# EFFECT OF POTASSIUM AND $GA_3$ ON GROWTH AND YIELD OF BROCCOLI


**MST. ASHRIN JAHAN**

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


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**BY**

**MST. ASHRIN JAHAN**

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**Approved by:**

**Prof. Md. Hasanuzzaman Akand**
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
**Supervisor**

**Prof. Dr. Md. Nazrul Islam**
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
**Co-supervisor**

**Prof. Dr. Mohammad Humayun Kabir**
Chairman
Examination Committee

# *DEPARTMENT OF HORTICULTURE*

*Sher-e-Bangla Agricultural University*
***Sher-e-Bangla Nagar, Dhaka-1207***


***Memo No: SAU/HORT/…………***  ***Date: ………………***

## *CERTIFICATE*

*This is to certify that the thesis entitled '**EFFECT OF POTASSIUM AND GA$_3$ ON GROWTH AND YIELD OF BROCCOLI**' submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE**, embodies the results of a piece of bona fide research work carried out by **MST. ASHRIN JAHAN**, Registration No. **11-04264** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

*Dated: June, 2017*
*Dhaka, Bangladesh*


***Prof. Md. Hasanuzzaman Akand***
*Department of Horticulture*
*Sher-e-Bangla Agricultural University*
*Dhaka-1207*

***Supervisor***

DEDICATED

TO

MY BELOVED PARENTS

# *ACKNOWLEDGEMENTS*

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## ABSTRACT

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during November 2016 to March 2017. The experiment consisted of two factors, such as Factor A: Potassium fertilizer (three levels) as $K_0$: 0 kg $K_2O$/ha (control), $K_1$: 75 kg $K_2O$/ha, $K_2$: 100 kg $K_2O$/ha and Factor B: Gibberellic acid-$GA_3$ (four levels) as $G_0$: 0 ppm $GA_3$ (control), $G_1$: 80 ppm $GA_3$, $G_2$: 100 ppm $GA_3$, $G_3$: 120 ppm $GA_3$. The two factorial experiment was laid out in Randomized Complete Block Design with three replications. Potassium and $GA_3$ influenced significantly on most of the studied parameters. In case of potassium, the highest curd yield (22.54 t/ha) was recorded from $K_2$ and the lowest curd yield (18.98 t/ha) was found from $K_0$. For $GA_3$, $G_3$ performed the highest curd yield (22.66 t/ha) and the lowest (18.64 t/ha) was from $G_0$. For combined effect, the highest curd yield (24.83 t/ha) was found from $K_2G_3$ and the lowest (16.57 t/ha) from $K_0G_0$. The highest benefit cost ratio (2.28) was noted from the combination of $K_2G_3$ and the lowest was found (1.55) from $K_0G_0$. So, 100 kg potassium per hectare with 120 ppm $GA_3$ can be used for broccoli production.

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## SOME COMMONLY USED ABBREVIATIONS

| FULL WORD | ABBREVIATION |
|---|---|
| Agro-Ecological Zone | AEZ |
| Bangladesh Bureau of Statistics | BBS |
| Co-efficient of variation | cv |
| Days After Transplanting | DAT |
| and others | *et al.* |
| Etcetera | etc |
| Food and Agriculture Organization | FAO |
| Gibberellic Acid | $GA_3$ |
| Journal | J. |
| Least Significance Difference | LSD |
| Muriate of Potash | MoP |
| Sher-e-Bangla Agricultural University | SAU |
| Soil Resources Development Institute | SRDI |
| Triple Superphosphate | TSP |

# CHAPTER I

# INTRODUCTION

# CHAPTER I

# INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is an important cole crop and it has high nutritional and good commercial value (Yoldas *et al*., 2008). Generally it is consumed mostly all over the world for its nutritional value as a source of various compounds such as vitamins, minerals, antioxidants, as well as its anticancer properties (Umar *et al*., 2013 and Pizetta *et al*., 2005). The edible portion of the broccoli plant consists of tender stem and unopened flower buds. The plants form a kind of head consisting of green buds and thick fleshy flower stalk. The terminal head rather loose, green in color and the flower stalks are longer than cauliflower (Bose *et al*., 2002). It can be harvested for a wide period of time than cauliflower (Thompson and Kelly, 1988). Unlike cauliflower, broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible. Broccoli is a minor vegetable in Bangladesh but is one of the important cole crops in Europe and USA and it is a commercial crop in India (Tindall, 1983 and Nonnecke, 1989).

In Bangladesh broccoli was introduced about two decades ago. Broccoli can be harvested for a wide period of time than the cauliflower (Thompson and Kelly, 1988). Broccoli is an Italian vegetable; however, due to increase in its popularity, there is a trend to increase cultivation by farmers, as well as consumption by consumers. Broccoli attracted more attention due to its multifarious use and it’s great nutritional value (Salunkhe and Kadam, 1998; Talalay and Fahey, 2001; Rangkadilok *et al*., 2004). Different factors may influence the growth, yield and quality of broccoli. Among them potassium and plant growth regulators can play an important role for increasing the production of broccoli in Bangladesh (Manjit Singh *et al*., 2011).

The average yield of broccoli is low in Bangladesh compared to other countries of the world and the low yield of this crop however is not an indication of low yielding potentiality of this crop (Islam *et al*., 2010). However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors manures and fertilizers generally play an important role. Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). Previous research has indicated that nutrients have important effects on the production and quality of broccoli (Belec *et al*., 2001; Moniruzzaman *et al*., 2007; Ambrosini *et al*., 2015).

Broccoli is a short duration crop, for that easily soluble fertilizer like as potassium. Potassium is also one of the important essential macro elements for the normal growth and development of plant. The potassium requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). According to Islam *et al*. (2010), Potassium is the most important nutrient for broccoli productivity. Increased plant resistance to diseases and drought stress, increased vegetable quality and increased efficiency of non-K nutrient use are the most important effects of K on plants (Armstrong, 1998). Broccoli is an important vegetable but have lacking and divergent information about potassium (K) fertilization in soil with a high K content and reported the highest yields of 12.5 t $ha^{-1}$ with 160 kg $ha^{-1}$ (Silva *et al*., 2016).

Plant growth regulators (PGRs) are organic compounds which are capable of modifying growth. It plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). Many reports so far been made to indicate a promising results on yield and quality of broccoli and other crops due to the use of different bio-chemical substances, such as Napthaline acetic acid (NAA), Gibberelic acid ($GA_3$), Indole acetic acid (IAA) etc. (Senthelhas *et al.,* 1987; Tadzhiryan, 1990; Tomar *et al*., 1991). Plant height, curd formation and curd size of curd can be increased with foliar application of plant growth regulators. $GA_3$ have a positive role on curd formation and curd size of broccoli (Sharma and Mishra, 1989). Application of $GA_3$ stimulates morphological characters like plant height, number of leaves, curd diameter, thickness of curd as well as the weight of the curd. The concentrations of these chemicals interacting with the environmental conditions play an important role in modifying the growth and yield components of broccoli. Application of $GA_3$ at 100 ppm produced the tallest plants, the largest curds and highest curd yields (Vijay and Ray, 2000). The optimum proportion of potassium fertilizer and $GA_3$ enhances the growth and development of broccoli as well as ensures the availability of other essential nutrients for the plant. In the above mention situation the experiment was conducted with the following objectives-

**Objectives:**

- To determine the optimum dose of potassium fertilizer on growth and yield of broccoli
- To find out the optimum level of $GA_3$ for obtaining higher yield of broccoli
- To find out the suitable combination of potassium and $GA_3$ for ensuring the higher growth and yield of broccoli.

# CHAPTER II

# REVIEW OF LITERATURE

# CHAPTER II

# REVIEW OF LITERATURE

Borccoli is an important vegetable crop in Bangladesh and specially valued for its nutrition value. Management of fertilizer especially potassium is the important factor that greatly affects the growth, development and yield of broccoli. Recently, there has been global realization of the important role of PGR's in increasing crop yield. So it is important to assess the effect of potassium and $GA_3$ for the best growth and yield of broccoli. However, very limited research reports on the performance of broccoli in response to potassium and $GA_3$ have been done in various part of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect re reviewed under the following headings:

## 2.1 Influence of potassium fertilizer on crop growth and yield

Fernandez *et al*. (2018) conducted an experiment with Avenger and Legacy cultivars including four levels of N, $P_2O_5$ and $K_2O$ as factors, arranging a total of 12 treatments. Results showed that Avenger and Legacy got the highest yields, 19.0 and 12.2 t N/ha, respectively with doses of 55 kg $K_2O$/ha.

Silva *et al*. (2016) carried out an experiment in Jaboticabal City, São Paulo, Brazil, aiming to evaluate the effect of different K doses (0, 50, 100, 150 and 200 kg/ha $K_2O$, in potassium chloride) on the yield of broccoli 'BRO 68' in Rhodic Eutrudox soil with a high K content. The broccoli responded positively but differently to potassium fertilization. The maximum yield of broccoli (12,476 kg/ha) was obtained with 160 kg/ha $K_2O$.

Uddain *et al*. (2010) conducted an experiment at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to study the effect of potassium on growth and yield of broccoli. Four levels of potassium (K) fertilizers viz. $K_0$ = 0 kg K/ha, $K_1$ = 50 kg K/ha, $K_2$ = 75 kg K/ha and $K_3$ = 100 kg/ha were used in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The highest plant height (55.82 cm), stem diameter (5.61 cm), number of leaves (13.64), leaf length (46.03 cm) at 60 DAT, shoot length (40.14 cm), root length (30.94 cm), fresh shoot weight (794.4 g), fresh root weight (84.42 g), main curd weight (260.0 g), curd diameter (17.52 cm), number of secondary curd (4.0), weight of secondary curd (166.0 g) and curd yield (14.19 t/ha) were recorded from $K_3$.

Wang *et al*. (2007) conducted a pot experiment to determine the effects of N, P and K on yield and quality of broccoli and reported that K was the most important element for yield. Additive effects were observed on yield and source-sink vitamin C [ascorbic acid] content when K was applied together with N or N + P. Application of N + P gave 110.8% higher yields than N alone. N application advanced the harvest. Significant positive correlations were found between yield and dry weight of leaves and plant size. They suggested that to obtain high yields and quality, N, P and K applications should be balanced.

Yang *et al.* (2006) conducted a field experiment for two years to study the effect of nitrogen, phosphorus and potassium on growth and yield of broccoli. Treatments comprised: 60:40:30, 120:80:50, 150:80:70 and 200:100:80 kg NPK/ha. They observed that plant height was increased through stem length, leaf length and breadth with increasing NPK and the highest plant height and number of leaves were obtained with 200:120:80 kg NPK/ha, respectively. The highest yield per plot was also obtained from the same treatment.

Brahma *et al*. (2002) carried out a field experiment to evaluate the effects of NPK fertilizers on the nutrient uptake, yield and quality of broccoli cv.KTS-1. The treatment comprised application of 80: 30: 20, 100: 60: 40, 150: 80: 60 and 200: 120: 80 kg NPK/ha. They reported that NPK at 200 : 120 : 80 kg /ha resulted in the highest values for head diameter (19.52 cm); cull head number (7.09); head yield (13.42 t/ha ); cull head yield (4.70 t/ha); total yield (18.11 t/ha); leaf N (3.90%) and K (2.75%) content; and protein (3.36%), total chlorophyll (0.46 mg/g) and ascorbic acid content (128.05 mg/kg/ha) and K (72.37 kg/ha).

Guan and Chen (2001) reported that there was a significant effect of N and K on growth and yield of broccoli especially N on growth and K on yield. Higher amount of nitrogen increase plant height, leaf length and stem diameter at least at a certain range. On the other hand, higher amount of potassium contribute higher curd weight, curd diameter and secondary curd number per plant at least at a certain range of K application.

## 2.2 Influence of $GA_3$ on crop growth and yield

Reza *et al.* (2015) carried out an experiment to find out the influence of $GA_3$ on growth, yield and yield contributing characters of broccoli *(Brassica oleracea var. Italica)*. Four levels of $GA_3$ *viz.* $G_1$: Control, $G_2$: 25 ppm $GA_3$, $G_3$: 50 ppm $GA_3$ and $G_4$: 75 ppm $GA_3$ was used in the experiment. The maximum plant height (31.5 cm), number of leaves (16.6/plant), number of main fingers (12.0/main curd), main curd length (21.3 cm), main curd diameter (19.3 cm), main curd weight (668.0 g/plant) and yield (24.5 t/ha) was found from the application of 50 ppm $GA_3$, while the minimum from control. It was revealed that, 50 ppm $GA_3$ gave maximum yield/ha (24.5 tons). It was also found that application of more than 50 ppm $GA_3$ reduced the yield of broccoli.

Thara *et al.* (2013) conducted an experiment at Horticulture Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Monhanpur, Nadia, West Bengal, India to determine the effect of $GA_3$, NAA and their combinations (applied as seedling dipping) on growth, yield and quality improvement of sprouting broccoli. The results clearly indicated significantly good response of the growth regulator applications on growth, yield and quality attributes of sprouting broccoli. $GA_3$ 30 mg/l + NAA 30 mg/l treatment ($T_{10}$) showed best result with respect to head weight, head diameter, plant height, plant spread, projected yield, number of sprouts/plant and sprout weight. $GA_3$ 60 mg/l treatment ($T_2$) took least number of days for head initiation, while $GA_3$ 80 mg/l treatment ($T_3$) proved to be the most effective among all treatments and required minimum days for head initiation to head maturity. Plant growth regulator treatments significantly improved carotene, total sugar and total chlorophyll content, with highest increase have been recorded in case of $T_1$ ($GA_3$ 40 mg/l), whereas maximum ascorbic content has been estimated with $T_9$ ($GA_3$ 20 mg/l + NAA 20 mg/l).

Manjit Singh *et al.* (2011) conducted a field experiment during the winter season on sprouting broccoli cultivar Palam Samridhi at Horticultural Research Centre and Department of Horticulture, H.N.B Garhwal University, Srinagar (Garhwal) Uttarakhand, India. 4 weeks old seedlings were treated before transplanting by dipping their roots for 24 h in different concentration of $GA_3$ (gibberellic acid), kinetin and their combinations solutions. The $GA_3$, kinetin and their combination significantly influenced the growth performance, yield and quality characters of sprouting broccoli. $GA_3$ 30 mg/L + kinetin 30 mg $L^{-1}$ treatment gave maximum growth and yield of sprouting broccoli whereas, highest vitamin A content found with 40 mg/L $GA_3$ and vitamin C was found maximum in $GA_3$ 20 mg/L + kinetin 20 mg/L dipping.

