EFFECT OF BORON AND MOLYBDENUM ON GROWTH AND YIELD OF BROCCOLI

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EFFECT OF BORON AND MOLYBDENUM ON GROWTH AND YIELD OF BROCCOLI

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CERTIFICATE

*This is to certify that the thesis entitled "**EFFECT OF BORON AND MOLYBDENUM ON GROWTH AND YIELD OF BROCCOLI** " submitted to the **Faculty of Agriculture**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **MD. ALTABUR RAHMAN**, Registration No. **18-09279** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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……………………………………….

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

An experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during October 2019 to February 2020 to study the effect of boron and molybdenum on growth and yield of broccoli. The experiment comprising of two factors, factor A**:** four levels of boron [B0=0kg/ha, B1=0.6kg/ha, B2=1.2kg/ha and B3=1.8 kg/ha] and factor B: four levels of molybdenum [M0=0kg/ha, M1=0.4kg/ha, M2=0.8kg/ha and M3=1.2 kg/ha]. The experiment was laid out in Randomized Complete Block Design with three replications. The significant differences were found in growth and yield contributing traits. Most of the parameters such as no. of leaves, leaf breadth, root length, main curd diameter and main curd weight were significantly influenced by the different boron and molybdenum dose. The highest yield (16.70t/ha) was found in the treatment B2 and the lowest (10.65 t/ha) from the treatment B0 and in case of molybdenum, the highest yield (16.09 t/ha) was recorded in M2 and the lowest yield (12.21 t/ha) recorded in M0. For combined effect highest yield (20.55 t/ha) was found from B2M2 and lowest (8.98 t/ha) was obtained from B0M0. The highest benefit cost ratio (2.65) was found in B2M2. So, the successful production of broccoli was found in combined application of 1.2 kg boron with 0.8 kg molybdenum per hectare.

LIST OF ABBREVIATED TERMS

ABBREVIATION	ELABORATIONS
AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
B	Boron
Cu	Copper(cuperrium)
CV	Coefficient of Variation
Df	Degree of Freedom
et al.	and others
i.e.	That is
Mn	Manganese
Mo	Molybdenum
MSS	Mean Sum of Square
N	Nitrogen
pH	Potential of hydrogen ion
ppm	Parts per million
RCBD	Randomized Complete Block Design
SE	Standard Error
TSS	Total Soluble Solids
RH	Relative Humidity
SRDI	Soil Resource Development Institute
Zn	Zinc
@	At the rate

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CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italic* L.), is an important member of "Cole" crops, belongs to the family Brassicaceae. Broccoli originated from west Europe (Prasad and Kumer, 1999). At present broccoli is cultivated in Europe, America and most of the Asian countries including Bangladesh. It is highly popular as fresh and as well as frozen vegetables. Broccoli was introduced and cultivated in Bangladesh about two decades ago. The edible portion of the broccoli plant consists of tender stem and unopened flower buds. Unlike cauliflower, broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible. It can be harvested for a wide period of time than cauliflower (Thompson and Kelly, 1988).

Broccoli contains a high amount of vitamin A, ascorbic acid and also contain amounts of thiamin, riboflavin, niacin, calcium and iron .It is tasty and more nutritious than any other vegetables of the same kind , considered a valuable source of vitamins, antioxidants, glucosinolates, and other compounds of proven anticancer activity (Parente *et al.*, 2013; Kumar and Srivastava, 2016) .This cole crop is not only economically important, but also has anticancerous properties which are contributed by sulforaphane glucosinolate (Verma*et al.*, 2014) and quinone reductase glutathione S-transferase (Kumar and Srivastava , 2016).

The per capita production of vegetable in Bangladesh is very low as compared to that of other countries consumption. Due to low production of vegetables, the present per capita consumption is only about 30g but it is 70 g with potato and sweet potato which is an alarming situation for vegetable consumption in Bangladesh. So, a large-scale production of broccoli can help to increase vegetable consumption and also supply required nutrition.

Boron represents one of the essential micronutrients necessary for proper plant growth, the latter becoming limited both when it is deficient or at elevated level of cole crops like broccoli (Davies *et al.*, 2011). It increases the growth and yield of plants because it stimulates division and elongation of the cell and development of its walls. Boron plays an important role in the metabolism of carbohydrates and proteins (Goldbach and Wimmer, 2007; Miwa *et al*., 2007). It is also crucial for the development of nitrogen-fixing cyanobacteria. Boron deficiency causes many anatomical, physiological, and biological disorders (Brown *et al*., 2002; Xu *et al*., 2007).

Molybdenum is a trace element. It is generally found in the soil and is required for the growth of most biological organisms including plants and animals. Moco binds to molybdenum-requiring enzymes (molybdoenzymes) which is found in most biological systems including plants, animals and prokaryotes (Jana, 2002). In the Brassicaceae family as broccoli, molybdenum deficiencies are strikingly pronounced and reproducible amongest many of its members. Visual effects in young plants include mottling, leaf cupping, grey tinting, and flaccid leaves which are often found on seedlings that remain dwarfed until dying (Kumar, 2012).

However, the yield of broccoli in Bangladesh is very poor compared to other countries. The main reason for poor growth and yield may be due to lack of information about its production technology and proper cultural management practices such as soil fertility management and moisture management. Hence, it is necessary to identify the suitable nutritional requirements of broccoli and to find out the optimum dose of boron and molybdenum to promote the production of this crop in Bangladesh. The aim of the investigation was to find out the effective combination of boron and molybdenum on growth and yield of broccoli.

Considering above factors, the present study was undertaken with following objectives

i) To find out the effect of different dose of boron on growth and yield of broccoli.

ii) To study the effect of different dose of molybdenum on growth and yield of broccoli.

iii) To find out the effect of suitable combination of boron and molybdenum on growth and yield of broccoli.

CHAPTER II
REVIEW OF LITERATURE

Broccoli is a nontraditional and grown as a winter crop of Bangladesh. It is one of the most important vegetable crops of the world, particularly from the nutritional status. In our country, a little attention has been given for the improvement of broccoli cultivars and recently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research on improvement and varietal development of broccoli. Among the micro nutrients, broccoli responses highly to boron and molybdenum. Application of boron and molybdenum influences the growth and yield of the crop. Investigations conducted by different workers also found that the application of different levels of boron and molybdenum influenced the growth and yield of various crops. Some of the important research findings available in this respect at home and abroad have been presented in this chapter as bellow:

2.1 Effect of boron on growth and yield of broccoli

Islam *et al*. (2015) conducted an experiment at the experimental field of department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the winter (Rabi) season of 2012-13 to find out significant and positive effect of boron application on the yield of broccoli. Control (without boron) treatment required highest days (48.92) for curd initiation but minimum days (61.75) for curd harvest. But L3, 2 kg/ha treatment showed the opposite result. 2 kg B/ha was found to be an optimum rate.

Hussain *et al*. (2012) conducted a field experiment to determine the effect of N and B on the yield and hollow stem disorder of broccoli which was performed at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during winter season, 2007-2008. They applied four levels of N as 0, 60, 120, 180 kg/ha and four levels of B as 0, 0.5, 1.0 and 1.5 kg/ha consisting sixteen treatments were applied in a split plot design with three replications. The curd yield of broccoli was significantly increased with boron application up to 1.0 kg/ha. Plant height was significantly influenced by the different levels of B and highest plant height (65.72 cm) was noted from the treatment receiving B at 1.0 kg/ha which was statistically similar to 0.5 and 1.5 kg B/ha. The interaction effect of N and B was founded significant on yield and quality of broccoli and the highest yield (16.68 t/ha) was recorded under 180 kg N and 1.0 kg B per hectare.

Firoz*et al.* (2008) studied an experiment which was conducted at the Hill Agricultural Research Station (HARS), Khagrachari during September 2002 to March 2003 on the effect of boron fertilizer on the yield of broccoli through. The treatment consisted of three broccoli cultivars, viz., Green Commet, Green King and Green Harmony with three levels of boron viz., 0, 1 and 2 kg/ha where boron was applied as solubor (20% B). They founded that a significant and positive effect of boron application on the yield of the broccoli. The 1.0 kg B/ha had the highest yield (512.30 g/plant) and also observed that application of boron at 1.0 kg/ha had the highest curd weight (294.60 g). Concerning varietal effect, curd weight as well as yield per plant significantly varied with different cultivars where Green Harmony performed the highest result (606.20 g/plant).

Moniruzzaman*et al.* (2007) carried out an experiment comprising six levels of boron (0, 0.5, 1, 1.5, 2 and 2.5 kg/ha) and two levels of nitrogen (100 and 200 kg/ha) during the winter (rabi) seasons of 2004-05 and 2005-06 at the Agricultural Research Station, Raikhali, Rangamati Hill District to find out the suitable doses of B and N for higher yield and good quality head of broccoli. There were three replication with twelve treatments. They founded that up to 1.5 kg/ha boron application increased plant height, number of leaves per plant, stem and curd diameter, length and width of the leaves, plant spread, main head weight and head yield both per plant and per hectare significantly. Maximum yield per hectare was observed at 2 kg B plus 200 kg nitrogen per hectare which was at par with 1.5 kg B plus 200 kg N per hectare and 1.5 kg B plus 100 kg nitrogen per hectare. Both the year, they founded that the latter combination (1.5 kg B/ha + 100 kg N/ha) gave the lowest hollow stem in broccoli.

Piezttta*et al.* (2005) observed the effect of boron fertilizer on the yields of broccoli, cauliflower and cabbage through a field experiment carried out in Sao Paulq , Brazil, on a sandy soil low in available boron. There were five dose of boron (0, 2, 4, 6 and 8 kg/ha B as borax) were applied in broccoli, cauliflower and cabbage. Organic manure, chemical fertilizers and borax were applied in the planting furrow before seedling transplant and plants were harvested at 63-93 days after planting date. The yield intervals obtained with broccoli cauliflower and cabbage varied according to the following intervals, 16.90-20.50 t/ha, 21.60-29.60 t/ha and 40.50-46.30 t/ha, respectively. The production observed in broccoli and cabbage yield was linear with boron levels and the boron effect on cauliflower yield was quadratic. For maximum cauliflower yield (30 t/ha), treatment with 5.10 kg/ha of B was necessary where as broccoli and cabbage were less sensitive than cauliflower to boron deficiency and toxicity. They also founded that the quality of the curds decreased when 2 or 6 kg/ha B was applied to cauliflower.

Annesar*et al.* (2004) conducting an experiment in glass house with various macro and micro nutrients which was carried out in 2004 at Wiehenstephan, Bavaria. In that experiment, broccoli was grown in plots with a black Baltic peat substrate. The typical nutrient deficiency symptoms of nitrogen, phosphorus and potassium under supply were described where over supply of nutrients produced necrotic spots on old leaves. No deficiency symptoms were found for magnesium, iron, zinc, copper and manganese. Boron and molybdenum deficiency and sodium chloride, boron, zinc and manganese over supplied caused severe damage.

Singh (2003) studied the effects of B on the growth and yield of cauliflower cv. Pusa Synthetic in Chiplima, Orissa, India during the rabi season of 1997/98 and 1998/99. The treatments consist of borax applied at various rates and methods such as 10 kg/ha as soil treatment, 5 kg/ha as soil Treatments + 0.25 as foliar spray at 45 and 65 days after planting, 5 kg/ha as soil treatment + 0.5% as foliar spray at 45 and 60 DAP, 0.25 or 0.5% as foliar spray at 45 and 65 DAP and 0.25 and 0.5% as foliar spray at 30, 45 and 60 DAP. It was founded that B significantly improved the vegetative growth and quality parameters of cauliflower. The greatest stalk length (6.78 cm) was observed with Borax applied at 10 kg/ha as soil treatment. In the experiment founded that when borax applied at 5 kg/ha as soil treatment + 0.25% as foliar spray at 45 and 60 DAP resulted in the highest number of leaves per plant (17.4), leaf area (374.6 cm), curd weight (510 g), curd width (15.68 cm), curd length (8.48 cm), curd yield per plot (16.23 kg), curd yield per ha (140.86 quintal), net profit (51203 rupees/ha) and benefit cost ratio (4.20).

Singh *et al.* (2002) conducted a field experiment with cauliflower (cv. Snowball-16) during the rabi season of 1996-99 in Bihar, India. In the experiment, four levels of B were applied at 0.05, 1.0 and 2.0 kg/ha as borax, 11% B and band placed around each plant one week after transplanting. Soil application of B significantly produced higher marketable curd yield of cauliflower over control in all three years. Application of boron upto 1.0 kg/ha significantly increased the yields of cauliflower. The highest B content in leaf tissue (23.77 mg/kg) and curds (19.31 mg/kg) was recorded upon treatment with 2.0 kg B/ha.and B concentration in the leaf tissue was higher than that in the marketable curds.

An experiment was conducted in BARI to investigate the effect of chemical fertilizer and manure on the yield of cabbage. It was findings that the application of NPKS and cow dung increased the yield component and head yield significantly, they also founded that the effect of Zn and Mo was beneficial. The highest head yield of 75t/ha was recorded the treatment combination applied N120 P100 S30 Zn5 MO1 kg/ha along with cow dung 5 t/ha (Anonymous. 1988).

Sanjay and Chaudhary (2002) conducted a field experiment on the effects of molybdenum (0.5 and 1 kg sodium molybdate/ha) and boron (10 and 20 kg borax/ha), applied alone or in combination with 25 t farmyard manure (FYM)/ha, on the yield and yield components of cauliflower cv. Pusa Snowball-1 were determined in a field experiment conducted in Kullu, Himachal Pradesh, India from October to March of 1995-97. They recorded that Molybdenum and boron application significantly increased curd diameter, weight and yield in the absence of FYM. Boron at 10 kg/ha and molybdenum at 0.5 kg/ha increased the yield by 32 and 14%, respectively. Application of FYM in addition to 100% recommended NPK which was enhanced the yield of cauliflower by about 27% compared to application of NPK alone.

The effect of molybdenum (0.5 and 1 kg sodium molybdate/ha) and boron (10 and 20 kg borax/ha), applied both alone or in combination with 25 ton farmyard manure/ha, on the yield and yield components of cauliflower cv. Pusa snowball-1 were determined by Kumar *et al.*(2002) in a field experiment conducted in Kullu, Himachal Pradesh, India from October to March of 1995-97. It was recorded that molybdenum and boron application significantly increased curd diameter, weight and yield in the absence of farmyard manure. Borax at 10 kg/ha and molybdenum at 0.5 kg/ha increased the yield by 32 and 14%, respectively. Application of FYM in addition to

10% recommended NPK enhanced the yield of cauliflower by about 27% than the application of NPK alone.

