INFLUENCE OF BORON ON GROWTH AND YIELD OF BROCCOLI CULTIVARS

UMME SALMA

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

UMME SALMA

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APPROVED BY:

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Prof. Dr. Md. Ismail Hossain	**Prof. Md. Hasanuzzaman Akand**
Department of Horticulture	Department of Horticulture
SAU, Dhaka	SAU, Dhaka
Supervisor	**Co-Supervisor**

Prof. Dr. Tahmina Mostarin
Chairman
Examination Committee

DEDICATED

TO

MY BELOVED PARENTS

Department of Horticulture

Sher-e-Bangla Agricultural University

Sher-e -Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled "**INFLUENCE OF BORON ON GROWTH AND YIELD OF BROCCOLI CULTIVARS**" submitted to the Department of Horticulture, 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 **UMME SALMA**, Registration No. **10-04027** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016
Dhaka, Bangladesh

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Prof. Dr. Md. Ismail Hossain
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

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The Author

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ABSTRACT

A field experiment comprising of three broccoli cultivars (V_1: Top Green, V_2: Green Magic and V_3: BARI Broccoli-1) with four different levels of boron (B_0: control, B_1: 1 kg/ha, B_2: 2 kg/ha and B_3: 3 kg/ha) was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during October, 2015 to February, 2016. The experiment was laid out in Randomized Complete Block Design with three replications. The significant variation was observed among the cultivars in different parameters. Green magic performed the highest yield (16.48 t/ha) and the lowest yield (13.38 t/ha) was found from BARI Broccoli-1. 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 cultivars and boron. The highest yield (17.12 t/ha) was found from the treatment B_2 and the lowest (13.14 t/ha) from the treatment B_0. For combined effect highest yield (18.16 t/ha) was found from V_2B_2 and lowest (12.45 t/ha) was obtained from $V_3B_{0.}$ The highest benefit cost ratio was found in $V_2B_{2.}$ So, Green magic cultivar with 2 kg boron was found suitable for growth and yield of broccoli.

LIST OF ABBREVIATED TERMS

ABBREVIATION		ELABORATIONS
%	:	Percent
@	:	At the rate
°C	:	Degree centigrade
AEZ	:	Agro-Ecological Zone
Anon.	:	Anonymous
ANOVA	:	Analysis of Variance
BARI	:	Bangladesh Agricultural Research Institute
BINA	:	Bangladesh Institute of Nuclear Agriculture
Cal.	:	Calorie
CV	:	Coefficient of Variation
DAT	:	Day After Transplanting
Df	:	Degrees of Freedom
DMRT	:	Duncan s Multiple Range Test
et al.	:	And others
g	:	Gram
i.e.	:	That is
J.	:	Journal
NS	:	Non Significant
pH	:	Hydrogen ion concentration
RCBD	:	Randomized Complete Block Design
RH	:	Relative humidity
SRDI	:	Soil Resource Development Institute

CONTENTS

LIST OF TABLES

Table No.	Title (contd.)	Page No.

LIST OF FIGURE

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica* L.), is an important member of "Cole" crops, belongs to the family Brassicaceae. Broccoli originated from west Europe (Prasad and Kumer, 1999). The word "Cole" means a group of highly differentiated plants originated from a single wild *Brassica oleracea* var. *oleracea* (*Sylvestris* L.) commonly known as wild cabbage (Bose and Som, 1986). In Bangladesh, broccoli was introduced about two decades ago.

Broccoli is grown in winter season in Bangladesh as an annual crop. It is environmentally better adapted and can withstand comparatively high temperature than cauliflower (Rashid *et al*., 1976). Its wider environmental adaptability, higher nutritive value, good taste and less risk to crop failure due to various biotic and abiotic factors indicate that there is enough scope for its promotional efforts. Its popularity to the consumers of urban area is increasing day by day in our country. But its cultivation has not spread much beyond the farms of different agricultural organizations. In our country broccoli cultivation are confined into a very limited area with a minimum production and its average yield is only about 10.5 metric tons per hectare (Anon., 2004) which is very low compared to other broccoli growing countries like 24 t/ha in Italy, 20 t/ha in Japan and 18 t/ha in Turkey (Ahmed *et al*., 2004).

Broccoli genotypes have also significant effect on yield of broccoli. Cultivar 'Captain' produced the highest total yield as well as top and lateral head yields, the largest top head weight and marked earliness which was followed by cultivars ‘Lucky’, ‘General’, ‘Griffen’, ‘Liberty’ and ‘Milady’ (Toth *et al*., 2007). Several broccoli genotypes are cultivated in our country those differ in yield. So, it is essential to identify high yielding genotypes to maximize broccoli yield.

The popularity of Broccoli is a recent phenomenon in Olericulture in Bangladesh. It is a horticultural hybrid closely related to Cauliflower and can be harvested for a longer period of time (Thompson and Kelly, 1985). It is a very tasty vegetable with an important source of carbohydrate, vitamins and minerals. It contains 5.5 g carbohydrate, 3.3 g protein, 3200 IU carotene, 0.16 mg B_1, 0.11 mg B_2, 118 mg vitamin C, 160 mg calcium and 1.6 mg iron (Rashid, 1999).

Boron is considered as a potential micronutrient that carries out various functions for plant growth and development. Application of boron significantly increases curd diameter, weight of curd, yield and quality of cauliflower (Kumar *et al.*, 2002). In cole crops like cauliflower and broccoli, boron requirement is high. It is essential for translocation of sugars, starches, nitrogen and sulpher (Randhawa and Bhali, 1976). Boron deficiency is now widespread in Bangladesh. This element deficiency causes many anatomical, physiological and biological changes. Hollow stem disorder is a major problem for broccoli production and is commonly associated with B deficiency (Shelp *et al*., 1992; Rahman *et al*., 1995).

However, the yield of broccoli in Bangladesh is very poor compared to that of 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 cultivars, to study in detail the nutritional requirements of broccoli and to find out the optimum dose of boron to promote the production of this crop in Bangladesh. The aim of the investigation was to find out the effective combination of boron and cultivar on growth and yield of broccoli.

Objectives:

The present investigation was therefore, carried out with a view to achieving the following objectives:

i. To identify the suitable cultivar for higher yield of broccoli;
ii. To find out the effect of boron on the yield contributing characters and yield of broccoli; and
iii. To find out the effective combination of boron and cultivar on growth and yield of broccoli.

CHAPTER II

REVIEW OF LITERATURE

Broccoli is a nontraditional and a winter crop of Bangladesh. It is one of the most important vegetable crops of the world, particularly from the nutritional point of view. In our country, a little attention has been given for the improvement of broccoli cultivars. 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. Application of boron influences the growth and yield of the crop. Investigations conducted by different workers also found that the application of different levels of boron 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.

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. There was a 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 L_3, 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 at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during winter season, 2007-2008 to determine the effect of N and B on the yield and hollow stem disorder of broccoli. 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. The 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 on yield and quality of broccoli was significant 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 the effect of boron fertilizer on the yield of broccoli through an experiment which was conducted at the Hill Agricultural Research Station (HARS), Khagrachari during September 2002 to March 2003. 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. Boron was applied as solubor (20% B). There was a significant and positive effect of boron application on the yield of the crop. The 1.0 kg B/ha had the highest yield (512.30 g/plant). The 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. Green Harmony performed the highest result (606.20 g/plant).

Moniruzzaman *et al.* (2007) conducted a field 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) at the Agricultural Research Station, Raikhali, Rangamati Hill District during the winter (rabi) seasons of 2004-05 and 2005-06 to find out the suitable doses of B and N for higher yield and good quality head of broccoli. There were twelve treatment replicated three times. They reported that boron application increased plant height, number of leaves per plant, length and width of the leaves, plant spread, main head weight and head yield both per plant and per hectare significantly up to 1.5 kg/ha. Maximum yield per hectare was obtained 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. The latter combination (1.5 kg B/ha + 100 kg N/ha) gave the lowest hollow stem in broccoli during both years.

Pieztta *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. Five boron levels (0, 2, 4, 6 and 8 kg/ha B as borax) were applied in broccoli, cauliflower and cabbage. Organic manure and chemical fertilizers, including 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 increase in 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. Broccoli and cabbage were less sensitive than cauliflower to boron deficiency and toxicity. Quality of the curds decreased when 2 or 6 kg/ha B was applied to cauliflower.

A glass house experiment by Annesar *et al.* (2004) with various macro and micro nutrients was carried out in 2004 at Wiehenstephan, Bavaria. Broccoli was grown in plots with a black beltic peat substrate. The typical nutrient deficiency symptoms of nitrogen, phosphorus and potassium under supply were described. 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, 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. B significantly improved the vegetative growth and quality parameters of cauliflower. The greatest stalk length (6.78 cm) was obtained with Borax applied at 10 kg/ha as soil treatment. 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).

Sanjay and Chaudhary (2002) conducted a field experiment to study 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. 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 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 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. 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% compared to application of NPK alone.

Singh *et al.* (2002) conducted a field experiment with cauliflower (cv. Snowball-16) during the rabi season of 1996-99 in Bihar, India. 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. 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. B concentration in the leaf tissue was higher than that in the marketable curds.

Sharma *et al*. (2002) conducted field experiments in Kandaghat, Himachal Pradesh, India, during 1993-94 and 1994-95 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. 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 obtained 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. They 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, revealed that 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 were analyzed by 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 if 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) studied 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. Similar 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.

Malewar *et al.* (1999) critical concentration of boron in cauliflower was established by graphical and statical methods, for which a pot trial was conducted 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. 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 reported 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. 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%) when applied through foliar sprays.

Ghosh and Hassan (1997) reported that 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 with cauliflower and reported that application B on clay loam soil from 2.2-8.8 kg/ha reduced hollow stem but had no effect on yield or curd mass. 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 that 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. 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. 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. Four rates of nitrogen (90, 120, 150 or

180 kg/ha) were applied 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. For B application of 10 kg/ha resulted in the highest 1000-seed weight and seed yield.

Kotur (1992) determined 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 ‘Pusa Kunwari’ (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. 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. Leaf water potential, stomatal opening and conductance, transpiration rate, hill reaction activity, net photosynthesis and intercellular CO_2 concentration were greatly reduced by b deficiency. 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 CO_2

concentration, suggesting the involvement of B in stomatal regulation. The decrease in net photosynthesis with B deficiency was, however, a non stomatal effect largely due to decreased hill reaction activity.

Thakur *et al.* (1991) conducted field trials during the winter seasons of 1985-86 and 1986-87, the effects of five rates of N application (80, 120, 160, 200 and 240 kg/ha), four rates of P application (100, 150, 200 and 250 kg/ha) and two rates of B application (0 and 20 kg/ha) on cauliflower cv. Pusa Snowball-1 were studied and reported that application of B increased the number of leaves/plant, DM content and curd yield and reduced leaf area, stalk length and incidence of stalk rot.

Shelp (1990) reported that 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 pertitioning of N into soluble (nitrate, ammonium, amino acids) and insoluble components of foliage (young and old leaves) and the florets was 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. Seed yield was positively correlated with soil and especially leaf B content. Applying B, N and k promoted growth, co_2 assimilation, nitrate reductase activity in leaves and DM accumulation.

Prasad and Singh (1988) screened eight genotypes of the Snowball group during 1985-86 for response to B using boric acid applied at the rate of 15 kg/ha to half the plots while no boron was applied to the other half. Under B application Pusa Snowball K1 gave the highest yield (15.4 t/ha) followed by Sel 5 (14.7 t/ha) with lowest yield observed in Kt 9 (8.8t/ha). Application of B significantly increased the yield (133%), curd weight, curd diameter, number of marketable curds and total plant weight. Yields from the control plots were highest in Sel 5 (10.2 t/ha) and pusa Snowball (10.1 t/ha) while Sel7 recorded the lowest yields (5.1 t/ha). There were significant differences between genotypes in response to B.