Studies on 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 $GA_3$ 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the leaves, shape index of head, length of root, fresh and dry weight of root. Except treatment $GA_3$ 75 ppm, gave better results for days required for head initiation and head maturity.

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, respectively). Combinations and higher concentrations of plant growth regulators proved less effective.

The growth and flowering response of a cold-requiring crop cauliflower (*Brassica oleracea* var. botrytis cv. '60 day') to a range of temperatures under 10 hour photoperiod and to growth regulator application were investigated by the Guo *et al*. (2004). Endogenous gibberellin ($GA_3$) concentrations were also assessed under these treatments. Flowering and growth of the inflorescence stalk were correlated with plant developmental stage at the time of a vernalizing cold treatment. Temperature and its duration also affected flowering and inflorescence development. The most effective temperature for inflorescence induction was $10^0$C. Flowering did not occur in non-vernalized plants ($25^0$C) even though they had been treated with $GA_3$. Application of $GA_3$ promoted inflorescence stalk elongation greatly in vernalized plants ($10^0$C), but less so in partially vernalized plants (15 or $20^0$C). Paclobutrazol sprayed at the 8-9 leaf stage significantly suppressed inflorescence stalk length and slightly delayed flower bud formation and anthesis. Vernalization at $10^0$C increased endogenous $GA_3$ content in both leaves and the inflorescence stalk irrespective of $GA_3$ treatment.

Vijay and Ray (2000) carried out an experiment that thirty day old cauliflower (cv. Pant Subhra) seedlings that were transplanted into experimental plots treated with 50 or 100 ppm $GA_3$, 5 or 10 ppm IBA, or 200 ppm NAA at 15 and 30 days of growth. The results clearly revealed that $GA_3$ at 100 ppm produced the tallest plants, the largest curds and highest curd yields.

Nidhi-Arora *et al.* (1997) conducted an experiment with Seeds of cauliflower (Brassica oleracea var. botrytis) cultivars Snowball 16 and Hisar 1 were cultured on MS medium without growth regulators, and cotyledons of resulting 5 to 6-day-old seedlings were cultured on 6 different modified MS media. Of the BAP [benzyladenine] concentrations, 2.0 mg/litre was best for shoot regeneration.

Addition of IAA (0.1 mg/litre) in combination with BAP (1.0, 2.0 and 5.0 mg/litre) showed that shoot regeneration was maximum at 0.1 mg IAA + 1.0 mg BAP/litre. The two cultivars differed significantly for percentage regeneration and Snowball 16 responded the best to in vitro culture.

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 respectively). They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

Aditya and Fordham (1995) carried out an experiment in the field and greenhouse to study the effects of cold exposure and $GA_3$ during early growth stages on the date of flowering of the tropical cauliflower cv. Early Patnai and the temperate cv. Lawyna. Flowering in cv. Early Patnai was advanced by approximately 25 days following vernalization (1 week at $10^0$C) of 3 week old plants. They reported that one week old plants failed to respond to this treatment suggesting juvenile phase lasting up to about the 6 leaf stage in this cultivar.

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 $GA_3$ and applied in three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days of transplanting. 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.

Reddy (1989) reported that exogenous application of $GA_3$ and Urea either alone or in combination enhanced curd size as well as yield. Greatest plant height at curd formation (58.2 cm), curd diameter at maturity (26.8 cm) and increase yield over the control (164%) were obtained with two application of $GA_3$.

Sharma and Mishra (1989) stated that plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulator. Several experiments were conducted to increase the yield of cauliflower. $GA_3$ and IAA have a positive effect on curd formation and size of cauliflower.

Muthoo *et al.* (1987) showed that the foliar application of different concentration of $GA_3$, NAA and molybdenum increased the average fresh and dry weight of leaves. Curd and yield of cauliflower among the individual treatments, gibberellic acid proved to be the best for the vegetative growth of curd and yield of cauliflower (q/ha) followed by naphthalene acetic acid. The effect of treatment combination $G_2N_2M_2$ (100 ppm $GA_3$, 120 ppm NAA and 0.2% molybdenum) gave best result for all parameters of growth and yield.

Patil *et al.* (1987) conducted an experiment in a field trial with the cultivar Pride of India applied $GA_3$ and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the $GA_3$ and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with $GA_3$ at 50 ppm followed by NAA at 50 ppm. Significant increase in number of outer and inner leaves was noticed with both $GA_3$ and NAA. Head formation and head maturity was 13 and 12 days earlier with 50 ppm $GA_3$. Maximum number of leaves and maximum yield (23.83 t/ha) were obtained with 50 ppm $GA_3$.

Mishra and Singh (1986) conducted an experiment with all possible combinations of the levels of nitrogen (0, 0.5, and 1.0 per cent), boron (0, 0.1, 0.2 per cent) and $GA_3$ (0, 25, and 50 ppm) in the form of Urea, boric acid, and $GA_3$ were sprayed on snowball-16 cauliflower respectively. Results revealed that there was significant increase in growth characters namely plant height, diameter of stem, number of leaves per plant, weight of plant, curd yield and nitrogen content in stem and leaves due to N, B and $GA_3$ applications. However, length of stem was increased only by $GA_3$ spray.

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 day old seedlings, CCC decreased the plant height, size of loose leaves, diameter of cabbage of head and finally the yield. $GA_3$ increased the plant height, number of loose leaves per plant, size of leaf and finally the yield.

Yabuta *et al*. (1981) reported that application of $GA_3$ had significantly increased marketable weight, petiole length, and number of leaves, leaf area and height of many leafy vegetables.

As per the above cited reviews, it may be concluded that potassium and $GA_3$ are the important factors for attaining optimum growth and as well as highest yield of broccoli. The literature revealed that the effects of potassium and $GA_3$ have not been studied well and have no definite conclusion for the production of broccoli in the agro climatic condition of Bangladesh.

# CHAPTER III

# MATERIALS AND METHODS

# CHAPTER III

# MATERIALS AND METHODS

The experiment was conducted to find out the effect of potassium and $GA_3$ on growth and yield of broccoli. The materials and methods that were used for conducting the experiment i.e. location, soil and climate condition of experimental site, materials used for the experiment, design of the experiment, data collection and data analysis procedure have been presented in this chapter.

## 3.1 Description of the experimental site

### 3.1.1 Experimental period

The present experiment was conducted within the time period of November 2016 to March 2017.

### 3.1.2 Description of experimental site

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989).

### 3.1.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature ($31.4^0$C) was recorded in the month of March 2017 while the minimum temperature ($12.4^0$C) in the month of January 2017. The highest humidity (78%) was recorded in the month of November, 2016, whereas the highest rainfall (30 mm) was recorded in the month of February 2017.

### 3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and Catayan exchange capacity 5.6 and 2.64 meq 100 g soil$^{-1}$, respectively. The results showed that the soil composed of 27% sand, 43% silt, 30% clay and organic matter 0.88%, which have been presented in Appendix II.

## 3.2 Experimental details

### 3.2.1 Planting materials

The seeds of hybrid broccoli (*Brassica oleracea var. italica*) namely Confident was used as planting materials for this experiment.

### 3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Potassium fertilizer (three levels) as

- i $K_0$: 0 kg $K_2O$/ha (control)
- ii. $K_1$: 75 kg $K_2O$/ha
- iii. $K_2$: 100 kg $K_2O$/ha

Factor B: Gibberellic acid-$GA_3$ (four levels) as

- i. $G_0$: 0 ppm $GA_3$ (control)
- ii. $G_1$: 80 ppm $GA_3$
- iii. $G_2$: 100 ppm $GA_3$
- iv. $G_3$: 120 ppm $GA_3$

There were 12 (3 × 4) treatments combination such as $K_0G_0$, $K_0G_1$, $K_0G_2$, $K_0G_3$, $K_1G_0$, $K_1G_1$, $K_1G_2$, $K_1G_3$, $K_2G_0$, $K_2G_1$, $K_2G_2$ and $K_2G_3$.

### 3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were allotted at random. There were 36 unit plots and the size of each plot was 1.2 m × 2.0 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

### 3.2.4 Preparation of the main field

The selected plot of the experiment was opened in the 2$^{nd}$ week of November 2016 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

### 3.2.5 Application of manure and fertilizers

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses (BARI, 2014) of broccoli.

**Table 1. Dose and method of application of fertilizers in broccoli field**

| Fertilizers and Manures | Dose/ha | Application (%) | | | |
|---|---|---|---|---|---|
| | | Basal | 10 DAT | 30 DAT | 50 DAT |
| Cowdung | 20 tonnes | 100 | -- | -- | -- |
| Urea | 300 kg | -- | 33.33 | 33.33 | 33.33 |
| TSP | 200 | 100 | -- | -- | -- |
| MoP | As per treatment | -- | 33.33 | 33.33 | 33.33 |

The total amount of cowdung and TSP was applied as basal dose at the time of land preparation. The total amount of urea and MoP was applied in three equal installments at 10, 30 and 50 day after transplanting.

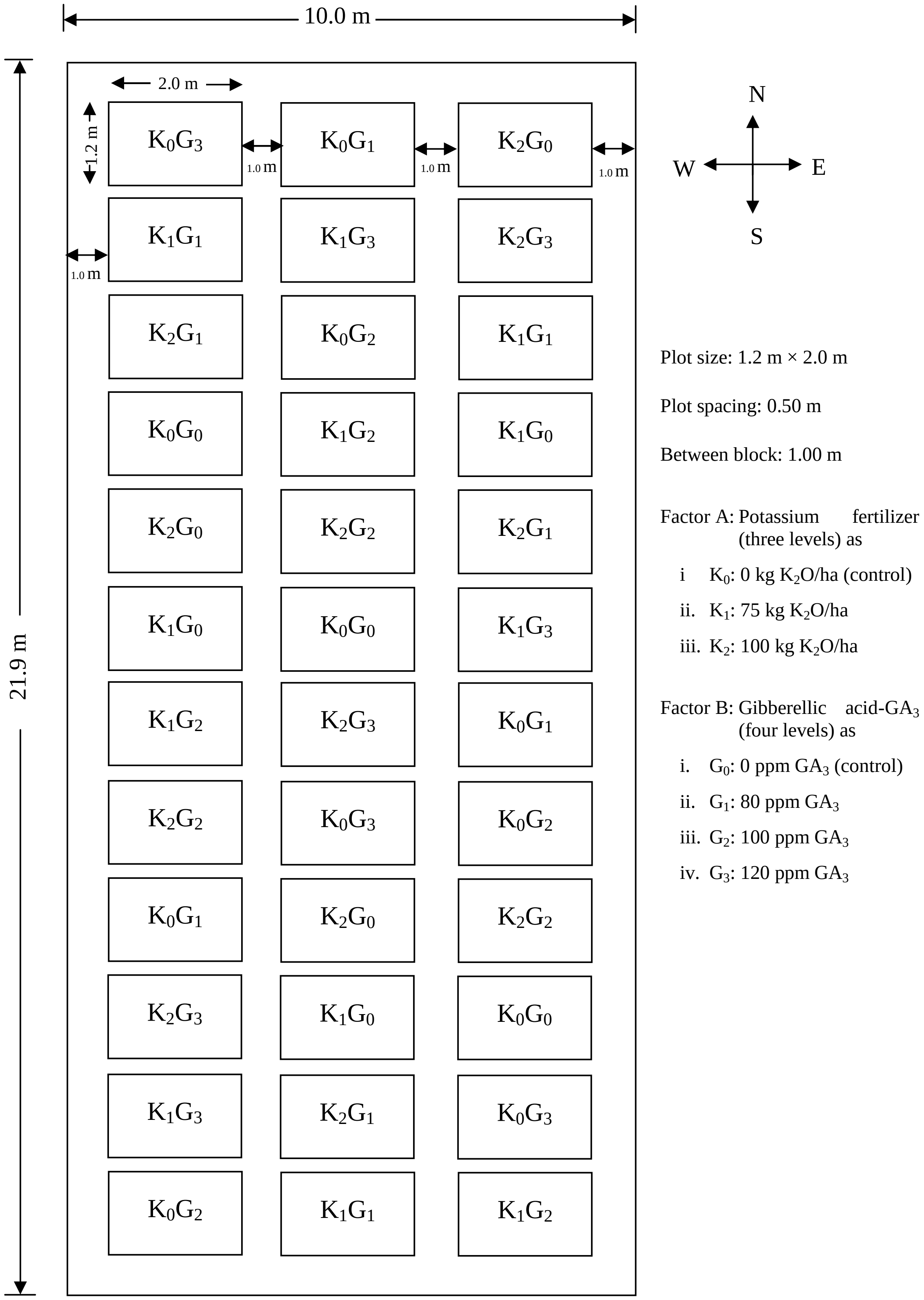



Figure 1. Layout of the experimental plot

### 3.3 Growing of crops

#### 3.3.1 Collection of seeds

The seeds of hybrid broccoli namely Confident was collected from Siddique Bazar market, Dhaka.

#### 3.3.2 Raising of seedlings

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 3 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in seedbed on November 02, 2016. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was done by polythene sheet over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall (Plate 1). Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth (Plate 2).

Plate 1. Seed sowing on seedbed for the experiment

Plate 2. Raised seedlings for the experiment

### 3.3.3 Transplanting of seedlings

Healthy and uniform seedlings of 33 days old seedlings were transplanting in the experimental plots on 04 December, 2016 (Plate 3). The seedlings were uploaded carefully from the seed bed to avoid damage of root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row was 60 cm and plant to plant was 40 cm. As a result there are 10 seedlings were accommodated in each plot according to the design of the plot size at 2.0 m × 1.2 m. The young transplanted seedlings were shaded by banana leaf sheath during day time to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling if necessary.

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

Plant growth regulator Gibberellic Acid ($GA_3$) was collected from Hatkhola Road, 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

Plate 3. Transplanted seedling on main field with tagging

litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 80 ml of this stock solution was diluted in 1 litre of distilled water to get 80 ppm $GA_3$ solution. In a similar way, 100 ppm and 120 ppm stock solutions were diluted to 1 litre of distilled water to get 100 ppm and 120 ppm solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. $GA_3$ as per treatment were applied at three times 15, 30 and 45 days after transplanting by a mini hand sprayer (Plate 4).