Sharma *et al*. (2002) conducted field experiments on a sandy loam soil to determine the response of cauliflower cv. Pusa Snowball K-1 to different levels of boron (5, 15, 25 kg borax/ha) through soil application in Kandaghat, Himachal Pradesh, India, during 1993-94 and 1994-95. Maximum plant height, number of brunches per plant, number of seeds per pod, seed yield per plant (32.67 g) and per hectare (9.80 q/ha) basis, 1000-seed weight and percent seed germination were recorded when 25 kg borax/ha was applied through soil application.

Jana and Mukhopadhaya (2002) conducted an experiment on the effect of boron, molybdenum and zinc on the yield and quality of cauliflower seed and also reported that higher seed yield and seed quality were observed by applying boron at the rate of 20 kg borax per hectare as compared to no boron application. The combined effect of boron, molybdenum and zinc showed significant increase in number of primary inflorescence stalks (8.70 per plant), pods per plant (1085.70) and seed yield (489.30 kg/ha).

An experiment was conducted by Prasad *et al.* (2000) with cauliflower cv. Pusa, conducted at Ranchi during 1993-96, found that the application of 1 kg B/ha was sufficient for mid-season cauliflower, irrespective of the application method (broadcast and hand placement in one and two installments, and foliar spraying were tested).

Waltert and Theiler (2003) conducted an experiment on the effects of growth of different cultivars of Cauliflower and Broccoli. It was analyzed that the diameter of curd, stem and weight of curd and showed that there was a strong correlation between the diameter of stem and plant biomass and diameter of stem and curd. Growth of stem and curd diameter is dependent on days after transplantation in the field, but dependence is even stronger where as it was related to the sum of maximum daily temperature. Growth of curd showed higher cultivar variation and was more sensitive to environmental factors than growth of stem. In consequence there is a higher variation between curds of one crop, which differs between cultivars. Depending on the correlations and the variation of harvesting period for cultivars can be predicted.

Yang *et al.* (2000) conducting an experiment on the effect of 8 B-Mo treatments on curd yield and active oxygen metabolism in broccoli. When the concentration of B were the same, catalase (CAT) actively and antiscorbutic (ASA) content increased with increases in Mo concentration and it was Similar to increases in CAT activity and ASA content were obtained with increases in B concentration at uniform Mo concentrations. The concentration of B and Mo at 6 and 5 g/litre, respectively, increased superoxide dismutase (SOD), peroxidase (POD), and nitrate reductase (NR) activity, decreased malondialdehyde content and autooxidation rate, inhibited membrane lipid peroxidation and increased curd yield.

Maleware*et al.* (1999) conducting an experiment and recorded that the critical concentration of boron in cauliflower was established by graphical and statical methods on cauliflower cv. Snowball-16 during 1995-96 using four levels of boron (0, 2.5, 5.0 and 7.5 mg/kg) and 20 representative soils low to high in available boron. Differential response to graded levels of boron of cauliflower in biomass production at mid bloom stage particularly in soils having low to marginal content of available boron was recorded. The magnitude of response was in the range of 45 to 50 percent higher yield over control and the plant critical concentration of boron was 21.0 and 20.40 mg/kg for the graphical and statical methods, respectively.

Kotur (1998) conducted a field experiment on cauliflower cv. Pusa snowball 1 and recorded that soil/foliar application of B (1.5 kg B/ha or o.1% boric acid) and Mo (1.5 kg B/ha or o.1% ammonium molybdate) significantly increased curd yield and respective nutrient contents in leaf tissue compared with the control. It was also founded that combined application of B+ Mo on soil synergistically increased curd yield by 12% and 17% compare with single application of B and Mo respectively. While the increase was significantly higher (17 and 27%) through foliar sprays application.

Ghosh and Hassan (1997) reported that the application of B as borax at 15 kg/ha on the cauliflower cv. Early Kunwari significantly produced plants with the highest number of leaves/plant (27.2), the largest curds (1048 g) and the higher yield (524 q/ha).

Betal*et al.* (1997) conducted an experiment and reported that application B on clay loam soil from 2.2-8.8 kg/ha reduced hollow stem of cauliflower but had no effect on yield or curd mass. The application of B on sandy loam soil, at 4.4 kg/ha produced maximum yield and curd mass, but the hollow stem disorder continued to decreases as B rates were increased up to 8.8 kg/ha.

Feng *et al.* (1994) reported on an experiment the application of B (2.5 borax/fedder) or Mo (500 g ammonium molybdate/fedder) to cauliflower plants of the cultivars Soltany and Amsheery significantly enhanced curd yield and quality in both cultivars. (1 fedder = 0.42 ha).

Kotur and kumar (1990) in trials during the winter season with the cultivar Pusa Snowball 1, supplied the plants B at 10 rates ranging from 0 (control) to 6.4 kg/ha (toxic level) one week after transplanting and the plants also received NPK fertilizers. In the control and at the toxic levels, plant survival was 47 and 40%, respectively. The yield of marketable curds increased from 4.0 t/ha in the control to the highest yield of 12.93 t/ha at 10 kg borax/ha and then decreased and data are also tabulated on net returns, hot water soluble B in soil, leaf mineral composition, and the relationship between marketable curd yield and boron application rates.

Mishra (1992) carried out a study on cauliflower cv. Patna Main during 1984-85 and 1985-86 on a sandy loam soil where applied four rates of nitrogen (90, 120, 150 or 180 kg/ha) in 3 or 4 equal split doses. B was applied at 10 or 15 kg/ha before transplanting. Of the N treatments, application of 150 kg/ha resulted in the highest 1000 seed weight and seed yield whereas B application of 10 kg/ha resulted in the highest 1000-seed weight and seed yield.

Kotur (1992) determined through an experiment that the effects of boron and lime application during 2 seasonal cultivation sequences (winter-rainy-winter seasons and rainy-winter-rainy seasons. WRW and RWR, respectively) with cultivars “Pusa snowball‟ (winter season) and “PusaKunwari‟ (rainy seasons). The soil was a sandy loam (Haplustaif). B application (0-3.75 kg/ha) significantly increased curd yield up to 1.5 kg/ha. With 1.5 kg B/ha, the yield from the WRW sequence was 84% higher than the control, whereas the yield from the RWR sequence was 65% higher than the control and the b concentration in leaves was increased.

Sharma and Tanuja (1991) induced boron deficiency in 60-day-old cauliflower cv. Pusa plants growing in sand by withholding B from the nutrient solution and founded that leaf water potential, stomatal opening and conductance, transpiration rate, hill reaction activity, net photosynthesis and intercellular CO2 concentration were greatly reduced by b deficiency. It was founded that Relative water content and sugar, starch and proline content increased, but total N, chlorophyll and chloroplast proteins decreased. These effects were reversed to some extent by resupplying B, although recovery was generally slow. A rapid and significant recovery occurred in transpiration rate, stomatal conductance and intercellular CO2 concentration, suggesting the involvement of B in stomata regulation whereas the decrease in net photosynthesis with B deficiency was, however, a non-stomata effect largely due to decreased hill reaction activity.

Shelp (1990) conducting an experiment on Broccoli (cv. Premium Crop) seeds were germinated in soil, and the seedlings were transferred to vermiculite 3 weeks later and grown in a greenhouse, they were supplied continuously with B at concentration ranging from 0.0 to 12.5 mg/litre. At commercial maturity, the partitioning of N into soluble (nitrate, ammonium, amino acids) and insoluble components of foliage (young and old leaves) and the florets was also investigated. Both B deficiency and toxicity increased the % soluble N, particularly as nitrate. B toxicity, but not deficiency, consistently affected the concentration and relative amino acid composition, was dependent upon the developmental stage of plant organ concerned and upon whether B was present in deficient or toxic levels.

In field and pot trials of rape seed (*Brassica campestris*) with B, N and K, Yang *et al.* (1989) reported that boron application increased plant boron content in all plant parts, but especially leaves higher amount and Seed yield was positively correlated with soil and especially leaf B content. Applying B, N and k promoted growth, co2 assimilation, nitrate reductase activity in leaves and DM accumulation.

Petracek and Sams (1987) carried out an experiment where broccoli (*Brassica oleracea*var*italic*) plants grown in perlite with nutrient solutions containing 0.08, 0.41, 0.61, 0.81, 4.06 or 8.11 ppm boron and observed that plants grown in either low (0.08 ppm) or high (8.11 ppm) boron concentrations developed at slower rates than plants in the other boron concentrations. The reduction in stomatal conductance of boron deficient plants coincided with the early signs of leaf thickening and chlorosis. Chlorophyll levels and net photosynthetic (pn) rates of plants in 0.08 ppm boron were significantly less than those in 0.41, 0.61 and 0.81 ppm boron and found that heads produced by plants in 0.08 ppm had small, chlorotic buds, scale covered stalks, and high levels of total phenols and fiber. Plants grown in 4.06 and 8.11 ppm boron had slightly chlorotic leaves throughout their life cycle and chlorotic leaf margins. It was also founded that stomatal conductance and transpiration rate were not affected by boron toxicity. Although the chlorophyll content and net photosynthetic (pn) rates were lower for plants in 4.06 and 8.1 ppm boron than for those in 0.41, 0.61, and 0.81 ppm boron, head size was slightly larger. The findings suggest that high boron concentrations, which induce boron toxicity symptoms in leaves, may stimulate head development.

2.1 Effect of molybdenum on growth and yield of broccoli

Mohamed *et al*. (2011) conducting an experiment on the effect of the foliar spraying with Molybdenum and Magnesium on vegetative growth and curd yields in Cauliflower (*Brassica oleraceaeL*.var. *botrytis*.). They treatment the plant by sprayed with 15, 30 and 45 µg/l Mo at 20, 40, 60 and 80 days after transplanting. In the experiment, it was founded that 30 and 45 µg/l Mo significantly improved vegetative growth parameters, curds yield and its components and chemical composition of leaves and curds.

Molybdenum is a trace element found in the soil and is required for growth of most biological organisms including plants and animals which Mock binds to molybdenum-requiring enzymes (molybdoenzymes) found in most biological systems including plants, animals and prokaryotes (Singh and Jhekr, 1991). The availability of molybdenum for plant growth is strongly dependent on the soil pH, concentration of adsorbing oxides (e.g. Fe oxides). It is extent of water drainage and organic compounds found in the soil colloids.

In alkaline soils, molybdenum becomes more soluble and is accessible to plants mainly in its anion form as MoO4.

Sharma (1995) conducted a field experiments with cauliflower and obtained the highest seed when 20 kg borax per hectare was applied in combination with 1.5 kg ammonium molybdate per hectare.

Farag*et al*. (1994) observedthat the application of B (2.5 kg borax/fedder) or Mo (500 g ammonium molybdate/fedder) to cauliflower plants of the cultivars Soltany and Amsheery, significantly enhanced curd yield and quality in both cultivars. (1 fedder = 0.42 ha).

Jaggi and Dixit (1995) carried out a field experiment withcauliflower cv. Parijat and reported that Mo application 80 or 160 g/ha increased cauliflower yield by 7-8 %.

Kotur (1995) made a study during Rabi 1987/88 with cauliflower cv. Pusa Snowball-1 and recorded that curd weight and diameter were increased by applying Mo at 0.1 or 1.5 kg/ha to the soil or at 0.1 or 0.2% ammonium molybdate as a foliar spray on 4 occasions at 12 day intervals.

Kotur (1998) conducted an experiment on cauliflower cv. Pusa Snowball 1 and reported that soil/foliar application of B (1.5 kg B/ha or 0.1% ammonium molybdate) significantly increased curd yield and the respective nutrient contents in leaf tissue compared with the control. It was founded that Combined application of B + Mo on soil synergistically increased curd yield by 12 %, and 17 % when compare with single application of B and Mo, respectively and while the increase was significantly higher (17 and 27 %)when applied through foliar sprays.

Sharma (2002) carried ouy an experiment on broccoli palant that maximum plant height, number of branches/plant and number of seeds/pod recorded at 25 kg borax/ha which was significant over 5 kg borax/ha. Similarly, maximum seed yield/plant and on hectare basis, 1000 seed weight and germination percentage were also recorded at 25 kg borax/ha. Molybdenum application had significant effect on plant height, number of branches/plant, number of seeds/pod, seeds yield/plant and on hectare basis. 1000 seed weight and percent seed germination and maximum value with respect to all the three character were obtained at 1.5 kg ammonium molybdate/ha soil application being statistically significant over 1.0 kg ammonium molybdate. The interaction of B and Mo was significant for seed yield/plant as well as per hectare basis during both the year.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. The experiment was started during rabi season (October 10, 2019 to February 18, 2020). The location of the experimental site was at 24.09 N latitude and 90.26E longitude.The altitude of the location was 8 m from the sea level according to the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.2 Characteristics of soil

Soil of the experimental field was silty loam in texture and it belongs to the Modhupur Tract (UNDP, 1988) under the AEZ No. 28. Soil sample of the experimental plot was collected from a depth of 0-20 cm before initiated the experiment and analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, and Dhaka and have been presented in Appendix I.

3.3 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and slightly rainfall during therabi season. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

The test crop used in the experiment was broccoli variety “Green Giant” and the seeds were collected from Siddique Bazar, Dhaka.

3.5 Seedbed preparation

Seedbed was prepared on 17 October, 2019 for raising seedlings of broccoli and the size of the seedbed was 1.6m×1.2m. The soil was well ploughed to loose friable and dried masses to obtained good tilth for making seedbed. Weeds, stubbles, dead roots and other residues were removed from the seedbed. Cow dung was applied and the soil was treated by Sevin 50WP @ 5kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm.

3.6 Seed treatment

Seeds were treated by Provax 200WP @ 3g/1kg seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.7 Seed sowing

Seeds were sown on 24October, 2019 in the seedbed. It was done thinly in lines spaced at 5cm distance. Seeds were sown at a depth of 2cm with covered a fine layer of soil followed by light watering by water cane. The sed bed were kept under with dry straw to maintain required temperature and moisture and straw was removed immediately after emergence of seed sprout. The shade was made with white polythene and bamboo mat to protect the young seedling from scorching sunshine and rain after germination.

3.8 Raising of seedlings

There were done watering and weeding for several times and No chemical fertilizers were applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 25 days old seedlings were transplanted into the experimental field on 22 November, 2019.