Petracek and Sams (1987) supplied 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. Heads produced by plants in 0.08 ppm had small, chlorotic buds, scale covered stalks, and high levels of total phenols and fibre. Plants grown in 4.06 and 8.11 ppm boron had slightly chlorotic leaves throughout their life cycle and chlorotic leaf margins. 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. Thi findings suggest that high boron concentrations, which induce boron toxicity symptoms in leaves, may stimulate head development.

Dutta (1984) reported that application of B (1 kg/ha) increase leaf area ratio (LAR), leaf area index (LAI), crop growth rate (CGR), number of branches/plant, number of pods/plant, seed weight/pod and decrease in chlorophyll content, net assimilation rate and other growth attributes of broccoli were unaffected.

2.2 Effect of cultivar on growth and yield of Broccoli

Apahidean *et al.* (2010) investigated the best way to produce broccoli. They tested three hybrids: ‘Fiesta F1’, ‘Marathon F1’ and ‘Belstar F1’, also different densities and different ways to set the crop in the field (with two rows or three rows). After cuting the main broccoli sprouts, secondary sprouts (also called side shoots) were start developed. Side shoots were varied in size and weight, depending on the hybrid but as general information, side shoots are smaller than main broccoli heads. Depending on weather cut side shoots at 3 to 5 day intervals for 2 to 3 weeks. Side shoots production was influenced by hybrids, densities and the way that the crop was set in the field. On the poster it will present the influence of side shoots upon final broccoli yields, to see its worth to keep broccoli plants after the main broccoli head its cut.

Charron *et al.* (2005) recorded that on myrosinase [thioglucosidase] catalyzes the hydrolysis of glucosinolates found in the Brassicaceae, generating a variety of bioactive reaction products that may aid in the prevention of some cancers and that are suppressive to soil-borne plant pathogens. Two cultivars each of broccoli (*Brassica oleracea* var. *italica)*, Brussels sprouts (B. oleracea var. gemmifera), cabbage (*B. oleracea* var. *capitat*a), cauliflower *(B. oleracea* var. *botrytis*), and kale (*B. oleracea* var. *acephala*) were grown during 2 autumn seasons and 2 spring seasons to determine if myrosinase activity varied by season. Regression models that included mean temperature and photosynthetic photon flux (PPF) during the growing seasons showed that climatic variables explained seasonal differences for myrosinase activity. Activity FW (FW=fresh weight; U g-1) and specific activity (U mg-1) were significantly ($p<=0.05$) affected by season, botanical group and group x season. Activity FW had a negative linear relationship with temperature, and a positive linear but negative quadratic relationship with PPF. Specific activity had a positive linear and a negative quadratic relationship with both temperature and PPF. Therefore the influence of climatic factors on myrosinase activity in Brassica species may affect the potential benefits of the glucosinolate-myrosinase system.

From the review, it is clear that different cultivars and boron levels have a relation with growth and yield of broccoli. These factors both singly and combinedly influenced plant growth and yield of broccoli. But the effect of these factors on growth and yield of broccoli have a little concern in detail under Bangladesh conditions. Therefore, it is very much essential to optimize the dose of boron and to evaluate the performance of available broccoli genotypes in respect of yield for successful cultivation of broccoli.

CHAPTER III

MATERIALS AND METHODS

This chapter includes major information regarding materials and methods that were used in conducting the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure and statistical analysis etc. The details of the experiment with its methods used are described below.

3.1 Experimental site

Broccoli plants were grown at the Horticulture Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The experiment was carried out during rabi season (October 12, 2015 to February 15, 2016). The location of the experimental site was at 23°75´ N latitude and 90°.34´ E longitude with an elevation of 8.45 meter from sea level.

3.2 Climate

The experimental area was located in the sub-tropical climatic zone, which was characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest period of the year. Details of weather data in respect of temperature (° C), rainfall (cm) and relative humidity (%) for the study period were collected from the Meteorological Department of Bangladesh, Agargoan, Dhaka, (Appendix II).

3.3 Soil

The soil of the experimental site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix I.

3.4 Plant materials used in the experiment

Top green, Green magic and BARI Broccoli-1 were used in the experiment. Top green and Green magic were collected from Siddique Bazar, Dhaka. BARI Broccoli-1 was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.5 Seedbed preparation

There were three seedbed prepared for three cultivar on 15 October, 2015 for raising seedlings of broccoli and the size of the seedbed was 3 m×1 m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. The soil of seedbed was treated by Sevin 50WP @ 5 kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm.

3.6 Treatment of seed

Provax 200WP @ 3g/1kg seeds was applied to treat the seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.7 Seed sowing

Sowing of seeds was done on 22 October, 2015 in the seedbed. It was done thinly in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil and then light irrigation by water can was done. Then the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. To protect the young seedlings from scorching sunshine and rain, a bamboo mat was provided to shade when the seeds were germinated.

3.8 Raising of seedlings

Watering and weeding were done several times. No chemical fertilizers were applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 30 days old seedlings were transplanted into the experimental field on 23 November 2015.

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. four levels of boron and three cultivars. The experimental plot was first divided into three blocks. Each block consisted of 12 plots. Thus, the total number of plots was 36. Different combinations of boron and cultivars were assigned randomly to each plot as per design of the experiment. The size of a unit plot was 2 m × 1.8 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 × 9 m.

3.10 Treatment of the experiment

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

Factor A. Three cultivars of broccoli

V_1: Top green

V_2: Green magic

V_3: BARI Broccoli-1

Factor B. Four doses of boron

B_0: No boron (control)

B_1: 1 kg/ha

B_2: 2 kg/ha

B_3: 3 kg/ha

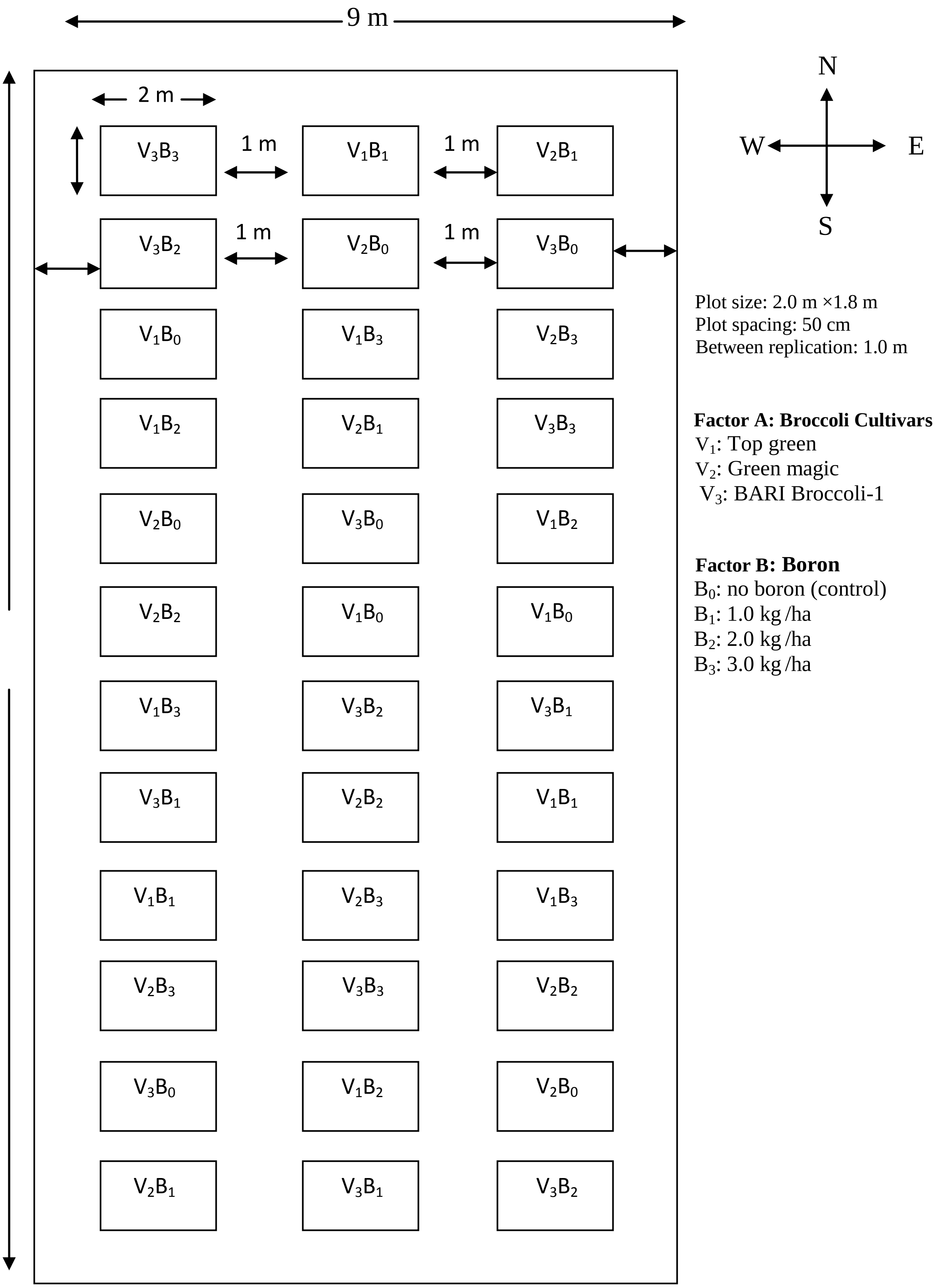


Figure 1. Layout of the experimental plot

There were 12 treatment combinations such as:

V_1B_0	V_2B_2
V_1B_1	V_2B_3
V_1B_2	V_3B_0
V_1B_3	V_3B_1
V_2B_0	V_3B_2
V_2B_1	V_3B_3

3.11 Cultivation procedure

3.11.1 Land preparation

First opening of the experimental area was on 15 October 2015 with a disc plough. Several ploughing and cross ploughing was done with a power tiller followed by laddering to bring about a good tilth. Leveling of the land, corners shaping was done. The clods were broken into pieces. The weeds, crop residues and stables were removed from the field. The doses of manure were applied and finally leveled. The soil of the plot was treated by Seven 50wp @ 5kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.

3.11.2 Application of manure and fertilizer

Manure and fertilizers that were applied 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) also as basal treatment. Urea was applied in three equal installments at 15, 30 and 45 days after transplanting in ring method. 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 tons	100	--	--	--
Urea	250 kg	--	33.33	33.33	33.33
TSP	150 kg	100	--	--	--
MP	200 kg	50	25	25	

Source: Fertilizer recommendation, BARC, 2013

3.11.3 Transplanting

The entire seedbed was irrigated before uprooting the seedlings to minimize the damage of roots. During the uprooting, care was taken so that root damage became minimum and some soil remained with the roots. Thirty days old healthy seedlings were transplanted at the spacing of 60 cm × 40 cm in the experimental plots on 23 November 2015. Thus the 15 plants were accommodated in each unit plot. In the afternoon, planting was done. Light irrigation was given immediately after transplanting around each seedling for their better establishment. To protect the transplanted seedlings from scorching sunlight, shading was done for five days with the help of transparent polythene, 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

Some seedlings were damaged after transplanting and gap filling was carried out with new seedlings from the seed bed.

3.12.2 Weeding

The plants were kept under careful observation. Significant number of weed were found in the control treatment. Weeding was done three times in these plots. At 10, 30 and 50 DAT 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, soils of each plot were pulverized by spade for easy aeration and it was done after each irrigation.

3.12.4 Irrigation

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

3.12.5 Earthing up

Earthing up was done by taking the soil from the space between the rows.

3.12.6 Insects and disease control

Very few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Sevin 80WP was dusted to the soil before irrigation to control these insect. Bird pests like nightingale (bulbuli) were seen visiting the broccoli field very frequently. The nightingale visited the fields from 8 to 11 a.m. and 4 to 6 p.m. The birds were found to 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 at different dates. When the plants formed compact curd, main curds were harvested. 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 26 January, 2016 and was completed on 11 February, 2016. The curds were harvested with 20 cm of stem that was attached with the sprouts.