Plate 4. Gibberellic acid applied on broccoli plant

### 3.3.5 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the broccoli seedlings.

#### 3.3.5.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplants were given shading and watering for 7 days for their proper establishment.

#### 3.3.5.2 Weeding

The hand weeding was done 15, 30 and 45 days after transplanting to keep the plots free from weeds.

#### 3.3.5.3 Irrigation

Light watering was given by a watering can at every morning and afternoon after transplanting. Following transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Beside this a routine irrigation was given at 3 days intervals (Plate 5).

Plate 5. Watering after potassium application

### 3.3.5.4 Earthing up

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

### 3.3.5.5 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedling in the field. In spite of Cirocarb 3G applications during final land preparation, few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. Birds pest such as nightingales (Bulbuli) were seen visiting the broccoli field very frequently. The birds found to puncture the newly initiated curd and were controlled by striking a kerosene tin of metallic container frequently during day time.

## 3.4 Harvesting

Harvesting of the broccoli was not possible on a certain or particular date because the curd initiation as well as curd at marketable size in different plants were not uniform. Only the marketable size curds were harvested with fleshy stalk by using as sharp knife (Plate 6). Before harvesting of the broccoli curd, compactness of the curd was tested by pressing with thumbs.

Plate 6. Maturity stage of broccoli plants

## 3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of this experiment (Plate 7). Data on plant height, number of leaves and length of largest leaf were collected at 20, 30, 40 and 50 days after transplanting (DAT) and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

Plate 7: Data collection for the experiment

### 3.5.1 Plant height

Plant height was measured from sample plants by using meter scale in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 10 days interval starting from 20 days after transplanting (DAT) and continued upto 50 DAT and at harvest to observe the growth rate of plants.

### 3.5.2 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 20 DAT and continued upto 50 DAT and at harvest.

### 3.5.3 Length of leaf

The length of largest leaf was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 20 DAT and continued upto 50 DAT and at harvest.

### 3.5.4 Breadth of leaf

The breadth of largest leaf was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 20 DAT and continued upto 50 DAT and at harvest.

### 3.5.5 Days to 1$^{st}$ curd initiation

Each plant of the experiment plot was kept under close observation to assess days of curd initiation. Total number of days from the date of transplanting to the curd initiation was calculated and recorded.

### 3.5.6 Stem length

Stem length was taken from the ground level to base of the curd during harvesting with a meter scale and was expressed in centimeter (cm).

### 3.5.7 Stem diameter

Stem diameter was measured at the point where the central stem was cut off. The diameter of the stem was recorded in three dimensions with scale and the average of three figures was taken into account in centimeter (cm).

### 3.5.8 Root length

Root length was measured from five randomly selected plant and their average were calculated and expressed in centimeter.

### 3.5.9 Primary curd weight

The curds from sample plants were harvested, cleaned and weighted by weighing machine and mean values was recorded and express in gram.

### 3.5.10 Primary curd diameter

The curds from sample plants were sectioned vertically at the middle position with a sharp knife. The primary curd diameter was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another side of the widest part of the sectioned curd and mean value was recorded.

### 3.5.11 Dry matter content of plant

At first plant parts of selected plant were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at $70^0$C for 72 hours until constant weight. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken.

### 3.5.12 Dry matter content of curd

At first curds of selected plant were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at $70^0$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.

### 3.5.13 Number of secondary curds per plant

The total number of secondary curds per plant was counted from each selected plant. Data were recorded as the average of 5 plants at random of each plot.

### 3.5.14 Secondary curds weight

The secondary curds from sample plants were harvested, cleaned and weighted. The weight of every secondary curd from each plant was weighted by weighing machine and added them in plant wise and finally means values was calculated and recorded.

### 3.5.15 Curd yield per plot

Curd yield per plot was recorded by multiplying average curd yield per plant with total number of plant within a plot and was expressed in kilogram (kg) and recorded plot wise.

### 3.5.16 Curd yield per hectare

The curd yield per hectare was measured by converted total curd yield per plot into yield per hectare and was expressed in ton (t).

## 3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different levels of potassium and $GA_3$ on growth and yield contributing characters of broccoli. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

## 3.7 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different levels of potassium and $GA_3$ for broccoli cultivation. All input cost included the cost for lease of land and interests on running capital in computing cost of production. The interests were calculated @ 12% in simple rate. The market price of broccoli was considered as local market for estimating the cost and return. Economic analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

# CHAPTER IV

# RESULTS AND DISCUSSION

# CHAPTER IV

# RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of potassium and $GA_3$ on growth and yield of broccoli. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following heads:

## 4.1 Plant height

Plant height of broccoli at 20, 30, 40, 50 DAT (days after transplanting) and at harvest showed significant differences due to different levels of potassium (Table 2 and Appendix III). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (22.23, 36.84, 52.87, 65.06 and 70.78 cm, respectively) was found from $K_2$ (100 kg $K_2O$/ha) which was statistically similar (21.88, 36.55, 52.51, 64.44 and 69.81 cm, respectively) to $K_1$ (75 kg $K_2O$/ha), while the shortest plant (18.28, 31.41, 47.19, 57.01 and 62.13 cm, respectively) was recorded from $K_0$ (0 kg $K_2O$/ha i.e. control condition) at the same days. Generally plant height increased with the application of potassium upto a certain level in broccoli. Uddain *et al*. (2010) reported similar findings from their study.

Different levels of $GA_3$ varied significantly in terms of plant height of broccoli at 20, 30, 40, 50 DAT and at harvest (Table 2 and Appendix III). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (22.02, 36.93, 53.08, 65.11 and 70.98 cm, respectively) was observed from $G_3$ (120 ppm $GA_3$) which was statistically similar (21.88, 36.30, 52.58, 64.33 and 70.09 cm, respectively) to $G_2$ (100 ppm $GA_3$) and closely followed (20.41, 34.45, 50.65, 61.82 and 67.12 cm, respectively) by $G_1$ (80 ppm $GA_3$), while the shortest plant (18.87, 32.04, 47.10, 57.41 and 62.11 cm, respectively) was recorded from $G_0$ (0 ppm $GA_3$ i.e. control condition) at same data recording days. Sharma and Mishra (1989) reported that plant height increased with foliar application of $GA_3$.

**Table 2. Effect of different levels of potassium and $GA_3$ on plant height at different days after transplanting (DAT) and at harvest of broccoli**

| Treatments | Plant height (cm) at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| **Levels of potassium** | | | | | |
| $K_0$ | 18.28 b | 31.41 b | 47.19 b | 57.01 b | 62.13 b |
| $K_1$ | 21.88 a | 36.55 a | 52.51 a | 64.44 a | 69.81 a |
| $K_2$ | 22.23 a | 36.84 a | 52.87 a | 65.06 a | 70.78 a |
| $LSD_{(0.05)}$ | 0.748 | 1.502 | 1.202 | 2.126 | 2.439 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Levels of $GA_3$** | | | | | |
| $G_0$ | 18.87 c | 32.04 c | 47.10 c | 57.41 c | 62.11 c |
| $G_1$ | 20.41 b | 34.45 b | 50.65 b | 61.82 b | 67.12 b |
| $G_2$ | 21.88 a | 36.30 a | 52.58 a | 64.33 a | 70.09 a |
| $G_3$ | 22.02 a | 36.93 a | 53.08 a | 65.11 a | 70.98 a |
| $LSD_{(0.05)}$ | 0.863 | 1.734 | 1.387 | 2.455 | 2.817 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 8.92 | 9.31 | 6.79 | 7.85 | 7.26 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of plant height of broccoli at 20, 30, 40, 50 DAT and at harvest (Table 3 and Appendix III). At 20, 30, 40, 50 DAT and at harvest, the tallest plant (24.66, 40.61, 56.30, 68.81 and 74.55 cm, respectively) was recorded from $K_2G_3$ (100 kg $K_2O$/ha and 120 ppm $GA_3$) treatment combination and the shortest plant (16.97, 30.04, 44.81, 50.74 and 54.52 cm, respectively) was recorded from $K_0G_0$ (0 kg $K_2O$/ha and 0 ppm $GA_3$ i.e. control condition) treatment combination at same days.

### 4.2 Number of leaves per plant

Statistically significant variation was recorded in terms of number of leaves per plant of broccoli at 20, 30, 40, 50 DAT and at harvest due to different levels of potassium (Figure 2 and Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the highest number of leaves per plant (7.70, 13.58, 20.47, 23.55 and 24.16, respectively) was observed from $K_2$ which was statistically similar (7.10, 13.35, 19.90, 23.02 and 23.57, respectively) to $K_1$, while the lowest number (5.30, 11.73, 16.05, 18.27 and 19.01, respectively) was attained from $K_0$ at the same days of observation.

Number of leaves per plant of broccoli at 20, 30, 40, 50 DAT and at harvest varied significantly due to different levels of $GA_3$ (Figure 3 and Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the highest number of leaves per plant (7.11, 14.04, 19.87, 22.89 and 23.58, respectively) was observed from $G_3$ which was statistically similar (7.07, 13.53, 19.56, 22.69 and 23.37, respectively) to $G_2$ and closely followed (6.59, 12.74, 18.64, 21.24 and 21.95, respectively) by $G_1$, while the lowest number (6.04, 11.22, 17.17, 19.62 and 20.09, respectively) was recorded from $G_0$ at same data recording days. Data revealed that number of leaves per plant increased with the application of gibberellic acid in broccoli. Lendve *et al.* (2010) found that application of 50 ppm $GA_3$ was found significantly superior in terms of number of the leaves of broccoli.

**Table 3. Combined effect of different levels of potassium and $GA_3$ on plant height at different days after transplanting (DAT) and at harvest of broccoli**

| Treatments | Plant height (cm) at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| $K_0G_0$ | 16.97 g | 30.04 g | 44.81 e | 50.74 e | 54.52 d |
| $K_0G_1$ | 17.95 fg | 31.18 fg | 47.55 d | 59.19 cd | 65.26 c |
| $K_0G_2$ | 19.29 ef | 32.43 e-g | 47.59 d | 57.86 d | 63.21 c |
| $K_0G_3$ | 18.90 ef | 31.99 fg | 48.79 d | 60.23 cd | 65.53 c |
| $K_1G_0$ | 20.43 de | 34.43 d-f | 48.85 d | 60.87 cd | 65.46 c |
| $K_1G_1$ | 21.48 cd | 36.61 b-d | 52.54 bc | 62.98 bc | 68.09 bc |
| $K_1G_2$ | 23.11 ab | 36.95 b-d | 54.52 ab | 67.62 ab | 72.81 ab |
| $K_1G_3$ | 22.51 bc | 38.20 a-c | 54.15 a-c | 66.29 ab | 72.87 ab |
| $K_2G_0$ | 19.22 ef | 31.66 fg | 47.64 d | 60.62 cd | 66.34 c |
| $K_2G_1$ | 21.79 b-d | 35.55 c-e | 51.88 c | 63.30 bc | 68.01 bc |
| $K_2G_2$ | 23.23 ab | 39.53 ab | 55.65 a | 67.52 ab | 74.24 a |
| $K_2G_3$ | 24.66 a | 40.61 a | 56.30 a | 68.81 a | 74.55 a |
| $LSD_{(0.05)}$ | 1.495 | 3.004 | 2.403 | 4.253 | 4.879 |
| Level of significance | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| CV(%) | 8.92 | 9.31 | 6.79 | 7.85 | 7.26 |

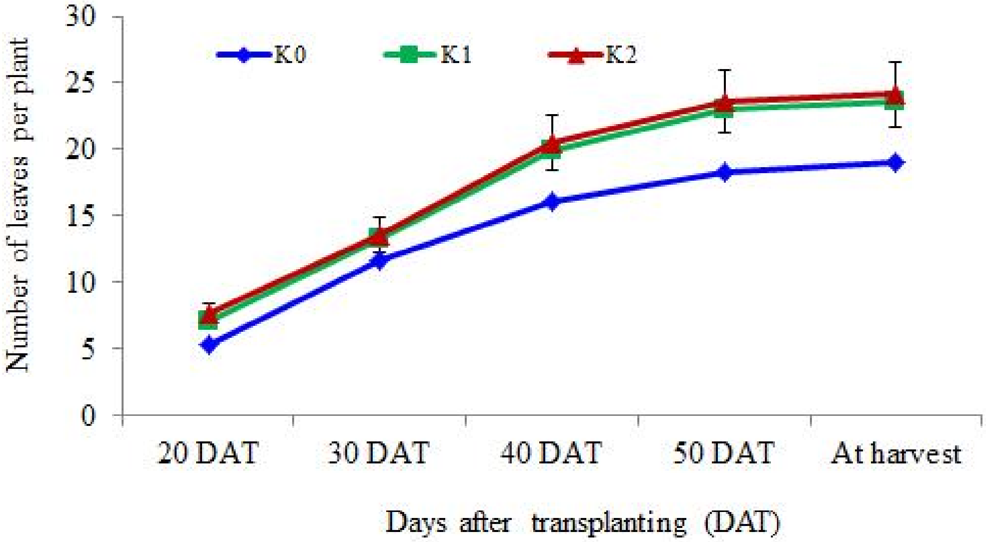
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)    $G_0$: 0 ppm $GA_3$ (control)

$K_1$: 75 kg $K_2O$/ha    $G_1$: 80 ppm $GA_3$

$K_2$: 100 kg $K_2O$/ha    $G_2$: 100 ppm $GA_3$

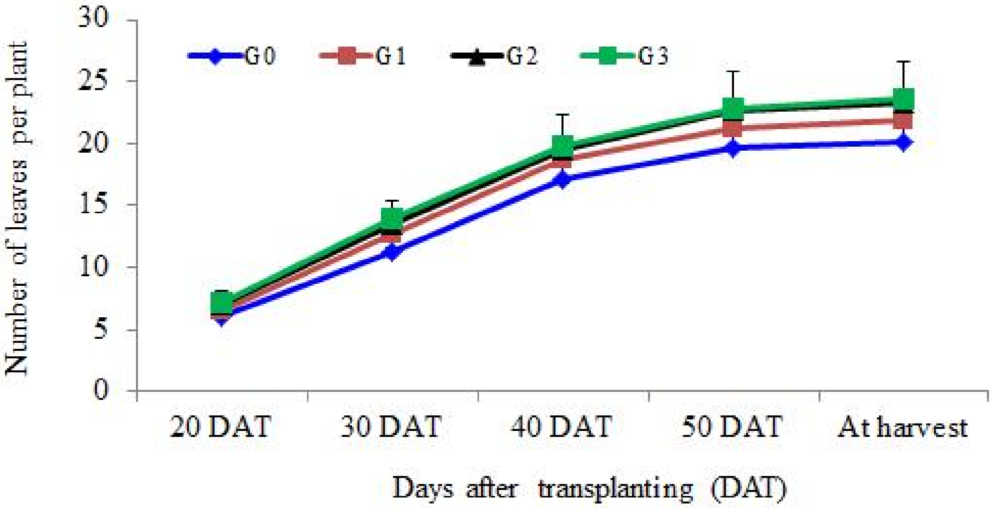
$G_3$: 120 ppm $GA_3$




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

Figure 2. Effect of different levels of potassium on number of leaves per plant of broccoli. (Vertical bars represent LSD value at 5% level of probability)




$G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 3. Effect of different levels of $GA_3$ on number of leaves per plant of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Combined effect of different levels of potassium and $GA_3$ showed statistically significant differences in terms of number of leaves per plant of broccoli at 20, 30, 40, 50 DAT and at harvest (Table 4 and Appendix IV). At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves per plant (8.67, 15.13, 22.40, 25.73 and 26.44, respectively) was recorded from $K_2G_3$ treatment combination and the minimum number (4.88, 10.27, 14.80, 17.60 and 18.12, respectively) was recorded from $K_0G_0$ treatment combination at same days.

