GROWTH AND YIELD OF BITTER GOURD (*Momordica charantia L.*) INFLUENCED BY GIBBERELIC ACID AND BORON

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By

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD OF BITTER GOURD (Momordica charantia L.) INFLUENCED BY GIBBERELIC ACID AND BORON"*** *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 (M.S.)*** *in* ***HORTICULTURE,*** *embodies the results of a piece of bona fide research work carried out by* ***SHAMMI AKTER,*** *Registration. No.* ***11-04285*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

The field experiment was carried during the period of April to June 2016 at Horticulture farm of Sher-e-Bangla Agricultural University Dhaka-1207, Bangladesh. The experiment was laid out in the Randomized Complete Block Design with three replications. Treatment consisted of four levels of plant growth regulator i.e. G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; and three levels of boron i.e. B_0=No boron, B_1= 15 ppm, B_2= 30 ppm. Result revealed that the vegetative growth namely plant height was highest (255.38 cm) in G_2B_2 and lowest (149.42 cm) in G_0B_0, number of primary branches plant^{-1} was highest (12.30) in G_2B_2 and lowest (4.09)in G_0B_0, number of secondary branches plant^{-1} were highest (9.22) in G_2B_2 and lowest (2.19) in G_0B_0. The reproductive development i.e. the number of male flowers plant^{-1} was highest (36.47) in G_2B_2 and lowest (14.23) in G_0B_0, number of female flowers plant^{-1} was highest (20.17) in G_2B_2 and lowest (9.20) in G_0B_0, number of fruits plant^{-1} was highest (17.33) in G_2B_2 and lowest (7.16) in G_0B_0 and yield was highest (39.06 t ha^{-1}) in G_2B_2 and lowest (21.66 t ha^{-1}) in G_0B_0. The combined effect G_2B_2 produced the best result for all vegetative growth, reproductive development and yield of bitter gourd. Therefore, the combination of G_2B_2 could be used to cultivate bitter gourd.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAS	Days after sowing
et al	And others
FAO	Food and Agriculture Organization
Min	Minimum
MoP	Muriate of Potash
N	Nitrogen
NS	Not significant
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCATION

Bitter gourd (*Momordica charantia* L.) is a tropical and subtropical vine of the family Cucurbitaceae. This herbaceous, tendril-bearing vine grows up to 5 m (16 ft) in length. It bears simple, alternate leaves 4–12 cm (1.6–4.7 in) across, with three to seven deeply separated lobes. Each plant bears separate yellow male and female flowers. The fruit is most often eaten green, or as it is beginning to turn yellow. At this stage, the fruit's flesh is crunchy and watery in texture, similar to cucumber, chayote or green bell pepper, but bitter. The skin is tender and edible. Seeds and pith appear white in unripe fruits; they are not intensely bitter and can be removed before cooking. Some sources claim the flesh (rind) becomes somewhat tougher and more bitter with age, but other sources claim that at least for the common Chinese variety the skin does not change and bitterness decreases with age. The Chinese variety are best harvested light green possibly with a slight yellow tinge or just before. The pith becomes sweet and intensely red; it can be eaten uncooked in this state, and is a popular ingredient in some Southeast Asian salads. When the fruit is fully ripe, it turns orange and mushy, and splits into segments which curl back dramatically to expose seeds covered in bright red pulp. It is widely grown as edible fruit, which is most bitter than all vegetables. The main problem of bitter gourd production is the male and female flower ratio. The number of male flower is more than the female flower due to high temperature and high humidity. Pollen viability is lost relatively rapidly. The stigma is usually receptive for 1 day before or after flower opening, after which it dries and turns brown. The plant growth regulators (PGR’s) are considered as a new generation agrochemical after fertilizers, pesticides and herbicides. In bitter gourd, it is possible to increase the yield by increasing the fruit set by using growth regulators. Use of PGR’s like GA 3 and NAA have an ability to modify the plant growth, sex ratios and yield contributing characters, while micro nutrient like boron will be a useful alternative to increase crop production (Shantappa et al., 2007). Growth regulators are known to have an effect on the production of earliest flower, yield (Gedam*et al*., 1998), ratio of male/female flower (Bisaria, 1974), number of fruits, weight of fruit (Gopalkrishman and Choudhury, 1978). Exogenous application of growth regulators has sifted the sex expression towards femaleness by increasing the production of female flower and suppressing the male flowers in bitter gourd (Parkash, 1974).

Boron is a micronutrient that is very much effective on bitter gourd production. The micronutrient is involved in enzyme systems as cofactors with the exception of Zn, Mn, Cu and B. These are capable of acting as ‘electron carriers’ in the enzyme systems and are responsible for the oxidative-reduction process in the plant system. Boron availability decreases with the increasing pH, and most of the total soil B is unavailable to the plants (Marschner, 1995; Borax, 2002). Boron is associated directly and indirectly with several plant functions, as it involves in the growth of cells in newly emerging shoots and roots while in some plants it is a crucial for boll formation, flowering, pollination, seed development and sugar transport (Takano *et al*., 2008; Miwa *et al*., 2008). Boron plays a supportive role in cell wall synthesis, lignification (Loomis and Durst, 1992) and cell wall structure (Fleischer *et al*. 1998).

Verma *et al*. (1984) reported that application of boron at 3 or 4 ppm gave the highest number of female flower per plant (28-32) and fruits per plant (23-26.4) in bitter gourd. Gedam *et al*. (1998) observed that application of boron 2, 4 and 6 ppm in bitter gourd increased fruit and seed yield and fruit maturity was earliest in the application of boron 4 ppm. Fruit yield was also highest in this treatment. But very little information regarding effect of zinc, iron and boron on growth, yield and quality of bitter gourd are available. Boron deficiency plays a significant role in yield reduction of many vegetables, including bitter gourd due to premature flower, square or boll shedding. It increases the pollen viability, helps in seed formation, protein synthesis and carbohydrate metabolism. So, the pollen viability increased as well as the fruit setting also increased ultimately.

Considering the above facts, the present experiment was conducted for the following objectives:

1. To test the effects of foliar spraying of GA_3 on the growth, yield and fruiting of bitter gourd.

2. To know the effect of boron on flowering and fruiting of bitter gourd.

3. To study the combine effect of GA_3 and boron on growth, flowering and fruiting of bitter gourd.

CHAPTER II

REVIEW OF LITERATURE

A field experiment was conducted at Horticulture farm of Sher-e-Bangla Agricultural University farm to study the growth, flowering and fruiting of bitter gourd (*Momordica charantia* L.) influenced by the growth regulator (GA3) and boron (B). Some related literature and research findings of different researchers have been cited below.

3.1 Effect of micronutrient

Mishra *et al*. (2015) stated that, gynoecious sex form in bitter gourd (*Momordica charantia* L.) has importance in hybrid breeding, but lack of easy and economic techniques to maintain gynoecious lines limits its use. Sex modification with chemicals can be an option in this regard. Bitter gourd is a typical monoecious (both male and female flower in same plant at separate nodes) plant. The gynoecious line was isolated from its related wild form *M. charantia* var. *muricata* L. Effects of concentrations of silver nitrate (SN), gibberellic acid (GA_3), and silver thiosulfate (STS) for induction of male flowers in the gynoecious variety DBGy-201 were determined. The STS at 3 and 6 mm induced staminal tissue in female flowers of gynoecious bitter gourd and GA_3 at 2.9 and 4.3 mm induced increased vegetative growth and rudimentary stamen production without viable pollen. The SN at 1.2 and 1.5 mm had no effect. The highest percentage (57.63%) of altered sex form was in plants treated with STS at 6 mm. Stamens were observed in female flowers that matured between 7 and 15 days after treatment. Induced hermaphrodite flowers had ovaries, stigma, styles, stamens, anthers, calyx, corolla, and petioles that were double the size of normal female flowers. Silver nitrate applied at 6 mm was best for inducing hermaphrodite sex form in the gynoecious line of bitter gourd.

Sandra *et al*. (2015) conducted an experiment and stated that the effect of plant growth regulators on vegetative growth, sex expression, fruit setting, seed yield and quality was studied for hybrid seed production in the parental lines of bitter gourd (*Momordica charantia* L.) hybrids, Pusa hybrid 1 and Pusa hybrid 2 in rainy and spring-summer season. Plant growth regulators namely GA_3 @ 50 ppm, NAA @ 200 ppm, maleic hydrazide @ 100 ppm, etherel @ 50 ppm were sprayed at three leaf and tendril initiation stage. The results showed that application of GA_3 significantly enhanced vine length, number of branches and nodes/vine, fruiting, seed yield and quality in the parental lines in both the seasons. The plants sprayed with growth regulators showed induction of female flowers at lower nodes with 3-5 more pistillate flowers per vine and higher sex ratio as compared to unsprayed control. In manually pollinated flowers, plants sprayed with GA_3 @ 50 ppm had higher fruit and seed setting, fruit weight and hybrid seed yield. All the growth regulators had positive influence on vegetative, flowering and fruit traits in both the seasons but effect of growth regulators were more evident in rainy than spring summer season. GA_3 @ 50 ppm, NAA @ 200 ppm, etherel @ 50 ppm were effective for enhancement in vegetative growth, fruit and seed yield and modification of sex expression but GA_3 @ 50 ppm sprayed twice at three leaf and tendril initiation stage was most effective for hybrid seed production of bitter gourd.

Arvindkumar *et al*. (2014) conducted and experiment and reported that the investigation was carried out to study the effect of plant growth regulators and micronutrient on seed longevity of bitter gourd Cv. Pusa Visesh at College of Agriculture, Raichur (Karnataka), India. Seed obtained after the crop imposed with treatment viz., two growth regulators viz., NAA (25 and 50 ppm), triacontanol (0.5 and 1.0 ppm) and boron (3.0 and 4.0 ppm) were used for foliar application at two concentrations with absolute control and water spray at two to four true leaf stage and then at 60 days after sowing (DAS), 75 DAS and 90 DAS in the Seed Technology field block. Results revealed that the moisture content increases gradually as storage period increased in all the treatments. Seeds stored in cloth bags under ambient storage condition and seed quality tested after every month end of storage period (February 10 – January 2011). Boron at 4 ppm maintained lower moisture content of seed (7.07%, 7.19% and 9.16%) after first, third and twelve months after storage respectively. Whereas seed quality viz., seed germination (88.50%, 91.00% and

85.50%) and electrical conductivity (0.318, 0.273 and 0.410 dSm-1) at the end of first, third and twelve months after storage, respectively.

Geeta *et al*. (2014) conducted an experiment to find out the effect of plant growth regulators on leaf biochemical parameters (chlorophyll pigments, sugars, nitrate reductase activity, total phenols) and fruit yield bitter gourd (Momordica charantia L.) was studied. The experiment consisted of foliar treatment with three plant growth regulators, GA_3 (20, 40 and 60ppm), NAA (50ppm) and CCC (100 and 200ppm) in two bittergourd varieties, MHBI–15 and Chaman Plus at 45 days after sowing (DAS). Results revealed significant difference between treatments on chlorophyll, sugar, total phenol content as also on nitrate reductase activity. Foliar application of CCC (200ppm) recorded maximum amount of total sugars (18.03% over Control), total phenol content (10.93%) as also nitrate reductase activity (16.12%). Among the treatments, application of GA_3 (20ppm) recorded maximum chlorophyll content (18.03% over Control). Highest increase in mean fruit yield over Control was recorded with application of GA_3 (20ppm) (39.88%), followed by CCC (200ppm) (34.15%) in both the cultivars.

Mia *et al*. (2014) found that, assessment of growth regulator and NPK fertilization effects are important tools for flower stimulation and yield improvement in cucurbits. This investigation demonstrates the comparative male-female flower induction and fruit yield of small sized bitter gourd treated with NPK fertilizers and plant growth regulators. Namely, two experiments having three replicates were conducted in a Randomized Complete Block Design (RCBD) with NPK fertilization and plant growth regulators-GA_3, NAA and Ethophon application on small sized bitter gourd-genotype BG5 at the research field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). In experiment 1, different doses of NPK fertilizers comprised of 10 treatments and in that of experiment 2, different levels of plant growth regulators indicated 10 treatments. The results indicated that application of different doses of NPK fertilizer and plant growth regulators significantly (< or = 0.05) influenced over the flower initiation and fruit setting. The application of N90-P45-K60 fertilizer along with Ethophon spraying resulted in the better yield of small sized bitter gourd.

Akter and Rahman (2013) conducted an experiment to find out the effect of foliar application of IAA And GA on sex expression, yield attributes and yield of bitter gourd (*Momordica Charantia* L.). Three concentrations of each of IAA viz. 2.5 (T_1), 5.0 (T_2) and 10 (T_3) ppm and GA_3 viz. 2.5 (T_4), 5.0 (T_5) and 10 (T_6) ppm were applied as foliar spray on bitter gourd. Results showed a positive stimulatory effect in the increase of female flowers at T3 where the male to female sex ratio was the lowest. The number of fruits, fresh weight of fruits and yield per plant were also found to be the highest at T_3.