3.14 Data collection

The data of the following characters were recorded from five plants randomly selected from each plot, except yield of curds, which was recorded plot wise.

3.14.1 Plant height

The height of the plant was measured from base to the tip of the longest leaf at 20, 40 and 60 days after transplanting (DAT). A meter scale was used to measure plant height of the plant and expressed in centimeter (cm).

3.14.2 Number of leaves per plant

The number of leaves per plant excluding the small leaves, which produced by axillary shoots was counted at 20, 40 and 60 days after transplanting.

3.14.3 Leaf length

The distance from the base of the petiole to the tip of the leaf was considered as length of leaf. 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).

3.14.4 Leaf breadth

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

3.14.5 Days required for curd initiation

Each plant of the experimental plot was kept under close observation from 40 DAT to count days required for curd initiation. Total number of days from the date of transplanting to the date of visible curd initiation was recorded.

3.14.6 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.

3.14.7 Length of root

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

3.14.8 Weight of root

The fresh weight of roots was recorded in weighting the total roots after cleaning. Average of 10 plants were recorded and expressed in gram. The weight of the roots was recorded immediately after harvest.

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 weight of main curd

Weight of the main curd per plant was recorded in gram excluding the weight of all secondary curds. It was measured by using a beam balance.

3.14.11 Number of secondary curd

When the secondary curds reached to marketable size, they were counted the small shoots were taken into consideration.

3.14.12 Weight of secondary curd

Weight of secondary curd was recorded by weighing the total marketable auxiliary curds of an individual plant.

3.14.13 Dry matter of leaves

At first 100 g leaves of selected plant was collected, cut into pieces and was dried under sunshine for a few days and then dried in an oven at 70°C for 72 hours before taking dry weight till it was constant. The dry matter was calculated using following formula:

$$\% \text{ Dry matter of leaves} = \frac{\text{Dry weight of leaves}}{\text{Fresh weight of leaves}} \times 100$$

3.14.14 Dry matter of curd

Sample of 100 g curd was taken, cut into pieces and was dried under direct sunshine for 3 days and then was dried in an oven at 70° c for 72 hours before taking the dry weight till it was constant. The dry matter was was calculated using following formula:

$$\% \text{ Dry matter of curd} = \frac{\text{Dry weight of curd}}{\text{Fresh weight of curd}} \times 100$$

3.14.15. Yield per plant

The yield per plant was calculated by adding the weight of all the main curd and the weight of all the secondary curds harvested, and it was measured in gram (g).

3.14.16 Yield per plot

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

3.14.17 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

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program to find out the significance of the difference for planting time and organic manure on yield and yield contributing characteristics of broccoli. The mean values of all the recorded characteristics were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different cultivars and boron levels. All input cost including the cost for lease of land and interests on running capital in computing the cost of production. 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:

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

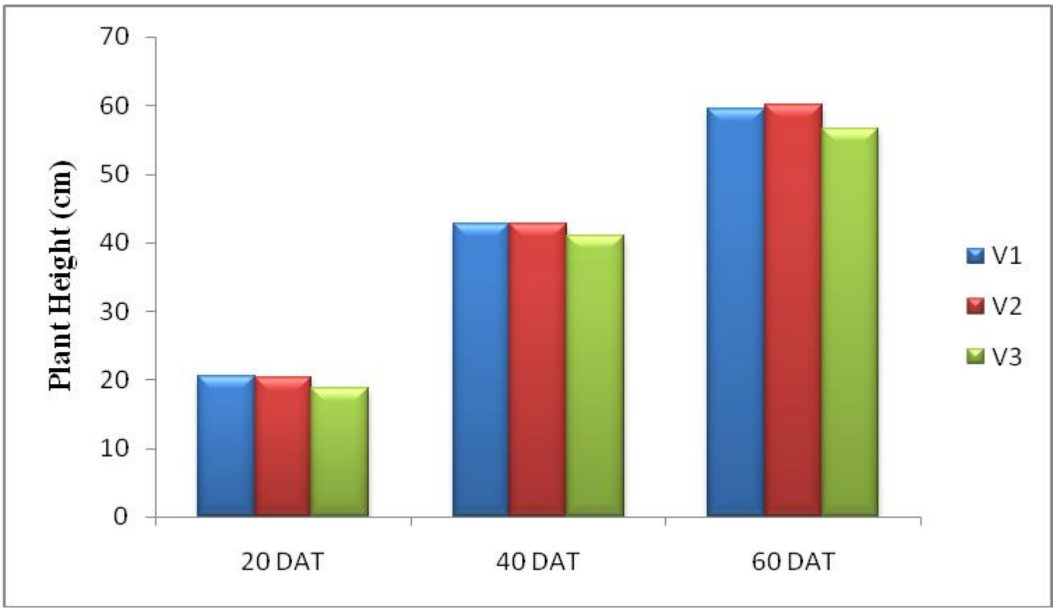
CHAPTER IV
RESULTS AND DISCUSSION

This experiment was conducted to determine the effect of boron on growth and yield of different cultivars of broccoli. Different growth and yield contributing characteristics were observed and data were recorded. The analysis of variance (ANOVA) of the data on different characters has been presented in Appendix (IV-VIII). The results have been shown and discussed and possible interactions are given under the following headings :

4.1 Plant height

Different cultivars showed significant influence on the height of broccoli plants at 20, 40 and 60 DAT (Fig. 2; Appendix IV). At 20 DAT, plant height of V_1 and V_2 are 20.46 cm and 20.40 cm respectively which are statistically similar. The highest plant height was obtained from V_1 which was 20.46 cm and the lowest plant height was obtained from V_3 which was 18.69 cm. At 40 DAT, plant height ranged from 40.92 to 42.75 cm. The highest plant height was obtained from V_2 (42.75 cm) and the lowest plant height was found from V_3 (40.92 cm). At 60 DAT, plant height ranged from 56.49 to 60.13 cm. Here also the highest height was observed in V_2 (60.13 cm) and the lowest was in V_3.

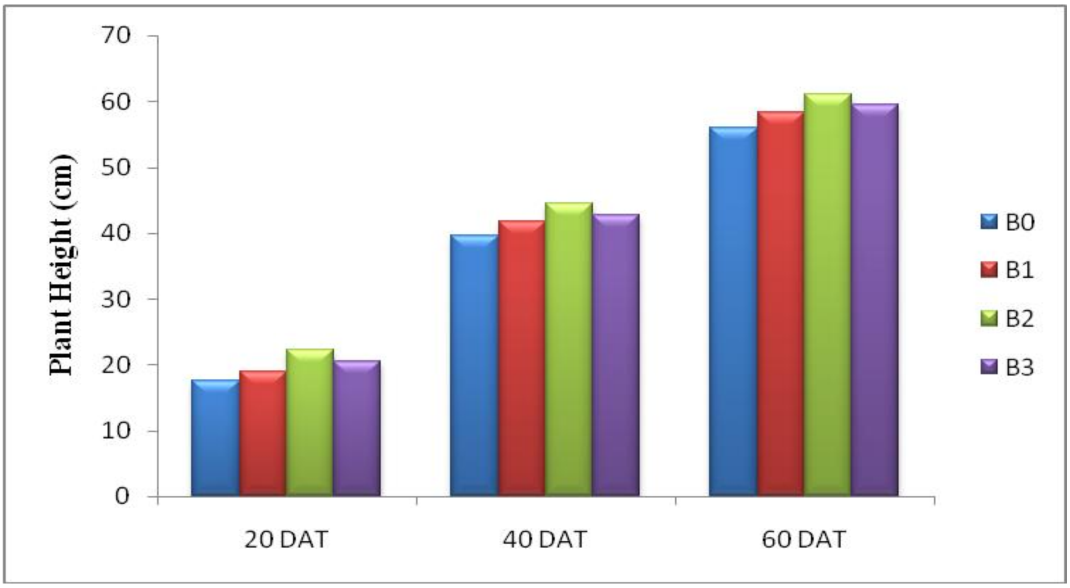
Different levels of boron differ significantly for plant height of broccoli at 20, 40 and 60 DAT (Fig. 3; Appendix IV). At 20 DAT, the longest plant (22.27 cm) was obtained from B_2 which was followed by B_3 (20.57 cm) and the



Days after transplanting

V_1: Top green, V_2: Green magic, V_3: BARI Broccoli-1

Fig. 2 Effect of different cultivars on plant height of broccoli



Days after transplanting

B_0: 0 kg/ha, B_1: 1 kg/ha, B_2: 2 kg/ha, B_3: 3 kg/ha

Fig. 3 Effect of different Boron levels on plant height of broccoli

shortest plant was obtained from B_0 (17.53 cm). At 40 DAT, the longest plant was recorded from B_2 (44.46 cm) which was followed by B_3 (42.80 cm) and the shortest plant was recorded from B_0 (39.58 cm). At 60 DAT, the longest plant was found from B_2 (61.02 cm) which was dissimilar to B_1(58.30 cm) and the shortest plant was obtained from the B_0 (55.92 cm). It was found that with the increase of boron level plant height increase significantly up to a certain level then decreased. More or less similar findings also reported by Firoz *et al.* (2008). .

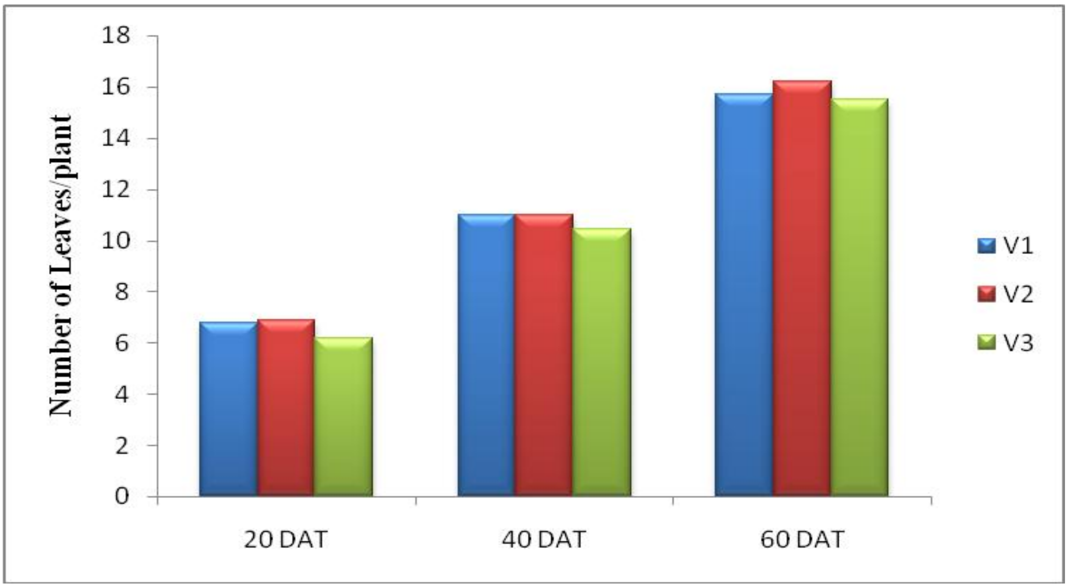
Significant variation was recorded due to the combined effect of cultivar and boron in terms of plant height of broccoli at 20, 40 and 60 DAT (Table 2; Appendix IV). At 20 DAT, plant height ranged from 16.33 cm to 23.13 cm. The highest plant height (23.13 cm) was obtained in combination V_2B_2 and the lowest (16.33 cm) was recorded from V_3B_0. At 40 DAT, plant height ranged from 38.67 cm to 45.20 cm. The longest plant height (45.20 cm) was observed in the treatment combination V_2B_2, consequently the shortest plant (38.67 cm) was obtained from V_3B_0. At 60 DAT, the height of plant ranged from 54.03 cm to 62.40 cm. The highest plant height was observed from V_2B_2 which was 62.40 cm, consequently the shortest plant was observed from V_3B_0 which was 54.03 cm. It was revealed that plant height increased with the increased in DAT and optimum level of boron ensured the tallest plant and excess amount causes decrease in plant height.