### 4.3 Leaf length

Leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest varied significantly due to different levels of potassium (Figure 4 and Appendix V). At 20, 30, 40, 50 DAT and at harvest, the longest leaf (16.63, 26.12, 37.40, 45.94 and 47.32 cm, respectively) was found from $K_2$ which was statistically similar (16.34, 25.69, 36.47, 44.06 and 45.33 cm, respectively) to $K_1$, while the shortest leaf (14.67, 22.41, 33.00, 35.68 and 37.17 cm, respectively) was recorded from $K_0$ at the same days.

Statistically significance variation was recorded for different levels of $GA_3$ in terms of leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest (Figure 5 and Appendix V). At 20, 30, 40, 50 DAT and at harvest, the longest leaf (16.79, 26.02, 37.33, 44.32 and 45.75 cm, respectively) was observed from $G_3$ which was statistically similar (16.44, 25.71, 36.80, 43.54 and 45.43 cm, respectively) to $G_2$ and closely followed (15.69, 24.43, 35.26, 41.50 and 42.63 cm, respectively) by $G_1$, while the shortest leaf (14.60, 22.78, 33.09, 38.20 and 39.28 cm, respectively) from $G_0$ at same data recording days.

Leaf length of broccoli at 20, 30, 40, 50 DAT and at harvest varied significantly due to the combined effect of different levels of potassium and $GA_3$ (Table 5 and Appendix V). At 20, 30, 40, 50 DAT and at harvest, the longest leaf (17.92, 27.77, 39.79, 49.87 and 51.08 cm, respectively) was recorded from $K_2G_3$ treatment combination and the shortest leaf (13.68, 20.36, 30.94, 34.54 and 35.25 cm, respectively) from $K_0G_0$ treatment combination at same days.

**Table 4. Combined effect of different levels of potassium and $GA_3$ on number of leaves per plant at different days after transplanting (DAT) and at harvest of broccoli**

| Treatments | Number of leaves per plant at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| $K_0G_0$ | 4.88 e | 10.27 f | 14.80 g | 17.60 e | 18.12 g |
| $K_0G_1$ | 5.33 e | 12.25 de | 16.82 ef | 18.87 e | 19.66 e-g |
| $K_0G_2$ | 5.47 e | 11.40 e | 15.93 fg | 18.33 e | 19.14 fg |
| $K_0G_3$ | 5.53 e | 13.00 cd | 16.67 ef | 18.27 e | 19.11 fg |
| $K_1G_0$ | 6.28 d | 11.60 e | 18.53 cd | 20.00 de | 20.58 d-f |
| $K_1G_1$ | 7.26 bc | 13.38 b-d | 19.95 bc | 23.07 bc | 23.53 bc |
| $K_1G_2$ | 7.73 bc | 14.40 ab | 20.60 b | 24.33 ab | 25.01 ab |
| $K_1G_3$ | 7.13 c | 14.00 a-c | 20.53 b | 24.67 ab | 25.18 ab |
| $K_2G_0$ | 6.95 cd | 11.80 e | 18.20 de | 21.27 cd | 21.58 c-e |
| $K_2G_1$ | 7.19 c | 12.58 de | 19.15 b-d | 21.80 cd | 22.66 cd |
| $K_2G_2$ | 8.00 ab | 14.80 a | 22.13 a | 25.40 ab | 25.94 a |
| $K_2G_3$ | 8.67 a | 15.13 a | 22.40 a | 25.73 a | 26.44 a |
| $LSD_{(0.05)}$ | 0.714 | 1.084 | 1.504 | 2.252 | 2.203 |
| Level of significance | 0.05 | 0.01 | 0.01 | 0.05 | 0.05 |
| CV(%) | 6.30 | 7.97 | 7.55 | 6.15 | 8.89 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

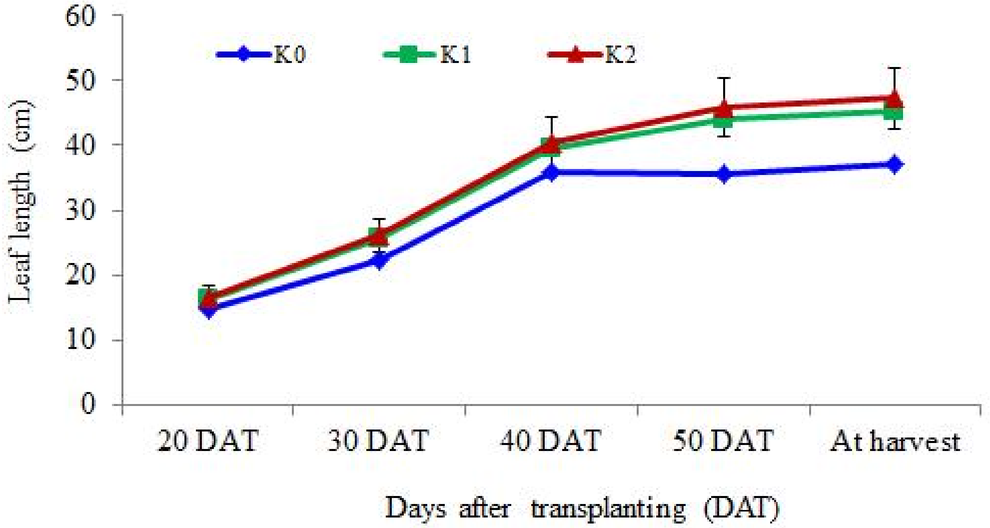
$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

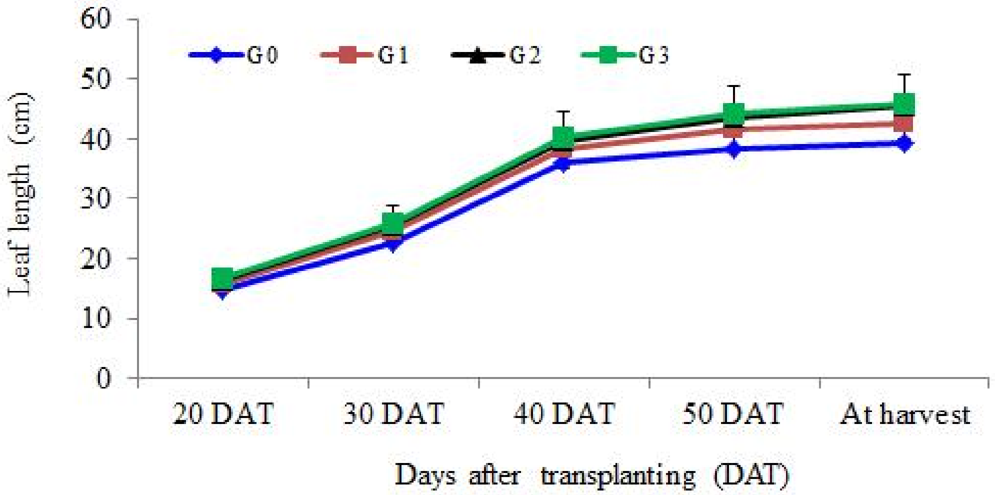
$G_3$: 120 ppm $GA_3$




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

Figure 4. Effect of different levels of potassium on leaf length of broccoli. (Vertical bars represent LSD value at 5% level of probability)




$G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 5. Effect of different levels of $GA_3$ on leaf length of broccoli. (Vertical bars represent LSD value at 5% level of probability)

**Table 5. Combined effect of different levels of potassium and $GA_3$ on leaf length at different days after transplanting (DAT) and at harvest of broccoli**

| Treatment | Leaf length (cm) at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| $K_0G_0$ | 13.68 f | 20.36 e | 30.94 f | 34.54 h | 35.25 g |
| $K_0G_1$ | 14.99 de | 23.30 cd | 33.58 de | 36.89 gh | 38.25 fg |
| $K_0G_2$ | 14.46 ef | 22.56 d | 32.64 ef | 34.34 h | 36.25 g |
| $K_0G_3$ | 15.55 de | 23.41 cd | 34.84 c-e | 36.95 gh | 38.93 fg |
| $K_1G_0$ | 15.02 de | 23.79 cd | 34.04 de | 39.65 fg | 40.86 ef |
| $K_1G_1$ | 16.20 b-d | 25.05 bc | 35.92 b-d | 43.39 de | 44.24 c-e |
| $K_1G_2$ | 17.26 ab | 27.03 ab | 38.53 ab | 47.04 a-c | 48.97 ab |
| $K_1G_3$ | 16.90 a-c | 26.88 ab | 37.38 a-c | 46.15 b-d | 47.24 a-c |
| $K_2G_0$ | 15.12 de | 24.19 cd | 34.30 de | 40.41 ef | 41.74 d-f |
| $K_2G_1$ | 15.88 cd | 24.95 bc | 36.27 b-d | 44.22 cd | 45.40 b-d |
| $K_2G_2$ | 17.60 a | 27.56 a | 39.23 a | 49.26 ab | 51.07 a |
| $K_2G_3$ | 17.92 a | 27.77 a | 39.79 a | 49.87 a | 51.08 a |
| $LSD_{(0.05)}$ | 1.157 | 1.961 | 2.456 | 3.190 | 3.807 |
| Level of significance | 0.05 | 0.05 | 0.01 | 0.01 | 0.05 |
| CV(%) | 9.47 | 6.68 | 7.82 | 9.28 | 8.77 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control) $G_0$: 0 ppm $GA_3$ (control)

$K_1$: 75 kg $K_2O$/ha $G_1$: 80 ppm $GA_3$

$K_2$: 100 kg $K_2O$/ha $G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

## 4.4 Leaf breadth

Leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest showed significant differences due to different levels of potassium (Table 6 and Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.55, 13.57, 17.24, 19.42 and 20.35 cm, respectively) was found from $K_2$ which was statistically similar (8.40, 13.29, 16.92, 18.74 and 19.87 cm, respectively) to $K_1$, while the lowest leaf breadth (7.60, 11.36, 14.89, 15.98 and 16.84 cm, respectively) was recorded from $K_0$ at the same days.

Due to application of different levels of $GA_3$ showed significant variation in terms of leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest (Table 6 and Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (8.77, 13.59, 17.25, 19.18 and 20.28 cm, respectively) was observed from $G_3$ which was statistically similar (8.64, 13.38, 16.99, 18.87 and 19.85 cm, respectively) to $G_2$ and closely followed (8.05, 12.63, 16.11, 17.76 and 18.65 cm, respectively) by $G_1$, whereas the lowest leaf breadth (7.26, 11.36, 15.06, 16.38 and 17.30 cm, respectively) was recorded from $G_0$ at same data recording days.

Combined effect of different levels of potassium and $GA_3$ varied significantly in terms of leaf breadth of broccoli at 20, 30, 40, 50 DAT and at harvest (Table 7 and Appendix VI). At 20, 30, 40, 50 DAT and at harvest, the highest leaf breadth (9.32, 14.73, 18.40, 20.98 and 21.85 cm, respectively) was recorded from $K_2G_3$ treatment combination and the lowest leaf breadth (6.79, 10.34, 13.67, 15.02 and 15.54 cm, respectively) from $K_0G_0$ treatment combination at same days.

## 4.5 Days to 1$^{st}$ curd initiation

Statistically significant variation was recorded in terms of days to 1$^{st}$ curd initiation of broccoli due to application of different levels of potassium (Figure 6 and Appendix VII). The maximum days to 1$^{st}$ curd initiation (56.00) was found from $K_0$, while the minimum days (53.25) was recorded from $K_2$ which was statistically similar (54.00) to $K_1$.