3.9 Layout and design

The field experiment was conducted by Randomized Complete Block Design (RCBD) with three replications. Two factors were used in the experiment viz. boron and molybdenum. The experimental plot was first divided into three blocks and each block consisted of 16 plots. Thus, the total number of plots was 48. Different combinations of boron and molybdenum were assigned randomly to each plot as per design of the experiment. The size of a unit plot was 1.6 m × 1.2 m. A distance of 0.5 m between the plots and 1.0 m between the blocks were kept. Thus the total area of the experiment was 27.6 m × 7.4 m.

3.10 Treatment of the experiment

The experiment consisted of two factors. Details were presented below:

Factor A. Four doses of boron

B0: 0(Control)

B1: 0.6 Kg /ha

B2: 1.2 Kg /ha

B3: 1.8 Kg /ha

Factor B. Four doses of molybdenum

M0= 0(Control)

M1= 0.4 Kg /ha

M2= 0.8 Kg /ha

M3= 1.2 Kg/ha

There were 16 treatment combinations such as:

B0M0	B2M0
B0M1	B2M1
B0M2	B2M2
B0M3	B2M3
B1M0	B3M0
B1M1	B3M1
B1M2	B3M2
B1M3	B3M3

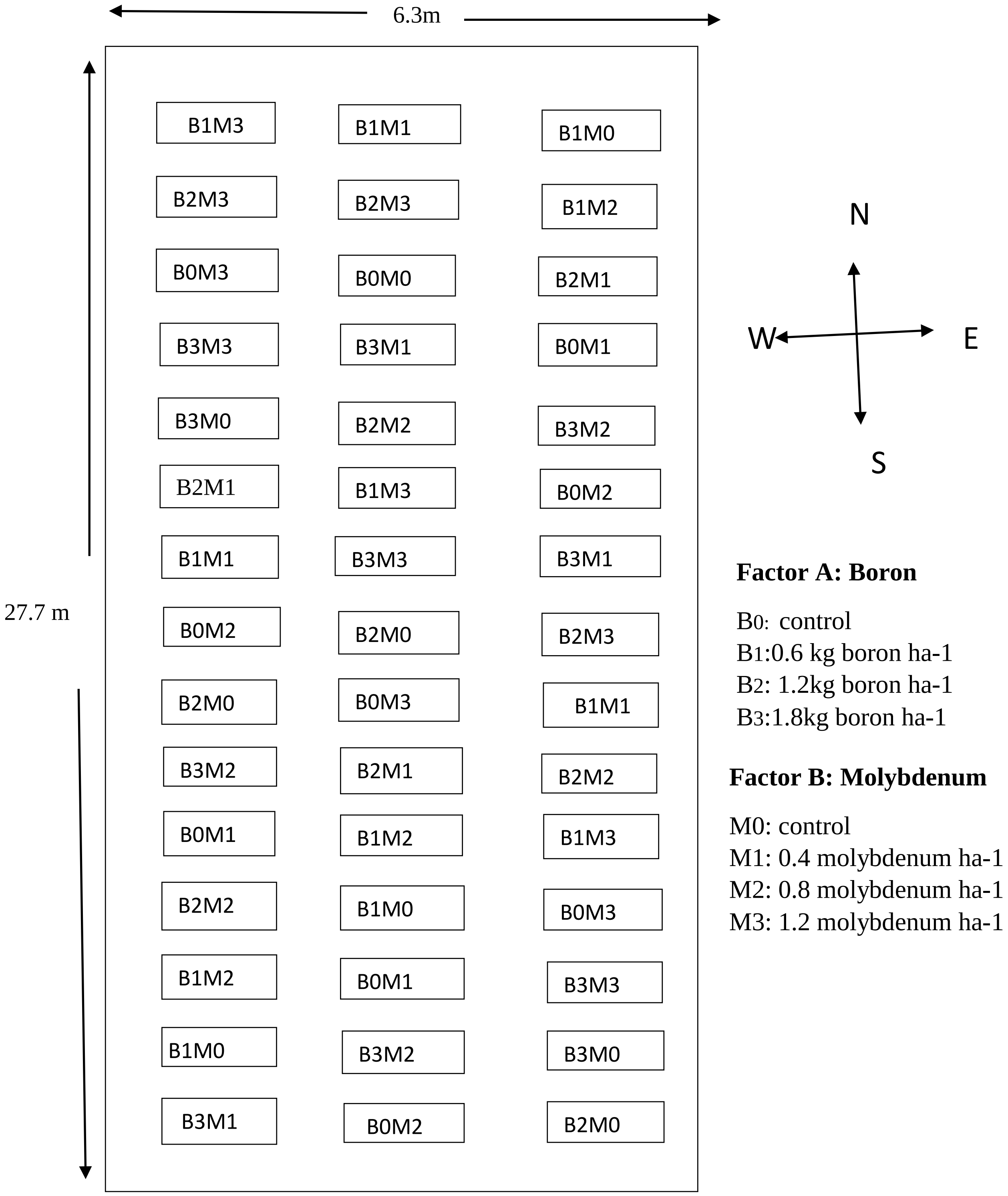

Figure 1. Field layout of the experimental plot

3.11 Cultivation procedure

3.11.1 Land preparation

First opening of the experimental area was on 15 October, 2019 with a disc plough. There were several ploughing and cross ploughing was done with a power tiller followed by laddering to bring about a good tilth and lose the soil. Leveling of the land by laddering, corners shaping also was done. The clods were broken into smaller pieces. The weeds, crop residues and stables were removed from the field with proper carefully. The doses of manure were applied and finally leveled the main field. The soil of the plot was treated by Seven 50wp @ 5kg/ha to protect from the attack of mole cricket, ants and cutworm of young plant.

3.11.2 Application of manure and fertilizer

Manure and fertilizers were applied in the main field which was presented in Table 1. The total amount of cowdung, TSP and half of the MP was applied to the plot during final land preparation as basal dose. Boron was applied as boric acid (16% B) and Ammonium molybdate also as basal treatment. Urea was applied in three equal installments at 15, 30 and 45 DAT and rest half of the MP was applied in two equal installments at 15 and 30 days after transplanting in ring method.

Table 1. Dose and date of application of fertilizers in broccoli field

Fertilizer and Manures	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	15 ton	100			
Urea	250 kg		33.33	33.33	33.33
TSP	150 kg	100			
MP	200 kg	50			

Source: Fertilizer Recommendation Guide-2016, BARI.

3.11.3 Transplanting

Healthy and uniform seedlings of 25 days old seedlings were transplanting in the experimental plots on 22 November, 2019.The entire seedbed was irrigated one hours before uprooting the seedlings to minimize the damage of roots. During the uprooting, carefully uprooted so that root damage became minimum and some soil remained with the roots. Thus, the 8 plants were accommodated in each unit plot. In the afternoon, planting was done and light irrigation was given immediately after transplanting around each seedling for their better establishment of the seedlings. To protect the transplanted seedlings from scorching sunlight, shading was done for five days with the help of transparent polythene, and watering was done up to five days until they became capable of establishing on their own root system.

3.12 Intercultural operations

3.12.1 Gap filling

The transplanted seedlings were kept under careful observation and very few seedlings were damaged after transplanting in the experimental plot. This damaged seedling was replaced by new seedlings from the same stock.

3.12.2 Weeding

The plot was kept under carefully observation because significant number of weed emerges in the field especially in control treatment. Weeding was done three times in these plots at 10, 30 and 50 DAT and weeding was done followed by irrigation in the plots considering the optimum time for removal weed.

3.12.3 Spading

For proper growth and development of seedlings, soils of each plot were pulverized by spade carefully for easy aeration and it was done after each irrigation.

3.12.4 Irrigation

There were light irrigation was done Just after transplanting of seedlings. A week after transplanting the requirement of irrigation was realized through visual estimation. When the plants had shown the wilting symptoms the entire plots were irrigated on the same day with a hospipe until properly wet the field.

3.12.5 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade carefully.

3.12.6 Insects and disease control

After the seedlings were transplanted, there were very few plants damaged by mole crickets and cut worms in the experimental plots. Dusban was dusted to the soil before irrigation to control these insect. The nightingale (bulbuli) were visited the fields from 8 to 11 a.m. and 4 to 6 p.m. and puncture the soft leaves and initiating curd and were controlled by striking of a metallic container.

3.13 Harvesting

According to maturity indices, main curds and secondary curds were harvested when the plants formed compact curd at different dates. After harvesting the main curd, secondary curds were formed from the leaf axils, which also developed into small secondary curds and these were also harvested over a period. Harvesting was started on 15 January, 2020. It was done for several date which was completed on 18 February, 2020. The curds were harvested with 20 cm of stem that was attached with the sprouts which increased the quality of curds.

3.14 Data collection

There were randomly selected six plants from each unit plot except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of the experiment. Data on plant height stem diameter, number of leaves, and length of large leaf and breadth of the leaf were collected at 20, 40 and 60 days after transplanting (DAT). During harvest and after harvest, all other yield contributing characters and yield parameters were recorded with carefully.

3.14.1 Plant height

Plant height was measured in centimeter from the ground level to the tip of the longest leaf and mean value was calculated leaf at 20, 40 and 60 days after transplanting (DAT). A meter scale was used to measure plant height of the plant

3.14.2 Diameter of stem

The diameter of stem was measured at the point where the central curd was cut off. The diameter of stem was recorded by slide calipers.

3.14.3 Number of leaves per plant

The total number of leaves per plant was counted with the observation of fully open leaves from each selected plant. Data were recorded at randomly as the average of 6 plants selected at random from the inner rows of each plot at 20, 40 and 60 days after transplanting (DAT).

3.14.4 Leaf length

The distance from the base of the petiole to the tip of the leaf was considered as length of leaf and it was measured also at 20, 40 and 60 DAT. A meter scale was used to measure the length of the large leaves and expressed in centimeter (cm).

3.14.5 Leaf breadth

The large leaf breadth was measured on 20, 40 and 60 DAT and was used a meter scale to measure the breadth of the large leaves and expressed in centimeter (cm).

3.14.6 Length of root

The length of root was measured using a meter scale. It was considered from the base of the plant to the tip of the root and was expressed in centimeter. After harvesting the secondary curds, root length was measured.

3.14.7 Weight of root

After cleaning, the fresh weight of roots was recorded by weighting and averaged of 10 plants which was recorded and expressed in gram. The weight of the roots was recorded immediately after harvest.

3.14.8 Diameter of curd diameter

The curd diameter was measured at one side to another of the top. The diameter of curd was recorded by slide calipers.

3.14.9 Diameter of main curd

The diameter of curd was measured by using a meter scale at the final harvest. Diameter of the curd was measured at different directions and finally the average of all directions was recorded and expressed in centimeter (cm).

3.14.10 Number of secondary curd

The secondary curd was counted with the small shoots were taken into consideration, when the secondary curds reached to marketable size.

3.14.11 Weight of secondary curd

The total marketable auxiliary curds of an individual plant weight were recorded by weighing of secondary curd.

3.14.12 Yield per plant

The total weight of the main curd and the weight of secondary curd which produced per plot converted into average and calculating the yield per plant in gram (g).

3.14.13 Yield per plot

The total weight of all the main curds and secondary curds produced in the respective plot calculated of the yield per plot was done by adding together. The yield of all plants in each unit plot was recorded and which was expressed in kilogram (kg).

3.14.14 Yield per hectare

The yield per hectare was calculated by converting from the per plot yield data to per hectare and was expressed in ton (t).

3.15 Statistical analysis

All the data were statistically analyzed by using statistics 10 computer package programs for different characters to find out the significance of the difference for different dose of boron and molybdenum on yield and yield contributing characteristics of broccoli. The mean values of all the treatments were calculated and analyses of variance for all the characters were performed by the F-test (variance ratio). The significance of the difference among the treatment combinations of means was estimated by least significance difference (LSD) at 5% level of probability.

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different boron and molybdenum levels. The cost of production was calculated by all input cost including the cost for lease of land and interests on running capital. The interests were calculated @ 10% in simple rate. The market price of broccoli was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to observe the effect of boron and molybdenum on growth and yield of broccoli under the soil and agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameter were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Plant height are significantly different for different dose of boron and molybdenum at 20, 40, 60 days after transplanting (DAT) of broccoli under the present trial (Figure 2 & Appendix-VI). At 20 DAT, the plant height observed from 17.31cm to 24.23 cm. The longest plant (24.23cm) was found in the dose of Boron application (B2) which was statically similar with B3 (23.97 cm) and the shortest plant (17.31 cm) was observed in B0. At 40 DAT, plant height ranged from 25.52 cm to 30.43 cm. The highest plant height (30.42 cm) was recorded from B2, while the lowest (25.52 cm) was recorded from B0 and there were significantly difference from one another. At 60 DAT, the plant height ranged from 41.31cm to 49.69cm. The highest plant height (49.69 cm) was recorded from B2, and the lowest (41.31 cm) was recorded from B0 and They were significantly different with different level of boron application. It was revealed that the plant height increased with the increased in days after transplanting (DAT) i.e., 20, 40 and 60 DAT and It was founded that plant height increase with different level of boron and at optimum level plant height maximum but excess dose decrease plant height and same findings also reported by Firoz *et al*. (2008).

