EFFECT OF DIFFERENT PLANTING TIMES AND APPLICATION OF GA_3 ON MOROHO-PHYSIOLOGICAL CHARCTERS AND YIELD OF BROCCOLI (*Brassica oleracea var. Italica*).

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*This is to certify that the thesis entitled **"EFFECT OF DIFFERENT PLANTING TIMES AND APPLICATION OF GA_3 ON MOROHO-PHYSIOLOGICAL CHARCTERS AND YIELD OF BROCCOLI (Brassica oleracea var. Italica)."** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL BOTANY,** embodies the result of a piece of bona fide research work carried out by **SAIFUL ISLAM,** Registration No. **11-04672** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2017
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Alhamdulillah

All admiration to Almighty Allah

''Allah will raise those who have believed among you and those who were given knowledge, by degrees''

Dedicated To

My Beloved Parents &
Respected Research Supervisor

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ABSTRACT

An experiment was conducted to study the morpho-physiological characters and yield of broccoli with different planting times and concentrations of GA_3 at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of October 2016 to May 2017. The experiment was consisted of two factors one is different planting times as- T_1: 1 November, T_2: 15 November and T_3: 30 November; another is levels of gibberellic acid-GA_3 as G_0: 0 ppm GA_3, G_1: 25 ppm GA_3, G_2: 50 ppm GA_3 and G_3: 75 ppm GA_3. This two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different planting times and GA_3 influenced significantly on most of the parameters. The maximum plant height (57.94 cm), number leaves plant^{-1} (17.80), longest leaf length (24.22 cm), diameter of stem (12.19 cm), curd diameter (41.13 cm), weight of curd (517.6 g) and yield (21.81ton ha^{-1}) was found in T_2 (15 November) and 57.25 cm, 17.72, 21.96 cm, 11.89 cm, 39.92 cm, 490.3 g and 21.69 ton ha^{-1} in G_2 (50 ppm) respectively. Whereas, lowest value of these parameters were found in T_3 (30 November) and G_3 (75 ppm). In case of combined effect the highest value was recorded from T_2G_2 and lowest recorded in T_3G_3. In view of overall performances, this study suggests that the transplanting time T_2 (15 November) and the foliar application of GA_3 (Gibberellic acid) at G_2 (50 ppm) independently as well as combinedly gave best performance. From the study it was also discovered that application of more than 50 ppm GA_3 reduced the yield characters and yield of broccoli.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
μg	=	Microgram

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea var. Italica*) is an important cole crop belongs to Brassicaceae family. Broccoli, originated from West Europe has now been dispersed in both the sub-tropical and tropical areas like Bangladesh. Yearly production of broccoli has been expanded 100 thousand tons in broccoli producing countries and Bangladesh has been hold 11th rank position of them (FAOSTAT, 2013). Broccoli is an important vegetable trim and has high nutritional and good commercial value (Yoldas *et al*., 2008). Now a days, broccoli attracted more attention due to its multifarious use and great nutritional value (Talalay and Fahey, 2001). It is low in sodium food, fat substance free and calories, high in vitamin C and good source of vitamin A, vitamin B2 and calcium. Sprouting broccoli has about 130 times more vitamin A contents than cauliflower and 22 times more than cabbage (Singh, 2007). Broccoli is planted in the winter season in Bangladesh. Flower heads develop relative to ambient temperatures (15-20^{o}C), and in the heat of summer, broccoli heads matured and produced flowers (Lorenz and Maynard, 1988). The temperature in Bangladesh remains fairly high up to mid -October and gradually goes down in mid-December. This cool period extends up to mid-February and then the temperature increase sharply thereafter. It is therefore important to study the effect of planting time for achieving optimum morpho - physiological growth and yield of broccoli (Das *et al.*, 2000). In recent years a great deal of research work has been reported on the uses of plant growth regulators in vegetable crops. Plant growth regulators modify the physiological processes within the plant, which ultimately affect the growth, yield and quality of the crop. Growth regulators are organic compounds other than nutrients; small amount of which are capable of modifying growth. Among plant growth regulators, GA_3 exhibited beneficial effect in several Cole crops by stimulating cell division or cell enlargement or both (Badawi and Sahhar, 1978). Broccoli seedlings are transplanted from seedbed to the main field. The time between uprooting and establishment of young and tender seedlings in the field is very critical. Vegetables, like, cabbage, cauliflower and tomato respond well to plant growth regulators in minimizing the transplanting shock and being encouraged to a quick growth. GA_3 have close relation with growth and yield of broccoli and determination of exact concentrations of GA_3 is important for growth and yield of broccoli. Due to the diversified use of productive land, it is necessary to increase the food production, and gibberellic acid (GA_3) may be a contributor in achieving the desired goal. The production of Broccoli can be increased by using GA_3. Broccoli was found to show a quick growth when treated with plant growth regulators (Islam *et al.*, 1993). Application of GA_3 stimulates morpho-physiological characters and yield of broccoli. Application of GA_3 with different planting dates play important role in modifying the growth and yield of broccoli. Gibberellic acid (GA_3) can also play an important role for better yield of broccoli. The application of GA_3 had significantly increased the number of fruits per plant than the untreated controls. GA_3 sprayed on flower cluster resulted to increase in fruit weight. Application of GA_3 at accurate concentration and right time have play to avoid flower and fruit dropping and the highest yield. Gibberellic acid has great effects on plant physiological systems including fruit setting, leaf expansion, germination, breaking dormancy, increasing fruit size, improving fruit quality and in many other aspects of plant growth and thereby increased crop production. Different planting times and concentrations of GA_3 influence plant growth and yield of broccoli but the effects of these factors on the morpho - physiological growth, yield and quality of broccoli have not been studied in details under Bangladesh conditions. Therefore, to get the quality yield such studies under Bangladesh conditions are needed. The present experiment will be undertaken to find out the optimum level of GA_3 and best time of application for obtaining maximum yield and quality of broccoli. With the view in mind, the research work was undertaken with the following objectives:

- To determine the optimum planting time in response to morpho-physiological characters and yield of broccoli.
- To find out appropriate concentration of GA_3 for increasing broccoli production.
- To determine the combine effect of optimum planting time and accurate concentration of GA_3 for better morpho-physiological growth and maximum yield.

CHAPTER II

REVIEW OF LITERATURE

Broccoli (*Brassica oleracea var. Italica*) is one of the most important vegetable crops in Bangladesh and received much attention to the researcher throughout the world. Plant growth regulators like gibberellic acid (GA_3) is one of most important elements for maximizing the yield of broccoli. Experimental evidences showed that there has a great influence of GA_3 on this crop. The fertilizer requirements, however, varies with the soil and cultural conditions. Application of this GA_3 has different modifying influences on growth, yield and quality; and yield contributing characters of broccoli as well as other crops. Research works have been done in various parts of the world more or less adequate but is not conclusive in Bangladesh. Some of the important and informative works conducted home and abroad in this aspect, have been reviewed in this chapter.

An experiment was conducted by Gautam *et al*. (2001) in Jorhat, Assam, India to determine the effect of different sowing dates, seed production methods and cultivars (Pusa Katki, Pusa Deepali, Selected Early Dawn, Early Chinese Prince and Heavy Silver Plate) on the growth and seed yield of early cauliflower. Curd yield significantly increased the seed yield in Pusa Deepli and Heavy Silver Plate. All cultivars differed significantly from each other in terms of seed yield. Selected Early Dawn recorded the highest yield (4.6 q/ha).

A field experiment was conducted by Bhangre *et al*. (2011) to study the effect of different varieties (Ganesh Broccoli and Pusa KTS-1) with five spacing in under Pune conditions. The data revealed that cv. Ganesh Broccoli performed superior over the cv. PUSA KTS-1 with days to 50% harvest (53.4 days), days to last harvest (68.4 days), curd diameter (10.81 cm), average weight of curd (154.80 g) and yield per hectare (70.75 q) while, cv. PUSA KTS-1 recorded significantly highest values for growth parameters.

A field experiment was conducted by Jana and Mukhopadhyay (2003) in Cooch Behar, West Bengal, India to determine the effect of sowing date and cultivar (Early Kunwari, First Crop, Kartika, Aghani and Improved Japanese) on the growth and curd yield of cauliflower. Improved Japanese gave the maximum plant height, leaf length, curd initiation and curd maturity. First Crop gave the highest leaf width while Aghani gave the highest net curd weight and curd yield.

An experiment was conducted by Ahammad and his colleagues (2009) at Jessore to observe the effect of planting date and variety on the yield of late planting broccoli. The potentiality of fruiting in the late season were evaluated for broccoli variety no. 4, 5, 6 and 12 by planting December 01, December 16, January 01, January 16 and February 01. A combination of December 01 planting with broccoli 5 variety performed better in respect of yield (57.07 t/ha). The variety broccoli 5 also showed potential fruiting capability during late winter season and February 01 planting produced 11 ton/ha of potential yield. All the four varieties showed potential fruiting capability during late winter season and February 01 planting produced 4-6 tons of potential yield during late season.

Alam (2007) observe that application of Miyobi had tremendous effect on growth and development of lentil. The rate of increase of dry matter/unit time/unit land area is the CGR. Maola (2005) reported that seed yield was strongly correlated with crop growth rate.

Adlakha and Verma (1964) observed that when sprayed three times at unspecified intervals with GA_3 at 50 and 100 ppm, the fruit setting increased by 5 % with higher concentration.

An experiment was carried out by Ngullie and Biswas (2014) at Krishi Vigyan Kendra, Mokokchung, Nagaland during Rabi season with the goal of standardizing the production technology of broccoli. Five varieties viz Inspiration, Aiswarya, Packman, Puspa and KTS 1 were tested in the study. The performances of different hybrids of this crop proved that there was ample scope to grow broccoli due to the prevailing suitable agro-climatic conditions of the region. Among all the varieties Packman was found most superior which gave highest yield (115.29 q/ha) in combination with best head formation.