**Table 6. Effect of different levels of potassium and $GA_3$ on leaf breadth at different days after transplanting (DAT) and at harvest of broccoli**

| Treatment | Leaf breadth (cm) at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| **Levels of potassium** | | | | | |
| $K_0$ | 7.60 b | 11.36 b | 14.89 b | 15.98 b | 16.84 b |
| $K_1$ | 8.40 a | 13.29 a | 16.92 a | 18.74 a | 19.87 a |
| $K_2$ | 8.55 a | 13.57 a | 17.24 a | 19.42 a | 20.35 a |
| $LSD_{(0.05)}$ | 0.384 | 0.446 | 0.692 | 0.717 | 0.774 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Levels of $GA_3$** | | | | | |
| $G_0$ | 7.26 c | 11.36 c | 15.06 c | 16.38 c | 17.30 c |
| $G_1$ | 8.05 b | 12.63 b | 16.11 b | 17.76 b | 18.65 b |
| $G_2$ | 8.64 a | 13.38 a | 16.99 a | 18.87 a | 19.85 a |
| $G_3$ | 8.77 a | 13.59 a | 17.25 a | 19.18 a | 20.28 a |
| $LSD_{(0.05)}$ | 0.444 | 0.516 | 0.798 | 0.828 | 0.893 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 9.95 | 7.14 | 8.68 | 9.05 | 8.45 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

**Table 7. Combined effect of different levels of potassium and $GA_3$ on leaf breadth at different days after transplanting (DAT) and at harvest of broccoli**

| Treatment | Leaf breadth (cm) at | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 30 DAT | 40 DAT | 50 DAT | At harvest |
| $K_0G_0$ | 6.79 d | 10.34 d | 13.67 e | 15.02 f | 15.54 f |
| $K_0G_1$ | 7.74 c | 11.87 c | 15.44 cd | 16.42 d-f | 17.24 de |
| $K_0G_2$ | 7.69 c | 11.41 c | 14.88 de | 15.55 ef | 16.49 ef |
| $K_0G_3$ | 8.16 bc | 11.83 c | 15.58 cd | 16.92 de | 18.08 de |
| $K_1G_0$ | 7.49 cd | 11.71 c | 15.64 cd | 16.95 de | 17.90 de |
| $K_1G_1$ | 8.22 bc | 13.09 b | 16.43 bc | 18.00 cd | 18.90 cd |
| $K_1G_2$ | 9.05 a | 14.16 a | 17.84 ab | 20.39 a | 21.78 a |
| $K_1G_3$ | 8.83 ab | 14.21 a | 17.77 ab | 19.64 ab | 20.90 ab |
| $K_2G_0$ | 7.50 cd | 12.04 c | 15.86 cd | 17.17 d | 18.46 cd |
| $K_2G_1$ | 8.20 bc | 12.93 b | 16.45 bc | 18.87 bc | 19.81 bc |
| $K_2G_2$ | 9.19 a | 14.57 a | 18.25 a | 20.67 a | 21.27 ab |
| $K_2G_3$ | 9.32 a | 14.73 a | 18.40 a | 20.98 a | 21.85 a |
| $LSD_{(0.05)}$ | 0.769 | 0.893 | 1.383 | 1.435 | 1.547 |
| Level of significance | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| CV(%) | 9.95 | 7.14 | 8.68 | 9.09 | 8.45 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

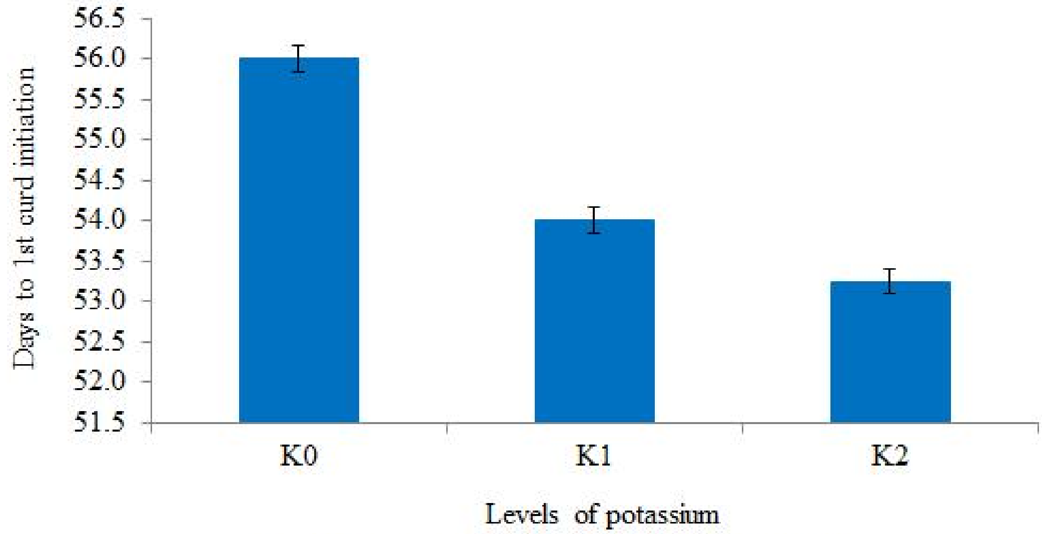
$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

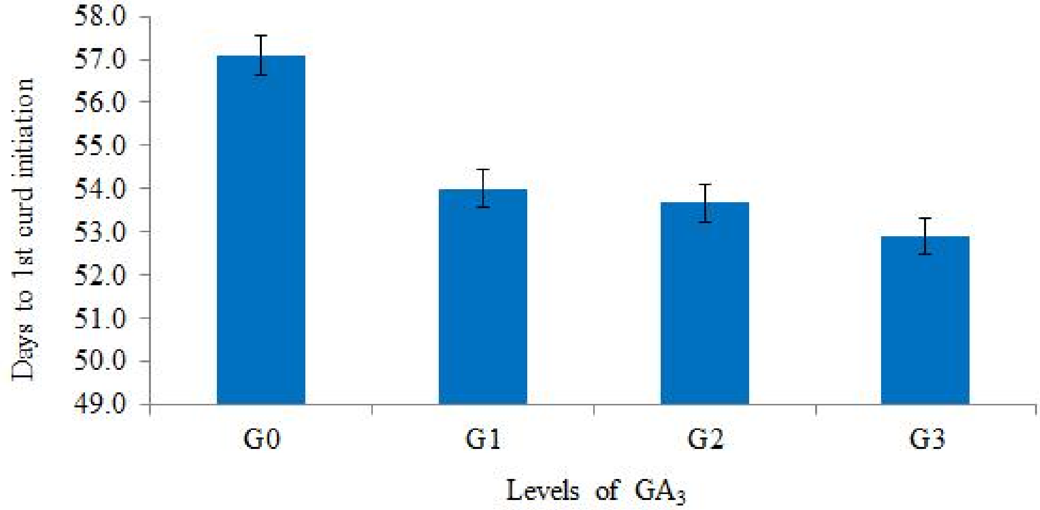
$G_3$: 120 ppm $GA_3$




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

Figure 6. Effect of different levels of potassium on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)




$G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 7. Effect of different levels of $GA_3$ on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Different levels of $GA_3$ varied significantly in terms of days to $1^{st}$ curd initiation of broccoli (Figure 7 and Appendix VII). The maximum days to $1^{st}$ curd initiation (57.11) was observed from $G_0$, whereas the lowest days (52.89) was recorded from $G_3$ which was statistically similar to $G_2$ and $G_1$. Lendve *et al.* (2010) reported that 75 ppm $GA_3$, gave better results to days required for head initiation.

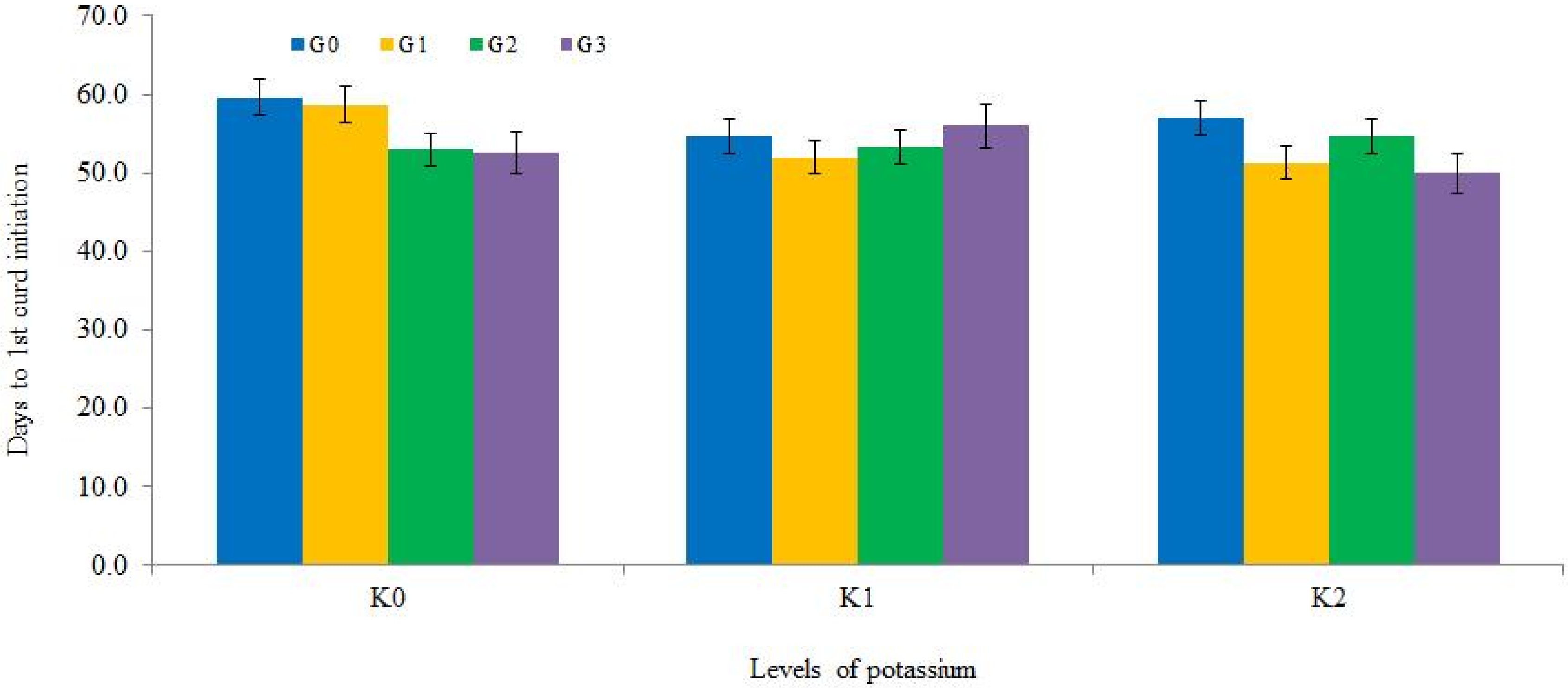
Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of days to $1^{st}$ curd initiation of broccoli (Figure 8 and Appendix VII). The maximum days to $1^{st}$ curd initiation (59.67) was recorded from $K_0G_0$ treatment combination and the minimum days (50.00) was recorded from $K_2G_3$ treatment combination.

### 4.6 Length of stem

Different levels of potassium showed significant differences in terms of length of stem of broccoli (Table 8 and Appendix VII). The highest length of stem (22.57 cm) was found from $K_2$ which was statistically similar (21.94 cm) to $K_1$, while the lowest length of stem (17.97 cm) was recorded from $K_0$. Similar findings also reported by Uddain *et al.* (2010) from their study.

Length of stem of broccoli varied significantly due to different levels of $GA_3$ (Table 8 and Appendix VII). The highest length of stem (21.93 cm) was observed from $G_3$ which was statistically similar (21.77 cm) to $G_2$ and closely followed (20.53 cm) by $G_1$, whereas the lowest length of stem (19.07 cm) was recorded from the control. Manjit Singh (2011) showed that $GA_3$ increase the length of stem of broccoli upto a certain limit.

Combined effect of different levels of potassium and $GA_3$ showed statistically significant variation in terms of length of stem of broccoli (Table 9 and Appendix VII). The highest length of stem (24.27 cm) was recorded from $K_2G_3$ and the lowest length of stem (16.59 cm) was recorded from $K_0G_0$ treatment combination.




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha $G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$K_2$: 100 kg $K_2O$/ha $G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 8. Combined effect of different levels of potassium and $GA_3$ on days to 1st curd initiation of broccoli. (Vertical bars represent LSD value at 5% level of probability)

**Table 8. Effect of different levels of potassium and $GA_3$ on yield contributing characters and yield of broccoli**

| Treatments | Length of Stem (cm) | Diameter of stem (cm) | Length of root (cm) | Weight of primary curd (g) | Diameter of primary curd (cm) |
|---|---|---|---|---|---|
| **Levels of potassium** | | | | | |
| $K_0$ | 17.97 b | 2.18 c | 19.33 c | 399.08 b | 7.56 b |
| $K_1$ | 21.94 a | 2.36 b | 21.89 b | 457.52 a | 8.20 a |
| $K_2$ | 22.57 a | 2.48 a | 22.98 a | 470.22 a | 8.60 a |
| $LSD_{(0.05)}$ | 1.965 | 0.107 | 0.767 | 21.19 | 0.423 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Levels of $GA_3$** | | | | | |
| $G_0$ | 19.07 b | 2.03 c | 19.12 c | 393.57 c | 7.10 c |
| $G_1$ | 20.53 ab | 2.32 b | 21.08 b | 439.59 b | 7.85 b |
| $G_2$ | 21.77 a | 2.47 a | 22.57 a | 465.17 a | 8.66 a |
| $G_3$ | 21.93 a | 2.54 a | 22.84 a | 470.75 a | 8.88 a |
| $LSD_{(0.05)}$ | 2.269 | 0.124 | 0.885 | 24.46 | 0.489 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 9.81 | 8.88 | 7.95 | 9.30 | 8.07 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

**Table 9. Combined effect of different levels of potassium and $GA_3$ on yield contributing characters and yield of broccoli**

| Treatments | Length of Stem (cm) | Diameter of stem (cm) | Length of root (cm) | Weight of primary curd (g) | Diameter of primary curd (cm) |
|---|---|---|---|---|---|
| $K_0G_0$ | 16.59 d | 1.97 g | 17.93 e | 350.65 f | 6.96 h |
| $K_0G_1$ | 19.09 b-d | 2.23 d-f | 19.52 c-e | 423.97 c-e | 7.51 e-h |
| $K_0G_2$ | 17.23 cd | 2.19 e-g | 19.25 de | 392.62 ef | 7.43 e-h |
| $K_0G_3$ | 18.96 b-d | 2.34 c-e | 20.64 cd | 429.07 e-f | 8.33 c-e |
| $K_1G_0$ | 20.40 a-d | 2.01 fg | 19.25 de | 425.38 c-e | 7.08 gh |
| $K_1G_1$ | 20.83 a-d | 2.29 de | 21.04 c | 440.18 cd | 7.95 d-g |
| $K_1G_2$ | 23.97 a | 2.58 ab | 24.02 ab | 495.84 ab | 9.21 a-c |
| $K_1G_3$ | 22.57 ab | 2.56 a-c | 23.26 ab | 468.66 a-c | 8.58 b-d |
| $K_2G_0$ | 20.22 a-d | 2.12 e-g | 20.17 cd | 404.67 de | 7.25 f-h |
| $K_2G_1$ | 21.67 a-c | 2.44 b-d | 22.67 b | 454.61 bc | 8.08 d-f |
| $K_2G_2$ | 24.12 a | 2.64 ab | 24.45 a | 507.05 a | 9.34 ab |
| $K_2G_3$ | 24.27 a | 2.73 a | 24.62 a | 514.53 a | 9.73 a |
| $LSD_{(0.05)}$ | 3.930 | 0.214 | 1.533 | 42.37 | 0.847 |
| Level of significance | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| CV(%) | 9.81 | 8.88 | 7.95 | 9.30 | 8.07 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

## 4.7 Diameter of stem

Diameter of stem of broccoli showed significant differences due to different levels of potassium (Table 8 and Appendix VII). The highest diameter of stem (2.48 cm) was found from $K_2$ which was closely followed (2.36 cm) by $K_1$, while the lowest diameter of stem (2.18 cm) was recorded from $K_0$. Similar findings also reported by Uddain *et al*. (2010) from their study in earlier.