Different levels of Molybdenum differed significantly for plant height of broccoli at 20, 40 and 60 DAT (Fig. 3 and Appendix IV). At 20 DAT, the plant height observed from

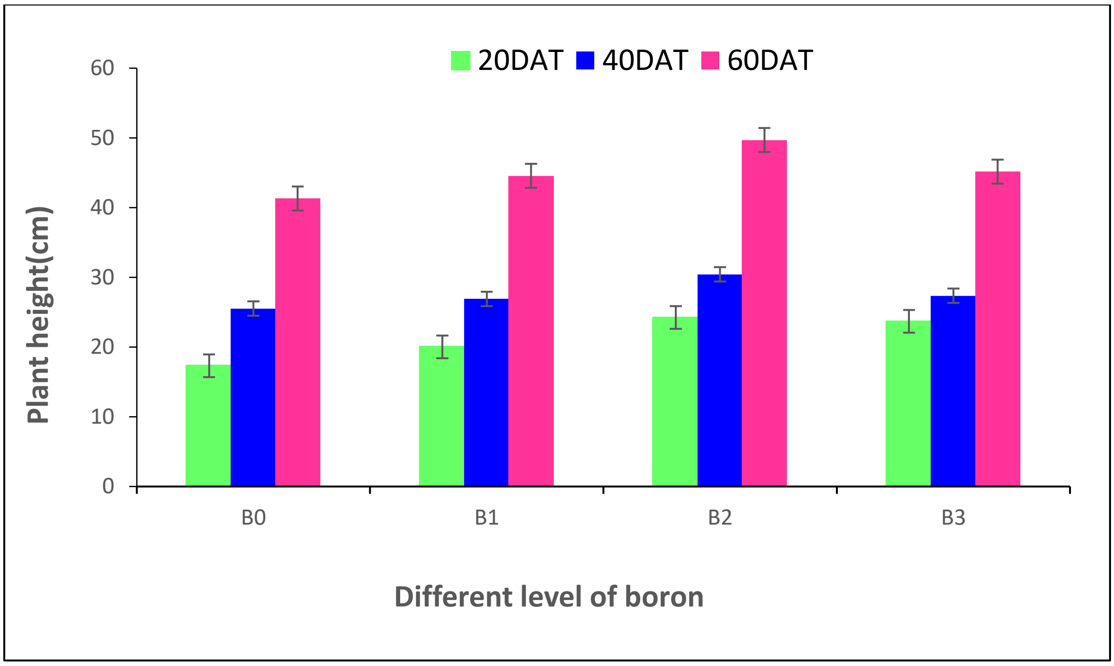

Figure 2. Effect of different Boron levels on plant height of broccoli

B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha

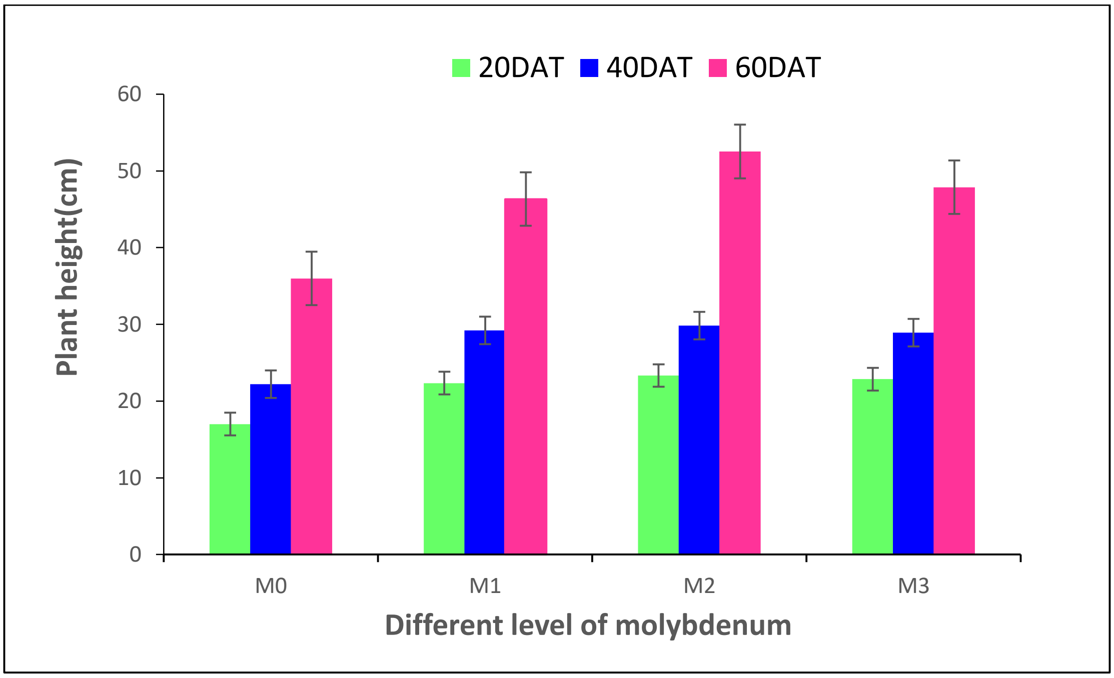

Figure 3. Effect of different levels molybdenum on plant height of broccoli

M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

17.00 cm to 23.34 cm. The longest plant (23.34 cm) was found in the dose of molybdenum application (M2) which was significantly similar with (22.85 cm) with M3 and the shortest plant was observed (17.00 cm) in M0. At 40 DAT, the plant height ranged from 22.21 cm to 29.83 cm. The longest plant height (29.83 cm) was recorded dose of Molybdenum M2 and the shortest plant was recorded (29.83cm) in M0 and significantly different from one another. At 60 DAT, the plant height ranged from 35.99 cm to 52.54 cm. The longest plant (52.54 cm) was found from M2 and the shortest (35.99 cm) plant was obtained from the M0 and they were significantly different from one dose to another.

Plant height were significantly influenced when combined application of boron and molybdenum in terms of plant height of broccoli at 20, 40 and 60 DAT (Table 2, and Appendix IV). At 20 DAT, plant height ranged from 13.39 cm to 28.54 cm. The highest plant height (28.54 cm) was obtained in combination of B2M2 and the lowest (13.39 cm) was recorded from B0M0. At 40 DAT, plant height ranged from 21.12 cm to 36.13 cm. The longest plant height (36.13 cm) was observed in the treatment combination B2M2, consequently the shortest plant (21.12 cm) was obtained from B0M0. At 60 DAT, the height of plant ranged from 33.27cm to 56.73 cm. The highest plant height was observed from B2M2 which was 56.73 cm, consequently the shortest plant was observed from B0M0 which was 33.27 cm. It was revealed that plant height increased with the increased in DAT and optimum level of boron and molybdenum combination ensured the tallest plant and excess amount causes decrease in plant height.

4.2 Stem diameter

Application of boron on broccoli plant showed significant effect at 20 DAT, 40 DAT and 60 DAT trials (Figure 4 & Appendix-IV). At 20 DAT, stem diameter ranged from 0.73 cm to 0.96 cm. The biggest diameter (0.96cm) recorded in B2 whereas smallest diameter found in B0. At 40 DAT, stem diameter ranged from 1.77 cm to 2.13 cm. The maximum diameter (2.13 cm) was recorded in B2 which was significantly similar to B3 whereas minimum diameter (1.77 cm) found in B0. At 60 DAT, stem diameter ranged from 4.05 cm to 4.39 cm. The maximum diameter (4.39 cm) founded in B2 and the minimum diameter (4.05 cm) recorded in B0. It was also founded by Default (2008).

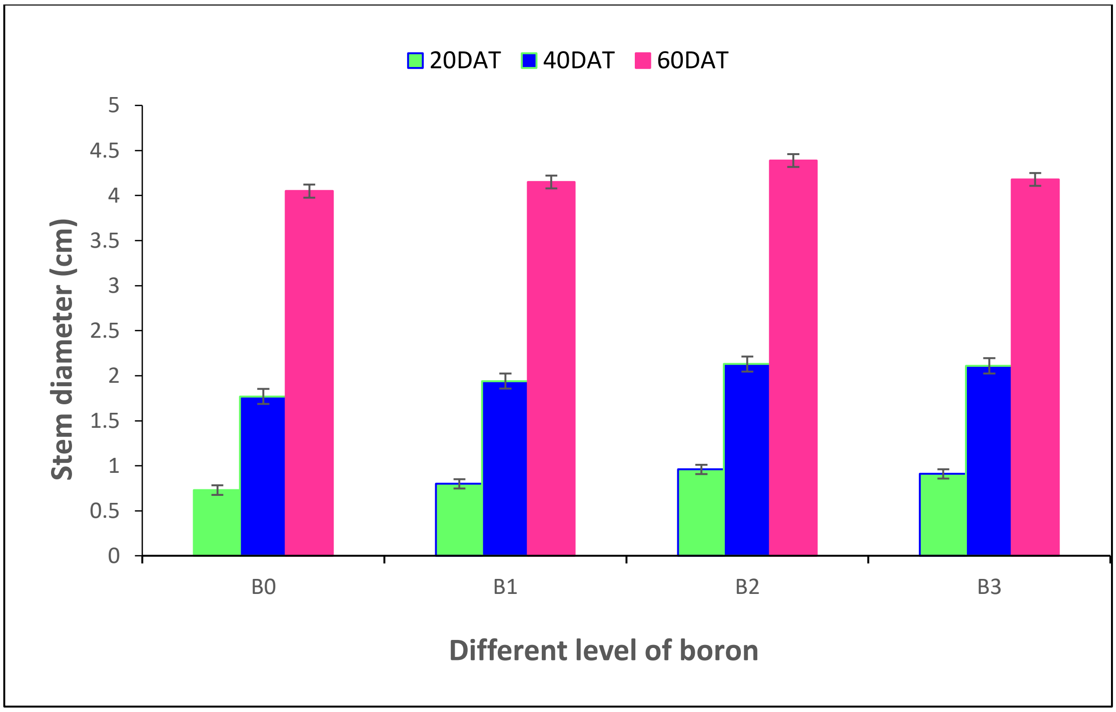

Figure 4. Effect of different dose of boron on stem diameter of broccoli

B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha

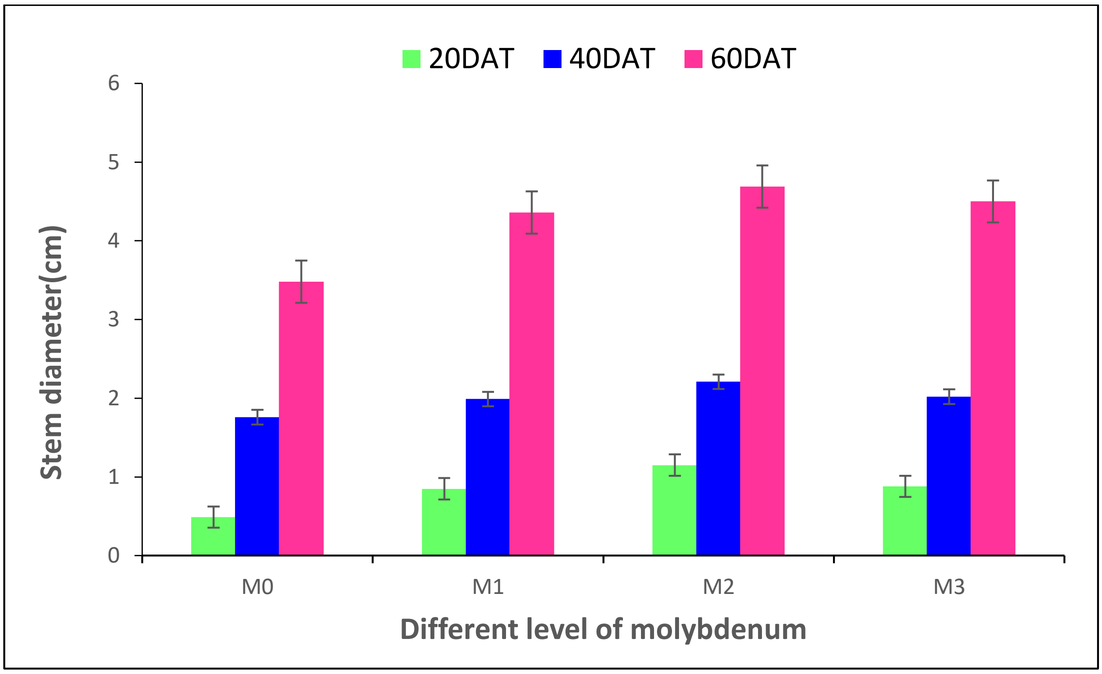

Figure 5. Effect of different dose of molybdenum on stem diameter of broccoli

M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

Table 2. Combined effect of boron and molybdenum on plant height and stem diameter at different days after transplanting (DAT) of broccoli

Treatment	Plant height(cm)			Stem Diameter(cm)		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
B0M0	13.39j	21.12k	33.27 l	0.44k	1.54 k	3.38 k
B0M1	17.84 hi	26.16 h	42.77 h	0.73h	1.78 i	4.15 h
B0M2	18.42 hi	27.36 g	44.01 g	1.00 cd	1.84 h	4.49 de
B0M3	19.59 gh	27.44 g	45.20 f	0.75 gh	1.94 g	4.40 ef
B1M0	14.26 j	21.23 k	34.78 k	0.47 jk	1.72 j	3.42 jk
B1M1	20.92 fg	28.47 e	46.59 e	0.80 g	1.84 h	4.26 gh
B1M2	21.59 ef	28.04 ef	47.27 e	1.02 c	2.07 e	4.67 b
B1M3	23.31 cde	29.87d	49.62 d	0.91 f	2.13 d	4.48 de
B2M0	16.86 i	22.79 j	36.64 j	0.53 ij	1.83 h	3.49 j
B2M1	25.05 bc	32.22 b	52.11 c	0.91 f	2.12 d	4.36 fg
B2M2	28.54 a	36.13a	56.73a	1.45 a	2.39 a	4.96 a
B2M3	25.42 b	30.57c	53.31 b	0.94 ef	2.19 c	4.60 bc
B3M0	23.49 cd	23.74 i	39.30 i	0.56 cde	1.97 f	3.64 i
B3M1	25.53 b	30.05cd	51.86 c	0.97 cde	2.24 b	4.69 b
B3M2	24.81 bcd	27.80fg	50.17 d	1.15 b	2.14 d	4.67 b
B3M3	23.11de	27.80fg	47.34 e	0.95 def	2.12 d	4.55 cd
CV(%)	12.17	11.33	9.96	13.37	5.95	7.15
LSD0.05	1.77	0.55	0.93	0.53	0.27	0.13

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha ; M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha.

Application of molybdenum on broccoli plant showed significant effect at 20DAT, 40DAT and 60 DAT (Figure 5 & Appendix-IV). At 20 DAT, stem diameter ranged from 0.49 cm to 1.15 cm. The biggest diameter (1.15 cm) recorded in M2 whereas smallest diameter (0.49 cm) found in M0. At 40 DAT, stem diameter ranged from 1.76 cm to 2.21 cm. The maximum diameter (2.21 cm) was recorded in M2 whereas minimum diameter (1.76cm) founded in M0. At 60 DAT, stem diameter ranged from 3.48 cm to 4.69 cm. The maximum diameter founded in M2 (4.69 cm) which was similar to M3 and the minimum diameter (3.48 cm) recorded in M0 and similar finding founded by Sanjay *et al*, (2002).

There was significant effect on stem diameter of combined application of boron and molybdenum at 20DAT, 40DAT and 60 DAT (Table-2 & Appendix-IV). At 20 DAT, stem diameter ranged from 0.44 cm to 1.45 cm. The maximum plant diameter (1.45 cm) observed in B2M2 combination and the minimum (0.44cm) plant diameter found in B0M0. At 40 DAT, stem diameter ranged from 1.54 cm to 2.39 cm. The maximum plant diameter (2.39 cm) observed in B2M2 combination and the minimum (1.54cm) plant diameter found in B0M0.At 60 DAT, stem diameter ranged from 3.38cm cm to 4.96 cm. The maximum plant diameter (4.96 cm) observed in B2M2 combination and the minimum (3.38 cm) plant diameter found in B0M0. It was revolved that stem diameter increased with increased combined dose of boron and molybdenum application but excess application of fertilizer reduced stem diameter.

