GROWTH, YIELD AND QUALITY OF BROCCOLI INFLUENCED BY PINCHING AND GIBBERELLIC ACID (GA_3)

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CERTIFICATE

*This is to certify that the thesis entitled '**Growth, Yield and Quality of Broccoli Influenced by Pinching and Gibberellic Acid (GA$_3$)**' 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 bonafide research work carried out by **Mariya Ahmed**, Registration No. **11-04312** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the Horticulture Farm and laboratory of Sher-e-Bangla Agricultural University, Dhaka during October 2016 to February 2017. The experiment consisted of two factors: Factor A: Pinching method (four levels) as- P_0: No pinching (control), P_1: Pinching apical meristem at 15 days after transplanting (DAT), P_2: Pinching apical meristem at 30 DAT and P_3: Pinching axillary buds at 45 DAT; and Factor B: Gibberellic acid-GA_3 (three levels) as- G_0: 0 ppm (control), G_1: 50 ppm and G_2:100 ppm GA_3. The two factor experiment was laid out in Randomized Complete Block Design with three replications. Pinching methods and gibberellic acid influenced significantly on most of the parameters. In case of pinching, the highest curd yield (29.8 t/ha) was found from P_1 and the lowest curd yield (19.9 t/ha) from P_0. For gibberellic acid, G_1 performed the highest curd yield (27.9 t/ha) and the lowest (20.4 t/ha) was from G_0. For combined effect, the highest curd yield (36.9 t/ha) was obtained from P_1G_1 and the lowest curd yield (15.7 t/ha) from P_0G_0. The highest benefit cost ratio (2.40) was noted from the combination of P_1G_1 and the lowest benefit cost ratio (1.09) from P_0G_0. So, pinching apical meristem at 15 DAT with 50 ppm GA_3 can be used for commercial broccoli production.

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SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Bangladesh Rice Research Institute	BRRI
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
Non significant	NS
Parts per million	ppm
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Triple Superphosphate	TSP

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. botrytis L.,) is an important cole crop belongs to family Brassicaceae and it has high nutritional and good commercial value (Yoldas *et al*., 2008). 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). Generally, broccoli 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). It is consumed mostly all over the world (Pizetta *et al*., 2005), highlighted mainly 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).

As a newly introduced crop 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. 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 pinching is considering as an important one for increasing yield because it promotes branching with more curds of broccoli (Irwin and Aarssen 2000). Use of different bio-chemical substances, such as Napthaline acetic acid (NAA), Gibberelic acid (GA_3), Indole acetic acid (IAA) etc. also been made to indicate a promising results on yield and quality of broccoli (Senthelhas *et al.,* 1987; Tadzhiryan, 1990; Tomar *et al*., 1991).

In Bangladesh broccoli attracted more attention due to its multifarious use and great nutritional value (Talalay and Fahey, 2001; Rangkadilok *et al*., 2004) but the unit production is comparatively low with the other countries. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities, use of traditional cultural practices like other cole crops etc. But successful production of broccoli depends on various factors of which pinching, plant growth regulators are the most important. Generally, farmers get only one curd not in desirable size from a single plant at a time. But if pinching is done carefully it could lead to the formation of several curds leading to the increased production of more marketable curd per plant. But practicing pinching and application of GA_3 produced consequently the healthy plants, the largest curds and highest curd yields of broccoli.

Pinching promotes formation of the lateral shoots at different stages of development in broccoli plant and it is practiced to promote branching and compactness of broccoli (Irwin and Aarssen, 2000). Damage to the shoot apex commonly causes release of lateral meristems from apical dominance in plants this has been shown in some species to increase seed production by stimulating lateral branching. Shoot apex removal may also reduce or prevent reproduction (Venecz and Aarssen, 1998). Many plants exhibit apical dominance, where the presence of the main stem apex inhibits the growth of the lateral branches. This inhibition is generally assumed to be mediated by hormonal control, but changes in environmental conditions can also modify the growth of lateral branches (Miguel *et al.,* 1998). Such conditions include shading, nutrient supply and damage to other branches. Seed production of broccoli revealed that removal of either the axillary or terminal head produced higher seed yield than when no buds were removed. It was therefore possible to harvest both a vegetable crop (760 kg/ha for axillary and 4380 kg/ha for terminal shoot removal) and seed crop without affecting the seed quality (Ghimire *et al.,* 1993).

Different reports revealed that for 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. (Tadzhiryan, 1990; Tomar *et al.*, 1991). Gibberellic acid (GA_3) is a promising plant growth regulator (PGRs) is capable of modifying growth and it is an organic compound. It plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). Plant height, curd formation and curd size can be increased with foliar application of GA_3 and it has 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 50 ppm produced the tallest plants, the largest curds and highest curd yields (Vijay and Ray, 2000). The optimum proportion of pinching and gibberellic acid enhances the growth and development of broccoli as well as ensures the availability of other essential nutrients for the plant.

Considering the above all facts and situation, the present experiment was conducted for fulfilling the following objectives:

- To evaluate the effect of pinching on growth, yield and quality of broccoli;
- To study the effect of GA_3 on growth, yield and quality of broccoli;
- To study the combined effects of pinching and GA_3 on growth, yield and quality of broccoli.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Broccoli is a biennial, thermo sensitive herbaceous important vitamin rich “Cole” crop in Bangladesh and the most widely grown vegetables in the temperate zones. Growth and curd development of broccoli are greatly influenced by growing environment. As a minor vegetable and newly introduced crop it has less attention by the researchers on various aspects especially pinching and plant growth regulators and a very few studies on the growth, yield quality of broccoli have been carried out in our climatic condition. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to pinching and plant growth hormone on broccoli and other related crops so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of pinching on crop growth, yield and quality

Abd El-Gawad (2007) carried out a field experiment during 2002/2003 and 2003/2004 seasons, to study the effect of three sowing dates, i.e., first of October, first of November and first of December, and four pinching treatments (pinching apical meristem, pinching mean head, pinching axillary buds and without pinching) on broccoli plants, Cultivar “Emperor” grown in Kaliobia under loam soil conditions. Plants of the second date (first of October) and pinching the main head at marketable stage produced the tallest plant, the highest number of leaves and siliques/plant, and the maximum seed yield.

Yesmin (2007) conducted an experiment on pinching of apical bud of cabbage at 30 DAT. She observed a significant variation on yield of cabbage in pinched plants with the non pinched plants.

Rabiul (2002) conducted an experiment on pinching at 30 DAT of the cabbage. He observed that pinching at 30 DAT showed significant effect on most of the parameters. Pinching had a significant variation in respect of gross yield per hectare. The plants with pinching treatment resulted the highest gross yield (73.8 t ha^{-1}) and the highest marketable yields, compared with non-pinched plants.

Jahan (2001) carried out an experiment to study the influence of different sources of nutrients and time of pinching of apical bud on yield of cabbage was studied at Bangladesh Agricultural University, Mymensingh. Experimental findings revealed that the organic and inorganic fertilizer with pinching produced maximum yield of cabbage.

Pressman *et al.* (1985) conducted an experiment on pinching of the broccoli cv. Green Duke at different stage of development (plants with 3, 5, 7, or 9 leaves). Pinching hastened extension of the lateral shoots and button formation and it increased the number of side shoots only when done at later stage of plant development. A close correlation was observed between shoot length and time to buttoning and inflorescence size. Apical bud removal at any stage caused a delay in buttoning and harvest. However, a gradual delay in pinching did not induce a parallel postponement in buttoning and inflorescence maturation. Early pinching resulted in higher yields than late pinching.

Palevitch and Pressmun (1983) carried out an experiment with two varieties of broccoli where Waltham 29 and Green Duke broccoli were pinched by hand 61-91 and 65-77 days after planting, respectively and the effects were assessed by on growth and yield of broccoli. Results of the experiment revealed that both cvs. after pinching resulted in the uniform development of several side shoots. With Waltham 29 pinching 77 days after planting enhanced marketable yields of broccoli, compared with non-pinched plants, but they were little affected by pinching on other dates. With Green Duke there was little difference in the yields of pinched and non-pinched plants. Pinching delayed harvest by 2-3 days but with Waltham 29 harvest, date was not affected.

2.2 Effect of plant growth regulators on crop growth and yield

Verma *et al*. (2018) conducted an experiment during rabi of two consecutive years i.e. 2013-14 and 2014-15 at horticultural farm of Birsa Agricultural University, Ranchi, Jharkhand, India. The treatments consisted of urea at three different concentrations of 0.5, 0.1 and 1.5%, GA_3 at three different concentrations of 25 ppm, 50 ppm and 75 ppm, B at three different concentrations of 1.0%, 1.5% and 2.0%. Different combinations of urea, Boron and GA_3 were sprayed twice at 20 and 40 days after transplanting and a control was used with no spray. The data pertaining to self-life of curd at ambient condition was recorded to be maximum which is of 4.09 days with GA_3 @ 75 ppm in both the years.

Vishwakarma *et al.* (2017) carried out an experiment at the Udai Pratap Autonomous College, Varanasi with nitrogen 0, 1 and 2% NAA in 60 and 120 ppm and Gibberellic acid 0, 50 and 100 ppm concentrations. Findings revealed that the maximum diameter (19.35 cm), fresh weight of curd (1432.75 g), yield (421 q/ha) and ascorbic acid content (24.68 mg/100g) were recorded at 2.0% nitrogen, 120 ppm NAA and 100 ppm GA_3. The application of nitrogen at 2.0%, NAA at 120 ppm and GA_3 at 100 ppm are recommended for better growth, yield and quality of broccoli.

Reza *et al*. (2015) conducted an experiment to find out the influence of GA_3 on growth, yield and yield contributing characters of broccoli. Four levels of GA_3 *viz.* C_1: Control, C_2: 25 ppm GA_3, C_3: 50 ppm GA_3 and C_4: 75 ppm GA_3 was used on 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). From the study it was also found that application of more than 50 ppm GA_3 reduced the yield of broccoli.

Mirdad (2014) conducted an experiment to improve the agricultural practices of broccoli production by using the K^+ and salicylic acid (SA). The results of the study revealed that the vegetative growth, cruds yield and its quality, WUE (water use efficiency) and leaf and crud mineral contents of broccoli plants irrigated with saline water increased significantly and successively as the SA concentration was increased up to 200 mg l^{-1}. The combined foliar application of 1000 mg l^{-1} K^+ with salicylic acid at 200 mg l^{-1} as foliar application is the most efficient combination treatment, which gave the best results to alleviate the deleterious impact of salinity stress on the vegetative growth, curd yield and its quality characters, leaf and curds chemical contents of broccoli plants irrigated with saline water.

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 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 took least number of days for head initiation, while GA_3 80 mg/l treatment 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).

Singh *et al*. (2011) carried out 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^{-1} + kinetin 30 mg L^{-1} treatment gave maximum growth and yield of sprouting broccoli whereas, highest vitamin A content found with 40 mg L^{-1} GA_3 and vitamin C was found maximum in GA_3 20 mg L^{-1} + kinetin 20 mg L^{-1}dipping.

Lendve *et al*. (2010) carried out studies on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) and found that application of GA 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 75 ppm, gave better results for days required for head initiation and head maturity.

Dhengle and Bhosale (2008) conducted an experiment to find out 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) in the field of 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.

Guo *et al*. (2004) conducted an experiment to investigate the growth and flowering response of a cold-requiring cauliflower (*Brassica oleracea* var. botrytis cv. '60 day') to a range of temperatures under 10 h photoperiod and to growth regulator application. 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 10^0C. Flowering did not occur in non-vernalized plants (25^0C) even though they had been treated with GA_3. Application of GA_3 promoted inflorescence stalk elongation greatly in vernalized plants (10^0C), but less so in partially vernalized plants (15 or 20^0C). Paclobutrazol sprayed at the 8-9 leaf stage significantly suppressed inflorescence stalk length and slightly delayed flower bud formation. Vernalization at 10^0C 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 10^0C) 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) conducted an experiment to determine 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) carried out an experiment and 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) conducted an experiment and stated that plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulator. GA_3 and IAA have a positive effect on curd formation and size of cauliflower.

Muthoo *et al.* (1987) carried out an experiment and observed 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 followed by naphthalene acetic acid.

Patil *et al.* (1987) conducted an experiment 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 maturity was 13 and 12 days earlier with 50 ppm GA_3 and recorded the maximum yield (23.83 t/ha) from 50 ppm GA_3.

Mishra and Singh (1986) carried out 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 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 and found that CCC decreased the plant height, size of loose leaves, diameter of head and finally the yield. GA_3 increased the plant height, size of leaf and finally the yield.

As per the above cited reviews, it may be concluded that pinching and gibberelelic acid are the important factors for attaining optimum growth and as well as highest yield and quality of broccoli. The literature revealed that the effects of pinching and gibberelelic acid 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 assess the growth, yield and quality of broccoli influenced by pinching and gibberellic acid (GA_3). 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 under the following headings-

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted from October 2016 to February 2017.

3.1.2 Location of the experimental site

The experiment was conducted at the Horticulture farm and laboratory 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 8.2 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 (26.5^0C) was recorded in the month of October 2016, whereas the minimum temperature (12.4^0C) in the month of January 2017. The highest humidity (81%) was recorded in the month of October, 2016 and the highest total rainfall (30 mm) was observed 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 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 organic matter 5.6 and 0.78%, 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 'PARAISO (Takii seed) were used as planting materials for this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Pinching method (four levels) as

i P_0: No pinching i.e., control

ii. P_1: Pinching apical meristem at 15 days after transplanting (DAT)

iii. P_2: Pinching apical meristem at 30 DAT

iv. P_3: Pinching axillary buds at 45 DAT

Factor B: Gibberellic acid-GA_3 (three levels) as

i. G_0: 0 ppm GA_3 i.e., control

ii. G_1: 50 ppm GA_3

iii. G_2: 100 ppm GA_3

There were 12 (4 × 3) treatments combination such as P_0G_0, P_0G_1, P_0G_2, P_1G_0, P_1G_1, P_1G_2, P_2G_0, P_2G_1, P_2G_2, P_3G_0, P_3G_1 and P_3G_2.

3.2.3 Design and layout of the experiment

The two factor 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 1.8 m × 1.6 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 2nd 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.