Different levels of $GA_3$ varied significantly in terms of diameter of stem of broccoli (Table 8 and Appendix VII). The highest diameter of stem (2.54 cm) was observed from $G_3$ which was statistically similar (2.47 cm) to $G_2$ and closely followed (2.32 cm) by $G_1$, whereas the lowest diameter of stem (2.03 cm) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of diameter of stem of broccoli (Table 9 and Appendix VII). The highest diameter of stem (2.73 cm) was recorded from $K_2G_3$ treatment combination and the lowest diameter of stem (1.97 cm) was recorded from $K_0G_0$ treatment combination. Sharma and Mishra (1989) reported that curd size increased with foliar application of $GA_3$.

## 4.8 Length of root

Statistically significant variation was recorded in terms of length of root of broccoli due to different levels of potassium (Table 8 and Appendix VII). The highest length of root (22.98 cm) was found from $K_2$ which was closely followed (21.89 cm) by $K_1$, while the lowest length of root (19.33 cm) was recorded from the control.

Different levels of $GA_3$ varied significantly in terms of length of root of broccoli (Table 8 and Appendix VII). The highest length of root (22.84 cm) was observed from $G_3$ which was statistically similar (22.57 cm) to $G_2$ and closely followed (21.08 cm) by $G_1$, whereas the lowest length of root (19.12 cm) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of length of root of broccoli (Table 9). The highest length of root (24.62 cm) was recorded from $K_2G_3$ treatment combination and the lowest length of root (17.93 cm) was recorded from $K_0G_0$.

### 4.9 Weight of Primary curd

Weight of primary curd of broccoli showed significant differences due to different levels of potassium (Table 8 and Appendix VII). The highest weight of primary curd (470.22 g) was found from $K_2$ which was statistically similar (457.52 g) to $K_1$, while the lowest weight of primary curd (399.08 g) was recorded from $K_0$. Similar findings also reported by Uddain *et al*. (2010) from their study.

Different levels of $GA_3$ varied significantly in terms of weight of primary curd of broccoli (Table 8 and Appendix VII). The highest weight of primary curd (470.75 g) was observed from $G_3$ which was statistically similar (465.17 g) to $G_2$ and closely followed (439.59 g) by $G_1$, whereas the lowest weight of primary curd (393.57 g) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of weight of primary curd of broccoli (Table 9 and Appendix VII). The highest weight of primary curd (514.53 g) was recorded from $K_2G_3$ treatment combination and the lowest weight of primary curd (350.65 g) was recorded from $K_0G_0$ treatment combination.

### 4.10 Diameter of primary curd

Diameter of primary curd of broccoli showed significant differences due to different levels of potassium (Table 8 and Appendix VII). The highest diameter of primary curd (8.60 cm) was found from $K_2$ which was statistically similar (8.20 cm) to $K_1$, while the lowest diameter of primary curd (7.56 cm) was recorded from $K_0$.

Different levels of $GA_3$ varied significantly in terms of diameter of primary curd of broccoli (Table 8 and Appendix VII). The highest diameter of primary curd (8.88 cm) was observed from $G_3$ which was statistically similar (8.66 cm) to $G_2$ and closely followed (7.85 cm) by $G_1$, whereas the lowest diameter of primary curd (7.10 cm) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of diameter of primary curd of broccoli (Table 9 and Appendix VII). The highest diameter of primary curd (9.73 cm) was recorded from $K_2G_3$ treatment combination and the lowest diameter (6.96 cm) was recorded from $K_0G_0$ treatment combination.

### 4.11 Dry matter content of plant

Dry matter content of plant of broccoli showed significant differences due to different levels of potassium (Table 10 and Appendix VIII). The highest dry matter content of plant (11.32 g) was found from $K_2$ which was statistically similar (11.09 g) to $K_1$, while the lowest dry matter content of plant (9.50 g) was recorded from $K_0$. Similar findings also reported by Uddain *et al*. (2010) from their study.

Different levels of $GA_3$ varied significantly in terms of dry matter content of plant of broccoli (Table 10 and Appendix VIII). The highest dry matter content of plant (11.28 g) was observed from $G_3$ which was statistically similar (11.14 g) to $G_2$ and closely followed (10.45 g) by $G_1$, whereas the lowest dry matter content of plant (9.71 g) was recorded from $G_0$. Lendve *et al*. (2010) found that application of $GA_3$ (50 ppm) was found significantly superior in terms of number of dry weight of the leaves.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of dry matter content of plant of broccoli (Table 11 and Appendix VIII). The highest dry matter content of plant (13.42 g) was recorded from $K_2G_3$ treatment combination and the lowest (9.60 g) was recorded from $K_0G_0$.

**Table 10. Effect of different levels of potassium and $GA_3$ on yield contributing characters and yield of broccoli**

| Treatments | Dry matter content of plant (%) | Dry matter content of curd (%) | Number of secondary curd per plant | Weight of secondary curd (g) | Curd yield per hectare (ton) |
|---|---|---|---|---|---|
| **Levels of potassium** | | | | | |
| $K_0$ | 9.50 b | 12.01 b | 2.47 b | 56.46 b | 18.98 b |
| $K_1$ | 11.09 a | 13.20 a | 2.87 a | 68.43 a | 21.91 a |
| $K_2$ | 11.32 a | 13.39a | 3.04 a | 70.85 a | 22.54 a |
| $LSD_{(0.05)}$ | 0.829 | 0.232 | 0.222 | 3.314 | 0.949 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Levels of $GA_3$** | | | | | |
| $G_0$ | 9.71 c | 12.22 c | 2.20 c | 53.89 c | 18.64 c |
| $G_1$ | 10.45 b | 13.07 b | 2.72 b | 63.08 b | 20.94 b |
| $G_2$ | 11.14 a | 13.43 a | 3.07 a | 70.88 a | 22.34 a |
| $G_3$ | 11.28 a | 13.54 a | 3.19 a | 73.13 a | 22.66 a |
| $LSD_{(0.05)}$ | 0.667 | 0.321 | 0.257 | 3.827 | 1.096 |
| Level of significance | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CV(%) | 8.21 | 9.01 | 9.38 | 7.09 | 8.82 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

**Table 11. Combined effect of different levels of potassium and $GA_3$ on yield contributing characters and yield of broccoli**

| Treatments | Dry matter content of plant (%) | Dry matter content of curd (%) | Number of secondary curd per plant | Weight of secondary curd (g) | Curd yield per hectare (ton) |
|---|---|---|---|---|---|
| $K_0G_0$ | 9.60 e | 11.74 g | 2.09 g | 47.04 f | 16.57 g |
| $K_0G_1$ | 10.74 de | 12.75 ef | 2.43 e-g | 58.74 c-e | 20.11 d-f |
| $K_0G_2$ | 10.67 de | 13.07 f | 2.38 fg | 55.70 e | 18.68 f |
| $K_0G_3$ | 11.14 cd | 13.47 ef | 2.98 b-d | 64.35 cd | 20.56 c-f |
| $K_1G_0$ | 11.31 cd | 13.78 de | 2.23 g | 57.14 e | 20.10 d-f |
| $K_1G_1$ | 11.98 bc | 14.15 cd | 2.83 d-f | 65.09 c | 21.05 c-e |
| $K_1G_2$ | 12.95 ab | 14.71 ab | 3.38 a-c | 77.81 ab | 23.90 ab |
| $K_1G_3$ | 12.65 ab | 14.52 bc | 3.04 b-d | 73.70 b | 22.60 bc |
| $K_2G_0$ | 11.20 cd | 13.76 de | 2.29 g | 57.50 de | 19.26 ef |
| $K_2G_1$ | 11.99 bc | 14.12 cd | 2.90 c-e | 65.41 c | 21.67 cd |
| $K_2G_2$ | 13.17 a | 14.95 ab | 3.44 ab | 79.14 ab | 24.42 ab |
| $K_2G_3$ | 13.42 a | 15.07 a | 3.54 a | 81.34 a | 24.83 a |
| $LSD_{(0.05)}$ | 0.967 | 0.470 | 0.445 | 6.628 | 1.898 |
| Level of significance | 0.05 | 0.05 | 0.05 | 0.01 | 0.05 |
| CV(%) | 8.21 | 9.01 | 9.38 | 7.09 | 8.82 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

### 4.12 Dry matter content of curd

Dry matter content of curd of broccoli showed significant differences due to different levels of potassium (Table 10 and Appendix VIII). The highest dry matter content of curd (13.39 g) was found from $K_2$ which was statistically similar (13.20 g) to $K_1$, while the lowest dry matter content of curd (12.01 g) was recorded from $K_0$.

Different levels of $GA_3$ varied significantly in terms of dry matter content of curd of broccoli (Table 10 and Appendix VIII). The highest dry matter content of curd (13.54 g) was observed from $G_3$ which was statistically similar (13.43 g) to $G_2$ and closely followed (13.07 g) by $G_1$, whereas the lowest dry matter content of curd (12.22 g) was recorded from $G_0$.

Combined effect of different levels of potassium and $GA_3$ varied significantly in terms of dry matter content of curd of broccoli (Table 11 and Appendix VIII). The highest dry matter content of curd (15.07 g) was recorded from $K_2G_3$ treatment combination and the lowest dry matter content of curd (11.74 g) was recorded from $K_0G_0$.

### 4.13 Number of secondary curd per plant

Different levels of potassium showed significant differences in terms of number of secondary curd per plant of broccoli (Table 10 and Appendix VIII). The highest number of secondary curd per plant (3.04) was found from $K_2$ which was statistically similar (2.87) to $K_1$, while the lowest number of secondary curd per plant (2.47) was recorded from $K_0$. Similar findings also reported by Uddain *et al*. (2010) from their study.

Statistically significant variation was recorded for different levels of $GA_3$ in terms of number of secondary curd per plant of broccoli (Table 10 and Appendix VIII). The highest number of secondary curd per plant (3.19) was observed from $G_3$ which was statistically similar (3.07) to $G_2$ and closely followed (2.72) by $G_1$, whereas the lowest number of secondary curd per plant (2.20) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of number of secondary curd per plant of broccoli (Table 11 and Appendix VIII). The highest number of secondary curd per plant (3.54) was recorded from $K_2G_3$ treatment combination and the lowest number of secondary curd per plant (2.09) was recorded from $K_0G_0$.

### 4.14 Weight of secondary curd

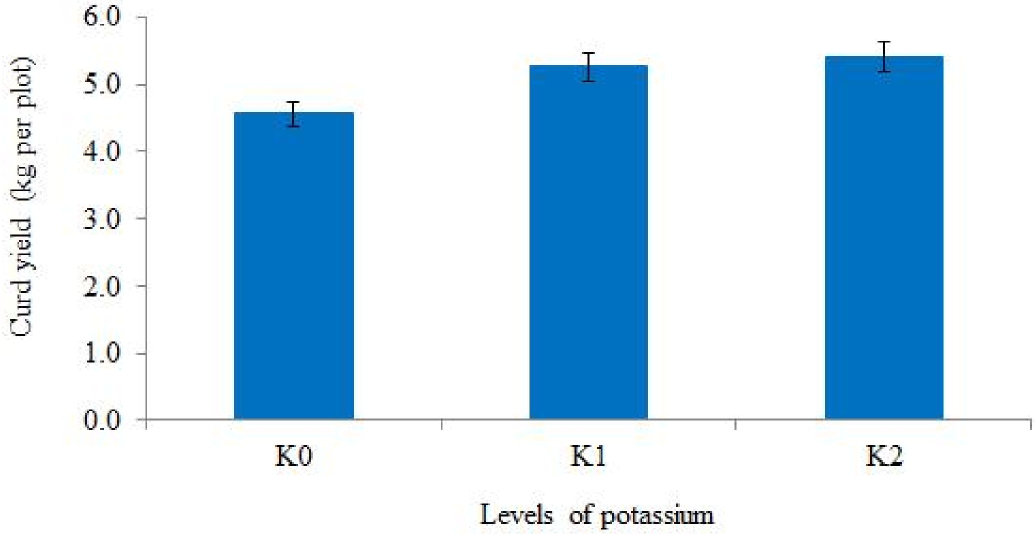
Weight of secondary curd of broccoli showed significant differences due to different levels of potassium (Table 10 and Appendix VIII). The highest weight of secondary curd (70.85 g) was found from $K_2$ which was statistically similar (68.43 g) to $K_1$, while the lowest weight of secondary curd (56.46 g) was recorded from $K_0$. Similar findings also reported by Uddain *et al*. (2010) from their study.

Different levels of $GA_3$ varied significantly in terms of weight of secondary curd (Table 10 and Appendix VIII). The highest weight of secondary curd (73.13 g) was observed from $G_3$ which was statistically similar (70.88) to $G_2$ and closely followed (63.08 g) by $G_1$, whereas the lowest weight of secondary curd (53.89 g) was recorded from $G_0$.

Statistically significant variation was recorded due to combined effect of different levels of potassium and $GA_3$ in terms of weight of secondary curd of broccoli (Table 11 and Appendix VIII). The highest weight of secondary curd (81.34 g) was recorded from $K_2G_3$ treatment combination and the lowest weight of secondary curd (47.04 g) was recorded from $K_0G_0$.

