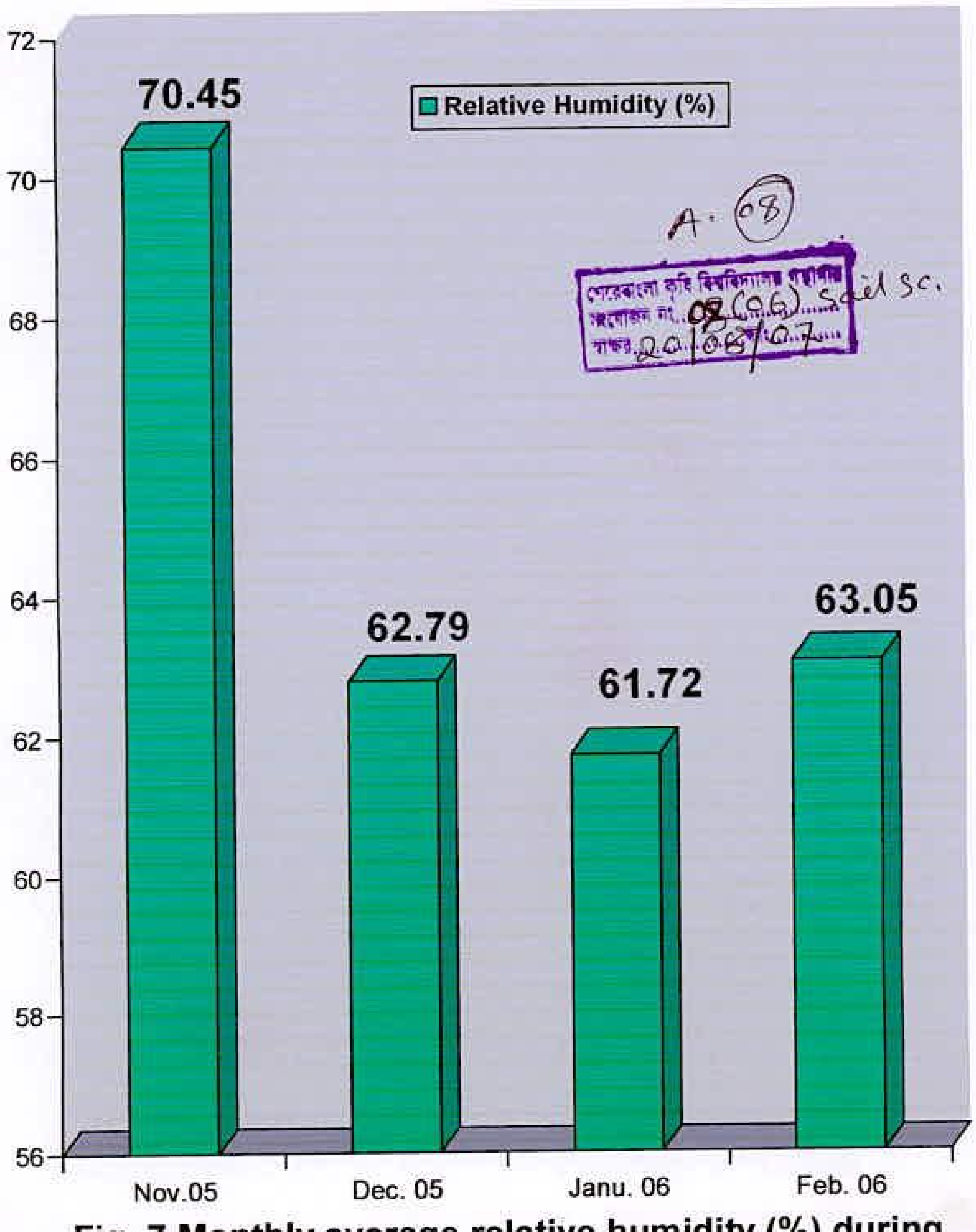

Fig. 7 Monthly average relative humidity (%) during Nov'05 to Feb'06