Briant (1974) sprayed GA_3 on the growth of leaves of young broccoli plant and viewed that total leaf weight and area were increased by GA_3.

Bora and Selman (1969) working with broccoli indicated that four foliar sprays of GA_3 (0, 5, 50 or 500 ppm) applied at 7, 17, 27 and 37 DAT increased the leaf area, weight and height of tomato plants.

Choudhury and Faruque (1972) observed that the percentage of seedless fruit increased with the increase in GA_3 concentration from 50 ppm to 100 ppm. However the fruit weight was found to decrease by GA_3.

Chern *et al.* (1983) submitted that one month old transplanted broccoli were sprayed with 1, 10 or 100 ppm GA_3 and observed that GA_3 at 100 ppm increased leaf area, plant height and stem fresh and dry weight but 10 ppm inhibited growth.

Dharmender *et al*. (1996) experienced that GA_3 alone or in combination with NAA (both at 25, 50 or 75 ppm) on the growth of cabbage (cv. Pride of India) in the field of Horticulture Farm S. K. A. College of Agriculture. Jobnner, Rajstan, India during rabi (winter) 1993-94. The best growth parameter like as plant height, plant spread, number of leaves, leaf area and days of maturity was observed following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm. GA_3 at 75 ppm reduced the mean number of days required to start head formation. The highest chlorophyll content in outer leaves was observed following treatment with NAA at 50 ppm.

Prasad *et al*. (2010) carried out a field experiment to study the response of varieties, spacing and aphid management on growth and yield of sprouting broccoli (*Brassica oleracea*) under West Bengal state. It expressed that variety Early You was found to be much suitable variety amongst the varieties which produced highest curd yield of 87.04 q/ha.

Patil, (1987) reported that gibberellic acid (GA_3) is a naturally occurring plant hormone that affects cell enlargement and division which leads to internodes elongation in stems. They have a dwarf reversing response e.g. it allows certain dwarf cultivars to grow to normal height when treated with GA_3. It also influence many developmental processes, particularly those controlled by temperature and light such as seed and plant dormancy, germination, seed stalk and fruit development are controlled by GA_3.

Gulnaz *et al.* (1999) informed that seeds of wheat treated with 10 ppm of GA_3 resulted in 36-43 % increase in dry weight at $13.11 dSm^{-1}$. The growth regulators (GA_3 at 10^{-5} M) increased total dry matter. Application of 10^{-5} M GA_3 on mustard at 40 or 60 days after sowing significantly increased total dry matter. Total dry matter of a crop is the output of net photosynthesis presoaking of seed of gram in varying concentrations of GA_3 showed the best results on dry weights. Application of GA_3 at 50 and 100 ppm in French bean increased leaf number over control.

Gabal *et al.*, (1999) reported that increased leaf number could intercept most of the incident radiation and result in higher dry matter production in faba bean.

Gustafson (1960) spraying of GA_3 on flower buds of the first 3 stages (35 and 70 ppm) and established that GA_3 increased fruit set but reduced fruit weight.

Giri *et al*. (2013) carried out a field experiment with the goal to determine the optimum rate of nitrogen (N) fertilizer for effective growth and yield of two varieties of broccoli in southern plain of Nepal. The experiment was laid out with including two varieties of broccoli (Calabrese and Green Sprouting) and five N rates. The effects of variety on total curd yield were significant. Green Sprouting produced 11% higher total curd than Calabrese.

Hathout *et al.* (1993) discovered that application of 10 ppm IAA as foliar sprays or to the growing media of broccoli plants had a stimulatory effect on plant growth, development and card which was accompanied by increases in endogenous auxin, gibberellins and cytokinin contents. However, IAA at 80 ppm had an inhibitory effect on plant growth and improvement, which was accompanied by increase in the level and activity of indigenous inhibitors and by low levels of auxins, cytokines and gibberellins.

Hossain (1974) searched the effect of GA_3 along with 4-CPA on the production of broccoli. He got that GA_3 applied with 50, 100 and 200 ppm produced an increased fruit set. However, GA_3 treatment reduced small size card production. A gradual increase in the yield/plant was obtained with higher concentration of GA_3.

Hatwar *et al.* (1999) carried out a field research with broccoli over two growing seasons (1993-94). The effects of GA_3 and 4-CPA on fruit yield and quality were investigated. Many of the treatments significantly increased fruit set percentage and total fruit yield.

Islam *et al.* (1993) found 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 3 different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days of transplanting. They determined 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 favourable both for higher yield and ascorbic acid content of cabbage.

Jansen (1970) reported that broccoli treated with GA_3 neither increased the yield nor accelerated fruit maturing. He also mentioned that increasing concentration of GA_3 reduced both the number and size of card.

Kaushik *et al.* (1974) in a research applied GA_3 at 1, 10 or 100 mg L^{-1} on two leaf stage and then at weekly interval until 5 leaf stage. They got that GA_3 increased the number and weight of fruits per plant at the highest concentration.

Lilov and Donchev (1984) observed that by the application of GA_3 at 20, 40 or 100 mg L^{-1} the yields were reduced compared with the non-treated control.

Leonard *et al.* (1983 observed that inflorescence development in broccoli grown under low light regimes was promoted by GA_3 application directly on the inflorescence.

Hossain et.al (2013) investigated the effect of different sowing dates on yield of broccoli genotype conducted at Agricultural Research Station, Thakurgaon ,Bangladesh during October 2009 to March 2010 .Three sowing dates viz. October 1, October 15 and October 30 were considered as factor A and broccoli variety viz., BARI broccoli-2, BARI broccoli-3, BARI broccoli- 4, BARI broccoli-9 and BARI Hybrid broccoli-4 considered as factor B. Early flowering (52.40 days) as well as early fruit harvesting (119.13 days) was occurred in October 1 sowing, whereas sowing on October 30 resulted in delayed flowering (71.73 days) and fruit harvesting (140.67 days), respectively. Number of fruits per plant was also the highest (27.40) in October 1 sowing and the lowest (13.73) was in October 30 sowing. Seed sowing of October 1 was found better in respect of yield (74.75 tha-1) compared to October 15 (58.55 tha-1) and October 30 (24.60 tha-1) sowing. Among the variety, BARI broccoli-2 produced the highest (68.12 tha-1) marketable yield followed by BARI broccoli-9 (56.51).

Muthoo *et al.* (1991) viewed that the foliar application of different concentration of GA_3, NAA and molybdenum improved the average fresh and dry weight of leaves. Curd and yield of cauliflower among the individual treatments, Gibberellic Acid proved to be the best for the vegetative growth of curd and yield of cauliflower (q/ha) followed by naphthalene acetic acid. The effect of treatment combination $G_2N_2M_2$ (100 ppm GA_3, 120 ppm NAA and 0.2% molybdenum) gave best result for all parameters of growth and yield.

Mishra and Singh (1986) worked on an experiment with all possible combinations of the levels of nitrogen, boron 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 exp[ressed that there was significant increase in growth characters namely plant height, diameter of stem, number of leaves per plant, weight of plant, curd yield and nitrogen content in stem and leaves due to N, B and GA_3 applications. However, length of stem was increased only by GA_3 spray.

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

Reddy *et al.* (1989) said 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. increase yield over the control (164%) were obtained with two application of GA_3.

Rapport, L. (1960) verified that GA_3 had no significant effect on fruit weight and size either at cool (11^0C) or warm (23°C) night temperatures; but it strikingly waned fruit size at an optimum temperature (17^0C).

Shittu and Adeleke (1999) researched the effects of foliar application of GA_3 (0, 10, 250 or 500 ppm) on growth and development of broccoli cv, 158-3 grown on pots. Plant height and number of leaves were significantly increased by GA_3 treatment. Plants treated With GA_3 with 250 ppm were the tallest plant with the highest number of leaves.

Sanyal *et al.*(1995) observed that the effects of plant growth regulators (IAA or NAA at 15, 25 or 50 ppm or GA_3 at 50, 75 or 100 ppm) and methods of plant growth regulator application on the quality of broccoli. Plant growth regulators had profound effects on fruit length, weight and sugar: acid ratio. The effects of foliar application of plant growth regulators were more profound than presoaking alone.

Saleh and Abdul (1980) performed an observed with GA_3 *(*25 or 50 ppm) applied 3 times in June or early July. They observed that GA_3 stimulated plant growth of broccoli. The substance decreased the total number of flowers per plant but increased the total yield compared with the control. GA_3 also improved fruit quality.

Studies on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) were studied by Lendve *et al*. (2010) observed that application of GA_3 @ 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the leaves, shape index of head, length of root, fresh and dry weight of root. Except treatment GA_3 @ 75 ppm, gave better results for days required for head initiation and head maturity.

Mehra and Batra (2005) evaluated six cauliflower cultivars (KJ-31, KT-9, KT-25, KPS-1, PSBK-1 and Pusa Snowball-1) in Hisar, Haryana, India. Among the cultivars, KT-25 gave highest yield (247.40 q/ha) followed by PSBK-1 (216.25 q/ha), KPS-1 (205.35 q/ha) and KJ-31 (193.10 q/ha), while the lowest yield was recorded in Pusa Snowball-1 (181.15 q/ha).

Sawhney and Greyson (1972) indicated that application of GA_3 induced multilocular, multicarpellary ovaries which were larger at anthesis than control upon pollination produced fruits which were significantly larger with higher fresh weight.

Singh *et al*. (2011) showed that 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 mixer significantly influenced the growth performance, yield and quality characters of broccoli. GA_3 30 mg l^{-1} + kinetin 30 mg l^{-1} treatment gave maximum growth and yield of broccoli.

Sharma and Mishra (1989) said that plant height, curd formation and curd size of cauliflower can increase with foliar application of plant growth regulator.