4.3 Number of leaves per plant

Application of boron exhibited a significantly influence on leaves number of broccoli plant at 20, 40 and 60 DAT (Figure 6 & Appendix-V). At 20 DAT, number of leaves ranged from 5.86 to 7.62. The maximum number of leaves (7.62) recorded in B2 that was different from other dose of boron application and the minimum number (5.86) was found in B0. At 40 DAT, the maximum number of broccoli leaves (11.45) was found in B2 and the minimum (9.19) was found in B0. At 60 DAT, there were significant differences found in number of leaves due to the application of different levels of boron. The maximum number of leaves (14.83) was found in B2 and the minimum (13.17) was found in B0. It was revealed that the number of leaves per plant increased with the increased in B application and with the advanced of DAT as well but excess application decrease plant height. Similar findings also recorded by Islam *et al.* (2015).

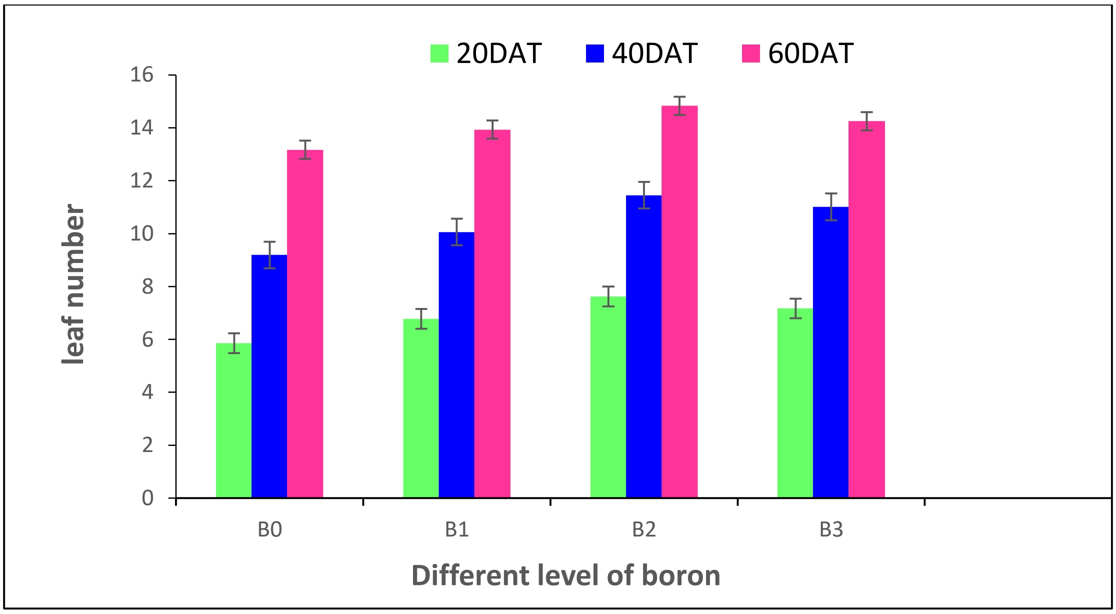

Figure 6. Effect of different dose of boron on leaf number of broccoli

B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha

Application of molybdenum showed a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT (Figure 7 & Appendix-V). At 20 DAT, number of leaves per plant ranged from5.86 to 7.44. The highest number of leaves (7.44) was found in M3 that was statistically similar to M2 while the minimum (5.86) was founded in M0. At 40 DAT, the maximum number of leaves (11.08) was found in M2 while the minimum (8.99) was found in M0. At 60 DAT, the maximum number of leaves (15.03) was found in M2 while the minimum (12.13) was found in M0. The number of leaves per plant increased with the increased in M application and with the advanced of DAT as well and excess amount of molybdenum application decrease in leaf number.

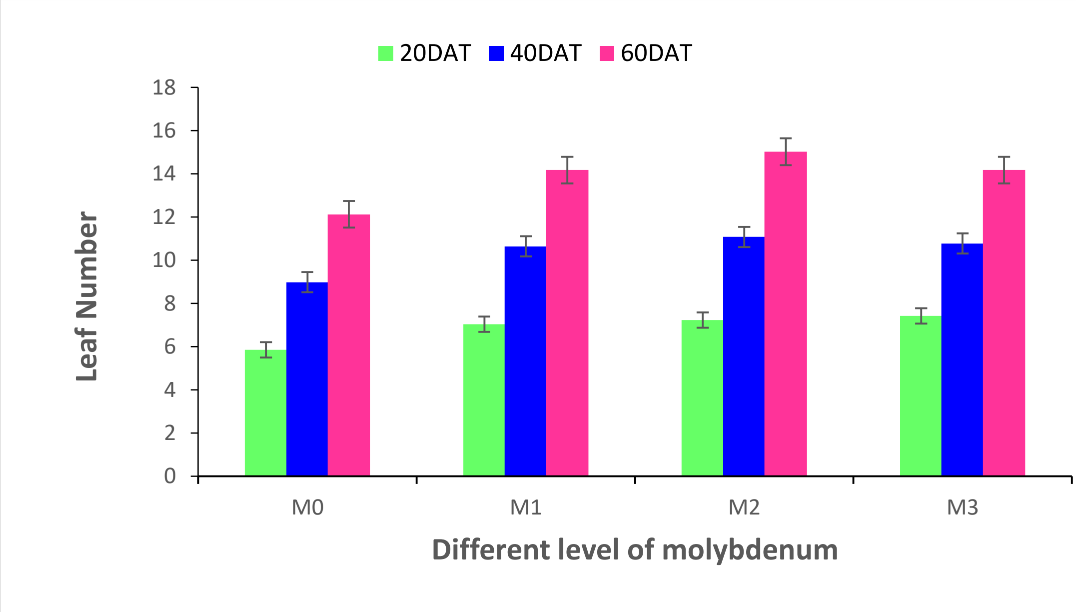

Figure 7. Effect of different dose of molybdenum on leaf number of broccoli

M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

The number of leaves was significantly influenced by the treatment combinations at 20, 40 and 60 DAT (Table 3& Appendix-V). At 20 DAT, number of leaves per plant ranged from 5.10 to 8.45. The maximum number of leaves (8.45) was recorded in B2M2, while the minimum (5.10) was recorded from B0M0. At 40 DAT, number of leaves per plant ranged from 8.10 to 12.82. The maximum number of leaves (12.82) was observed in B2M2 and the minimum (8.10) was recorded from B0M0. At 60 DAT, number of leaves per plant ranged from 11.59 to 16.17. The maximum number of leaves (16.17) was observed in B2M2 and the minimum (11.59) was recorded from B0M0. It was appeared that number of leaves did not differ significantly due to the combined application of different levels of boron and molybdenum.

4.4 Leaf length

There were significant influences of different boron dose on broccoli leaf length at 20, 40 and 60 DAT (Figure 8 & Appendix-V). At 20 DAT, leaf length ranged from 11.85 cm to 13.44 cm. The maximum (13.44 cm) leaf length recorded in B2 whereas the minimum (11.85) leaf length recorded in B0. At 40 DAT, leaf length ranged from 27.95 cm to 32.21 cm and there are significantly differ among the dose of boron. The maximum (32.21cm) leaf length recorded in B2 whereas the minimum (27.95cm) leaf length recorded in B0. At 60 DAT, leaf length ranged from 38.34 cm to 41.47 cm and showed significantly differ among the dose of boron. The maximum (41.47 cm) leaf length recorded in B2 whereas the minimum (38.34 cm) leaf length recorded in B0.

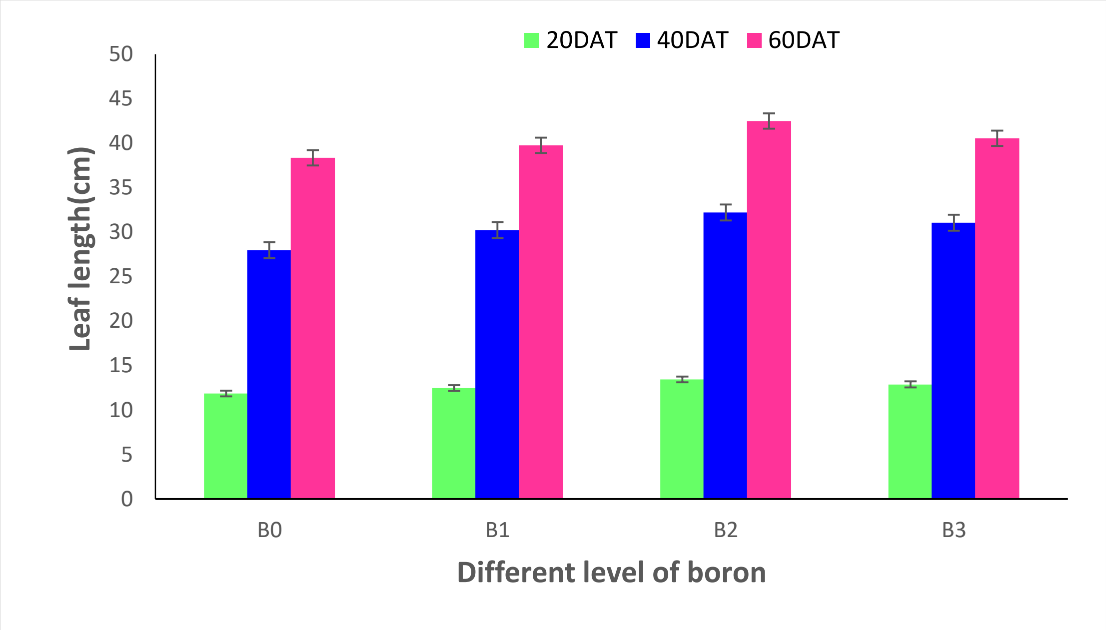

Figure 8. Effect of different dose of boron on leaf length of broccoli

B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha

There were significant influences of different molybdenum dose on broccoli leaf length at 20, 40 and 60 DAT (Figure 9 & Appendix-V). At 20 DAT, leaf length ranged from 9.98cm to 13.71 cm. The maximum (13.71 cm) leaf length recorded in M3where as the minimum (9.98 cm) leaf length recorded in M0. At 40 DAT, leaf length ranged from 27.72 cm to 32.51 cm and there were significantly differ among the dose of molybdenum. The maximum (31.63cm) leaf length recorded in M2 whereas the minimum (27.72 cm) leaf length recorded in M0. At 60 DAT, leaf length ranged from 36.30 cm to 42.58 cm and showed significantly differs among the dose of molybdenum. The maximum (21.58 cm) leaf length recorded in M2 whereas the minimum (36.30cm) leaf length recorded in M0 and similarities also founded by Sharma *et al.* (2002).

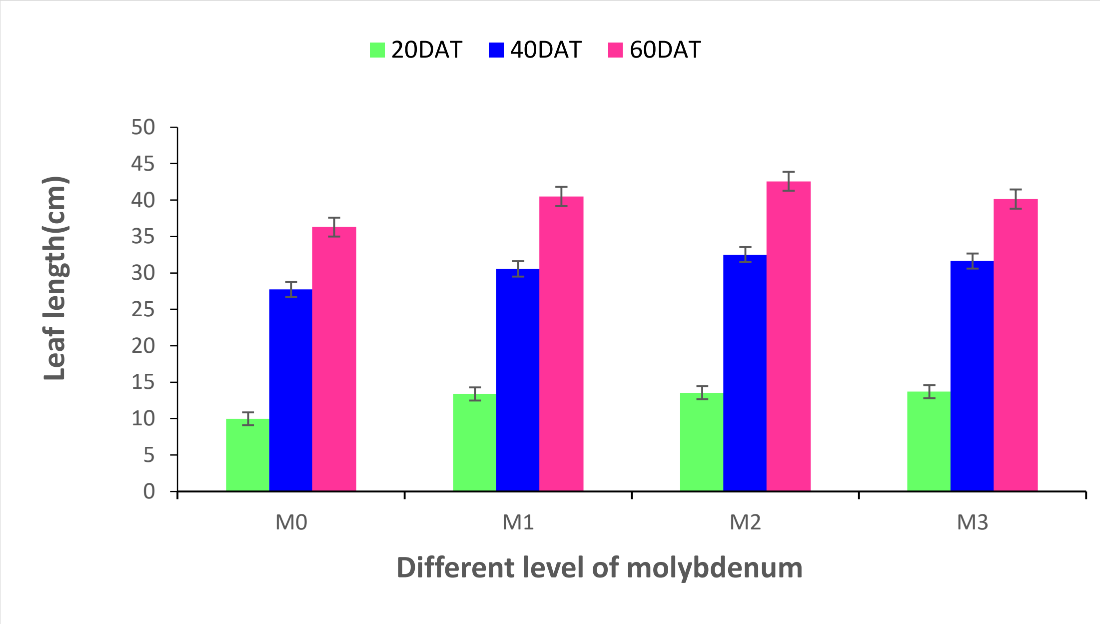

Figure 9. Effect of different dose of molybdenum on leaf length of broccoli

M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

Application of combined dose of Boron and molybdenum had a significant effect on the length of leaves of broccoli plants at 20, 40 and 60 DAT (Table 3 & Appendix-V). At 20 DAT, leaf length ranged from 9.10 cm to 14.77 cm. The longest leaves are produced by B2M2 and the smallest leaves are produced by B0M0 combination of fertilizer. At 40 DAT, leaf length ranged from 24.52cm to 34.49 cm. The longest leaf (34.49) was recorded in B2M2, and while the smallest (24.52 cm) was found in B0M0.At 60 DAT, leaf length ranged from 35.22 cm to 44.04 cm. The largest leaf (44.04 cm) was observed in B2M2 and while the smallest (35.22 cm) was recorded from B0M0.

