# GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY DIFFERENT LEVELS OF BORON AND GIBBERELLIC ACID


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# *CERTIFICATE*

*This is to certify that the thesis entitled **"GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY DIFFERENT LEVELS OF BORON AND GIBBERELLIC ACID** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **NUSRAT JAHAN**, Registration No. **13-05475** 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.*

***June, 2020***

***Dhaka, Bangladesh***

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**Dedicated to**

**My**

**Beloved Parents**

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## GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY DIFFERENT LEVELS OF BORON AND GIBBERELLIC ACID


## ABSTRACT

The experiment was carried out at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2018 to March 2019 to evaluate the growth and yield of cabbage as influenced by different levels of boron and gibberellic acid ($GA_3$). The experiment comprised of two different factors such as, Factor A: four $GA_3$ levels *viz*. $G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$ and $G_3$ = 130 ppm $GA_3$ and Factor B: three levels of boron application *viz*. $B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$ and $B_2$ = 8 kg B $ha^{-1}$. The experiment was set up in Randomized Complete Block Design with three replications. Regarding $GA_3$ application, the treatment $G_2$ (100 ppm $GA_3$) produced the highest marketable cabbage yield (44.13 t $ha^{-1}$) and $G_0$ (No $GA_3$) produced the lowest (39.43 $tha^{-1}$). For boron (B) application, $B_1$ (4 kg B $ha^{-1}$) gave the highest marketable cabbage yield (45.38 t $ha^{-1}$) $B_0$ (No B) produced the lowest (36.57 $tha^{-1)}$. For combined effect, $G_2B_1$ (100 ppm $GA_3$ + 4 kg B $ha^{-1}$) gave the highest marketable cabbage yield (47.71 t $ha^{-1}$) and the lowest (34.49 t $ha^{-1}$) was from $G_0B_0$ (No $GA_3$ + No B $ha^{-1}$). Considering economic analysis, $G_2B_1$ showed the highest gross return (Tk 572520), net return (Tk 392400) and BCR (3.18) whereas $G_0B_0$ gave the lowest gross return (Tk. 413880), net return (Tk. 241841) and BCR (2.40). So, it can be concluded that 100 ppm $GA_3$ and 4 kg Boron is suitable for cabbage production compare to other treatment combinations.

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## ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| ABA | = | Abscisic acid |
| AEZ | = | Agro-Ecological Zone |
| BBS | = | Bangladesh Bureau of Statistics |
| Ca | = | Calcium |
| CCC | = | Chlorocholine Chloride |
| CV % | = | Percent Coefficient of Variation |
| DAS | = | Days After Sowing |
| DAT | = | Days After Planting |
| DMRT | = | Duncan's Multiple Range Test |
| *et al.,* | = | And others |
| FAO | = | Food and Agricultural Organization |
| $GA_3$ | = | Gibberellic acid |
| GM | = | Geometric mean |
| IAA | = | Indole acetic acid |
| IBA | = | Indole butyric acid |
| K | = | Potassium |
| LSD | = | Least Significant Difference |
| M.S. | = | Master of Science |
| NAA | = | Naphthalene acetic acid |
| NaOH | = | Sodium hydroxide |
| P | = | Phosphorus |
| ppm | = | Parts per million |
| SAU | = | Sher-e-Bangla Agricultural University |
| UNDP | = | United Nations Development Programme |
| USA | = | United States of America |
| var. | = | Variety |
| WHO | = | World Health Organization |
| µg | = | Microgram |

# Chapter I

# Introduction

# CHAPTER I

# INTRODUCTION

Cabbage *(Brassica oleracea*var**.** *capitata*L.) belongs to the family Cruciferae and is the most important leafy vegetables in Bangladesh (Hoq *et al.*, 2014). It is a biennial and herbaceous crop, which is widely grown in temperate regions of the world (Alfred and Thomas, 2007). The cultivation of cabbage in Bangladesh is mainly limited to winter months. The edible portion of the cabbage plant is known as ‘head’ that is made up of numerous thick and overlapping smooth leaves. As a vegetable, cabbage has high nutritive value (Adelanwa and Medugu. 2015). An edible portion of 100 g of cabbage contains energy value of 24 Cal, moisture 90.2g, protein 1.6g, fat 0.2g, fiber 0.9g, carbohydrate 4.8g, calcium 0.05g phosphorus 0.04g, vit-B1 0.06mg, Vit-B2 0.05mg, Vit-B5 0.4mg and Vit-C 55mg (Rumeza, *et al.*, 2006).

Cabbage is one of the fiber leading vegetables in the world, which is extensively grown in Bangladesh (Rashid, 1993). In Bangladesh, the ranking of cabbage is third concerning production and first in relation to per hectare yield of winter vegetables.It is cultivated in a part of 18620 hectares of land with gross production of 322000 tons containing per hectare yield of 17.33 tons (BBS, 2020). However, the yield of cabbage in Bangladesh is incredibly low compared to developed countries (FAO, 1999). This low yield of cabbage could be raised by adopting improved production practices. Adoption of improved production practice including judicious application of manures and fertilizers can significantly increase the yield of cabbage. Nutrients could also be applied both from organic and inorganic sources. Micronutrients using have positive effect for soil health in regard to the properties of soil by water holding capacity, texture, structure, soil aeration, color, microbial activity etc.

The production of cabbage can be increased by using $GA_3$. Cabbage was found to show a quick growth when treated with plant growth regulators (Islam *et al.*, 1993). Application of $GA_3$ stimulates morphological characters like plant height, number of leaves, head diameter, thickness of head as well as the weight of head.Nasiruddin and Roy (2011) reported that due to the diversified use of productive land, it is necessary to increase the food production, and gibberellic acid ($GA_3$) may be a contributor in achieving the desired goal. The production and marketability of cabbage can be increased by using growth regulator and nutrient. Cabbage was found to show a quick growth when treated with plant growth regulators. Application of $GA_3$ stimulates morpho-physiological, and yield and yield contributing characters of cabbage (Singh, 2018). Further, the less is the input cost, the greater is the margin of profit when yield remains the same.

Plant fertilization is one of the most important factors affecting plant quality (Savci, 2012).Boron is a microelement which required with small quantities play a vital role in plant growth and development (Mohsen *et al.*, 2016).Boron plays a vital role in cell division, sugar translocation, movement of growth regulators within the plant and lignin synthesis (Aparna and Puttaiah, 2012).

In Bangladesh fertilizer application rate has increased than earlier in crop production but application of micronutrients has largely been neglected. Therefore, rational and optimum use of micronutrient coupled with recommended fertilizers would be beneficial for increasing cabbage yield per unit area. Boron is also an essential micronutrient for the growth of plant new cells. However, in case of cole crops such as cauliflower, broccoli and cabbage, boron requirement is very high. Boron normally becomes less available to plants with increasing soil pH (Hassan *et al.*, 2018).

Therefore, studies on management practices, particularly on the management of $GA_3$ and boron would help in increasing quality and yield of cabbage. Available information during this regard under Bangladesh conditions is insufficient. The current study, therefore, conductedto seek out the influence of $GA_3$ and boron in presence of recommended doses with other fertilizers. However, the present study was under taken with the following objectives:

1. To study the effect of $GA_3$ and boron for growth and yield contributing characters of cabbage and
2. To determine the suitable combination of $GA_3$ and boron for ensuring the better growth and higher yield of cabbage.

# Chapter II

# Review of Literature

# CHAPTER II

# REVIEW OF LITERATURE

Cabbage is one of the most vital leafy vegetables in Bangladesh, as well as in the world. Researches on various side of its production technology have been carried out worldwide. Among these researches a limited number of works have been done on $GA_3$ and boron. Very few numbers of works were reported where the effect of $GA_3$ and/or in combination with boron on cabbage was studied. However, some of the researches and their findings related to the present study carried out at home and abroad are reviewed in this chapter under the following headings.

## 2.1 Effect of $GA_3$

Singh (2018) investigated the effect of Gibberellic acid and Nitrogen on yield and marketability of cabbage (*Brassica oleracea* var. *capitata* L.) cv. Pride of India". The experiment was set up with Randomized Complete Block Design(factorial) having sixteen treatments combining two factors (four each) like $N_0G_0$, $N_0G_1$, $N_0G_2$, $N_0G_3$, $N_1G_0$, $N_1G_1$, $N_1G_2$, $N_1G_3$, $N_2G_0$, $N_2G_1$, $N_2G_2$, $N_2G_3$, $N_3G_0$, $N_3G_1$, $N_3G_2$ and $N_3G_3$ which were replicated three times. The data were recorded for pre harvest parameters like Plant height, number of leaves per plant and plant canopy while post-harvest observations like fresh weight of the whole plant, fresh weight of heads, diameter of head, thickness of head and yield of head and economic of production. The significantly superior results were observed with the treatment $N_1G_3$ (8Kg Nitrogen and 20 ppm $GA_3$ respectively) while minimum with control ($N_0G_0$).

An experiment was conducted by Roy and Nasiruddin (2011) to study the effect of $GA_3$ on growth and yield of cabbage. The experiment was consisted of four concentrations of $GA_3$, *viz*., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm $GA_3$. The highest diameter (23.81 cm) of cabbage head was found in 50 ppm $GA_3$ while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm $GA_3$). The application of different concentrations of $GA_3$was influenced independently on the growth and yield of cabbage. Significantly the highest yield (104.66 t $ha^{-1}$) was recorded from 50 ppm $GA_3$.

Influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) were studied by Lendve *et al.* (2010)found that application of GA @50 ppm was significantly superior over most of the treatments in terms of number of the leaves, plant spread, circumference of stem, left area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root. The treatment GA@ 75 ppm which exxhibited better results for days required for head initiation and head maturity.

Yu *et al.* (2010) conducted an experiment with '8398' cabbage *(Brassica oleracea* var. *capitata* L.) plants with 7 true leaves and 'Jingfeng No. 1' cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and 'Jingfeng No. 1' cabbage plants vernalized for 21 days were treated by high temperature of $37^0$C for 12 hours to explore the changes of endogenous hormone during devernalization in cabbage. The results showed that: $GA_3$ content had less changes, IAA content rose and ABA content decreased during devernalization. Compared with CK (vernalization period), $GA_3$ and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower $GA_3$ and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

A study was conducted by Roy *et al.* (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and $GA_3$ on growth and yield of cabbage. The two-factor experiment consisted of four levels of starter solution, viz., 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of $GA_3$, viz., 0, 25, 50 and 75ppm. The application of starter solution and different concentrations of $GA_3$ influenced independently and also in combination on the growth and yield of cabbage. The highest yield (104.93 t $ha^{-1}$) was obtained from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t $ha^{-1}$) was recorded from the control. Significantly the highest yield (104.66 t $ha^{-1}$) was found from the treatment of 50 ppm $GA_3$, while the lowest yield (66.56 t $ha^{-1}$) was recorded from control. In case of combined effect, the highest yield of cabbage (121.33 t $ha^{-1}$) was obtained from the treatment combination of 1.5% starter solution + 50 ppm $GA_3$ followed by 1.5% starter solution + 75 ppm $GA_3$ (115.22 t $ha^{-1}$), while the lowest yield (57.11 t $ha^{-1}$) was produced by the control treatment. Economic analysis revealed that 1.5% starter solution + 50 ppm $GA_3$ treatment was the best treatment combinationin respect of net return (Tk. 173775 $ha^{-1}$) with a benefit cost ratio of 3.52.

A field experiment was conducted by Chauhan and Tandel (2009) during the *Rabi* season at Agronomy farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari. Results showed that spray of $GA_3$ and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant growth regulator treatments for growth, yield and quality characters of cabbage was $GA_3$@100 $mgl^{-1}$ foliar spray at 30 and 45 days after transplanting (DAT) followed by NAA @100 $mgl^{-1}$ foliar spray at 30 and 45 DAT.

The effect of $GA_3$ and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was investigated by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of Agriculture, Parbhani. The highest yield was obtained with $GA_3$ at 50 ppm followed by NAA at 50 ppm (332.01 and 331.06 q $ha^{-1}$, respectively) Combinations and higher concentrations of plant growth regulators proved less effective.

An experiment was conducted by Yadav *et al*. (2000) in Rajasthan, India, during the rabi season of 1996-97 to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 250, 500 and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height (28.4 cm) and plant spread (0.18 m ) was resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q $ha^{-1}$) was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm. Leaf area was the highest in 2 sprays of 500 ppm succinic acid.

Dharmender *et al.* (1996) conducted an experiment to find out the effect of $GA_3$ or NAA (both at 25, 50 or 75 ppm) on the yield of cabbage (cv. Pride of India) in the field at Jobner, Rajstan, India. They recorded the highest yield following treatment with $GA_3$ at 50 ppm followed by NAA at 50 ppm (557.54 and 528.66 q $ha^{-1}$ respectively). They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

Islam *et al.* (1993) determined the effective concentration of NAA and $GA_3$ for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and $GA_3$. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm $GA_3$ was suitable both for higher yield and ascorbic acid content of cabbage.

Patil *et al.* (1987) conducted an experiment in a field trial with the cultivar Pride applied $GA_3$ and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. The maximum plant height and head diameter and head weight were noticed with $GA_3$ at 50 ppm. Significant increase in number of outer and inner leaves was noticed with both $GA_3$. Head formation and head maturity was 13 and 12 days earlier with 50 ppm $GA_3$.The Maximum number of leaves and the highest yield (63.83 t $ha^{-1}$) were obtained with 50 ppm $GA_3$.

Islam (1985) conducted an experiment at the Bangladesh Agricultural University Farm, Mymensingh with applying various growth regulators (CCC, $GA_3$, NAA and IBA) at 30 days after transplanting of 32 days old seedlings and found that $GA_3$ increased the plant height, number of loose leaves per plant, size of leaf and finally the yield.

### 2.2 Effect of boron (B)

For better yield, application of macro-elements is no doubt an important consideration but provision of micro-elements is also equally important. Among the micro nutrients, the essential role of boron was first demonstrated by Waring (1953). The basic role of boron lies in stabilizing certain constituent of cell wall and plasma membrane and enhancing membrane permeability, cell elongation, cell division, tissue differentiation and metabolism of nucleic acid, carbohydrate, proteins, auxins and phenols. Boron Shows a dynamic role as a stabilizers of the cell wall pectic network (Brown *et al.* 2005). It encourages the firmness and rigidity of the structure of cell wall. It also enhances sugar and hydrocarbons, passage through phloem. Moeinian *et al.* (2011).

Research works with Boron in broccoli is restricted to the reproductive phase, since its larger demand and importance since pollen grain germination up to the pollen tube growth reflecting on fecundation and growth of the flowers (Prado, 2008). During the vegetative phase, B demand is relatively low in comparison with the reproductive one. But little is known about the effects of boron specially when in association with N in excess.

Micro nutrients are as essential as macro nutrients because important growth processes depend on them. The basic role of boron lies in stabilizing certain constituent of cell wall and plasma membrane and enhancing membrane permeability, cell elongation, cell division, tissue differentiation and metabolism of nucleic acid, carbohydrate, protein, auxin and phenols. Application of boron to plant increased chlorophyll content (Sharma and Ramchndra, 1990). Boron is thus essential for plant growth and development as translocation of sugar and quality production depends on boron (Vasconcelos *et al.* 2011). However, the boron deficiency in soil caused by removal of boron by crops is not fully replenished by fertilizer applications. In contrast, high concentration and unbalance ratios of both, macro and micro nutrients lead to undesirable plant growth and development (Hall, 2002). As reported by Ouda and Mahadeen (2008) that plant growth is severely depressed by boron deficiency but high concentration of boron also reduces quality of crop. Foliar application of micronutrient to plant is the most effective and safest way.

Hooda *et al.* (1984) obtained increased height of plant, number of branches, number of fruits and yields in tomato by zinc and boron application. The highest fruit yield was 529.88q $ha^{-1}$ with 7.5kg $ZnSO_4$ + 3.75 kg borax $ha^{-1}$ as compared to control (444.17q $ha^{-1}$).

Shelp and Shattuk (1987) observed that different concentration of boron (0.025, 1.0, 2.5 and 12.5mg 1 liter) increased the optimum plant height, head yield and maximum fresh weight of curd in cauliflower CV. White tip.

Favorable impact of curd initiation in cauliflower with the application in soil and foliar spray of boron has been reported. In this context, Rao *et al.* (1990) noted that foliar application of boron at 0.25% as borax resulted in early initiation of curd in cauliflower. In another experiment conducted by Panigrahi *et al.* (1990), recorded increase in size of curd with application of boron at 0.2% as compared to control. However, Singh and Jhekr (1991) investigated and found that maximum attainment of plant height and decrease in curd initiation period significantly with the application of 0.5% boron as compared to other concentrations.

Singh and Verma (1991) reported application of boron at 2kg $ha^{-1}$ alone or in combination with Zn or K, resulted in optimum plant growth, the highest yield and income $ha^{-1}$ in tomato.

Sharma *et al.* (1994) reported on increased yield with increasing B application up to 0.5mg per liter but decreased at higher rates in cauliflower. Singh and Singh (1994) reported to have increased fruit set, total number of $fruitplant^{-1}$ and $yieldplant^{-1}$ by spraying 1.5ppm of boron.

Sharma (1995) found that different levels of boron (0, 10, 20 and 30 kg borax $ha^{-1}$) increased the plant height, number of branches $plants^{-1}$, number of fruits per plant, fruit yield per plot and fruit yield $ha^{-1}$. Thereafter, all the above, parameters decreased with higher level of boron.