Several experiments were conducted to increase the yield of cauliflower. GA_3 and IAA have a positive effect on curd formation and size of cauliflower.

The research was conducted by Firoz *et al*. (2008) at the Hill Agricultural Research Station (HARS), Khagrachari. The treatment formed of three broccoli varieties, viz., Green Commet, Green King and Green Harmony with three levels of boron. Concerning varietal effect, curd weight as well as yield per plant significantly varied with different varieties, however, Green Harmony performed the highest result (606.2 g/plant) and the other two varieties given statistically similar result. Curd yield also showed similar result.

The effects of planting dates and varieties on broccoli (*Brassica oleracea* L. var. *italica Plenck*) growth and yield were researched by Nooprom *et al*. (2013) at Prince of Songkla University, Hat Yai, Songkhla province, southern Thailand. The trial was done to select the suitable planting dates and broccoli varieties for commercial production during the dry season. From January to June, the Top Green, Green Queen and Yok Kheo had seedling survival rates of 76.53-100.00% except the Special. The Yok Kheo had the highest total yield of 12.31 and10.65 t ha^{-1} when the planting in January and March, respectively. The Yok Kheo is an interesting new hybrid variety which producing the yield higher than the Top Green which is popular variety grown in southern Thailand. The yield of the Green Queen was not significantly different from the Top Green. It can be harvested at 11.67 and 9.38 days earlier than the Top Green and Yok Kheo, respectively.

The effects of transplanting date on the performance of cauliflower cultivars Pusa Early Synthetic, Pusa Deepali, Bharat Mukut, White Queen, Hemantika

Kartika and Bharat Jyoti were practised by Thapa and Pati (2003) in West Bengal, India. Among the cultivars, Pusa Deepali recorded the greatest plant height (47.64 cm), number of leaves per plant (17.29), leaf area (414.67 cm2), curd size (175.56 cm2), curd weight (409.46 g) and curd yield (242.64 quintal/ha), and the lowest number of days to curd initiation (93.43) and maturity (107.83).

The effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was studied by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of Agriculture, Parbhani. The maximum 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 showed less effective.

Trautwein (2002) laid out a field experiment with 1 purple and 10 green flowering cauliflowers and reported the highest percentage of marketable plants was found in the varieties Panther and Celio (91 and 88%), while with the variety Shannon only 60% was marketable. The maximum average cauliflower weight was found in the purple varieties Graffiti and Trevi (1062 and 1056 g), and the lowest in Alverda (779 g). The shape and the density of the flower and the appearance of unwanted leaflets in the flower were found in a 3-7 assessment scheme. The overall rating was best for Celio and Trevi. Graffiti, Amfora and Navona had a better `rating. Alverda, Esmeraldo and Kosmos were intermediate, and Universal and Shannon were poor.

The growth and flowering response of a cold-requiring cauliflower (*Brassica oleracea* var. botrytis) to a range of temperatures under 10 hour photoperiod and to growth regulator application were searched by Guo *et al*. (2004). Endogenous Gibberellin (GA_3) concentrations were also assessed and found that 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 and anthesis. Vernalization at 10^0C increased endogenous GA_3 content in both leaves and the inflorescence stalk irrespective of GA_3 treatment.

Tomar and Ramgiry (1997) indicated that broccoli plant treated with GA_3 showed significantly greater number of branches $plant^{-1}$ than untreated controls.

Vijay and Ray (2000) worked 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.

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

CHAPTER III

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. It contains a short description of location of the experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc.

3.1 Location of the experimental plot

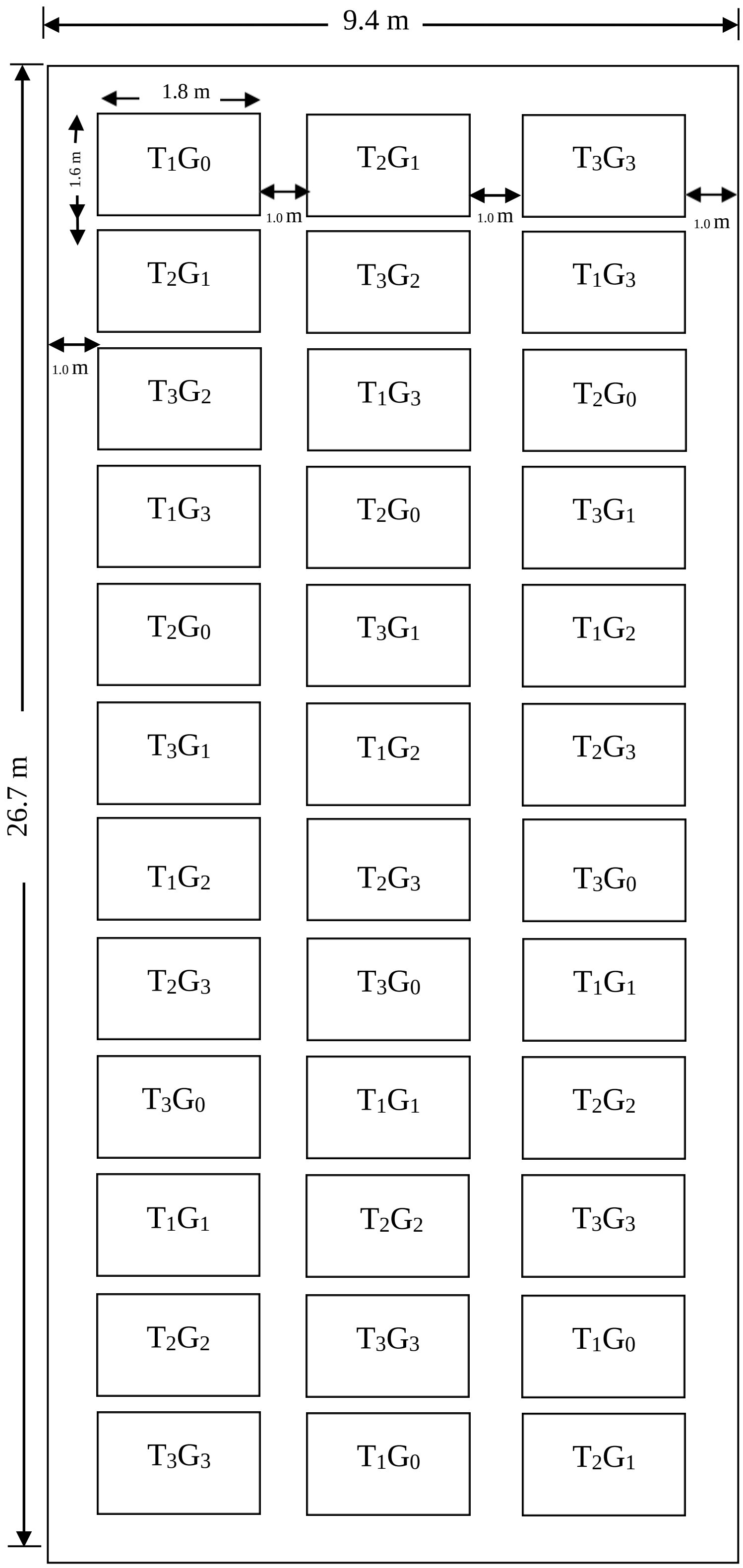
The research was conducted at the Agricultaral Botany Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, and Dhaka 1207. The location of the site was $23^0 74^/$ N latitude and $90^0 35^/$ E longitude with an elevation of 8.2 meter from sea level (Appendix I).

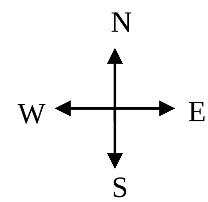
3.2 Experimental period

The experiment was carried out during the Rabi season from October 2016 to May 2017. Seedlings were transplanted on 01 November, 2016, 15 November 2016 and 30 November 2016, transplanted to main field at 25 days seedling and were harvested up to 30 May, 2017.

3.3 Characteristics of soil

The soil of the experiment was Non- calcareous, dark gray, medium high land. The soil texture was silty loam with a pH 6.7. Soil samples of the experimental plot were collected from a depth of 0 to 30 cm before conducting the experiment. The experimental site was a medium high land (Appendix III**).**





Plot size: 1.8 m × 1.6 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Transplanting time

T_1: 01 November

T_2: 15 November

T_3: 30 November

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

G_0: 0 ppm GA_3 (control)

G_1: 25 ppm GA_3 (50 mg/l)

G_2: 50 ppm GA_3 (75 mg/l)

G_3: 75 ppm GA_3 (100 mg/l)

Design: Layout of the experimental plot

3.4 Climatic condition

The experimental area was under the sub-tropical monsoon climate, The average maximum temperature during the period of experiment was 26.82˚C and the average minimum temperature was 17.14˚C. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the period of the experiment were collected from Weather Station of Agargaon , Dhaka (Appendix II).

3.5 Agro-ecological region

The experimental field belongs to the agro-ecological region of the Modhupur Tract (AEZ-28). The landscape comprises level upland, closely or broadly dissected terraces associated with either shallow or broad, deep valleys.

3.6 Crops: Broccoli *(Brassica oleracea var. Italica)*

3.7 Variety: Green crown

3.8 Source of seed: Sakata Seed Company

3.9 Treatment

Factor A: Transplanting Time	Factor B: Concentration of GA_3
a) T_1= 1 November	1. G_0: Control (No GA_3)
b) T_2= 15 November	2. G_1: 25 ppm GA_3
c) T_3= 30 November	3. G_2: 50 ppm GA_3
	4. G_3: 75 ppm GA_3

There were all together 36 treatments combination were used.