Biradar *et al*. (2012) reported that the itter gourd is an important vegetable crop since its fruits are brought to use either as vegetable or medicinal purpose. A compound known as charantin, present in the bitter gourd is used in the treatment of diabetes in reducing blood sugar level. In the present days due to increase in number of diabetic patients there is more demand to meet the requirement. The available literature on cucurbits said that, growth regulators had significant effect on conversion of sex ratio of flowers, which helps in enhancing the yields of the crop. Keeping this as an objective a study on Effect of plant growth regulators on yield, biochemical and physiological characters of bitter gourd (Momordicacharantia L.) was conducted during Rabi 2007-08 at University of Agri - cultural Sciences, Dharwad. Foliar application of the plant growth regulators such as Gibberlic acid (GA_3) at 20, 40, and 60ppm, naphthalene acetic acid (NAA) at 50ppm and cycocel (CCC) at 100 and 200 ppm, was done at 45 days after sowing. Application of plant growth regulators significantly increased the biochemical and physiological characters in bittergourd such as chlorophyll content (Chl a, Chl b and total chlorophyll), nitrate ReductaseActivity (NRA), sugar content (reducing, non-reducing and total sugars), and total phenol content. Among the different treatments GA_3 @ 20 ppm was most effective in increasing the fruit yield and yield components such as No. of female flowers, no of fruits per plant as compared to control.

Shahzad (2012) stated that, the improve in growth of plants is important in present day life, where food - and its quality- often falls short. With the steady population growth, it is certainly important to ensure plants used for food and otherwise are grown in optimum conditions and have a high yield. This book covers a study conducted to evaluate the growth response of the bitter gourd plant Momordica charantia to growth regulator treatments of the hormone Gibberellic acid to determine the optimum concentration required for enhanced growth. Gibberellin increases both cell elongation and cell division, as evidenced by increases in cell length and cell number in response to applications of GA. This book should help the botanists and agriculturists around the world to observe the best growth in plants and serve as an example for future publications that also focus on plant growth regulators.

Ashrafuzzaman *et al.* (2010) stated that, an experiment was conducted to investigate the effect of GABA (GA_3 1% & SBA Brassicasteroids as STC 0.3%) application on growth, yield and yield contributing traits of bitter gourd. GABA was applied at 0.5, 1.0, 1.5 and 2.0 mg L-1 as foliar spray at 30 days after sowing, while control plants received no GABA. The experiment was laid out in a randomized complete block design (RCBD) with four replications. Result showed that GABA had positive regulatory effect on morphological growth, yield and yield related traits of bitter gourd; nonetheless GABA application at 1.5 mg L-1 was found the most effective in improving length and diameter of main vine, individual branch length, number of branches, total branch length, number of nodes per plant, vine diameter, days to first male and female flowering, numbers of male and female flower, number of fruit, weight of individual fruit, length and diameter of fruit, percentage of fruit set and number of seeds per fruit. Hence GABA application at 1.5 mg L-1 as foliar spray could be the suitable concentration for enhancing growth and yield of bitter gourd.

Hossain *et al*. (2006) reported that, the flowering and fruiting of two varieties of bitter gourd (Tia and Biruttam) as affected by six levels of GA_3 concentrations viz. 0, 25, 40, 55, 70 and 85 ppm was studied in the Crop Botany Field Laboratory of Bangladesh

Agricultural University, Mymensingh during the period from February to May 2005. Application of GA_3 at pre-flowering stage in bitter gourd plant significantly influenced flowering behavior and fruiting characteristics. It was observed that individual fruit weight was the maximum by application of GA_3 at 40 ppm but at higher concentration (>40 ppm) fruit yield declined. The results showed that variety Tia produced higher yield (1.454 kg/plant) than the variety Biruttam (1.367 kg/plant). Effect of different level of GA_3 concentrations were statistically different from each other.

David et al. (2005) conducted an experiment and found that plants treated with GA_3 showed significantly greater plant height, number of branches/plant, number of fruit/plant and yield than untreated controls. GA_3 treatment at the seedling stage offered valuable scope for obtaining higher commercial tomato yields.

The effects of NAA (25 and 100 ppm) and Maleic hydrazide (50 and 100 ppm), applied at the 2-true leaf stage, and sowing date (15-day intervals from 10 September to 25 October) on the growth of *Lagenaria siceraria* (cv. Kiyari Lao) was investigated by Bumrah and Datto (2001) during rabi 1999-2000 in India. They observed that plants sprayed with NAA at 25 ppm and MH at 50 ppm produced the highest yields (5.48 and 4.86 kg/plant, respectively. Yield decreased with later sowing dates from 5.49 to 2.62 kg/plant.

Wang and Wang (2001) conducted an experiment to find out the effect of CPPU (forchlorfenuron) application on growth, yield and quality of bitter gourd. Application of CPPU to the ovary at anthesis within the concentration of 10-50 mg/litre accelerated fruit growth by increasing the length, diameter and fresh weight of fruits, while 100 mg/litre inhibited fruit growth. HPLC analysis showed that the endogenous ZT (zeatin) content of fruit was lowered and the endogenous ABA (abscisic acid) content was improved by CPPU treatments at the concentration of 20 and 100 mg/litre, and that the endogenous contents of IAA and GA_3 (gibberellic acid) were significantly improved by application of CPPU at 20 mg/liters, reaching a peak value 6 day after anthesis.

Al-Masoum and Al-Masri (1999) reported that Cucumber cv. Beit Alpha was grown in a greenhouse in 1996-97 and ethephon applied at 250 ppm, 350 ppm and 450 ppm at the seedling stage (2-4 true leaves). Data were collected on the total yield, early yield, late yield, number of female flowers, number of male flowers, days to the first male flowers, days to first female flowers, number of nodes to the first female flower, number of nodes to the first male flower and plant height. All the cases positive result was found from ethephon treated plants. Ethephon induced femaleness (pistillate flowers) on the main stem that led to greater fruit production.

Goutom *et al.* (1998) conducted an experiment in 1992 where bitter gourd plants were sprayed 40, 55, 70, 80 and 100 days after sowing with 15, 25 and 35 ppm GA_3, 50, 100 and 150 ppm NAA, 50, 100 and 150 ppm Ethephon, 100, 200, 200 and 300 ppm Maleic Hydrazide, 2, 4 and 6 ppm boron and with water (control). GA_3 at 35 ppm produced the earliest female flower and NAA at 50 ppm produced the earliest male flower. Fruit maturity was the earliest in plants treated with 50 ppm NAA or 4 ppm boron. Fruit and seed yields were also the highest in these treatments.

Susmita *et al*. (1998) conducted an experiment and reported that foliar application of GA_3 (5 PPM/litre). They found that it reduced the vegetative phase and extended the flowering phase of *Momordica charantia* L. GA_3 promoted the female flowering, fruit setting, and fruit development. It also increased the length, girth, weight and quality of fruits.

Jutamanee and Mongkolporn (1996) stated that, the study of plant growth regulators and levels of irrigation on fruit development of bitter gourd (Momordica charantia L.) cv. Khiewyoke 68 consisted of 3 experiments. Experiment 1: Using of plant growth regulators to induced pistillate flowers in bitter gourd. Fifty and 100 ppm of NAA 25, 50 ppm of ethephon and 5, 25 ppm of paclobutrazol were sprayed to plant when the third leaf expanded and the following week. All kinds of plant growth regulators increased number of pistillate flowers, especially 50 ppm of ethephon induced the highest number of pistillate flower. The height of plants treated with 25 ppm paclobutrazol were retared, compared with untreated trees. The experiment 2: Using of plants growth regulators on fruit development of bitter gourd. Giberellin at concentration of 10, 25 or 50 ppm was sprayed to the plants when they reached 45 days after gemination. Giberellin at all concentrations had no effect on total yields and had no effect on increasing width, lenght and fresh weight. Furthemore, using of giberellin increased the number of abnormal fruits. The experiment 3. Effect of irrigation levels on fruit development of bitter gourd. The experiment consisted of 3 levels of irrigation, namely 100, 150 and 200 percent of potential evapotranspiration (PET). The irrigation level of 200 percent gave the highest total yield, compared with 100 and 150 percent PET. Diameter, lenght and fresh weight were not different among the treatments but treatment of 200 percent PET gave the best growth rate, compared with the others.

Islam (1995) conducted a trial with different concentrations of GA3 like 0, 10, 25, 50 and100 ppm. He stated that application of GA_3 was effective in improving the yield and yield components of bitter gourd when applied at low concentration of 10 ppm. The inhibitory effect of GA_3 applied at the rate of 100 ppm was observed on production of fruits with lesser number of filled seeds, dry matter of seeds, weight of 100 seeds, seed yield and percent seed vigor index. Irrespective of concentration, the application of GA_3 reduced the total number of staminate flowers. The ratio between the staminate and pistillate flowers as well as fruit setting was low. The number, length, diameter and weight of fruits were not influenced by GA_3 application.

Arora *et al.* (1988) conducted an experiment and stated that two season field trials with cv. *Lagenaria cylindrica*. The plants were sprayed with 5 different growth regulators at the 2 and 4 true leaf stages. The total yield (2.39 kg/plant) was the highest in plants treated with Ethrel (ethephon) at 100 ppm. The average control yield was 0.69 kg/plant.

Effect of boron

Sultana *et al.* (2017) stated that boron is an essential plant nutrient which plays an integral role during cell division, sugar transportation, reproduction as well as in the physiological and biochemical events occurring in plants, especially related to the enhancement of quality of crops. Boron has also been found imperative for human health, as it is involved in mineral and hormonal metabolism, enzyme action and other important cell membrane functions. Therefore, keeping in view the importance of this micronutrient, this study was planned to assess the effects of boron on the yield and quality of bitter gourd. Three replicated field experiments were laid down in a randomized complete block design with six treatments. Control, recommended NPK, 0.5, 0.75, 1 and 1.25 kg boron/ha along with recommended NPK. The results showed that boron had a significant effect on bitter gourd fruit yield and the highest yield (14.1 t/ha) was obtained in the treatment where 1.25 kg/ha boron was applied while the low yield (5 t/ha) was obtained from control. The visual quality parameters (size, girth and weight) were significantly improved by boron application and it was increased with increasing boron levels. The highest boron concentration (30 ppm) in bitter gourd fruit was noted in the treatment where highest boron (1.25 kg boron/ha) was applied, whereas minimum boron concentration (7.8 ppm) was found in control, where no boron was applied. The results also revealed that boron has nonsignificant effects on the uptake of N and P, but had a significant effect on the uptake of K and Zn.

Vala and Savaliya (2014) conducted an experiment and reported that the effect of zinc, iron and boron on yield of bitter gourd cv. PUSAVISHESH was studies. The experiment consisted of eighteen treatment combinations, comprising of three levels of zinc viz., control (Zn_0), $ZnSO_4$ 0.5 per cent (Zn_1) and $ZnSO_4$ 1.0 per cent (Zn_2), three levels of iron viz., control (Fe_0), $FeSO_4$ 0.5 per cent (Fe_1) and $FeSO_4$ 1.0 per cent (Fe_2) and two levels of boron viz., control (B_1) and B_4O_7 0.1 per cent (B_2). Among different levels of zinc (0.0, 0.5 and 1.0%), Zn_1 ($ZnSO_4$ 0.5%) significantly increased fruit yield (15.65 t/ha. Among different levels of iron (0.0, 0.5 and 1.0%), Fe_1 ($FeSO_4$ 0.5%) significantly increased fruit yield (t/ha) (15.37 t/ha). Among different levels of boron (0.0 and 0.1 %), B_1 ($Na_2B_4O_7$ 0.1%) significantly increased fruit yield (t/ha) (14.96 t/ha). While among all the interactions of zinc, iron and boron, Fe_1Zn_1($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) significantly obtained highest fruit yield (16.33 t/ha) over control. The result based on one season data, it can be summarized that foliar application of micronutrients, $ZnSO_4$ 0.5 per cent + $FeSO_4$ 0.5 per cent at 30, 45 and 60 days after sowing along with a recommended dose of NPK (60+60+60 kg/ha) and FYM 20 tonnes/ha to the bitter gourd crop cv. 'Pusa Vishesh' was the most beneficial treatment for obtaining higher vegetative growth and yield of bitter gourd.

Sinha *et al*. (2009) stated that, at some concentrations boron (B) is toxic to bitter gourd (*Momordica charantia* L.). There is a need to determine how bitter gourd responds to B concentration. Plants of cv. Jhalari were exposed to 0.003 to 3.3 mg·L−1 of B for 32 days in refined sand. Plants exhibited best growth and total biomass at 0.33 mg·L−1 of B. Visible B deficiency symptoms were observed in plants treated with 0.003 mg·L−1 of B at day 25 manifest as blackening of the growing tip, reduction in size of plants, development of necrotic areas in young leaves, and thickening of the lamina of mature leaves, which later became leathery and eventually brittle. Toxicity symptoms developed at 3.3 mg·L−1 of B and at d 21 margins of old leaves became chlorotic. Exposure to <0.33 and >0.33 mg·L−1 of B reduced total biomass, chlorophyll a and b, carotenoid, and proline contents and activity of catalase and enhanced activities of the antioxidant enzymes peroxidase, superoxidase dismutase, ascorbate peroxidase, and polyphenol oxidase in leaves. Lipid peroxidation decreased, and tissue B concentration increased with an increase in B supplied. Values for deficiency, threshold of deficiency, threshold of toxicity, and toxicity were 5.4, 8, 58, and 120 μg·g−1 dry matter, respectively, in young leaves of bitter gourd, which could be helpful in predicting the B status of bitter gourd under field conditions.