Combined application of Zn, Mn and B at 30 and 60 days after transplanting resulted into increased plant height, number of branches per plant, number of fruits per plant and fruit yield $plant^{-1}$ as compare to control in tomato (Bose and Tripathi, 1996).

Batal *et al.* (1997) reported that on clay loam soil, increasing borax from 2.2 to 8.8kg $ha^{-1}$ reduced hollow stem but had no effect on yield or curd mass. On the sandy loam soil, borax at 4.4kg $ha^{-1}$ maximized yield and curd mass.

Simatupang (1997) found the effect of borax application on growth, yield and quality of cauliflower. Three cultivars of cauliflower, Cirateun, Early snowball and Berastagi along with 3 doses of borax (0, 7.5 and 15 kg $ha^{-1}$) were tested. Berastagi cultivar had a better yield than the others did. Application of 15 kg $ha^{-1}$ borax increased the yield about 26.55 percent and improved the curd quality in terms of dimension and hardness. Borax application at 15 kg $ha^{-1}$ increased the Weight of curd in Berastagi up to 15.5 percent, in cirateum 27.18 percent and in

Early snowball up to 53.57 percent.

Choudhary and Mukherjee (1999) reported that plant height, no. of leaves per plant, days taken to curd initiation, days taken to curd maturity, biological yield, average weight to curd and total marketable yield per hectare were significantly higher in 0.5 percent boron and 6ppm zinc concentration spray. Besides, these, he also pointed out that days taken to curd initiation was advanced as a result of application of boron at 0.5% as foliar spray.

Sharma *et al.* (1999) reported that direct application of borax at 18kg $ha^{-1}$ in soil or foliar application of 0.3 percent borax solution enhanced yield in cauliflowers, cabbage and kohl rabi by 16.1, 12.1 and 11.5 percent, respectively over control.

Singh *et al.* (2002) conducted an experiment with four levels of B applied at 0, 0.5, 1.0 and 2.0 kg $ha^{-1}$ (as borax) as band placed around each plant one week after transplanting. Soil application of B significantly produced higher marketable curd yield of cauliflower over control. Application of B up to 1.0 kg $ha^{-1}$ significantly increased the yields. Blackish curds appeared in the control.

In cabbage, significant increase in number of leaves after first spray of 0.5% borax was recorded by Sarma *et al.* (2003) and also found that among all the different treatments, the highest number of wrapper leaves and compactness of head was found by 0.5% borax treatment.

Singh *et al*. (2003) reported that in cauliflower cv. Pusa synthetic, the treatments consisted of borax applied at various rates and methods, B significantly improved the vegetative growth and quality parameters of cauliflower. The maximum leaf stalk (6.78cm) was obtained with borax applied at 10kg $ha^{-1}$ as soil application. Borax applied at 5kg $ha^{-1}$ as soil application + 0.25% as foliar spray at 45 and 60 DAT, resulted in the highest number of leaves per plant (17.4), leaf area (374.6cm), curd weight (510.0g), curd width (15.68cm), curd length (8.48cm), curd yield per plot (16.23kg), curd yield per ha (Rs. 140.86), net profit

(51,203rupees ha$^{-1}$) and benefit : cost ratio (4:20).

Bishnu *et al.* (2004) documented the effects of boron levels on cauliflower curd production. Six levels of boron (0kg, 5kg, 10kg, 15kg, 20kg, and 25kg borax ha$^{-1}$) were tested. It was reported that growth (plant height, leaf number, leaf length and fresh biomass production) was affected by the boron levels. The maximum plant height (42.05cm) was observed when the crop was supplied in 25kg borax ha$^{-1}$ which was almost 13.95 percent higher than that of non-treated control crop. Maximum leaf numbers (12.73 plant$^{-1}$) and leaf length (38.91cm) were fertilized with 10kg borax ha$^{-1}$. Highly significant effect of boron levels was observed on the curd production.

Sarma *et al.* (2005) documented that application of 0.5% borax recorded the highest yield and harvest index of cabbage. The highest quality of protein and ascorbic acid content was found by same concentration of borax. While a significant improvement in the quality of radish root particularly ascorbic acid, reducing sugar and total sugar were obtained with the application of 0.1% borax as reported by Singh *et al.*, (2006).

A pot experiment was conducted to investigate the effect of B levels on growth, yield and yield components of cabbage in calcareous soils of Bangladesh. There were eight level of B [0, 1, 2, 3, 4, 5, 6, 7 kg B ha$^{-1}$] as boric acid in treatments. It was reported that growth, yield and other yield contributing characters of cabbage significantly affected by Boron levels. The head weight and other growth and yield contributing parameters of cabbage increased up to 4kg B ha$^{-1}$ and decreased gradually with the increase of B level (74.0 Kg B ha$^{-1}$). The higher the head weight (811.33g) and maximum yield increase of 116.82% was obtained from treatment with Borax 4 kg ha$^{-1}$ (Alam, 2007).

In Broccoli, Moniruzzaman *et al*. (2007) revealed that boron application increased plant height, number of leaves per plant, length and width of leaves, plant spread, main head weight and head yield both per plant and per hectare significantly up to 1.5 kg $ha^{-1}$. While in another experiment conducted by Agarwal and Ahmad (2007) on Broccoli, boron gave the highest stalk length while the highest curd diameter, curd weight and compact curd quality was obtained with boron, Zinc, manganese and copper combination of fertilizer.

Nayanmani and Gogoi (2007) revealed that the growth attributes of cauliflower cv. Pusa Katki were influenced by different level of boron significantly.

An experiment was conducted by Ouda and Mahadeen (2008) to know the effect of fertilizers on growth, yield, yield components, quality and certain nutrient content in broccoli, and revealed that plant growth was severely depressed by deficiency of Boron.

Kumar *et al.* (2010) revealed that the efficacy of various levels of boron and molybdenum as foliar, and soil application on growth, yield and economics of cauliflower cv. Snowball K-1. Among the various treatments, borax 20kg $ha^{-1}$ + sodium molybdate 2 kg $ha^{-1}$ as soil application in combination of recommended dose of NPK gave the maximum height of plant, length of leaf, width of leaf, total weight of plant, width of curd, average weight of curd and yield of curd. Foliar application of boron @ 100ppm + molybdenum @ 50 ppm along with recommended dose of NPK gave the highest growth and yield among all the foliar application treatments.

Sitapara *et al.* (2011) revealed that two foliar sprays (at 15 and 30 DAT) of boric acid at 0.2 percent and of gibberellic acid @ 100ppm were found better for growth attributes (*viz*. plant height, number of leaves, stem length, stem diameter, days taken for marketable curd etc.) yield attributes (viz. diameter, volume and weight of curd) and ultimately the early curd yield of cauliflower cultivar “Snowball 16”.

The influence of $CaCl_2$ and borax on growth, yield and quality of tomato was investigated during the years 2009 and 2010. It was reported that Borax alone significantly enhanced the number of branches per plant, fruits per cluster, fruit per plant, fruit weight and total soluble solid content of the fruit (Abdur and Haq, 2012).

Devi *et al.* (2012) revealed that the effects of foliar application of borax @ 0.1% solution on cabbage *[Brassica oleracea* (L.) Var. *capitata].* The growth (plant height, leaf number, leaf length and fresh biomass production) was affected by the boron levels. The foliar spray was done twice at 25 and 50 days after transplanting (DAT). It showed significant increase in plant height, number of leaves, shoot weight, dry weight, root fresh weight and dry weight & yield. The head size (diameter) was increased with application of borax.

Singh *et al.* (2014) showed that doses of boron significantly affected the vegetative growth parameters except at 15 DAT. Application of 2.0 kg $ha^{-1}$ borax resulted in higher values in terms of growth parameters, when compared with application of 1.0 kg $ha^{-1}$. However, days of $1^{st}$, 50% and 100% curd initiation remained unchanged due to different doses of boron. Application of boron at 2.0 kg $ha^{-1}$ resulted in significantly highest circumference of curd (68.38cm), fresh weight of curd (481.89g), diameter of curd (10.48%) and yield of curd (214.47q $ha^{-1}$) over rest of the doses. However, differences in circumference of curd, fresh weight of curd and yield of curd due to both the higher doses of boron were not found significant.

Banerjee *et al.* (2015) reported that application of Boric acid @ 0.3% or liquid Boron @ 1.5g $L^{-1}$ at 30 days after planting gave the highest net return as well as benefit-cost.

Islam *et al.* (2015) reported that early green variety of broccoli, showed a significant and positive effect of boron application on the yield. Boron @ 2kg $ha^{-1}$, showed the best performance regarding head diameter (19.04cm), minimum number of days for curd initiation (48.92) and the maximum yield (32.19 t $ha^{-1}$).

Singh *et al.* (2015) conducted an investigation to examine the optimum application dose of NPK and boron application on broccoli in irrigated agro - ecosystem of western Uttar Pradesh during Rabi 2009-10 and 2010-11. The investigation revealed that Application of 120kg N + 60kg P +40 Kg $K_2O$ + 15kg B $ha^{-1}$ gave maximum plant height $^{-1}$ (65.33cm), number of leaves $plant^{-1}$(18.26), length of longest leaf (52.99cm), spread of plant (55.53cm)and stem diameter (4.47cm), which were significantly higher than that of control. Similarly, the same treatment resulted in significantly higher curd diameter (13.69cm), Length of curd (16.33cm), weight of curd $plant^{-1}$ (286.89g) and total yield (148.51q $ha^{-1}$), over control.

# Chapter III

# Materials and Methods

# CHAPTER III

# MATERIALS AND METHODS

The experiment was carried out at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2018 to March 2019 to study the growth and yield of cabbage as influenced by different levels of boron and gibberellic acid ($GA_3$). The materials and methods that were used for conducting the experiment are presented under the following headings:

## 3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

## 3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details on the meteorological data of airtemperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix II.

## 3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experimental plotare presented in Appendix III.

### 3.4 Test crop

The test crop;green cabbage was used for the experiment. The variety, Atlas-70 was considered for the present study.

### 3.5 Experimental details

#### 3.5.1 Treatments

The experiment comprised of two factors.

**Factor A: $GA_3$ - 4 levels**

1. $G_0$ = Control (No $GA_3$)
2. $G_1$ = 70 ppm $GA_3$
3. $G_2$ = 100 ppm $GA_3$
4. $G_3$ = 130 ppm $GA_3$

**Factor B: Boron - 3 levels**

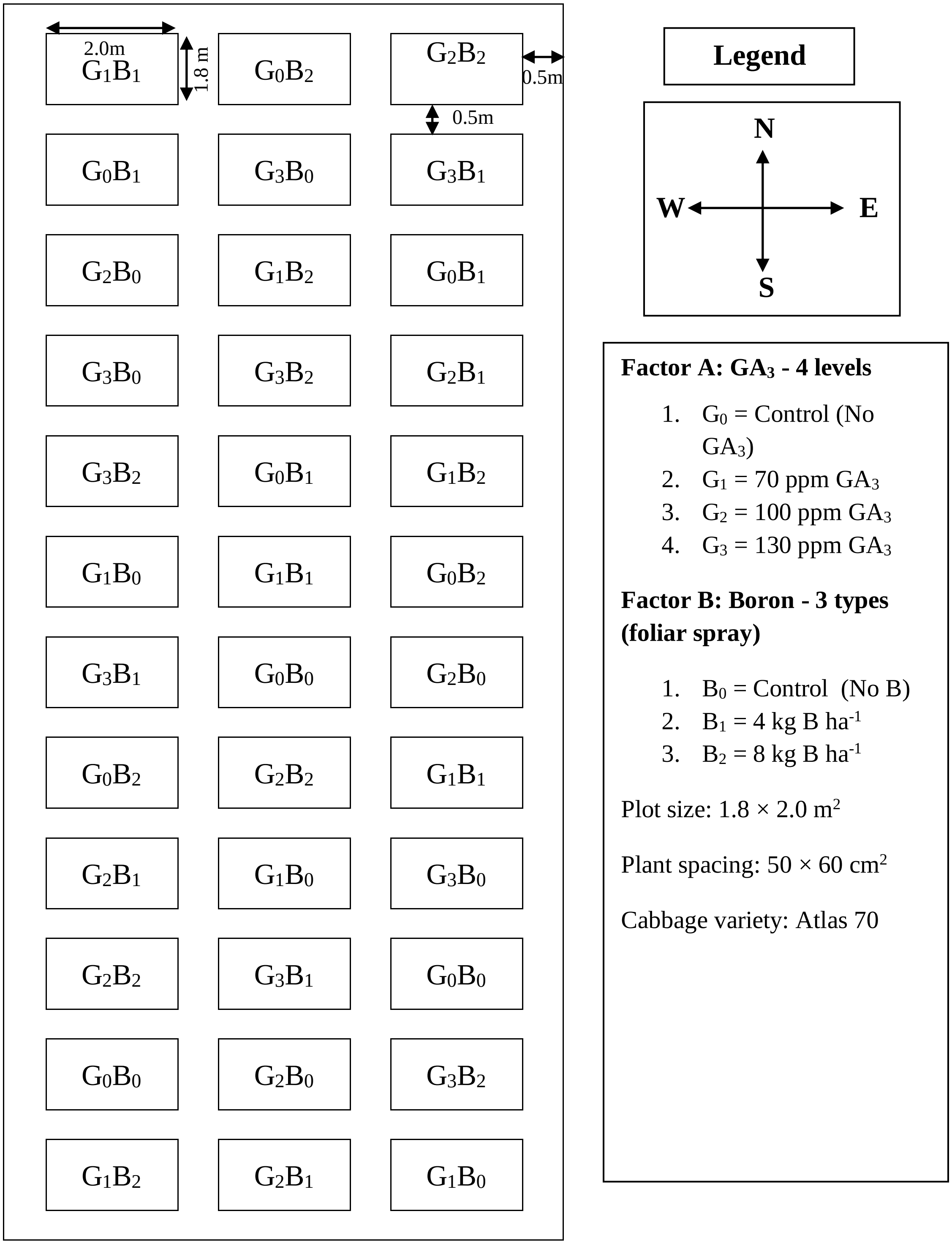
1. $B_0$ = Control (No B)
2. $B_1$ = 4 kg B $ha^{-1}$
3. $B_2$ = 8 kg B $ha^{-1}$

**Treatment combinations -** Twelve treatment combinations were as follows: $G_0B_0$, $G_0B_1$, $G_0B_2$, $G_1B_0$, $G_1B_1$, $G_1B_2$, $G_2B_0$, $G_2B_1$, $G_2B_2$, $G_3B_0$, $G_3B_1$ and $G_3B_2$.

#### 3.5.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of $GA_3$ and boron.$GA_3$consisted of 4 different concentrations and boron consisted of 3 different levels. The 12 treatment combinations of the experiment were assigned. The area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatment combinations were allotted at random.The size of each unit plot was1.8 m × 2.0 m.

The distance between blocks and plots were 0.5 m and 0.5 m respectively.Thelayout of the experiment field is presented below:




Layout of the experimental plot

### 3.6 Variety used and seed collection

The cabbage variety; Atlas-70 was used for the present study. The seeds of this variety were collected from Siddik Bazar, Dhaka.

### 3.7 Raising of seedlings

The land selected for nursery beds were well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the well rotten cowdung was mixed with the soil at the rate of 5 kg/bed. Size of each seed bed was 3.om × 1.om that was raised above the ground level. One seed bedwas prepared for raising the seedlings. Ten (10) grams of seeds were sown in the seed bed on 1$^{st}$week of October 2018. After sowing, the seeds were covered lightly with fine soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

### 3.8 Preparation of the main field

The plot selected for the experiment was opened in the last week of October, 2019 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 30$^{th}$October 2018. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

### 3.9 Fertilizers and manure application

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of BARI (2017).

| Nutrients | Manures/fertilizers | Doses $ha^{-1}$ |
|---|---|---|
| - | Cowdung | 10 ton |
| N | Urea | 350 kg |
| P | TSP | 250 kg |
| K | MoP | 300 kg |
| B | Boric acid | As per treatment |

The entire amount of cowdung , TSP , MOP and Boric acid was applied as basal dose at the time of land preparation. Urea was applied in three installments at 10, 30 and 50 days after transplanting.

### 3.10 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 1st November, 2018 maintaining a spacing of 50 cm × 60 cm. There were 12 seedlings transplanted in each plot. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

### 3.11 Collection, preparation and application of growth regulator

Plant growth regulator Gibberellic Acid ($GA_3$) was collected from Karwan Bazar, Dhaka. A 1000 ppm stock solution of $GA_3$ was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one liter of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 70 ml of this stock solution was diluted in 1 liter of distilled water to get 70 ppm $GA_3$ solution. In a similar way, 100 ppm stock solutions were diluted to 1 liter of distilled water to get 100 ppm solution.

Again, 130 ppm stock solutions were diluted to 1 liter of distilled water to get 130 ppm solution. $GA_3$ as per treatment were applied at four times 15, 30 and 45, 60 days after transplanting by a mini hand sprayer.

### 3.12 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the cabbage.

#### 3.12.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was crushed. A few gaps filling was done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

#### 3.12.2 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Irrigation was also applied as and when necessary.

#### 3.12.3 Plant protection

The crop was protected from the attack of insect-pest by spraying Melathion 45 EC at the rate of 2 ml/L water. The insecticide application was done fortnightly as a matter of routine work from transplanting up to the end of head formation.

### 3.13 Harvesting

Harvesting of the cabbage was not possible on a certain or particular date because the head initiation as well as head at marketable size in different plants were not uniform. Only the compact marketable heads were harvested with fleshy stalk by using as sharp knife. The crop was harvested depending upon the maturity of the crop. Before harvesting of the cabbage head, compactness of the head was tested by pressing with thumbs. Harvesting was done manually. Proper care was taken during harvesting to prevent damage of cabbage head. Harvesting was started from 15 February, 2019 and completed by 10 March, 2019.