4.2 Number of leaves per plant

Different cultivars showed a significant influence on the number of leaves of broccoli plant at 20, 40 and 60 DAT (Fig. 4; Appendix IV). At 20 DAT leaf number ranged from 6.18 cm to 6.90 cm. The highest number of leaves (6.90) was found in V_2 and the lowest number of leaves was observed in V_3. At 40 DAT, maximum number of leaves was found in V_1 (11.01) and the minimum number of leaves (10.46) was found in V_3. At 60 DAT, the maximum number of leaves (16.18) was found in V_2, while the minimum number of leaves (15.52) was found in V_3.

Number of leaves per plant differs significantly due to different levels of boron at 20, 40 and 60 DAT (Fig. 5; Appendix IV). At 20 DAT, the highest number of leaves (7.42) was observed from B_2 which was followed by the value (6.80) due to the level of B_3. The minimum number (5.89) was recorded from B_0. At 40 DAT, the maximum number of leaves per plant was recorded from B_2 and the value was (12.54) followed by B_3 (11.56). On the other hand, the minimum number was recorded from B_0 (9.20). At 60 DAT, the maximum number of leaves per plant was found from B_2 (17.67) which was followed by B_3 (16.74) and B_1 (15.18), whereas the minimum number was recorded from B_0(13.60). It was found that maximum number of leaves per plant was obtained from optimum level of boron. Similar results also reported by Islam *et al*. (2015).

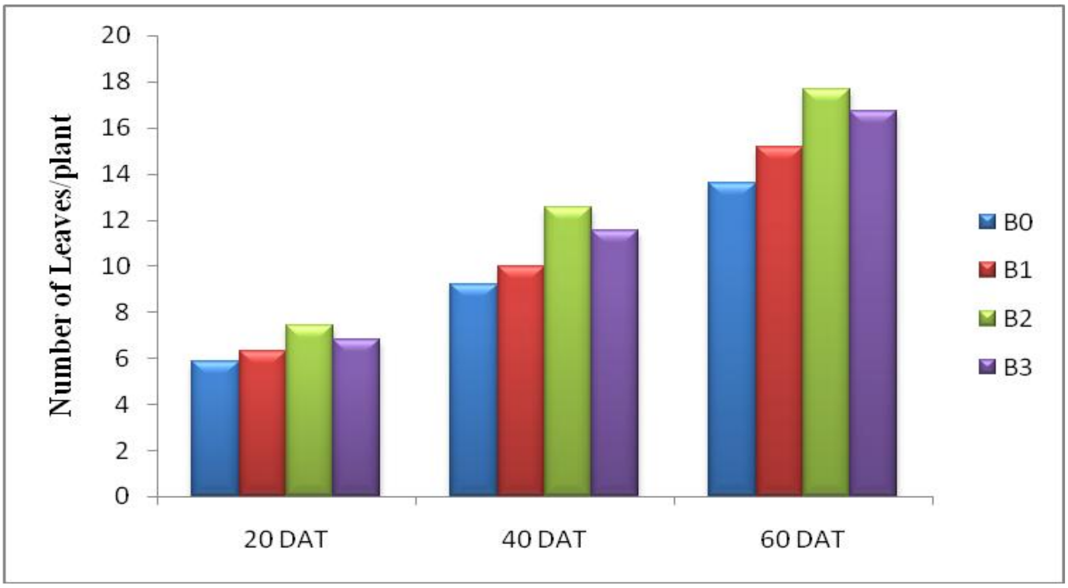
The number of leaves was significantly influenced by the treatment combinations at 20, 40 and 60 DAT (Table 2; Appendix IV). The number of



Days after transplanting

V_1: Top green, V_2: Green magic, V_3: BARI Broccoli-1

Fig. 4 Effect of different cultivars on number of leaves per plant of broccoli



Days after transplanting

B_0: 0 kg/ha, B_1: 1 kg/ha, B_2: 2 kg/ha, B_3: 3 kg/ha

Fig. 5 Effect of different boron levels on number of leaves per plant of broccoli

Table 2. Combined effect of different cultivar and boron level on plant height and number of leaves of broccoli

Treatment	Plant height (cm) at			Number of leaves per plant at		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
V_1B_o	18.27 de	39.90 f	56.40 e	6.00 ef	9.67 cd	13.33 g
V_1B_1	20.00 cd	42.70 cd	59.47 bcd	6.53 cd	10.10 c	14.93 e
V_1B_2	22.50 ab	44.67 ab	61.67 ab	7.50 b	12.67 a	17.70 ab
V_1B_3	21.10 bc	43.67 abc	60.20 abc	7.00 bc	11.60 b	16.80 bcd
V_2B_0	18.00 ef	40.17 ef	57.33 de	6.00 ef	9.20 de	13.80 fg
V_2B_1	19.00 de	42.40 cd	59.90 bc	6.53 cd	10.27 c	15.73 de
V_2B_2	23.13 a	45.20 a	62.40 a	8.03 a	12.83 a	18.07 a
V_2B_3	21.50 abc	43.23 bc	60.87 abc	7.03 bc	11.67 b	17.13 abc
V_3B_0	16.33 f	38.67 f	54.03 f	5.67 f	8.73 e	13.67 g
V_3B_1	18.13 def	40.00 ef	55.53 ef	5.93 ef	9.57 cde	14.87 ef
V_3B_2	21.20 bc	43.50 bc	59.00 cd	6.73 cd	12.13 ab	17.23 abc
V_3B_3	19.10 de	41.50 de	57.40 de	6.37 de	11.40 b	16.30 cd
CV %	6.68	7.23	5.24	7.63	8.11	5.28
LSD (0.05)	1.87	1.59	2.22	0.51	0.87	1.10

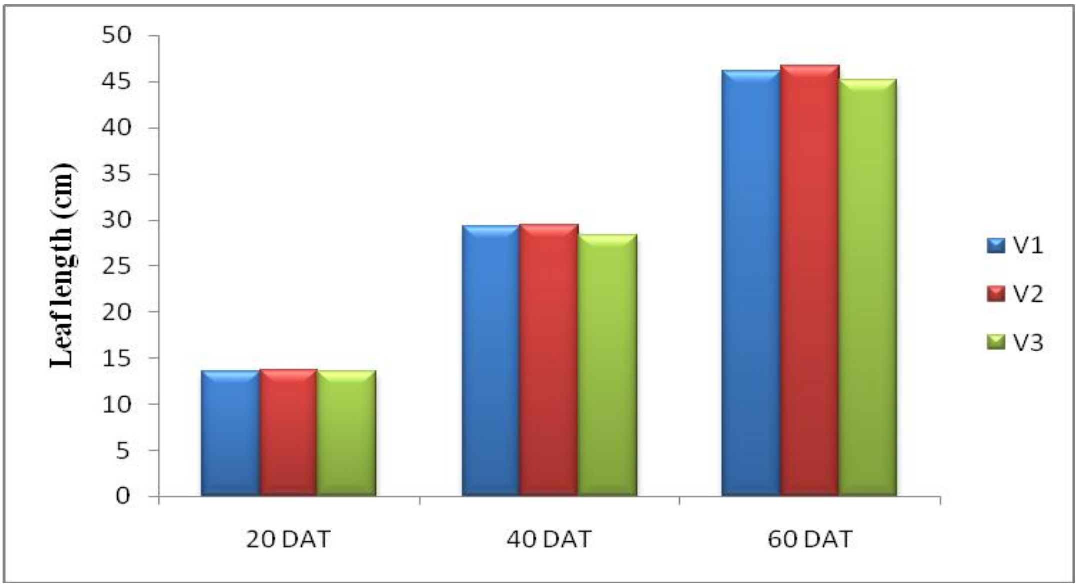
Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

leaves per plant ranged from 5.67 to 8.03. The maximum number of leaves (8.03) was recorded from V_2B_2, while the minimum number was recorded in V_3B_0. At 40 DAT, the number of leaves per plant ranged from 8.73 to 12.83. The highest number (12.83) of leaves was found in V_2B_2, consequently the lowest number was found from V_3B_0. At 60 DAT, the number of leaves per plant ranged from 13.33 to 18.07. The maximum number of leaves (18.07) was recorded from V_2B_2 and the minimum number (13.33) was recorded from V_1B_0.

4.3 Leaf length

There had a significant influence of cultivars on broccoli plant in respect of leaf length at 40 and 60 DAT (Fig. 6; Appendix V). At 20 DAT, non significant values were found. The leaf length ranged from 13.49 to 13.64. The longest leaf (13.64) was obtained from V_2, which was statistically similar with V_1 and V_3. At 40 DAT, leaf length ranged from 28.35 to 29.37. The longest leaf was found in V_2 (29.37 cm) and the shortest leaf was found from V_3 (28.35 cm). At 60 DAT, leaf length ranged from 45.20 to 46.62. The longest leaf was found from V_2 (46.62 cm) and the shortest leaf was recorded from V_3 (45.20 cm).

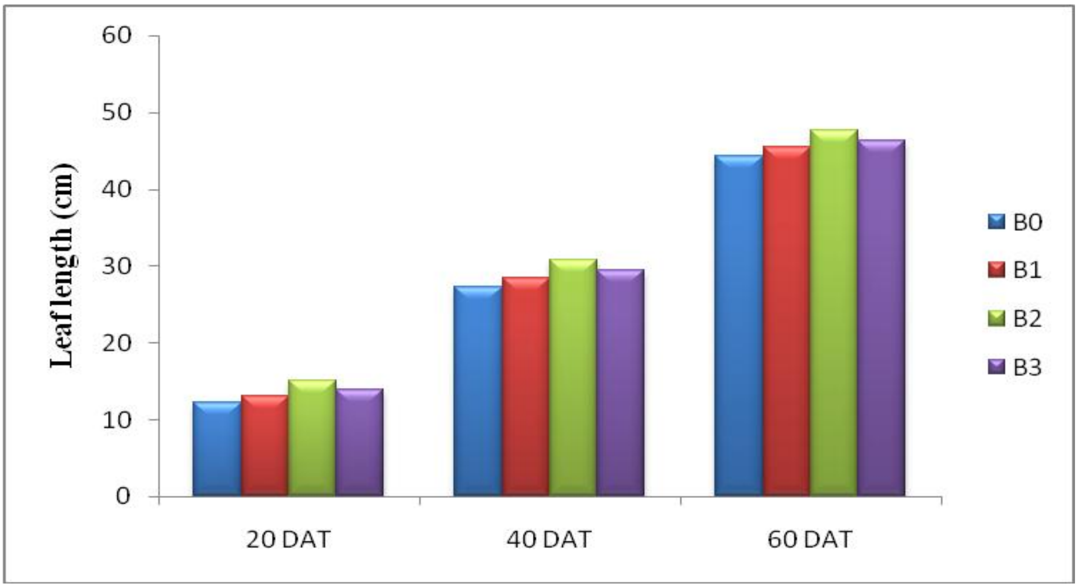
Boron level had a significant influence on the length of leaves of broccoli plants at 20, 40 and 60 DAT (Fig. 7; Appendix V). At 20 DAT, leaf length ranged from 12.24 cm to 15.01 cm. Boron level B_2 produced the longest leaf (15.01 cm), while the lowest (12.24 cm) was found in control plots (B_0). At 40