### 4.15 Curd yield per plot

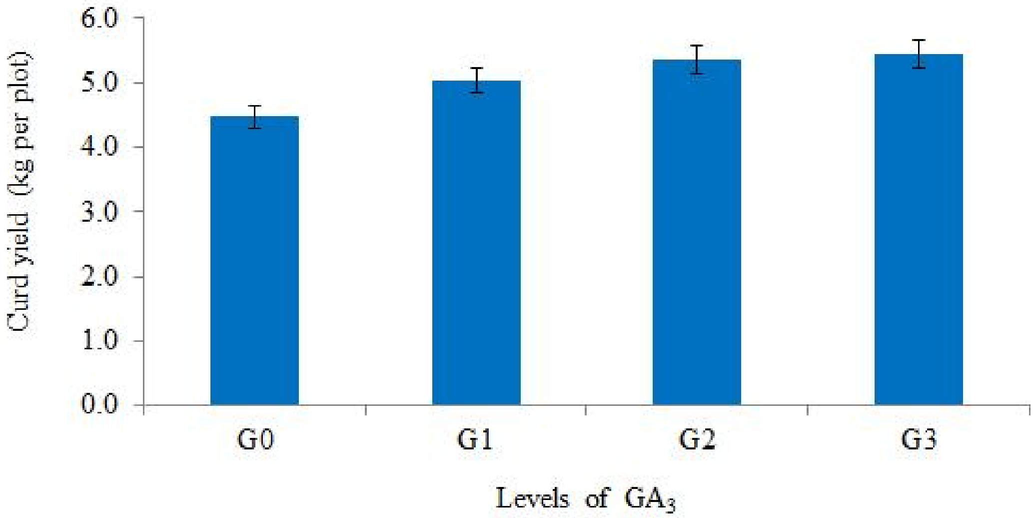
Different levels of potassium showed significant differences in terms of curd yield per plot of broccoli (Figure 9 and Appendix VIII). The highest curd yield per plot (5.41 kg) was found from $K_2$ which was statistically similar (5.26 kg) to $K_1$, while the lowest curd yield per plot (4.56 kg) was recorded from $K_0$.




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

Figure 9. Effect of different levels of potassium on curd yield per plot of broccoli. (Vertical bars represent LSD value at 5% level of probability)




$G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 10. Effect of different levels of $GA_3$ on curd yield per plot of broccoli. (Vertical bars represent LSD value at 5% level of probability)

Statistically significant variation was recorded for different levels of $GA_3$ in terms of curd yield per plot (Figure 10 and Appendix VIII). The highest curd yield per plot (5.44 kg) was observed from $G_3$ which was statistically similar (5.36 kg) to $G_2$ and closely followed (5.03 kg) by $G_1$, whereas the lowest curd yield per plot (4.47 kg) was recorded from $G_0$. Dhengle and Bhosale (2008) reported that higher concentrations of plant growth regulators proved less effective for curd yield per plot.

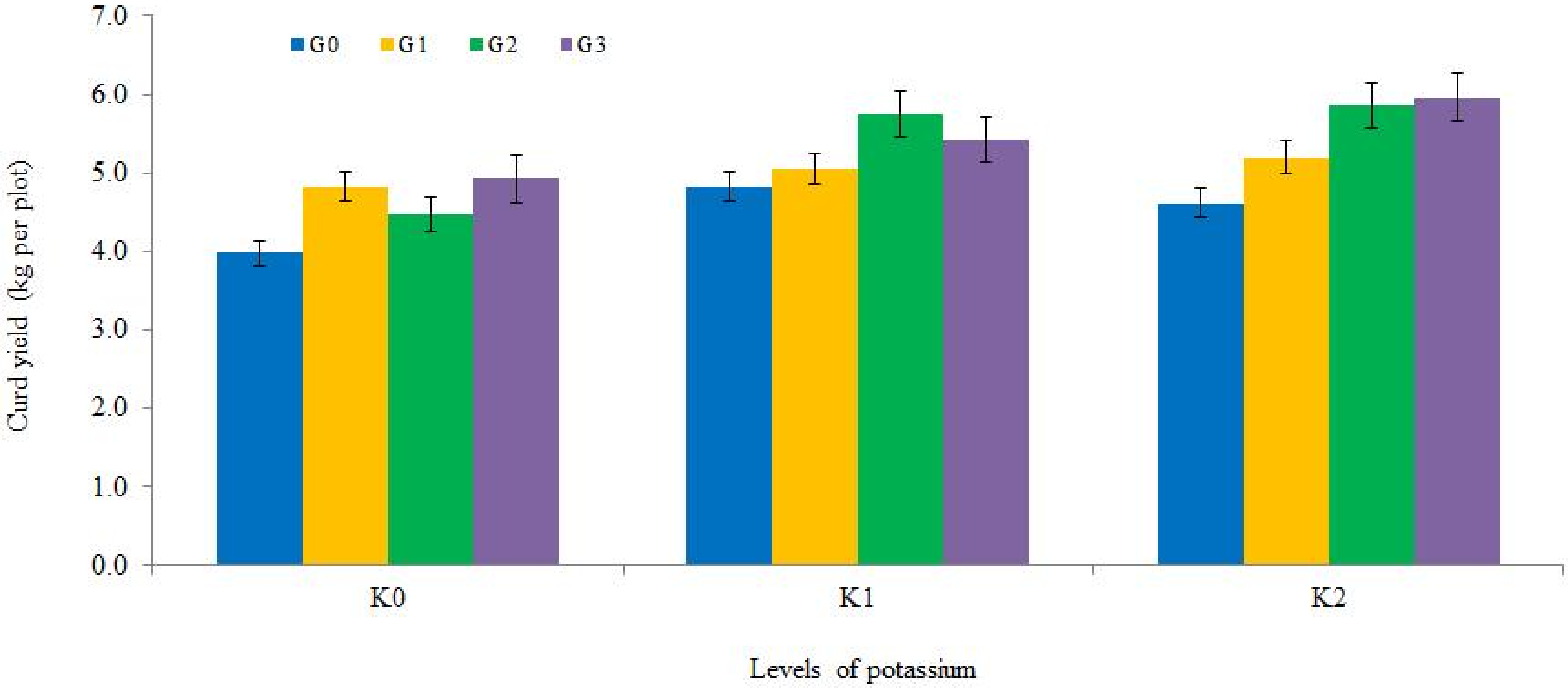
Curd yield per plot of broccoli varied significantly due to combined effect of different levels of potassium and $GA_3$ (Figure 11 and Appendix VIII). The highest curd yield per plot (5.96 kg) was recorded from $K_2G_3$ and the lowest curd yield per plot (3.98 kg) was recorded from $K_0G_0$.

### 4.16 Curd yield per hectare

Curd yield per hectare of broccoli showed significant differences due to different levels of potassium (Table 10 and Appendix VIII). The highest curd yield per hectare (22.54 ton) was found from $K_2$ which was statistically similar (21.91 ton) to $K_1$, while the lowest curd yield per hectare (18.98 ton) was recorded from $K_0$.

Different levels of $GA_3$ varied significantly in terms of curd yield per hectare (Table 10 and Appendix VIII). The highest curd yield per hectare (22.66 ton) was observed from $G_3$ which was statistically similar (22.34 ton) to $G_2$ and closely followed (20.94 ton) by $G_1$, whereas the lowest curd yield per hectare (18.64 ton) was recorded from $G_0$. $GA_3$ have a positive role on curd formation and curd size of broccoli (Sharma and Mishra, 1989). Vijay and Ray (2000) reported that $GA_3$ at 100 ppm produced the largest curds.

Combined effect of different levels of potassium and $GA_3$ showed statistically significant variation in terms of curd yield per hectare of broccoli (Table 11 and Appendix VIII). The highest curd yield per hectare (24.83 ton) was recorded from $K_2G_3$ treatment combination and the lowest curd yield per hectare (16.57 ton) was recorded from $K_0G_0$.




$K_0$: 0 kg $K_2O$/ha (control) $K_1$: 75 kg $K_2O$/ha $G_0$: 0 ppm $GA_3$ (control) $G_1$: 80 ppm $GA_3$

$K_2$: 100 kg $K_2O$/ha $G_2$: 100 ppm $GA_3$ $G_3$: 120 ppm $GA_3$

Figure 11. Combined effect of different levels of potassium and $GA_3$ on curd yield per plot of broccoli. (Vertical bars represent LSD value at 5% level of probability)

### 4.17 Economic analysis

Cost of production and benefit cost of broccoli cultivation presented in Table 12 and Appendix IX. Price of broccoli was considered as per present market price. The economic analysis presented under the following heads-

#### 4.17.1 Cost of production

Costs for land preparation, fertilizers, $GA_3$, seeds, manpower and all operational cost from seeds sowing to harvesting of broccoli were recorded as per plot and converted into hectare.

#### 4.17.2 Gross return

The combination of different level of potassium and $GA_3$ showed different value in terms of gross return under the trial of broccoli production (Table 12). The highest gross return (744,900 Tk./ha) was obtained from the treatment combination $K_2G_3$ and the second highest gross return (732,600 Tk./ha) was found in $K_2G_2$, whereas the lowest gross return (497,100 Tk./ha) was obtained from $K_0G_0$.

#### 4.17.3 Net return

In case of net return, application of different level of potassium and $GA_3$ showed different levels of net return under the present trial (Table 12). The highest net return (417,996 Tk./ha) was found from the treatment combination $K_2G_3$ and the second highest net return (406,141 Tk./ha) was obtained from the combination $K_2G_2$. The lowest (175,872 Tk./ha) net return was obtained $K_0G_0$.

#### 4.17.4 Benefit cost ratio

In the application of different level of potassium and $GA_3$, the highest benefit cost ratio (2.28) was noted from the combination of $K_2G_3$ and the second highest benefit cost ratio (2.24) was estimated from the combination of $K_2G_2$. The lowest benefit cost ratio (1.55) was obtained from $K_0G_0$ (Table 12). From economic point of view, it is apparent from the above results that the combination of $K_2G_3$ was best than rest of the combination in broccoli cultivation.

**Table 12. Cost and return of broccoli cultivation as influenced by different levels of potassium and $GA_3$**

| Treatments | Cost of production (Tk./ha) | Yield of broccoli (t/ha) | Gross return (Tk./ha) | Net return (Tk./ha) | Benefit cost ratio |
|---|---|---|---|---|---|
| $K_0G_0$ | 321,228 | 16.57 | 497,100 | 175,872 | 1.55 |
| $K_0G_1$ | 323,231 | 20.11 | 603,300 | 280,069 | 1.87 |
| $K_0G_2$ | 323,676 | 18.68 | 560,400 | 236,724 | 1.73 |
| $K_0G_3$ | 324,122 | 20.56 | 616,800 | 292,679 | 1.90 |
| $K_1G_0$ | 323,315 | 20.10 | 603,000 | 279,685 | 1.87 |
| $K_1G_1$ | 325,318 | 21.05 | 631,500 | 306,182 | 1.94 |
| $K_1G_2$ | 325,763 | 23.90 | 717,000 | 391,237 | 2.20 |
| $K_1G_3$ | 326,208 | 22.60 | 678,000 | 351,792 | 2.08 |
| $K_2G_0$ | 324,010 | 19.26 | 577,800 | 253,790 | 1.78 |
| $K_2G_1$ | 326,014 | 21.67 | 650,100 | 324,086 | 1.99 |
| $K_2G_2$ | 326,459 | 24.42 | 732,600 | 406,141 | 2.24 |
| $K_2G_3$ | 326,904 | 24.83 | 744,900 | 417,996 | 2.28 |

Price of broccoli @ Tk. 30/kg (according to Kawran Bazar market, Dhaka)

$K_0$: 0 kg $K_2O$/ha (control)
$K_1$: 75 kg $K_2O$/ha
$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)
$G_1$: 80 ppm $GA_3$
$G_2$: 100 ppm $GA_3$
$G_3$: 120 ppm $GA_3$

# CHAPTER V

# SUMMARY AND CONCLUSION

# CHAPTER V

# SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during November 2016 to March 2017. The experiment consisted of two factors, such as Factor A: Potassium fertilizer (three levels) as $K_0$: 0 kg $K_2O$/ha (control), $K_1$: 75 kg $K_2O$/ha, $K_2$: 100 kg $K_2O$/ha and Factor B: Gibberellic acid-$GA_3$ (four levels) as $G_0$: 0 ppm $GA_3$ (control), $G_1$: 80 ppm $GA_3$, $G_2$: 100 ppm $GA_3$, $G_3$: 120 ppm $GA_3$. The two factorial experiment was laid out in Randomized Complete Block Design with three replications.

In case of different levels of potassium, at 20, 30, 40, 50 DAT and harvest, the tallest plant (22.23, 36.84, 52.87, 65.06 and 70.78 cm, respectively) was found from $K_2$, while the shortest plant (18.28, 31.41, 47.19, 57.01 and 62.13 cm, respectively) was recorded from $K_0$. At 20, 30, 40, 50 DAT and harvest, the highest number of leaves per plant (7.70, 13.58, 20.47, 23.55 and 24.16, respectively) was found from $K_2$, while the lowest number (5.30, 11.73, 16.05, 18.27 and 19.01, respectively) was recorded from $K_0$ at the same days. At 20, 30, 40, 50 DAT and harvest, the longest leaf (16.63, 26.12, 37.40, 45.94 and 47.32 cm, respectively) was found from $K_2$, while the shortest leaf (14.67, 22.41, 33.00, 35.68 and 37.17 cm, respectively) was recorded from $K_0$ at the same days. At 20, 30, 40, 50 DAT and harvest, the highest leaf breadth (8.55, 13.57, 17.24, 19.42 and 20.35 cm, respectively) was found from $K_2$, while the lowest leaf breadth (7.60, 11.36, 14.89, 15.98 and 16.84 cm, respectively) was recorded from $K_0$ at the same days. The maximum days to 1$^{st}$ curd initiation (56.00) was found from $K_0$, while the minimum days (53.25) was recorded from $K_2$. The highest weight of primary curd (470.22 g) was found from $K_2$, while the lowest (399.08 g) was recorded from $K_0$. The highest number of secondary curd per plant (3.04) was found from $K_2$, while the lowest (2.47) was recorded from $K_0$. The highest curd yield per hectare (22.54 ton) was found from $K_2$, while the lowest curd yield (18.98 t/ha) was recorded from $K_0$.

For $GA_3$, at 20, 30, 40, 50 DAT and harvest, the tallest plant (22.02, 36.93, 53.08, 65.11 and 70.98 cm, respectively) was observed from $G_3$, while the shortest plant (18.87, 32.04, 47.10, 57.41 and 62.11 cm, respectively) was recorded from $G_0$. At 20, 30, 40, 50 DAT and harvest, the highest number of leaves per plant (7.11, 14.04, 19.87, 22.89 and 23.58, respectively) was observed from $G_3$, while the lowest number (6.04, 11.22, 17.17, 19.62 and 20.09, respectively) was recorded from $G_0$ at same data recording days. At 20, 30, 40, 50 DAT and harvest, the longest leaf (16.79, 26.02, 37.33, 44.32 and 45.75 cm, respectively) was observed from $G_3$, while the shortest leaf (14.60, 22.78, 33.09, 38.20 and 39.28 cm, respectively) was recorded from $G_0$ at same data recording days. At 20, 30, 40, 50 DAT and harvest, the highest leaf breadth (8.77, 13.59, 17.25, 19.18 and 20.28 cm, respectively) was observed from $G_3$, whereas the lowest leaf breadth (7.26, 11.36, 15.06, 16.38 and 17.30 cm, respectively) was recorded from $G_0$. The maximum days to $1^{st}$ curd initiation (57.11) was observed from $G_0$, whereas the lowest days (52.89) was recorded from $G_3$. The highest weight of primary curd (470.75 g) was observed from $G_3$, whereas the lowest weight of primary curd (393.57 g) was recorded from $G_0$. The highest number of secondary curd per plant (3.19) was observed from $G_3$, whereas the lowest number (2.20) was recorded from $G_0$. The highest curd yield per hectare (22.66 ton) was observed from $G_3$, whereas the lowest curd yield (18.64 t/ha) was recorded from the control.