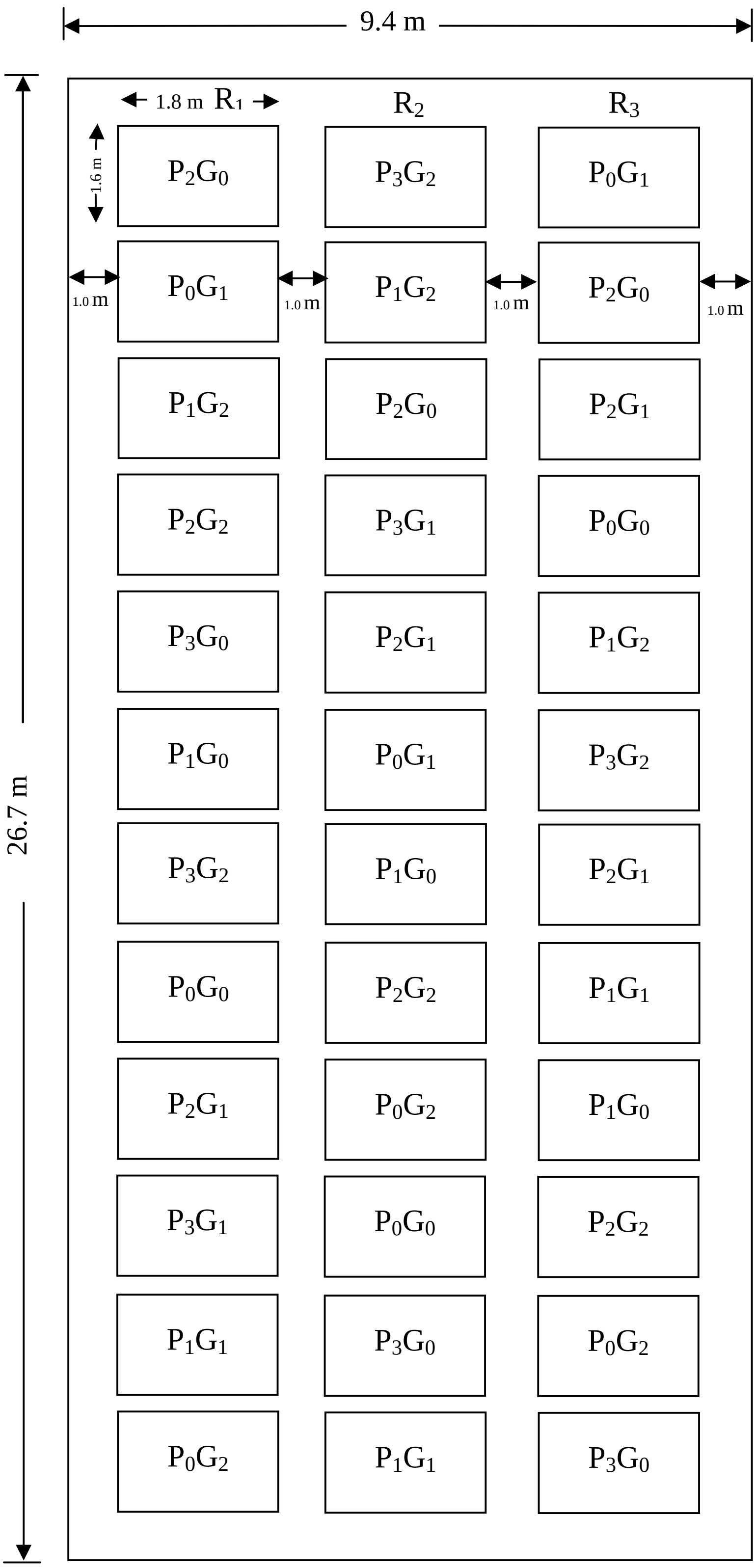
3.2.5 Application of manure and fertilizers

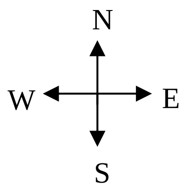
Manures and fertilizers were applied to the experimental plot considering the FRG (Fertilizer Recommendation Guide), 2005 of broccoli as per follows:

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	12 tonnes	100	--	--	--
Urea	250 kg	--	33.33	33.33	33.33
TSP	200 kg	100	--	--	--
MoP	100 kg	--	33.33	33.33	33.33
Gypsum	20 kg	100	--	--	--
Zinc sulphate	10 kg	100	--	--	--

The total amount of cowdung, TSP, Gypsum and Zinc sulphate was applied as basal dose during land preparation, whereas urea and MoP was applied in three equal installments at 10, 30 and 50 day after transplanting (DAT).





Plot size: 1.8 m × 1.6 m

Between block: 1.00 m

Plot spacing: 0.50 m

Plant spacing: 60 cm × 40 cm

Factor A: Pinching method (four levels) as

i. P_0: No pinching i.e. control

ii. P_1: Pinching apical meristem at 15 days after transplanting (DAT)

iii. P_2: Pinching apical meristem at 30 DAT

iv. P_3: Pinching axillary buds at 45 DAT

Factor B: Gibberellic acid-GA_3 (three levels) as

i. G_0: 0 ppm GA_3 i.e., control

ii. G_1: 50 ppm GA_3

iii. G_2: 100 ppm GA_3

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Collection of seeds

The seeds of hybrid broccoli namely ‘PARAISO (Takii seed) 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 insects 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 October 24, 2016. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth. Seeds were germinated after 6-7 days of seeds sowing

Plate 1. Photograph showing seedlings raised in the seed bed

3.3.3 Transplanting of seedlings

Healthy and uniform seedlings of 21 days old seedlings were transplanting in the experimental plots on November 21, 2016. The seedlings were uprooting carefully from the seed bed to avoid damage to the 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 12 seedlings were accommodated in each plot according to the design of the plot size at 1.8 m × 1.6 m. The young transplanted seedlings were shaded by banana leaf sheath during day 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.

Plate 2. Photograph showing transplanted seedlings in the experimental plot

3.3.4 Application of pinching and GA_3 treatments

3.3.4.1 Pinching techniques

The apical meristem were removed by a sharp blade at 15 DAT in P_1 treatment and this operation was done after 30 DAT in P_2 treatment. The auxiliary buds were removed by a sharp blade at 45 DAT in P_3 treatment. The rest of the plots were kept without pinching operation as control.

Plate 3. Photograph showing pinching technique

Plate 4. Photograph showing pinched broccoli plant

3.3.4.2 Collection, preparation and application of 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 litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e., 50 ml of stock solution was diluted in 1 litre of distilled water to get 50 ppm GA_3 solution. Similarly, 100 ppm stock solutions were diluted to 1 litre of distilled water to get 100 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 10, 20 and 30 DAT by a mini hand sprayer.

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 DAT to keep the experimental plots free from weeds.

3.3.5.3 Earthing up

Earthing up was done at 50 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.3.5.4 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 (common Bulbuli) were seen visiting the broccoli field very frequently. The nightingale visited the fields in the morning and afternoon. 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. Before harvesting of the broccoli curd, compactness of the curd was tested by pressing with thumbs.

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, 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. Data on plant height, number of leaves/plant, leaf length and length breadth were collected at 50, 60, 70 DAT and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.5.1 Plant height

Plant height was measured from five randomly selected plants by using meter scale in centimeter from the ground level to the tip of the longest leaf at 10 days interval starting from 50 DAT and continued upto 70 DAT and at harvest and their mean value was calculated.

3.5.2 Number of leaves per plant

Number of leaves per plant was counted from five randomly selected plants at 10 days interval starting from 50 DAT and continued upto 70 DAT and at harvest and their average was recorded.

3.5.3 Leaf length

Leaf length was measured from five randomly selected plants at 10 days interval starting from 50 DAT and continued upto 70 DAT and at harvest and their average was recorded.

3.5.4 Leaf breadth

Leaf breadth was counted from five randomly selected plants at 10 days interval starting from 50 DAT and continued upto 70 DAT and at harvest and their average was recorded.

3.5.5 Days to 1st 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 Days to curd harvest

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

3.5.7 Stem length

Stem length was taken from the ground level to base of the curd of plant during harvesting. A meter scale used to measure stem length and was expressed in centimeter (cm).

3.5.8 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).

3.5.9 Root length

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

3.5.10 Number of 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 selected at random of each plot at during harvest.

3.5.11 Individual curd weight

The curds from sample plants were harvested, cleaned and weighted. Every primary curd were weighted in grams by weighing machine and mean values was counted.

Plate 5. Photograph showing broccoli in marketable size

3.5.12 Curd diameter

The curds from sample plants were sectioned vertically at the middle position with a sharp knife after harvest. 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 in plot wise.

3.5.13 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 70^0C 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. The dry matter contents of curd were computed by simple calculation from the weight recorded by the following formula:

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

3.5.14 Total weight of curd per plant

Total weight of curd per plat was recorded by weighting primary and secondary curd per plant that was finally harvested from each plant in plot wise and was expressed in gram.

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 and recorded plot wise.

3.5.16 Curd yield per hectare

The curd yield per hectare was calculated by converting total curd yield per plot into yield per hectare and was expressed in ton.

3.6 Storage condition on shelf life

The harvest broccoli stored in different storage condition to estimate shelf life and different quality of broccoli. The three mature broccoli curds were selected from each treatment. The selected broccoli was stored in open, normal polythene and perforated polythene both in room and refrigerator for estimation of shelf life. In normal polythene, the bag thickness was 0.05 mm and the size was 25 cm × 30 cm. In perforated polythene, ten holes of 1.95 mm diameter were created by drilling on the surface of the polythene bag randomly. Broccoli curd was kept into the polythene bag in the days of harvest and broccoli was placed randomly in refrigerator controlling 8^0C and in the room temperature for open condition. Shelf life was counted from the date of curd harvesting up to the date at which the head started to loss its green color at storage. The changes of florets color (just started to yellowish) were recorded by eye observation.

3.7 Analysis of biochemical parameters

3.7.1 Determination of ascorbic acid (vitamin C) content in fresh broccoli

Quantitative determination of ascorbic acid content of broccoli at harvesting stage from different treatment was estimated following the method No. 967.21 (AOAC, 2005). The applied method was as follows:

Reagents

i) Metaphosphoric acid solution (3% HPO_3): Prepared by dissolving pellets of HPO_3 in glass distilled water.

ii) Standard ascorbic acid solution: 100 mg of ascorbic acid was weighted, dissolved and made up to 100 ml with 3% HPO_3 and diluted to 0.1 mg/ml (10 ml HPO_3 of 1 mg/ml) immediately before use.

iii) Dye solution: Fifty milligram of 2,6-Dichlorophenol indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. The mixture was cooled, diluted with distilled water upto 200 ml, stored in a refrigerator and standardizes every day before use.

Procedure

Five (5) grams of fresh curd sample was crushed in a mortar and mixed well with 3% HPO_3 upto 100 ml in a volumetric flask. It was filtered with whatman filter paper 40. Then 5 ml aliquot of HPO_3 extract of the sample was taken and titrated with dye solution.

Standardization of dye

Five (5) milliliter of standard ascorbic acid solution was taken and titrated with dye factor until a faint pink colour persists for 15 seconds.

Dye factor = ml of standard ascorbic acid taken × conc. of ascorbic acid/ml of dye consumed.

Calculation

$$a = bcd\frac{100}{ef}$$

Where, a = Ascorbic acid mg/100g

b = Titration reading

c = Dye factor

d = Volume made upto (100 ml)

e = Aliquot of extract (5 ml)

f = Weight of the sample

3.7.2 Determination of β carotene by spectrophotometer

Carotenoids exhibit certain absorption spectrum exposed to specific wave length. An absorption spectrum depends on the unique absorption characteristics of a compound. These absorption properties will be utilized to make quantitative determination of carotene.

Procedure

Two (2) grams of sample (broccoli) was taken in a clean mortar. The sample was then grinded in the mortar with 80% acetone in presence of quartz sand (very small amount) and calcium carbonate (0.5mg). The resulting coloured solution was then filtered by continuous washing with 80% acetone. The filtered was collected in a 50 ml volumetric flask and made to a final volume of 50 ml with 80% acetone. The filtered colored solution was carefully transferred to a separatory funnel and 20 ml petroleum ether was added to the solution. The funnel was shaken and placed for 20 minutes. The lower aqueous phase was discarded very carefully keeping the ether layer. To the ether layer, about 5 ml ethanol containing 5% KOH was added and shaken well and kept about 10 hours for complete saponification. Then, water was added gently to the saponified solution. By adding water, two distinct phases were visible. The lower aqueous phase was discarded carefully. The upper phase containing β carotene was washed with water several times for complete remove of KOH. The ether layer containing β carotene was transferred to a 25 ml volumetric flask and the flask was volume upto the mark by adding petroleum ether. From the petroleum ether extract, β carotene was estimated with the spectrophotometer at 451 nm wave length against petroleum ether as blank, by using the equation proposed by Shiraishi (1972).

$$\beta \text{ carotene (mg/g)} = 3.984\ (OD_{451})\ V/\ 1000\ W$$

Where,

V = Final volume of the petroleum ether β carotene extract (ml)

W = Fresh weight of the sample taken (g)

OD_{451} = Spectrophotometer reading at 451 nm wave length.

For evidence, the calculated results of β carotene were multiplied by 100.

3.7.3 Determination of calcium

Total calcium content was determined from dried curd materials digesting with a mixture (5:1) of concentrated HNO_3 and $HClO_4$ (Nitric-perchloric acid) as described by Piper (1966) for determination of total Ca content.

Digestion solution

Nitric-perchloric solution, Conc. perchloric acid (100 ml) was added to 500 ml concentrated HNO_3 to prepared nitric-perchloric solution.

Digestion procedure

i. Oven dried broccoli sample of 0.5 g was taken in a 50 ml boiling flask.

ii. Then 5 ml of nitric-perchloric acid solution was added to the boiling flask.

iii. The flask was placed on cool hot plate and the temperature was turned to 375^0F and the digestion was allowed for 2 hours.

iv. The flask was then removed and 15 ml distilled water was added to the flask. The flask was agitated and heated to dissolve the ash.

v. The contents were filtered through a filter paper (Whatman No.42) in a 100 ml volumetric flask and then distilled water was added to make the volume upto the mark (stock solution).

Dilution of sample solution

An amount of 10 ml curd extract (stock solution) was taken in a 100 ml volumetric flask and 1 ml of lanthanum chloride was added and then distilled water was added to make the volume upto the mark.

Measurement of absorbance by AAS:

The instrument (Atomic Absorption Spectrophotometer, Model No. 170-30, HITACHI. Japan) was calibrated with standard solutions of Ca and a calibration curve was prepared by the series of standard solution. Atomic absorption spectrophotometer readings of each standard solutions plant extracts were recorded at wave length of 422.8 nm.

Calculation:

$$\text{Total Ca (\%)} = (S-B) \times (100\text{ ml}/10\text{ml}) \times (100\text{ml}/0.5\text{g}) \times 1/10^4$$

3.7.4 Determination of potassium

Five milli-liter of digest curd sample were taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample was measured within the range of standard solutions. The absorbance was measured by atomic absorption flame photometer.

3.7.5 Determination of phosphorus

Phosphorus was digested from the curd sample with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for curd sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.7.6 Determination of iron

Dried plant materials were digested with concentrated HNO_3 and $HClO_4$ (Nitric-perchloric acid) mixture of the determination of total Fe as described by Piper (1966) for determination of total calcium content.

Digestion procedure

i. Oven dried broccoli sample of 0.5 g was taken in a 50 ml boiling flask.
ii. Then 5 ml of nitric-perchloric acid solution was added to the boiling flask.
iii. The flask was placed on cool hot plate and the temperature was turned to 375^{o} F and the digestion was allowed for 2 hours.
iv. The flask was then removed and 15 ml distilled water was added to the flask. The flask was agitated and heated to dissolve the ash.
v. The contents were filtered through a filter paper (What man No.42) in a 100 ml volumetric flask and then distilled water was added to make the volume upto the mark (stock solution).

Measurement of absorbance by AAS:

The instrument (Atomic Absorption Spectrophotometer, Model No. 170-30, HITACHI, Japan) was calibrated with standard solutions of Fe and a calibration curve was prepared by the series of standard solution. Atomic absorption spectrophotometer readings of each standard solutions plant extracts were recorded at wave length of 248.3 nm.

Calculation:

$$\text{Fe in plant (mg kg}^{-1}\text{) = Fe in the filtrate (mg L}^{-1}\text{)} \times 100 \text{ ml/0.5 g}$$

3.8 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different pinching and gibberellic acid on growth, yield and quality 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).