Days after transplanting

V_1:Top green, V_2: Green magic, V_3: BARI Broccoli-1

Fig. 6 Effect of different cultivars on leaf length of broccoli



Days after transplanting

B_0: 0 kg/ha, B_1: 1 kg/ha, B_2: 2 kg/ha, B_3: 3 kg/ha

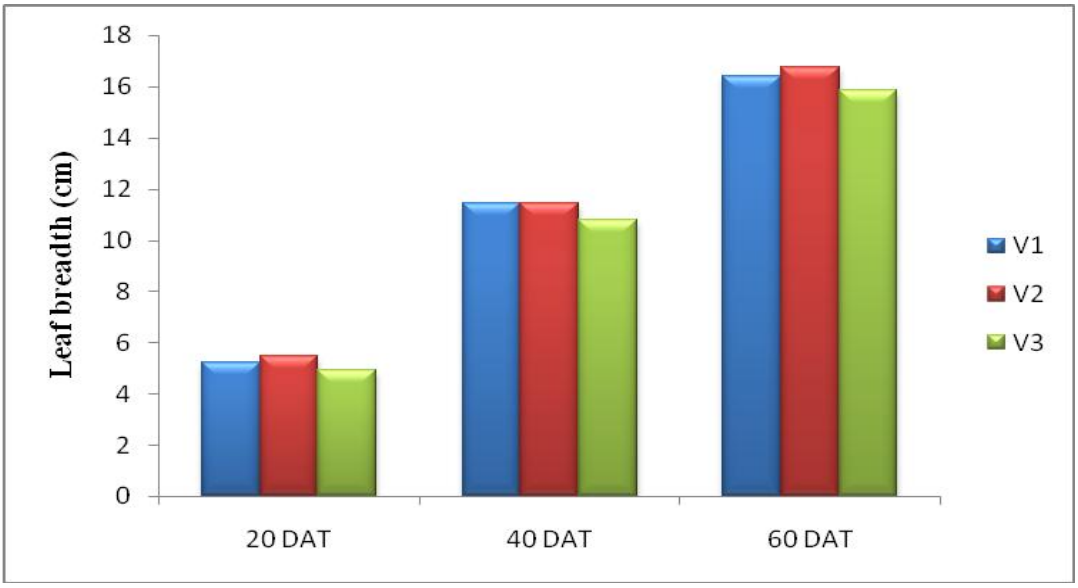
Fig. 7 Effect of different boron level on leaf length of broccoli

DAT, leaf length ranged from 27.24 cm to 30.82 cm. The largest leaf (30.82 cm) was found from B_2 and the smallest leaf (27.24 cm) was found from the treatment $B_{0.}$ At 60 DAT, leaf length ranged from 44.27 cm to 47.71 cm. The largest leaf (47.71 cm) was recorded from B_2 which was followed by B_3 (46.31 cm). On the other hand, the smallest leaf was recorded from B_0 (44.27 cm).

Combined effect of cultivar and boron showed significant variation on leaf length of broccoli (Table 3; Appendix V). At 20 DAT, the longest leaf (15.13 cm) was recorded from the treatment combination V_2B_2, while the shortest leaf (11.93 cm) was from the treatment combination (V_3B_0). At 40 DAT, leaf length ranged from 26.67 cm to 31.50 cm. The largest leaf (31.50 cm) was recorded from combination of V_2B_2 while the shortest leaf (26.67 cm) was observed in V_3B_0. At 60 DAT, leaf length ranged from 43.53 cm to 48.60 cm. The longest leaf (48.60 cm) was recorded from V_2 while the smallest leaf (43.53 cm) was observed in V_3B_0.

4.4 Leaf breadth

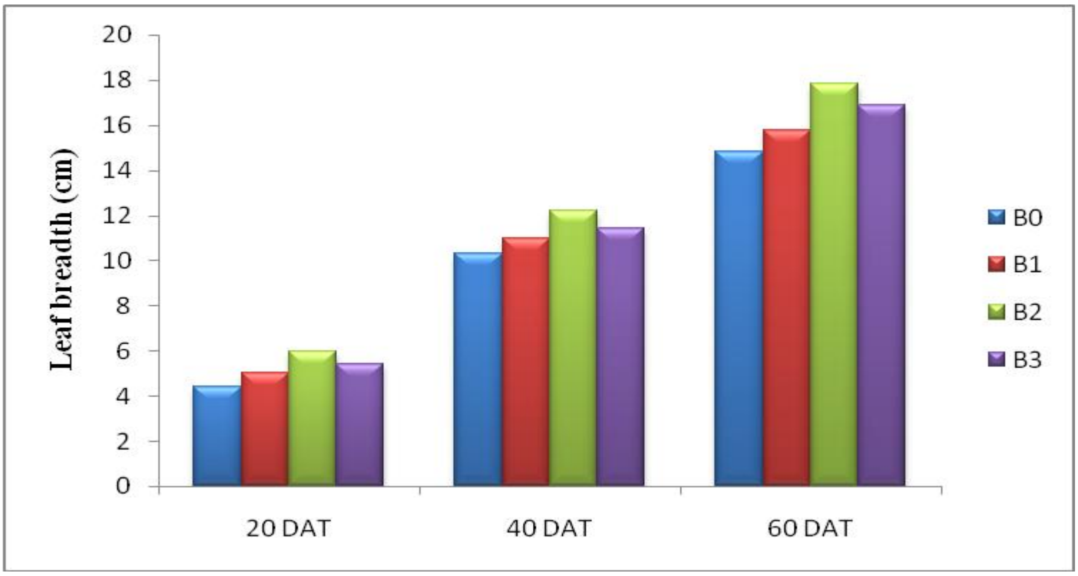
Leaf breadth varied significantly among the cultivars (Fig. 8; Appendix V). At 20 DAT, leaf breadth of broccoli plants varied from 4.92 cm to 5.46 cm. V_2 produced the largest leaf breadth (5.46 cm) whereas V_3 produced the smallest leaf breadth (4.92 cm). At 40 DAT, leaf breadths were more or less similar among the cultivars. The largest leaf breadth (11.45 cm) was found in V_2 which was statistically similar to V_1 (11.45 cm) and the smallest leaf breadth was found in V_3 (10.80 cm). At 60 DAT, leaf breadth ranged from 15.87 cm to



Days after transplanting

V_1: Top green, V_2: Green magic, V_3: BARI Broccoli-1

Fig. 8 Effect of different cultivar on leaf breadth of broccoli



Days after transplanting

B_0: 0 kg/ha, B_1: 1 kg/ha, B_2: 2 kg/ha, B_3: 3 kg/ha

Fig. 9 Effect of different boron level on leaf breadth of broccoli

16.73 cm. Cultivar V_2 produced the largest leaf breadth (16.73 cm) whereas the smallest leaf breadth (15.87 cm) was recorded in V_3.

Leaf breadth differs significantly due to the different level of boron at 20, 40 and 60 DAT (Fig. 9; Appendix V). At 20 DAT, the largest leaf breadth was recorded from B_2 (5.99 cm) that was followed by B_3 (5.40 cm) and it was identical to B_1 (5.04 cm). On the other hand, the smallest leaf breadth was found in B_0 (control plots) which value was 4.39 cm. At 40 DAT, leaf breadth ranged from 10.33 cm to 12.22 cm. The largest leaf breadth (12.22 cm) was recorded from B_2 while the smallest leaf breadth (10.33 cm) was recorded from B_0 (control). At 60 DAT, leaf breadth ranged from 14.84 cm to 17.83 cm. The largest leaf breadth was found from B_2 (17.83 cm) which was followed by B_3 (16.90 cm). The smallest leaf breadth (14.84 cm) was from B_0. It was revealed that optimum dose of boron ensure the highest leaf breadth and excess dose causes decrease in leaf breadth.

The leaf breadth was significantly influenced by the treatment combinations of boron and cultivars at 20, 40 and 60 DAT (Table 3; Appendix V). At 20 DAT, the leaf breadth ranged from 4.06 cm to 6.23 cm. The largest leaf breadth (6.23 cm) was found in treatment combination V_2B_2 and the smallest leaf breadth (4.06 cm) was found in treatment combination V_3B_0. AT 40 DAT, leaf breadth ranged from 9.80 cm to 12.66 cm. The largest leaf breadth (12.66 cm) was recorded from treatment combination V_2B_2, while the smallest leaf breadth (9.80 cm) was found from V_3B_0. At 60 DAT, leaf breadth ranged from 14.20 cm to 18.40 cm. Similarly, treatment combination V_2B_2 produced the largest

Table 3. Combined effect of different cultivar and boron level on leaf length and leaf breadth of broccoli

Treatment	Leaf length (cm) at			Leaf breadth (cm) at		
	20 DAT	**40 DAT**	**60 DAT**	**20 DAT**	**40 DAT**	**60 DAT**
V_1B_o	12.47 fg	27.60 ef	44.53 ef	4.46 g	10.80 def	15.00 hi
V_1B_1	13.37 de	28.87 d	45.53 cde	5.03 ef	11.06 def	16.00 efg
V_1B_2	15.10 a	30.77 ab	47.60 ab	6.00 ab	12.33 ab	17.80 ab
V_1B_3	13.47 cde	29.73 bcd	46.60 bcd	5.40 cde	11.60 bc	16.76 cde
V_2B_0	12.33 fg	27.47 f	44.73 def	4.63 g	10.40 fg	15.33 fgh
V_2B_1	13.03 ef	28.70 de	46.33 bcde	5.33 de	11.23 cde	16.13 def
V_2B_2	15.13 a	31.50 a	48.60 a	6.23 a	12.66 a	18.40 a
V_2B_3	14.07 bcd	29.80 bcd	46.80 abc	5.66 bcd	11.50 cd	17.06 bcd
V_3B_0	11.93 g	26.67 f	43.53 f	4.06 h	9.80 g	14.20 i
V_3B_1	13.07 ef	27.53 ef	44.80 def	4.76 fg	10.60 ef	15.13 ghi
V_3B_2	14.80 ab	30.20 bc	46.93 abc	5.73 bc	11.66 bc	17.30 bc
V_3B_3	14.17 bc	29.00 cd	45.53 cde	5.13 ef	11.13 cdef	16.86 cde
CV %	8.61	9.53	8.82	5.40	5.12	6.56
LSD (0.05)	0.74	1.22	1.96	0.38	0.78	0.98

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

leaf breadth (18.40 cm), while the treatment combination V_3B_0 produced the smallest leaf breadth (14.20 cm).

4.5 Days required for curd initiation

The different cultivars were significantly influenced on the number of days required for curd initiation (Table 4; Appendix VI). It was varied from 51.05 to 52 days. The lowest (51.05 days) were required for curd initiation in cultivar V_1 and the highest (52.00 days) were required for curd initiation in cultivar $V_{3.}$

Application of boron fertilizer significantly influenced the days to curd initiation (Table 5; Appendix VI). The highest number of days (53.97 days) to curd initiation was recorded from control treatment B_0 which was followed by the treatment B_1 (52.11 days) and the lowest number of days was recorded with B_2 having 48.89 days. More or less similar result also reported by Islam *et al*. (2015).

There was a significant combined effect of cultivar and boron fertilizer on the days to curd initiation of broccoli (Table 6; Appendix VI). The lowest number of days (48 days) was required to curd initiation in the V_2B_2 treatment. On the other hand, the highest number of days (54 days) was required to curd initiation in the treatment V_3B_0.

4.6 Root weight

There had no significant influence of cultivars on the broccoli plant in respect of root weight (Table 4; Appendix VI). The root weight ranged from 21.20 to 22.33 gm. The maximum weight (22.33 gm) of roots was obtained from the cultivar V_2 and the minimum weight (21.20 gm) of roots was obtained from V_1 cultivar.

The result of boron treatment showed highly significant on weight of roots of broccoli (Table 5; Appendix VI). The maximum effect in this parameter was observed with of B_2 treatment having (23.76 gm) which was statistically identical to B_3 having the value 22.44 gm. On the other hand, the minimum weight (19.67 gm) of root was recorded from the treatment B_0 (control).

The combined effect of cultivar and boron levels showed significant difference on the root weight of broccoli plants (Table 6; appendix VI). The value ranged from 19.40 to 24.96 gm. The maximum weight (24.96 g) of roots was recorded from the treatment combination of V_2B_2 while the lowest weight (19.40 g) of roots was recorded from the treatment combination V_1B_0.

4.7 Root length

There was significant influence of cultivars on the broccoli plants in respect of root length (Table 4; Appendix VI). The root length ranged from 18.55 to 19.33 cm. The maximum root length was produced by the cultivar V_2 and the value was 19.33 cm which was statistically similar to V_3 (19.20 cm). But in case of

V_1 which produce the minimum length of roots that was 18.55 cm which was statistically dissimilar to V_2 and V_3.