Gedam *et al*. (1998) observed that application of boron 2, 4 and 6 ppm in bitter gourd increased fruit and seed yield and fruit maturity was earliest in the application of boron 4 ppm.

Verma *et al*. (1984) reported that application of boron at 3 or 4 ppm gave the highest number of female flower per plant (28-32) and fruits per plant (23-26.4) in bitter gourd.

CHAPTER III

MATERIALS AND METHODS

The present experiment was undertaken at Horticulture farm of Sher-e-Bangla Agricultural University farm to study the growth, flowering and fruiting of bitter gourd (*Momordica charantia* L.) influenced by the growth regulator (GA3) and boron (B).

3.1 Experimental Site

The study was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from April to June 2016. The experimental field was located at 90^0 22' E longitudes and 23^0 41' N latitude at an altitude of 8.6 meters above the sea level. The land was in Agro-Ecological Zone of Madhupur tract (AEZ No-28). It was deep red brown terrace soil. The soil was sandy loam in texture having pH 5.47 to 5.63. The physical and chemical characteristics of the soil have been presented in appendix I.

3.2 Climate

The experimental area was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season (April to July) and scantly of rainfall during the rest of the year. The monthly total rainfalls, average sunshine hour, temperature during the study period (April to July 2016) are presented in appendix II.

3.3 Planting materials used for experiment

Seeds of Gajkorola were collected from the Bangladesh Agricultural Development Corporation (BADC), Gabtoli, Dhaka, Bangladesh. The seed rate was maintained at 6 kg per hectare.

3.4 Treatments of the Experiment

The experiment consisted of two factors as follows. The first factor was hormone doses and second factor was boron application.

***Factor A:* Hormone doses**

i. G_0=No hormone
ii. G_1=50 mg/l
iii. G_2=100 mg/l
iv. G_3=150 mg/l

***Factor B:* Boron doses**

i. B_0=No boron
ii. B_1= 15 ppm
iii. B_2= 30 ppm

Treatments combinations were consisted with the following

B_0G_0, B_0G_1, B_0G_2, B_0G_3, B_1G_0, B_1G_1, B_1G_2, B_1G_3, B_2G_0, B_2G_1, B_2G_2, B_2G_3

3.5 Application of growth regulator

The selected growth regulators were applied per the treatment.

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment was divided into three blocks and consisted of 12 plots. Each unit plot in from of raised bed was 1.20 m^2 (1.2 m × 1.0 m) in size. Altogether there were 36-unit plots in experiment. The treatments were randomly assigned to each of the block. Spacing was maintained for this experiment 60 cm × 60 cm. The distance between two blocks and two of plots both were l.0 m.

3.7 Land preparation

The land, which was selected to conduct the experiment, was opened on 14 April by disc plough. After opening the land with a tractor, it was ploughed and cross-ploughed six times with a power tiller and laddering to break up the soil clods to obtain level the land followed each ploughing.

3.8 Manures and fertilizer application

The organic and inorganic fertilizer was applied as per the recommendation of fertilizer recommendation guide (2012).

Fertilizers	**Doses ha^{-1}**
Cowdung	15 ton
Urea	150 kg
TSP	125 kg
MoP	100 kg

The recommended dose of the above mentioned organic and inorganic fertilizer was applied during final land preparation where ½ doses of urea was applied at the time of land preparation. The rest amount of urea was applied at 40 DAS for better vegetative growth. The boron was applied in each plot as per the treatment.

3.9 Sowing of seeds and selecting of seedlings

The seeds were sown directly in the main filed (making pit for seed sowing) on 13th April 2016. First germination was noticed at 18th April, 2016. 2 to 3 seeds were sown in each pit at 2 to 3 cm depth and when the seedlings attained healthy enough (10-15 cm height and hard enough) then one healthy seedling was selected to remain in each pit and others were thinned out. During seed sowing 60 cm × 60 cm spacing was maintained.

3.10 Intercultural operations

The crop was kept free from weeds by regular weeding and irrigated as when required.

3.10.1 Gap filling

Research filed was checking regularly to ensure healthy crops. As per the routine work injured, dead, and weak seedlings were replaced by new vigor seedling from the same stock of the experiment.

3.10.2 Weeding

Weeds free research filed is the first priority, as for why weeding was done whenever it was necessary to keep the plots free from weeds.

3.10.3 Irrigation

Irrigation was done whenever it was necessary. According to the crops requirement, irrigation was done.

3.10.4 Vine management

Stormy weather may cause the tendering vine of the plants fell down from the supports (Trellis). For proper growth and development of the plants the vines were managed upward with the help of iron rope by hand.

3.10.5 Pest control

There was a plan to protect the plant from the attack of insects-pests specially fruit flies and fruit borer by spraying of pesticides. Since there was no incidence of disease no fungicide was applied in the crop field during the experimental period.

3.10.6 Trellis

Six bamboo poles were set slantingly keeping 5 feet high from the ground level in every plot. The poles were connected to one another tightly by iron rope in such a way that they make opposite “V” shaped. A net from rope were placed on iron rope. Thus, a trellis for each plot was made for creeping the vines of crop.

3.11 Harvesting

Total 6 times harvesting was done. Harvesting was done at seven days interval from every plant of every plot for collecting data.

3.12 Collection of experimental data

Data were recorded on the following parameters.

a) Vine length (cm)
b) Number of leaves plant^{-1}
c) Leaf area (cm^2)
d) Number of primary branches plant^{-1}
e) Number of secondary branches plant^{-1}
f) Number of male flowers plant^{-1}
g) Number of female flowers plant^{-1}
h) Number of fruits plant^{-1}
i) Fruits length (cm)
j) Fruits diameter (cm)
k) Individual fruit weight (g)
l) Fruit weight plant^{-1}(g)
m) Fruit yield ha^{-1} (ton)

3.13 Data collection procedure

3.13.1 vine length

Vine length of plant was measured from the ground to the longest end of the stem and expressed in centimeter (cm).

3.13.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at every sampling dates.

3.13.3 Leaf area

Leaf length and leaf breadth of plant was measured the leaves and expressed in centimeter (cm). Then this value is converted to leaf area and expressed as centimeter square (cm^2).

3.13.5 Number of primary plant^{-1}

Total number of primary branches was counted from each plant of the treatment and mean value was calculated.

3.13.6 Number of secondary branches plant^{-1}

Total number of secondary branches was counted at two times from each plant of the treatment.

3.12.7 Number of male and female flowers

Total number of male and female flowers was counted from three randomly selected plants per plot.

3.12.5 Number of fruit plant^{-1}

Number of fruit was counted from first harvest stage to last harvest. The total number of fruits per plant was counted and average number of fruit was recorded.

3.13.8 Length and diameter of fruit

Length of 10 randomly selected fruits per plot was measured after each harvest and then the average was taken. Diameter of the same 10 randomly selected fruits

3.13.9 Individual fruit weight

After each harvest, the weight of randomly selected 10 fruits per plot was recorded and then the average weight (g) per fruit was calculated.

3.13.10 Fruit yield

To estimate yield, all the six plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plot was measured. The yield per hectare was calculated considering the area covered by the plants.

3.16 Statistical analysis

The recorded data on different parameters were statistically analyzed using SPSS software and mean separation was done by Duncan’s test at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSIONS

The chapter represent the result and discussion for the flowering and fruiting of bitter gourd (*Momordica charantia* L.) influenced by the growth regulator (GA3) and boron (B).

4.1 Effect of growth regulator and boron on bitter gourd

4.1.1 Vine length

4.1.1.1 Effect of growth regulator

Vine length of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 1, Appendix III). Vine length showed an increasing trend up to harvest but after 60 DAS the trending range is lower than 30-60 DAS. The longest vine length (66.91 cm, 200.92 am and 217.01 cm at 30 DAS, 60 DAS and harvest time, respectively) was found in G_2 growth regulator treatment at all sampling dates. The shortest vine length (55.39 cm, 186.08 cm and 202.67 cm at 30 DAS, 60 DAS and at harvest time, respectively) was recorded in G_0 at all sampling dates. The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al.* (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.1.2 Effect of boron

Different doses of boron application produced a significant vine length of bitter gourd (Figure 1, Appendix III). The longest vine length (68.18 cm, 242.56 cm, 246.01 cm at 30, 60 DAS and harvest time, respectively) was recorded in B_2 treatment and shortest vine length (56.09 cm, 143.73 cm, 155.65 cm at 30, 60 DAS and harvest time, respectively) in B_0 treatment. The findings of Sultana *et* *al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

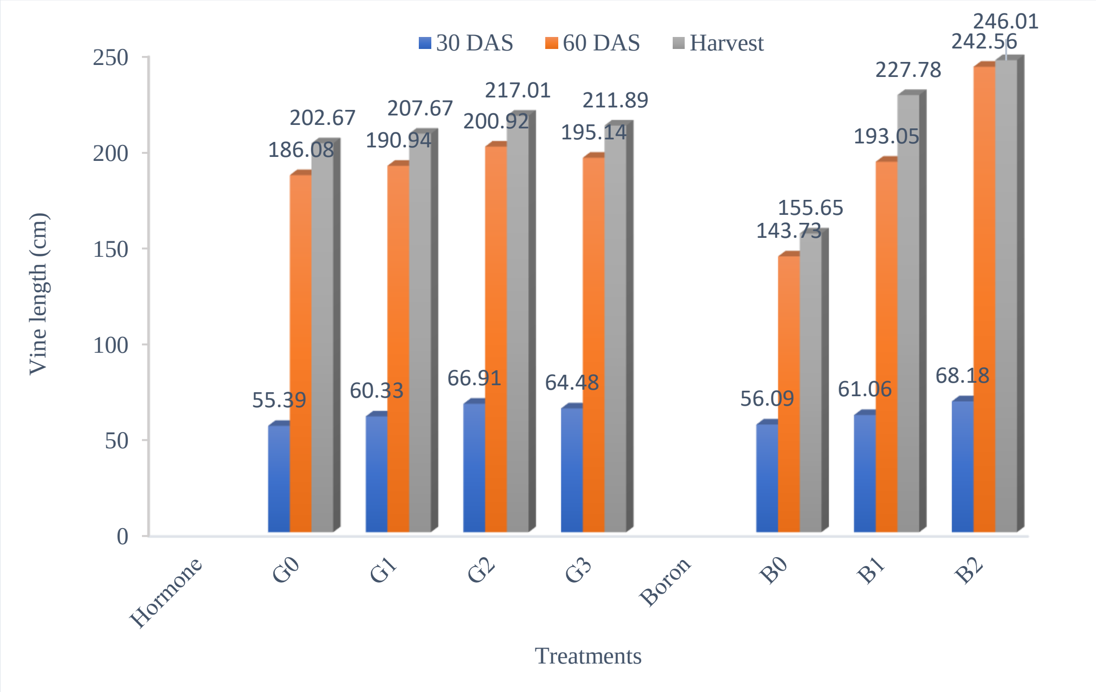

Figure 1. Effect of hormone and boron on plant height of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.1.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed a wide range of variation of vine length among the treatment combination (Table 1, Appendix III). The highest vine length due to combine effect was found in G_2B_2 (75.32 cm, 250.33 cm and 255.38 cm at 30, 60 DAS and harvest time, respectively) where lowest was recorded in G_0B_0 (50.44 cm, 137.35 cm, 149.42 cm at 30, 60 DAS and at harvest time, respectively) compared to others combinations.

Table 1. Interaction effect of hormone and boron on vine length

Treatments	Vine length (cm) at		
	30 DAS	60 DAS	Harvest
G_0B_0	50.44 h	137.35 l	149.42 l
G_1B_0	55.52 g	141.84 k	155.45 k
G_2B_0	60.24 e	150.31 i	160.29 i
G_3B_0	58.17 f	145.42 j	157.42 j
G_0B_1	55.53 g	185.65 h	220.19 h
G_1B_1	60.20 e	190.64 g	225.31 g
G_2B_1	65.18 c	200.23 e	235.35 e
G_3B_1	63.33 d	195.68 f	230.26 f
G_0B_2	60.19 e	235.25 d	238.41 d
G_1B_2	65.27 c	240.33 c	242.26 c
G_2B_2	75.32 a	250.33 a	255.38 a
G_3B_2	71.95 b	244.32 b	247.99 b
SE (±)	0.238	0.302	0.182
CV (%)	0.50	0.19	0.10

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.2 Number of leaves plant^{-1}

4.1.2.1 Effect of growth regulator

The statistically significant variation of number of leaves plant^{-1} was found due to application of plant growth regulator (Figure 2, Appendix IV). Number of leaves plant^{-1} showed an increasing trend up to harvest but after 60 DAS the trending range is lower than 30 to 60 DAS. The maximum number of leaves plant^{-1} (10.54, 37.89 and 42.22 at 30, 60 DAS and harvest time, respectively) was found in growth regulator treated area (G_2) at all sampling dates. The lowest number of leaves plant^{-1} was recorded in G_0 (7.83, 28.56 and 33.14 at 30, 60 DAS and at harvest). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-

Masoum and Al-Masri (1999), Goutom *et al*. (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al*. (1988).