3.9 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different pinching method and gibberellic acid for broccoli cultivation. All input cost included the cost for lease of land and interests on running capital in computing the 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

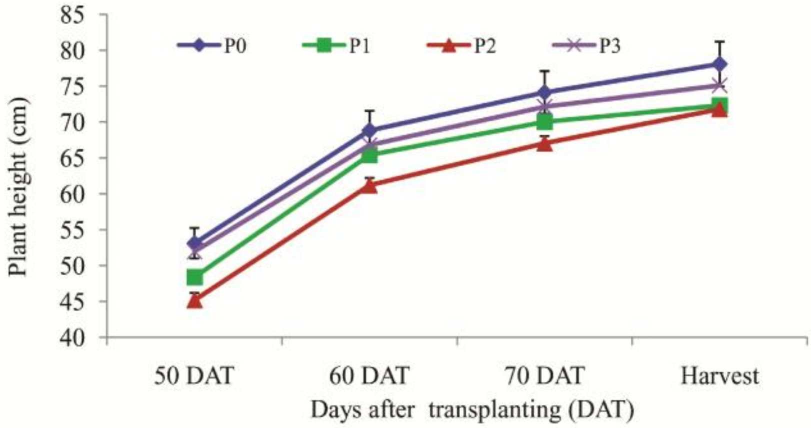
RESULTS AND DISCUSSION

The experiment was conducted to assess the growth, yield and quality of broccoli influenced by pinching and gibberellic acid (GA_3). The analysis of variance (ANOVA) of the data on different growth, yield and quality parameters are presented in Appendices III-X. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

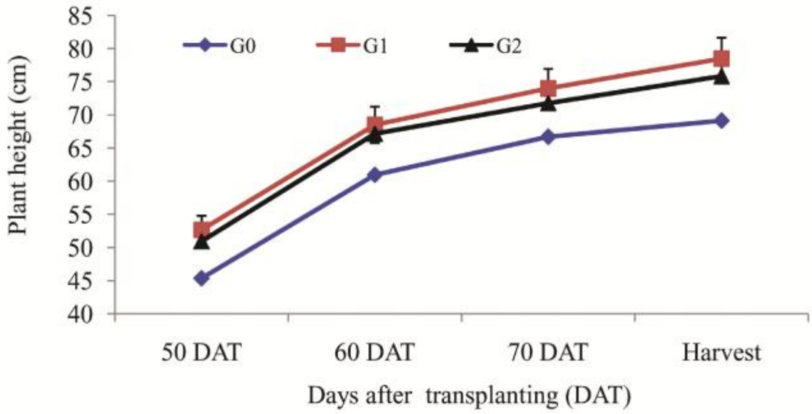
Plant height of broccoli at 50, 60, 70 days after transplanting (DAT) and at harvest showed statistically significant differences due to pinching methods (Appendix III). At 50, 60, 70 DAT and at harvest, the tallest plant (53.1, 68.8, 74.1 and 78.1 cm, respectively) was recorded from P_0 (no pinching i.e., control) treatment which was statistically similar (51.9, 66.8, 72.1 and 75.1 cm, respectively) to P_3 (pinching axillary buds at 45 DAT), whereas the shortest plant (45.2, 61.2, 67.0 and 71.8 cm, respectively) was found from P_2 (pinching apical meristem at 30 DAT) which was followed (48.4, 65.4, 70.0 and 72.3 cm, respectively) by P_1 (pinching apical meristem at 15 DAT) treatment (Fig. 2). Pressman *et al.* (1985) reported the longest plant from non pinching plant.

Statistically significant variation was recorded in terms of plant height of broccoli at 50, 60, 70 DAT and at harvest due to levels of GA_3 (Appendix III). At 50, 60, 70 DAT and at harvest, the tallest plant (52.7, 68.5, 74.0 and 78.5 cm, respectively) was observed from G_1 (50 ppm GA_3) treatment which was statistically similar (50.9, 67.2, 71.8 and 75.3 cm, respectively) to G_2 (100 ppm GA_3), while the shortest plant (45.4, 60.9, 66.7 and 69.1 cm, respectively) was recorded from G_0 (0 ppm GA_3 i.e., control) treatment (Fig. 3). Sharma and Mishra (1989) reported from their study that plant height increased with foliar application of GA_3.



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT
P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

Fig. 2. Effect of pinching methods on plant height of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3
G_2: 100 ppm GA_3

Fig. 3. Effect of levels of GA_3 on plant height of broccoli.

Combined effect of pinching methods and levels of GA_3 varied significantly on plant height of broccoli at 50, 60, 70 DAT and at harvest (Appendix III). At 50, 60, 70 DAT and at harvest, the tallest plant (55.9, 71.4, 75.9 and 81.6 cm, respectively) was observed from P_0G_1 (no pinching i.e., control and 50 ppm GA_3) treatment combination which was statistically similar with P_0G_2, P_1G_1, P_3G_1 and P_3G_2 and the shortest plant (38.2, 53.2, 58.1 and 62.2 cm, respectively) was found from P_2G_0 (pinching apical meristem at 30 DAT and 0 ppm GA_3 i.e., control) treatment combination (Table 2).

4.2 Number of leaves per plant

Pinching methods varied significantly in terms of number of leaves per plant of broccoli at 50, 60, 70 DAT and at harvest (Appendix IV). At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (21.0, 27.0, 32.0 and 35.7, respectively) was found from P_1 treatment which was statistically similar (19.9, 27.3, 31.4 and 35.2, respectively) to P_2, while the lowest number (18.4, 24.1, 27.9 and 31.0, respectively) was recorded from P_0 which was statistically similar (19.3, 25.9, 28.6 and 31.9, respectively) to P_3 treatment (Fig. 4). Palevitch and Pressmun (1983) reported that pinching resulted in the uniform development of several side shoots.

Number of leaves per plant of broccoli at 50, 60, 70 DAT and at harvest showed statistically significant differences due to levels of GA_3 (Appendix IV). At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (21.2, 28.2, 31.5 and 35.7, respectively) was recorded from G_1 treatment which was statistically similar (20.6, 26.8, 30.9 and 34.4, respectively) to G_2 treatment, whereas the lowest number (17.1, 23.3, 27.5 and 30.3, respectively) was observed from G_0 treatment (Fig. 5). Data revealed that different level of GA_3 produced different number of leaves per plant. Although number of leaves per plant is a genetical character but the management practices also influences number of leaves per plant and for that it was varied for different level of GA_3. Lendve *et al*. (2010) found that application of GA_3 50 ppm was found significantly superior in terms of number of the leaves.

Table 2. Combined effect of pinching methods and levels of gibberellic acid on plant height at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Plant height (cm) at			
	50 DAT	60 DAT	70 DAT	Harvest
P_0G_0	48.2 cd	65.4 b-e	71.8 a-d	72.7 c-e
P_0G_1	55.9 a	71.4 a	75.9 a	81.6 a
P_0G_2	55.2 a	69.6 ab	74.7 ab	79.9 ab
P_1G_0	45.9 d	61.8 e	67.9 cd	70.2 e
P_1G_1	53.0 a-c	68.8 ab	74.8 ab	77.1 a-d
P_1G_2	46.2 d	65.7 b-e	67.3 d	69.6 e
P_2G_0	38.2 e	53.2 f	58.1 e	62.2 f
P_2G_1	49.2 b-d	67.0 a-d	73.1 a-d	78.2 a-c
P_2G_2	48.3 cd	63.4 de	69.9 a-d	74.9 b-e
P_3G_0	49.1 b-d	63.5 c-e	68.9 b-d	71.4 de
P_3G_1	53.4 ab	68.6 ab	73.4 a-d	77.1 a-d
P_3G_2	53.5 ab	68.3 a-c	74.1 a-c	76.8 a-d
$LSD_{(0.05)}$	4.47	4.35	5.72	5.40
Level of significance	0.05	0.05	0.05	0.05
CV(%)	5.31	4.92	6.77	4.92

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

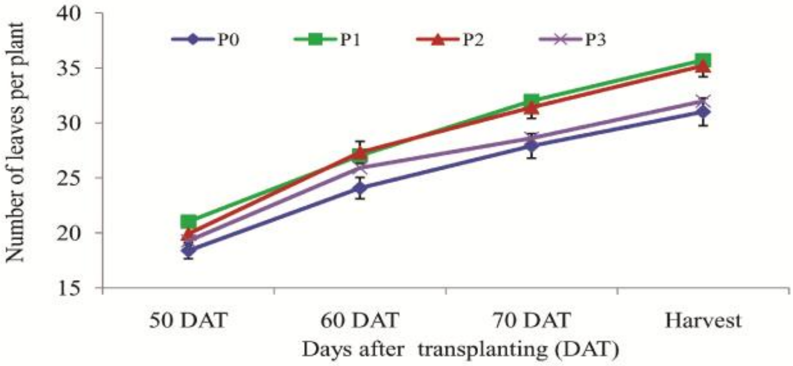
P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

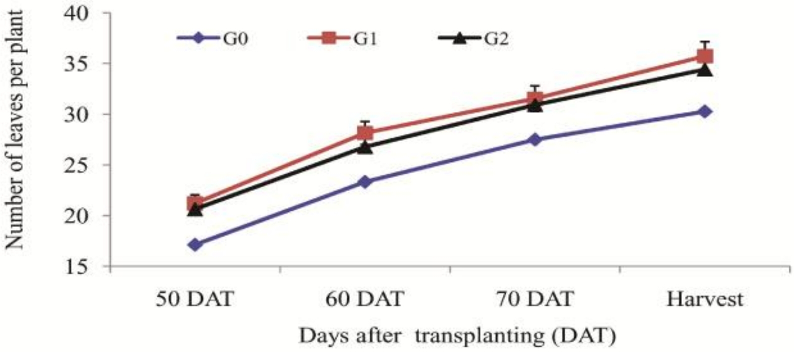
G_2: 100 ppm GA_3



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

Fig. 4. Effect of pinching methods on number of leaves per plant of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Fig. 5. Effect of levels of GA_3 on number of leaves per plant of broccoli.

Statistically significant variation was recorded in terms of number of leaves per plant of broccoli at 50, 60, 70 DAT and at harvest due to the combined effect of pinching methods and levels of GA_3 (Appendix IV). At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (22.8, 29.3, 34.1 and 38.2, respectively) was found from P_1G_1 treatment combination, while the lowest number (16.3, 20.9, 25.6 and 27.3, respectively) was recorded from P_0G_0 treatment combination (Table 3).

4.3 Length of largest leaf

Statistically significant differences was observed in terms of length of largest leaf of broccoli at 50, 60, 70 DAT and at harvest due to pinching methods (Appendix V). At 50, 60, 70 DAT and at harvest, the longest length of largest leaf (43.4, 49.2, 53.2, 54.9 cm, respectively) was observed from P_1 treatment which was statistically similar (42.2, 48.1, 50.8 and 52.5 cm, respectively) to P_2 treatment, whereas the lowest length (39.5, 45.4, 48.3 and 50.7 cm, respectively) was found from P_0 treatment which was statistically similar (40.0, 46.5, 48.9 and 51.6 cm, respectively) to P_3 treatment (Fig. 6). Pressman *et al.* (1985) reported that pinching hastened extension of the lateral shoots.

Levels of GA_3 showed significant variation in terms of length of largest leaf of broccoli at 50, 60, 70 DAT and at harvest (Appendix V). At 50, 60, 70 DAT and at harvest, the longest length of largest leaf (43.9, 49.5, 52.8 and 55.1 cm, respectively) was recorded from G_1 treatment which was followed (42.3, 48.1, 51.0 and 53.2 cm, respectively) by G_2 treatment and the lowest length (37.6, 44.3, 47.1 and 48.9 cm, respectively) from G_0 treatment (Fig. 7).

Length of largest leaf of broccoli at 50, 60, 70 DAT and at harvest differ significantly for the combined effect of pinching methods and levels of GA_3 (Appendix V). At 50, 60, 70 DAT and at harvest, the longest length of largest leaf (47.1, 51.9, 57.2 and 58.8 cm, respectively) was observed from P_1G_1, whereas the lowest length (35.9, 42.2, 45.9 and 47.1 cm, respectively) was found from P_0G_0 treatment combination (Table 4).

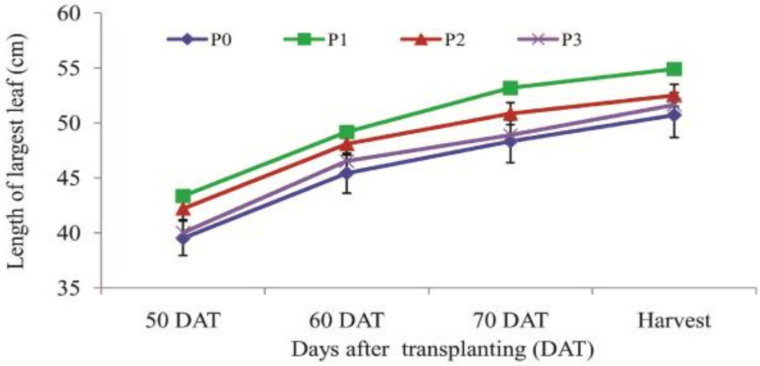
Table 3. Combined effect of pinching methods and levels of gibberellic acid on number of leaves per plant at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Number of leaves per plant at			
	50 DAT	60 DAT	70 DAT	Harvest
P_0G_0	16.3 f	20.9 f	25.6 d	27.3 f
P_0G_1	20.1 cd	26.2 cd	29.6 b	33.7 cd
P_0G_2	18.7 de	25.1 de	28.5 bc	32.0 de
P_1G_0	18.0 ef	24.3 e	29.2 b	33.6 cd
P_1G_1	22.8 a	29.9 a	34.1 a	38.2 a
P_1G_2	22.3 ab	26.9 bc	32.7 a	35.3 bc
P_2G_0	17.7 ef	24.1 e	28.1 bc	31.2 e
P_2G_1	21.2 a-c	29.3 a	33.2 a	37.2 ab
P_2G_2	20.9 a-c	28.5 ab	32.9 a	37.2 ab
P_3G_0	16.5 f	23.9 e	27.1 cd	29.0 f
P_3G_1	20.7 bc	27.2 bc	29.2 b	33.8 cd
P_3G_2	20.7 bc	26.6 cd	29.6 b	33.1 c-e
$LSD_{(0.05)}$	1.78	1.63	1.55	2.02
Level of significance	0.05	0.05	0.05	0.01
CV(%)	5.35	6.69	5.05	6.56

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

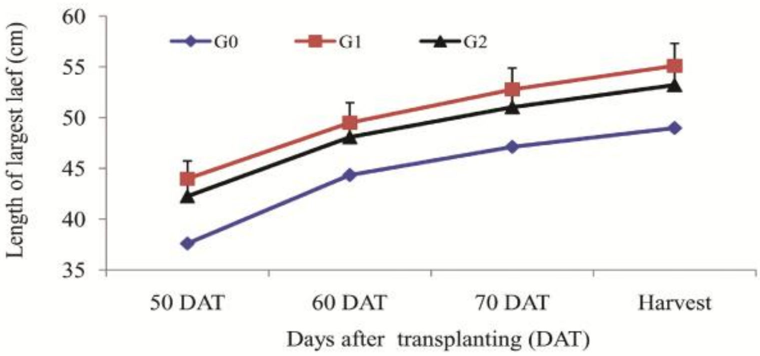
P_0: No pinching (control)
P_1: Pinching apical meristem at 15 DAT
P_2: Pinching apical meristem at 30 DAT
P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)
G_1: 50 ppm GA_3
G_2: 100 ppm GA_3



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT
P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

Fig. 6. Effect of pinching methods on length of largest leaf of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3
G_2: 100 ppm GA_3

Fig. 7. Effect of levels of GA_3 on length of largest leaf of

Table 4. Combined effect of pinching methods and levels of gibberellic acid on length of largest leaf at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Length of largest leaf (cm) at			
	50 DAT	60 DAT	70 DAT	Harvest
P_0G_0	35.9 e	42.2 e	45.9 e	47.1 d
P_0G_1	40.9 cd	47.5 cd	49.8 cd	52.7 c
P_0G_2	41.6 cd	46.7 d	49.3 d	52.3 c
P_1G_0	40.0 d	46.9 cd	50.4 cd	52.1 c
P_1G_1	47.1 a	51.9 a	57.2 a	58.8 a
P_1G_2	42.9 cd	48.7 b-d	51.9 bc	53.9 bc
P_2G_0	37.3 e	44.2 e	46.7 e	47.8 d
P_2G_1	45.8 ab	50.7 ab	53.5 b	55.8 b
P_2G_2	43.5 bc	49.4 bc	52.4 bc	53.9 bc
P_3G_0	37.1 e	44.1 e	45.5 e	48.9 d
P_3G_1	41.9 cd	47.9 cd	50.6 cd	53.2 c
P_3G_2	40.9 cd	47.6 cd	50.5 cd	52.8 c
$LSD_{(0.05)}$	2.64	2.218	2.34	2.25
Level of significance	0.01	0.01	0.05	0.05
CV(%)	4.78	5.77	6.74	5.54

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

4.4 Breadth of largest leaf

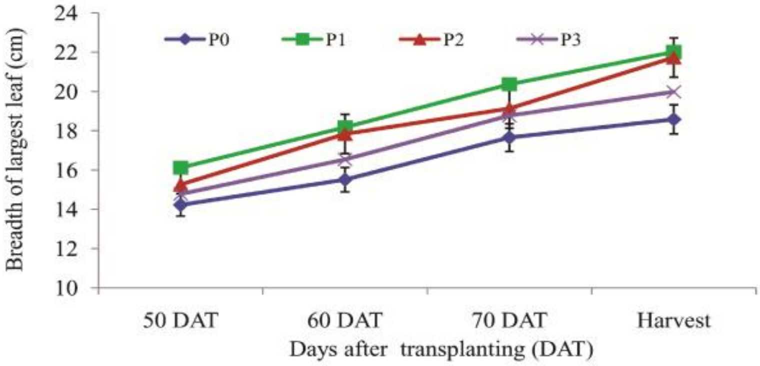
Pinching methods varied significantly in terms of breadth of largest leaf of broccoli at 50, 60, 70 DAT and at harvest (Appendix VI). At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (16.1, 18.2, 20.4 and 22.0 cm, respectively) was recorded from P_1 treatment, which was statistically similar (15.3, 17.8, 19.1 and 21.7 cm, respectively) to P_2 treatment, whereas the lowest breadth (14.2, 15.5, 17.7 and 18.6 cm, respectively) was observed from P_0 treatment which was closely followed (14.8, 16.5, 18.8 and 19.9 cm, respectively) by P_3 treatment (Fig. 8).