Root length was significantly influenced by the boron treatment (Table 5; Appendix VI). The longest root (21.44 cm) was obtained from B_2 treatment and the shortest root (16.76 cm) was recorded from control (B_0) treatment. This result partially supports the findings of Trechan and Grewar (1981) who stated that the application of 10 kg borax per hectare produced maximum root length (27.88 cm) in radish. When dose of borax was increased beyond 10 kg borax/ha, the length of root per plant was decreased gradually (Maury and Singh, 1985).

The combined effect of cultivar and boron on broccoli plant found to be significant (Table 6; Appendix VI). The length of root ranged from 16.30 to 22.16 cm. The longest root was recorded from the treatment combination V_2B_2 (22.16 cm) while the shortest root was recorded from the treatment combination V_1B_0 (16.30 cm).

4.8 Diameter of stem

Significant variation among the cultivars had been observed in the diameter of stem of broccoli (Table 4; Appendix VI). The diameter of stem ranged from 3.41 cm to 3.86 cm. The maximum diameter of stem (3.86 cm) was recorded from the V_1 cultivar followed by V_2 cultivar. On the other hand, the minimum diameter of stem (3.41 cm) was observed from the cultivar V_3.

Table 4. Effect of different cultivar on days required for curd initiation, root weight, root length, stem diameter of broccoli

Cultivar	Days required for curd initiation	Root weight (g)	Root length (cm)	Stem diameter (cm)
V_1	51.05 b	21.20	18.55 b	3.86 a
V_2	51.17 ab	22.33	19.33 a	3.71 b
V_3	52.00 a	21.58	19.20 a	3.41 c
CV %	10.27	8.24	8.67	9.94
LSD (0.05)	0.85	----	0.70	0.14

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 5. Effect of different boron level on days required for curd initiation, root weight, root length, stem diameter of broccoli

Treatment	Days required for curd initiation	Root weight (g)	Root length (cm)	Stem diameter (cm)
B_0	53.97 a	19.67 b	16.76 c	3.20 d
B_1	52.11 b	20.95 b	18.41 b	3.53 c
B_2	48.89 d	23.76 a	21.44 a	4.12 a
B_3	50.66 c	22.44 a	19.50 b	3.80 b
CV %	10.27	8.24	8.67	9.94
LSD (0.05)	0.98	1.38	1.16	0.17

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 6. Combined effect of different cultivar and boron level on days required for curd initiation, root weight, root length, stem diameter of broccoli

Treatments	Days required for curd initiation	Root weight (g)	Root length (cm)	Stem diameter (cm)
V_1B_o	53.90 a	19.40 d	16.30 g	3.46 fgh
V_1B_1	51.33 bcd	20.50 cd	17.66 efg	3.88 bcd
V_1B_2	49.00 ef	23.33 ab	21.16 ab	4.16 ab
V_1B_3	50.00cde	21.60 bcd	19.10 cde	3.95 abcd
V_2B_0	54.00 a	19.66 d	17.00 fg	3.35 gh
V_2B_1	52.33 ab	21.23 bcd	18.50 def	3.52 efg
V_2B_2	48.00 f	24.96 a	22.16 a	4.21 a
V_2B_3	50.33 cde	23.46 ab	19.66 cde	3.78 cde
V_3B_0	54.00 a	19.93 cd	17.00 fg	2.78 i
V_3B_1	52.66 ab	21.13 bcd	19.06 cde	3.21 h
V_3B_2	49.66 def	23.00 ab	21.00 abc	3.98 abc
V_3B_3	51.66 bc	22.26 bc	19.73 bcd	3.68 def
CV %	10.27	8.24	8.67	9.94
LSD (0.05)	1.69	2.392	2.012	0.289

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

The stem diameter of plant was found to be significantly influenced due to the application of boron fertilizer (Table 5; Appendix VI). The stem diameter of plant increased as the progressed of plant growth. The plants under B_2 gave maximum (4.12 cm) stem diameter. This was followed by B_3 (3.80 cm), while the lowest stem diameter (3.20 cm) was found from control (B_0) treatment.

The combined effect of cultivar and boron levels was found to be significant on diameter of stem (Table 6; Appendix VI). It was ranged from 2.78 cm to 4.21 cm. The maximum diameter of stem (4.21 cm) was recorded from the treatment combination V_2B_2 and minimum stem diameter (2.78 cm) was recorded from the treatment combination V_3B_0.

4.9 Main curd diameter

Different cultivars showed significant influence on curd diameter of broccoli plants (Table 7; Appendix VII). The maximum curd diameter (15.97 cm) was recorded from V_2 while the minimum curd diameter (15.45 cm) was observed in V_3. This result revealed that the curd diameter differed with the different cultivars.

Application of boron exhibited significant influence on curd diameter of broccoli plants (Table 8; Appendix VII). The maximum curd diameter (16.58 cm) was recorded from the treatment B_2, which was followed by the treatment B_3 (16.12 cm) and it was statistically identical. On the other hand, the minimum curd diameter was recorded from the treatment B_0 (14.36 cm). These result partially supported by Moniruzzaman *et al*. (2007).

Curd diameter was significantly influenced by the treatment combination of cultivar and boron (Table 9; Appendix VII). The maximum curd diameter (17.03 cm) was observed in the treatment combination of V_2B_2 while the minimum curd diameter (14.06 cm) was recorded from the combination of V_3B_0. Main curd diameter is important for curd yield. Diameter of curd was significantly influenced by different boron levels.

4.10 Main curd weight

Different cultivars had significant effect on the weight of main curd (Table 7; Appendix VII). The maximum weight of main curd was recorded from the cultivar V_2 (333.37 g) which was followed by the cultivar V_1 (310.68 g). The minimum weight of main curd was recorded from the cultivar V_3 (260.10 g).

The weight of main curd per plant as influenced by boron fertilizers had significant effect (Table 8; Appendix VII). The highest weight of main curd per plant (361.31 g) was obtained from the treatment B_2 which was followed by B_3 (326.48 g). On the other hand, the lowest weight of main curd (256.64 g) was recorded from the treatment B_0 (control). It has been showed that optimum dose of boron ensures the highest weight of main curd.

The combined effect of cultivar and boron levels had significant influence on the main curd weight of broccoli (Table 9; Appendix VII). It was ranged from 245.07 g to 363.27 g. The maximum main curd weight (363.27 g) was recorded from the treatment combination V_2B_2 and the minimum weight of main curd was recorded from the treatment combination V_3B_0.

4.11. No. of secondary curd

The effect of different cultivars was significant in respect of number of secondary curd per plant (Table 7; Appendix VII). It was ranged from 3.00 to 3.18. The maximum number of secondary curd (3.18) per plant was produced by the cultivar V_2 which was statistically similar to V_3 (3.06) and minimum number of secondary curd (3.00) per plant was produced by the cultivar V_1.

The result of boron fertilizer treatment showed significant effect on the number of secondary curd per plant of broccoli (Table 8; Appendix VII) . The highest number of secondary curd (3.73) per plant was obtained from the treatment B_2 which was followed by the treatment B_3 (3.38). The lowest number of secondary curd was obtained from the treatment B_0 (2.34).

The number of secondary curd per plant was influenced significantly by the treatment combination (Table 9; Appendix VII). The highest number of secondary curd (4.03) was obtained from the treatment combination (V_2B_2) and the lowest secondary curd (2.20) was noted in the control treatment (V_1B_0).

4.12. Weight of secondary curd

There had no significant influence of cultivars on the broccoli plant in respect of weight of secondary curd (Table 7; Appendix VII). It was ranged from 62.10 to 62.47 g. The highest weight of secondary curd (62.47 g) was observed in the cultivar V_2. The lowest weight of secondary curd (62.10 g) was found in the cultivar V_3.

Table 7. Effect of different cultivar on main curd diameter, main curd weight, no. of secondary curd and weight of secondary curd of broccoli

Treatments	Main curd diameter (cm)	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)
V_1	15.64 ab	310.68 a	3.00 b	62.10
V_2	15.97 a	333.37 b	3.18 a	62.47
V_3	15.45 b	260.10 b	3.06 a	62.14
CV%	9.53	10.63	6.93	8.66
LSD (0.05)	0.48	12.67	0.17	----

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

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

Treatments	Main curd diameter (cm)	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)
B_0	14.36 c	256.64 d	2.34 d	59.27 d
B_1	15.69 b	303.40 c	2.88 c	61.47 c
B_2	16.58 a	361.31 a	3.73 a	65.10 a
B_3	16.12 ab	326.48 b	3.38 b	63.12 b
CV %	9.53	10.63	6.93	8.66
LSD (0.05)	0.55	22.18	0.20	1.01

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 9. Combined effect of different cultivar and boron level on main curd diameter, main curd weight, no. of secondary curd and weight of secondary curd of broccoli

Treatments	Main curd diameter (cm)	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)
V_1B_o	14.40 c	285.40 d	2.20 g	58.76 f
V_1B_1	15.73 b	309.00 bcd	2.76 ef	61.43 de
V_1B_2	16.50 ab	361.20 a	3.70 ab	64.86 ab
V_1B_3	15.93 b	327.13 abc	3.36 bcd	63.33 bc
V_2B_0	14.60 c	239.47 e	2.43 fg	59.73 ef
V_2B_1	15.66 b	292.40 cd	2.76 ef	61.90 cd
V_2B_2	17.03 a	363.27 a	4.03 a	65.76 a
V_2B_3	16.56 ab	334.37 ab	3.50 bc	62.50 cd
V_3B_0	14.06 c	245.07 e	2.40 g	59.30 f
V_3B_1	15.66 b	308.80 bcd	3.10 de	61.06 de
V_3B_2	16.20 ab	359.47 a	3.46 bc	64.66 ab
V_3B_3	15.86 b	317.93 bcd	3.26 cd	63.53 bc
CV%	9.53	10.63	6.93	8.66
LSD (0.05)	0.96	38.41	0.36	1.75

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Weight of secondary curd per plant was significantly influenced by the application of different boron levels (Table 8; Appendix VII). The maximum weight of secondary curd (65.10 g) was obtained from the treatment B_2 which was followed by the treatment B_3 (63.12 g). On the other hand, the minimum weight of secondary curd was obtained from the treatment B_0 (control).

Combined effect of cultivar and different boron levels showed significant difference on the weight of secondary curd per plant (Table 9; Appendix VII). It was ranged from 58.76 to 65.76 g. The maximum weight of secondary curd (65.76 g) was found from the treatment combination V_2B_2 while the minimum weight of secondary curd (58.76 g) was obtained from the treatment combination V_3B_0.

4.13. Dry matter of leaves

The production of dry matter of broccoli leaves varied significantly due to the different cultivars (Table 10; Appendix VII). The highest percent dry matter (9.60 %) of leaves was recorded from the cultivar V_2, which was statistically similar to the cultivar V_1(9.58%). But in case of V_3, the lowest percent dry matter (8.42%).

The effect of boron treatment was found significant in respect of dry matter leaves per plant (Table 11; Appendix VII). The maximum dry matter (10.95%) of leaves per plant was recorded from the treatment B_2 and the minimum dry matter (7.88%) of leaves per plant was recorded from the treatment B_0 (control).

The combined effect of different cultivars and boron levels in respect of dry weight of leaves of broccoli was statistically significant (Table 12, Appendix VII). It was ranged from 7.20% to 11.40%. The maximum dry weight (11.40%) of leaves was found from the treatment combination V_2B_2 and the minimum dry weight (7.20%) was found from the treatment combination V_3B_0.

4.14. Dry matter of curd

The dry matter of broccoli curd varied significantly due to the cultivars (Table 10; Appendix VII). The highest percent dry matter (18.78%) was recorded from the cultivar V_2, which was statistically similar to the cultivar V_1. The lowest dry matter production (17.85%) was recorded from the cultivar V_3.