4.1.2.2 Effect of boron

Application of boron produced significant number of leaves plant^{-1} of bitter gourd at all sampling dates (Figure 2, Appendix IV). The maximum number of leaves plant^{-1} (13.71, 45.88 and 49.99) at 30, 60 DAS and at harvest time) was recorded in B_2 treatment and minimum number of leaves (5.22, 21.22, 26.47) at 30, 60 DAS and at harvest time, respectively) was found in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

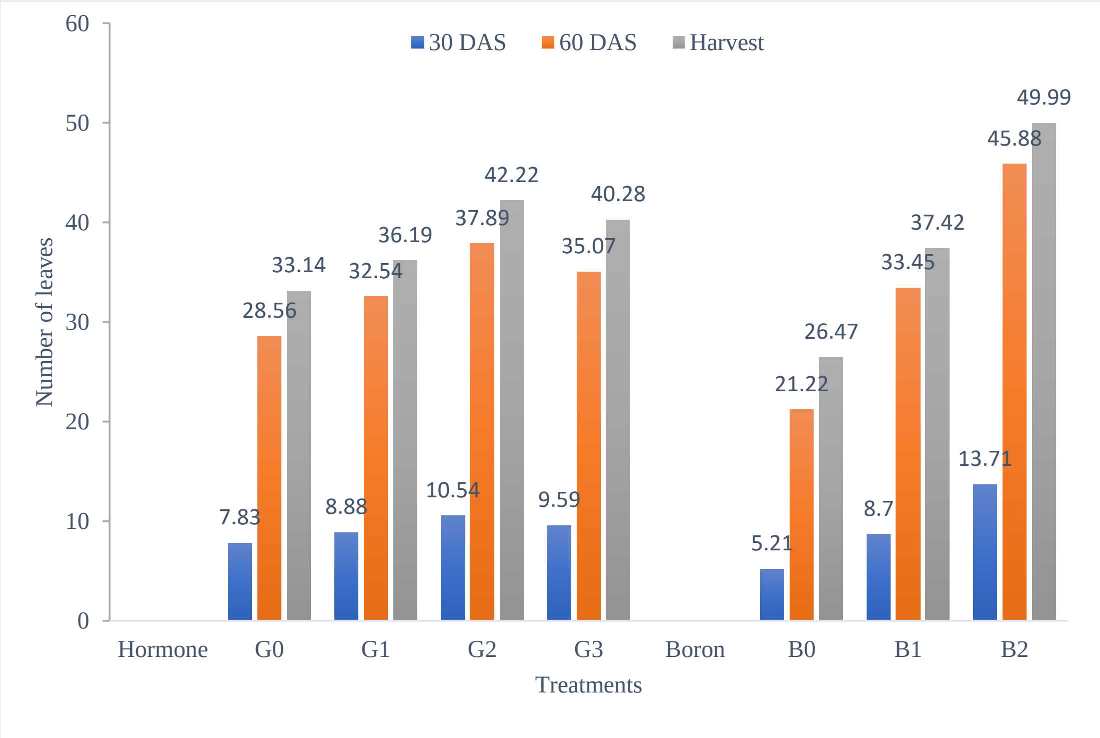

Figure 2. Effect of hormone and boron on number of leaves plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.2.3 Interaction effect of growth regulator and boron

Interaction effect of plant growth regulator and boron showed a wide range of variation on number of leaves plant^{-1} among the treatment combination (Table 2, Appendix IV). The highest number of leaves plant^{-1} due to combine effect was found in G_2B_2 (15.29, 50.19 and 56.27 at 30 DAS, 60 DAS and at harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (4.15, 17.25 and 22.16 at 30 DAS, 60 DAS and at harvest time, respectively).

Table 2. Combine effect of hormone and boron on number of leaves plant^{-1}

Treatments	Number of leaves plant^{-1} at		
	30 DAS	60 DAS	Harvest
G_0B_0	4.15 k	17.25 l	22.16 l
G_1B_0	5.24 j	20.23 k	25.20 k
G_2B_0	6.13 i	25.19 i	30.19 i
G_3B_0	5.34 j	22.20 j	28.32 j
G_0B_1	7.19 h	28.19 h	32.14 h
G_1B_1	8.17 g	32.14 g	35.20 g
G_2B_1	10.20 e	38.29 e	40.19 f
G_3B_1	9.23 f	35.17 f	42.14 e
G_0B_2	12.42 d	40.24 d	45.13 d
G_1B_2	13.20 c	45.26 c	48.18 c
G_2B_2	15.29 a	50.19 a	56.27 a
G_3B_2	14.19 b	47.82 b	50.37 b
SE (±)	0.124	0.143	0.124
CV (%)	1.32	0.59	0.32

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.3 Leaf area

4.1.3.1 Effect of growth regulator

Leaf area of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 3, Appendix IV). The leaf area was recorded at 60 DAS, because this stage vegetative growth was higher than other growth stage. The highest leaf area was found in G_2 (65.19 cm^2) and the lowest vine length was recorded in G_0 (55.48 cm^2). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.3.2 Effect of boron

Different doses of boron application produced a significant leaf area of bitter gourd (Figure 3, Appendix IV). The highest leaf area was recorded in B_2 treatment (75.18 cm^2) and lowest in B_0 treatment (45.49 cm^2). This might be due to higher vegetative growth was found in boron treated area. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al.* (1984) are close conformity with the present finding.

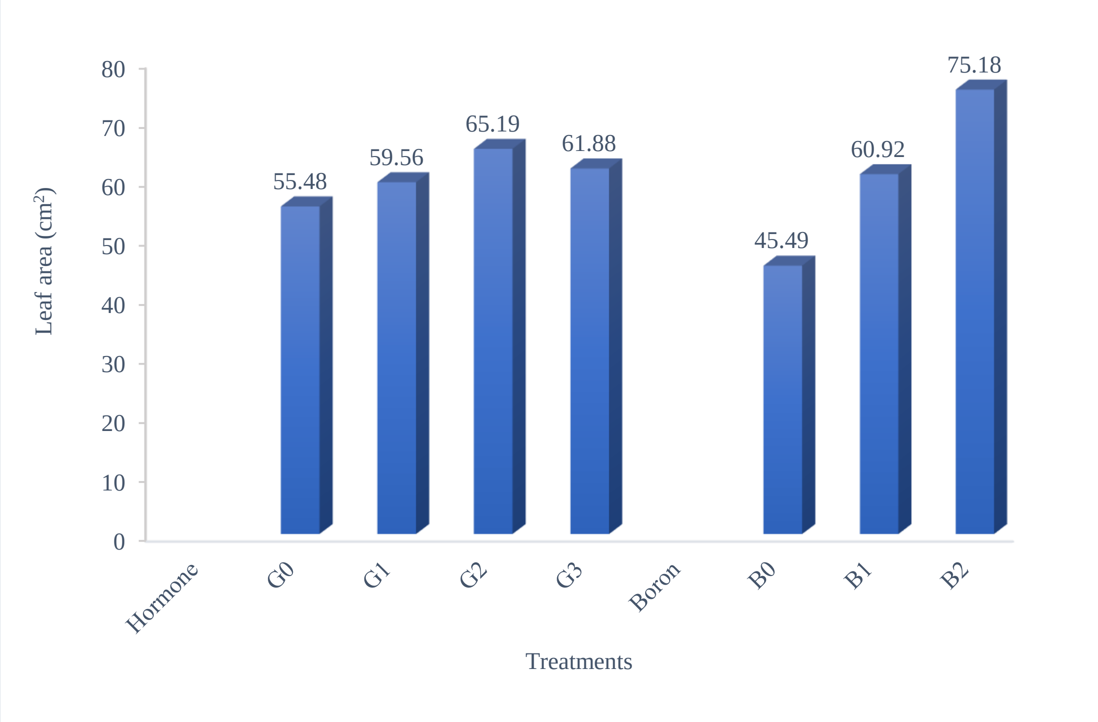

Figure 3. Effect of hormone and boron on leaf area of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.3.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed a wide range of variation of leaf area among the treatment combination (Table 3, Appendix IV). Due to combine effect the highest leaf area was found in G_2B_2 (80.19 cm^2) compared to others combinations where lowest was recorded in G_0B_0 (40.17 cm^2).

Table 3. Interaction effect of hormone and boron on leaf area

Treatments	Leaf area (cm^2)
G_0B_0	40.17 l
G_1B_0	44.30 k
G_2B_0	50.21 i
G_3B_0	47.28 j
G_0B_1	56.17 h
G_1B_1	60.16 g
G_2B_1	65.17 e
G_3B_1	62.17 f
G_0B_2	70.11 d
G_1B_2	74.23 c
G_2B_2	80.19 a
G_3B_2	76.19 b
SE (±)	0.122
CV (%)	0.21

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.4 Number of branches plant^{-1}

4.1.4.1 Effect of growth regulator

Due to application of plant growth regulator, the number of branches plant^{-1} showed statistically significant variation (Figure 4, Appendix V). The maximum value of number of branches plant^{-1} (8.81 and 8.90 at 60 DAS and at harvest time, respectively) was found in G_2. The minimum number of number of branches plant^{-1} (6.21 and 6.15 at 60 DAS and at harvest time, respectively) was recorded in G_0. The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al*. (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al*. (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al*. (1988).

4.1.4.2 Effect of boron

When boron was applied, the number of branches plant^{-1} showed significant variation of bitter gourd (Figure 4, Appendix V). The highest number of branches plant^{-1} (10.66 and 10.73 at 60 DAS and at harvest time, respectively) was recorded in B_2 treatment and minimum number of branches (4.96 and 4.90 at 60 DAS and harvest time, respectively) was in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

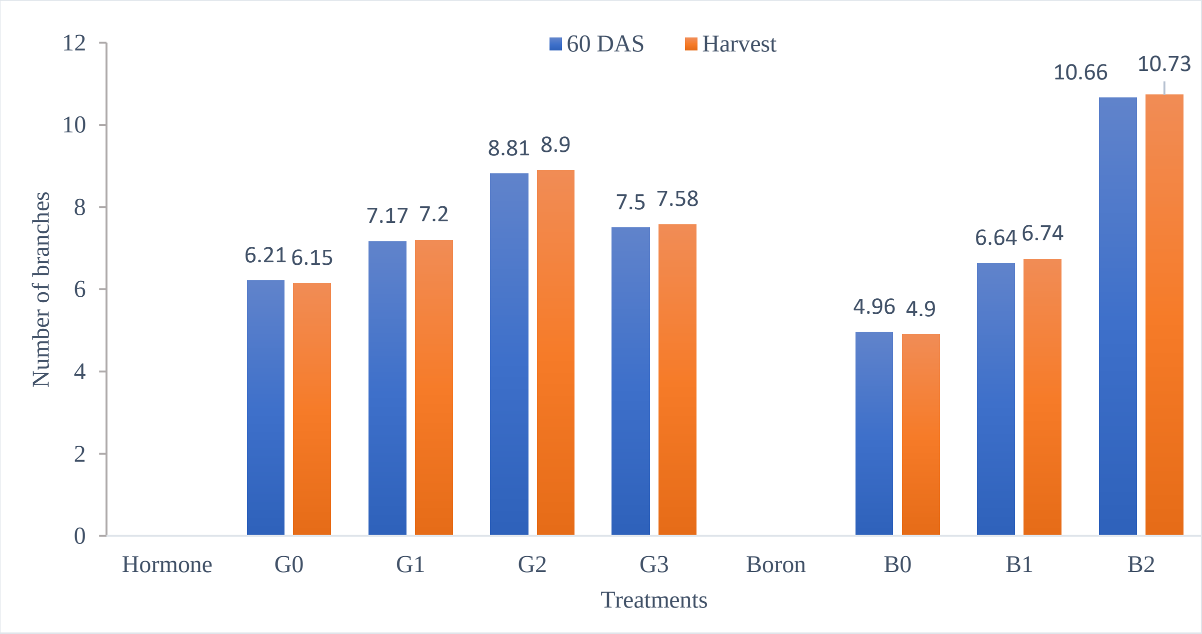

Figure 4. Effect of hormone and boron on number of branches plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.4.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron produced a wide range of variation of number of branches plant^{-1} among the treatment combination (Table 4, Appendix V). Because of the combine effect, the highest number of branches plant^{-1} was found in G_2B_2 (12.16 and 12.30 at 60 DAS and harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (4.28 and 4.09 at 60 DAS and harvest time, respectively).