Statistically significant variation was observed in terms of breadth of largest leaf of broccoli at 50, 60, 70 DAT and at harvest due to levels of GA_3 (Appendix VI). At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (15.9, 18.3, 20.4 and 21.9 cm, respectively) was observed from G_1 treatment which was closely followed (15.4, 17.2, 19.3 and 21.0 cm, respectively) by G_2 treatment, while the lowest breadth (13.9, 15.5, 17.2 and 18.8 cm, respectively) was found from G_0 treatment (Fig. 9).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of breadth of largest leaf of broccoli at 50, 60, 70 DAT and at harvest (Appendix VI). At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (17.1, 20.1, 22.3 and 23.9 cm, respectively) was recorded from P_1G_1 and the lowest breadth (12.7, 13.8, 15.8 and 16.9 cm, respectively) was observed from P_0G_0 treatment combination (Table 5).

4.5 Days to 1st curd initiation

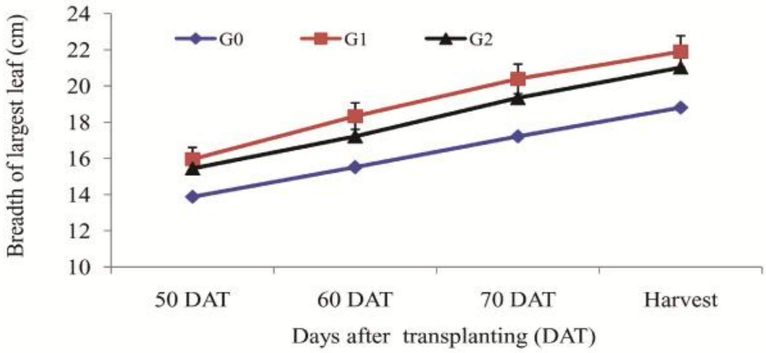
Days to 1st curd initiation of broccoli showed statistically significant differences due to pinching methods (Appendix VII). The maximum days to 1st curd initiation (46.1) were found from P_0 treatment, while the minimum days (41.1) were observed from P_1 treatment which was statistically identical to P_2 and P_3 treatments (Table 6).



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

Fig. 8. Effect of pinching methods on breadth of largest leaf of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Fig. 9. Effect of levels of GA_3 on breadth of largest leaf of broccoli

Table 5. Combined effect of pinching methods and levels of gibberellic acid on breadth of largest leaf at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Breadth of largest leaf (cm) at			
	50 DAT	60 DAT	70 DAT	Harvest
P_0G_0	12.7 g	13.8 f	15.8 g	16.9 g
P_0G_1	15.2 cd	16.6 de	18.8 de	19.5 ef
P_0G_2	14.8 de	16.2 de	18.4 e	19.3 ef
P_1G_0	15.2 cd	17.3 cd	19.0 c-e	20.4 de
P_1G_1	17.1 a	20.1 a	22.3 a	23.9 a
P_1G_2	16.0 bc	17.2 cd	19.8 c	21.8 bc
P_2G_0	13.9 ef	15.6 e	16.6 fg	18.9 f
P_2G_1	16.2 b	19.5 ab	20.8 b	23.3 a
P_2G_2	15.7 b-d	18.5 bc	19.9 bc	22.9 ab
P_3G_0	13.7 f	15.4 e	17.4 f	18.9 f
P_3G_1	15.3 b-d	17.2 cd	19.7 cd	20.9 cd
P_3G_2	15.3 b-d	17.0 d	19.2 c-e	20.1 d-f
$LSD_{(0.05)}$	0.86	1.30	0.93	1.12
Level of significance	0.05	0.05	0.01	0.01
CV(%)	6.37	4.50	6.88	7.20

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Levels of GA_3 showed statistically significant variation in terms of days to 1^{st} curd initiation of broccoli (Appendix VII). The maximum days to 1^{st} curd initiation (44.7) was observed from G_0 treatment which was statistically similar (43.3 days) to G_2, whereas the minimum days (41.4) from G_1 treatment (Table 6) which was statistically similar to G_2 treatment. Lendve *et al*. (2010) reported that 75 ppm GA_3, which gave better results for days required for head initiation.

Statistically significant variation was recorded due to the combined effect of pinching methods and levels of GA_3 in terms of days to 1^{st} curd initiation of broccoli (Appendix VII). The maximum days to 1^{st} curd initiation (48.0) was observed from P_0G_0 treatment combination which was statistically identical to P_3G_0 treatment combination and similar to P_0G_1, P_0G_2, P_1G_2 and P_2G_1 treatment combination and the minimum days (35.3) was found from P_1G_1 treatment combination (Table 7).

4.6 Days to curd maturity

Days to curd maturity of broccoli varied significantly due to pinching methods (Appendix VII). The maximum days to curd maturity (67.2) were recorded from P_0 treatment which was statistically similar (64.7 days) to P_3 treatment, while the minimum days (62.4) were observed from P_1 which was statistically identical (63.6 days) to P_2 treatment and similar to P_3 treatment (Table 6). Palevitch and Pressmun (1983) reported that pinching delayed harvest by 2-3 days.

Statistically significant variation was recorded in terms of days to curd maturity of broccoli due to levels of GA_3 (Appendix VII). The maximum days to curd maturity (66.3) was found from G_0 treatment which was statistically similar (64.7 days) to G_2 treatment, whereas the minimum days (62.5) were observed from G_1 treatment (Table 6) and similar to G_2 treatment.

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of days to curd maturity of broccoli (Appendix VII). The maximum days to curd maturity (69.3) was recorded from P_0G_0 which was statistically identical to P_3G_0 treatment combination and similar to P_0G_1, P_0G_2, P_1G_2 and P_2G_1 treatment combination and the minimum days (57.0) was found from P_1G_1 treatment combination (Table 7).

Table 6. Effect of pinching methods and levels of gibberellic acid on different yield contributing characters of broccoli

Treatments	Days to 1st curd initiation	Days to curd maturity	Length of stem (cm)	Diameter of stem (mm)	Length of largest root (cm)
Pinching methods					
P_0	46.1 a	67.2 a	24.1 c	17.9 c	15.3 b
P_1	41.1 b	62.4 b	26.3 a	24.2 a	16.5 a
P_2	42.0 b	63.6 b	25.8 ab	22.2 ab	16.4 a
P_3	43.3 b	64.7 ab	24.7 bc	20.5 b	15.9 ab
$LSD_{(0.05)}$	2.63	2.96	1.28	1.95	0.81
Level of significance	0.01	0.05	0.01	0.01	0.05
Levels of gibberellic acid					
G_0	44.7 a	66.3 a	22.6 c	18.5 c	14.3 c
G_1	41.4 b	62.5 b	27.4 a	24.2 a	17.6 a
G_2	43.3 ab	64.7 ab	25.7 b	20.9 b	16.1 b
$LSD_{(0.05)}$	2.27	2.56	1.11	1.69	0.70
Level of significance	0.05	0.05	0.01	0.01	0.01
CV(%)	4.25	5.58	5.18	9.39	5.14

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Table 7. Combined effect of pinching methods and levels of gibberellic acid on different yield contributing characters of broccoli

Treatments	Days to 1st curd initiation	Days to curd maturity	Length of stem (cm)	Diameter of stem (mm)	Length of largest root (cm)
P_0G_0	48.0 a	69.3 a	21.9 f	16.6 f	13.4 g
P_0G_1	46.3 ab	67.0 a-c	25.7 c-e	19.6 d-f	16.5 cd
P_0G_2	44.0 a-d	65.3 a-c	24.7 de	17.5 f	15.9 c-e
P_1G_0	42.0 b-d	63.0 bc	23.5 ef	21.8 c-e	15.2 d-f
P_1G_1	35.3 e	57.0 d	29.3 a	28.9 a	18.6 a
P_1G_2	46.0 a-c	67.3 ab	26.2 b-d	21.8 c-e	15.6 de
P_2G_0	41.0 cd	63.3 bc	21.3 f	16.9 f	13.7 fg
P_2G_1	43.7 a-d	64.7 a-c	28.5 ab	25.5 b	18.2 ab
P_2G_2	41.3 b-d	62.7 bc	27.5 a-c	24.3 bc	17.2 bc
P_3G_0	47.7 a	69.0 a	23.6 ef	18.8 ef	14.9 e-g
P_3G_1	40.3 d	61.3 cd	26.2 b-d	22.8 b-d	17.1 bc
P_3G_2	42.0 b-d	63.3 bc	24.4 de	19.9 d-f	15.9 c-e
$LSD_{(0.05)}$	4.55	5.12	2.21	3.37	1.39
Level of significance	0.01	0.01	0.05	0.05	0.05
CV(%)	4.25	5.58	5.18	9.39	5.14

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

4.7 Length of stem

Statistically significant variation was recorded in terms of length of stem of broccoli due to pinching methods (Appendix VII). The highest length of stem (26.3 cm) was observed from P_1 treatment which was statistically similar (25.8 cm) to P_2, whereas the lowest length of stem (24.1 cm) was recorded from P_0 treatment which was statistically similar (24.7 cm) to P_3 treatment (Table 6).

Length of stem of broccoli varied significantly in terms of due to levels of GA_3 (Appendix VII). The highest length of stem (27.4 cm) was observed from G_1 treatment which was followed (25.7 cm) by G_2 treatment, while the lowest length of stem (22.6 cm) was found from G_0 treatment (Table 6). Singh (2011) showed that GA_3 increase the length of stem upto a certain limit of GA_3 concentration.

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of length of stem of broccoli (Appendix VII). The highest length of stem (29.3 cm) was observed from P_1G_1 which was statistically similar to P_1G_2 and P_2G_1 treatment combination and the lowest length of stem (21.9 cm) was found from P_0G_0 treatment combination (Table 7).

4.8 Diameter of stem

Diameter of stem of broccoli showed statistically significant differences due to pinching methods (Appendix VII). The highest diameter of stem (24.3 mm) was recorded from P_1 treatment which was statistically similar (22.2 mm) to P_2 treatment, while the lowest diameter of stem (17.9 mm) was observed from P_0 treatment which was closely followed (20.5 mm) by P_3 treatment (Table 6).

Statistically significant variation was recorded in terms of diameter of stem of broccoli due to levels of GA_3 (Appendix VII). The highest diameter of stem (24.2 mm) was found from G_1 treatment which was followed (20.9 mm) by G_2 treatment, whereas the lowest diameter of stem (18.5 mm) from G_0 treatment (Table 6).

Diameter of stem of broccoli showed statistically significant variation due to the combined effect of pinching methods and levels of GA_3 (Appendix VII). The highest diameter of stem (28.9 mm) was observed from P_1G_1 treatment combination, while the lowest diameter of stem (16.6 mm) was attained from P_0G_0 treatment combination (Table 7).

4.9 Length of largest root

Statistically significant variation was recorded in terms of length of largest root of broccoli due to pinching methods (Appendix VII). The highest length of largest root (16.5 cm) was found from P_1 treatment which was statistically similar (16.4 cm) to P_2 treatment, whereas the lowest length of largest root (15.3 cm) was recorded from P_0 treatment which was statistically similar (15.9 cm) to P_3 treatment (Table 6).

Length of largest root of broccoli showed statistically significant variation in terms of due to levels of GA_3 (Appendix VII). The highest length of largest root (17.6 cm) was found from G_1 treatment which was followed (16.1 cm) by G_2, while the lowest length of largest root (14.3 cm) from G_0 treatment (Table 6).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of length of largest root of broccoli (Appendix VII). The highest length of largest root (18.6 cm) was recorded from P_1G_1 which was statistically similar to P_2G_1 treatment combination and the lowest length of largest root (13.4 cm) was found from P_0G_0 treatment combination (Table 7).

4.10 Number of curds per plant

Number of curds per plant of broccoli showed statistically significant differences due to pinching methods (Appendix VIII). The highest number of curds per plant (2.67) was observed from P_1 treatment which was closely followed (2.38) by P_2, while the lowest number of curds per plant (1.00) was found from P_3 treatment (Table 8). Pressman *et al.* (1985) reported that pinching hastened button formation. Abd El-Gawad (2007) reported that pinching plant produced highest number of curds per plant.

Statistically significant variation was recorded in terms of number of curds per plant of broccoli due to levels of GA_3 (Appendix VIII). The highest number of curds per plant (1.95) was recorded from G_1 treatment, whereas the lowest number (1.73) was found from G_0 which was statistically similar (1.80) to G_2 treatment (Table 8).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of number of curds per plant of broccoli (Appendix VIII). The highest number of curds per plant (2.87) was observed from P_1G_1 which was statistically similar to P_1G_0 treatment combination, while the lowest number (1.00) was found from P_3G_0 treatment combination which was statistically similar to P_3G_1 and P_3G_2 treatment combination (Table 9).

4.11 Weight of individual curd

Pinching methods showed statistically significant differences in terms of weight of individual curd of broccoli (Appendix VIII). The highest weight of individual curd (500.6 g) was observed from P_3 treatment which was closely followed (375.9 g) by P_0, while the lowest weight of individual curd (253.2 g) was found from P_2 which was statistically similar (266.4 g) to P_1 treatment (Table 8).

Weight of individual curd of broccoli showed statistically significant variation due to levels of GA_3 (Appendix VIII). The highest weight of individual curd (375.5 g) was found from G_1 treatment which was closely followed (350.1 g) by G_2 and the lowest weight (321.7 g) from G_0 treatment (Table 8).

Statistically significant variation was recorded for the combined effect of pinching methods and levels of GA_3 in terms of weight of individual curd of broccoli (Appendix VIII). The highest weight of individual curd (511.9 g) was observed from P_3G_1 treatment combination which was statistically identical to P_3G_0 treatment combination and similar to P_3G_1 and P_3G_2 treatment combination, whereas the lowest weight (203.4 g) was found from P_2G_0 treatment combination (Table 9).