The effect of boron treatment was found significant in respect of dry matter production of broccoli (Table 11; Appendix VII). It was ranged from 16.93% to 19.71%. The maximum dry matter of curd (19.71%) was obtained from the treatment B_2, which was followed by the treatment B_3 (18.47%). On the other hand, the minimum dry matter of curd (16.93%) was obtained from the treatment B_0 (control).

The combined effect of different cultivars and boron levels were significant on the percent dry matter of broccoli curd (Table 12; Appendix VII). The maximum percent dry matter of broccoli curd (20.53) was found from the treatment combination of V_2B_2 and minimum percent dry weight (16.57) was recorded from the treatment combination of V_3B_0.

Table 10. Effect of different boron level on dry matter of leaves and dry matter of curd of broccoli

Treatments	Dry matter of leaves (%)	Dry matter of curd (%)
V_1	9.58 a	18.20 ab
V_2	9.60 a	18.78 a
V_3	8.42 b	17.85 b
CV%	7.51	7.62
LSD (0.05)	0.49	0.87

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 11. Effect of different cultivar on dry matter of leaves and dry matter of curd of broccoli

Treatments	Dry matter of leaves (%)	Dry matter of curd (%)
B_0	7.88 d	16.93 c
B_1	8.44 c	18.00 b
B_2	10.95 a	19.71 a
B_3	9.52 b	18.47 b
CV%	7.51	7.62
LSD (0.05)	0.51	1.00

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 12.Combined effect of different cultivar and boron level on dry matter of leaves and dry matter of curd of broccoli

Treatments	Dry matter of leaves (%)	Dry matter of curd (%)
V_1B_o	8.33 def	16.90 ef
V_1B_1	9.10 cd	17.86 bcdef
V_1B_2	11.23 a	19.50 ab
V_1B_3	9.67 bc	18.53 bcde
V_2B_0	8.13 ef	17.33 def
V_2B_1	8.63 de	18.47 bcde
V_2B_2	11.40 a	20.53 a
V_2B_3	10.23 b	18.80 abcd
V_3B_0	7.20 g	16.57 f
V_3B_1	7.60 fg	17.66 cdef
V_3B_2	10.23 b	19.10 abc
V_3B_3	8.67 de	18.10 bcdef
CV%	7.51	7.62
LSD (0.05)	0.88	1.74

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

4.15. Yield per plant

The curd yield per plant was varied significantly due to different cultivar. (Table 13; Appendix VIII). The maximum yield per plant (395.84 g) was produced by the cultivar V_2, which was statistically similar to the cultivar V_1 while the lowest yield per plant (322.24 g) was produced by the cultivar V_3.

The effect of different boron treatments found significant on the yield per plant of broccoli (Table 14; Appendix VIII). The highest yield per plant (411.78 g) was produced by the plants grown with treatment B_2 which was followed by the treatment B_3 (388.64 g). The lowest yield per plant (315.80 g) was found from the treatment B_0 (control). Similar results also reported by Moniruzzaman *et al*. (2007).

Curd yield per plant was found to be statistically significant by the combined effect of different cultivars and boron levels (Table 15; Appendix VIII). The highest yield (437.67 g) was recorded from the treatment combination of V_2B_2 and the lowest yield (299.20 g) was obtained from the treatment combination of V_3B_0.

4.16. Yield per plot

Different cultivars showed a significant influence on yield per plot of broccoli plants (Table 13; Appendix VIII). The maximum yield (5.90 kg) per plot was recorded in V_2 while the minimum yield (4.82 kg) per plot was observed in V_3.

Table 13. Effect of different cultivar on yield of broccoli

Treatments	Yield per plant (g)	Yield per plot (kg)
V_1	372.78 ab	5.60 b
V_2	395.84 a	5.90 a
V_3	322.24 c	4.82 c
CV%	7.54	8.22
LSD (0.05)	4.87	0.23

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Table 14. Effect of different boron level on yield of broccoli

Treatments	Yield per plant (g)	Yield per plot (kg)
B_0	315.80 d	4.73 d
B_1	364.81 c	5.45 c
B_2	411.78 a	6.16 a
B_3	388.64 b	5.83 b
CV%	7.54	8.22
LSD (0.05)	15.25	0.26

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Application of boron exhibited a significant influence on yield per plot (Table 14, appendix VII). The maximum yield (6.16 kg) was obtained from the treatment B_2 which was followed by the treatment B_3 (5.83 kg). The minimum yield (4.73 kg) was obtained from the treatment B_0 (control).

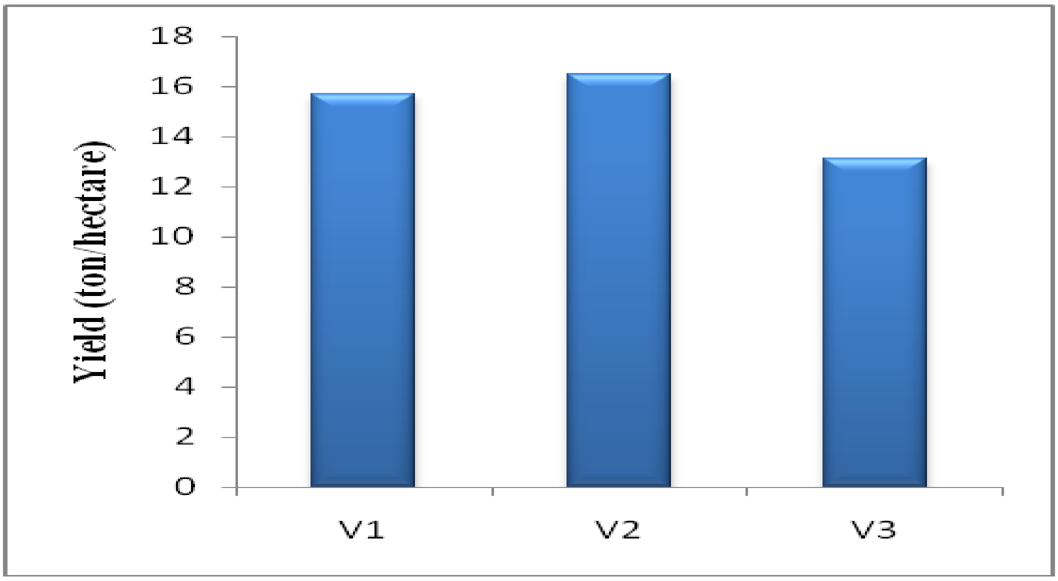
There was significant variation among the treatment combinations of cultivars and boron levels (Table 15; Appendix VII). The maximum yield per plot (6.54 kg) was observed in the treatment combination V_2B_2 and the minimum yield (4.48 kg) was recorded from the treatment combination V_3B_0.

4.17. Yield per hectare

The yield per hectare of broccoli was significantly influenced by the different cultivars (Table 13; Appendix VIII). The maximum yield (16.48 t/ha) was recorded from V_2 while the minimum yield (13.38 t/ha) was observed in V_3.

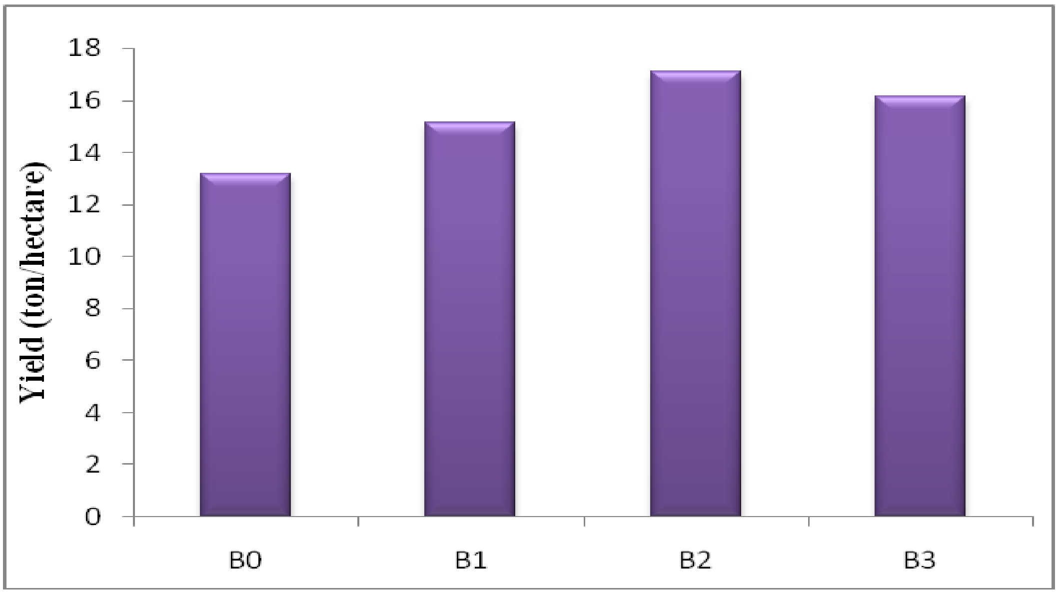
Yield per hectare of broccoli was significantly influenced by the different boron levels (Table 14; Appendix VII). The maximum yield (17.12 t/ha) was obtained from the treatment B_2 while the minimum yield (13.14 t/ha) was obtained from the treatment B_0 (control).

Yield per hectare was significantly influenced by the treatment combination of cultivar and boron levels (Table 15; Appendix VIII). Yield per hectare ranged from 12.45 to 18.16 t/ha. The maximum yield (18.16 t) per hectare was observed in the treatment combination V_2B_2 while the minimum yield (12.45 t) per hectare was observed in the treatment combination V_3B_0.



V_1: Top green, V_2: Green magic, V_3: BARI Broccoli-1

Fig. 10 Effect of different cultivar on yield of broccoli



B_0: 0 kg/ha, B_1: 1 kg/ha, B_2: 2 kg/ha, B_3: 3 kg/ha

Fig. 11 Effect of different boron level on yield of broccoli

Table 15.Combined effect of different cultivar and boron level on yield of broccoli

Treatments	Yield per plant (g)	Yield per plot (kg)	Yield per hectare (t)
V_1B_o	343.83 e	5.15 e	14.31 e
V_1B_1	370.43 cde	5.51 de	15.29 cde
V_1B_2	410.20 ab	6.15 ab	17.08 ab
V_1B_3	390.47 bc	5.82 bcd	16.16 bc
V_2B_0	304.37 f	4.56f	12.66 f
V_2B_1	354.30 de	5.31 e	14.74 de
V_2B_2	437.67 a	6.54 a	18.16 a
V_2B_3	400.33 bc	6.04 bc	16.59 bc
V_3B_0	299.20 f	4.48 f	12.45 f
V_3B_1	369.87 cde	5.54 de	15.39 cde
V_3B_2	387.47 bcd	5.81 bcd	16.13 bcd
V_3B_3	375.13 cde	5.62 cde	15.61 cde
CV%	7.54	8.22	8.22
LSD (0.05)	25.35	0.43	1.29

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

4.18 Economic analysis

4.18.1 Gross return

In the combination of cultivar and boron different gross return were recorded under the trial (Table16). The highest gross return (Tk. 4,50,000.00) was obtained from V_2B_2 and the second highest gross return (Tk. 4,22,500.00) was obtained in V_1B_2. The lowest gross return (Tk. 3,00,000.00) was obtained from V_3B_0.

4.18.2 Net return

In this experiment, different treatment combination showed different net return (Table16). The highest net return (Tk. 2,96,930.00) was obtained from V_2B_2 and the second highest net return (Tk. 2,69,980.00) was obtained from $V_1B_{2.}$ The lowest net return (Tk. 1,49,350.00) was obtained from $V_3B_{0.}$

4.18.3 Benefit cost ratio

The benefit cost ratio was found different due to different treatment combinations (Table 16). The highest (2.93) benefit cost ratio was found from V_2B_2 and the second highest benefit cost ratio (2.73) was estimated V_1B_2. The lowest benefit cost ratio (1.99) was obtained from V_3B_0. From economic point of view, it is revealed from the above result that V_2B_2 was more profitable than rest of the treatment combinations of cultivar and boron for broccoli production.