### 3.14 Data Collection and Recording

Five plants were selected randomly from each unit plot for recording data on crop parameters and the yield of cabbage were taken plot wise. The following parameters were recorded during the study:

#### 3.14.1 Growth parameters

1. Plant height (cm)
2. Number of loose leaves plant$^{-1}$
3. Leaf length (cm)
4. Leaf breadth (cm)
5. Plant spread (cm)

#### 3.14.2 Yield contributing parameters

1. Percent of (% )dry matter of head
2. Head diameter (cm)
3. Thickness of head (cm)
4. Stem length at harvest (cm)
5. Percent of (%) dry matter of stem

#### 3.14.3 Yield parameters

1. Fresh weight plant$^{-1}$ (g)
2. Gross yield plot$^{-1}$ (kg)
3. Gross yield ha$^{-1}$ (t)
4. Marketable yield plant$^{-1}$ (g)
5. Marketable yield plot$^{-1}$ (kg)
6. Marketable yield ha$^{-1}$ (t)

### 3.14.4 Economic analysis

1. Total cost of production (Tk. $ha^{-1}$)
2. Gross return (Tk. $ha^{-1}$)
3. Net return (Tk. $ha^{-1}$)
4. Benefit Cost Ratio (BCR)

## 3.15 Procedure of recording data

### 3.15.1 Growth parameters

**Plant height (cm)**

Plant height was recorded at 30 and50 days after transplanting(DAT) and at harvest of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured in centimeter (cm) from the ground level to the tip of the leaves.

**Number of loose leaves plant$^{-1}$**

Number of loose leaves plant$^{-1}$ was counted at different days after transplanting (DAT) of crop duration. Leaves number plant$^{-1}$was recorded from pre-selected 5 plants by counting all leaves from each plot and mean was calculated. It was recorded at 30 and 50 DAT and at harvest.

**Leaf length (cm)**

Leaf length was measured by using a meter scale. The measurement was taken from base to tip of the leaf. Average length of leaves was taken from five random selected plants from inner rows of each plot. Data was recorded at30 and 50 DAT and at harvest. Mean was calculated in centimeter (cm).

**Leaf breadth (cm)**

Leaf breadth was recorded as the average of five leaves selected at random from the plant of inner rows of each plot at 30 and 50 DAT and at harvest. Thus, mean was calculated in centimeter (cm).

**Plant spread**

The spread of plant was measured with a meter scale as the horizontal distance covered by the plant. The data were recorded from 5 randomly selected plants at 30 and 50 DAT and at harvest. The mean value was counted and calculated in centimeter (cm).

### 3.15.2 Yield contributing parameters

**Percent (%) dry matter of head**

At first head from selected plant were collected, cut into pieces and 100 g fresh cabbage head was taken and was dried under sun for a few days. Samples were then dried in an electric oven at 70°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and expressed as percent (%) dry matter content of cabbage head with the following formula:

$$\text{Percent dry matter of head} = \frac{\text{Oven dry weight of head(g)}}{\text{Fresh weight of head (g)}} \times 100$$

**Head diameter (cm)**

Diameter of head was measured with a meter scale in centimeter(cm) from 5 selected plants at harvest. The mean was then calculated.

**Thickness of head (cm)**

Thickness of head was measured in centimeter (cm) from five plants at harvestand then the mean was calculated.

**Stem length at harvest (cm)**

Stem length of five selected plants was recordedin centimeter (cm) from base to top of the stem at random at the time of harvest in inner rows of each plot. Thus, mean was calculated.

**Dry matter of stem (%)**

At the time of harvest, stem was collected from 5 selected plantsand these were cut into pieces and one hundred gram fresh stem was taken and was dried under sun for a few days. Samples were then dried in an oven at 70°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken and expressed as percent (%) dry matter content of stem.

$$\text{Percent dry matter of stem} = \frac{\text{Oven dry weight of stem(g)}}{\text{Fresh weight of stem(g)}} \times 100$$

### 3.15.3 Yield parameters

**Fresh weight plant$^{-1}$ (g)**

At the time of harvest, head weight was taken from five selected plants after removing soil, roots and other stables from the plants and then mean was calculated in gram (g).

**Gross yield plot$^{-1}$ (kg)**

Gross yield per plot was obtained by multiplying average gross weight of head per plant with total number of plants within a plot and was calculated in kilogram.

**Gross yield ha$^{-1}$ (t)**

The gross yield per hectare was obtained by converting gross yield per plot into yield per hectare and was calculated in metric ton. Yield included with folded and unfolded leaves of cabbage.

**Marketable yield plant$^{-1}$ (g)**

After harvest of head from selected plants from each unit plot, the unfolded leaves were removed from the head and the head weighted by a weighing machine .The weight of head as in gram marketable yield per plant.

**Marketable yield plot$^{-1}$ (kg)**

Marketable yield per plot was obtained by multiplying average marketable yield weight of head per plant with total number of plants within a plot and was calculated in kilogram. Marketable yield included only the yield of marketable head.

**Marketable yield ha$^{-1}$ (t)**

The marketable yield per hectare was obtained by converting marketable yield per plot into yield per hectare and was calculated in metric ton.

**3.15.4 Economic analysis**

To find out the cost effectiveness of different treatments on cabbage production with $GA_3$and boron, the procedure of economic analysis was done in details following the method as described by (Alam *et al*., 1989).

**Total cost of production(Tk.ha$^{-1}$)**

All the material and non-material input cost, interest on fixed capital and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix XI.

**Gross return (Tk. ha$^{-1}$)**

Gross return was calculated on the basis of mature cabbage head sale. The price of cabbage was assumed to be Tk. 12.00 kg$^{-1}$ basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

**Net return(Tk.ha$^{-1}$)**

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

**Benefit cost ratio (BCR)**

The economic indicator BCR was calculated by the following formula for each treatment combination.

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

## 3.16 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

# Chapter IV

# Results and Discussion

# CHAPTER IV

# RESULTS AND DISCUSSION

Cabbage is an important winter vegetable in Bangladesh. $GA_3$ and boron are important factor to increase cabbage yield. With this respect the experiment was conducted to find out the growth and yield of cabbage as influenced by $GA_3$ boron. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices. The results have been presented and discusses with the help of table and graphs and possible interpretations are given under the following sub-headings:

## 4.1 Growth parameters

### 4.1.1 Plant height

Significant influence was found on plant height of cabbage with different levels of $GA_3$ (Fig. 1 and Appendix IV).The highest plant height (25.28, 37.61 and 50.65 cm) at (30, 50 DAT and at harvest, respectively) was recorded from the treatment $G_3$ (130 ppm $GA_3$),which was statistically identical with $G_2$ (100 ppm $GA_3$) at all observations.The lowest plant height (21.48, 29.12 and 41.68cm) was recorded from the control treatment $G_0$ (No $GA_3$). Similar trends of result were reported by Singh (2018) and Yadav *et al.* (2000) followed by Patil *et al.* (1987) who noticed that the maximum plant height was with $GA_3$ at 50 ppm.

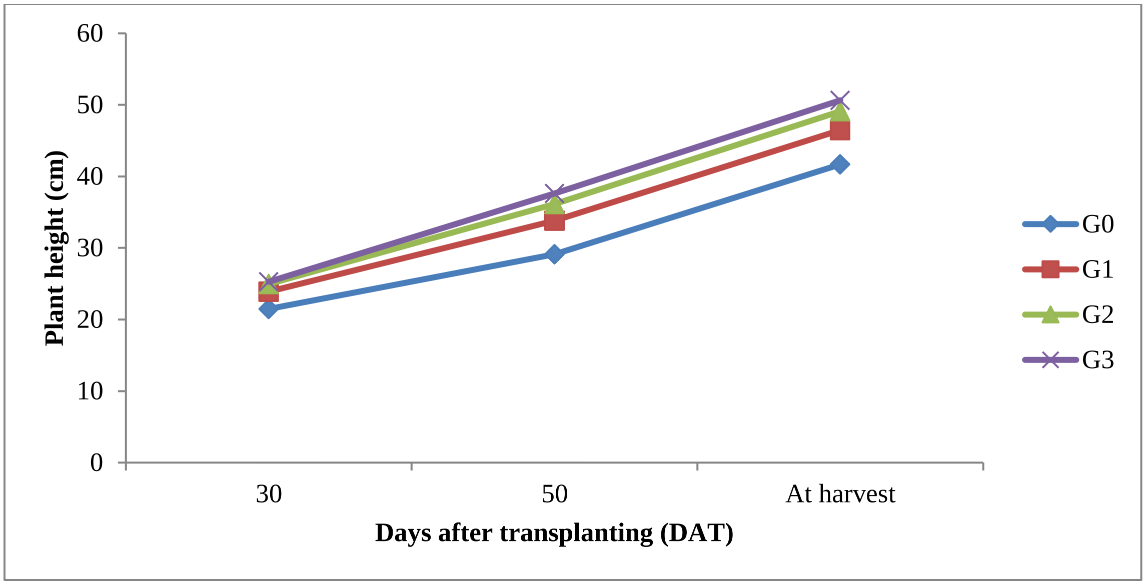



Fig. 1. Effect of $GA_3$ on plant height of cabbage ($LSD_{0.05}$ = 1.049, 2.031 and 2.230 at 30, 50 and at harvest, respectively)

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$and $G_3$ = 130 ppm $GA_3$

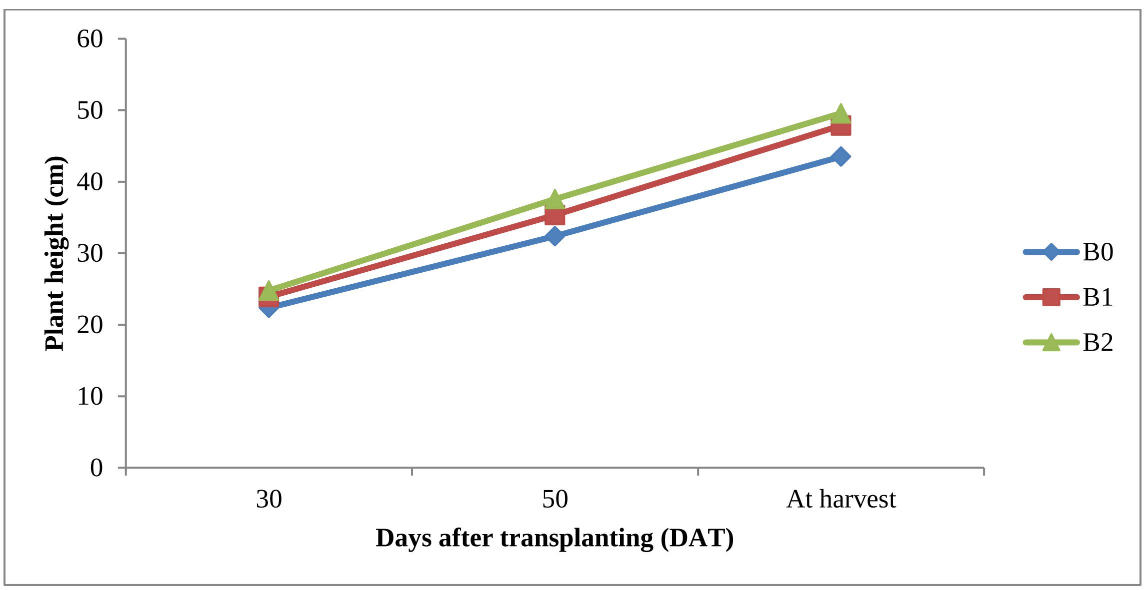



Fig. 2. Effect of boron on plant height of cabbage ($LSD_{0.05}$ = 0.960, 1.061 and 1.683 at 30, 50 and at harvest, respectively)

$B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$and $B_2$ = 8 kg B $ha^{-1}$

Different levels of Boron showed significant variation on plant height of cabbage (Fig. 2 and Appendix IV). Results indicated that the highest plant height (24.78, 37.60 and 49.58 cm) was found from the treatment $B_2$ (8 kg B $ha^{-1}$) which was statistically identical to $B_1$ (4 kg B $ha^{-1}$) at 30 DAT but at 50 DAT and at harvest it was significantly different from other treatments. The lowest plant height (22.36, 32.39 and 43.51 cm) was recorded from the control treatment $B_0$ (No B $ha^{-1}$) at all observations. Similar trends of result also observed by Devi *et al.* (2012), Hussain *et al.* (2012), Prasad and Yadav (2003) and Singh *et al.* (2003).

Table 1. Combined effect of $GA_3$ and boron on plant height of cabbage

| Treatments | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAT | 50 DAT | At harvest |
| $G_0B_0$ | 20.82 f | 27.68 g | 39.75 i |
| $G_0B_1$ | 21.13 f | 27.75 g | 42.50 h |
| $G_0B_2$ | 22.71 de | 32.23 ef | 44.01 gh |
| $G_1B_0$ | 22.23 e | 30.85 f | 43.16 h |
| $G_1B_1$ | 24.31 c | 35.01 cd | 48.18 de |
| $G_1B_2$ | 24.56 c | 35.97 cd | 49.31 cd |
| $G_2B_0$ | 23.02 de | 33.62 de | 45.69 fg |
| $G_2B_1$ | 25.45 b | 36.81 bc | 50.48 bc |
| $G_2B_2$ | 26.53 a | 38.34 ab | 52.06 ab |
| $G_3B_0$ | 23.42 d | 34.13 de | 47.06 ef |
| $G_3B_1$ | 25.99 ab | 38.53 ab | 51.93 b |
| $G_3B_2$ | 26.55 a | 40.54 a | 55.24 a |
| $LSD_{0.05}$ | 0.881 | 2.275 | 2.061 |
| CV(%) | 7.03 | 8.00 | 7,79 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$ and $G_3$ = 130 ppm $GA_3$
$B_0$ = Control (No B ), $B_1$ = 4 kg B $ha^{-1}$ and $B_2$ = 8 kg B $ha^{-1}$

Plant height of cabbage at different growth stages was varied significantly due to combined effect of $GA_3$ and boron (Table1 and Appendix IV). It was found that the highest plant height (26.55, 40.54 and 55.24 cm) was observed from the treatment combination of $G_3B_2$at 30,50 DAT and at harvest, respectively . The lowest plant height (20.82, 27.68 and 39.75cm) was recorded from the treatment combination of $G_0B_0$ which was significantly different from other treatment combinations at harvest but at 30 and 50 DAT it was statistically identical with $G_0B_1$.

### 4.1.2 Number of loose leaves plant$^{-1}$

Significant influence was found for number of loose leaves plant$^{-1}$of cabbage as influenced by different levels of $GA_3$ (Fig. 3 and Appendix V). Results revealed that the highest number of loose leaves plant$^{-1}$(11.20, 15.27 and 20.00) at(30,50DATand at harvest respectively) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was significantly different from other treatments followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$). The lowest number of loose leaves plant$^{-1}$(8.12, 12.33 and 17.02) was recorded from the control treatment $G_0$ (No $GA_3$). Singh (2018) and Lendve *et al.* (2010) also found similar trends of result with the present study. Patil *et al.* (1987) also reported similar result and found that maximum number of loose leaves was achieved with 50 ppm $GA_3$.