Table 8. Effect of pinching methods and levels of gibberellic acid on different yield contributing characters and yield of broccoli

Treatments	Number of curds per plant	Weight of individual curd (g)	Diameter of curd (cm)	Dry matter content in curd (%)	Curd yield per plant (g)
Pinching methods					
P_0	1.27 c	375.9 b	8.55 b	12.9 c	478.4 c
P_1	2.67 a	266.4 c	7.96 c	14.8 a	714.1 a
P_2	2.38 b	253.2 c	7.69 d	14.8 a	608.3 b
P_3	1.00 d	500.6 a	9.12 a	13.5 b	500.6 c
$LSD_{(0.05)}$	0.13	16.9	0.26	0.511	52.9
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of gibberellic acid					
G_0	1.73 b	321.7 c	8.08 b	13.7 b	490.1 c
G_1	1.95 a	375.5 a	8.61 a	14.4 a	671.7 a
G_2	1.80 b	350.1 b	8.30 b	13.9 ab	564.2 b
$LSD_{(0.05)}$	0.11	14.7	0.23	0.44	45.8
Level of significance	0.01	0.01	0.01	0.05	0.01
CV(%)	7.24	4.96	6.21	4.73	9.40

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Table 9. Combined effect of pinching methods and levels of gibberellic acid on different yield contributing characters and yield of broccoli

Treatments	Number of curds per plant	Weight of individual curd (g)	Diameter of curd (cm)	Dry matter content in curd (%)	Curd yield per plant (g)
P_0G_0	1.07 f	353.0 c	8.32 cd	12.4 f	375.8 g
P_0G_1	1.40 e	386.3 b	8.71 bc	13.3 d-f	540.8 d-f
P_0G_2	1.33 e	388.7 b	8.62 bc	13.1 ef	518.5 ef
P_1G_0	2.67 ab	245.1 e	7.82 e	14.8 ab	651.9 c
P_1G_1	2.87 a	309.7 d	8.49 bc	15.3 a	887.3 a
P_1G_2	2.47 bc	244.4 e	7.57 ef	14.4 a-c	603.1 c-e
P_2G_0	2.20 d	203.4 f	7.31 f	14.2 b-d	447.4 fg
P_2G_1	2.53 bc	294.0 d	7.98 de	15.2 a	746.9 b
P_2G_2	2.40 cd	262.3 e	7.79 e	14.9 ab	630.5 cd
P_3G_0	1.00 f	485.1 a	8.88 ab	13.4 c-e	485.1 f
P_3G_1	1.00 f	511.9 a	9.25 a	13.6 c-e	511.9 ef
P_3G_2	1.00 f	504.9 a	9.22 a	13.6 c-e	504.9 ef
$LSD_{(0.05)}$	0.22	29.3	0.45	0.89	91.5
Level of significance	0.05	0.01	0.05	0.05	0.01
CV(%)	7.24	4.96	6.21	4.73	9.40

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

4.12 Diameter of curd

Diameter of curd of broccoli showed statistically significant differences due to pinching methods (Appendix VIII). The highest diameter of curd (9.12 cm) was recorded from P_3 treatment which was closely followed (8.55 cm) by P_1, whereas the lowest diameter of curd (7.69 cm) was found from P_2 which was closely followed (7.96 cm) by P_1 treatment (Table 8).

Statistically significant variation was recorded in terms of diameter of curd of broccoli due to levels of GA_3 (Appendix VIII). The highest diameter of curd (8.61 cm) was observed from G_1 treatment, while the lowest diameter of curd (8.08 cm) was found from G_0 which was statistically similar (8.30 cm) to G_2 treatment (Table 8).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of diameter of curd of broccoli (Appendix VIII). The highest diameter of curd (9.25 cm) was recorded from P_3G_1 which was statistically identical to P_3G_2 treatment combination and similar to P_3G_0 treatment combination and the lowest diameter (7.31 cm) was found from P_2G_0 treatment combination (Table 9).

4.13 Dry matter content in curd

Dry matter content in curd of broccoli showed statistically significant differences due to pinching methods (Appendix VIII). The highest dry matter content in curd (14.8%) was observed from P_1 treatment which was statistically similar (14.8%) to P_2 and the lowest dry matter content in curd (12.9%) was found from P_0 which was closely followed (13.5%) by P_1 treatment (Table 8).

Statistically significant variation was recorded in terms of dry matter content in curd of broccoli due to levels of GA_3 (Appendix VIII). The highest dry matter content in curd (14.4%) was recorded from G_1 treatment which was statistically similar (13.9%) to G_2, whereas the lowest dry matter content in curd (13.7%) was found from G_0 treatment (Table 8).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of dry matter content in curd of broccoli (Appendix VIII). The highest dry matter in curd (15.3%) was found from P_1G_1 which was statistically identical to P_2G_1 treatment combination and similar to P_1G_0, P_1G_2 and P_2G_2 treatment combination, while the lowest dry mater content in curd (12.4%) was recorded from P_0G_0 treatment combination (Table 9).

4.14 Curd yield per plant

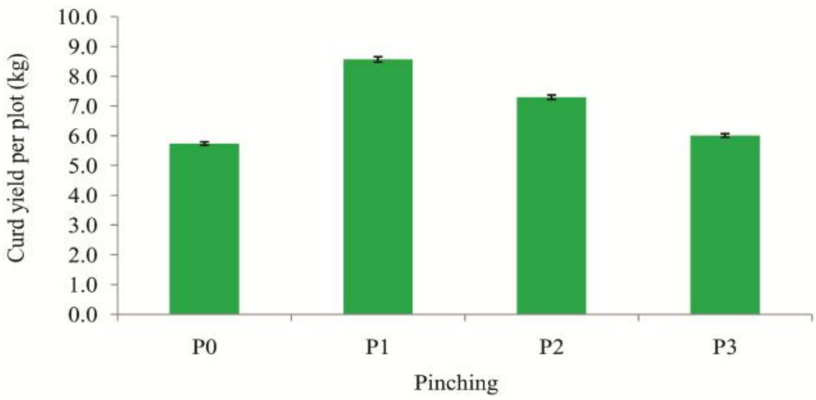
Curd yield per plant of broccoli showed statistically significant differences due to pinching methods (Appendix VIII). The highest curd yield per plant (714.1 g) was recorded from P_1 treatment which was closely followed (608.3 g) by P_2, whereas the lowest curd yield per plant (478.4 g) was found from P_0 which was statistically similar (500.6 g) to P_3 treatment (Table 8). Abd El-Gawad (2007) reported highest curd yield per plant from pinching plants.

Statistically significant variation was recorded in terms of curd yield per plant of broccoli due to levels of GA_3 (Appendix VIII). The highest curd yield per plant (671.7 g) was found from G_1 treatment which was closely followed (564.2 g) by G_2, while the lowest curd yield per plant (490.1 g) was recorded from G_0 treatment (Table 8).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of curd yield per plant of broccoli (Appendix VIII). The highest curd yield per plant (887.3 g) was recorded from P_1G_1 treatment combination and the lowest curd yield per plant (375.8 g) was observed from P_0G_0 treatment combination (Table 9).

4.15 Curd yield per plot

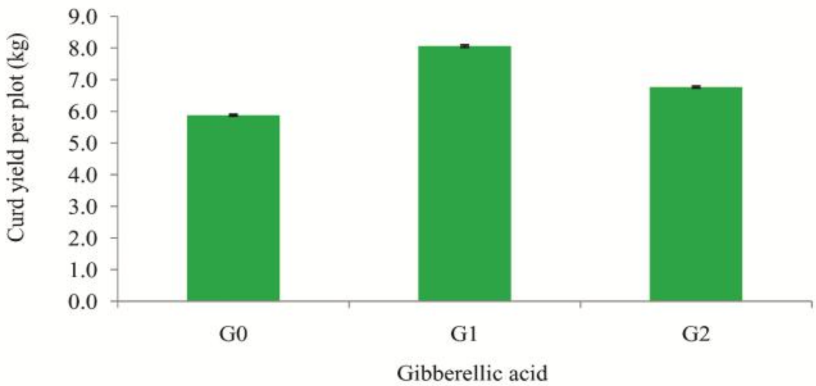
Statistically significant variation was recorded in terms of curd yield per plot of broccoli due to pinching methods (Appendix VIII). The highest curd yield per plot (8.57 kg) was found from P_1 treatment which was closely followed (7.30 kg) by P_2, while the lowest curd yield per plot (5.74 kg) was recorded from P_0 which was statistically similar (6.01 kg) to P_3 treatment (Fig. 10).



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

Fig.10. Effect of pinching methods on curd yield per plot of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Fig.11. Effect of levels of GA_3 on curd yield per plot of broccoli.

Levels of GA_3 varied significantly in terms of curd yield per plot of broccoli (Appendix VIII). The highest curd yield per plot (8.06 kg) was observed from G_1 treatment which was closely followed (6.77 kg) by G_2, whereas the lowest curd yield per plot (5.88 kg) was recorded from G_0 treatment (Fig. 11). Dhengle and Bhosale (2008) reported that higher concentrations of plant growth regulators proved less effective for curd yield per plot.

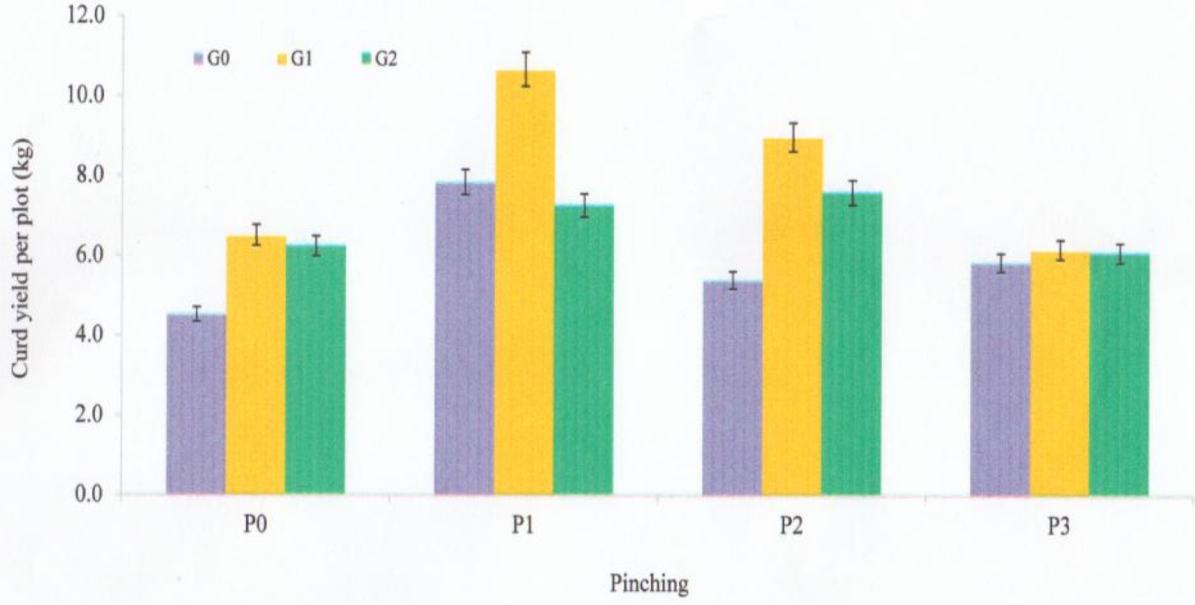
Curd yield per plot of broccoli varied significantly due to the combined effect of pinching methods and levels of GA_3 (Appendix VIII). The highest curd yield per plot (10.7 kg) was observed from P_1G_1 which was statistically identical to P_3G_0 treatment combination and similar to P_0G_1, P_0G_2, P_1G_2 and P_2G_1 treatment combination, while the lowest curd yield per plot (4.51 kg) was recorded from P_0G_0 treatment combination (Fig. 12).

4.16 Curd yield per hectare

Curd yield per hectare of broccoli varied significantly due to pinching methods (Appendix VIII). The highest curd yield per hectare (29.8 ton) was found from P_1 treatment which was closely followed (25.4 ton) by P_2, whereas the lowest curd yield per hectare (19.9 ton) was observed from P_0 which was statistically similar (20.9 ton) to P_3 treatment (Fig. 13). Abd El-Gawad (2007) recorded highest yield when pinching main head at early stage.

Statistically significant variation was recorded in terms of curd yield per hectare of broccoli due to levels of GA_3 (Appendix VIII). The highest curd yield per hectare (27.9 ton) was recorded from G_1 treatment which was closely followed (23.5 ton) by G_2, while the lowest curd yield per hectare (20.4 ton) was found from G_0 treatment (Fig. 14). Vijay and Ray (2000) reported that GA_3 at 100 ppm produced the largest curds.

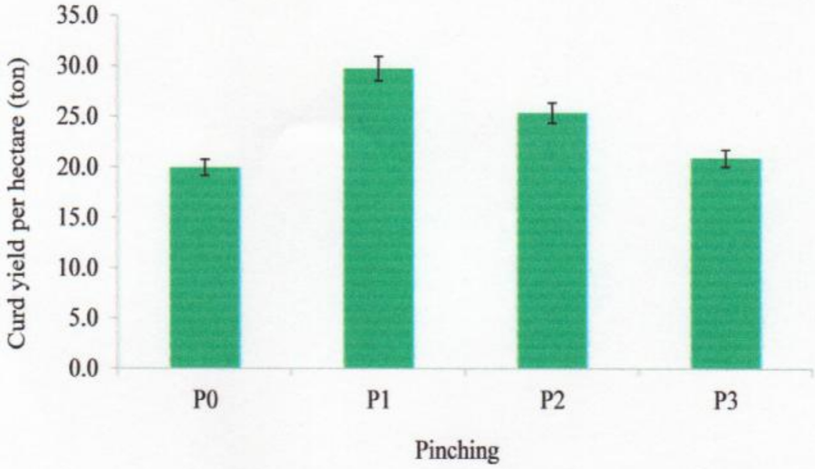
Combined effect of pinching methods and levels of GA_3 varied significantly in terms of curd yield per hectare of broccoli (Appendix VIII). The highest curd yield per hectare (36.9 ton) was found from P_1G_1, whereas the lowest curd yield per hectare (15.7 ton) was observed from P_0G_0 treatment combination (Fig. 15).



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT G_2: 100 ppm GA_3

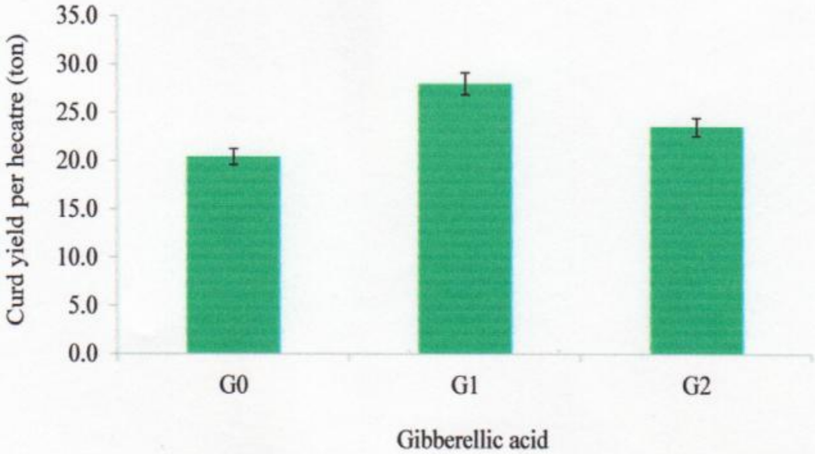
Fig. 12. Effect of pinching methods and different levels of GA_3 on curd yield per plot of broccoli.



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

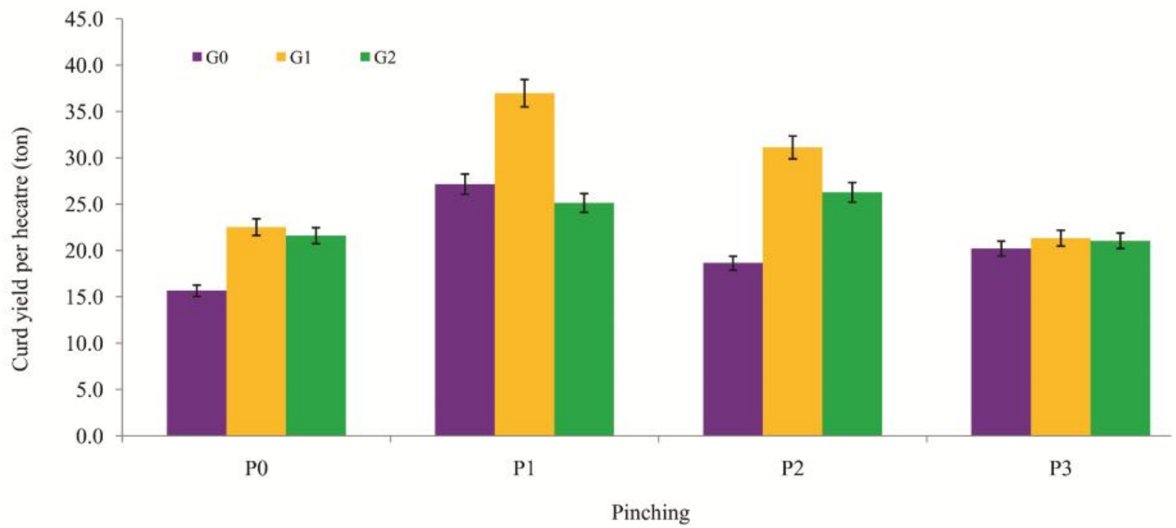
Fig. 13. Effect of pinching methods on curd yield per hectare of broccoli.