3.10 Experimental Design: Randomized Completely Block Design (RCBD)

3.11 No. of replication: 03

3.12 Total No. of Plots: 36

3.13 Plot size: 1.8m × 1.6m

3.14 Crop husbandry

3.15 Raising of seedlings

Seedlings of broccoli were grown in three seed beds of 1m x 1m size. The dirt was very much arranged and changed over into free friable condition in getting great tilt. All weeds, stubbles and dead roots were evacuated. Ten grams of seeds were sown in every seedbed. The seeds were sown in the seedbed on 10 October, 2016; 25 October 2016 and 10 November 2016 separately. Seeds were then secured with completed light soil. At that point shading was given by bamboo tangle (chatai) to shield youthful seedlings from burning daylight and precipitation. Light watering, weeding and mulching were done as and when important to give seedlings a decent condition for development.

3.16 Land preparation

The land preparation was started at 1 august 2016 by ploughing and cross ploughing followed by laddering. The corner of the land was spaded and visible large clods were broken into small pieces. Weeds and stubbles were removed from the field. The layout of the experiment was done in according with the design adopted. Finally, individual plots were prepared by using spade before organic manure application.

3.17 Manure treatments under investigation

The sources of N, P_2O_5, K_2O as Urea, TSP and MP were applied, respectively as recommended dose (BARI 2015). The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal installments at 25, 35 and 45 days after seedling transplanting (DAT). Well-rotten cow dung 10 t ha^{-1} also applied during final land preparation.

Table 1. Fertilizer and manure applied for the experimental field preparation. Manure and fertilizers were used as recommended by BARI (2005).

Manure / Fertilizers	**Rate/ha**	**Application (%)**			
		Basal	25 DAT	35 DAT	45 DAT
Cow dung	20 ton	100	-	-	-
Urea	100kg	-	33.33	33.33	33.33
TSP	200 kg	100	-	-	-
MP	220 kg	100	-	-	-

3.18 Preparation and application of GA_3

The amount of powdery GA_3 is 25mg with small amount of ethanol to dilute and then mixed in 1 liter of water turn as per requirement of 25 ppm. Similarly, 50mg and 75mg of powdery GA_3 used to prepare 50ppm and 75ppm Ga_3 solution respectively.

3.19 Transplanting and after care

Healthy 20 days old seedlings were transplanted on 1November, 2016 in the afternoon and light irrigation was given around each seedling for their better establishment. Each unit plot accommodated 12 plants. The transplanted seedlings were protected from scorching sunlight early in the morning by providing shed using banana leaf sheath and remove just before sun set daily, until the seedlings were established.

3.20 Pinching

Pinching was done by sharp blades, removing the apex of seedling with three to four leaves. First pinching was done on 2nd September 2017 (10 DAT) and the second at 12 September 2017 (20 DAT).

3.21 Gap filing

Dead, injured and weak seedlings were replaced by new healthy seedlings from the stock kept on the border line of the experiment.

3.22 Intercultural operation

3.22.1 Weeding

Weeding was done three times in each plot to keep the plot clear.

3.22.2 Irrigation

Light irrigation was given just after transplanting of the seedlings. A week after transplanting the requirement of irrigation was envisaged. Wherever the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.22.3 Pest and Disease control

Few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Cut worms were controlled both mechanically and spraying Diazinon 60 EC @ 0.55 Kg per hectare. Some of the plants were infected by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2g /liter of water was sprayed in the field. Bird pests such as Nightingale (Common Bulbuli) visited the fields from 8 to 11 a.m. and 4 to 6 p.m. The birds were found to make puncture in the soft leaves and initiating curd and they were controlled by Striking of a metallic container.

3.22.4 Harvesting

The harvesting was not possible to be done on a particular date because curd initiations as well as curd maturation period in different plants were not similar probably due to pinching and use of different manures and genetic characters of plant. The compact mature curds were only harvested. After harvesting the main curd, secondary stems were developed from the leaf axils and produced small secondary curds. Those were harvested over a period of time. The crop under investigation was harvested for the first time on 25 January, 2017 and the last harvesting was done on 15 April, 2017. The curds were harvested in compact condition before the flower buds were opened.

3.23 Methods of Data collection

The data pertaining to the following characters were recorded from ten (5) plants randomly selected from each unit plot, except yield of curds which was recorded plot wise. Data on plant height was collected at 20, 40 days after transplanting and also at harvest. All other parameters were recorded at following headlines.

Data on the above mentioned crop characters were as follows:

- Plant height
- Number of leaves per plant
- Leaf length
- Leaf breadth
- Plant canopy

- Diameter of stem
- Percent dry matter of leaf
- Percent dry matter of curd
- Number of curd per plant
- Weight of primary curd
- Yield per plant
- Yield per hectare

3.23.1 Plant height (cm)

The height of each sample plant was measured unit plot wise from the base to the tip of main stem of the five randomly selected plants.

3.23.2 Number of leaves per plant

The number of leaves of each sample plant was counted unit plot wise from five randomly selected plants and then averaged.

3.23.3 Leaf length (cm)

A meter scale was used to measure the length of leaves. Leaf length of five randomly selected plants was measured in centimeter (cm) at harvest. It was measured from the base of the petiole to the tip of the leaf. All the leaves of each plant were measured separately. Only the smallest young leaves at the growing point of the plant were excluded from measuring.

3.23.4 Leaf breadth (cm)

Leaf breadth of five randomly selected plants was measured in centimeter (cm) at harvest from the widest part of the lamina with a meter scale and average breadth was recorded in centimeter (cm). All the leaves of each plant were measured separately. Only the smallest young leaves at the growing point of the plant were excluded from measuring.

3.23.5 Plant canopy (cm)

Plant canopy was measured by taking the diameter of the canopy of an individual plant in several directions with a meter scale and finally the average was taken and was expressed in centimeter (cm).

3.23.6 Diameter of stem (cm)

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

3.23.7 Percent dry matter of leaf

A sample of 100 g of leaves was collected and dried under direct sunshine for 72 hours and then dried in an oven at 70^0 C for 3 days. After oven drying, leaves were weighed. The dry weight was recorded in gram (g) with an electric balance. Dry matter of leaf was calculated by the following formula:

$$\text{Percent dry matter} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.23.8 Percent dry matter of curd

A sample of 100 g of curd was collected and was dried under direct sunshine for 72 hours and then dried in an oven at 70^0C for 3 days. After oven drying, curds were weighed. The dry weight was recorded in gram (g) with an electric balance. The percentage of dry matter was calculated by the following formula:

$$\text{Percent dry matter} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.23.9 Number of curds

Only primary curds were counted when the curds reached marketable size. The secondary curds and the small stems were not taken into consideration.

3.23.10 Weight of curd (g)

Weight of the central curd was recorded excluding the weight of all secondary curds and was expressed in gram (g).

3.23.11 Yield per plant (g)

The yield per plant was calculated by accumulating weight of central curds harvested and the yield was weighed in gram (g).

3.23.12 Yield per hectare (ton)

The yield per hectare was calculated by converting the per plot yield data to per hectare and was expressed in ton (t).

3.24 Statistical analysis

Data statistically analyzed by randomized complete block design through MSTAT-C software and Duncan's multiple range tests was used to analyze the growth, yield and quality characters of tomato to find out the statistical significance. The significance of the difference was evaluated by Duncan's Multiple Range Test (DMRT) for interpretation of the results at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of GA_3 and optimum planting date on morpho-physiological characters and yield of broccoli. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices III-VII. The recorded results have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub- headings:

4.1 Plant height

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences on plant height at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the tallest plant (39.56, 48.19 and 57.94 cm, respectively) was recorded from T_2 (15 November),) while the shortest plant (26.84, 38.47 and 44.26 cm respectively) was recorded from T_3 (30 November) at 20 DAT, 40 DAT and at harvest, respectively (Figure 1). The above result indicate that suitable time for transplanting of broccoli may accelerate plant height of broccoli. Similar results also reported by Ahmed (2014). M.A. Rahman (2016) also stated similarly about this.

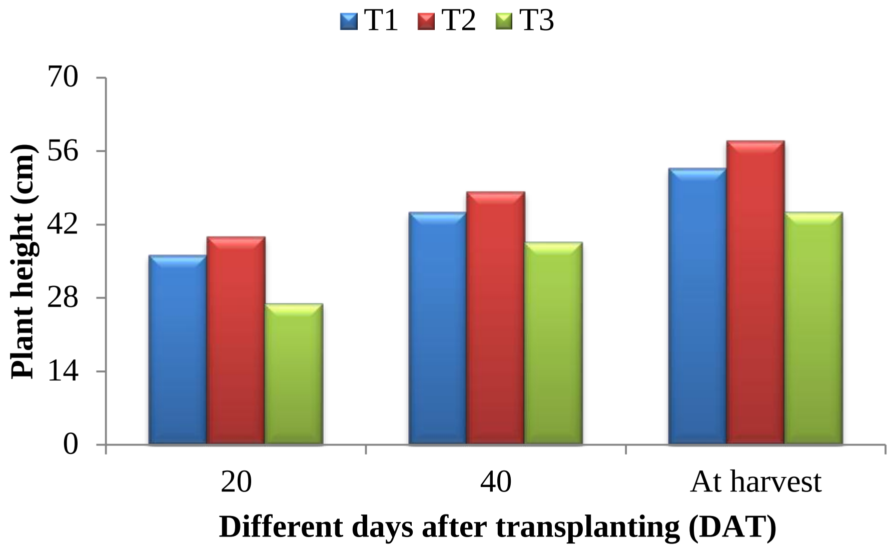


Figure 1. Effect of transplanting time on the plant height of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 2.29, 2.56 and 2.32 at 20, 40 DAT and at harvest, respectively)

Effect of GA_3

Plant height of broccoli varied significantly due to different levels of GA_3 at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the tallest plant 38.71, 42.38 and 49.72 cm, respectively was found from G_2 (50 ppm) whereas the shortest plant 30.04, 39.04 and 46.14 respectfully was recorded from G_0 (control, i.e. 0 ppm GA_3) at 20, 40 DAT and at harvest, respectively (Figure 2). Similar results also reported by Ahmed (2014). This finding indicates that GA_3 might be involved in cell elongation and increase plant height of broccoli. Another research found that the tallest plant (23.8, 36.3, 50.8, 57.3 and 62.5 cm, respectively) was found from 75 ppm GA_3 (Yoldas *et al*., 2008).