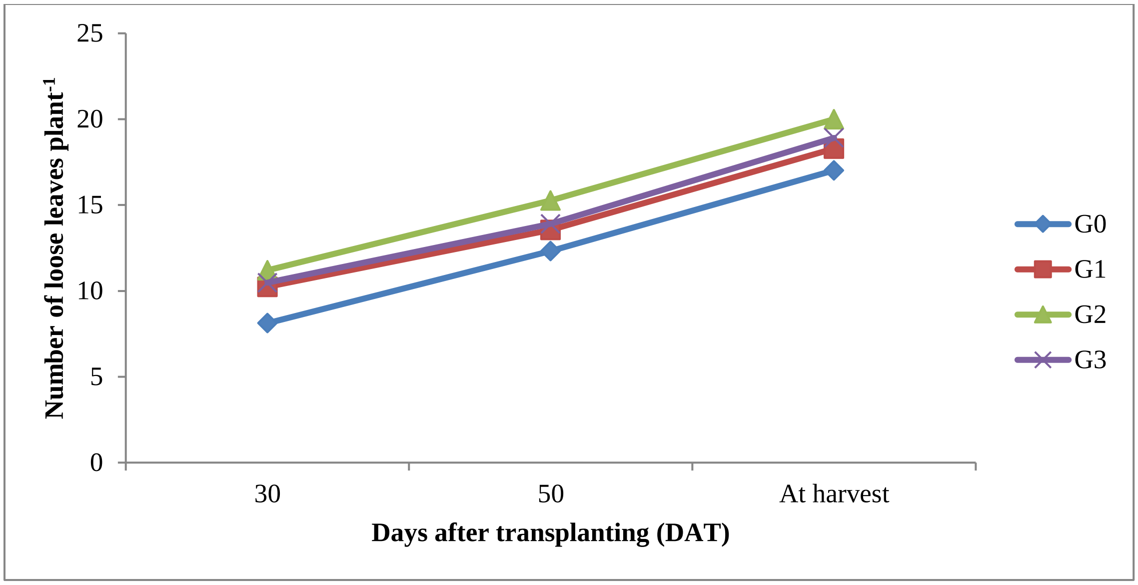



Fig. 3. Effect of $GA_3$ on number of loose leaves plant$^{-1}$ of cabbage ($LSD_{0.05}$ = at 30, 50 and at harvest, respectively)

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

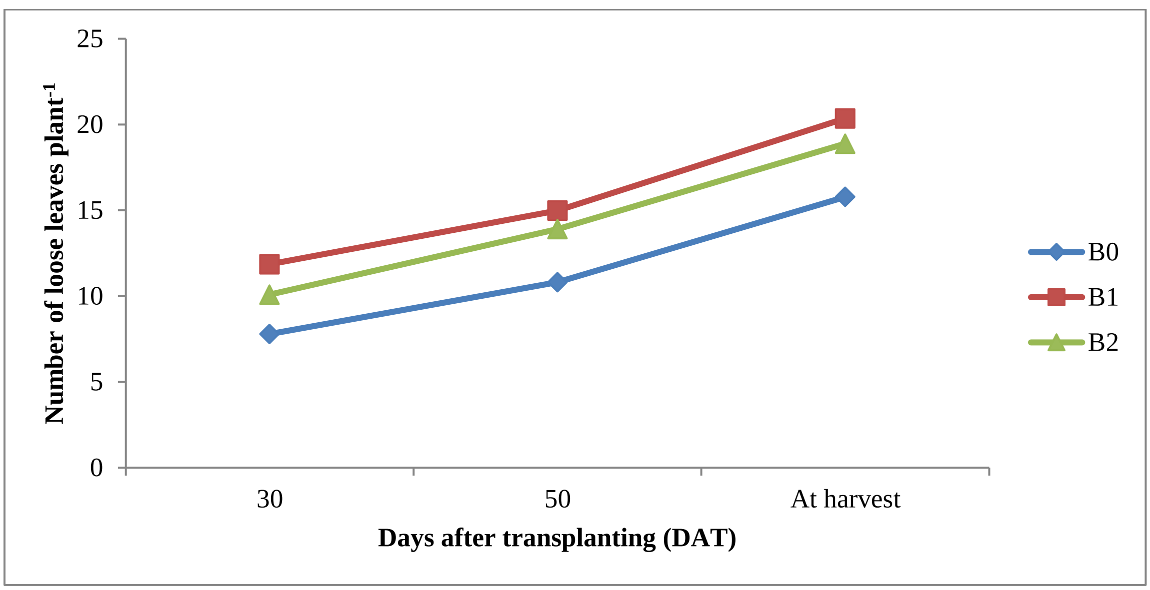



Fig. 4. Effect of boron on number of loose leaves plant$^{-1}$ of cabbage ($LSD_{0.05}$ = at 30, 50 and at harvest, respectively)

$B_0$ = Control (No B), $B_1$ = 4 kg B ha$^{-1}$, $B_2$ = 8 kg B ha$^{-1}$

Different levels of Boron showed significant variation on number of loose leaves plant$^{-1}$ of cabbage (Fig. 4 and Appendix V). Results indicated that the highest number of loose leaves plant$^{-1}$ (11.86, 14.99 and 20.36) was found from the treatment $B_1$ (4 kg B ha$^{-1}$) which was significantly different from other treatments; whereas, the lowest number of loose leaves plant$^{-1}$ (7.79, 10.82 and 15.78) was recorded from the control treatment $B_0$ (No B). Prasad and Yadav (2003) and Devi *et al.* (2012) also found similar result with the present study.

Number of loose leaves plant$^{-1}$ of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 2 and Appendix V). It was found that the highest number of loose leaves plant$^{-1}$ (11.79, 16.85 and 21.96) was observed from the treatment combination of $G_2B_1$ which was statistically identical with the treatment combination of $G_3B_1$. The lowest number of loose leaves plant$^{-1}$ (7.25, 9.76 and 14.91) was recorded from the treatment combination of $G_0B_0$ which was statistically similar with $G_1B_0$ and $G_3B_0$.

Table 2. Combined effect of $GA_3$ and boron on number of loose leaves plant$^{-1}$ of cabbage

| Treatments | Number of loose leaves plant$^{-1}$ | | |
|---|---|---|---|
| | 30 DAT | 50 DAT | At harvest |
| $G_0B_0$ | 7.25 h | 9.76 g | 14.91 g |
| $G_0B_1$ | 8.97 e | 13.09 de | 18.26 de |
| $G_0B_2$ | 8.58 ef | 12.74 de | 17.69 ef |
| $G_1B_0$ | 7.58 gh | 10.42 fg | 15.43 g |
| $G_1B_1$ | 10.50 bc | 14.13 c | 19.68 bc |
| $G_1B_2$ | 10.09 c | 14.52 bc | 18.96 cd |
| $G_2B_0$ | 8.33 f | 12.50 e | 17.14 f |
| $G_2B_1$ | 11.79 a | 16.58 a | 21.96 a |
| $G_2B_2$ | 10.88 b | 15.28 b | 20.09 b |
| $G_3B_0$ | 7.86 g | 10.68 f | 15.66 g |
| $G_3B_1$ | 11.45 a | 16.10 a | 21.55 a |
| $G_3B_2$ | 9.55 d | 13.48 d | 18.80 d |
| $LSD_{0.05}$ | 0.753 | 0.771 | 0.801 |
| CV(%) | 7.96 | 8.11 | 8.26 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B) ,$B_1$ = 4 kg B ha$^{-1}$, $B_2$ = 8 kg B ha$^{-1}$

### 4.1.3 Leaf length (cm)

Significant variation was found onleaf length of cabbage due to application different levels of $GA_3$ (Table 3 and Appendix VI). Results revealed that the highest leaf length (25.31 cm, 31.00 cm and 32.49 cm) at (30, 50 DATand at harvest respectively) was recorded from the treatment $G_3$ (130 ppm $GA_3$) which was statistically identical to $G_2$ (100 ppm $GA_3$) whereas the lowest leaf length (21.01, 25.49 and 27.25 cm) at 30, 50 DAT and at harvest, respectively was recorded from the control treatment $G_0$ (No $GA_3$).

Different levels of Boron showed significant variation on leaf length of cabbage as influenced by different doses of boron (B) (Table 3 and Appendix VI). Results indicated that the highest leaf length (24.95, 30.47 and 32.23 cm) was found from the treatment $B_2$ (8 kg B $ha^{-1}$) which was statistically identical with $B_1$ (4 kg B $ha^{-1}$) at 50 DAT and at harvest. The lowest leaf length (22.00, 26.78 and 28.50 cm) was recorded from the control treatment $B_0$ (No B). The result obtained from the present study was similar trends of the result of Bishnu *et al.* (2004).

Leaf length of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 3 and Appendix VI). It was found that the highest leaf length (26.48, 32.24 and 32.25 cm) was observed from the treatment combination of $G_3B_2$which showed statistically similar result to the treatment combination of $G_2B_2$ and $G_3B_1$.The lowest leaf length (19.75, 23.95 and 25.80 cm) was recorded from the treatment combination of $G_0B_0$ which was statistically similar with the treatment combination of $G_0B_1$.

Table 3. Effect of $GA_3$ and boron and their combined effect on leaf length of cabbage

| Treatments | Leaf length (cm) | | |
|---|---|---|---|
| | 30 DAT | 50 DAT | At harvest |
| Effect of $GA_3$ | | | |
| $G_0$ | 21.01 c | 25.49 c | 27.25 c |
| $G_1$ | 23.28 b | 28.44 b | 30.46 b |
| $G_2$ | 24.77 a | 30.24 a | 32.87 a |
| $G_3$ | 25.31 a | 31.00 a | 32.49 a |
| $LSD_{0.05}$ | 0.7043 | 0.8965 | 1.621 |
| CV(%) | 6.98 | 9.55 | 6.29 |
| Effect of boron | | | |
| $B_0$ | 22.00 c | 26.78 b | 28.50 b |
| $B_1$ | 23.82 b | 29.12 a | 31.57 a |
| $B_2$ | 24.95 a | 30.47 a | 32.23 a |
| $LSD_{0.05}$ | 0.9309 | 1.593 | 1.837 |
| CV(%) | 6.98 | 9.55 | 6.29 |
| Combined effect of $GA_3$ and boron | | | |
| $G_0B_0$ | 19.75 h | 23.95 g | 25.80 g |
| $G_0B_1$ | 20.47 gh | 24.70 fg | 26.55 g |
| $G_0B_2$ | 22.82 f | 27.80 e | 29.38 e |
| $G_1B_0$ | 21.02 g | 25.42 f | 27.38 f |
| $G_1B_1$ | 24.09 de | 29.81 cd | 31.65 c |
| $G_1B_2$ | 24.72 cd | 30.08 cd | 32.35 c |
| $G_2B_0$ | 23.36 ef | 28.36 e | 30.06 de |
| $G_2B_1$ | 25.14 bc | 30.60 bc | 33.64 b |
| $G_2B_2$ | 25.80 ab | 31.75 a | 34.92 a |
| $G_3B_0$ | 23.88 e | 29.38 d | 30.78 d |
| $G_3B_1$ | 25.57 b | 31.37 ab | 34.45 a |
| $G_3B_2$ | 26.48 a | 32.24 a | 32.25 c |
| $LSD_{0.05}$ | 0.7924 | 0.9888 | 0.7741 |
| CV(%) | 6.98 | 9.55 | 6.29 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (NO B), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

### 4.1.4 Leaf breadth (cm)

Significant influence was found on leaf breadth of cabbage as influenced by different levels of $GA_3$ (Table 4 and Appendix VII). Results revealed that the highest leaf breadth (14.79, 18.64 and 20.53 cm) at (30, 50 DAT and at harvest, respectively) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was significantly different from other treatments which was followed by $G_3$ (130 ppm $GA_3$) and the lowest leaf breadth (12.18, 14.62 and 15.81 cm) was recorded from the control treatment $G_0$ (No $GA_3$).

Different levels of Boron showed significant variation on leaf breadth of cabbage (Table 4 and Appendix VII). Results indicated that the highest leaf breadth (15.20, 18.87 and 20.37 cm) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which was statistically identical with $B_2$ (8 kg B $ha^{-1}$) at 30 and 50 DAT but at harvest it was significantly different. The lowest leaf breadth (11.04, 13.58 and 14.99 cm) was recorded from the control treatment $B_0$ (No B) which was significantly different from other treatments.

Leaf breadth of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 4 and Appendix VII). It was found that the highest leaf breadth (16.44, 21.08 and 23.24 cm) was observed from the treatment combination of $G_2B_1$ which was statistically identical to the treatment combination of $G_3B_1$. The lowest leaf breadth (10.27, 12.99 and 14.17 cm) was recorded from the treatment combination of $G_0B_0$ which was statistically identical to the treatment combination of $G_1B_0$ and $G_3B_0$.

Table 4. Effect of $GA_3$ and boron and their combined effect on leaf breadth of cabbage

| Treatments | Leaf breadth (cm) | | |
|---|---|---|---|
| | 30 DAT | 50 DAT | At harvest |
| Effect of $GA_3$ | | | |
| $G_0$ | 12.18 c | 14.62 c | 15.81 d |
| $G_1$ | 13.32 b | 16.23 b | 17.05 c |
| $G_2$ | 14.79 a | 18.64 a | 20.53 a |
| $G_3$ | 13.62 b | 16.99 b | 18.40 b |
| $LSD_{0.05}$ | 0.5556 | 0.8014 | 0.9912 |
| CV(%) | 7.21 | 8.67 | 8.19 |
| Effect of boron | | | |
| $B_0$ | 11.04 b | 13.58 b | 14.99 c |
| $B_1$ | 15.20 a | 18.87 a | 20.37 a |
| $B_2$ | 14.19 a | 17.41 a | 18.47 b |
| $LSD_{0.05}$ | 1.290 | 1.060 | 1.802 |
| CV(%) | 7.21 | 8.67 | 8.19 |
| Combined effect of $GA_3$ and boron | | | |
| $G_0B_0$ | 10.27 g | 12.99 f | 14.17 e |
| $G_0B_1$ | 13.36 ef | 15.62 cd | 16.72 cd |
| $G_0B_2$ | 12.92 ef | 15.24 d | 16.52 cd |
| $G_1B_0$ | 10.62 g | 13.28 ef | 14.60 e |
| $G_1B_1$ | 14.94 bc | 18.05 b | 18.69 b |
| $G_1B_2$ | 14.41 cd | 17.36 b | 17.85 bc |
| $G_2B_0$ | 12.36 f | 14.62 de | 16.24 d |
| $G_2B_1$ | 16.44 a | 21.08 a | 23.24 a |
| $G_2B_2$ | 15.58 ab | 20.23 a | 22.12 a |
| $G_3B_0$ | 10.92 g | 13.42 ef | 14.96 e |
| $G_3B_1$ | 16.07 a | 20.74 a | 22.83 a |
| $G_3B_2$ | 13.87 de | 16.80 bc | 17.40 cd |
| $LSD_{0.05}$ | 0.9624 | 1.281 | 1.230 |
| CV(%) | 7.21 | 8.67 | 8.19 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

### 4.1.5Plant spread (cm)

Significant variation was found on plant spread due to application of different concentration of $GA_3$ (Table 5 and Appendix VIII). The highest plant spread (23.60, 48.42 and 61.81 cm) at (30,50DAT and at harvest respectively) was recorded in $G_3$ (130 ppm $GA_3$) which was statistically identical to $G_2$ (100 ppm $GA_3$) whereas the lowest plant spread (15.46, 36.40 and 50.87 cm) was recorded from the control treatment $G_0$ (No $GA_3$). Similar trends of the result also observed by Singh (2018) and Lendve *et al.* (2010).

Different levels of Boron showed significant variation on plant spread of cabbage (Table 5 and Appendix VIII). Results indicated that the highest plant spread (23.30, 47.59 and 60.53 cm) was found from the treatment $B_2$ (8 kg B $ha^{-1}$) which was significantly different from other treatments at all growth stages followed by $B_1$ (4 kg B $ha^{-1}$) whereas the lowest plant spread (16.70, 38.96 and 51.55 cm) was recorded from the control treatment $B_0$ (No B). Similar trends of result also observed by Singh *et al.* (2003).

Plant spread of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 5 and Appendix VIII). It was found that the highest plant spread (27.06, 52.99 and 62.76 cm) was observed from the treatment combination of $G_3B_2$ which was statistically identical to the treatment combination of $G_2B_2$. The lowest plant spread (13.92, 34.84 and 47.52 cm) was recorded from the treatment combination of $G_0B_0$ which was statistically identical with the treatment combination of $G_0B_1$ and $G_1B_0$.

Table 5. Effect of $GA_3$ and boron and their combined effect on plant spread of cabbage

| Treatments | Plant spread (cm) | | |
|---|---|---|---|
| | 30 DAT | 50 DAT | At harvest |
| Effect of $GA_3$ | | | |
| $G_0$ | 15.46 c | 36.40 c | 50.87 c |
| $G_1$ | 19.50 b | 42.71 b | 54.07 b |
| $G_2$ | 22.29 a | 47.24 a | 59.60 a |
| $G_3$ | 23.60 a | 48.42 a | 61.81 a |
| $LSD_{0.05}$ | 1.53 | 2.671 | 2.021 |
| Effect of boron | | | |
| $B_0$ | 16.70 c | 38.96 c | 51.55 c |
| $B_1$ | 20.65 b | 44.53 b | 56.09 b |
| $B_2$ | 23.30 a | 47.59 a | 60.53 a |
| $LSD_{0.05}$ | 2.08 | 2.223 | 2.942 |
| Combined effect of $GA_3$ and boron | | | |
| $G_0B_0$ | 13.92 f | 34.84 h | 47.52 f |
| $G_0B_1$ | 14.58 f | 35.62 h | 48.62 f |
| $G_0B_2$ | 17.43 e | 40.45 g | 51.78 e |
| $G_1B_0$ | 15.18 f | 36.48 h | 49.92 f |
| $G_1B_1$ | 21.10 c | 46.03 d | 54.41 d |
| $G_1B_2$ | 21.78 c | 47.33 cd | 55.19 cd |
| $G_2B_0$ | 17.83 de | 42.52 f | 52.44 e |
| $G_2B_1$ | 22.29 c | 48.96 bc | 56.58 bc |
| $G_2B_2$ | 26.31 a | 51.96 a | 61.30 a |
| $G_3B_0$ | 19.25 d | 40.28 e | 53.42 de |
| $G_3B_1$ | 24.04 b | 49.78 b | 57.85 b |
| $G_3B_2$ | 27.06 a | 52.99 a | 62.76 a |
| $LSD_{0.05}$ | 1.823 | 1.867 | 1.863 |
| CV(%) | 8.88 | 9.09 | 8.34 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

## 4.2 Yield contributing parameters

### 4.2.1 Percent (%) dry matter of stem

Significant influence was found on percent dry matter of cabbage stem due to application of different concentrations of $GA_3$ (Table 6 and Appendix IX). The highest dry matter of stem (12.89%) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$) whereas the lowest dry matter of stem (11.12%) was recorded from the control treatment $G_0$ (No $GA_3$). Chauhan and Tandel (2009) agreed to the findings of the present study.

Different levels of Boron showed significant variation on percent dry matter of cabbage stem (Table 6 and Appendix IX). Results indicated that the highest dry matter of stem (13.17%) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which was statistically identical to $B_2$ (8 kg B $ha^{-1}$) whereas the lowest dry matter of stem (10.65%) was recorded from the control treatment $B_0$ (No B). Similar trends of result were also observed by Devi *et al.* (2012).

Percent dry matter of cabbage stem was varied significantly due to combined effect of $GA_3$ and boron (Table 6 and Appendix IX). It was found that the highest dry matter of stem (13.77%) was observed from the treatment combination of $G_2B_1$ which was statistically identical to the treatment combination of $G_2B_2$, $G_3B_1$ and $G_1B_1$. The lowest dry matter of stem (9.78%) was recorded from the treatment combination of $G_0B_0$ which was statistically similar to the treatment combination of $G_1B_0$.