Table 3. Combined effect of boron and molybdenum on leaf number and leaf length at different days after transplanting (DAT) of broccoli

Treatment	Leaf number			Leaf length(cm)		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
B0M0	5.10m	8.10 k	11.59 j	9.10k	24.52l	35.22l
B0M1	5.67k	9.29 j	13.38h	12.64g	28.36k	39.21 h
B0M2	6.15j	9.47 ij	13.77 gh	12.76fg	29.17 i	39.37gh
B0M3	6.52i	9.92 hi	13.97fg	12.92f	29.76 h	39.54g
B1M0	5.49l	8.49 k	11.72j	9.35j	28.82ij	35.72k
B1M1	6.88g	10.37 gh	14.39ef	13.28e	30.21g	40.37f
B1M2	7.25ef	10.43 g	14.85 cd	13.36e	30.71f	41.23e
B1M3	7.52d	10.94 ef	14.79cde	13.87c	31.12ef	41.64d
B2M0	6.17j	9.30 j	12.41i	10.20i	28.82 ij	36.87j
B2M1	8.08b	11.15 de	15.18bc	14.37b	32.21c	42.760 b
B2M2	8.45a	12.82 a	16.17a	14.77a	34.49a	44.04a
B2M3	7.80c	12.13 b	15.38 b	14.42b	33.30b	42.23a
B3M0	6.68h	10.09 gh	12.84i	11.27h	28.72jk	37.40i
B3M1	7.55d	11.80 bc	15.39b	13.29e	31.42de	41.86d
B3M2	7.35e	11.60 cd	15.31 b	13.36e	31.66d	41.70 d
B3M3	7.11f	10.53 fg	14.69de	13.64d	32.37c	41.19 e
CV(%)	9.06	7.99	6.24	8.77	4.54	4.26
LSD0.05	0.15	0.45	0.47	0.19	0.42	0.27

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B_0: 0kg/ha, B_1:0.6kg/ha, B_2:1.2kg/ha, B_3:1.8kg/ha ; M_0:0kg/ha, M_1:0.4kg/ha, M_2:0.8kg/ha, M_3:1.2kg/ha

4.5 Leaf breadth

There are significant influences of different boron dose on broccoli leaf breadth at 20, 40 and 60 DAT (Figure 10 & Appendix-VI). At 20 DAT, leaf breadth ranged from 4.09 cm to 6.28 cm. The maximum (6.28cm) leaf breadth recorded in B2 whereas the minimum (4.09 cm) leaf breadth recorded in B0. At 40 DAT, leaf breadth ranged from 9.87 cm to 10.89 cm and there are significantly differ among the dose of boron. The maximum (10.89 cm) leaf breadth recorded in B2 whereas the minimum (9.87 cm) leaf breadth recorded in B0. At 60 DAT, leaf breadth ranged from 14.06 cm to 17.21 cm and showed significantly differ among the dose of boron. The maximum (17.21 cm) leaf breadth recorded in B2 whereas the minimum (14.06 cm) leaf breadth recorded in B0. It was observed that leaf breadth of broccoli increase with increase the dose of boron but excess dose decrease leaf breadth and was also found by Sharma *et al*. (2002).

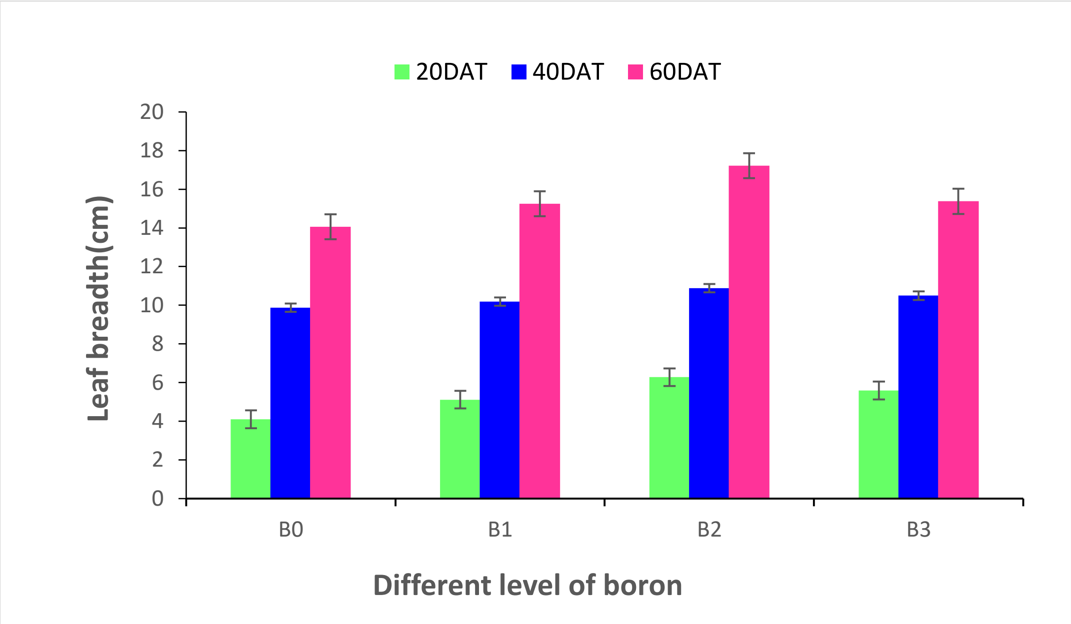

Figure 10. Effect of different dose of boron on leaf breadth of broccoli

B_0: 0kg/ha, B_1:0.6kg/ha, B_2:1.2kg/ha, B_3:1.8kg/ha

There are significant influences of different molybdenum dose on broccoli leaf breadth at 20, 40 and 60 DAT (Figure 11 & Appendix-VI). At 20 DAT, leaf breadth ranged from 5.01 cm to 5.45 cm. The maximum (5.45 cm) leaf breadth recorded in M2 which was similar to M3 and whereas the minimum (5.01 cm) leaf breadth recorded in M0. At 40 DAT, leaf breadth ranged from 9.06 cm to 10.79 cm and there were significantly differ among the dose of boron. The maximum (10.79 cm) leaf breadth recorded in M2 whereas the minimum (9.06 cm) leaf breadth recorded in M0. At 60 DAT, leaf breadth ranged from 14.90 cm to 17.69 cm. The maximum (17.69 cm) leaf breadth recorded in M2 which was significantly similar to M3 whereas the minimum (14.90 cm) leaf breadth recorded in M0.

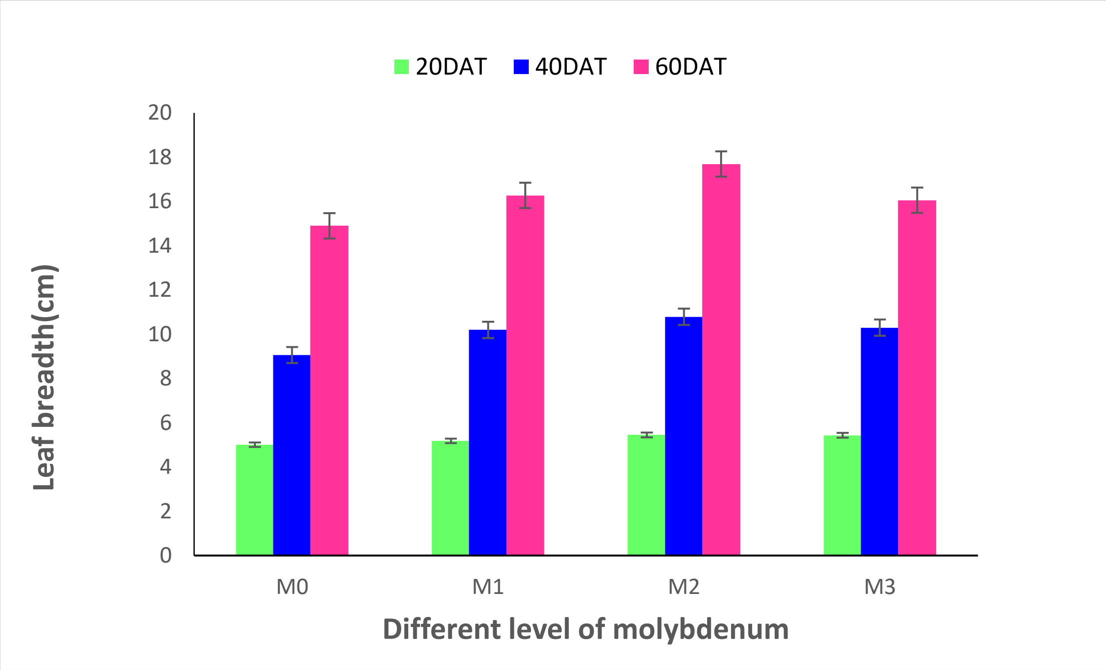

Figure11. Effect of different dose of molybdenum on leaf breadth of broccoli

M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

Application of combined dose of boron and molybdenum had significantly effect on breadth of leaves of broccoli plant at 20, 40 and 60 DAT (Table 4 & Appendix-VI). At 20 DAT, leaf Breadth ranged from 3.78 cm to 6.67 cm. The longest leave breadth (6.67 cm) was found in B2M2 and the smallest leave breadth was found in B0M0 combination of fertilizer. At 40 DAT, leaf breadth ranged from 9.62 cm to 11.64 cm. The maximum leaf breadth (11.64 cm) was recorded in B2M2, and while the smallest

(9.62 cm) was found in B0M0.At 60 DAT, leaf breadth ranged from 12.67 cm to 18.42 cm. The maximum leaf breadth (18.42 cm) was recorded in B2M2 and while the smallest (12.67 cm) was recorded from B0M0.

Table 4. Combined effect of boron and molybdenum on leaf breadth at different days after transplanting (DAT) of broccoli

Treatment	Leaf breadth(cm)		
	20 DAT	40DAT	60 DAT
B0M0	3.78 j	9.62 i	12.67 g
BOM1	4.12 i	9.93 h	14.37 f
B0M2	4.17 i	9.98 h	14.44 f
B0M3	4.32 i	9.96 h	14.76 ef
B1M0	4.76 h	10.02 h	14.87 ef
B1M1	4.82 h	10.10 fgh	16.91bcd
B1M2	5.21 g	10.24 efg	16.98 bc
B1M3	5.67 de	10.37e	16.25 bcd
B2M0	6.03 c	10.30 ef	15.75 de
B2M1	6.07 c	10.67 d	17.25 ab
B2M2	6.67 a	11.64a	18.42 a
B2M3	6.34 b	10.94 b	17.45 ab
B3M0	5.47 ef	10.29 ef	16.31 bcd
B3M1	5.72 d	10.89 bc	16.54 bcd
B3M2	5.76 d	10.08 gh	16.91 bcd
B3M3	5.40 fg	10.72 cd	15.76 cde
CV(%)	10.59	3.79	7.21
LSD0.05	0.21	0.32	1.25

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha; M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

4.6 Root length:

Boron exhibited a significant influence on root length of broccoli plants. Root length ranged from 20.39 cm to 22.04 cm (Table 5 & Appendix-VII). There were maximum (22.04 cm) root length found in B2 which was significantly similar to B1 and B3 and whereas the minimum (20.39 cm) recorded in B0. Long root plays an important role on broccoli growth and yield. Plant uptakes nutrition from soil through root.

Application of molybdenum was also effect on broccoli root length (Table 6 & Appendix-VII). It was ranged from 16.35 cm to 23.41 cm. There were maximum (23.41 cm) root length found in M2 which was similar to M1 and M3 and whereas the minimum (16.35 cm) recorded in M0. It was observed that root length increase to increase the dose of boron and molybdenum and similarities findings by Petracek (2007).

Table 5. Effect of boron on root length, root weight, curd length and curd diameter at different days after transplanting (DAT) of broccoli

Treatment	Root length(cm)	Root weight(g)	Curd length(cm)	Curd diameter (cm)
B0	20.39b	24.69c	12.37d	12.53d
B1	21.69a	26.14b	13.95c	13.33c
B2	22.04a	28.53a	14.77a	14.08a
B3	21.87a	26.25b	14.07b	13.82b
$LSD_{0.05}$	0.62	0.17	0.10	0.19

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B_0: 0kg/ha, B_1:0.6kg/ha, B_2:1.2kg/ha, B_3:1.8kg/ha.

The root length was significantly influenced by combined treatment of broccoli plant (Table 7). The longest root length (24.96 cm) was found in B2M2 combination which was statistically similar with dose of combined treatment whereas smallest root (15.62 cm) length was observed in B0M0 combination of broccoli. It was revealed that root length increase with increasing of combined dose of fertilizer but no or less fertilizer decrease root length.

Table 6. Effect of molybdenum on root length, root weight, curd length and curd diameter at different days after transplanting (DAT) of broccoli

Treatment	Root length(cm)	Root weight(g)	Curd length(cm)	Curd diameter(cm)
M0	16.35b	25.35c	12.27c	12.76c
M1	23.17a	27.08a	14.22b	13.52b
M2	23.41a	26.97a	14.40a	13.85a
M3	23.06a	26.23b	14.27b	13.63b
$LSD_{0.05}$	0.63	0.17	0.10	0.19

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
M_0:0kg/ha, M_1:0.4kg/ha, M_2:0.8kg/ha, M_3:1.2kg/ha

4.7 Root weight

Boron exhibited a significant influence on root weight of broccoli plants (Table 5 & Appendix-VII). Root length ranged from 24.69 g to 28.53 g. There were maximum (28.53 g) root weight found in B2 whereas the minimum (24.69 g) recorded in B0. Application of molybdenum was also effected on broccoli root weight (Table 6 & Appendix-VII). It was ranged from 25.35 g to 27.08 g. There were maximum (27.08 g) root weight found in M1where as the minimum (25.35 g) recorded in M0. Root weight increased with higher dose of boron and molybdenum but excess high dose decrease root weight and similarities examined by Petracek (2007).

The root weight was significantly influenced by combined treatment of broccoli plant weight (Table 7 & Appendix-VII). The biggest root weight (29.67 g) was found in B2M2 combination whereas the smallest root weight (23.63 g) was observed in B0M0 combination of broccoli. It was revealed that root weight increase with increasing of combined dose of fertilizer but no or less or higher fertilizer decrease root weight.

4.8 Main curd length

Boron significantly influenced on curd length which increase broccoli yield weight (Table 5 & Appendix-VII). Application of different dose boron the curd length ranged from 12.37 cm to 14.77 cm. The longest curd found in B2 and whereas smallest found in B0 combination. It expressed that increasing the dose of increasing the curd length but excess dose decreasing curd length.

Application of molybdenum was also influenced curd length of broccoli weight (Table 6 & Appendix-VII). It was ranged from 12.27 cm to 14.40 cm. The longest curd recorded in M2 dose whereas smallest curd found in M0. It was expressed that the dose of boron and molybdenum to increase the curd length but excess dose decrease curd length and it was also founded similarities by Yang (2000).

Application of combined dose of boron and molybdenum effect on broccoli curd length weight (Table 7 & Appendix-VII). It was ranged from 11.19 cm to 15.95 cm. The longest length found in B2M2 combination whereas smallest curd was founded in B0M0 Combination.