G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Fig. 14. Effect of levels of GA_3 on curd yield per hectare of broccoli.



P_0: No pinching i.e. control P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT P_3: Pinching axillary bud at 45 DAT

G_0: 0 ppm GA_3 i.e., control) G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Fig. 15. Effect of pinching methods and levels of GA_3 on curd yield per hectare of broccoli.

4.17 Storage condition on shelf life of curd

4.17.1 Storage in room temperature and in open condition

Shelf life of broccoli curd storage in room temperature and in open condition showed statistically significant differences due to pinching methods (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in open condition (2.96 days) was found from P_1 treatment and the lowest (2.52 days) was recorded from P_0 which was closely followed (2.63 days and 2.70 days) by P_3 and P_2 treatment and they were statistically similar (Table 10).

Statistically significant variation was recorded in terms of shelf life of broccoli curd storage in room temperature and in open condition due to levels of GA_3 (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in open condition (2.81 days) was found from G_1 treatment which was statistically similar (2.72 days) to G_2, whereas the lowest (2.58 days) was observed from G_0 treatment (Table 10).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of shelf life of broccoli curd storage in room temperature and in open condition (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in open condition (3.11 days) was recorded from P_1G_1 treatment combination which was statistically similar to P_1G_0, P_1G_2, P_2G_1 and P_2G_2 treatment combination, while the lowest (2.44 days) was found from P_0G_0 treatment combination (Table 11).

4.17.2 Storage in room temperature and in polythene bag

Pinching methods showed statistically significant differences in terms of shelf life of broccoli curd storage in room temperature and in polythene bag (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in polythene bag (3.48 days) was recorded from P_1 treatment which was statistically similar (3.37 days) to P_2, whereas the lowest (3.11 days) was observed from P_0 which was statistically similar (3.26 days) to P_3 treatment (Table 10).

Table 10. Effect of pinching methods and levels of gibberellic acid on shelf life of broccoli in room and refrigerator temperature in different preservation materials

Treatments	Shelf life under room temperature and the condition of			Shelf life under refrigerator and the condition of		
	Open	Polythene bag	Perforated polythene bags	Open	Polythene bag	Perforated polythene bags
Pinching methods						
P_0	2.52 b	3.11 c	4.67 c	24.8 b	28.8 c	30.6 c
P_1	2.96 a	3.48 a	5.15 a	26.6 a	30.9 a	33.2 a
P_2	2.70 b	3.37 ab	5.04 ab	26.4 a	30.5 ab	32.9 ab
P_3	2.63 b	3.26 bc	4.82 bc	25.0 b	29.7 bc	32.0 b
$LSD_{(0.05)}$	0.180	0.198	0.225	0.55	1.12	1.06
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Levels of gibberellic acid						
G_0	2.58 b	3.14 b	4.67 c	24.6 c	28.1 c	30.1 c
G_1	2.81 a	3.47 a	5.17 a	26.9 a	31.6 a	33.9 a
G_2	2.72 ab	3.30 ab	4.92 b	25.7 b	30.2 b	32.5 b
$LSD_{(0.05)}$	0.156	0.171	0.195	0.47	0.97	0.92
Level of significance	0.05	0.01	0.01	0.01	0.01	0.01

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

P_0: No pinching (control)
P_1: Pinching apical meristem at 15 DAT
P_2: Pinching apical meristem at 30 DAT
P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)
G_1: 50 ppm GA_3
G_2: 100 ppm GA_3

Table 11. Combined effect of pinching methods and levels of gibberellic acid on shelf life of broccoli in room and refrigerator temperature in different preservation materials

Treatments	Shelf life under room temperature and the condition of			Shelf life under refrigerator and the condition of		
	Open	Polythene bag	Perforated polythene bags	Open	Polythene bag	Perforated polythene bags
P_0G_0	2.44 c	2.89 d	4.44 e	23.3 e	26.9 e	29.2 g
P_0G_1	2.56 bc	3.22 b-d	4.78 c-e	25.7 c	29.9 cd	31.4 d-f
P_0G_2	2.56 bc	3.22 b-d	4.78 c-e	25.3 cd	29.7 d	31.1 d-g
P_1G_0	2.89 ab	3.44 a-c	5.00 cd	26.0 bc	29.3 d	31.2 d-g
P_1G_1	3.11 a	3.67 a	5.56 a	28.2 a	33.4 a	36.0 a
P_1G_2	2.89 ab	3.33 a-c	4.89 cd	25.7 c	30.1 cd	32.4 c-e
P_2G_0	2.56 bc	3.11 cd	4.56 de	24.6 d	27.0 e	29.4 fg
P_2G_1	2.89 ab	3.56 ab	5.44 ab	27.9 a	32.5 ab	35.4 ab
P_2G_2	2.78 a-c	3.44 a-c	5.11 bc	26.8 b	31.9 a-c	33.9 bc
P_3G_0	2.56 bc	3.11 cd	4.67 c-e	24.4 d	29.2 d	30.6 e-g
P_3G_1	2.67 bc	3.44 a-c	4.89 cd	25.7 c	30.7 b-d	33.0 cd
P_3G_2	2.67 bc	3.22 b-d	4.89 cd	25.0 cd	29.2 d	32.4 c-e
$LSD_{(0.05)}$	0.312	0.343	0.390	0.95	1.95	1.84
Level of significance	0.05	0.05	0.05	0.01	0.01	0.05
CV(%)	6.79	6.14	4.68	5.18	4.83	6.38

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Shelf life of broccoli curd storage in room temperature and in polythene bag showed statistically significant differences due to levels of GA_3 (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in polythene bag (3.47 days) was observed from G_1 treatment which was statistically similar (3.30 days) to G_2, while the lowest (3.14 days) was recorded from G_0 treatment (Table 10).

Statistically significant variation was recorded due to the combined effect of pinching methods and levels of GA_3 in terms of shelf life of broccoli curd storage in room temperature and in polythene bag (Appendix IX). The highest shelf life of broccoli curd storage in room temperature and in polythene bag (3.67 days) was observed from P_1G_1 and the lowest (2.89 days) was recorded from P_0G_0 treatment combination (Table 11).

4.17.3 Storage in refrigerator and in perforated polythene bag

Shelf life of broccoli curd storage in refrigerator and in perforated polythene bag showed statistically significant differences due to pinching methods (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (5.15 days) was found from P_1 treatment which was statistically similar (5.04 days) to P_2, while the lowest (4.67 days) was recorded from P_0 which was statistically similar (4.82 days) to P_3 treatment (Table 10).

Statistically significant variation was recorded in terms of shelf life of broccoli curd storage in refrigerator and in perforated polythene bag due to levels of GA_3 (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (5.17 days) was found from G_1 treatment which was closely followed (4.92 days) by G_2, whereas the lowest (4.67 days) was observed from G_0 treatment (Table 10).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (5.56 days) was observed from P_1G_1, while the lowest (4.44 days) was recorded from P_0G_0 treatment combination (Table 11).

4.17.4 Storage in refrigerator and in open condition

Statistically significant differences was recorded in terms of shelf life of broccoli curd storage in refrigerator and in open condition showed due to pinching methods (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in open condition (26.6 days) was recorded from P_1 treatment which was statistically similar (26.4 days) to P_2, whereas the lowest (24.8 days) was observed from P_0 which was statistically similar (25.0 days) to P_3 treatment (Table 10).

Shelf life of broccoli curd storage in refrigerator and in open condition showed statistically significant variation was recorded due to levels of GA_3 (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in open condition (26.9 days) was recorded from G_1 treatment which was closely followed (25.7 days) by G_2, while the lowest (24.6 days) was found from G_0 treatment (Table 10).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of shelf life of broccoli curd storage in refrigerator and in open condition (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in open condition (28.2 days) was found from P_1G_1 and the lowest (23.3 days) was observed from P_0G_0 treatment combination (Table 11).

4.17.5 Storage in refrigerator and in polythene bag

Shelf life of broccoli curd storage in refrigerator and in polythene bag showed statistically significant differences due to pinching methods (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in polythene bag (30.9 days) was recorded from P_1 treatment which was statistically similar (30.5

days) to P_2, while the lowest (28.8 days) was observed from P_0 which was statistically similar (29.7 days) to P_3 treatment (Table 10).

Statistically significant variation was recorded in terms of shelf life of broccoli curd storage in refrigerator and in polythene bag due to levels of GA_3 (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in polythene bag (31.6 days) was observed from G_1 treatment which was closely followed (30.2 days) by G_2 and the lowest (28.1 days) was recorded from G_0 treatment (Table 10).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of shelf life of broccoli curd storage in refrigerator and in polythene bag (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in polythene bag (33.4 days) was observed from P_1G_1 which was statistically similar to P_2G_1 and P_2G_2 treatment combination, while the lowest (26.9 days) was found from P_0G_0 treatment combination (Table 11).

4.17.6 Storage in refrigerator and in perforated polythene bag

Shelf life of broccoli curd storage in refrigerator and in perforated polythene bag showed statistically significant differences due to pinching methods (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (33.2 days) was found from P_1 treatment which was statistically similar (32.9 days) to P_2, whereas the lowest (30.6 days) was observed from P_0 which was closely followed (32.0 days) by P_3 treatment (Table 10).

Levels of GA_3 showed statistically significant differences in terms of shelf life of broccoli curd storage in refrigerator and in perforated polythene bag due to (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (33.9 days) was recorded from G_1 treatment which was closely followed (32.5 days) by G_2, while the lowest (30.1 days) was found from G_0 treatment (Table 10).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (Appendix IX). The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (36.0 days) was found from P_1G_1 treatment combination which was statistically similar to P_2G_1 and the lowest (29.2 days) from P_0G_0 treatment combination (Table 11).

4.18 Biochemical parameters

4.18.1 Ascorbic acid

Ascorbic acid content of broccoli showed statistically significant differences due to pinching methods (Appendix X). The highest ascorbic acid content of broccoli (85.0 mg/100 g) was found from P_1 treatment which was statistically similar (84.2 mg/100 g) to P_2, while the lowest (80.5 mg/100 g) was recorded from P_0 which was statistically similar (81.7 mg/100 g) to P_3 treatment (Table 12).

Statistically significant variation was recorded in terms of ascorbic acid content of broccoli due to levels of GA_3 (Appendix X). The highest ascorbic acid content of broccoli (85.8 mg/100 g) was found from G_1 treatment, whereas the lowest (81.8 mg/100 g) was recorded from G_0 which was statistically similar (81.0 mg/100 g) to G_2 treatment (Table 12).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of ascorbic acid content of broccoli (Appendix X). The highest ascorbic acid content of broccoli (89.8 mg/100 g) was found from P_1G_1, while the lowest (77.3 mg/100 g) was observed from P_0G_0 treatment combination (Table 13).

4.18.2 ß-carotene

Pinching methods showed statistically non-significant differences in terms of ß-carotene content of broccoli (Appendix X). The highest ß-carotene content of broccoli (575.7 µg/100 g) was recorded from P_1 treatment, whereas the lowest (566.4 µg/100 g) was observed from P_0 treatment (Table 12).

Table 12. Effect of pinching methods and levels of gibberellic acid on different nutrient content of broccoli

Treatments	Ascorbic acid (mg/100 g)	ß-carotene (µg/100 g)	Calcium (mg/100 g)	Potassium (ppm)	Phosphorus (ppm)	Iron (mg/100 g)
Pinching methods						
P_0	80.5 c	566.4	47.7 c	289.9	65.6 b	0.70 d
P_1	85.0 a	575.7	50.1 a	294.5	68.7 a	0.92 a
P_2	84.2 ab	575.0	49.7 ab	292.5	67.1 ab	0.81 b
P_3	81.7 bc	569.1	48.1 bc	290.7	66.0 b	0.76 c
$LSD_{(0.05)}$	3.14	--	1.80	--	2.45	0.044
Level of significance	0.05	NS	0.05	NS	0.05	0.01
Levels of gibberellic acid						
G_0	81.8 b	561.3 b	43.5 c	267.9 c	61.1 c	0.71 c
G_1	85.8 a	583.1 a	53.0 a	310.7 a	72.3 a	0.88 a
G_2	81.0 b	570.2 b	50.2 b	297.0 b	67.1 b	0.80 b
$LSD_{(0.05)}$	2.72	9.10	1.56	5.25	2.12	0.038
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	5.88	4.88	3.76	4.12	3.74	5.13

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Table 13. Combined effect of pinching methods and levels of gibberellic acid on different nutrient content of broccoli

Treatments	Ascorbic acid (mg/100 g)	ß-carotene (µg/100 g)	Calcium (mg/100 g)	Potassium (ppm)	Phosphorus (ppm)	Iron (mg/100 g)
P_0G_0	77.3 c	554.1 d	42.3 c	267.4 de	60.9 ef	0.61 f
P_0G_1	81.9 bc	573.9 b-d	50.3 b	302.1 bc	69.4 bc	0.76 de
P_0G_2	82.4 bc	571.2 cd	50.6 b	300.1 bc	66.5 cd	0.73 e
P_1G_0	89.0 a	568.2 cd	45.4 c	272.7 d	63.9 de	0.85 bc
P_1G_1	89.8 a	596.5 a	55.7 a	320.1 a	76.3 a	1.03 a
P_1G_2	76.5 c	562.4 cd	49.1 b	290.7 c	65.6 cd	0.87 bc
P_2G_0	78.6 bc	555.7 d	42.2 c	257.4 e	57.5 f	0.68 ef
P_2G_1	89.6 a	591.6 ab	55.0 a	317.9 a	73.8 ab	0.91 b
P_2G_2	84.2 ab	577.7 a-c	51.7 b	302.2 bc	69.9 bc	0.85 bc
P_3G_0	82.2 bc	567.2 cd	43.9 c	274.3 d	61.9 d-f	0.70 e
P_3G_1	81.8 bc	570.4 cd	51.0 b	302.8 b	69.8 bc	0.81 cd
P_3G_2	81.1 bc	569.6 cd	49.5 b	295.1 bc	66.4 cd	0.76 de
$LSD_{(0.05)}$	5.44	18.2	3.11	10.5	4.24	0.076
Level of significance	0.01	0.05	0.05	0.01	0.01	0.05
CV(%)	5.88	4.88	3.76	4.12	3.74	5.13

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

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

ß-carotene content of broccoli showed statistically significant differences in terms of due to levels of GA_3 (Appendix X). The highest ß-carotene content of broccoli (583.1 µg/100 g) was observed from G_1 treatment, while the lowest (561.3 µg/100 g) was recorded from G_0 which was statistically similar (570.2 µg/100 g) to G_2 treatment (Table 12).

Statistically significant variation was recorded due to the combined effect of pinching methods and levels of GA_3 in terms of ß-carotene content of broccoli (Appendix X). The highest ß-carotene content of broccoli (596.5 µg/100 g) was observed from P_1G_1 and the lowest (554.1 µg/100 g) was recorded from P_0G_0 treatment combination (Table 13).

4.18.3 Calcium

Calcium content of broccoli showed statistically significant differences due to pinching methods (Appendix X). The highest calcium content of broccoli (50.1 mg/100 g) was observed from P_1 treatment which was statistically similar (49.7 mg/100 g) to P_2, while the lowest (47.7 mg/100 g) was found from P_0 which was statistically similar (48.1 mg/100 g) to P_3 treatment (Table 12).

Statistically significant variation was recorded in terms of calcium content of broccoli due to levels of GA_3 (Appendix X). The highest calcium content of broccoli (53.0 mg/100 g) was recorded from G_1 treatment which was statistically similar (50.2 mg/100 g) to G_2, whereas the lowest (43.5 mg/100 g) was found from G_0 treatment (Table 12).

Combined effect of pinching methods and levels of GA_3 showed statistically significant variation in terms of calcium content of broccoli (Appendix X). The highest calcium content of broccoli (55.7 mg/100 g) was recorded from P_1G_1, while the lowest (42.3 mg/100 g) was found from P_0G_0 treatment combination (Table 13).