### 4.2.2Head diameter (cm)

Significant variation was found on head diameter of cabbage due to application of different levels of $GA_3$ (Table 6 and Appendix IX). Results revealed that the highest head diameter (14.68 cm) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$) whereas the lowest head diameter (12.25 cm) was recorded from the control treatment $G_0$ (No

$GA_3$). The result obtained from the present study was similar trends of the findings of Roy and Nasiruddin (2011) who found that 50 ppm $GA_3$ gave the highest diameter (23.81 cm) of cabbage head.

Significant differences were observed on head diameter due to application Boron (Table 6 and Appendix IX). Results indicated that the highest head diameter (14.59 cm) was found from $B_1$ (4 kg B $ha^{-1}$) which was statistically identical to $B_2$ (8 kg B $ha^{-1}$) whereas the lowest head diameter (11.51 cm) was recorded from the control treatment $B_0$ (No B). The result obtained from the present study was similar with the findings of Devi *et al.* (2012).

Head diameter of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 6 and Appendix IX). It was found that the highest head diameter (15.12 cm) was observed from the treatment combination of $G_2B_1$ which was statistically similar to the treatment combination of $G_3B_1$. The lowest head diameter (10.21 cm) was recorded from the treatment combination of $G_0B_0$which showed significantly similar result with the treatment combination of $G_1B_0$.

**4.2.3 Thickness of head (cm)**

Significant influence was found on thickness of cabbage head as influenced by different doses of $GA_3$ (Table 6 and Appendix IX). The highest thickness of head (15.80 cm) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$) and the lowest thickness of head (13.01 cm) was recorded from the control treatment $G_0$ (No $GA_3$). Similar trends of result were also observed by Singh (2018).

Different levels of Boron showed significant variation on thickness of cabbage head (Table 6 and Appendix IX). Results indicated that the highest thickness of head (15.12 cm) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which was statistically similar to $B_2$ (8 kg B $ha^{-1}$) whereas the lowest thickness of head (12.13 cm) was recorded from the control treatment $B_0$ (No B).

Table 6. Effect of $GA_3$ and boron and their combined effect on yield contributing parameters of cabbage.

| Treatments | Yield contributing parameters | | | | |
|---|---|---|---|---|---|
| | % dry matter of stem | Head diameter (cm) | Thickness of head (cm) | Stem length at harvest (cm) | % dry matter of head |
| Effect of $GA_3$ | | | | | |
| $G_0$ | 11.12 c | 12.25 c | 13.01 c | 15.20 c | 7.81 c |
| $G_1$ | 11.93 b | 13.26 b | 13.91 b | 17.40 b | 8.25 b |
| $G_2$ | 12.89 a | 14.68 a | 15.80 a | 19.00 a | 8.68 a |
| $G_3$ | 12.09 b | 13.54 b | 14.24 b | 20.07 b | 8.35 b |
| $LSD_{0.05}$ | 0.444 | 0.419 | 0.827 | 0.631 | 0.310 |
| Effect of boron | | | | | |
| $B_0$ | 10.65 b | 11.51 b | 12.13 b | 14.87 c | 7.44 b |
| $B_1$ | 13.17 a | 14.58 a | 15.12 a | 16.81 a | 8.82 a |
| $B_2$ | 12.56 a | 13.91 a | 14.68 a | 15.33 b | 8.55 a |
| $LSD_{0.05}$ | 1.578 | 0.777 | 1.381 | 0.187 | 0.282 |
| Combined effect of $GA_3$ and boron | | | | | |
| $G_0B_0$ | 9.78 g | 10.21 g | 11.86 f | 13.36 g | 7.17 f |
| $G_0B_1$ | 12.16 cd | 12.39 e | 14.33 cd | 13.94 de | 8.28 d |
| $G_0B_2$ | 11.66 de | 12.52 e | 13.43 de | 13.73 e | 8.00 de |
| $G_1B_0$ | 10.39 fg | 10.45 fg | 12.18 f | 13.49 fg | 7.23 f |
| $G_1B_1$ | 13.19 ab | 14.19 c | 15.27 abc | 14.45 bc | 8.79 bc |
| $G_1B_2$ | 12.72 bc | 13.55 d | 14.84 bc | 14.29 c | 8.74 bc |
| $G_2B_0$ | 11.43 e | 13.16 e | 13.03 e | 13.78 e | 7.90 e |
| $G_2B_1$ | 13.77 a | 15.12 a | 16.19 a | 15.04 a | 9.20 a |
| $G_2B_2$ | 13.32 a | 14.45 bc | 15.58 ab | 14.58 b | 8.93 ab |
| $G_3B_0$ | 10.67 f | 10.82 f | 12.51 ef | 13.57 f | 7.46 f |
| $G_3B_1$ | 13.56 a | 14.86 ab | 15.93 a | 14.90 a | 9.02 ab |
| $G_3B_2$ | 12.54 c | 13.33 d | 14.89 bc | 14.06 d | 8.56 c |
| $LSD_{0.05}$ | 0.567 | 0.570 | 0.950 | 0.189 | 0.283 |
| CV(%) | 8.67 | 8.42 | 7.50 | 8.80 | 6.03 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

Thickness of cabbage head was varied significantly due to combined effect of $GA_3$ and boron (Table 6 and Appendix IX). It was found that the highest thickness of head (16.19 cm) was observed from the treatment combination of $G_2B_1$ which was statistically similar with the treatment combination of $G_3B_1$ and $G_2B_2$. The lowest thickness of head (11.06 cm) was recorded from the treatment combination of $G_0B_0$ which was statistically identical with the treatment combination of $G_1B_0$.

### 4.2.4 Stem length at harvest (cm)

Significant influence was found on stem length at harvest of cabbage due to application of different doses of $GA_3$ (Table 6 and Appendix IX). Results revealed that the highest stem length at harvest (19.00 cm) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$) whereas the lowest stem length at harvest (15.20 cm) was recorded from the control treatment $G_0$ (No $GA_3$). Lendve *et al.* (2010) reported similar findings from their earlier experiment.

Different levels of Boron showed significant variation on stem length at harvest of cabbage due to application of different levels of boron (B) (Table 6 and Appendix IX). The highest stem length at harvest (16.81 cm) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which was significantly different from other treatments followed by $B_2$ (8 kg B $ha^{-1}$) whereas the lowest stem length at harvest (14.87 cm) was recorded from the control treatment $B_0$ (No B). The result obtained from the present study was similar with the findings of Prasad and Yadav (2003).

Stem length at harvest of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 6 and Appendix IX). It was found that the highest stem length at harvest (15.04 cm) was observed from the treatment combination of $G_2B_1$ which showed similar to combination of $G_3B_1$.The lowest stem length at harvest (13.36 cm) was recorded from the treatment combination of $G_0B_0$ which showed significantly similar result to the treatment combination of $G_1B_0$.

### 4.2.5 Percent (%) dry matter of head

Significant influence was found on percent dry matter of head of cabbage as influenced by different doses of $GA_3$ (Table 6 and Appendix IX). Results revealed that the highest dry matter of head (8.68%) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which showed significantly different result from other treatments followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$) and the lowest dry matter of head (7.81%) was recorded from the control treatment $G_0$ (No $GA_3$). Devi *et al.* (2012) and Dharmander *et al.* (1996) got the similar trend of results in their observation.

Different levels of Boron showed significant variation on percent dry matter of head of cabbage (Table 6 and Appendix IX). Results indicated that the highest dry matter of head (8.82%) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which showed significantly similar result with $B_2$ (8 kg B $ha^{-1}$) whereas the lowest dry matter of head (7.44%) was recorded from the control treatment $B_0$ (No B).

Percent dry matter of head of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 6 and Appendix IX). It was found that the highest dry matter of head (9.20%) was observed from the treatment combination of $G_2B_1$ which was statistically similar with the treatment combination of $G_2B_2$ and $G_3B_1$. The lowest dry matter of head (7.17%) was recorded from the treatment combination of $G_0B_0$ which showed significantly identical result with the treatment combination of $G_1B_0$ and $G_3B_0$.

## 4.3 Yield parameters

### 4.3.1 Fresh weight of head plant$^{-1}$ (g)

Significant variations were found on fresh weight of head plant$^{-1}$ of cabbage as influenced by different concentration of $GA_3$ (Table 7 and Appendix X). Results revealed that the highest fresh weight plant$^{-1}$ (1547.00 g) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was statistically different from other treatments whereas the lowest fresh weight plant$^{-1}$ (1346.00 g) was recorded from the control treatment $G_0$ (No $GA_3$). The result obtained from the present study was similar trends of the findings of Lendve *et al.* (2010).

Different levels of Boron performed significant variation on fresh weight plant$^{-1}$ of cabbage (Table 7 and Appendix X). Results indicated that the highest fresh weight plant$^{-1}$ (1580.00 g) was found from the treatment $B_1$ (4 kg B ha$^{-1}$) which showed significantly different result from other treatments followed by $B_2$ (8 kg B ha$^{-1}$) whereas the lowest fresh weight plant$^{-1}$ (1270.00 g) was recorded from the control treatment $B_0$ (No B).

Fresh weight plant$^{-1}$of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). It was found that the highest fresh weight plant$^{-1}$(1688.00 g) was observed from the treatment combination of $G_2B_1$ which was followed by $G_3B_1$. The lowest fresh weight plant$^{-1}$(1235.00 g) was recorded from the treatment combination of $G_0B_0$.

### 4.3.2Gross yield plot$^{-1}$ (kg)

Significant variation was found on gross yield plot$^{-1}$of cabbage due to application of different levels of $GA_3$ (Table 7 and Appendix X). The highest gross yield plot$^{-1}$(18.56 kg) was recorded from the treatment $G_2$ (100 ppm $GA_3$) which was significantly different from other treatments; whereas, the lowest gross yield plot$^{-1}$ (16.15 kg) was recorded from the control treatment $G_0$ (No $GA_3$).

Different levels of Boron showed significant variation on gross yield plot$^{-1}$of cabbage (Table 7 and Appendix X). Results indicated that the highest gross yield plot$^{-1}$ (18.96 kg) was found from the treatment $B_1$ (4 kg B ha$^{-1}$) followed by $B_2$ (8 kg B ha$^{-1}$) whereas the lowest gross yield plot$^{-1}$ (15.24 kg) was recorded from the control treatment $B_0$ (No B).

Gross yield plot$^{-1}$of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). The highest gross yield plot$^{-1}$ (20.25 kg) was recorded from the treatment combination $G_2B_1$, which showed significantly similar result with $G_3B_1$. The lowest gross yield plot$^{-1}$ (14.82 kg) was recorded in $G_0B_0$ which was statistically identical to $G_1B_0$.

### 4.3.3 Gross yield ha$^{-1}$ (t)

Different concentration of $GA_3$ showed significant difference on gross yield ha$^{-1}$of cabbage (Table 7 and Appendix X). Results revealed that the highest gross yield (51.56 t ha$^{-1}$) was calculated from the treatment $G_2$ (100 ppm $GA_3$), which showed significantly different result from other treatments; whereas, the lowest gross yield (44.85 t ha$^{-1}$) was from the control treatment $G_0$ (No $GA_3$).

Different levels of boron had also significant effect on gross yield ha$^{-1}$of cabbage (Table 7 and Appendix X). The highest gross yield (52.67 t ha$^{-1}$) was computed from the treatment $B_1$ (4 kg B ha$^{-1}$) followed by $B_2$ (8 kg B ha$^{-1}$); whereas, the lowest gross yield (42.33 t ha$^{-1}$) was computed from the control treatment $B_0$ (No B).

Gross yield ha$^{-1}$of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). It was found that the highest gross yield (56.25 t ha$^{-1}$) was calculated from $G_2B_1$, which was statistically similar to $G_3B_1$; whereas, the lowest gross yield ha$^{-1}$ (41.18 t ha$^{-1}$) was recorded from $G_0B_0$.

Table 7. Effect of $GA_3$ and boron on fresh weight plant$^{-1}$, gross yield plot$^{-1}$, gross yield ha$^{-1}$, marketable yield plant$^{-1}$ and marketable yield plot$^{-1}$.

| Treatments | | Yield parameters | | | |
|---|---|---|---|---|---|
| | Fresh weight plant$^{-1}$ (g) | Marketable yield plant$^{-1}$ (g) | Gross yield plot$^{-1}$ (kg) | Marketable yield plot$^{-1}$ (kg) | Gross yield ha$^{-1}$ (t) |
| Effect of $GA_3$ | | | | | |
| $G_0$ | 1346.00 d | 1183.00 d | 16.15 c | 14.19 c | 44.85 d |
| $G_1$ | 1416.00 c | 1248.00 c | 16.99 b | 14.97 b | 47.21 c |
| $G_2$ | 1547.00 a | 1324.00 a | 18.56 a | 15.89 a | 51.56 a |
| $G_3$ | 1449.00 b | 1262.00 b | 17.39 b | 15.15 b | 48.31 b |
| $LSD_{0.05}$ | 6.354 | 7.903 | 0.5650 | 0.3213 | 0.5426 |
| CV(%) | 10.08 | 8.46 | 10.07 | 8.47 | 10.08 |
| Effect of boron | | | | | |
| $B_0$ | 1270.00 c | 1097.00 c | 15.24 c | 13.17 b | 42.33 c |
| $B_1$ | 1580.00 a | 1361.00 a | 18.96 a | 16.34 a | 52.67 a |
| $B_2$ | 1468.00 b | 1304.00 b | 17.62 b | 15.65 a | 48.94 b |
| $LSD_{0.05}$ | 5.758 | 5.695 | 0.8972 | 1.257 | 1.530 |
| CV(%) | 10.08 | 8.46 | 10.07 | 8.47 | 10.08 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B), $B_1$ = 4 kg B ha$^{-1}$, $B_2$ = 8 kg B ha$^{-1}$

### 4.3.4 Marketable yield plant$^{-1}$ (g)

Significant influence was found on marketable yield plant$^{-1}$ of cabbage as due to application of different levels of $GA_3$ (Table 7 and Appendix X). The highest marketable yield plant$^{-1}$ (1324.00 g) was recorded from the treatment $G_2$ (100 ppm $GA_3$) followed by $G_3$ (130 ppm $GA_3$); whereas, the lowest marketable yield plant$^{-1}$ (1183.00 g) was recorded from the control treatment $G_0$ (No $GA_3$).

Different levels of Boron showed significant variation on marketable yield plant$^{-1}$ of cabbage (Table 7 and Appendix X). Results indicated that the highest marketable yield plant$^{-1}$ (1361.00 g) was found from the treatment $B_1$ (4 kg B ha$^{-1}$)

followed by $B_2$ (8 kg B $ha^{-1}$); whereas, the lowest marketable yield $plant^{-1}$ (1097.00 g) was recorded from the control treatment $B_0$ (No B).

Marketable yield $plant^{-1}$ of cabbage varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). It was found that the highest marketable yield $plant^{-1}$ (1431.00 g) was observed from the treatment combination of $G_2B_1$ which was followed by $G_3B_1$. The lowest marketable yield $plant^{-1}$ (1035.00 g) was performed by treatment combination of $G_0B_0$.

### 4.3.5 Marketable yield $plot^{-1}$ (kg)

Significant influence was found for marketable yield $plot^{-1}$of cabbage as affected by different doses of $GA_3$ (Table 7 and Appendix X). Results revealed that the highest marketable yield $plot^{-1}$ (15.89 kg) was recorded from $G_2$ (100 ppm $GA_3$) which was followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$); whereas, the lowest marketable yield $plot^{-1}$ (14.19 kg) was recorded from the control treatment.

Different levels of Boron showed significant variation on marketable yield $plot^{-1}$ of cabbage (Table 7 and Appendix X). Results indicated that the highest marketable yield $plot^{-1}$(16.34 kg) was found from the treatment $B_1$ (4 kg B $ha^{-1}$) which was statistically identical to $B_2$ (8 kg B $ha^{-1}$); whereas, the lowest marketable yield $plot^{-1}$ (13.17 kg) was recorded from the control treatment $B_0$ (No B).

Marketable yield $plot^{-1}$ of cabbage varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). It was found that the highest marketable yield $plot^{-1}$ (17.18 kg) was observed from $G_2B_1$ which was statistically similar to $G_3B_1$. The lowest marketable yield $plot^{-1}$ (12.42 kg) was recorded from $G_0B_0$ which showed statistically similar result to $G_1B_0$.

### 4.3.6 Marketable yield $ha^{-1}$ (t)

Significant variations were found on marketable yield $ha^{-1}$of cabbage due to application of different doses of $GA_3$ (Fig. 5 and Appendix X). Results revealed that the highest marketable yield $ha^{-1}$(44.13 t $ha^{-1}$) was recorded from $G_2$ (100 ppm $GA_3$) which was followed by $G_1$ (70 ppm $GA_3$) and $G_3$ (130 ppm $GA_3$). The lowest marketable yield $ha^{-1}$(39.43 t $ha^{-1}$) was found from control treatment $G_0$ (No $GA_3$). Generally, $GA_3$ increased yield contributing characters and finally the yield of cabbage (Islam 1985). Similar result was also observed by Singh (2018). Patil *et al.* (1987) reported the maximum yield (63.83 t $ha^{-1}$) with 50 ppm, $GA_3$). Islam *et al.* (1993) also reported that two sprays with 50 ppm $GA_3$ was suitable for higher yield of cabbage.