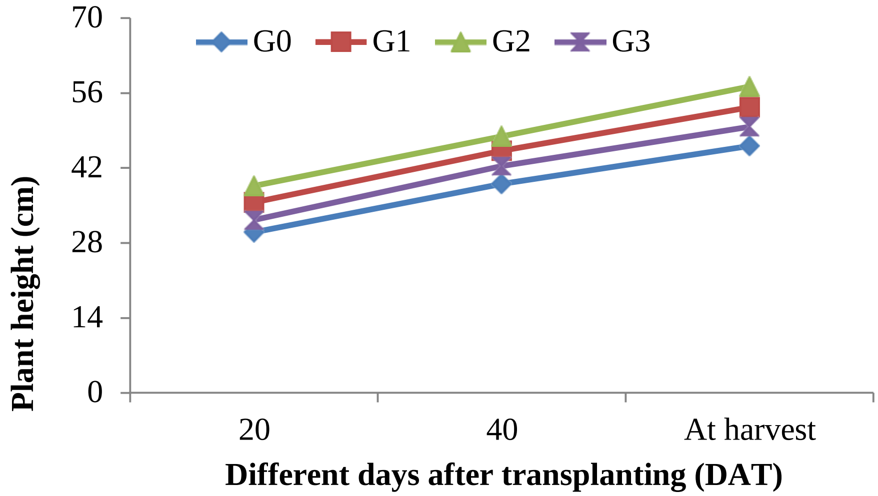


Figure 2. Effect of different levels of gibberelic acid on the plant height of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 2.64, 2.96 and 2.67 at 20, 40 DAT and at harvest, respectively)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different transplanting time and levels of GA_3 showed statistically significant variation in terms of plant height of broccoli at 20, 40 DAT and at harvest (Appendix IV). At 20, 40 DAT and at harvest, the tallest plant (43.61, 53.33 and 63.41 cm, respectively) was recorded from T_2G_2 which was statistically similar with T_2G_1 at 20, 40 DAT and at harvest having plant height of 40.98, 69.39 and 60.62 cm respectively. The shortest plant (20.26, 34.69 and 39.71cm respectively) from T_3G_0 (0 ppm GA_3) treatment combination similar to T_3G_3 having 24.33, 37.70 and 42.60 cm respectively at 20, 40 DAT and at harvest (Table 1). Thus we speculate that combined effect might be responsible for plant height of broccoli. Ahmed (2014) found that at 20, 30, 40, 50 DAT and at harvest, the tallest plant (25.4, 38.7, 53.6, 60.6 and 64.9 cm, respectively) was recorded from V_1G_2 (green magic with 75 ppm GA_3) and the shortest plant (18.5, 30.6, 44.0, 46.7 and 49.7 cm, respectively) from V_2G_0 (early green with 0 ppm GA_3) treatment combination. This statement partially support the data by (Singh, N.P., 2007) and Bhangre *et al*. (2011).

Table 1. Interaction effect of transplanting time and different levels of gibberelic acid on the plant height of broccoli at different days after transplanting

Treatment combinations	Plant height (cm) at different days after transplanting (DAT)		
	20	40	At harvest
T_1G_0	31.14 de	38.89 d-f	46.48 f-h
T_1G_1	38.08 bc	46.50 bc	54.30 cd
T_1G_2	40.51 ab	48.78 ab	59.11 ab
T_1G_3	34.70 cd	42.95 cd	50.65 d-f
T_2G_0	35.72 cd	43.55 cd	52.23 c-e
T_2G_1	40.98 ab	49.39 ab	60.22 ab
T_2G_2	**43.61 a**	**53.33 a**	**63.41 a**
T_2G_3	37.94 bc	46.50 bc	55.91 bc
T_3G_0	23.26 f	34.69 f	39.71 i
T_3G_1	27.78 ef	39.83 de	45.49 gh
T_3G_2	32.01 de	41.67 c-e	49.23 e-g
T_3G_3	24.33 f	37.70 ef	42.60 hi
$LSD_{(0.05)}$	**4.58**	**5.12**	**4.63**
CV (%)	**7.91**	**6.93**	**5.3**

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

4.2 Leaves plant^{-1}

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences on leaves plant^{-1} at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the tallest plant (11.05, 13.64 and 17.80 cm respectively) was recorded from T_2 (15 November) while the shortest plant (7.77, 9.63 and 13.50 cm respectively) was recorded from T_3 (30 November) at 20 DAT, 40 DAT and at harvest, respectively (Figure 3). This finding indicates that GA_3 might be involved in cell elongation and increase no. of leaves per plant. Ahmed and Wajid (2004) and M.A. Rahman (2016) found similar result.

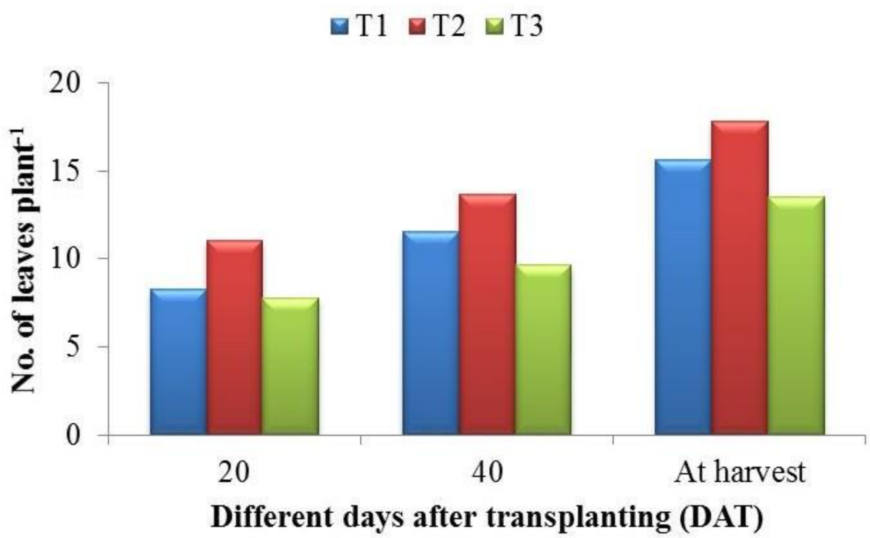


Figure 3. Effect of transplanting time on the no. of leaves plant^{-1} of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 0.43, 0.68 and 0.70 at 20, 40 DAT and at harvest, respectively)

Effect of GA_3

Leaves plant^{-1} of broccoli varied significantly due to different levels of GA_3 at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the highest number of leaves 10.24, 13.71 and 17.72 respectively was found from G_2 (50 ppm) whereas the shortest plant 8.01, 9.89 and 13.59 respectfully was recorded from G_3 (75 ppm GA_3) at 20, 40 DAT and at harvest, respectively (Figure 4). This finding indicates that GA_3 might be involved in cell elongation and increase no. of leaves per plant. Lendve *et al*. (2010) found that application of GA3 @ 50 ppm was found significantly superior in terms of number of the leaves.

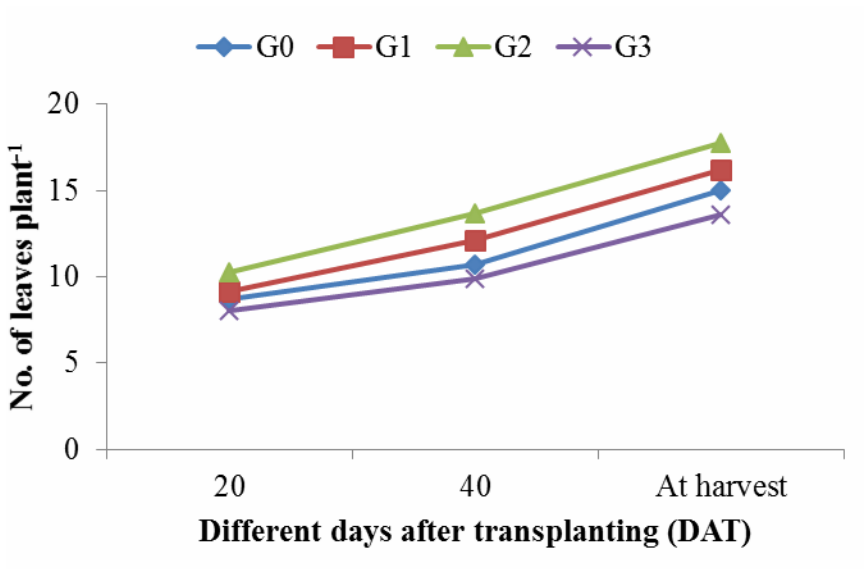


Figure 4. Effect of different levels of gibberelic acid on the no. of leaves plant^{-1} of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 0.50, 0.78 and 0.80 at 20, 40 DAT and at harvest, respectively)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different transplanting time and levels of GA_3 showed statistically significant variation in terms of no. of leaves plant^{-1} of broccoli at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the highest no. of leaves (12.44, 16.64 and 20.30 , respectively) was recorded from T_2G_2 which was followed by T_1G_2 having 11.17, 14.78 and 18.49 no. of leaves at 20, 40 DAT and at harvest respectively. The lowest no of leaves (7.520,9.327 and 13.18 respectively) were from T_3G_0 (0 ppm GA_3) treatment combination which was statistically similar to T_3G_1 having 13.18 no. of leaves at harvest. (Table 2). At 20, 30, 40, 50 DAT and at harvest, the maximum number of leaves per plant (7.47, 9.33, 18.1, 22.8 and 24.0, respectively) was found from V_1G_2 (Green magic and 75 ppm GA_3), whereas the minimum number (4.53, 8.13, 14.7, 18.1 and 20.0, respectively) from V_2G_0 (Early green and 0 ppm GA_3) was found by Ahmed (2014). This statement partially support the data. Foliar application of GA_3 in November increased number of leaves of broccoli plants (Ngullie and Biswas, 2014).