Table 4. Interaction effect of hormone and boron on number of branches plant^{-1}

Treatments	Number of branches plant^{-1} at	
	60 DAS	Harvest
G_0B_0	4.28 i	4.09 i
G_1B_0	5.16 h	5.20 h
G_2B_0	6.16 g	6.14 g
G_3B_0	4.25 i	4.18 i
G_0B_1	5.15 h	5.16 h
G_1B_1	6.16 g	6.19 g
G_2B_1	8.13 e	8.26 e
G_3B_1	7.14 f	7.34 f
G_0B_2	9.20 d	9.20 d
G_1B_2	10.19 c	10.21 c
G_2B_2	12.16 a	12.30 a
G_3B_2	11.11 b	11.21 b
SE (±)	0.097	0.125
CV (%)	1.05	1.68

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.5 Number of secondary branches plant^{-1}

4.1.5.1 Effect of growth regulator

The number of secondary branches plant^{-1} of bitter gourd showed statistically significant variation because of application of plant growth regulator (Figure 5, Appendix VI). The highest values of number of secondary branches plant^{-1} (7.22 and 7.20 at 60 DAS and at harvest time, respectively) was found in G_2. The minimum number of secondary branches plant^{-1} (4.17 and 4.17 at 60 DAS and at harvest time, respectively) was recorded in G_0. The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.5.2 Effect of boron

Different doses of boron application produced a significant number of secondary branches plant^{-1} of bitter gourd (Figure 5, Appendix VI). The highest value of number of secondary branches plant^{-1} was recorded in B_2 treatment (7.67 and 7.69 at 60 DAS and harvest, respectively) and the minimum number of secondary branches was in B_0 treatment (3.64 and 3.68 at 60 DAS and harvest, respectively). The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

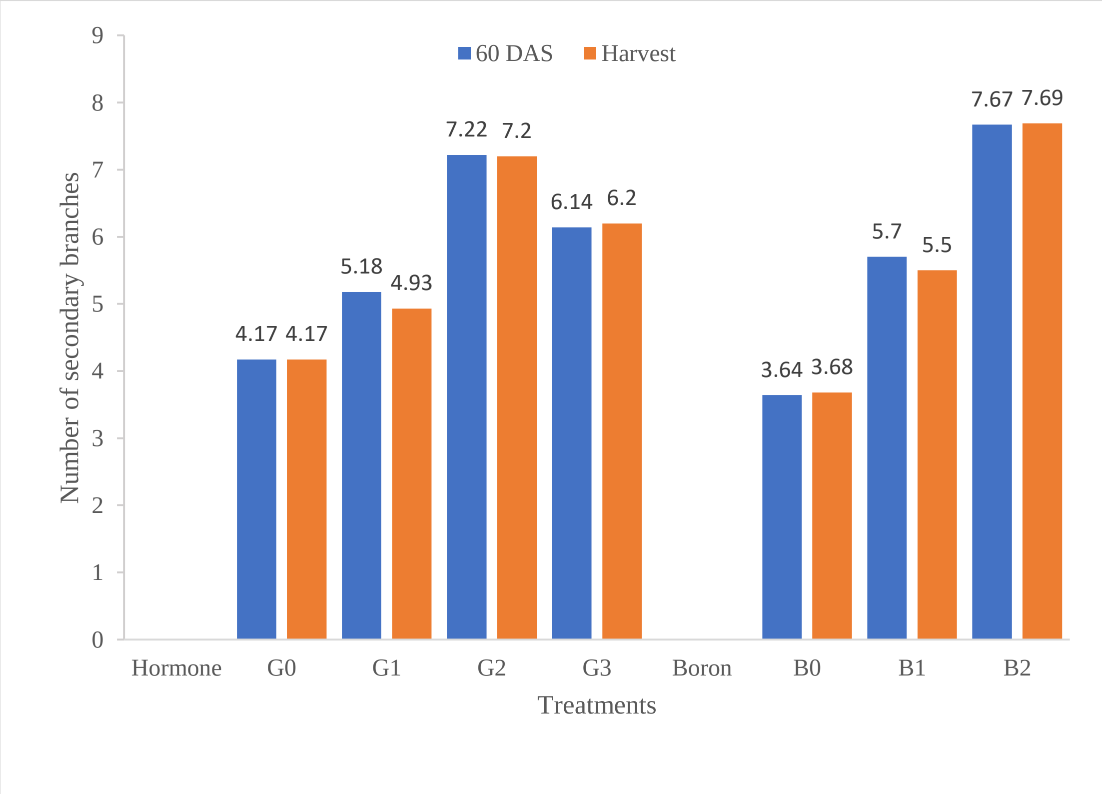

Figure 5. Effect of hormone and boron on number of secondary branches plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.5.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed a wide range of variation on number of secondary branches plant^{-1} among the treatment combinations (Table 5, Appendix VI). The highest values of number of secondary branches plant^{-1} due to combine effect was found in G_2B_2 combinations (9.20 and 9.22 at 60 DAS and harvest time, respectively) while the lowest value of the same trait was recorded in G_0B_0 combinations (2.14 and 2.19 at 60 DAS and harvest time, respectively).

Table 5. Interaction effect of hormone and boron on number of secondary branches plant^{-1}

Treatments	Number of secondary branches plant^{-1} at	
	60 DAS	Harvest
G_0B_0	2.14 h	2.19 g
G_1B_0	3.17 g	3.15 fg
G_2B_0	5.17 e	5.20 de
G_3B_0	4.10 f	4.18 ef
G_0B_1	4.16 f	4.12 ef
G_1B_1	5.20 e	4.50 e
G_2B_1	7.28 c	7.19 bc
G_3B_1	6.17 d	6.19 cd
G_0B_2	6.14 d	6.20 cd
G_1B_2	7.17 c	7.14 c
G_2B_2	9.20 a	9.22 a
G_3B_2	8.15 b	8.23 ab
SE (±)	0.064	0.298
CV (%)	1.40	6.51

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.6 Total number of male flowers plant^{-1}

4.1.6.1 Effect of growth regulator

The statistically significant variation of total number of male flowers plant^{-1} was recorded with the application of plant growth regulator (Figure 6, Appendix VII). The total number of male flowers plant^{-1} was highest in G_2 treatment (28.35) and the lowest value of total number of male flowers plant^{-1} was recorded in G_0 (22.38). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.6.2 Effect of boron

Total number of male flowers plant^{-1} showed significant variations with the application of different doses of boron application (Figure 6, Appendix VII). The highest value of total number of male flowers plant^{-1} (33.38) was recorded in B_2 treatment and the lowest value of number of male flowers (17.36) in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

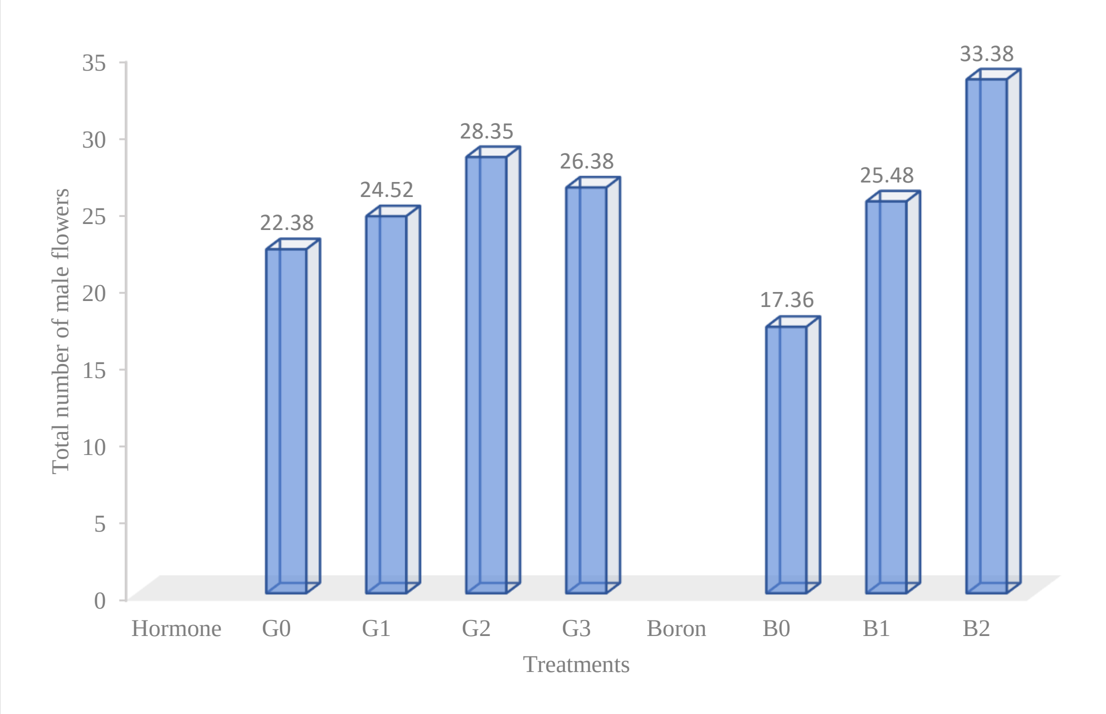

Figure 6. Effect of hormone and boron on total number of male flowers plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.6.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron didn't show a wide range of variation of total number of male flowers plant^{-1} among the treatment combination (Table 6, Appendix VII). The highest value of total number of male flowers plant^{-1} due to combine effect was found in G_2B_2 (36.47) while the lowest value of this same trait was recorded in G_0B_0 (14.23).

Table 6. Interaction effect of hormone and boron on total number of male flowers plant^{-1}

Treatments	Total number of male flowers plant^{-1}
G_0B_0	14.23 l
G_1B_0	16.39 k
G_2B_0	20.41 i
G_3B_0	18.42 j
G_0B_1	22.55 h
G_1B_1	24.76 g
G_2B_1	28.19 e
G_3B_1	26.44 f
G_0B_2	30.37 d
G_1B_2	32.41 c
G_2B_2	36.47 a
G_3B_2	34.29 b
SE (±)	0.139
CV (%)	0.67

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.7 Total number of female flowers plant^{-1}

4.1.7.1 Effect of growth regulator

The total number of female flowers plant^{-1} of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 7, Appendix VII). The total number of female flowers plant^{-1} showed the highest value in G_2 treatment (16.19). The lowest value of total number of female flowers plant^{-1} was recorded in G_0 (13.24). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.7.2 Effect of boron

Different doses of boron application produced a significant total number of female flowers plant^{-1} of bitter gourd (Figure 7, Appendix VII). The highest total number of female flowers plant^{-1} was recorded in B_2 treatment (18.68) and lowest in B_0 treatment (10.71). The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

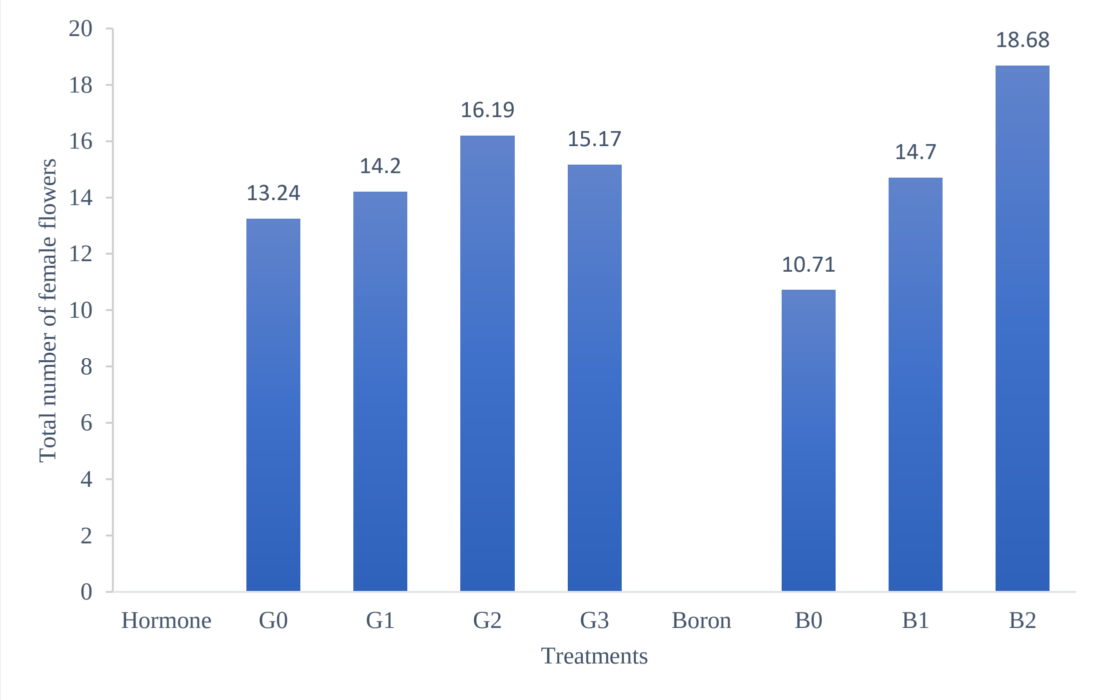

Figure 7. Effect of hormone and boron on total number of female flowers plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.7.3 Interaction effect of growth regulator and boron

The total number of female flowers plant^{-1} showed non-significant variations due to interaction effect between plant growth regulator and boron (Table 7, Appendix VII). Due to combine effect, the maximum values of total number of female flowers plant^{-1} was found in G_2B_2 (20.17) while the lowest value was recorded in G_0B_0 (9.20).