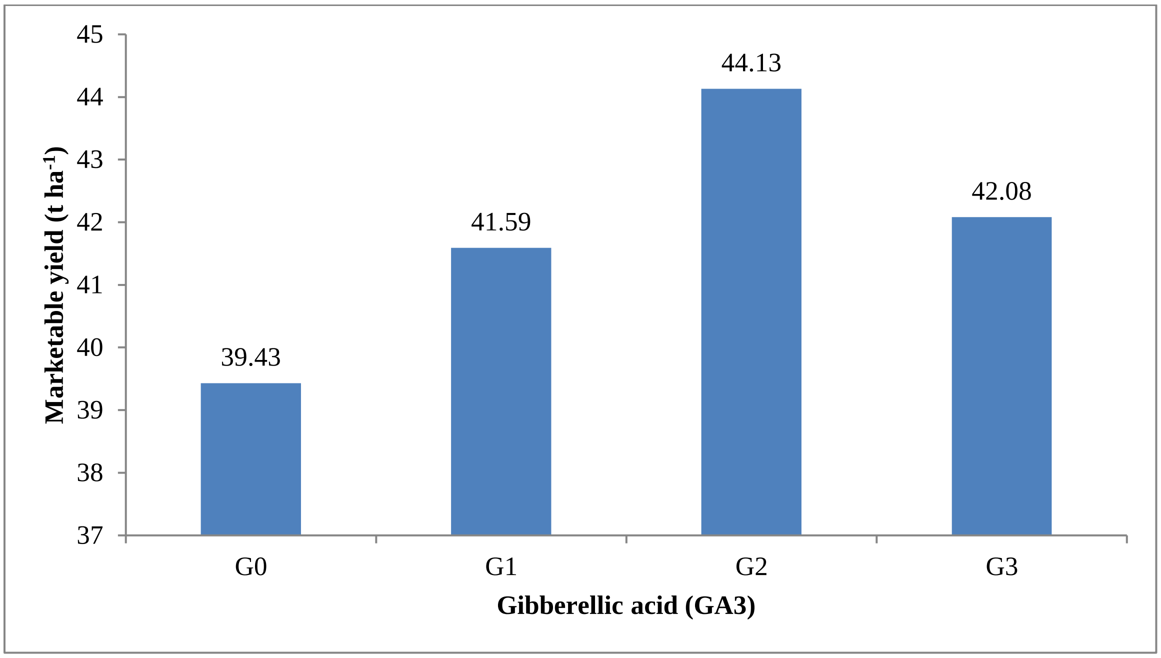



Fig. 5. Effect of $GA_3$ on marketable yield of cabbage ($LSD_{0.05}$ = 1.006)

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

Different levels of Boron showed significant variation on marketable yield $ha^{-1}$of cabbage (Fig. 6 and Appendix X). The highest marketable yield $ha^{-1}$ (45.38 t $ha^{-1}$) was found from $B_1$ (4 kg B $ha^{-1}$) which was followed by $B_2$ (8 kg B $ha^{-1}$) whereas the lowest marketable yield $ha^{-1}$(36.57 t $ha^{-1}$) was recorded from the control treatment $B_0$ (No B). The result obtained from the present study was similar trends of the findings of Devi *et al.* (2012) and Hussain *et al.* (2012).

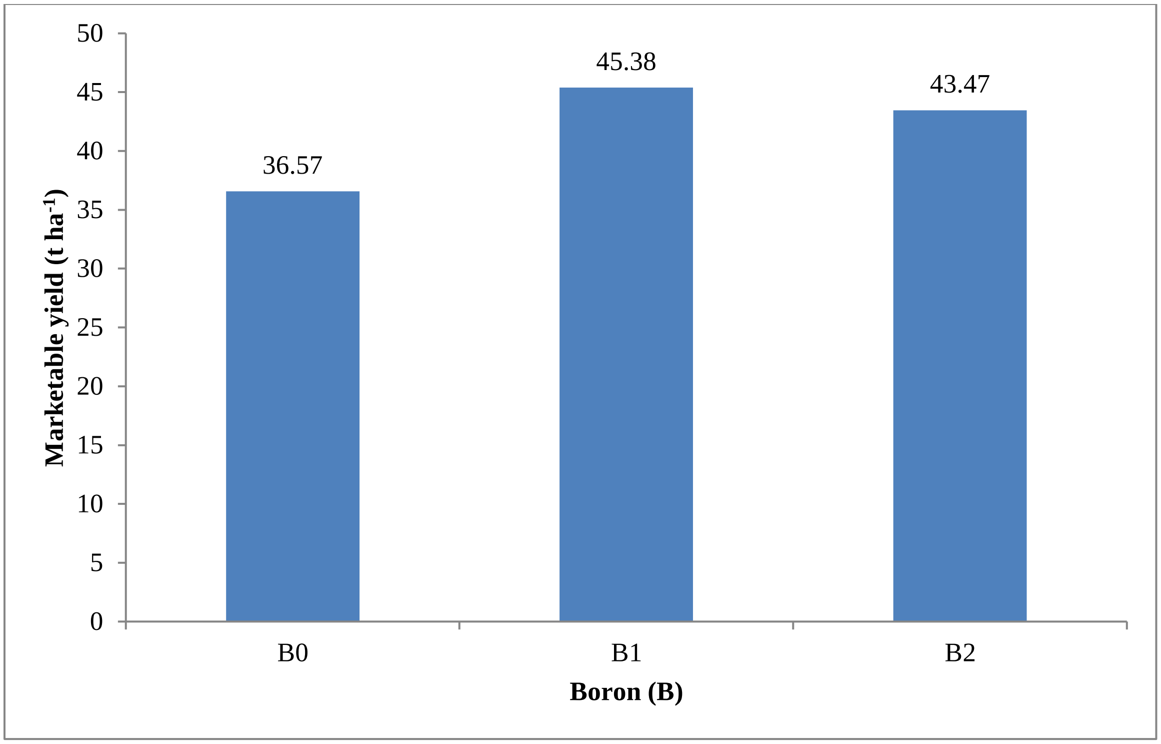



Fig. 6. Effect of boron on marketable yield $ha^{-1}$ of cabbage ($LSD_{0.05}$ = 1.232)

$B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

Marketable yield $ha^{-1}$of cabbage was varied significantly due to combined effect of $GA_3$ and boron (Table 8 and Appendix X). It was found that the highest marketable yield $ha^{-1}$ (47.71 t $ha^{-1}$) was observed from the treatment combination of $G_2B_1$ which was statistically similar with the treatment combination of $G_3B_1$. The lowest marketable yield $ha^{-1}$ (34.49 t $ha^{-1}$) was recorded from the treatment combination of $G_0B_0$ which was statistically similar with the treatment combination of $G_1B_0$.

Table 8. Combined effect of $GA_3$ and boron on yield parameters of cabbage

| Treatments | Yield parameters | | | | | |
|---|---|---|---|---|---|---|
| | Fresh weight plant$^{-1}$ (g) | Marketable yield plant$^{-1}$ (g) | Gross yield plot$^{-1}$ (kg) | Marketable yield plot$^{-1}$ (kg) | Gross yield ha$^{-1}$ (t) | Marketable yield ha$^{-1}$ (t) |
| $G_0B_0$ | 1235.00 j | 1035.00 k | 14.82 g | 12.42 h | 41.18 g | 34.49 h |
| $G_0B_1$ | 1422.00 f | 1271.00 f | 17.07 de | 15.25 de | 47.41 de | 42.36 de |
| $G_0B_2$ | 1379.00 g | 1243.00 g | 16.55 ef | 14.92 e | 45.96 ef | 41.44 e |
| $G_1B_0$ | 1236.00 j | 1076.00 j | 14.84 g | 12.92 gh | 41.22 g | 35.88 gh |
| $G_1B_1$ | 1564.00 d | 1354.00 c | 18.77 c | 16.25 bc | 52.15 c | 45.12 bc |
| $G_1B_2$ | 1448.00 e | 1313.00 d | 17.38 d | 15.76 cd | 48.26 d | 43.78 cd |
| $G_2B_0$ | 1352.00 h | 1176.00 h | 16.22 f | 14.11 f | 45.05 f | 39.21 f |
| $G_2B_1$ | 1688.00 a | 1431.00 a | 20.25 a | 17.18 a | 56.25 a | 47.71 a |
| $G_2B_2$ | 1601.00 c | 1364.00 c | 19.21 bc | 16.37 b | 53.37 bc | 45.48 bc |
| $G_3B_0$ | 1256.00 i | 1102.00 i | 15.08 g | 13.22 g | 41.88 g | 36.73 g |
| $G_3B_1$ | 1646.00 b | 1389.00 b | 19.76 ab | 16.67 ab | 54.88 ab | 46.31 ab |
| $G_3B_2$ | 1445.00 e | 1296.00 e | 17.34 d | 15.56 d | 48.16 d | 43.21 de |
| $LSD_{0.05}$ | 10.87 | 12.25 | 0.6199 | 0.5565 | 1.907 | 1.742 |
| CV(%) | 10.08 | 8.46 | 10.07 | 8.47 | 10.08 | 8.46 |

Means followed by same letter(s) in a column do not differ significantly at 5% level of LSD.

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B), $B_1$ = 4 kg B ha$^{-1}$, $B_2$ = 8 kg B ha$^{-1}$

### 4.4 Partial economic analysis

For the calculation of cost of production, all material and non-material input cost like land preparation, cabbage seed cost, manure and fertilizer cost, boron and $GA_3$ purchase cost, application cost of irrigation and manpower for all the operation, interest on fixed capital of land (Leased land by loan basis) and miscellaneous cost were considered from planting seed to harvesting of cabbage per hectare basis (Table 9 and Appendix XI). Price of cabbage was considered at market rate @ Tk. 12 kg$^{-1}$. The economic analysis is presented under the following headlines:

### 4.4.1 Total cost of production

Different combination of $GA_3$ and boron showed dissimilarity in terms of cost of production $ha^{-1}$ (Table 9 and Appendix XI). The highest cost of production $ha^{-1}$ (Tk184379) was obtained from the treatment combination of $G_3B_2$ (130 ppm $GA_3$ + 8 kg B $ha^{-1}$) followed by $G_2B_1$. The lowest gross return (Tk172039) obtained from the treatment combination of $G_0B_0$ (No $GA_3$ +No B) which is very nearest to the treatment combination of $G_1B_1$.

### 4.4.2 Gross return

Different combination of $GA_3$ and boron showed dissimilarity in gross return (Table 9 and Appendix XI). Gross return was calculated on the basis of sale of cabbage. The highest gross return (Tk. 572520) was obtained from the treatment combination of $G_2B_1$ (100 ppm $GA_3$ + 4 kg B $ha^{-1}$) followed by $G_3B_1$ and $G_2B_2$ (Tk. 555720 and 545760, respectively) which also showed promising results on gross return. The lowest gross return (Tk. 413880) obtained from the treatment combination of $G_0B_0$ (No $GA_3$+No B) which is very nearest to the treatment combination of $G_1B_0$.

### 4.4.3 Net return

Different combination of $GA_3$ and boron showed significant variation in net returns (Table 9 and Appendix XI). The highest net return (Tk. 392400) was obtained from the treatment combination of $G_2B_1$ (100 ppm $GA_3$ + 4 kg B $ha^{-1}$) followed by the treatment combination of $G_3B_1$ and $G_2B_2$ which showed second and third highest net return, respectively (Tk. 373962 and 363019, respectively) compared to other treatment combinations. The lowest net return (Tk. 241841) obtained from the treatment combination of $G_0B_0$ (No $GA_3$ + No B) which was nearest to the treatment combination of $G_1B_0$ (Tk. 254699).

### 4.4.4 Benefit cost ratio (BCR)

Different combination of $GA_3$ and boron showed significant variation on benefit cost ration (BCR) for cabbage production (Table 9 and Appendix XI). Results showed that the highest BCR (3.18) was found from the treatment combination of $G_2B_1$ (100 ppm $GA_3$ + 4 kg B $ha^{-1}$) followed by $G_1B_1$ and $G_3B_1$ (3.03 and 3.06, respectively). The lowest BCR (2.40) was obtained from the treatment combination of $G_0B_0$ (No $GA_3$ + No B) which was very close to the treatment combination of $G_1B_0$ (2.41).

From economic point of view, it was evident from the above results that the treatment combination of $G_2B_1$ (100 ppm $GA_3$ + 4 kg B $ha^{-1}$) and also $G_1B_1$ (70 ppm $GA_3$ + 4 kg B $ha^{-1}$) and $G_2B_2$ (100ppm $GA_3$ + 8 kg B $ha^{-1}$) were more profitable than rest of the treatment combinations.

Table 9. Partial economic analysis of cabbage production as influenced by $GA_3$ and boron

| Treatments | Yield ($t\ ha^{-1}$) | Total cost of production (Tk. $ha^{-1}$) | Gross return (Tk. $ha^{-1}$) | Net return (Tk. $ha^{-1}$) | BCR |
|---|---|---|---|---|---|
| $G_0B_0$ | 34.49 | 172039 | 413880 | 241841 | 2.40 |
| $G_0B_1$ | 42.36 | 174660 | 508320 | 333660 | 2.91 |
| $G_0B_2$ | 41.44 | 177281 | 497280 | 319999 | 2.81 |
| $G_1B_0$ | 35.88 | 175861 | 430560 | 254699 | 2.45 |
| $G_1B_1$ | 45.12 | 178482 | 541440 | 362958 | 3.03 |
| $G_1B_2$ | 43.78 | 181103 | 525360 | 344257 | 2.90 |
| $G_2B_0$ | 39.21 | 177499 | 470520 | 293021 | 2.65 |
| $G_2B_1$ | 47.71 | 180120 | 572520 | 392400 | 3.18 |
| $G_2B_2$ | 45.48 | 182741 | 545760 | 363019 | 2.99 |
| $G_3B_0$ | 36.73 | 179137 | 440760 | 261623 | 2.46 |
| $G_3B_1$ | 46.31 | 181758 | 555720 | 373962 | 3.06 |
| $G_3B_2$ | 43.21 | 184379 | 518520 | 334141 | 2.81 |

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B $ha^{-1}$), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

# Chapter V

# Summary and Conclusion

# CHAPTER V

## SUMMARY AND CONCLUSION

An experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka to study the growth and yield of cabbage as influenced by different levels of boron and gibberellic acid ($GA_3$). The experiment comprised of two different factors such as (1) four $GA_3$ levels *viz*. $G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$ and $G_3$ = 130 ppm $GA_3$ and (2) three levels of boron application *viz*. $B_0$ = Control (No B), $B_1$ = 4 kg B $ha^{-1}$ and $B_2$ = 8 kg B $ha^{-1}$. The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 12 treatment combinations. The experimental plot was treated as per treatment with $GA_3$ and boron. Data on different growth and yield and yield contributing parameters and also on cost of production were recorded and analyzed statistically. Results showed all the parameters studied in the present study were significantly influenced by different levels of $GA_3$, boron (B) and their combined effect.

Different growth parameters, influenced by $GA_3$, the highest plant height (25.28, 37.61 and 50.65 cm), leaf length (25.31, 31.00 and 32.49 cm) and plant spread (23.60, 48.42 and 61.81cm) at 30 and 50 DAT and at harvest, respectively were recorded from $G_3$ (130 ppm $GA_3$) but the highest number of loose leaves $plant^{-1}$ (11.20, 15.27 and 20.00) and leaf breadth (14.79, 18.64 and 20.53 cm) at 30 and 50 DAT and at harvest, respectively were recorded from $G_2$ (100 ppm $GA_3$). Conversely, the lowest plant height (21.48, 29.12 and 41.68 cm), number of loose leaves $plant^{-1}$ (8.12, 12.33 and 17.02), leaf length (21.01, 25.49 and 27.25 cm), leaf breadth (12.18, 14.62 and 15.81 cm) and plant spread (15.46, 36.40 and 50.87 cm) at 30 and 50 DAT and at harvest, respectively were recorded from the control treatment $G_0$ (No $GA_3$).

The yield and yield contributing parameters influenced by $GA_3$, the highest dry matter of stem (12.89%), head diameter (14.68 cm), thickness of head (15.80 cm), stem length at harvest (19.00 cm), dry matter of head (8.68%), fresh weight plant$^{-1}$ (1547.00 g), gross yield plot$^{-1}$ (18.56 kg), gross yield ha$^{-1}$ (51.56 t ha$^{-1}$), marketable yield plant$^{-1}$ (1324.00 g), marketable yield plot$^{-1}$ (15.89 kg) and marketable yield ha$^{-1}$ (44.13 t ha$^{-1}$) were recorded from the treatment $G_2$ (100 ppm $GA_3$). On the other hand, the lowest dry matter of stem (11.12%), head diameter (12.25 cm), thickness of head (13.01 cm), stem length at harvest (15.20 cm), dry matter of head (7.82%), fresh weight plant$^{-1}$ (1346.00 g), gross yield plot$^{-1}$ (16.15 kg), gross yield ha$^{-1}$ (44.85 t ha$^{-1}$), marketable yield plant$^{-1}$ (1183.00 g), marketable yield plot$^{-1}$ (14.19 kg) and marketable yield ha$^{-1}$ (39.43 t ha$^{-1}$) were recorded from the control treatment $G_0$ (No $GA_3$).