Table 16. Cost and return of broccoli cultivation as influenced by cultivar and boron

Treatment combination	Cost of production (Tk./ha)	Yield of broccoli (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
V_1B_o	151200	14.31	350000	198800	2.31
V_1B_1	151860	15.29	375000	223140	2.40
V_1B_2	152520	17.08	422500	269980	2.73
V_1B_3	153840	16.16	400000	246160	2.60
V_2B_0	151750	12.66	310000	158250	2.04
V_2B_1	152410	14.74	350000	197590	2.29
V_2B_2	153070	18.16	450000	296930	2.93
V_2B_3	154390	16.59	400000	245610	2.54
V_3B_0	150650	12.45	300000	149350	1.99
V_3B_1	151310	15.39	375000	223690	2.47
V_3B_2	151970	16.13	400000	248030	2.63
V_3B_3	153290	15.61	387500	234210	2.52

V_1: Top green

V_2: Green magic

V_3: BARI Broccoli-1

B_0: 0 kg/ha

B_1: 1 kg/ha

B_2: 2 kg/ha

B_3: 3 kg/ha

CHAPTER V

SUMMARY AND CONCLUSIONS

An experiment was conducted to find out the effect of different cultivars and boron levels on the growth and yield of broccoli at the horticulture of the Sher-e- Bangla Agricultural University, Dhaka, during the period from October, 2015 to March, 2016. There are two factors. Factor A :cultivar, there are three cultivars, viz. V_1: Top green, V_2: Green magic, and V_3: BARI Broccoli-1 and four levels of boron fertilizer viz. B_0: 0 kg/ha, B_1 :1 kg/ha, B_2: 2 kg /ha and B_3: 3 kg /ha and thus there were altogether twelve (12) treatment combinations.

The two factor experiment was conducted in randomized complete block design with three replications. The size of unit plot was 2m × 1.8 m. 15 tons of well decomposed cow dung per hectare was supplied to the land and uniformly incorporated to the soil. Nitrogen was applied in three equal splits after transplanting. Thirty days old seedlings were transplanted at a spacing of 60 cm × 40 cm in the experimental plots on 22 November, 2015 and harvested on 26 January to 11 February, 2016.

Five plants from each plot were randomly selected and identified with tag for the collection of data. The yield was recorded from all plants of each plot. Data were recorded on the plant height, number of leaves per plant, length of leaf, breadth of leaf (at 20, 40 and 60 DAT), days to curd initiation, length of root, weight of root, stem diameter, diameter of primary curd, weight of primary curd, number of secondary curd, weight of secondary curd per plant, percent dry matter of leaves, percent dry matter of curd, 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 result of the experiment revealed that all the parameters except plant height, leaf length, root weight, no. of secondary curd and weight of secondary curd were significantly influenced by the different cultivars. The V_2 produced the higher plant height (60.13 cm), number of leaves per plant (16.18), leaf breadth (16.73 cm), and leaf length (46.62 cm) than other cultivar at 60 DAT. The highest root length (19.33 cm), root weight (22.33 cm), weight of main curd (333.37 g), main curd diameter (15.97 cm) per plant was recorded from the V_2. The maximum yield per plant (395.84 g), yield per plot (5.90 kg) and yield per hectare (16.48 t) were obtained from the cultivar V_2 and the minimum yield per plant (322.24 g), yield per plot (4.82 kg) and yield per hectare (13.38 t) were obtained from the cultivar V_3.

Application of boron played an important role on the growth and yield of broccoli. Boron significantly influenced the results of all parameters, the maximum height of plant (61.02 cm), number of leaves (17.67), leaf length (47.71 cm) and leaf breadth (17.83 cm) at 60 DAT was obtained from the treatment B_2 which was higher than the other treatment. The maximum root weight (23.76 g), root length (21.44 cm), main curd weight (361.31 g), main curd diameter (16.58 cm), no. of secondary curd (3.73), weight of secondary curd (65.10 g), percent dry matter of leaves (10.95), percent dry matter of curd (19.71) were obtained from the treatment B_2 which was 2 kg B/ha. The highest yield per plant (411.78 g), yield per plot (6.16 kg) and yield per hectare (17.12 t) were recorded from the treatment B_2. The lowest yield per plant (315.80 g), yield per plot (4.73 kg), and yield per hectare (13.14 t) were recorded from the control (B_0) treatment.

The combined effect of cultivar and boron levels significantly influenced almost all the parameters of the broccoli. The maximum yield per plant (437.67 g), yield per plot (6.54 kg), yield per hectare (18.16 t) were obtained from the treatment combination V_2B_2. On the other hand the minimum yield per plant (299.20 g), yield per plot (4.48 kg), and yield per hectare (12.45 t) were obtained from the treatment combination V_3B_0.

From the economic point of view, the highest gross return (Tk. 4,50,000.00) was obtained from the treatment combination V_2B_2 and the lowest gross return (Tk. 3,00000.00) was obtained from V_3B_0. The highest net return (Tk. 2,96,930.00) was found from the treatment combination V_2B_2 and the lowest (Tk. 1,49,350.00) net return was obtained from V_3B_0. In the different cultivar and boron levels the highest benefit cost ratio (2.93) was noted from the combination of V_2B_2 and the lowest benefit cost ratio (1.99) was obtained from V_3B_0.

Conclusions:

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

i. Green Magic cultivar of broccoli has better vegetative growth and yield.
ii. Application of boron improves the vegetative growth and quantitative parameters of broccoli and its application to the soil also increased the head yield of broccoli.
iii. In combination of cultivars and boron levels the highest yield was found with the combination of 2 kg B/ha and Green Magic cultivar.

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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 experimental field

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

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)	13.00
Exchangeable K(me/100 g soil)	0.10
Available S (ppm)	33

Source: SRDI, 2013

Appendix II. Monthly record of air temperature, relative humidity and Rainfall of the experimental site during the period from October, 2015 to February, 2015

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-1212

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 number of leaf

Source of variation	Degrees of freedom (df)	Mean Square of					
		Plant height (cm) at			Number of leaf at		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	34.176	23.042	46.382	0.108	0.503	4.257
Cultivar (A)	2	124.404**	126.647**	132.332**	9.543**	36.348**	44.867**
Boron (B)	3	111.871**	113.002**	125.010**	11.631**	61.646**	86.432**
A x B	6	80.167*	59.758*	129.268**	7.807*	20.677*	31.977*
Error	22	26.971	19.452	38.018	2.064	6.009	9.296

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

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

Source of variation	Degrees of freedom (df)	Mean Square of					
		Leaf length (cm) at			Leaf breadth (cm) at		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	4.887	5.533	66.809	0.353	0.486	3.021
Cultivar (A)	2	3.143NS	57.377**	88.242**	7.767**	13.380**	36.481**
Boron (B)	3	37.028**	63.576**	95.986**	12.098**	17.015**	46.095**
A x B	6	14.582*	31.049*	67.771*	4.026*	12.704*	22.282*
Error	22	4.259	11.566	21.538	1.152	4.713	7.458

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VI . Analysis of variance of the data on days required for curd initiation, root weight, root length and stem diameter

Source of variation	Degrees of freedom (df)	Mean Square of			
		Days required for curd initiation	Root weight (g)	Root length (cm)	Stem diameter (cm)
Replication	2	5.472	8.902	20.701	0.041
Cultivar (A)	2	101.372**	7.875NS	94.121**	1.262*
Boron (B)	3	125.430**	85.623**	104.005**	4.093**
A x B	6	61.426*	55.516*	78.951*	1.406*
Error	22	21.988	17.932	31.059	0.643

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VII . Analysis of variance of the data on curd diameter, main curd weight, no. of secondary curd, weight of secondary curd, dry matter of leaves and dry matter of curds

Source of variation	Degrees of freedom (df)	Mean Square of					
		Main curd diameter (cm)	Main curd weight (g)	No. of secondary curd	Weight of secondary curd (g)	Dry matter of leaves (%)	Dry matter of curd (%)
Replication	2	2.290	249.51	0.021	9.991	0.787	2.108
Cultivar (A)	2	29.637**	1406.03**	6.195**	19.014NS	30.896**	64.250**
Boron (B)	3	24.808**	5201.43**	9.876**	82.570**	49.280**	75.811**
A x B	6	19.771*	411.14*	3.697*	44.302*	19.005*	35.811*
Error	22	7.142	132.67	1.005	15.549	6.046	23.237

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix VIII. Analysis of variance of the data on yield per plant, yield per plot and yield per hectare

Source of variation	Degrees of freedom (df)	Mean Square of		
		Yield/plant (g)	Yield/plot (kg)	Yield/ha (t)
Replication	2	443.5	0.184	1.208
Cultivar (A)	2	2409.3**	1.504**	12.686**
Boron (B)	3	45510.2**	1.251**	78.063**
A x B	6	6428.8**	1.488**	10.935**
Error	22	535.4	0.196	1.917

* Significant at 0.05 level of probability; ** Significant at 0.01 level of probability and NS Non-significant

Appendix IX. Cost of production of broccoli (per hectare)

A. Input cost

Treatment combination	Labour cost	Ploughing cost	Seed cost	Insecticide/ pesticide	Irrigation	Manure and fertilizer				Boric acid	Sub Total(A)
						Cowdung	Urea	TSP	MP		
V_1B_o	15000	10000	5500	5000	5000	30000	7500	6000	8000	0.00	92000
V_1B_1	15000	10000	5500	5000	5000	30000	7500	6000	8000	600.00	92600
V_1B_2	15000	10000	5500	5000	5000	30000	7500	6000	8000	1200.00	93200
V_1B_3	15000	10000	5500	5000	5000	30000	7500	6000	8000	2400.00	94400
V_2B_0	15000	10000	6000	5000	5000	30000	7500	6000	8000	0.00	92500
V_2B_1	15000	10000	6000	5000	5000	30000	7500	6000	8000	600.00	93100
V_2B_2	15000	10000	6000	5000	5000	30000	7500	6000	8000	1200.00	93700
V_2B_3	15000	10000	6000	5000	5000	30000	7500	6000	8000	2400.00	94900
V_3B_0	15000	10000	5000	5000	5000	30000	7500	6000	8000	0.00	91500
V_3B_1	15000	10000	5000	5000	5000	30000	7500	6000	8000	600.00	92100
V_3B_2	15000	10000	5000	5000	5000	30000	7500	6000	8000	1200.00	92700
V_3B_3	15000	10000	5000	5000	5000	30000	7500	6000	8000	2400.00	93900

V_1: Top green

V_2: Green magic

V_3: BARI Broccoli-1

B_0: 0 kg/ha

B_1: 1 kg/ha

B_2: 2 kg/ha

B_3: 3 kg/ha

Appendix IX. Contd.

B. Overhead cost (Tk./ha)

Treatment combination	Cost of lease of land for 6 months (10% of value of land Tk. 10,00,000/year	Miscellaneous cost (TK. 5% of input cost	Interest on running capital for 6 months (Tk.10% of cost/year)	Subtotal (Tk.)	Total cost of production (Tk./ha) Input cost + overhead cost
V_1B_o	50000	4600	4600	59200	151200
V_1B_1	50000	4630	4630	59260	151860
V_1B_2	50000	4660	4660	59320	152520
V_1B_3	50000	4720	4720	59440	153840
V_2B_0	50000	4625	4625	59250	151750
V_2B_1	50000	4655	4655	59310	152410
V_2B_2	50000	4685	4685	59370	153070
V_2B_3	50000	4745	4745	59490	154390
V_3B_0	50000	4575	4575	59150	150650
V_3B_1	50000	4605	4605	59210	151310
V_3B_2	50000	4635	4635	59270	151970
V_3B_3	50000	4695	4695	59390	153290

V_1: Top green

V_2: Green magic

V_3: BARI Broccoli-1

B_0: 0 kg/ha

B_1: 1 kg/ha

B_2: 2 kg/ha

B_3: 3 kg/ha