Table 7. Interaction effect of hormone and boron on total number of female flowers plant^{-1}

Treatments	Total number of female flowers plant^{-1}
G_0B_0	9.20 l
G_1B_0	10.26 k
G_2B_0	12.21 i
G_3B_0	11.18 j
G_0B_1	13.33 h
G_1B_1	14.16 g
G_2B_1	16.19 e
G_3B_1	15.16 f
G_0B_2	17.19 d
G_1B_2	18.18 c
G_2B_2	20.17 a
G_3B_2	19.16 b
SE (±)	0.073
CV (%)	0.62

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.8 Total number of fruits plant^{-1}

4.1.8.1 Effect of growth regulator

Statistically significant variation of total number of fruits plant^{-1} was found in plant growth regulator application area (Figure 8, Appendix VIII). The maximum value of total number of fruits plant^{-1} was in G_2 (13.59) and the minimum value of this trait was in G_0 (10.47). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.8.2 Effect of boron

Different doses of boron application produced a significantly total number of fruits plant^{-1} of bitter gourd (Figure 8, Appendix VIII). The highest total number of fruits plant^{-1} was recorded in B_2 treatment (15.72) and lowest in B_0 treatment (8.69). The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

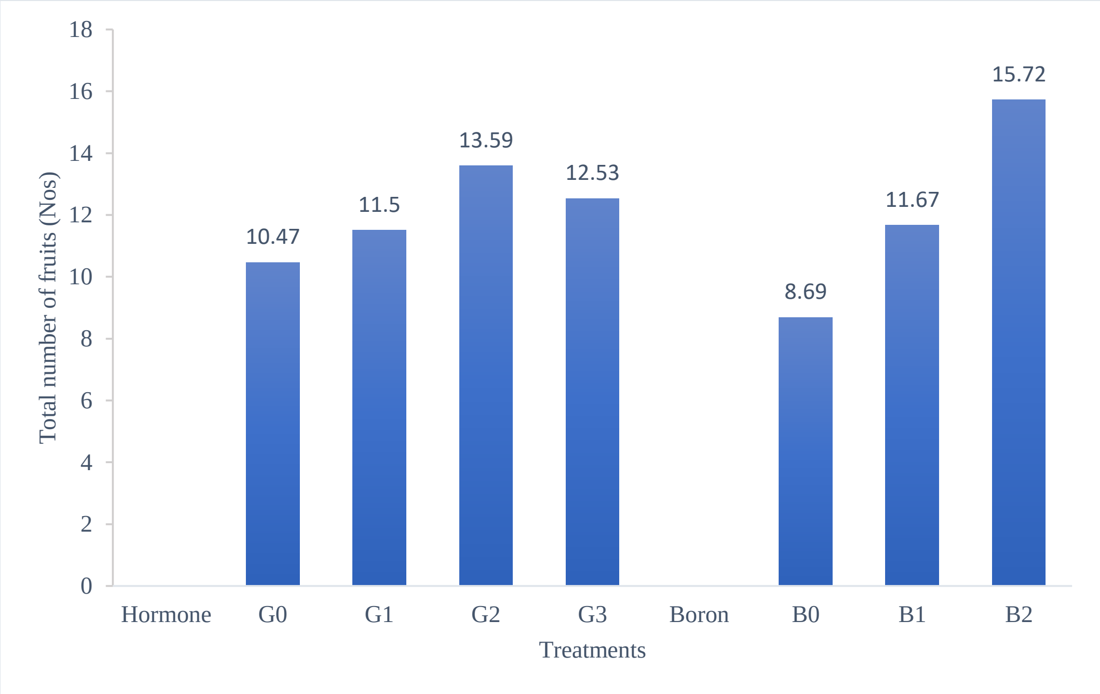

Figure 8. Effect of hormone and boron on total number of fruits plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.8.3 Interaction effect of growth regulator and boron

Interaction effect of plant growth regulator and boron didn't show a wide range of variation of total number of fruits plant^{-1} among the treatment combinations (Table 8, Appendix VIII). Though, the interaction showed non-significant effect, the highest total number of fruits plant^{-1} was found in G_2B_2 (17.33) compared to others combinations where lowest was recorded in G_0B_0 (7.16).

Table 8. Interaction effect of hormone and boron on total number of fruits plant^{-1}

Treatments	Total number of fruits plant^{-1}
G_0B_0	7.16 k
G_1B_0	8.20 j
G_2B_0	10.19 h
G_3B_0	9.19 i
G_0B_1	10.14 h
G_1B_1	11.12 g
G_2B_1	13.24 e
G_3B_1	12.16 f
G_0B_2	14.12 d
G_1B_2	15.18 c
G_2B_2	17.33 a
G_3B_2	16.23 b
SE (±)	0.071
CV (%)	0.73

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.9 Fruit length

4.1.9.1 Effect of growth regulator

Fruit length of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 9, Appendix VIII). The highest fruit length was found in growth regulator treated area and G_2 produced maximum (21.97 cm). The lowest fruit length was recorded in G_0 treated area (18.54 cm). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.9.2 Effect of boron

Different doses of boron application produced a significant fruit length of bitter gourd (Figure 9, Appendix VIII). The highest fruit length was recorded in B_2

treatment and lowest in B_0 treatment. The values of fruit length in B_2 and B_0 was 26.67 cm and 13.76 respectively. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

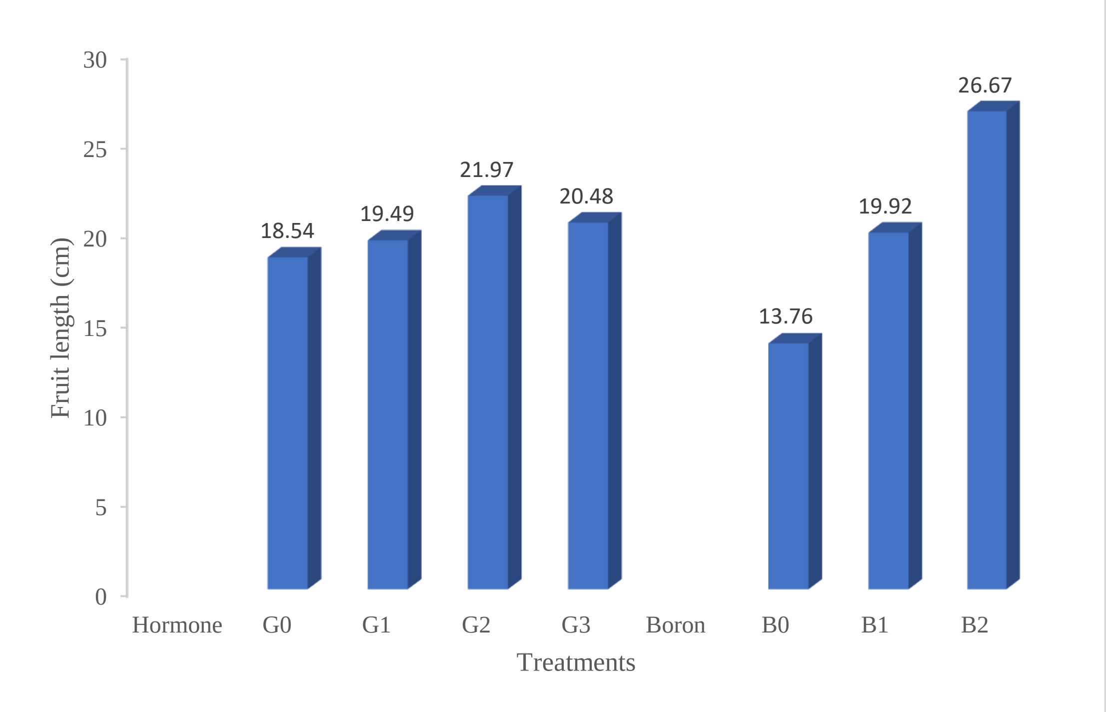

Figure 9. Effect of hormone and boron on fruit length of bitter gourd

G_0=No hormone, G_1= 50 mg/L, G_2=100mg/L, G_3=150mg/L; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.9.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed a wide range of variation of fruit length among the treatment combinations (Table 9, Appendix VIII). The highest fruit length due to combine effect was found in G_2B_2 (28.25 cm) where lowest was recorded in G_0B_0 (12.24 cm).

Table 9. Interaction effect of hormone and boron on fruit length

Treatments	Fruit length (cm)
G_0B_0	12.24 l
G_1B_0	13.19 k
G_2B_0	15.50 i
G_3B_0	14.12 j
G_0B_1	18.21 h
G_1B_1	19.15 g
G_2B_1	22.15 e
G_3B_1	20.16 f
G_0B_2	25.15 d
G_1B_2	26.13 c
G_2B_2	28.25 a
G_3B_2	27.15 b
SE (±)	0.129
CV (%)	0.72

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.10.2 Fruit diameter

4.1.10.1 Effect of growth regulator

The fruit diameter of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 10, Appendix VIII). The highest fruit girth was recorded in G_2 (6.49 cm) and the lowest fruit diameter was recorded in G_0 (3.58 cm). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.10.2 Effect of boron

Different doses of boron application produced a significant fruit diameter of bitter gourd (Figure 10, Appendix VIII). The highest fruit diameter (6.67 cm) was recorded in B_2 treatment and lowest (3.72 cm) was in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

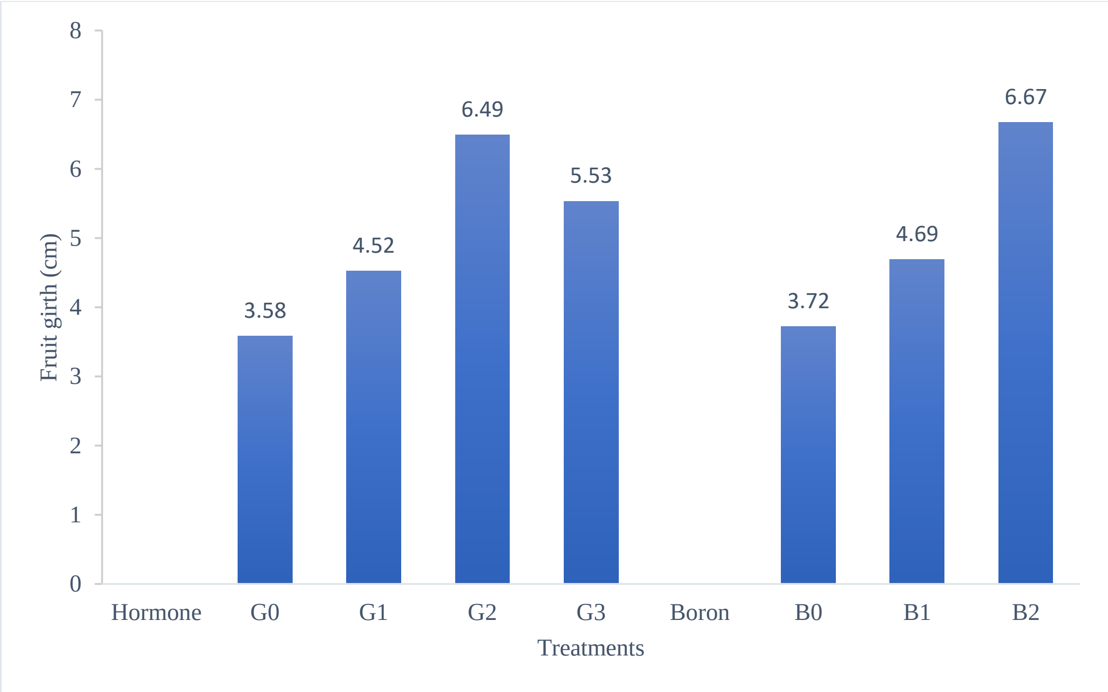

Figure 10. Effect of hormone and boron on fruit diameter of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.10.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed non-significant impact of fruit girth among the treatment combinations (Table 10, Appendix VIII). In spite of having non-significant effect, the highest fruit girth was obtained in G_2B_2 (8.17 cm) while the lowest was recorded in G_0B_0 (2.40 cm).