Again, different growth parameters influenced by different boron (B) levels, the highest plant height (24.78, 37.60 and 49.58 cm), leaf length (24.95, 30.47 and 32.23 cm) and plant spread (23.30, 47.59 and 60.53 cm) at 30 and 50 DAT and at harvest, respectively were found from $B_2$ (8 kg B ha$^{-1}$); while, the highest number of loose leaves plant$^{-1}$ (11.86, 14.99 and 20.36) and leaf breadth (15.20, 18.87 and 20.37 cm) at 30 and 50 DAT and at harvest, respectively were found from $B_1$ (4kg B ha$^{-1}$) whereas the lowest plant height (22.36, 32.39 and 43.51 cm), number of loose leaves plant$^{-1}$ (7.79, 10.82 and 15.78), leaf length (22.00, 26.78 and 28.50 cm), leaf breadth (11.04, 13.58 and 14.99 cm) and plant spread (16.70, 38.96 and 51.55 cm) at 30 and 50 DAT and at harvest, respectively were recorded from the control treatment $B_0$ (No B).

Different yield and yield contributing parameters influenced by different boron (B) levels, the highest dry matter of stem (13.17%), head diameter (14.50 cm), thickness of head (15.12 cm), stem length at harvest (16.81 cm),dry matter of head (8.82%), fresh weight plant$^{-1}$ (1580.00 g), gross yield plot$^{-1}$ (18.96 kg), gross yield ha$^{-1}$ (52.67 t ha$^{-1}$), marketable yield plant$^{-1}$ (1361.00 g), marketable yield plot$^{-1}$

(16.34 kg) and marketable yield $ha^{-1}$ (45.38 t $ha^{-1}$) were recorded from $B_1$ (4 kg B $ha^{-1}$). On the other hand, the lowest dry matter of stem (10.65%), head diameter (11.51 cm), thickness of head (12.13 cm), stem length at harvest (14.87 cm),dry matter of head (7.44%), fresh weight $plant^{-1}$ (1270.00 g), gross yield $plot^{-1}$ (15.24 kg), gross yield $ha^{-1}$ (42.33 t $ha^{-1}$), marketable yield $plant^{-1}$ (1097.00 g), marketable yield $plot^{-1}$ (13.17 kg) and marketable yield $ha^{-1}$ (36.57 t $ha^{-1}$) were recorded from control treatment $B_0$ (No B).

Considering different growth parameters, influenced by combined effect of $GA_3$ and boron, the highest plant height (26.55, 40.54 and 54.24 cm), leaf length (26.48, 32.24 and 32.25 cm) and plant spread (27.06, 52.99 and 62.76 cm) at 30 and 50 DAT and at harvest, respectively were observed from the treatment combination of $G_3B_2$while the highest number of loose leaves $plant^{-1}$ (11.79, 16.58 and 21.96) and leaf breadth (16.44, 21.08 and 23.24 cm) at 30 and 50 DAT and at harvest, respectively were observed from the treatment combination of $G_2B_1$. Reversely, the lowest plant height (20.82, 27.68 and 39.75 cm), number of loose leaves $plant^{-1}$ (7.25, 9.76 and 14.91), leaf length (19.75, 23.95 and 25.80 cm), leaf breadth (10.27, 12.99 and 14.17 cm) and plant spread (13.92, 34.84 and 47.52 cm) at 30 and 50 DAT and at harvest, respectively were recorded from the treatment combination of $G_0B_0$.

The yield and yield contributing parameters influenced by combined effect of $GA_3$ and boron, the highest dry matter of stem (13.77%), head diameter (15.12 cm), thickness of head (16.19 cm), stem length at harvest (15.04 cm), dry matter of head (9.21%), fresh weight $plant^{-1}$ (1688.00 g), gross yield $plot^{-1}$ (20.25 kg), gross yield (56.25 t $ha^{-1}$), marketable yield $plant^{-1}$ (1431.00 g), marketable yield $plot^{-1}$ (17.18 kg) and marketable yield (47.71 t $ha^{-1}$) were observed from the treatment combination of $G_2B_1$. On the other hand, the lowest dry matter of head (9.78%), head diameter (10.21 cm), thickness of head (11.86 cm), stem length at harvest (13.36 cm), dry matter of stem (7.17%), fresh weight $plant^{-1}$ (1235.00 g), gross yield plot$^{-1}$ (14.82 kg), gross yield ha$^{-1}$ (41.18 t ha$^{-1}$), marketable yield plant$^{-1}$ (1035.00 g), marketable yield plot$^{-1}$ (12.42 kg) and marketable yield ha$^{-1}$ (34.49 t ha$^{-1}$) were recorded from the treatment combination of $G_0B_0$.

The economic analysis showed that the highest gross return (Tk. 572520), net return (Tk. 392400) and BCR (3.18) were found from the treatment combination of $G_2B_1$ (100 ppm $GA_3$ + 4 kg B ha$^{-1}$) whereas the lowest gross return (Tk. 413880.00), net return (Tk. 241841) and BCR (2.40) was obtained from the treatment combination of $G_0B_0$ (No $GA_3$ +No B).

## Conclusion

It may be concluded from the result that $G_2B_1$ (100 ppm $GA_3$ + 4 kg B ha$^{-1}$) performed the best in producing higher yield of cabbage than other treatments comprised with other $GA_3$ and boron levels under the present study. Similarly, interactions of $G_2$ (100 ppm $GA_3$) and $B_1$ (4 kg B ha$^{-1}$) showed its superiority in producing higher cabbage yield and economic return.

## Recommendation

The present research work has been carried out at the Sher-e-Bangla Agricultural University in one season only. Therefore, further trial of this work may be conducted in different AEZ of Bangladesh before the final recommendation.

# References

# REFERENCES


Abdur, R.A.B. and Haq, I. (2012). Foliar application of calcium chloride and borax influences plant growth, yield and quality of tomato *(Lycopersicon esculentum Mill)*. fruit .*Turk J. Agric.,***36**: 695-701.

Adelanwa, E.B. and Medugu, J.M. (2015). Variation of the nutrient composition of red and green cabbage (*Brassica oleracea*) with respect to age at harvest. *J. Appl. Agric. Res*., **7**: 183-189.

Agarwal, A.and Ahmed, Z. (2007). Response of cauliflower, (*Brassica oleracea Var*. botrytis Sub variety cauliflower) to micronutrients application in high attributes cold desird of Ladakh. *Indian J. Agric. Sci.,* **77**(2): 104-105.

Alam, M.N. (2007). Effect of boron levels on growth and yield of cabbage in calcareous soils of Bangladesh. *Res.J. Agric. Biolo. Sci.,* **3**(6): 858-865.

Alam, M.S., Iqbal, M.T., Amin, M.S. and Gaffer, M.A. (1989). *Krishitattik Foshaler Utpadon O Unnayan* (In Bengali). T. M. Jubair Bin Iqbal, Manik Potal. Meghai, *Sirajgonj*. pp. 231-239.

Alfred, R.C. and Thomas,S. (2007). World Food: Production and Use. John Wiley and Sons, New Jersey, United States, pp. 464.

Aparna, H. and Puttaiah, E. T. (2012). Residual effect of zinc and boron on growth and yield of french bean (*Phaseolus vulgaris* L.) -rice (*Oryza sativa* L.) cropping system. *Int. J. Environ. Sci*., **3**(1): 167-171.

Banerjee, A., Mukherjee, S. and Rahman, R.H. (2015). Assessment of the performance of different forms of boron on yield of cauliflower in West Bengal condition. *Indian Res. J. Ext. Edu.,* **15**(4): 149.

BARI (Bangladesh Agricultural Research Institute). (2017). Krishi Projukti Hat Boi. P. 504.

Batal, K.M. Granberry, D.M., Jr. Mullinix, B.G. (1997). Nitrogen, Magnesium and boron applications effect cauliflower yield, curd mass and hollow stem disorder. *Hort. Sci.,* **32**(1): 75-78.

BBS. (2020). Yearbook of Agricultural Statistics - 2019. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka, pp. 669.

Bishnu, P., Adhikary, H., Ghale, M.S.,Chiranjibi, A., Surya, D. and Durga, B. (2004). Effect of different levels of boron on cauliflower *(Brassica oleracea* var. botrytis) curd production on acid soil of malepatan. *Nepal, Agric. Res. J.,* **5**: 65.

Bose, U.S. and Tripathi, S.K. (1996). Effect of micronutrients on growth and yied of cauliflower. *Ann. Agril. Res.,***18**(9): 391-392.

Brown, P.H., Welch, R.N. and Nickel, C.E.E. (2005). A micronutrient essential for higher plants. *Plant physol*., **85**: 801-803.

Chauhan,U. M. and Tandel, Y.N. (2009). Effect of plant growth regulators on growth, yield and quality of cabbage (*Brassica oleracea* var. capitata L.) cv. Golden Acre. *The Asian J. Hort.,* **4**(2): 512-514.

Choudhary, D. and Mukharjee, S. (1999). Effect of boron and zinc concentration on growth and yield of cauliflower,(*Brassica oleracea* var. botrytis.) cv.Snowball -16. *Haryana J. Hort. Sci.,* **28**(1and 2): 119-120.

Devi, N., Montessori, Devi, R.K., Bhanishana and Das, R. (2012). Enhancement of physicological efficiency of cabbage *(Brassica oleracea.* var capitata L.). using foliar nutrition of boron. *Crop Res.,* **43** (1, 2 and 3): 76-80.

Dharmender, K., Hujar, K.D. Paliwal, R. and Kumar, D. (1996). Yield and yield attributes of cabbage as influenced by GA3 and NAA. *Crop Res. Hisar*, **12**(1): 120-122.

Dhengle, R.P. and Bhosale, A.M. (2008). Effect of plant growth regulators on yield of cabbage *(Brassica oleraceae* var. capitata). *Int. J. Plant Sci.*, **3**(2): 376-378.

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

FAO. (1988). Production Year Book. Food and Agricultural Organizations of the United Nations Rome, Italy. pp. 190-193.

FAO. (1999). Production Yearbook. Food and Agriculture Organization of United Nations, Rome, Italy, pp. 147-148.

Gomez, K.H. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. *Int. Sci. Pub.*, Jhon wiley and Sono, New York. pp. 680.

Hall, J.L. (2002). Cellular mechanisms for heavy metal detoxification and tolerance. *J. Exp. Bot.*, **53**(366): 1-11.

Harris, K.D. and Mathuma, V. (2015). Effect of foliar application of boron and zinc on growth and yield of tomato (*Lycopersicon esculentum* Mill). *Asian J. Pharma. Sci. Technol.*, **5**(2): 74-78.

Hassan, M.R., Julie, S.N. and Akber, A. (2018). Influence of micronutrient (boron) for the growth and yield of cauliflower. *Biosci. Agric. Res.*, **18**(01): 1464-1469.

Hooda, R.S., Sindhu, A.S., Pandita, M.L. and Kallo, G.K. (1984). Effect of zinc and boron and their methods of applications on growth and yield of tomato variety HS - 110. *Haryana J. Hort. Sci.*,**12**(1-2): 46-47.

Hoq, M.S., Matin, M.A., Hossain, T.M.B. and Hossain, S. (2014). Cabbage (*Brassica oleracea* var. capitata) and cauliflower (*Brassica oleracea* var. botrytis) marketing in selected areas of Bangladesh. *BangladeshJ. Agric. Res.*,**39**(1): 127-141.

Hussain, M.J., Karim, A.J.M.S., Solaiman, A.R.M. and Haque, M.N. (2012). Effects of nitrogen and boron on the yield and hollow stem disorder of broccoli *(Brassica oleracea* var. itallica). *The Agriculturists.*,**10**(2): 36-45.

Islam, M.A., Siddiqua, A. and Kashem, M.A. (1993). Effect of growth regulators on growth, yield and ascorbic acid content of cabbage. *Bangladesh J. Agril. Sci.*, **20**(1): 21-27.

Islam, M.T. (1985). The effect of some growth regulators on yield and biomass production of cabbage. *Punjab Veg. Grower.*, **20**: 11-16.

Islam, M., Haque, M.A., Raza, M.M. and Rahman, M.M. (2015). Contribution of boron doses on growth and yield of different broccoli genotypes. *Int. J. Sustain. Corp. Prod.*,**10**(2): 14-20.

Kumar, S., Singh, S.S., Singh, P.K. and Singh, V.N. (2010). Response of cauliflower *(Brassica oleracea* var. botrytis) to boron and molybdenum application. *Veg. Sci.*,**37**(1): 40-43.

Lendve, V. H., Chavan, S. D., Barkule, S. R. and Bhosale, A. M. (2010). Effect of foliar application of growth regulators on growth of cabbage cv. Pride of India. *The Asian J. Hort.*, **5**(2): 475-478.

Moeinian, R.M., Zargari, K. and Hasanpour, J. (2011). Effect of boron foliar spraying application on quality characteristics growth parameters of wheat grain under drought stress. Ann. *J. Agric. Environ. Sci*., **10**: 593-599.

Mohsen, J., Tahereh, A., Naser, S.and Shahryar, D. (2016). Impact of foliar application of nano micronutrient fertilizers and titanium dioxide nanoparticles on the growth and yield components of barley under supplemental irrigation. *ActaagriculturaeSlovenica*., **107**(2): 265 – 276.

Moniruzzaman, M., Rahman, S.M.L., Kibria, M.G., Rahman, M.A. and Hossain, M.M. (2007). Effect of boron and nitrogen on yield and hollow stem of broccoli. *J. Soil Nature*.,**1**(3): 24-29.

Nasiruddin, K.M. and Roy, R. (2011). Effect of different level of $GA_3$ on growth and yield of cabbage. *J. Environ. Sci. Nat.Resour*., **4**(2):79-82.

Nayanmani, B. and Gogoi, S. (2007). Effect of boron and molybdenum, on seed production of early cauliflower (*Brassica oleracea* L. var. *botrytis*) cv. PusaKatki .*Veg. Sci*., **34**(1): 86-88.

Ouda, B.A., Mahadeen, A.Y., (2008). Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea* var. Italica). *Int. J. Agric. Biol.*,**10**: 627-632.

Panigrahi, U.C., Pattanayak, N.B. and Das, C. (1990). A note on the effect of micronutrients on yield and quality of cauliflower seed in acid red soil of Orissa. *Orissa J. Hort*., **18**(1-2): 62-64.

Patil, A.A., Maniur, S.M. and Nalwadi, U.G. (1987). Effect $GA_3$ and NAA on growth and yield of cabbage. *South Indian Hort.*, **35**(5): 393-394.

Prado, R.M. (2008). *Nutricao de Plantas. EditoraUnesp, Sao Paulo*, Brasil, P 407.

Prasad,V.M. and Yadav, D. (2003). Effect of foliar application of boron and molybdenum on the growth and yield of cauliflower cv. Snowball-16. *New Agricalturist.,* **14**(1 and 2): 121-122.

Rao, V.L., Ravi-Shankar, C. and Babu, V.G. (1990). Effect of B and Mo in maturity, yield and curd quality in cauliflower. *The Andhra Agric. J*., **37**(1): 42-46.

Rashid, M.M. (1993). *ShabjeeBiggan* (in Bengali). First edition, Bangla Academy, Dhaka, pp. 179-196.

Roy, R. and Nasiruddin, K.M. (2011). Effect of different level of $GA_3$ on growth and yield of cabbage. *J. Environ. Sci. Nat. Resour.,* **4**(2): 79-82.

Roy, R., Rahim, M.A. and Alam, M.S. (2010). Effect of starter solution and $GA_3$ on growth and yield of cabbage. *J. Agrofor. Environ.,***3**(2): 187-192.

Rumeza, H., Zarfar, I.,Mudassar, I.,Shaheena,H.and Masooma,R.(2006). Use of vegetables as nutritional food: role in human health. *J. Agric. Biol.Sci.,***1**(1): 18-22.

Sarma, P. Goswami, R.K. and Deka, B.C. (2005). Effect of foliar application of micronutrients on yield and quality of cabbage. *Crop Res. Hisar.,***30**(1): 68-72.

Sarma, P., Goswami, R.K. and Deka, B.C. (2003). Effect of foliar application of micronutrients on growth characters of cabbage (*Brassica oleracea* var. capitala) under Assam condition. *Orissa J. Hort*., **31**(2): 51-53.

Savci, S. (2012). An agricultural pollutant: chemical fertilizer. *Int. J. Environ. Sci. Dev*., **3**(1): 77-80.

Sharma, P.N. and Ramchandra, T. (1990). Water relation and photo synthesis in mustard plant subjected to boron deficiency. *Indian J. Plant Phsiol.,* **33**: 150-154.

Sharma, A.K.,Rattan, R.S. and Pathania, A.K. (1994). Effect of boron application on cauliflower. *Agric. Sci. Digest (Karnal).,* **14**(4): 219-222.

Sharma, S.K. (1995). Response of boron and calcium nutrition on plant growth, fruit and seed yield of tomato. *Veg. Sci.,***22**(1): 27-29.

Sharma, S.K., Singh, H. and Kohli, U.K. (1999). Influence of boron and zinc on seed yield and quality in radish. *Seeds Res.,* **27**(2): 154-157.

Shelp, B.J. and Shattuk, V.L. (1987). Boron nutrition and mobility and its relation to hollow stem and the elemental composition of green grown cauliflower, *J. plantNutr.*, **10**(2): 142-163.

Simatupang, S. (1997). Effect of borax fertilizer on growth, yield and quality of three cauliflower cultivars. *J. Hort. (Indonesia),***6**(5): 465-468.

Singh, R.N., Singh, S., Karmakar, S. and Singh, S. (2002). Effect of boron application on cauliflower in an acid alfisol. *J. Res. Birsa Agric.* Univ., **14**(1): 61-63.

Singh, A.K. and Jhekr, O.P. (1991). Effect of B and Mo, in curd yield of cauliflower. *Himachal J. Agric. Res.,***70**(1-2): 137-142.

Singh, A.K. and Singh, C.S. (1994). Response of tomato to boron application. *Punjab Hort. J.*, **34**(1-2): 86-89.