Table 2. Interaction effect of transplanting time and different levels of gibberelic acid on the no. of leaves plant^{-1} of broccoli at different days after transplanting

Treatment combinations	No. of leaves plant^{-1} at different days after transplanting (DAT) 20		40		at harvest	
T_1G_0	7.93	d-f	10.77	c-e	15.30	d-f
T_1G_1	8.07	de	12.01	c	16.16	de
T_1G_2	9.86	c	13.75	b	17.90	bc
T_1G_3	7.21	ef	9.75	d-f	13.11	gh
T_2G_0	10.77	b	12.02	c	16.64	cd
T_2G_1	11.27	b	14.78	b	18.49	b
T_2G_2	12.44	a	16.64	a	20.30	a
T_2G_3	9.71	c	11.10	cd	15.78	de
T_3G_0	7.52	ef	9.33	f	13.18	gh
T_3G_1	8.05	de	9.64	ef	13.97	fg
T_3G_2	8.41	d	10.75	c-e	14.97	ef
T_3G_3	7.12	f	8.82	f	11.89	h
LSD $_{(0.05)}$	**0.87**		**1.35**		**1.39**	
CV (%)	**5.67**		**6.88**		**5.25**	

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

4.3 longest leaf length

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences in terms of length of leaf at 20, 40 DAT and at harvest .At 20, 40 DAT and at harvest, the highest length of leaf (7.66, 17.38 and 24.22 cm respectively) was recorded from T_2, while the lowest length (5.004, 10.23 and 15.53 cm, respectively) was recorded from T_3 at 20, 40 DAT and at harvest, respectively (Figure 5). The above result indicate that suitable time for transplanting of broccoli may accelerate the increasing leaf length. Similar results also reported by Ahmed and Wajid (2004).

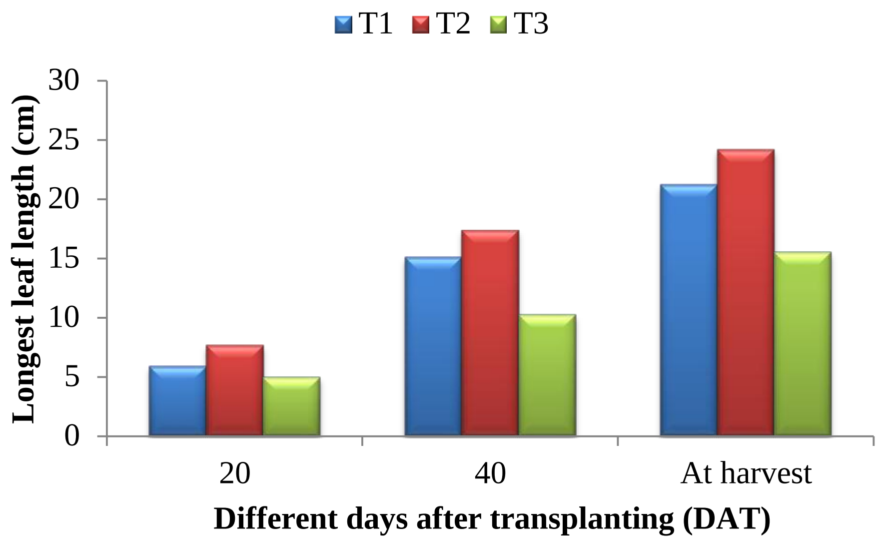


Figure 5. Effect of transplanting time on the longest leaf length of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 0.34, 0.63 and 0.74 at 20, 40 DAT and at harvest, respectively)

Effect of GA_3

Length of leaf of broccoli varied significantly due to different levels of GA_3 at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the highest length of leaf (6.52, 15.67 and 21.96 cm respectively) was recorded from G_2 which was statistically similar (6.39, 14.61 and 20.64 cm, respectively) to $G_{1.}$ The lowest length (5.779, 12.94 and 18.88 cm, respectively) was found from G_0 at 20, 40 DAT and at harvest, respectively (Figure 6). This finding indicates that GA_3 might be involved in cell elongation and increase the size of leaves. Similar results was also reported by Ahmed (2014) and Ngullie and Biswas (2014).

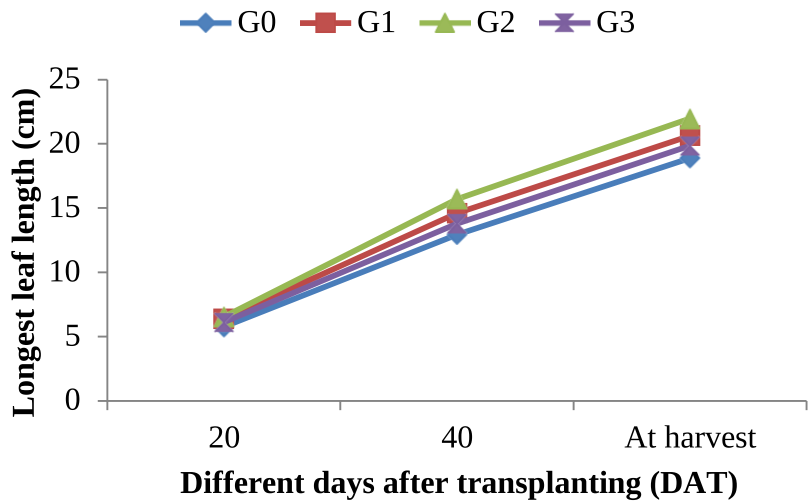


Figure 6. Effect of different levels of gibberelic acid on the longest leaf length of broccoli at different days after transplanting (LSD $_{(0.05)}$ = 0.39, 0.73 and 0.85 at 20, 40 DAT and at harvest, respectively)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different planting time and levels of GA_3 showed statistically significant variation in terms of length of leaf of broccoli at 20, 40 DAT and at harvest (Appendix VI). At 20, 40 DAT and at harvest, the highest length of leaf (8.04, 19.30 and 25.34 cm, respectively) was found from T_2G_2 and the lowest length (4.54, 8.93 and 13.83 cm, respectively) from T_1G_0 (Table 3). At 20, 30, 40, 50 DAT and at harvest, the highest length of leaf (17.6, 26.0, 34.9, 42.6 and 43.9 cm, respectively) was found from V_1G_2 (Green magic and 75 ppm GA_3) and the lowest length (13.5, 19.6, 28.1, 31.7 and 33.4 cm, respectively) from V_2G_0 (Early green and 0 ppm GA_3) was reported by Ahmed (2014). This study partially supported the by the findings of Prasad *et al*. (2010).

Table 3. Interaction effect of transplanting time and different levels of gibberelic acid on the longest leaf length of broccoli at different days after transplanting

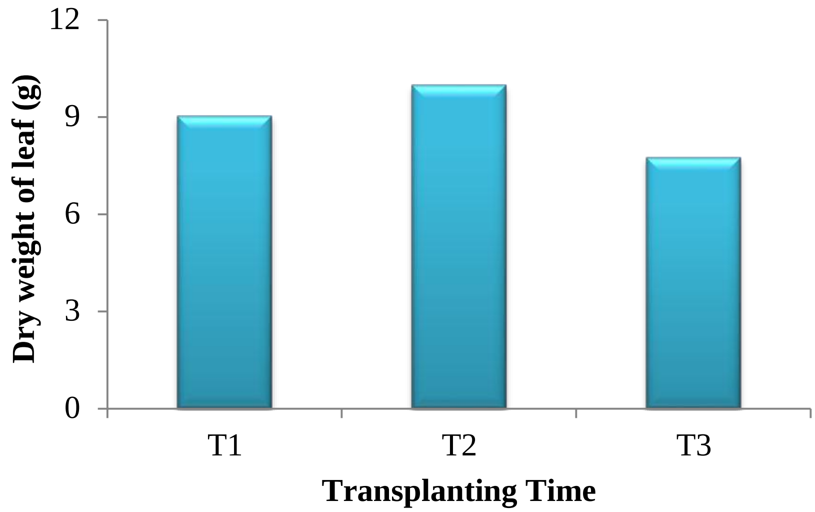
Treatment combinations	Longest leaf length (cm) at different days after transplanting (DAT)		
	20	40	At harvest
T_1G_0	5.55 de	14.60 d	19.67 d
T_1G_1	6.11 cd	15.06 cd	21.49 c
T_1G_2	6.28 c	15.95 bc	23.51 b
T_1G_3	5.75 cde	14.97 cd	20.29 cd
T_2G_0	7.24 b	15.30 cd	23.16 b
T_2G_1	7.93 a	18.34 a	24.30 ab
T2G2	**8.04 a**	**19.30 a**	**25.34 a**
T_2G_3	7.46 ab	16.56 b	24.06 ab
T_3G_0	4.54 f	8.93 g	13.83 g
T_3G_1	5.14 ef	10.44 f	16.12 ef
T_3G_2	5.25 e	11.77 e	17.03 e
T_3G_3	5.08 ef	9.79 fg	15.15 fg
LSD $_{(0.05)}$	**0.67**	**1.26**	**1.47**
CV (%)	**6.42**	**5.22**	**4.27**

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

4.4 Dry weight of leaves

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences in terms of dry weight of leaves. The highest dry weight of leaves (9.98 gm) was recorded from T_2 which was followed (9.03 gm) by T_1, while the lowest dry matter content of leaves (7.75 gm) was found from T_3 (Figure 7). Weight of dry leaves of broccoli increased in mid-November planting varieties found by Ahammad *et. al.* (2009).