Table 10. Interaction effect of hormone and boron on fruit girth

Treatments	Fruit girth (cm)
G_0B_0	2.40 g
G_1B_0	3.15 f
G_2B_0	5.14 d
G_3B_0	4.20 e
G_0B_1	3.18 f
G_1B_1	4.22 e
G_2B_1	6.18 c
G_3B_1	5.19 d
G_0B_2	5.16 d
G_1B_2	6.18 c
G_2B_2	8.17 a
G_3B_2	7.19 b
SE (±)	0.073
CV (%)	1.78

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.11.2 Individual fruit weight

4.1.11.1 Effect of growth regulator

Individual fruit weight of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 11, Appendix IX). The highest individual fruit weight was found in growth regulator treatment G_2 (113.68 g). The lowest individual fruit weight was recorded in G_0 (103.6 g). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.11.2 Effect of boron

Application of boron produced a significant individual fruit weight of bitter gourd (Figure 11, Appendix IX). The highest individual fruit weight (165.36 g) was recorded in B_2 treatment and lowest (75.37 g) was in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

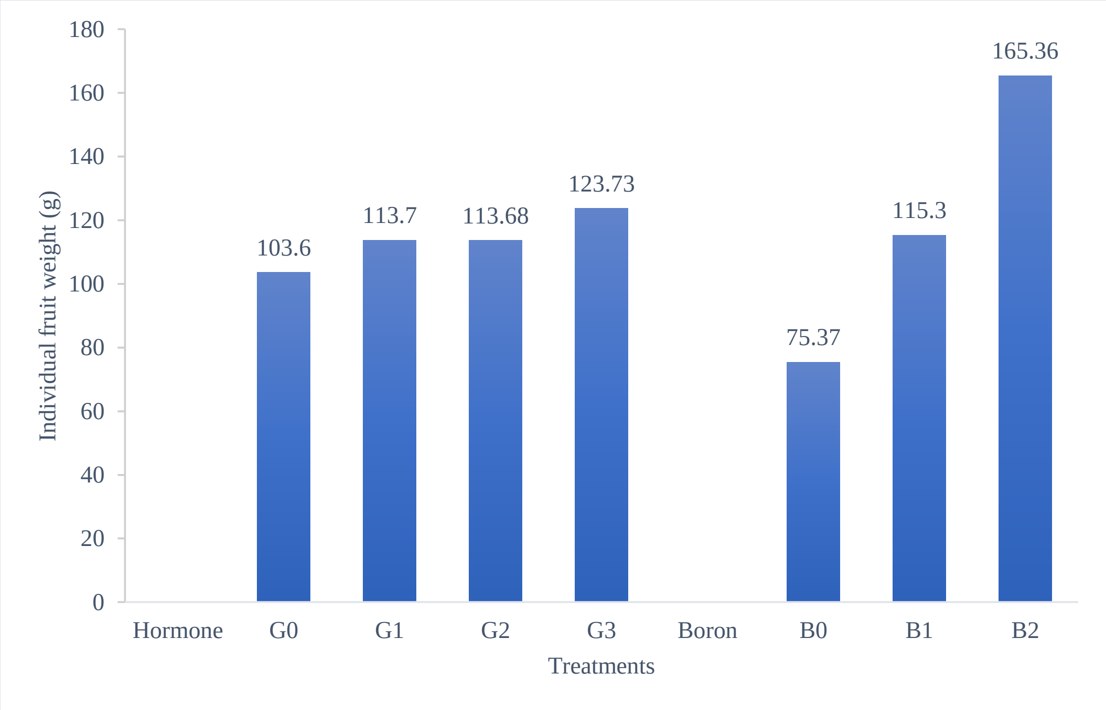

Figure 11. Effect of hormone and boron on individual fruit weight of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.11.3 Interaction effect of growth regulator and boron

Interaction effect of plant growth regulator and boron showed non-significant impact of individual fruit weight (Table 11, Appendix IX). Though having non-significant effect, the highest individual fruit weight due to combine effect was found in G_2B_2 (180.34 g) compared to others combinations where lowest was recorded in G_0B_0 (60.29 g).

Table 11. Interaction effect of hormone and boron on individual fruit weight

Treatments	Individual fruit weight (g)
G_0B_0	60.29 l
G_1B_0	70.42 k
G_2B_0	90.41 i
G_3B_0	80.37 j
G_0B_1	100.20 h
G_1B_1	110.31 g
G_2B_1	130.30 e
G_3B_1	120.39 f
G_0B_2	150.32 d
G_1B_2	160.35 c
G_2B_2	180.34 a
G_3B_2	170.42 b
SE (±)	0.100
CV (%)	0.10

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.12 Fruit weight plant^{-1}

4.1.12.1 Effect of growth regulator

The fruit weight plant^{-1} of bitter gourd showed statistically significant variation due to application of plant growth regulator (Figure 12, Appendix IX). The highest fruit weight plant^{-1} was found in G_2 treatment (1924.0 g) and the lowest fruit weight plant^{-1} was recorded in G_0 treatment (1190.2 g). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang (2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al*. (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.12.2 Effect of boron

Application of different doses of boron produced significant fruit weight plant^{-1} of bitter gourd (Figure 12, Appendix IX). The highest fruit weight plant^{-1} was recorded in B_2 treatment and lowest in B_0 treatment. The values of fruit weight plant^{-1} in B_2 and B_0 was 2611.98 g and 667.34 g, respectively. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

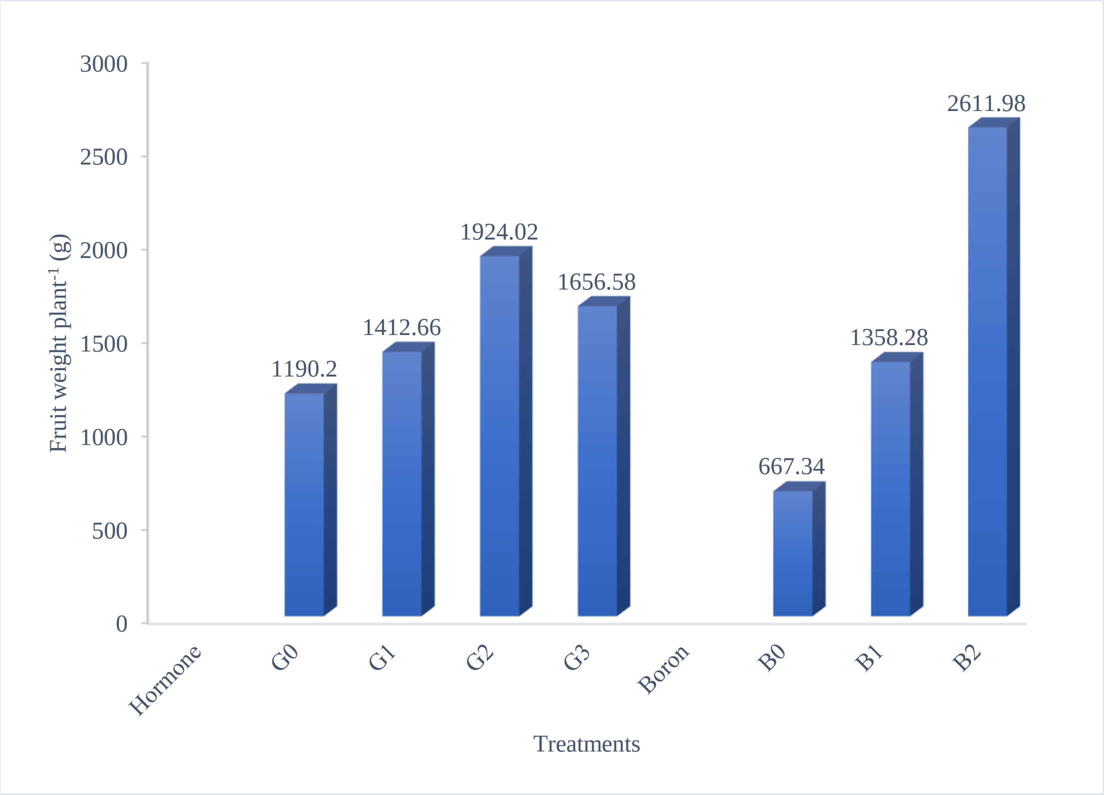

Figure 12. Effect of hormone and boron on fruit weight plant^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.12.3 Interaction effect of growth regulator and boron

Interaction effect between plant growth regulator and boron showed a wide range of variation of fruit weight plant^{-1} among the treatment combinations (Table 12, Appendix IX). The highest fruit weight plant^{-1} due to combine effect was found in G_2B_2 (3124.70 g) compared to others combinations where lowest was recorded in G_0B_0 (431.50 g).

Table 12. Interaction effect of hormone and boron on fruit weight plant^{-1}

Treatments	Fruit weight (g) plant^{-1}
G_0B_0	431.50 l
G_1B_0	577.25 k
G_2B_0	921.65 i
G_3B_0	738.94 j
G_0B_1	1016.01 h
G_1B_1	1227.07 g
G_2B_1	1725.69 e
G_3B_1	1464.34 f
G_0B_2	2123.09 d
G_1B_2	2433.66 c
G_2B_2	3124.70 a
G_3B_2	2766.46 b
SE (±)	16.71
CV (%)	1.10

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

4.1.13 Fruit yield ha^{-1}

4.1.13.1 Effect of growth regulator

Due to application of plant growth regulator the fruit yield ha^{-1} showed a wide range of variation (Figure 13, Appendix IX). The highest fruit yield ha^{-1} was found in G_2 treatment (42.22 t ha^{-1}) where the lowest fruit yield ha^{-1} was recorded in G_0 treated area (37.22 t ha^{-1}). The similar finding also reported by Mishra *et al*. (2015), Sandra *et al*. (2015), Arvindkumar *et al*. (2014), Geeta *et al*. (2014), Mia *et al*. (2014), Akter and Rahman (2013), Biradar *et al*. (2012), Shahzad (2012), Ashrafuzzaman *et al.* (2010), Hossain *et al*. (2006), Wang and Wang

(2001), Al-Masoum and Al-Masri (1999), Goutom *et al.* (1998), Susmita *et al.* (1998), Jutamanee and Mongkolporn (1996), Islam (1995), Arora *et al.* (1988).

4.1.13.2 Effect of boron

Boron application produced significant fruit yield ha^{-1} of bitter gourd (Figure 13, Appendix IX). The highest fruit yield ha^{-1} (45.83 t ha^{-1}) was recorded in B_2 treatment and the lowest value (33.66 t ha^{-1}) of this trait was in B_0 treatment. The findings of Sultana *et al*. (2017), Vala and Savaliya (2014), Sinha *et al*. (2009), Gedam *et al*. (1998), Verma *et al*. (1984) are close conformity with the present finding.

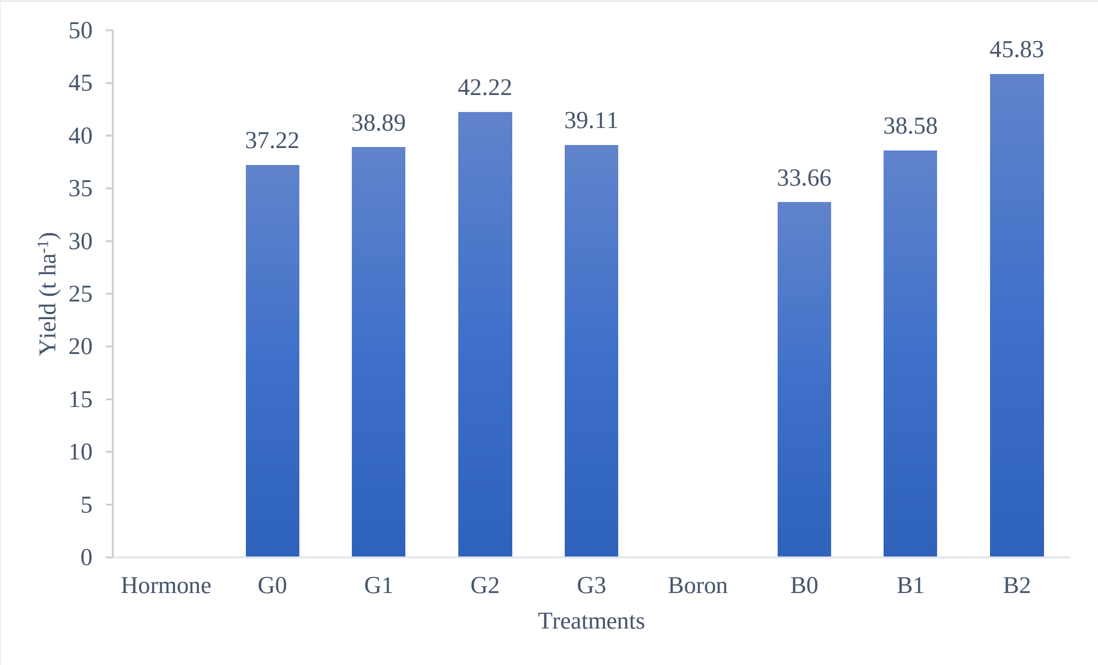

Figure 13. Effect of hormone and boron on fruit yield ha^{-1} of bitter gourd

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm

4.1.13.3 Interaction effect of growth regulator and boron

The interaction effect between plant growth regulator and boron showed a wide range of variation of fruit yield ha^{-1} among the treatment combinations (Table 13, Appendix IX). The highest fruit yield ha^{-1} was found in G_2B_2 (39.03 t ha^{-1}) while the lowest value of fruit yield ha^{-1} was recorded in G_0B_0 (21.66 t ha^{-1}).

Table 13. Interaction effect of hormone and boron on fruit yield ha^{-1}

Treatments	Fruit yield ha^{-1} (t ha^{-1})
G_0B_0	21.66 h
G_1B_0	24.01 f-h
G_2B_0	26.02 e-g
G_3B_0	23.13 gh
G_0B_1	26.67 ef
G_1B_1	27.65 e
G_2B_1	31.59 cd
G_3B_1	28.33 de
G_0B_2	33.33 bc
G_1B_2	35.00 bc
G_2B_2	39.03 a
G_3B_2	36.12 ab
SE (±)	0.968
CV (%)	4.04

G_0=No hormone, G_1= 50 mg/l, G_2=100mg/l, G_3=150mg/l; B_0=No boron, B_1= 15 ppm, B_2=30 ppm; SE= Standard error, CV= Coefficient of variation

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University to find out the flowering and fruiting of bitter gourd (*Momordica charantia* L.) as influenced by the growth regulator (GA3) and boron (B).

Result revealed that vegetative growth and reproductive characters were highest for the application of growth regulator (GA3) and boron (B).