Due to combined effect of different levels of potassium and $GA_3$, at 20, 30, 40, 50 DAT and harvest, the tallest plant (24.66, 40.61, 56.30, 68.81 and 74.55 cm, respectively) was recorded from $K_2G_3$ treatment combination and the shortest plant (16.97, 30.04, 44.81, 50.74 and 54.52 cm, respectively) was recorded from $K_0G_0$. At 20, 30, 40, 50 DAT and harvest, the highest number of leaves per plant (8.67, 15.13, 22.40, 25.73 and 26.44, respectively) was recorded from $K_2G_3$ treatment combination and the lowest number (4.88, 10.27, 14.80, 17.60 and 18.12, respectively) was recorded from $K_0G_0$ at same days. At 20, 30, 40, 50 DAT and harvest, the longest leaf (17.92, 27.77, 39.79, 49.87 and 51.08 cm, respectively) was recorded from $K_2G_3$ treatment combination and the shortest leaf (13.68, 20.36, 30.94, 34.54 and 35.25 cm, respectively) was recorded from $K_0G_0$ at same days. At 20, 30, 40, 50 DAT and harvest, the highest leaf breadth (9.32, 14.73, 18.40, 20.98 and 21.85 cm, respectively) was recorded from $K_2G_3$ treatment combination and the lowest leaf breadth (6.79, 10.34, 13.67, 15.02 and 15.54 cm, respectively) was recorded from $K_0G_0$ at same days. The maximum days to 1$^{st}$ curd initiation (59.67) was recorded from $K_0G_0$ treatment combination and the minimum days (50.00) was recorded from $K_2G_3$. The highest weight of primary curd (514.53 g) was recorded from $K_2G_3$ treatment combination and the lowest weight of primary curd (350.65 g) was recorded from $K_0G_0$. The highest number of secondary curd per plant (3.54) was recorded from $K_2G_3$ treatment combination and the lowest number (2.09) was recorded from $K_0G_0$. The highest curd yield per hectare (24.83 ton) was recorded from $K_2G_3$ treatment combination and the lowest curd yield per hectare (16.57 ton) was recorded from the $K_0G_0$.

The highest gross return (744,900 Tk./ha) was obtained from the treatment combination $K_2G_3$ and the lowest gross return (497,100 Tk./ha) was obtained from $K_0G_0$. The highest net return (417,996 Tk./ha) was found from the treatment combination $K_2G_3$ and the lowest (175,872 Tk./ha) net return was obtained $K_0G_0$. The highest benefit cost ratio (2.28) was noted from the combination of $K_2G_3$ and the lowest BCR (1.55) was obtained from $K_0G_0$ (Table 12). From economic point of view, it is apparent from the above results that the combination of $K_2G_3$ was best than rest of the combination in broccoli cultivation.

**Conclusion**

- 100 kg $K_2O$ shows better yield and yield attributes than other potassium doses;
- Among the different concentration of $GA_3$, broccoli shows better response with 120 ppm which was similar to 100 ppm of $GA_3$ and
- Finally, 100 kg $K_2O$ with 120 ppm $GA_3$ encouraged superior growth, yield contributing characters and yield of broccoli.

**Recommendation:**

- The experiment was conducted only one growing season at Horticulture farm of Sher-e-Bangla Agricultural University;
- In this experiment higher level of potassium and $GA_3$ showed the best result. So further higher level of K and $GA_3$ can be experimented for achieving higher yield.
- Before final recommendation we may conduct such type of experiment in different agro ecological zones in Bangladesh.

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# APPENDICES

# APPENDICES

**Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2016 to March 2017**

| Month | Air temperature (ºc) | | Relative humidity (%) | Total Rainfall (mm) | Sunshine (hr) |
|---|---|---|---|---|---|
| | Maximum | Minimum | | | |
| November, 2016 | 25.8 | 16.0 | 78 | 00 | 6.8 |
| December, 2016 | 22.4 | 13.5 | 74 | 00 | 6.3 |
| January, 2017 | 24.5 | 12.4 | 68 | 00 | 5.7 |
| February, 2017 | 27.1 | 16.7 | 67 | 30 | 6.7 |
| March, 2017 | 31.4 | 19.6 | 54 | 11 | 8.2 |

**Source:** Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

**Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka**

**A. Morphological characteristics of the experimental field**

| Morphological features | Characteristics |
|---|---|
| Location | Horticulture farm field , SAU, Dhaka |
| AEZ | Madhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |

**B. Physical and chemical properties of the initial soil**

| Characteristics | Value |
|---|---|
| % Sand | 27 |
| % Silt | 43 |
| % clay | 30 |
| Textural class | Sandy loam |
| pH | 5.6 |
| Catayan exchange capacity | 2.64 meq 100 g/soil |
| Organic matter (%) | 0.88 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20.00 |
| Exchangeable K (me/100 g soil) | 0.10 |
| Available S (ppm) | 45 |

**Appendix III. Analysis of variance of the data on plant height of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Plant height (cm) at | | | | |
| | | 20 DAT | 30 DAT | 40 DAT | 50 DAT | Harvest |
| Replication | 2 | 0.313 | 1.633 | 1.905 | 3.600 | 7.548 |
| Levels of Potassium (A) | 2 | 57.370** | 111.893** | 121.668** | 241.013** | 269.684** |
| Levels of $GA_3$ (B) | 3 | 19.555** | 43.333** | 66.240** | 108.309** | 144.035** |
| Interaction (A×B) | 6 | 2.002* | 8.614* | 5.104* | 26.108* | 31.741* |
| Error | 22 | 0.780 | 3.147 | 2.014 | 6.307 | 8.301 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix IV. Analysis of variance of the data on number of leaves per plant of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Number of leaves per plant at | | | | |
| | | 20 DAT | 30 DAT | 40 DAT | 50 DAT | Harvest |
| Replication | 2 | 0.063 | 0.088 | 0.134 | 0.054 | 0.138 |
| Levels of Potassium (A) | 2 | 18.720** | 12.181** | 69.301** | 101.521** | 95.434** |
| Levels of $GA_3$ (B) | 3 | 2.269** | 13.655** | 13.130** | 20.653** | 23.225** |
| Interaction (A×B) | 6 | 2.860* | 1.566** | 2.797** | 5.090* | 4.442* |
| Error | 22 | 0.178 | 0.410 | 0.789 | 1.768 | 1.692 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix V. Analysis of variance of the data on leaf length of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Leaf length (cm) at | | | | |
| | | 20 DAT | 30 DAT | 40 DAT | 50 DAT | Harvest |
| Replication | 2 | 0.097 | 0.413 | 0.019 | 0.032 | 1.140 |
| Levels of Potassium (A) | 2 | 13.470** | 49.421** | 64.527** | 358.365** | 347.176** |
| Levels of $GA_3$ (B) | 3 | 8.429** | 19.574** | 32.529** | 67.257** | 81.331** |
| Interaction (A×B) | 6 | 7.772* | 8.440* | 10.041** | 15.989** | 14.275* |
| Error | 22 | 0.467 | 1.341 | 2.103 | 3.550 | 5.054 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix VI. Analysis of variance of the data on leaf breadth of broccoli at different days after transplanting (DAT) and harvest as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | Leaf breadth (cm) at | | | | |
| | | 20 DAT | 30 DAT | 40 DAT | 50 DAT | Harvest |
| Replication | 2 | 0.005 | 0.243 | 0.053 | 0.097 | 0.060 |
| Levels of Potassium (A) | 2 | 3.154** | 17.317** | 19.429** | 39.993** | 43.427** |
| Levels of $GA_3$ (B) | 3 | 4.278** | 9.116** | 8.820** | 14.469** | 16.073** |
| Interaction (A×B) | 6 | 4.929* | 8.213* | 4.204* | 2.185* | 1.968* |
| Error | 22 | 0.206 | 0.278 | 0.667 | 0.718 | 0.835 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix VII. Analysis of variance of the data on days to 1st curd initiation, stem length, stem diameter, and roots length and roots fresh weight per plant of broccoli as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Days to 1st curd initiation | Length of stem (cm) | Diameter of stem (cm) | Length of root (cm) | Weight of primary curd (g) | Diameter of primary curd (cm) |
| Replication | 2 | 0.083 | 1.197 | 0.000 | 0.483 | 30.837 | 0.004 |
| Levels of Potassium (A) | 2 | 24.250* | 74.823** | 0.274** | 41.997** | 17273.557** | 3.311** |
| Levels of $GA_3$ (B) | 3 | 30.991** | 15.867** | 0.459** | 26.308** | 11144.773** | 5.980** |
| Interaction (A×B) | 6 | 24.435** | 4.279* | 5.217* | 2.190* | 1773.904* | 6.063* |
| Error | 22 | 5.386 | 1.458 | 0.016 | 0.820 | 626.166 | 0.250 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix VIII. Analysis of variance of the data on primary curd diameter and primary curd weight and secondary curd number and weight of broccoli as influenced by different levels of potassium and $GA_3$**

| Source of variation | Degrees of freedom | Mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | Dry matter content of plant (%) | Dry matter content of curd (%) | Number of secondary curd per plant | Weight of secondary curd (g) | Curd yield per plot (kg) | Curd yield per hectare (ton) |
| Replication | 2 | 0.253 | 0.017 | 0.003 | 1.760 | 0.002 | 0.031 |
| Levels of Potassium (A) | 2 | 11.713** | 6.656** | 1.043** | 712.765** | 2.500** | 43.409** |
| Levels of $GA_3$ (B) | 3 | 4.697** | 1.989** | 1.745** | 682.480** | 1.730** | 30.037** |
| Interaction (A×B) | 6 | 2.079* | 1.227* | 2.261* | 57.590** | 4.641* | 4.198* |
| Error | 22 | 0.337 | 0.075 | 0.069 | 15.323 | 0.072 | 1.256 |

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

**Appendix IX. Per hectare production cost of broccoli**

**A. Input cost**

| Treatments | Labour cost | Ploughing cost | Seed Cost | Water for plant Establishment | Manure and fertilizers | | | | | Insecticide/ pesticides | Sub total (A) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cowdung | Urea | MoP | TSP | $GA_3$ | | |
| $K_0G_0$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 0 | 2,700 | 0 | 13,000 | 202,900 |
| $K_0G_1$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 0 | 2,700 | 1800 | 13,000 | 204,700 |
| $K_0G_2$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 0 | 2,700 | 2200 | 13,000 | 205,100 |
| $K_0G_3$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 0 | 2,700 | 2600 | 13,000 | 205,500 |
| $K_1G_0$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 1,875 | 2,700 | 0.00 | 13,000 | 204,775 |
| $K_1G_1$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 1,875 | 2,700 | 1800 | 13,000 | 206,575 |
| $K_1G_2$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 1,875 | 2,700 | 2200 | 13,000 | 206,975 |
| $K_1G_3$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 1,875 | 2,700 | 2600 | 13,000 | 207,375 |
| $K_2G_0$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 2,500 | 2,700 | 0 | 13,000 | 205,400 |
| $K_2G_1$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 2,500 | 2,700 | 1800 | 13,000 | 207,200 |
| $K_2G_2$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 2,500 | 2,700 | 2200 | 13,000 | 207,600 |
| $K_2G_3$ | 60,000 | 44,000 | 25,000 | 32,000 | 25,000 | 1,200 | 2,500 | 2,700 | 2600 | 13,000 | 208,000 |

$K_0$: 0 kg $K_2O$/ha (control)

$K_1$: 75 kg $K_2O$/ha

$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)

$G_1$: 80 ppm $GA_3$

$G_2$: 100 ppm $GA_3$

$G_3$: 120 ppm $GA_3$

**Appendix IX. Per hectare production cost of broccoli (Cont'd)**

**B. Overhead cost (Tk./ha)**

| Treatments | Cost of lease of land (12% of value of land Tk. 15,00000/year | Miscellaneous cost (Tk. 5% of the input cost | Interest on running capital for 6 months (Tk. 12% of cost/year) | Sub total (Tk.) (B) | Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)] |
|---|---|---|---|---|---|
| $K_0G_0$ | 90,000 | 10,145 | 18,183 | 118,328 | 321,228 |
| $K_0G_1$ | 90,000 | 10,235 | 18,296 | 118,531 | 323,231 |
| $K_0G_2$ | 90,000 | 10,255 | 18,321 | 118,576 | 323,676 |
| $K_0G_3$ | 90,000 | 10,275 | 18,347 | 118,622 | 324,122 |
| $K_1G_0$ | 90,000 | 10,239 | 18,301 | 118,540 | 323,315 |
| $K_1G_1$ | 90,000 | 10,329 | 18,414 | 118,743 | 325,318 |
| $K_1G_2$ | 90,000 | 10,349 | 18,439 | 118,788 | 325,763 |
| $K_1G_3$ | 90,000 | 10,369 | 18,465 | 118,833 | 326,208 |
| $K_2G_0$ | 90,000 | 10,270 | 18,340 | 118,610 | 324,010 |
| $K_2G_1$ | 90,000 | 10,360 | 18,454 | 118,814 | 326,014 |
| $K_2G_2$ | 90,000 | 10,380 | 18,479 | 118,859 | 326,459 |
| $K_2G_3$ | 90,000 | 10,400 | 18,504 | 118,904 | 326,904 |

$K_0$: 0 kg $K_2O$/ha (control)
$K_1$: 75 kg $K_2O$/ha
$K_2$: 100 kg $K_2O$/ha

$G_0$: 0 ppm $GA_3$ (control)
$G_1$: 80 ppm $GA_3$
$G_2$: 100 ppm $GA_3$
$G_3$: 120 ppm $GA_3$