4.9 Main curd diameter

Boron significantly influenced on curd diameter which increase broccoli yield weight (Table 5 & Appendix-VII). Application of different dose boron the curd diameter ranged from 12.53 cm to 14.08 cm. The maximum curd diameter (14.08cm) found in B2 and whereas minimum (12.53 cm) found in B0 combination. It expressed that increasing the dose of increasing the curd diameter but excess dose decreasing curd diameter which was also decrease broccoli yield.

Application of molybdenum was also influenced curd diameter of broccoli weight (Table 6 & Appendix-VII). It was ranged from 12.76 cm to 13.85 cm. The maximum curd diameter (13.85 cm) recorded in M2 dose whereas smallest curd (12.76 cm) found in M0. It was also observed by Moniruzzaman *et al.* (2007).

Application of combined dose of boron and molybdenum effect on broccoli curd diameter weight (Table 7 & Appendix-VII). It was ranged from 11.93 cm to 14.76

cm. The maximum curd diameter(14.76 cm) found in B2M2 combination whereas smallest curd diameter (11.93 cm) were founded in B0M0 Combination**.**

Table 7. Combined effect of boron and molybdenum on root length, root weight, curd length and curd diameter at different days after transplanting (DAT) of broccoli

Treatment	Root length(cm)	Root weight(cm)	Curd length(cm)	Curd diameter(cm)
B0M0	15.62 d	23.63K	11.19l	11.93 i
B0M1	21.67 c	25.34h	12.42j	12.47 h
B0M2	21.77 c	25.76 g	12.42j	12.67gh
B0M3	22.49 bc	24.04 j	13.21h	13.05 fg
B1M0	15.96 d	24.06j	11.72 k	12.68 gh
B1M1	23.04abc	26.43 f	14.43 e	13.43ef
B1M2	23.44abc	26.65 ef	14.71 d	13.77de
B1M3	24.32ab	27.45 d	14.95 c	13.45 e
B2M0	16.33 d	26.87 e	12.74i	12.98 g
B2M1	24.32ab	28.65b	15.28b	14.32b
B2M2	24.96 a	29.67a	15.95a	14.76 a
B2M3	22.57abc	28.94 b	15.12bc	14.23 b
B3M0	17.48 d	26.83e	13.44g	13.43ef
B3M1	23.64abc	27.89c	14.73d	13.84cd
B3M2	23.48ac	25.80 g	14.29e	14.21bc
B3M3	22.86abc	24.47 i	13.82f	13.79de
CV(%)	10.38	6.35	7.13	3.52
$LSD_{0.05}$	1.26	0.34	0.20	0.38

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha; M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha**.**

4.10 Main curd weight

Different boron dose had significant influence on the weight of main curd weight (Table 8 & Appendix-VIII). The maximum weight of curd was found in B2 (363.16 g) which was smaller to 360. 26 g.The minimum weight of main curd was recorded from the dose B0 (216.80 g).

The weight of main curd per plant as influenced by molybdenum fertilizers had significant effect (Table 9 & Appendix VIII). The highest weight of main curd (353.28 g) was obtained from the treatment M2 and the lowest weight of main curd was founded in (248.06 g) was recorded from the treatment M0. It has been showed that optimum dose of molybdenum ensures the highest weight of main curd. It was expressed that the dose of boron and molybdenum to increase the main curd weight but excess dose decrease main curd weight and It was also founded similarities by Yang (2000).

The combined effect of boron and molybdenum levels had significant influence on the main curd weight of broccoli (Table 10 & Appendix VIII). It was ranged from 175.56 g to 464.89 g. The maximum main curd weight (464.89 g) was recorded from the treatment combination B2M2 and the minimum weight (175.56 g) of main curd was recorded from the treatment combination B0M0.

4.11 Number of secondary curd

Different boron dose had significant influence on the number of secondary curd weight (Table 8 & Appendix-VIII). The maximum number of curd was found in B2 (3.22). The minimum number of secondary curd was recorded from the dose B0 (2.38).

The number of secondary curd as influenced by molybdenum fertilizers had significant effect (Table 9 & Appendix VIII). The maximum number of secondary curd (2.80) was obtained from the treatment M3 and the minimum number of secondary curd was founded in (2.56) was recorded from the treatment M0. It was observed that the number of secondary curd of broccoli higher optimum dose of boron and molybdenum but excess dose reduced and similarities also founded by Thapa (2016).

The combined effect of boron and molybdenum levels had significant influence on the secondary curd number of broccoli (Table 10 & Appendix VIII). It was ranged from 2.17 to 3.50. The maximum number of secondary curd (3.50) was recorded from the treatment combination B2M2 and the minimum number of secondary curd (2.17) was recorded from the treatment combination B0M0.

4.12 Weight of secondary curd

Different boron dose had significant influence on the weight of secondary curd weight (Table 8 & Appendix-VIII). The maximum weight of curd was found in B2 (70.22 g). The minimum weight of secondary curd was recorded from the dose B0 (62.77 g).

The weight of secondary curd per plant as influenced by molybdenum fertilizers had significant effect (Table 9 & Appendix VIII). The highest weight of secondary curd (69.19 g) was obtained from the treatment M2 and the lowest weight of secondary curd was founded in (62.35 g) was recorded from the treatment M0. It has been showed that optimum dose of molybdenum ensures the highest weight of secondary curd. It was observed that the weight of secondary curd of broccoli higher optimum dose of boron and molybdenum but excess dose reduced and similarities also founded by Thapa (2016).

The combined effect of boron and molybdenum levels had significant influence on the secondary curd weight of broccoli (Table 10 & Appendix VIII). It was ranged from 59.42 g to 74.82 g. The maximum secondary curd weight (74.82 g) was recorded from the treatment combination B2M2 and the minimum weight (59.42 g) of secondary curd was recorded from the treatment combination B0M0.

Table 8. Effect of boron on main curd weight, no. of secondary curd and weight of secondary curd of broccoli

Treatment	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)
B0	216.80c	2.38d	62.77d
B1	283.14b	2.55c	66.77c
B2	363.16a	3.22a	70.22a
B3	360.26a	2.73b	68.22b
$LDS_{0.05}$	5.51	0.07	0.58

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha.

Table 9. Effect of molybdenum on main curd weight, no. of secondary curd and weight of secondary curd at different days after transplanting (DAT) of broccoli

Treatment	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)
M0	248.06d	2.56 b	62.35c
M1	304.01c	2.79a	67.46b
M2	353.28a	2.74a	69.19a
M3	317.99b	2.80a	68.98a
LSD 0.05	5.51	0.07	0.58

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha.

Table 10. Combined effect of boron and molybdenum on main curd weight, no. of secondary curd and weight of secondary curd at different days after transplanting (DAT) of broccoli

Treatment	Main curd weight (g)	Number of secondary curd	Weight of secondary curd(g)
B0M0	175.56l	2.17h	59.42 i
B0M1	192.78k	2.45ef	62.475 gh
B0M2	254.98h	2.27 gh	63.54 g
B0M3	243.87 i	2.63 d	65.26 f
B1M0	218.38 j	2.64d	61.56 h
B1M1	298.63 fg	2.64 d	66.70 e
B1M2	310.67 e	2.37 fg	68.53 d
B1M3	304.86ef	2.57 de	70.29 c
B2M0	218.67 j	2.63 d	63.17g
B2M1	334.76 d	3.16 b	70.73c
B2M2	464.89a	3.50a	74.82a
B2M3	434.31b	3.60a	72.16 b
B3M0	379.63c	2.79c	64.85 f
B3M1	389.87c	2.91 c	69.94c
B3M2	382.60c	2.81c	69.87 c
B3M3	288.93 g	2.42 f	68.22 d
CV(%)	11.05	13.24	3.98
LSD 0.05	11.03	0.14	1.16

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha; M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha

4.13 Yield per plant

The curd yield of broccoli plant varied from plant to plant due to different dose of boron application (Table-11). The maximum curd yield per plant (433.38 g) found in

B2 which was similar to B3 and the minimum curd yield (279.57g) per plant recorded in B0.

Application of different dose of molybdenum significantly effect on curd yield per plant which was ranged from 310.41 g to 422.27 g (Table-12). The maximum curd yield per plant (422.27 g) found in M2 whereas the lowest curd yield per plant (310.41 g) recorded in M0.

There were statistically significant found due application of different combined dose of boron and molybdenum (Table-13). The maximum curd yield per plant (539.72 g) found in B2M2 whereas the lowest curd yield per plant (235.38 g) recorded in B0M0. It was founded that combined dose of broccoli increase yield per plant but excess dose decrease yield per plant and similarities also observed by Saha (2010).

Table 11. Effect of boron on yield per plant, yield per plot and yield per hectare of broccoli

Treatment	Yield pet plant (g)	Yield per plot (kg)	Yield per hectare (t)
B0	279.57 c	2.24 c	10.65c
B1	349.90b	2.80b	13.34b
B2	433.38a	3.47a	16.70a
B3	428.48a	3.43a	16.61a
$LSD_{0.05}$	5.84	0.05	0.61

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B_0: 0kg/ha, B_1:0.6kg/ha, B_2:1.2kg/ha, B_3:1.8kg/ha

4.14 Yield per plot

The curd yield of broccoli plot varied due to different dose of boron application weight (Table 11). The maximum curd yield per plant (3.47 kg) found in B2 which was similar to B3 and the minimum curd yield (2.24 kg) per plant recorded in B0.

Application of different dose of molybdenum significantly effect on curd yield per plant weight (Table 12). It was ranged from 2.49 kg to 3.38 kg. The maximum curd yield per plant (3.38 kg) found in M3 whereas the lowest curd yield per plant (2.49 kg) recorded in M0.

There were statistically significant found due application of different combined dose of boron and molybdenum weight (Table 13). The maximum curd yield per plant (4.33 kg) found in B2M2 whereas the lowest curd yield per plant (1.88 kg) recorded in B0M0. It was founded that combined dose of broccoli increase yield per plot but excess dose decrease yield per plot and similarities also observed by Saha (2010).

Table 12. Effect of molybdenum on yield per plant, yield per plot and yield per hectare of broccoli

Treatment	Yield pet plant (g)	Yield per plot (kg)	Yield per hectare (t)
M0	310.41d	2.49d	12.21c
M1	371.47c	3.10b	14.17b
M2	422.47a	2.98c	16.09a
M3	386.97b	3.38a	14.75b
$LSD_{0.05}$	5.84	0.05	0.61

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
M_0:0kg/ha, M_1:0.4kg/ha, M_2:0.8kg/ha, M_3:1.2kg/ha**.**

4.15 Yield per hectare

The yield per hectare of broccoli was significantly affected by the different dose of boron (Table 11). The maximum yield (16.70 t/ha) was founded in B2 which was similar toB3 and whereas the minimum yield (10.61 t/ha).

Application of molybdenum was significantly influenced on the yield per hectare weight (Table 12). The maximum yield (16.09t/ha) was recorded from the treatment M2 while the minimum yield (12.21 t/ha) was found in the treatment M0 (control).

The treatment combination of boron and molybdenum was significantly influenced on broccoli yield per hectare weight (Table 13). It was ranged from 8.98 t/ha to 20.55 t/ha. The maximum yield (20.55t/ha) was recorded in B2M2 combination whereas the minimum yield (8.98 t/ha) found in the treatment combination B0M0. It was founded that combined dose of broccoli increase yield per hectare but excess dose decrease yield per hectare and similarities also observed by Saha (2010)

Table 13. Combined effect of boron on yield per plant, yield per plot and yield per hectare at different days after transplanting (DAT) of broccoli

Treatment	Yield per plant(g)	Yield per plot(kg)	Yield per hectare(t)
B0M0	235.38 l	1.88 k	8.98 i
B0M1	255.26 k	2.04 j	9.71 hi
B0M2	318.52 i	2.55 h	12.12 f
B0M3	309.13 i	2.47 h	11.78 fg
B1M0	279.94 j	2.24 i	10.67gh
B1M1	365.33 gh	2.92 fg	13.91e
B1M2	379.20 f	3.03e	14.43de
B1M3	375.15 fg	3.00ef	14.33de
B2M0	281.84 j	2.25 i	10.76 gh
B2M1	405.49 e	3.24d	15.55d
B2M2	539.72a	4.33a	20.55a
B2M3	506.47b	4.05b	19.31 b
B3M0	444.48 d	3.56c	18.43 bc
B3M1	459.81c	3.68c	17.52 c
B3M2	452.47 cd	3.62c	17.24 c
B3M3	357.15 h	2.86 g	13.60e
CV (%)	12.20	11.10	11.88
LSD 0.05	11.67	0.10	1.22

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
B0: 0kg/ha, B1:0.6kg/ha, B2:1.2kg/ha, B3:1.8kg/ha; M0:0kg/ha, M1:0.4kg/ha, M2:0.8kg/ha, M3:1.2kg/ha.

4.16 Economic analysis

4.16.1 Gross return

There were significant different founded in gross return of combined application of boron and molybdenum (Table 14). The maximum gross return (Tk. 616500.00) recorded in B2M2 and the second highest gross return (Tk. 579300.00) was found in B2M3.The lowest return (Tk. 269400) was recorded in B0M0.

4.16.2 Net return

In this experiment, different treatment combination showed different net return (Table14). The highest net return (Tk. 461340.00) was obtained from B2M2 and the second highest net return (Tk. 423870.00) was obtained from B2M3. The lowest net return (Tk. 118750.00) was obtained from B0M0.