Vine length showed an increasing trend up to harvest but after 60 DAS the trending range is lower than 30-60 DAS. The vine length was at 30 DAS 55.39 cm, 60.33 cm, 66.91 cm and 64.48 cm, at 60 DAS 186.08 cm, 190.94 cm, 200.92 cm and 195.14 cm, at harvest 202.67 cm, 207.67 cm, 217.01 cm and 211 cm. The highest vine length was found in growth regulator treatment G_2 at all sampling dates. The lowest vine length was recorded at G_0 at all sampling dates. The highest vine length was recorded in B_2 treatment and lowest in B_0 treatment. The values of vine length in B_2 and B_0 was 68.18 cm, 242.56 cm, 246.01 cm and 56.09 cm, 143.73 cm, 155.65 cm at 30 DAS, 60 DAS and harvest time, respectively. The highest vine length due to combine effect was found in G_2B_2 (75.32 cm, 250.33 cm and 255.38 cm at 30 DAS, 60 DAS and harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (50.44 cm, 137.35 cm, 149.42 cm at 30 DAS, 60 DAS and harvest time, respectively).

Number of leaves plant^{-1} showed an increasing trend up to harvest but after 60 DAS the trending range is lower than 30 to 60 DAS. The number of leaves plant^{-1} was at 30 DAS 7.83, 8.88, 10.54 and 9.59; at 60 DAS 28.56, 32.54, 37.89 and 35.07; at harvest 33.314, 36.19, 42.22 and 40.28. The highest number of leaves plant^{-1} was found in growth regulator treated area (G_2) at all sampling dates. The lowest number of leaves plant^{-1} was recorded in G_0 (7.83, 28.56 and 33.14 at 30 DAS, 60 DAS and at harvest). The highest number of leaves plant^{-1} was recorded in B_2 treatment and lowest in B_0 treatment. The values of number of leaves plant^{-}

^{1} in B_2 and B_0 was 13.71, 45.88 and 49.99; 5.21, 21.22 and 26.47 at 30 DAS, 60 DAS and harvest time, respectively. The highest number of leaves plant^{-1} due to combine effect was found in G_2B_2 (15.29, 50.19 and 56.27 at 30 DAS, 60 DAS and harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (4.15, 17.25 and 22.16 at 30 DAS, 60 DAS and harvest time, respectively).

The leaf area was recorded at 60 DAS, because this stage vegetative growth was higher than other growth stage. The highest leaf area was found in G_2 (65.19 cm^2) and the lowest vine length was recorded in G_0 (55.48 cm^2). The highest leaf area was recorded in B_2 treatment (75.18 cm^2) and lowest in B_0 treatment (45.49 cm^2). This might be due to higher vegetative growth was found in boron treated area. Due to combine effect the highest leaf area was found in G_2B_2 (80.19 cm^2) compared to others combinations where lowest was recorded in G_0B_0 (40.17 cm^2).

The number of branches plant^{-1} was 6.21, 7.17, 8.81 and 7.5 at 60 DAS; 6.15, 7.2, 8.9 and 7.58 at harvest. The highest value of number of branches plant^{-1} was found in G_2 (8.81 and 8.9) at all sampling dates. The lowest vine length was recorded in G_0 (6.21 and 6.15) at all sampling dates. The highest number of branches plant^{-1} was recorded in B_2 treatment and lowest in B_0 treatment. The values of number of branches plant^{-1} in B_2 and B_0 was 10.66 and 10.73; 4.96 and 4.9 at 60 DAS and harvest time, respectively. Because of the combine effect, the highest number of branches plant^{-1} was found in G_2B_2 (12.16 and 12.30 at 60 DAS and harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (4.28 and 4.09 at 60 DAS and harvest time, respectively).

The number of secondary branches plant^{-1} was 4.17, 5.18, 7.22 and 6.14 at 60 DAS, at harvest 4.17, 4.93, 7.2 and 6.2 was recorded. The highest number of secondary branches plant^{-1} was found in G_2 at all sampling dates. The lowest number of secondary branches plant^{-1} was recorded in G_0 at all sampling dates. The highest value of number of secondary branches plant^{-1} was recorded in B_2

treatment (7.67 and 7.69 at 60 DAS and harvest, respectively) and lowest in B_0 treatment (4.17 and 4.17 at 60 DAS and harvest, respectively). Interaction produced non-significant values of number of secondary branches plant^{-1}. But the highest number of secondary branches plant^{-1} due to combine effect was found in G_2B_2 (9.20 and 9.22 at 60 DAS and harvest time, respectively) compared to others combinations where lowest was recorded in G_0B_0 (2.14 and 2.19 at 60 DAS and harvest time, respectively).

The total number of male flowers plant^{-1} was highest in G_2 treatment (28.35) and the lowest total number of male flowers plant^{-1} was recorded in G_0 (22.38). The highest value of total number of male flowers plant^{-1} was recorded in B_2 treatment and lowest in B_0 treatment. The values of total number of male flowers plant^{-1} in B_2 and B_0 was 33.38 and 17.36, respectively. The highest total number of male flowers plant^{-1} due to combine effect was found in G_2B_2 (36.47) compared to others combinations where lowest was recorded in G_0B_0 (14.23).

The total number of female flowers plant^{-1} showed the highest value in G_2 treatment (16.19). The lowest total number of female flowers plant^{-1} was recorded in G_0 (13.24). The highest total number of female flowers plant^{-1} was recorded in B_2 treatment (18.68) and lowest in B_0 treatment (10.71). Due to combine effect, the highest total number of female flowers plant^{-1} was found in G_2B_2 (20.17) compared to others combinations where lowest was recorded in G_0B_0 (9.20).

The total number of fruits plant^{-1} was in plant growth regulator treated area is 10.47, 11.5, 13.59 and 12.53. The highest total number of fruits plant^{-1} was in G_2 (13.59) and the lowest value of this trait was in G_0 (10.47). The highest total number of fruits plant^{-1} was recorded in B_2 treatment (15.72) and lowest in B_0 treatment (8.69). The values of total number of fruits plant^{-1} in boron application area was 8.69, 11.67 and 15.72. Though, the interaction showed non-significant effect, the highest total number of fruits plant^{-1} was found in G_2B_2 (17.33) compared to others combinations where lowest was recorded in G_0B_0 (7.16).

The highest fruit length was found in growth regulator treated area and G_2 produced maximum (21.97 cm). The lowest fruit length was recorded in G_0 treated area (18.54 cm). The highest fruit length was recorded in B_2 treatment and lowest in B_0 treatment. The values of fruit length in B_2 and B_0 was 13.76 cm and 26.67, respectively. The highest vine length due to combine effect was found in G_2B_2 (28.25 cm) compared to others combinations where lowest was recorded in G_0B_0 (12.24 cm).

The highest fruit girth length was recorded in G_2 (6.49 cm) and the lowest vine length was recorded in G_0 (3.58 cm). The highest fruit girth was recorded in B_2 treatment and lowest in B_0 treatment. The values of fruit girth in B_2 and B_0 was 6.67 cm and 3.72 cm, respectively. In spite of non-significant effect, the highest fruit girth was obtained in G_2B_2 (8.17 cm) compared to others combinations where lowest was recorded in G_0B_0 (2.40 cm).

The highest individual fruit weight was found in growth regulator treatment G_2 (113.68 g). The lowest individual fruit weight was recorded in G_0 (103.6 g). The highest individual fruit weight was recorded in B_2 treatment and lowest in B_0 treatment. The values of vine length in B_2 and B_0 was 165.36 g and 75.37 g, respectively. Though non-significant combine effect, the highest individual fruit weight due to combine effect was found in G_2B_2 (180 g) compared to others combinations where lowest was recorded in G_0B_0 (60.29 g).

The highest fruit weight plant^{-1} was found in G_2 treatment (1924.0 g) and the lowest fruit weight plant^{-1} was recorded in G_0 treatment (1190.2 g). The highest fruit weight plant^{-1} was recorded in B_2 treatment and lowest in B_0 treatment. The values of fruit weight plant^{-1} in B_2 and B_0 was 2612 g and 667.34 g, respectively. The highest fruit weight plant^{-1} due to combine effect was found in G_2B_2 (3124.70 g) compared to others combinations where lowest was recorded in G_0B_0 (431.50 g).

The highest fruit yield ha^{-1} was found in G_2 treatment (32.22 t ha^{-1}) where the lowest fruit yield ha^{-1} was recorded in G_0 treated area (27.22 t ha^{-1}). The highest fruit yield ha^{-1} (35.83 t ha^{-1}) was recorded in B_2 treatment and the lowest value

(23.66 t ha^{-1}) of this trait was in B_0 treatment. The highest fruit yield ha^{-1} was found in G_2B_2 (39.03 t ha^{-1}) while the lowest value of fruit yield ha^{-1} was recorded in G_0B_0 (21.66 t ha^{-1}).

The application of plant growth regulator and boron showing a pronounce effect on vegetative, reproductive and yield contributing character of bitter gourd. In case of plant growth regulator, it showed an increasing trend up to G_2 and then showed decreasing trend. But, for the boron application it showed increasing trend up to B_2. So, to verify this increasing trend of boron fertilization, should to carry out more research with increasing the boron levels.

Thus, it can be concluded that, application of plant growth regulator and boron fertilization on bitter gourd helped to get higher vegetative growth and reproductive development as well as yield of bitter gourd.

Recommendation

1. The same experiment should have carried out in different AEZs of Bangladesh.
2. Before recommend to the farmers level, more research needed by increasing and decreasing the treatments.

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APPENDIX

Appendix I. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
pH	6.00-6.63
Organic mater	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41meq / 100 g soil

Source: Soil resource and development institute (SRDI), Dhaka

Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from April to May 2016.

Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
April, 2016	32.5	20.4	64	65.8	5.9
May, 2016	35.7	26.6	75	180.3	6.2
June, 2016	36.5	18.3	82	281	6.1

Source: Sher-e-Bangla Agricultural University Weather Station

Appendix III. Anova of effect of plant growth regulator and boron on vine length

Sources of variation	Degrees of freedom	Mean square Vine length (cm) at		
		30 DAS	60 DAS	Harvest
Rep	2	0.991	1.8	0.75301
Hormone	3	443.170	29300.2	27403.2
Boron	2	229.908	329.4	334.942
Hormone×Boron	6	7.437	1.0	9.66926
Error	22	0.096	0.1	0.04022

Appendix IV. **Anova of effect of plant growth regulator and boron on number of leaves**

Sources of variation	Degrees of freedom	Mean square Number of leaves at			Leaf area (cm^2)
		30 DAS	60 DAS	Harvest	
Rep	2	0.390	0.30	0.39	0.35
Hormone	3	218.921	1824.26	1662.32	2646.00
Boron	2	11.777	141.06	149.52	149.85
Hormone×Boron	6	0.351	1.33	8.63	0.44
Error	22	0.015	0.04	0.01	0.02

Appendix V. **Anova of effect of plant growth regulator and boron on number of branches**

Sources of variation	Degrees of freedom	Mean square Number of branches at	
		60 DAS	Harvest
Rep	2	0.274	0.386
Hormone	3	102.921	106.552
Boron	2	10.435	11.590
Hormone×Boron	6	0.857	0.981
Error	22	0.006	0.016

Appendix VI. **Anova of effect of plant growth regulator and boron on number of secondary branches**

Sources of variation	Degrees of freedom	Mean square Number of secondary branches at	
		60 DAS	Harvest
Rep	2	0.2806	0.2101
Hormone	3	48.5510**	48.5634**
Boron	2	15.5106**	16.2731**
Hormone×Boron	6	0.0018^{NS}	0.0925^{NS}
Error	22	0.0063	0.1340

Appendix VII. **Anova of effect of plant growth regulator and boron on number of male and female flowers**

Sources of variation	Degrees of freedom	Mean square Number of flowers	
		Male	Female
Rep	2	1.553	0.358**
Hormone	3	770.292**	190.523**
Boron	2	58.744**	14.468*
Hormone×Boron	6	0.081*	0.008
Error	22	0.029	0.008

Appendix VIII. **Anova of effect of plant growth regulator and boron fruits characters**

Sources of variation	Degrees of freedom	Mean square Fruit characters		
		No. of total fruits	Fruits length (cm)	Fruits girth (cm)
Rep	2	0.323	0.370	0.3484
Hormone	3	149.397**	500.299**	27.1411**
Boron	2	16.145**	19.338**	14.2881**
Hormone×Boron	6	0.005 NS	0.160**	0.0167 NS
Error	22	0.008	0.021	0.0080

Appendix IX. **Anova of effect of plant growth regulator and boron on fruits weight**

Sources of variation	Degrees of freedom	Mean square Fruit weight		
		Individual fruit weight (g)	Fruit weight $plant^{-1}$ (g)	Fruit yield ha^{-1} (ton)
Rep	2	1.13954	6852.31	10.528
Hormone	3	24393.7**	1.166E+07**	449.528**
Boron	2	1508.22**	898483**	39.139 **
Hormone×Boron	6	4.832E-03 NS	36604.6**	0.972 NS
Error	22	0.01510	290.928	1.407

** Means significant at 1% level of significant and * Means significant 5% level of significant. Here NS means non-significant