4.18.4 Potassium

Statistically non-significant variation was observed in terms of potassium content of broccoli due to pinching methods (Appendix X). The highest potassium content of broccoli (294.5 ppm) was recorded from P_1 treatment, whereas the lowest (289.9 ppm) was observed from P_0 treatment (Table 12).

Levels of GA_3 varied significantly in terms of potassium content of broccoli due to (Appendix X). The highest potassium content of broccoli (310.7 ppm) was observed from G_1 treatment, while the lowest (267.9 ppm) was recorded from G_0 which was closely followed (297.0 ppm) by G_2 treatment (Table 12).

Statistically significant variation was recorded due to the combined effect of pinching methods and levels of GA_3 in terms of potassium content of broccoli (Appendix X). The highest potassium content of broccoli (320.1 ppm) was observed from P_1G_1 and the lowest (267.4 ppm) was recorded from P_0G_0 treatment combination (Table 13).

4.18.5 Phosphorus

Phosphorus content of broccoli showed statistically significant differences due to pinching methods (Appendix X). The highest phosphorus content of broccoli (68.7 ppm) was found from P_1 treatment which was statistically similar (67.1 ppm) to P_2, whereas the lowest (65.6 ppm) was recorded from P_0 which was statistically similar (66.0 ppm) to P_3 treatment (Table 12).

Statistically significant variation was recorded in terms of phosphorus content of broccoli due to levels of GA_3 (Appendix X). The highest phosphorus content of broccoli (72.3 ppm) was observed from G_1 treatment, while the lowest (61.1 ppm) was found from G_0 which was closely followed (67.1 ppm) by G_2 treatment (Table 12).

Combined effect of pinching methods and levels of GA_3 varied significantly in terms of phosphorus content of broccoli (Appendix X). The highest phosphorus content of broccoli (76.3 ppm) was observed from P_1G_1, whereas the lowest (60.9 ppm) was found from P_0G_0 treatment combination (Table 13).

4.18.6 Iron

Statistically significant variation was recorded in terms of iron content of broccoli due to pinching methods (Appendix X). The highest iron content of broccoli (0.92 mg/100 g) was found from P_1 treatment which was closely followed (0.81 mg/100 g) to P_2, whereas the lowest (0.70 mg/100 g) was recorded from P_0 which was closely followed (0.76 mg/100 g) by P_3 treatment (Table 12).

Levels of GA_3 showed statistically significant differences in terms of iron content of broccoli (Appendix X). The highest iron content of broccoli (0.88 mg/100 g) was recorded from G_1 treatment, while the lowest (0.71 mg/100 g) was observed from G_0 which was closely followed (0.80 mg/100 g) by G_2 treatment (Table 12).

Iron content of broccoli showed significant differences due to the combined effect of pinching methods and levels of GA_3 (Appendix X). The highest iron content of broccoli (1.03 mg/100 g) was recorded from P_1G_1, whereas the lowest (0.61 mg/100 g) was observed from P_0G_0 treatment combination (Table 13).

4.19 Economic analysis

Input costs for land preparation, fertilizer, pinching, GA_3, fertilizers and manpower required for all the operations from seed sowing to harvesting of broccoli were recorded as per plot and converted into cost/hectare (Appendix XI). Price of broccoli was considered as per present market rate basis. The economic analysis presented under the following headings-

4.19.1 Gross return

The combination of pinching method and GA_3 showed different value in terms of gross return under the trial (Table 14). The highest gross return (BDT 813,340/ha) was obtained from the treatment combination P_1G_1 and the second highest gross return (BDT 684,640/ha) was found in P_2G_1. The lowest gross return (BDT 360,180/ha) was obtained from P_0G_0.

4.19.2 Net return

In case of net return, pinching method and GA_3 showed different levels of net return under the present trial (Table 14). The highest net return (BDT 474,984/ha) was found from the treatment combination P_1G_1 and the second highest net return (BDT 346,284/ha) was obtained from the combination P_2G_1. The lowest net return (BDT 29,392/ha) was obtained from P_0G_0.

4.17.3 Benefit cost ratio

In the pinching method and GA_3 the highest benefit cost ratio (2.40) was noted from the combination of P_1G_1 and the second highest benefit cost ratio (2.02) was estimated from the combination of P_2G_1. The lowest benefit cost ratio (1.09) was obtained from P_0G_0 (Table 14). From economic point of view, it is apparent from the above results that the combination of P_1G_1 was better than rest of the combination in broccoli cultivation.

Table 14. Cost and return of broccoli cultivation as influenced by pinching methods and levels of gibberellic acid

Treatments	Cost of production (BDT/ha)	Yield of broccoli (t/ha)	Gross return (BDT/ha)	Net return (BDT/ha)	Benefit cost ratio
P_0G_0	330,788	15.66	360,180	29,392	1.09
P_0G_1	332,791	22.53	495,660	162,869	1.49
P_0G_2	333,236	21.60	475,200	141,964	1.43
P_1G_0	336,353	27.16	597,520	261,167	1.78
P_1G_1	338,356	36.97	813,340	474,984	2.40
P_1G_2	338,801	25.13	552,860	214,059	1.63
P_2G_0	336,353	18.64	410,080	73,727	1.22
P_2G_1	338,356	31.12	684,640	346,284	2.02
P_2G_2	338,801	26.27	577,940	239,139	1.71
P_3G_0	338,579	20.21	444,620	106,041	1.31
P_3G_1	340,582	21.33	469,260	128,678	1.38
P_3G_2	341,027	21.04	526,000	184,973	1.54

Price of broccoli @ BDT 22/kg

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted Horticulture farm and laboratory of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October 2016 to February 2017 to assess the growth, yield and quality of broccoli influenced by pinching and gibberellic acid (GA_3). The seeds of hybrid broccoli (*Brassica oleracea var. italica*) namely 'PARAISO (Takii seed) were used as planting materials for this experiment. The experiment consisted of two factors: Factor A: Pinching method (four levels) as- P_0: No pinching (control), P_1: Pinching apical meristem at 15 days after transplanting (DAT), P_2: Pinching apical meristem at 30 DAT and P_3: Pinching axillary buds at 45 DAT; and Factor B: Gibberellic acid-GA_3 (three levels) as- G_0: 0 ppm GA_3 (control), G_1: 50 ppm GA_3 and G_2:100 ppm GA_3. The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield and quality parameters were recorded and statistically significant variation was observed for different recorded parameters.

For different pinching methods, at 50, 60, 70 DAT and at harvest, the tallest plant (53.1, 68.8, 74.1 and 78.1 cm, respectively) was recorded from P_0, whereas the shortest plant (45.2, 61.2, 67.0 and 71.8 cm, respectively) from P_2. At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (21.0, 27.0, 32.0 and 35.7, respectively) was found from P_1 treatment, while the lowest number (18.4, 24.1, 27.9 and 31.0, respectively) from P_0. At 50, 60, 70 DAT and at harvest, the highest length of largest leaf (43.4, 49.2, 53.2, 54.9 cm, respectively) was observed from P_1 treatment, whereas the lowest length (39.5, 45.4, 48.3 and 50.7 cm, respectively) from P_0. At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (16.1, 18.2, 20.4 and 22.0 cm, respectively) was recorded from P_1 treatment, whereas the lowest breadth (14.2, 15.5, 17.7 and 18.6 cm, respectively) from P_0. The maximum days to 1st curd initiation (46.1) were found from P_0 treatment, while the minimum days (41.1) were observed from P_1. The maximum days to curd maturity (67.2) were recorded from P_0 treatment, while the minimum days (62.4) from P_1. The highest number of curds per plant (2.67) was observed from P_1 treatment, while the lowest number (1.00) from P_3. The highest weight of individual curd (500.6 g) was observed from P_3 treatment, while the lowest weight (253.2 g) from P_2 treatment. The highest diameter of curd (9.12 cm) was recorded from P_3 treatment, whereas the lowest diameter of curd (7.69 cm) from P_2. The highest curd yield per hectare (29.8 ton) was found from P_1 treatment, whereas the lowest (19.9 ton) from P_0. The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (33.2 days) was found from P_1 treatment, whereas the lowest (30.6 days) was observed from P_0. The highest ascorbic acid content of broccoli (85.0 mg/100 g) was found from P_1 treatment, while the lowest (80.5 mg/100 g) was recorded from P_0. The highest iron content of broccoli (0.92 mg/100 g) was found from P_1 treatment, whereas the lowest (0.70 mg/100 g) from P_0.

In case of different levels of GA_3, at 50, 60, 70 DAT and at harvest, the tallest plant (52.7, 68.5, 74.0 and 78.5 cm, respectively) was observed from G_1, while the shortest plant (45.4, 60.9, 66.7 and 69.1 cm, respectively) from G_0. At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (21.2, 28.2, 31.5 and 35.7, respectively) was recorded from G_1 treatment, whereas the lowest number (17.1, 23.3, 27.5 and 30.3, respectively) from G_0 treatment. At 50, 60, 70 DAT and at harvest, the highest length of largest leaf (43.9, 49.5, 52.8 and 55.1 cm, respectively) was recorded from G_1 treatment and the lowest length (37.6, 44.3, 47.1 and 48.9 cm, respectively) from G_0 treatment. At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (15.9, 18.3, 20.4 and 21.9 cm, respectively) was observed from G_1 treatment, while the lowest breadth (13.9, 15.5, 17.2 and 18.8 cm, respectively) from G_0 treatment. The maximum days to 1^{st} curd initiation (44.7) was observed from G_0 treatment, whereas the minimum days (41.4) from G_1 treatment. The maximum days to curd maturity (66.3) was found from G_0 treatment, whereas the minimum days (62.5) from G_1 treatment. The highest number of curds per plant (1.95) was recorded from G_1

treatment, whereas the lowest number (1.73) from G_0. The highest weight of individual curd (375.5 g) was found from G_1 treatment and the lowest weight (321.7 g) from G_0 treatment. The highest diameter of curd (8.61 cm) was observed from G_1 treatment, while the lowest diameter of curd (8.08 cm) from G_0. The highest curd yield per hectare (27.9 ton) was recorded from G_1 treatment, while the lowest curd yield per hectare (20.4 ton) from G_0 treatment. The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (33.9 days) was recorded from G_1 treatment, while the lowest (30.1 days) from G_0 treatment. The highest ascorbic acid content of broccoli (85.8 mg/100 g) was found from G_1 treatment, whereas the lowest (81.8 mg/100 g) from G_0. The highest iron content of broccoli (0.88 mg/100 g) was recorded from G_1 treatment, while the lowest (0.71 mg/100 g) was observed from G_0.

Due to the combined effect of different pinching methods and levels of GA_3, at 50, 60, 70 DAT and at harvest the tallest plant (55.9, 71.4, 75.9 and 81.6 cm, respectively) was observed from P_0G_1 and the shortest plant (38.2, 53.2, 58.1 and 62.2 cm, respectively) from P_2G_0. At 50, 60, 70 DAT and at harvest, the highest number of leaves per plant (22.8, 29.3, 34.1 and 38.2, respectively) was found from P_1G_1, while the lowest number (16.3, 20.9, 25.6 and 27.3, respectively) from P_0G_0 treatment combination. At 50, 60, 70 DAT and at harvest, the highest length of largest leaf (47.1, 51.9, 57.2 and 58.8 cm, respectively) was observed from P_1G_1, whereas the lowest length (35.9, 42.2, 45.9 and 47.1 cm, respectively) from P_0G_0 treatment combination. At 50, 60, 70 DAT and at harvest, the highest breadth of largest leaf (17.1, 20.1, 22.3 and 23.9 cm, respectively) was recorded from P_1G_1 and the lowest breadth (12.7, 13.8, 15.8 and 16.9 cm, respectively) from P_0G_0 treatment combination. The maximum days to 1st curd initiation (48.0) was observed from P_0G_0 and the minimum days (35.3) from P_1G_1 treatment combination. The maximum days to curd maturity (69.3) was recorded from P_0G_0 and the minimum days (57.0) from P_1G_1 treatment combination. The highest number of curds per plant (2.87) was observed from P_1G_1, while the lowest number (1.00) from P_3G_0, P_3G_1 and P_3G_2

treatment combination. The highest weight of individual curd (511.9 g) was observed from P_3G_1, whereas the lowest weight (203.4 g) from P_2G_0 treatment combination. The highest diameter of curd (9.25 cm) was recorded from P_3G_1 and the lowest diameter (7.31 cm) from P_2G_0 treatment combination. The highest curd yield per hectare (36.9 ton) was found from P_1G_1, whereas the lowest (15.7 ton) was observed from P_0G_0 treatment combination. The highest shelf life of broccoli curd storage in refrigerator and in perforated polythene bag (36.0 days) was observed from P_1G_1 and the lowest (29.2 days) from P_0G_0 treatment combination. The highest ascorbic acid content of broccoli (89.8 mg/100 g) was found from P_1G_1, while the lowest (77.3 mg/100 g) from P_0G_0 treatment combination. The highest iron content of broccoli (1.03 mg/100 g) was recorded from P_1G_1, whereas the lowest (0.61 mg/100 g) from P_0G_0 treatment combination.

The highest gross return (BDT 813,340/ha) was obtained from the treatment combination P_1G_1 and the lowest (BDT 360,180/ha) from P_0G_0. The highest net return (BDT 474,984/ha) was found from the treatment combination P_1G_1 and the lowest net return (BDT 29,392/ha) from P_0G_0. The highest benefit cost ratio (2.40) was noted from the combination of P_1G_1 and the lowest (1.09) was obtained from P_0G_0. From economic point of view, it is apparent from the above results that the combination of P_1G_1 was better than rest of the combination in broccoli cultivation.

Conclusion

Among the combination of different pinching methods and gibberellic acid pinching apical meristem at 15 DAT with 50 ppm GA_3 induced superior growth, yield and quality of broccoli.

References

REFERENCES

Abd El-Gawad, H.G., El-Gizawy, A.M., Solaiman, M.M. and Abou El-Yazied, A. (2007). Effects of sowing date and pinching on broccoli seed production. *Hort. Sci*., **13**: 45-51.

Aditya, N. and Fordham, S.E. (1995). Effects of cold exposure and GA_3 during early growth stages on the date of flowering of the tropical cauliflower. *Indian J. Plant Physiol*., **32**(1): 111-115.

Alam, M.S., Iqbal, T.M.T., Amin, M. and Gaffar, M.A. (1989). Krishitattic Fasaler Utpadan O Unnayan (in Bengali). T.M. Jubair Bin Iqbal, Sirajgonj. pp. 231-239.

Anonymous. (1989). Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

AOAC (Association of Official Analytical Chemist). (2005). Official methods of analysis of AOAC International. 18th edition, Dr. William Horwitz, Editor, Dr. George W. Latimer, jr., Assistant Editor. Published by AOAC International, Suite 500, 481 North Frederick Avenue, Gaithersburg, Maryland, 20877-2417, USA.

Bose, T. K., Kabir, J., Maity, T.K., Parthasarathy, V.A. and Som, M.G. (2002). Vegetable Crops in India. Naya Prokash. Calcatta.

Dharmender, K., Hujar, K.D. Paliwal, R. and Kumar, D. (1996). Yield and yield attributes of cabbage as influenced by GA_3 and NAA. *Crop Res. Hisar.*, **12**(1): 120-122.

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

FRG (Fertilizer Recommendation Guide. (2005). Bangladesh Agriculture Research Council (BARC), Farmgate, Dhaka. p. 237.

Ghimire, A.J., Bhattarai, M.R. and Khanal, R. (1993). Effect of removing terminal or axillary heads on the yield and quality of seeds of broccoli cultivar Green Sprouting. *Pakhribas Agril. Centre*, **77**: 1-6.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). *Intl. Rice Res. Inst., A Willey Int. Sci*., pp. 28-192.

Guo, D.P., Shah, G.A., Zeng, G.W. and Zheng, S. (2004). The interaction of plant growth regulators and vernalization on the growth and flowering of cauliflower (*Brassica oleracea* var. botrytis). *Plant Growth Regulation*. **43**(2): 163-171.

Irwin, D.L. and Aarssen, W. L. (2000). Testing for cost of apical dominance in vegetation, field studies of three species, *Botany Fennici*, **33**: 123-128.