4.16.3 Benefit cost ratio

The benefit cost ratio was found different due to different treatment combinations (Table 14). The maximum (2.65) benefit cost ratio was found from B2M2 and the second highest benefit cost ratio (2.48) was estimated B2M3. The lowest benefit cost ratio (1.19) was obtained from B0M0. From economic point of view, it is revealed from the above result that B2M2 was more profitable than rest of the treatment combinations of boron and molybdenum for broccoli Production

Table 14. Cost and return of broccoli cultivation as influenced by different dose of boron and molybdenum

Treatment	Cost of production (tk)	Yield of broccoli(t)	Gross return(tk)	Net return (tk)	Benefit cost ratio
B0M0	150650	8.98	179600	28950	1.19
B0M1	151750	9.71	194200	42450	1.28
B0M2	152010	12.12	242400	90390	1.59
B0M3	152405	11.78	235600	83195	1.55
B1M0	153080	10.67	213400	59860	1.39
B1M1	153540	13.91	278200	124660	1.81
B1M2	153890	14.43	288600	134710	1.88
B1M3	154200	14.33	286600	132400	1.86
B2M0	154500	10.76	215200	60700	1.39
B2M1	154875	15.55	311000	156125	2.01
B2M2	155160	20.55	411000	255840	2.65
B2M3	155430	19.31	386200	230770	2.48
B3M0	155980	18.43	368600	212620	2.36
B3M1	156325	17.52	350400	194075	2.24
B3M2	156850	17.24	344800	187950	2.19
B3M3	157260	13.6	272000	114740	1.73

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

B0:0kg/ha,B1:0.6kg/ha,B2:1.2kg/ha,B3:1.8kg/haM0:0kg/ha,M1:0.4kg/ha,M2:0.8kg/ha,M3:1.2kg/ha.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted to find out the "Effect of boron and molybdenum on the growth and yield of broccoli" at the horticulture farm of the Sher-e- Bangla Agricultural University, Dhaka, during the period from October, 2015 to March, 2016. The experiment comprised of two factors. Factor A: Boron, there are four level of boron fertilizer viz. B0: 0 kg/ha, B1: 0.6 kg/ha, B2: 1.2 kg/ha, and B3: 1.8 kg/ha and Factor B, there are four level of molybdenum fertilizer viz. M0: 0kg/ha, M1: 0.4kg, M2:0.8kg and M3: 1.2kg.

Five plants from each plot were randomly selected and identified with tag for the collection of data but the yield was recorded from all plants of each plot. Data were recorded on the plant height, stem diameter, number of leaves per plant, length of leaf, breadth of leaf (at 20, 40 and 60 DAT), length of root, weight of root, diameter of primary curd, length of primary curd, weight of primary curd, number of secondary curd, weight of secondary curd per plant, yield per plant, yield per plot and yield per hectare. All collected data were statistically analyzed and the means were compared with the least significant difference (LSD) values.

The experiment exhibited that there were significantly influenced on different parameter. Application of boron, at 20,40 and 60 DAT the tallest plant (24.23 cm, 30.43 cm and 49.69 cm) was recorded from B2, whereas shortest plant (17.31cm, 25.52cm and 41.31cm) was recorded from B0. At 20, 40 and 60 DAT the maximum stem diameter (0.96 cm, 2.13 cm and 4.39 cm) was recorded from B2, whereas minimum stem diameter (0.73cm, 1.77 cm and 4.05cm) was recorded from B0. At 20, 40 and 60 DAT the maximum leaf number (7.62, 11.45 and 14.83) was recorded from B2, whereas lowest leaf number (5.86, 9.19 and 13.17) was recorded from B0. At 20, 40 and 60 DAT the highest leaf length (13.44 cm, 32.21 cm and 42.47 cm) was recorded from B2, whereas lowest leaf length (11.86 cm, 27.95 cm and 38.34 cm) was recorded from B0. At 20, 40 and 60 DAT the highest leaf breadth (6.28 cm, 10.89 cm and 17.22 cm) was recorded from B2, whereas lowest leaf breadth (4.1 cm, 9.87 cm and14.06 cm) was recorded from B0. The longest root length (22.04 cm) was founded in B2 and whereas shortest root length (20.39cm) was recorded founded in B0. The highest root weight (28.53 cm) recorded in B2 and the minimum root weight (24.69cm) was recorded in B0. The maximum curd length (14.77cm) founded in B2 and minimum (12.37 cm) recorded in B0. The highest curd diameter (14.08 cm) was founded in B2 and whereas lowest curd diameter (12.37cm) was recorded in B0. The maximum main curd weight (363.16 g) recorded in B2 and minimum main curd weight (216.80 g) founded in B0. The highest no of secondary curd (3.22) observed in B2 whereas lowest no of secondary curd (2.38) founded in B0. The highest weight of secondary curd (70.22 g) recorded in B2 and whereas lowest weight (62.77 g) of secondary curd founded in B0. The maximum yield per plant (422.47 g) was recorded in B2 and the minimum yield per plant(310.41g) was recorded in B0. The maximum yield per plot (3.47 kg) was recorded in B2 and the minimum yield per plot (2.24 kg) was recorded in B0. The maximum yield per hectare (16.70 t) was recorded in B2 and the minimum yield per hectare (10.65 t) was recorded in B0.

Application of Molybdenum at 20, 40 and 60 DAT the tallest plan t (23.34cm,29.83cm and 52.54cm) was recorded from M2, whereas shortest plant (17cm, 22.22 cm and 35.99 cm) was recorded from M0. At 20, 40 and 60 DAT the maximum stem diameter (1.15 cm, 2.21cm and 4.69 cm) was recorded from M2, whereas minimum stem diameter (0.49 cm, 1.76 cm and3.48 cm) was recorded from M0. At 20,40 and 60 DAT the maximum leaf number (7.24,11.08 and 15.03) was recorded from M2, whereas lowest leaf number (5.86, 8.99 and 12.13) was recorded from M0. At 20,40 and 60 DAT the highest leaf length (13.56cm, 32.51cm and 42.58 cm) was recorded from M2, whereas lowest leaf length (9.98cm, 27.72cm and 36.3cm) was recorded from M0. At 20,40 and 60 DAT the highest leaf breadth (5.45 cm,10.79 cm and 17.69 cm) was recorded from M2, whereas lowest leaf breadth (5.01cm, 9.08cm and 14.9cm) was recorded from M0. The longest root length (23.41 cm) was founded in M2 and whereas shortest root length (16.35 cm) was recorded founded in M0. The highest root weight (26.97 cm) recorded in M2 and the minimum root weight (25.35 cm) was recorded in M0. The maximum curd length (14.40 cm) founded in M2 and minimum (12.27 cm) recorded in M0. The highest curd diameter (13.85 cm) was founded in M2 and whereas lowest curd diameter (12.76 cm) was recorded in M0. The maximum main curd weight (353.28 g) recorded in M2 and minimum main curd weight (248.06 g) founded in M0. The highest no of secondary curd (2.80) observed in M3 whereas lowest no of secondary curd (2.56) founded in M0. The highest weight of secondary curd (69.19g) recorded in M2 and whereas lowest weight (62.35g) of secondary curd founded in M0.The maximum yield per plant (422.47) was recorded in M2 and the minimum yield per plant(310.41 g) was recorded in M0. The maximum yield per plot (3.38 kg) was recorded in M2 and the minimum yield per plot (2.49kg) was recorded in M0. The maximum yield per hectare (16.09t) was recorded in M2 and the minimum yield per hectare (12.21t) was recorded in M0.

Due to the interaction effect of boron and organic molybdenum, at 20, 40 and 60 DAT the tallest plant (28.54 cm,36.13cm and 56.73 cm) was recorded from B2M2, while the shortest (13.39cm,21.12 cm and 33.27 cm) was found from B0M0. At 20,40 and 60 DAT the maximum stem diameter (1.45 cm, 2.39 cm and 4.96 cm) was recorded from B2M2, whereas minimum stem diameter (0.44 cm, 1.54 cm and 3.38 cm) was recorded from B0M0. At 20, 40 and 60 DAT the maximum leaf number (8.45, 12.82 and 16.17) was recorded from B2M2, whereas lowest leaf number (5.10, 8.10 and 11.59) was recorded from B0M0. At 20,40 and 60 DAT the highest leaf length (14.77cm, 34.49cm and 44.04 cm) was recorded from B2M2, whereas lowest leaf length (9.10 cm, 24.52 cm and 35.22 cm) was recorded from B0M0. At 20,40 and 60 DAT the highest leaf breadth (6.67 cm, 11.64cm and 18.42 cm) was recorded from B2M2, whereas lowest leaf breadth (3.78 cm, 9.62 cm and 12.67 cm) was recorded from B0M0. The longest root length (24.96 cm) was founded in B2M2 and whereas shortest root length (15.62 cm) was recorded founded in B0M0.The highest root weight (29.67cm) recorded in B2M2 and the minimum root weight (23.63 cm) was recorded in B0M0. The maximum curd length (15.95cm) founded in B2M2 and minimum (11.19 cm) recorded in B0M0. The highest curd diameter (14.76 cm) was founded in B2M2 and whereas lowest curd diameter (11.93 cm) was recorded in B0M0. The maximum main curd weight (464.89 g) recorded in B2M2 and minimum main curd weight (175.56 g) founded in BOM0.The highest no of secondary curd (3.50) observed in B2M2 whereas lowest no of secondary curd (2.17) founded in B0M0.The highest weight of secondary curd (74.82) recorded in B2M2 and whereas lowest weight (59.42 g) of secondary curd founded in B0M0.The maximum yield per plant (539.72 g) was recorded in B2M2 and the minimum yield per plant (235.38 g) was recorded in B0M0. The maximum yield per plot (4.33 kg) was recorded in B2M2 and the minimum yield per plot (1.88 kg) was recorded in B0M0. The maximum yield per hectare (20.55 t) was recorded in B2M2 and the minimum yield per hectare (8.98 t) was recorded in B0M0.

The highest gross return (Tk. 411000) was obtained from the treatment combination B2M2 and the lowest gross return (Tk. 179600) was obtained from B0M0. The highest net return (Tk. 255840) was found from the treatment combination B2M2 and the lowest (Tk. 28950) net return was obtained B0M0. In the different planting time and organic manure, the highest benefit cost ratio (2.65) was noted from the combination of B2M2 and the lowest benefit cost ratio (1.19) was obtained from B0M0.

It was revealed that the above results that the combination of B2M2 was more suitable in consideration of yield contributing characters and yield and consideration value for money concept.

Conclusions:

Considering the findings of the experiment, it can be concluded that,

i. Application of boron improves the vegetative growth and quantitative parameters of broccoli and its application to the soil also increased the head yield and weight of broccoli.

ii. Application of molybdenum plays a significant effect on vegetative and yield contributing parameter of broccoli.

iii. In combination of boron and boron molybdenum the highest yield was found with the combination of 1.2 kg B/ha and 0.8 kg Mo/ha.

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APPENDICES

Appendix I. Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Horticulture Garden , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Source:SRDI, khamarbari road,Dhaka-1215, 2019.

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source:SRDI, khamarbari road,Dhaka-1215, 2019.

Appendix II. Monthly record of air temperature, relative humidity and Rainfall of the experimental site during the period from October, 2019 to February, 2020

Month	Air temperature (C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
October, 2015	29.18	18.25	81.10	38
November, 2015	28.79	18.55	82.52	83.1
December, 2015	25.33	14.50	84.07	0.00
January, 2016	21.72	10.18	83.63	Trace
February, 2016	26.78	15.50	75.20	26.10

Source: Bangladesh Meteorological Department (Climate and weather division) Agargaon, Dhaka-1207

Appendix III. Nutritive value of 1 lb of selected cole crops for comparison

Kind of product	Broccoli	Cauliflower	Cabbage
Refuse percent	39.00	55.00	27.00
Food energy (cal.)	103.00	63.00	49.00
Protein (g)	9.10	4.90	4.60
Fat (g)	0.60	0.40	0.70
Carbohydrate (g)	15.20	10.00	17.50
Calcium (mg)	360.00	45.00	152.00
Phosphorus (mg)	211.00	147.00	103.00
Iron (mg)	3.60	2.20	1.70
Ascorbic acid (mg)	327.00	141.00	173.00
Riboflavin (mg)	0.59	0.22	0.21
Thiamin	0.26	0.21	0.23
Niacin	2.50	1.20	0.90

Source: Thompson and Kelly (1988)

Appendix IV. Analysis of variance of the data on plant height and stem diameter

Source of variation	Degrees of freedom (df)	Mean Square of					
		Plant height (cm) at			Stem diameter(cm) at		
		20 DAT	40DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	3.951	24.596	51.284	0.0268	0.029	0.039
Boron(B)	3	385.493	491.390*	1093.278*	1.534*	1.521*	0.442^{NS}
Molybdenum(M)	3	256.826*	552.181*	1097.343*	1.482*	1.471*	0.491^{NS}
B x M	9	18.44*	14.92*	26.83*	0.080*	0.104*	0.112^{NS}
Error	30	12.528	13.567	18.832	0.019	0.136	0.682

* Significant at 5% level of probability, and NS-Non-significant

Appendix V. Analysis of variance of the data on leaf number and leaf length

Source of variation	Degree of freedom	Mean Square of					
		Leaf number at			Leaf length (cm) at		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	0.657	3.837	1.852	58.431	0.493	29.421
Boron(B)	3	23.548*	6.482NS	5.381^{NS}	251.522*	237.371*	226.241*
Molybdenum(M)	3	18.923*	4.451NS	4.270^{NS}	283.422*	268.738*	278.635*
B x M	9	1.520*	1.384*	1.571^{NS}	7.921*	16.952*	15.347*
Error	30	1.236	2.672	3.416	25.632	15.361	21.534

***** Significant at 5% level of probability, and NS- No- significant

Appendix VI. Analysis of variance of the data on leaf breadth

Source of variation	Degrees of freedom (df)	Mean Square of leaf breadth(cm)		
		20 DAT	40 DAT	60 DAT
Replication	2	53.423	0.327	26.621
Boron(B)	3	221.622*	215.3821*	217.821*
Molybdenum(M)	3	245.492*	241.912*	262.541*
B x M	9	6.372*	13.623*	14.734*
Error	30	23.822	13.732	18.273

***** Significant at 5% level of probability.

Appendix VII. Analysis of variance of the data on root length, root weight, main curd length and main curd diameter

Source of variation	Degrees of freedom	Mean Square of			
		Root length	Root weight	Curd length(cm)	Curd diameter(cm)
Replication	2	24.51	7.53	5.423	7.586
Boron(B)	3	103.542**	85.352**	26.532*	35.153*
Molybdenum(M)	3	117.532**	75.517**	36.834*	45.935*
B x M	9	86.632*	62.581*	2.310*	1.734*
Error	30	22.634	29.703	3.823	3.381

* Significant at 1% level of probabilityand ** Significant at 5% level of probability.

Appendix VIII. Analysis of variance of the data on main curd weight, number of secondary curd and weight of secondary

Source of variation	Degrees of freedom	Mean Square of		
		Main curd weight (g)	Number of secondary curd	Weight of secondary curd(g)
Replication	2	275.34	1.643	13.632
Boron(B)	3	5573.642**	11.846**	94.763**
Molybdenum(M)	3	4485.732**	14.643**	74.624**
B x M	9	573.623*	4.742*	42.791*
Error	30	137.640	1.745	13.942

* Significant at 1% level of probability and **Significant at 5% level of probability.

Plate 1. Photograph of field preparation

Plate 2. Photograph of growth data recording

Plates 3. Photograph of harvesting

Plates 4. Photograph of yield data recording