T_1= 01 November, T_2 = 15 November, T_3= 30 November

Figure 7. Effect of transplanting time on the dry weight of leaf of broccoli (LSD $_{(0.05)}$ = 0.42)

Effect of GA_3

Dry weight of leaves of broccoli varied significantly due to different levels of GA_3 (Appendix VII). The highest dry matter content of leaves (9.82 gm) was found from G_2 which was statistically similar (9.18 gm) to G_1, whereas the lowest dry matter content of leaves (8.07 gm) was recorded from G_3 (Figure 8). Lendve *et al*. (2010) found that application of GA_3 50 ppm was found significantly superior in terms of number of dry weight of the leaves.

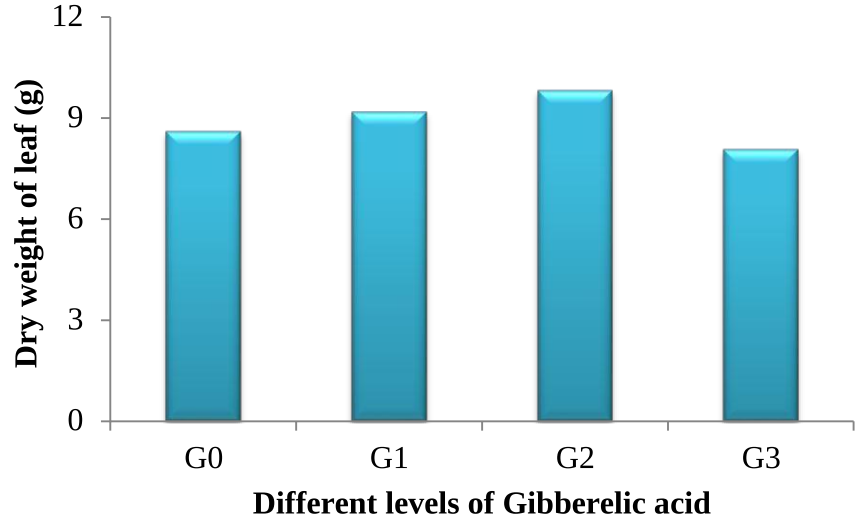


Figure 8. Effect of different levels of gibberelic acid on the dry weight of leaf of broccoli (LSD $_{(0.05)}$ = 0.48)

Combined effect of different transplanting time and levels of GA_3

Combined effect of planting time and levels of GA_3 showed statistically significant variation in terms of dry weight of leaves (Appendix VIII.). The highest dry weight of leaves (11.13 g) was recorded from T_2G_2 followed by T_2G_1 (10.27 g) and the lowest dry matter content of leaves (7.13 g) from T_3G_3 which was statistically similar with T_3G_0 (7.40 cm) and T_3G_1 (7.87 cm) (Table 4). Ahammad *et. al.* (2009) supported this stated.

4.5 Stem length (cm)

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences in terms of stem length (Appendix VI). The highest length of stem (24.17 cm) was found from T_2 which was followed (21.27 cm) by T_1, while the lowest length (16.04 cm) was found from T_3 (Figure 9). Similar results also reported by Ahmed and Wajid (2004).

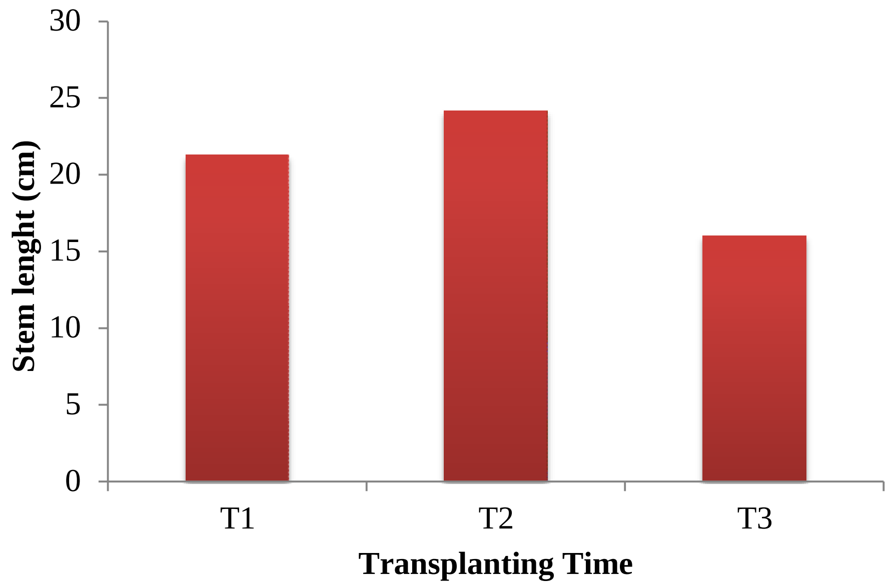


Figure 9. Effect of transplanting time on the stem length of broccoli (LSD $_{(0.05)}$ = 0.59)

Effect of GA_3

Stem length of broccoli varied significantly due to different levels of GA_3 (Appendix VI). The highest length of stem (21.42 cm) was recorded from G_2 followed by 20.53 cm by G_1, 20.19 cm by G_3 and the lowest length (19.85 cm) was found from G_0 (Figure 10). Singh *et. al.* (2011) showed that GA_3 increase the length of stem upto a certain limit of GA_3 concentration.

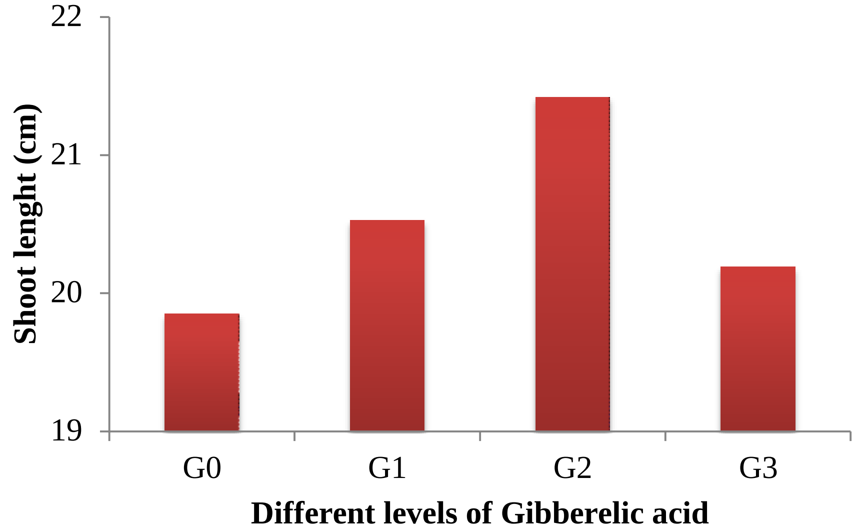


Figure 10. Effect of different levels of gibberelic acid on the stem length of broccoli (LSD $_{(0.05)}$ = 0.68)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different planting time and levels of GA_3 showed statistically significant variation in terms of length of stem (Appendix VI). The highest stem length (25.36 cm) was recorded from T_2G_2 followed by statistically similar T_2G_1 (24.21 cm) and the lowest length (15.41 cm) from T_3G_0 which was statistically similar to T_3G_1 (16.04 cm) (Appendix IX) (Table 4). Ahmed (2014) reported that the highest length of stem (25.5 cm) was recorded from V_1G_2 (Green magic and 75 ppm GA3) and the lowest length (16.8 cm) from V_2G_0 (Early green and 0 ppm GA3). This statement partially supported by Rahman (2016) research data.

4.6 Stem diameter (cm)

Effect of transplanting time

Different planting time of broccoli showed statistically significant differences in terms of diameter of stem (Appendix VI). The highest diameter of stem (12.19 cm) was recorded from T_2 which was followed (11.08 cm) by T_1, while the lowest diameter (7.97 cm) was found from T_3 (Figure 11). Nooprom *et al*. (2013) reported different diameter of stem for different variety.

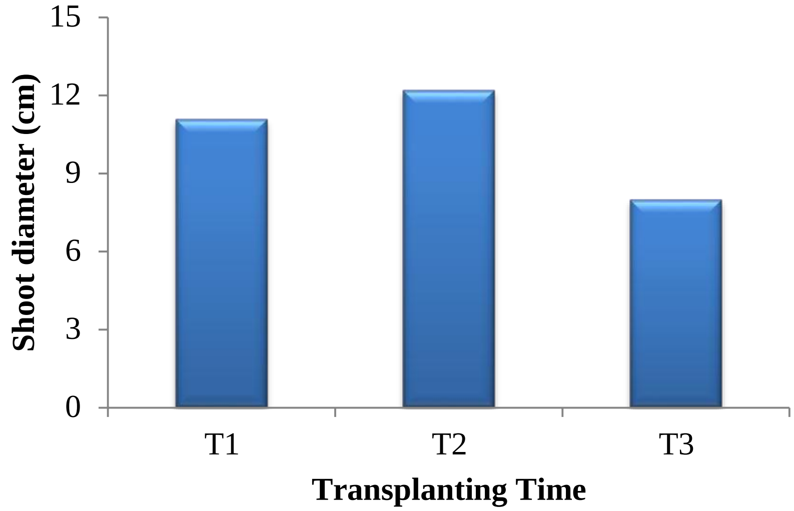


Figure 11. Effect of transplanting time on the stem diameter of broccoli (LSD $_{(0.05)}$ = 0.53)

Effect of GA_3

Diameter of stem of broccoli varied significantly due to different levels of GA_3 (Appendix VI). The highest diameter of stem (11.89 cm) was found from G_2 followed by G_1 (10.75 cm) and the lowest diameter (7.25 cm) was recorded from G_3 followed by G_0 (9.93cm) (Figure 12). Sharma and Mishra, (1989) reported that curd size increased with foliar application of GA_3.