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

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

Jahan, I. (2001). Effect of different sources of nutrients and time of pinching of apical bud on growth and yield of cabbage. MS Thesis, Dept. Hort, Bangladesh Agril. Univ., Mymensingh, pp. 35-78.

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

Miguel, L.C., Longnecker, N.E., Ma, Q., Osborne, L. and Atkins, C.A. (1998). Branch development in *Lupinus angustifolius* not all branches have the same potential growth rate. *J. Expt. Bot*., **49**(320): 547–553.

Mirdad, Z.M. (2014). Effect of K^+ and salicylic acid on broccoli (*Brassica oleraceae* var. Italica) plants grown under saline water irrigation. *J. Agril. Sci*., **6**(10): 57-66.

Mishra, H.P. and Singh, B.P. (1986). Studies on nutrients and growth regulators interaction in “Snowball-6” cauliflower (*Brassica oleracea* var. *botrytis*). *Prog. Hort*., **18**(1-2): 77-82.

Muthoo, A.K., Kmar, S. and Maurya, A.N. (1987). Studies on the effect of foliar application of GA_3 NAA and molybdenum on growth and yield of cauliflower (*Brassica oleracea* var. *botrytis*). *Haryana J. Hort. Sci*., **16**(1&2): 115-120.

Nidhi-Arora, N., Yadav, R., Yadav, R.C., Chowdhury, J.B. and Arora, N. (1997). Role of IAA and BAP on plant regeneration in cultured cotyledons of cauliflower. *Cruciferae Newsl*., **19**: 41-42.

Nonnecke, I. L. (1989). Vegetable production. Van Nostrand Reinhold, New York. pp. 394-399.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Dept. Agric. Circ., p. 929.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. pp. 403-430.

Palevitch, D. and Pressman. E. (1983). Apex removal and single harvest yield of side shoots of broccoli. *HortSci.,* **8**(5): 411-412.

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

Piper, G.S. (1966). Soil and Plant Analysis. Adelaide University Press, Australia.

Pizetta, L.C., Ferreira, M.E., Cruz, M.C.P.D. and Barbosa, J.C. (2005). Response of boron fertilization on broccoli, cauliflower and cabbage planted in sandy soil. *J. Plant Nutri*., **26**(12): 2587-2549.

Pressman, E., Shaked, R. and Aviram, H. (1985). Lateral shoot development in broccoli *(Brassica oleracea* var. Italia). The effect of pinching date. *Sci. Flort*., **26**(1): 1-7

Rabiul, S.M. (2002). Effect of planting time, mulching and pinching on growth and yield of cabbage. M. S. Thesis, Dept. of Hort., Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 66-69.

Rangkadilok, N., Nicolas, M.E., Bennett, R.N., Eagling, D.R., Premier, R.R., Taylor, W.J. (2004). The effect of sulfur fertilizer on glucoraphanin levels in broccoli (*B. oleracea* L. var. *italica*) at different growth stages. *J. Agric. Food Chem*., **52**: 2632-2639.

Reddy, S.A. (1989). Effect of foliar application of urea and gibberellic acid on cauliflower (*Brassica oleracea* var. *botrytis*). *J. Res. APAU.* **17**(1): 79-80.

Reza, M., Islam, M., Hoque, A., Sikder, R.K., Mehraj, H. and Uddin, A.F.M.J. (2015). Influence of Different GA_3 Concentrtions on Growth and Yield of Broccoli. *American-Eurasian J. Sci. Res*., **10**(5): 332-335.

Senthelhas, P.C., Caetano, J.R.G. and Teixeira. N.T. (1987). The effect of IAA and foliar Nitrogen on wheat, *Ecosistema*. **12**: 123-128.

Sharma, S.K. and Mishra, R.C. (1989). Effect of growth regulators on flower morphometrics with reference to insect pollinators. *Indian J. Agril. Sci.,* **59**(8): 546-547.

Shiraishi, S. (1972). Colour Development in Citrus Fruit Bull. *Fukuoka Hort. Res. Sta*. **2**: 1-72.

Singh, M., Rana, D.K., Rawat, J.M.S. and Rawat, S.S. (2011). Effect of GA_3 and kinetin on growth, yield and quality of sprouting broccoli (*Brassica oleracea* var. italica). *J. Hort. Forst*., **3**(9): 282-285.

Tadzhiryan, O.K. (1990). Effect of Ga_3 on bio-chemical characteristics of the grain in wheat in the M_1 and M_2, *Biologicheskii Zhurnal Aremehii*. **43**(1): 77-79.

Talalay, P. and Fahey, J.W. (2001). Phytochemicals from Cruciferous plants protect against cancer by modulating carcinogen metabolism. *Am. Soc. Nutr. Sci*., **23**: 3027-3033.

Thara, N.L., Shelp, B.J.V.I., Shatuck, D. and Kokazov, N.I. (2013). Effect of nitrogen. phosphorus and potassium on growth and yield of broccoli (*Brassica oleracea* L.) cv. KSTS-1. *Veg. Sci*., **29**(2): 154-156.

Thompson, H.C. and Kelly, W.C. (1988). Cole Crops. In: Vegetable Crops McGraw Hill Book Co. New York. p. 15, 280-281, 370.

Tindall, H.D. (1983). Vegetables in the Tropics. Macmillan Education Ltd. Basingstoke Hampshire , London. P. 176.

Tomar, V.P.S., Sing, G.D. and Keshwa, G.L. (1991). Effect of plant growth chemicals on morpho-physiological characters of late sown wheat. *Indian J. Agron*., **36**(1): 7-11.

Umar, S., Anjana, A.N.A. and Khan, N.A. (2013). Nitrate management approaches in leafy vegetables. Nitrate in leafy vegetables: toxicity and safety measures. IK International Publishing House Pvt. Ltd, New Delhi, pp. 166-181.

Venecez, J.I. and Aarssen, W.L. (1998). Effects of shoot apex removal in *lythrum salicaria* (Lythraceae): assessing the costs of reproduction and apical dominance. *Annals of Botany Fennici*, **35**: 101-111.

Verma, S., Sengupta, S., Agarwal1, B.K., Jha, K.K., Mishra, S., Rajak, R. and Rani, V. (2018). Enhanced shelf life of Broccoli (*Brassica oleracea* var. *Italica*) at ambient condition due to foliar application of boron, urea and GA_3. *Int. J. Curr. Microbiol. App. Sci.,* **Special Issue-7**: 926-929.

Vijay, K. and Ray, N. (2000). Effect of plant growth regulators on cauliflower cv. Pant subhra. *Orissa J. Hort.*, **28**(1): 65-67.

Vishwakarma, S., Bala, S., Kumar, P., Prakash, N., Kumar, V., Singh, S.S and Singh, S.K. (2017). Effect of nitrogen, naphthalene acetic acid and Gibberellic acid on growth, yield and quality of broccoli (*Brassica oleracea* var. italica L.) Cv. 'Sante'. *J. Pharmaco. & Phytochem*., SP1: 188-194.

Yesmin. A. (2007). Effects of fertilizer management and pinching on growth and yield of cabbage. MS Thesis, Dept. Hort., Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 66-68.

Yoldas, F., Ceylan, S., Yagmur B., Mordogan, N. (2008). Effect of nitrogen fertilizer on yield quality and nutrient content in broccoli. *J. Plant Nutr*., **31**: 1333-1343.

Appendices

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from October, 2016 to February 2017

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
October, 2016	26.5	19.4	81	22
November, 2016	25.8	16.0	78	00
December, 2016	22.4	13.5	74	00
January, 2017	24.5	12.4	68	00
February, 2017	27.1	16.7	67	30

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

Appendix II. Characteristics of the soil of experimental field

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Expeimental 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
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka-1212

Appendix III. Analysis of variance of the data on plant height at different days after transplanting (DAT) and at harvest of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		50 DAT	60 DAT	70 DAT	Harvest
Replication	2	0.063	0.542	1.759	10.180
Pinching methods (A)	3	116.953**	93.045**	82.196**	74.764**
Levels of GA_3 (B)	2	176.238**	194.920**	168.272**	273.009**
Interaction (A×B)	6	18.938*	16.644*	35.691*	30.470*
Error	22	6.953	6.610	11.427	10.182

**: 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 at different days after transplanting (DAT) and at harvest of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square			
		Number of leaves per plant at			
		50 DAT	60 DAT	70 DAT	Harvest
Replication	2	0.423	0.463	0.134	0.048
Pinching methods (A)	3	11.186**	19.583**	36.852**	49.029**
Levels of GA_3 (B)	2	58.723**	73.803**	56.831**	97.681**
Interaction (A×B)	6	14.104*	4.532*	5.083*	6.136**
Error	22	1.107	0.925	0.835	1.419

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

Appendix V. Analysis of variance of the data on length of largest leaf at different days after transplanting (DAT) and at harvest of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square			
		Length of largest leaf (cm) at			
		50 DAT	60 DAT	70 DAT	Harvest
Replication	2	0.856	0.371	0.637	1.720
Pinching methods (A)	3	29.464**	24.649**	43.478**	29.074**
Levels of GA_3 (B)	2	130.485**	85.386**	100.840**	118.352**
Interaction (A×B)	6	11.424**	10.943**	5.586*	5.216*
Error	22	2.431	1.715	1.905	1.767

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

Appendix VI. Analysis of variance of the data on breadth of largest leaf at different days after transplanting (DAT) and at harvest of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square			
		Breadth of largest leaf (cm) at			
		50 DAT	60 DAT	70 DAT	Harvest
Replication	2	0.007	0.055	0.034	0.178
Pinching methods (A)	3	5.831**	13.559**	11.256**	23.250**
Levels of GA_3 (B)	2	14.074**	24.340**	31.579**	30.269**
Interaction (A×B)	6	3.655*	1.914*	1.354**	1.720**
Error	22	0.258	0.587	0.300	0.435

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

Appendix VII. Analysis of variance of the data on different yield contributing characters of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square				
		Days to 1st curd initiation	Days to curd harvest	Length of stem (cm)	Diameter of stem (mm)	Length of largest root (cm)
Replication	2	0.694	0.444	1.020	0.497	0.075
Pinching methods (A)	3	42.843**	37.657*	8.943**	64.490**	2.594*
Levels of GA_3 (B)	2	32.028*	42.528*	72.967**	96.969**	33.103**
Interaction (A×B)	6	39.287**	35.157**	5.140*	12.436*	1.901*
Error	22	7.210	9.141	1.708	3.962	0.678

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

Appendix VIII. Analysis of variance of the data on yield contributing characters and yield of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square						
		Number of curds per plant	Weight of individual curd (g)	Diameter of curd (cm)	Dry matter content in curd (%)	Curd yield per plant (g)	Curd yield per plot (kg)	Curd yield per hectare (ton)
Replication	2	0.008	156.391	0.036	0.030	2425.646	0.349	4.211
Pinching methods (A)	3	6.019**	119151.99**	3.624**	7.839**	105979.42**	15.261**	183.992**
Levels of GA_3 (B)	2	0.148**	8692.483**	0.829**	1.298*	100132.54**	14.419**	173.841**
Interaction (A×B)	6	0.050*	1213.899**	0.153*	1.958*	20729.91**	2.985**	35.989**
Error	22	0.017	299.557	0.072	0.273	2922.57	0.421	5.074

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

Appendix IX. Analysis of variance of the data on shelf life of broccoli in room and refrigerator temperature in preservation materials as influenced by different pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square					
		Shelf life under room temperature and the condition of			Shelf life under refrigerator and the condition of		
		Open	Polythene bag	Perforated polythene bags	Open	Polythene bag	Perforated polythene bags
Replication	2	0.003	0.027	0.009	0.059	0.337	0.897
Pinching methods (A)	3	0.320**	0.226**	0.421**	7.972**	7.843**	12.569**
Levels of GA_3 (B)	2	0.153*	0.335**	0.750**	15.575**	37.287**	45.462**
Interaction (A×B)	6	0.328*	0.371*	0.132*	1.589**	4.812**	3.784*
Error	22	0.034	0.041	0.053	0.313	1.319	1.183

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

Appendix X. Analysis of variance of the data on different nutrient content of broccoli as influenced by pinching methods and levels of gibberellic acid

Source of variation	Degrees of freedom	Mean square					
		Ascorbic acid (mg/100 g)	ß-carotene (µg/100 g)	Calcium (mg/100 g)	Potassium (ppm)	Phosphorus (ppm)	Iron (mg/100 g)
Replication	2	4.289	34.934	0.858	23.620	1.089	0.000
Pinching methods (A)	3	40.019*	184.911^{NS}	11.745*	37.486^{NS}	16.660*	0.077**
Levels of GA_3 (B)	2	77.513**	1441.867**	290.175**	5730.820**	380.893**	0.084**
Interaction (A×B)	6	68.542**	298.514*	10.816*	246.367**	24.684**	0.005*
Error	22	10.328	115.393	3.383	38.378	6.265	0.002

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance; NS: Non-significant

Appendix XI. Per hectare production cost (BDT) of broccoli

A. Input cost

Treatments	Labour cost	Ploughing cost	Seedling Cost	Water for plant Establishment	Pinching cost	Manure and fertilizers				GA_3 cost	Insecticide/ Pesticides	Sub total (A)
						Cowdung	Urea	TSP	MP			
P_0G_0	65,000	42,000	20,000	35,000	0	25,000	1,200	1,875	2,700	0.00	13,000	205,775
P_0G_1	65,000	42,000	20,000	35,000	0	25,000	1,200	1,875	2,700	1800.00	13,000	207,575
P_0G_2	65,000	42,000	20,000	35,000	0	25,000	1,200	1,875	2,700	2200.00	13,000	207,975
P_1G_0	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	0.00	13,000	210,775
P_1G_1	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	1800.00	13,000	212,575
P_1G_2	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	2200.00	13,000	212,975
P_2G_0	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	0.00	13,000	210,775
P_2G_1	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	1800.00	13,000	212,575
P_2G_2	65,000	42,000	20,000	35,000	5,000	25,000	1,200	1,875	2,700	2200.00	13,000	212,975
P_3G_0	65,000	42,000	20,000	35,000	7,000	25,000	1,200	1,875	2,700	0.00	13,000	212,775
P_3G_1	65,000	42,000	20,000	35,000	7,000	25,000	1,200	1,875	2,700	1800.00	13,000	214,575
P_3G_2	65,000	42,000	20,000	35,000	7,000	25,000	1,200	1,875	2,700	2200.00	13,000	214,975

P_0: No pinching (control)
P_1: Pinching apical meristem at 15 DAT
P_2: Pinching apical meristem at 30 DAT
P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)
G_1: 50 ppm GA_3
G_2: 100 ppm GA_3

Appendix XII. Per hectare production cost of broccoli (Cont’d)

B. Overhead cost (BDT/ha)

Treatments	Cost of lease of land (12% of value of land BDT 16,00000/year	Miscellaneous cost (BDT 5% of the input cost	Interest on running capital for 6 months (BDT 12% of cost/year)	Sub total (BDT) (B)	Total cost of production (BDT/ha) [Input cost (A)+ overhead cost (B)]
P_0G_0	96,000	10,289	18,724	125,013	330,788
P_0G_1	96,000	10,379	18,837	125,216	332,791
P_0G_2	96,000	10,399	18,862	125,261	333,236
P_1G_0	96,000	10,539	19,039	125,578	336,353
P_1G_1	96,000	10,629	19,152	125,781	338,356
P_1G_2	96,000	10,649	19,177	125,826	338,801
P_2G_0	96,000	10,539	19,039	125,578	336,353
P_2G_1	96,000	10,629	19,152	125,781	338,356
P_2G_2	96,000	10,649	19,177	125,826	338,801
P_3G_0	96,000	10,639	19,165	125,804	338,579
P_3G_1	96,000	10,729	19,278	126,007	340,582
P_3G_2	96,000	10,749	19,303	126,052	341,027

P_0: No pinching (control)

P_1: Pinching apical meristem at 15 DAT

P_2: Pinching apical meristem at 30 DAT

P_2: Pinching axillary buds at 45 DAT

G_0: 0 ppm GA_3 (control)

G_1: 50 ppm GA_3

G_2: 100 ppm GA_3