Singh, A.K. and Thakur, O.P. (1991). Effect of boron and molybdenum on curd yield of cauliflower (*Brassica oleracea* L. var. botrytis). *J. Agric. Res*., 17(1 and 2): 137-142.

Singh, B., Yadav, P.K., Maurya, R.P. and Singh, P. (2003). Effect of spacing and $GA_3$ on yield of knol-khol (*Brassica oleracea*) *Haryana J. Hort. Sci*., **32**(3 and 4): 293-94.

Singh, B.R., Singh, K. and Mishra, S.P. (2006). A note on effect of foliar spray of boron on the quality of Radish *(Raphanus sativas* L.). The *Orissa J. Hort.,***34**(1): 101-102.

Singh, H.N. (2018). Effect of gibberellic acid and nitrogen on yield and marketability of cabbage (*Brassica oleracea* var. capitata L.) cv. pride of India. *J. Pharmac.Phytochem*.,**7**(3): 900-903.

Singh, M.K. Chand, T., Kumar, M., Singh, V.K., Lodhi, S.K., Singh, V.P., and Sirohi, V.S. (2015). Response of different doses of NPK and boron on growth and yield of broccoli (*Brassica oleracea* var. *itallica*). *Int. J. Bio-res. Stress Manag.,* **6**(1): 108-112.

Singh, R., Bengal, M., Bose, U.S. and Gurjar. P.S. (2014). Response of dfferent methods of boron and nitrogen application on growth and yield of cauliflower (*Brassica oleracea* var. botrytis L.). *Environ. Ecology.,***32**(3): 842-848.

Singh, S.S. and Verma, S.K. (1991). Influence of potassium, zinc and boron on growth and yield of tomato (*Lycopersican escultentum* Mill.). *Veg. Sci*., **18**(2):122-129.

Sitapara, H.H., Vihol, N.J., Patel, M.J. and Patel, J.S. (2011). Effect of growth regulators and micronutrients on growth and yield of cauliflower. C.V. ‘SNOWBALL- 16’. *The Asian J. Hort.,***6**(2): 348-351.

UNDP. (1988). Land Resource Apprisal of Bangladesh for Agricultural Development Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome, Italy. p. 577.

Vasconcelos, A.C.F., Nascomento, C.W.A. and Fiho, F.C. (2011). Distribution of zinc in maize plants as a function of soil and foliar Zn supply. *Int. Res. J. Agric. Sci. Soil Sci.*, **1**(1): 1-5.

Waring, E.J. (1953). Some problems in cauliflower growing. Agri. Gaz. N.S.W.6/4: 466- 470.

Yadav, R. L., Dhaka, R. S. and Fageria, M. S. (2000). Effect of $GA_3$, NAA and succinic acid on growth and yield of cabbage cv. golden acre. *Haryana J. Hort. Sci.*, **29**(3 and 4): 269-270.

Yu, X. H., Li, W.P., Jiang, X. M., Liu, D. and Zhang, Y. (2010). Changes of endogenous hormone during devernalization in cabbage. *China Veg.*, **20**: 38-41.

# Appendices

## APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

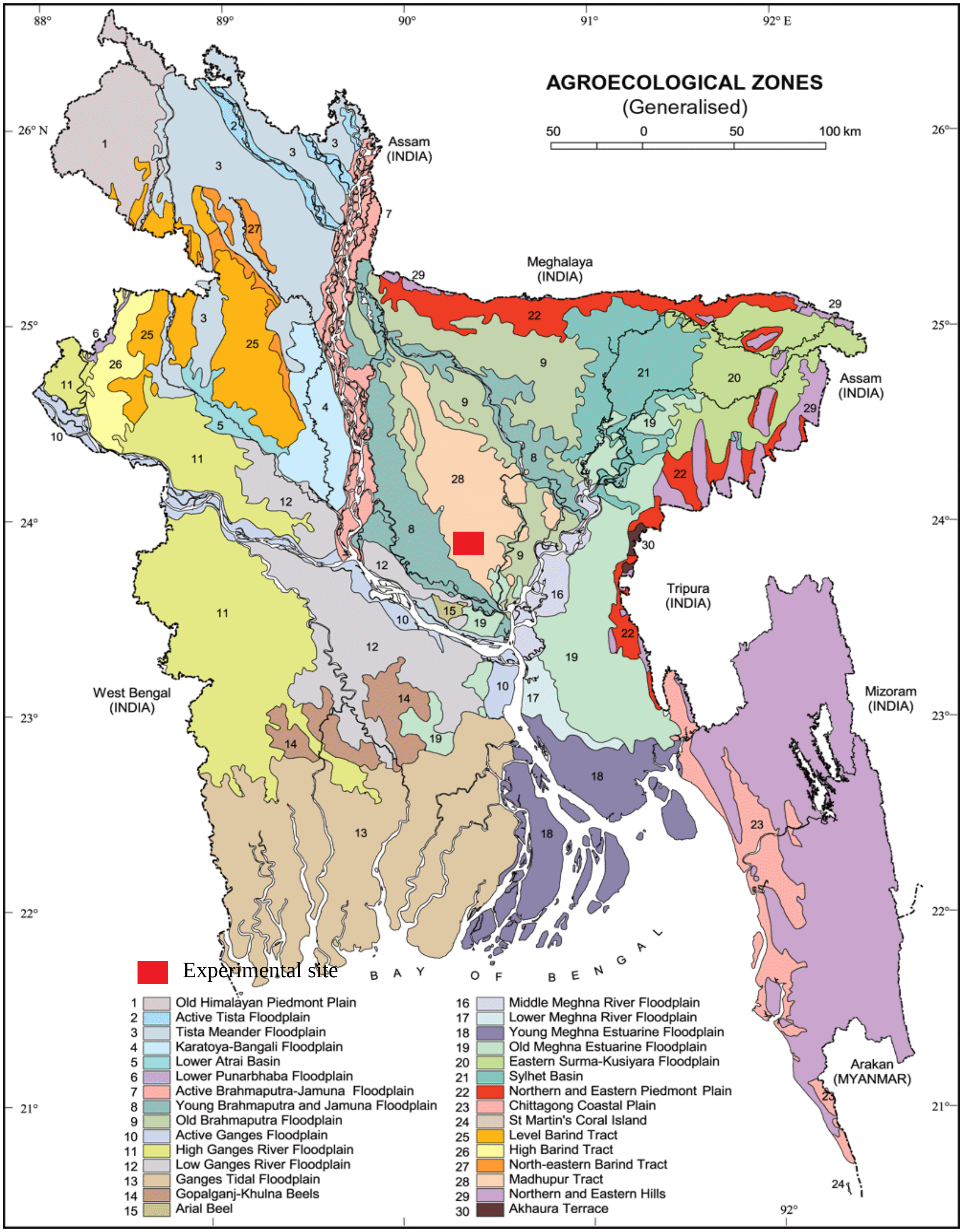



Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from September 2019 to December 2019.

| Year | Month | Air temperature (°C) | | | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|---|
| | | *Max* | *Min* | *Mean* | | |
| 2018 | September | 30.8 | 21.80 | 26.30 | 71.50 | 78.52 |
| 2018 | October | 30.42 | 16.24 | 23.33 | 68.48 | 52.60 |
| 2018 | November | 28.60 | 8.52 | 18.56 | 56.75 | 14.40 |
| 2018 | December | 25.50 | 6.70 | 16.10 | 54.80 | 0.0 |

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

| **Morphological features** | **Characteristics** |
|---|---|
| Location | Horticulture Farm, SAU, Dhaka |
| *AEZ* | Modhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |
| Flood level | Above flood level |
| Drainage | Well drained |
| Cropping pattern | Not Applicable |

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

| **Characteristics** | **Value** |
|---|---|
| Partical size analysis % Sand | 27 |
| %Silt | 43 |
| % Clay | 30 |
| Textural class | Silty Clay Loam (ISSS) |
| pH | 5.6 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20 |
| Exchangeable K ( meq/100 g soil) | 0.1 |
| Available S (ppm) | 45 |

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of effect of $GA_3$ and boron on plant height of cabbage

| Sources of variation | Degrees of freedom | Mean square of plant height (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 50 DAT | At harvest |
| Replication | 2 | 0.920 | 0.542 | 0.123 |
| Factor A | 3 | 30.35* | 174.03** | 205.70* |
| Factor B | 2 | 27.66* | 99.05* | 191.91* |
| AB | 6 | 1.0632** | 6.111** | 2.613* |
| Error | 22 | 0.196 | 1.977 | 3.442 |

* = Significant at 5% level    ** = Significant at 1% level

Appendix V. Mean square of effect of $GA_3$ and boron on number of loose leaves plant$^{-1}$ of cabbage

| Sources of variation | Degrees of freedom | Mean square of number of leaves plant$^{-1}$ (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 50 DAT | At harvest |
| Replication | 2 | 0.885 | 0.905 | 0.192 |
| Factor A | 3 | 8.782** | 18.22* | 15.17** |
| Factor B | 2 | 32.320* | 78.05* | 77.10* |
| AB | 6 | 0.899** | 1.656** | 1.789* |
| Error | 22 | 0.704 | 0.584 | 0.514 |

* = Significant at 5% level    ** = Significant at 1% level

Appendix VI. Mean square of effect of $GA_3$ and boron on leaf length of cabbage

| Sources of variation | Degrees of freedom | Mean square of leaf length (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 50 DAT | At harvest |
| Replication | 2 | 1.549 | 0.220 | 4.413 |
| Factor A | 3 | 33.21* | 54.03* | 59.70* |
| Factor B | 2 | 26.62** | 41.83* | 47.35* |
| AB | 6 | 0.958** | 2.179** | 4.763* |
| Error | 22 | 0.219 | 0.541 | 3.749 |

* = Significant at 5% level    ** = Significant at 1% level

Appendix VII. Mean square of effect of $GA_3$ and boron on leaf breadth of cabbage

| Sources of variation | Degrees of freedom | Mean square of leaf breadth (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 50 DAT | At harvest |
| Replication | 2 | 0.157 | 0.010 | 0.030 |
| Factor A | 3 | 10.35* | 25.18* | 36.88* |
| Factor B | 2 | 56.51* | 89.70* | 89.29* |
| AB | 6 | 0.809** | 4.508* | 7.289* |
| Error | 22 | 0.323 | 0.572 | 0.528 |

* = Significant at 5% level    ** = Significant at 1% level

Appendix VIII. Mean square of effect of $GA_3$ and boron on plant spread of cabbage

| Sources of variation | Degrees of freedom | Mean square of plant spread (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 50 DAT | At harvest |
| Replication | 2 | 0.280 | 0.157 | 0.0730 |
| Factor A | 3 | 156.14* | 299.76* | 199.99* |
| Factor B | 2 | 177.220* | 317.36* | 201.042* |
| AB | 6 | 8.666* | 15.144* | 8.786* |
| Error | 22 | 1.032 | 1.116 | 1.609 |

* = Significant at 5% level  ** = Significant at 1% level

Appendix IX. Mean square of effect of $GA_3$ and boron on yield contributing parameters of cabbage

| Sources of variation | Degrees of freedom | Mean square of yield contributing parameters | | | | |
|---|---|---|---|---|---|---|
| | | % dry matter of head | Head diameter (cm) | Thickness of head (cm) | Stem length at harvest (cm) | % dry matter of stem |
| Replication | 2 | 0.344 | 0.0653 | 0.105 | 0.085 | 0.168 |
| Factor A | 3 | 5.615* | 11.085* | 9.452* | 1.295** | 1.143** |
| Factor B | 2 | 28.042* | 42.140* | 35.353* | 5.556* | 6.447* |
| AB | 6 | 0.287** | 1.193** | 0.694** | 0.603** | 0.079** |
| Error | 22 | 0.602 | 0.914 | 0.458 | 0.167 | 0.111 |

* = Significant at 5% level  ** = Significant at 1% level

Appendix X. Mean square of effect of $GA_3$ and boron on yield parameters of cabbage

| Sources of variation | Degrees of freedom | Mean square of yield parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fresh weight plant$^{-1}$ (g) | Gross yield plot$^{-1}$ (kg) | Gross yield ha$^{-1}$ (t) | Marketable yield plant$^{-1}$ (g) | Marketable yield plot$^{-1}$ (kg) | Marketable yield ha$^{-1}$ (t) |
| Replication | 2 | 13.25 | 0.193 | 1.483 | 18.349 | 0.804 | 6.220 |
| Factor A | 3 | 6294.6* | 9.056* | 69.89* | 302.31* | 4.349** | 33.568* |
| Factor B | 2 | 2961.7* | 42.61* | 328.9* | 2316.1* | 33.38* | 257.37* |
| AB | 6 | 696.92* | 1.004** | 7.728* | 923.14* | 0.133** | 1.029** |
| Error | 22 | 41.243 | 0.134 | 0.268 | 52.354 | 0.138 | 1.058 |

* = Significant at 5% level  ** = Significant at 1% level

## Appendix XI: Cost of production of cabbage per hectare

### A. Input cost (Tk. $ha^{-1}$)

| Treatments | Cost of land preparation and cultivation with labor | Seed cost | Insecticide cost (Tk. $ha^{-1}$) | Irrigation | Cowdung | Fertilizer | | | Cost of boric acid | $GA_3$ cost | Seed bed preparation and seed sowing cost | Transplanting cost with labor | Subtotal (A) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Urea | TSP | MoP | | | | | |
| $G_0B_0$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 0 | 0 | 5000 | 20000 | 119450 |
| $G_0B_1$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 2400 | 0 | 5000 | 20000 | 121850 |
| $G_0B_2$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 4800 | 0 | 5000 | 20000 | 124250 |
| $G_1B_0$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 0 | 3500 | 5000 | 20000 | 122950 |
| $G_1B_1$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 2400 | 3500 | 5000 | 20000 | 125350 |
| $G_1B_2$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 4800 | 3500 | 5000 | 20000 | 127750 |
| $G_2B_0$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 0 | 5000 | 5000 | 20000 | 124450 |
| $G_2B_1$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 2400 | 5000 | 5000 | 20000 | 126850 |
| $G_2B_2$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 4800 | 5000 | 5000 | 20000 | 129250 |
| $G_3B_0$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 0 | 6500 | 5000 | 20000 | 125950 |
| $G_3B_1$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 2400 | 6500 | 5000 | 20000 | 128350 |
| $G_3B_2$ | 27000 | 7500 | 14000 | 15000 | 15000 | 4900 | 6250 | 4800 | 4800 | 6500 | 5000 | 20000 | 130750 |

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B $ha^{-1}$), $B_1$ = 4 kg B $ha^{-1}$, $B_2$ = 8 kg B $ha^{-1}$

**B. Overhead cost (Tk. ha$^{-1}$), Cost of production (Tk. ha$^{-1}$), Gross return (Tk. ha$^{-1}$), Net return (Tk. ha$^{-1}$) and BCR**

| Treatments | Overhead cost | | | Subtotal (B) | Subtotal (A) | Total cost of production (A+B) | Yield (t ha$^{-1}$) | Gross return (Tk. ha$^{-1}$) | Net return (Tk. ha$^{-1}$) | BCR |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cost of leased land for 6 months (8% of value of land 10,00,000/-) | Miscellaneous cost (Tk. 5% of the input cost) | Interest on running capital for 6 months (8% of cost year$^{-1}$) | | | | | | | |
| $G_0B_0$ | 40000 | 5972.5 | 6617 | 52589 | 119450 | 172039 | 34.49 | 413880 | 241841 | 2.41 |
| $G_0B_1$ | 40000 | 6092.5 | 6718 | 52810 | 121850 | 174660 | 42.36 | 508320 | 333660 | 2.91 |
| $G_0B_2$ | 40000 | 6212.5 | 6819 | 53031 | 124250 | 177281 | 41.44 | 497280 | 319999 | 2.81 |
| $G_1B_0$ | 40000 | 6147.5 | 6764 | 52911 | 122950 | 175861 | 35.88 | 430560 | 254699 | 2.45 |
| $G_1B_1$ | 40000 | 6267.5 | 6865 | 53132 | 125350 | 178482 | 45.12 | 541440 | 362958 | 3.03 |
| $G_1B_2$ | 40000 | 6387.5 | 6966 | 53353 | 127750 | 181103 | 43.78 | 525360 | 344257 | 2.90 |
| $G_2B_0$ | 40000 | 6222.5 | 6827 | 53049 | 124450 | 177499 | 39.21 | 470520 | 293021 | 2.65 |
| $G_2B_1$ | 40000 | 6342.5 | 6928 | 53270 | 126850 | 180120 | 47.71 | 572520 | 392400 | 3.18 |
| $G_2B_2$ | 40000 | 6462.5 | 7029 | 53491 | 129250 | 182741 | 45.48 | 545760 | 363019 | 2.99 |
| $G_3B_0$ | 40000 | 6297.5 | 6890 | 53187 | 125950 | 179137 | 36.73 | 440760 | 261623 | 2.46 |
| $G_3B_1$ | 40000 | 6417.5 | 6991 | 53408 | 128350 | 181758 | 46.31 | 555720 | 373962 | 3.06 |
| $G_3B_2$ | 40000 | 6537.5 | 7092 | 53629 | 130750 | 184379 | 43.21 | 518520 | 334141 | 2.81 |

**Selling price = 12.00 Tk kg$^{-1}$

$G_0$ = Control (No $GA_3$), $G_1$ = 70 ppm $GA_3$, $G_2$ = 100 ppm $GA_3$, $G_3$ = 130 ppm $GA_3$

$B_0$ = Control (No B ha$^{-1}$), $B_1$ = 4 kg B ha$^{-1}$, $B_2$ = 8 kg B ha$^{-1}$