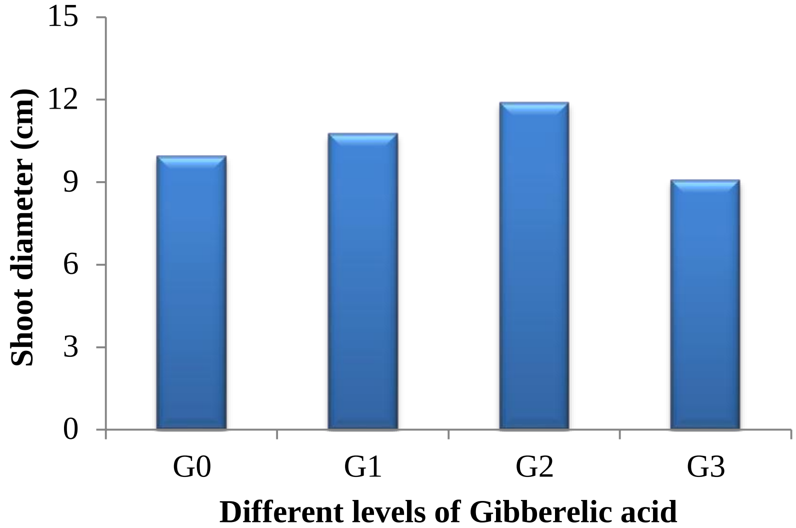


Figure 12. Effect of different levels of gibberelic acid on the stem diameter of broccoli (LSD $_{(0.05)}$ = 0.62)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different varieties and levels of GA_3 showed statistically significant variation in terms of diameter of stem (Appendix VII). The highest diameter of stem (13.70 cm) was found from T_2G_2 which was statistically same to T_2G_1 (12.85 cm) and T_1G_2 (12.74 cm). The lowest diameter (7.25 cm) from T_3G_3 which was statistically same to T_3G_0 (7.49 cm) and T_3G_1 (7.91 cm) (Table 4). Ahmed (2014) found that the highest diameter of stem (4.56 cm) was found from V_1G_2 (Green magic and 75 ppm GA_3 and the lowest diameter (3.33 cm) from V_2G_0 (Early green and 0 ppm GA_3). This statement partially supported by the data of previous findings (Islam *et al.*, 1993).

4.7 Days required from transplanting to first visible curd

Effect of transplanting time

Days required from transplanting to first visible curd showed statistically significant differences for different transplanting time of broccoli. The maximum days required from transplanting to first visible curd (55 DAT) was recorded from T_3 which was statistically similar (51.63 DAT) to T_1, while the minimum days (46.42 DAT) was found from T_2 (Figure 13). Similar results also reported by Ahmed and Wajid (2004).

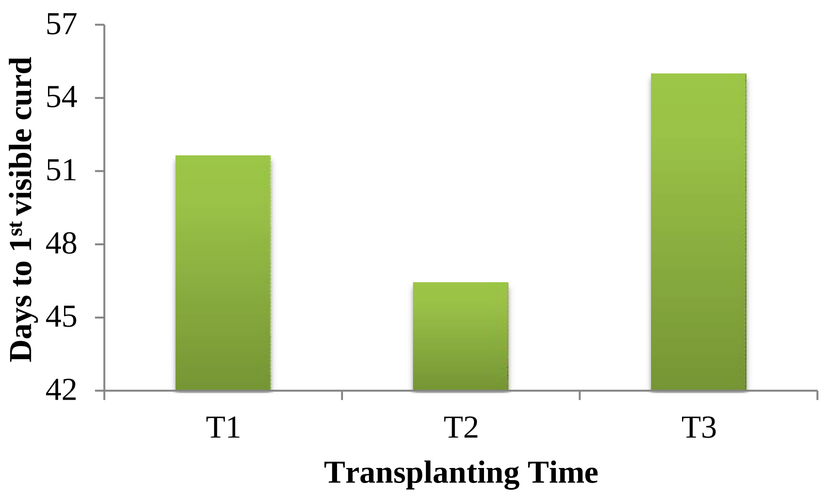


Figure 13. Effect of transplanting time on the days to 1st visible curd of broccoli (LSD $_{(0.05)}$ = 1.39)

Effect of GA_3

Different levels of GA_3 varied significantly in terms of days required from transplanting to first visible curd of broccoli. The minimum days required from transplanting to first visible curd 48.56) was found from G_2 whereas the maximum days (53.33) was recorded from G_3 (figure 14). Lendve *et al*. (2010) reported that 75 ppm GA_3, which gave better results for days required for head initiation.

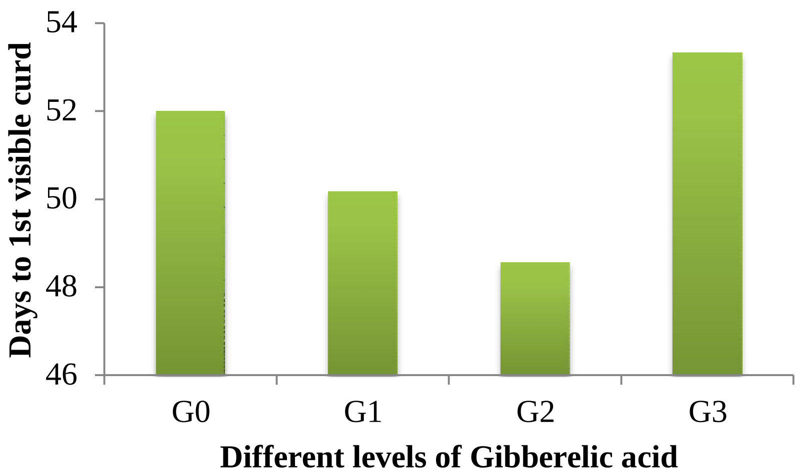


Figure 14. Effect of different levels of gibberelic acid on the days to 1st visible curd of broccoli (LSD $_{(0.05)}$ = 1.61)

Combined effect of different transplanting time and levels of GA_3

Statistically significant variation in terms of days required from transplanting to first visible curd due to the combined effect of different transplanting time and levels of GA_3 (Appendix IX). The minimum days required from transplanting to first visible curd (44.33) was recorded from T_2G_2 which was statistically same to T_2G_1 (43.33) and T_2G_0 (46.67) the maximum days (58) from T_3G_3 which was statistically similar to T_3G_0 (56) (Table 4). Ahmed (2014) reported that the minimum days required from transplanting to first visible curd (48) was recorded from V_1G_2 (Green magic and 75 ppm GA_3) and the maximum days (61) from V_2G_0 (Early green and 0 ppm GA_3). This statement partially support the data. Lendve *et al*. (2010) reported that 50 ppm GA_3, which gave better result for days required to head initiation.

Table 4. Interaction effect of transplanting time and different levels of gibberelic acid on the dry weight of leaf, stem length, stem diameter and days to 1st visible curd of broccoli

Treatment combinations	Dry weight of leaf (g)	Stem length (cm)	Stem diameter (cm)	Days to 1st visible curd
T_1G_0	8.88 d-f	20.71 d	10.72 b	53.33 bc
T_1G_1	9.42 c-e	21.33 cd	11.49 b	51.53 cd
T_1G_2	9.73 bc	22.00 c	12.74 a	49.00 de
T_1G_3	8.10 f-h	21.05 cd	9.38 c	52.67 c
T_2G_0	9.54 b-d	23.43 b	11.60 b	46.67 ef
T_2G_1	10.27 b	24.21 ab	12.85 a	45.33 f
T_2G_2	**11.13 a**	**25.36 a**	**13.70 a**	**44.33 a**
T_2G_3	9.00 c-e	23.70 b	10.59 b	49.33 de
T_3G_0	7.40 hi	15.41 f	7.49 d	56.00 ab
T_3G_1	7.87 g-i	16.04 ef	7.91 d	53.67 bc
T_3G_2	8.60 e-g	16.90 e	9.24 c	52.33 c
T_3G_3	7.13 i	15.80 ef	7.25 d	58.00 g
LSD $_{(0.05)}$	**0.84**	1.18	**1.07**	**2.78**
CV (%)	**5.54**	3.4	**6.06**	**3.22**

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

4.8 Length of curd per plant

Effect of transplanting time

Length of primary curd showed statistically significant differences due to different planting time of broccoli under the present trial The highest length of primary curd (12.94 cm) was recorded from T_2 which was followed (10.9 cm) by T_1, while the lowest weight of primary curd (9.03cm) was recorded from T_3 (Figure 15). Length of primary curd varied might be due to genetical and environmental influences as well as management practices.If curd length increase weight as well as yield will increase so it has an effect. Nooprom *et al*. (2013) reported different length of primary curd for different varieties.

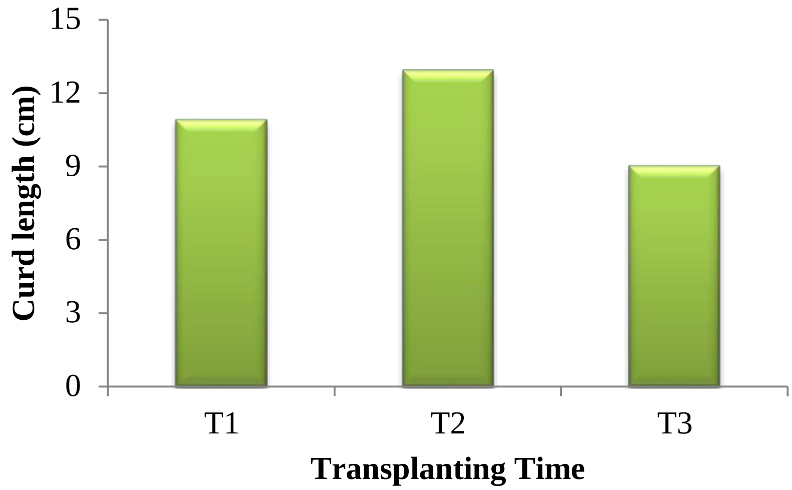


Figure 15. Effect of transplanting time on the curd length of broccoli (LSD $_{(0.05)}$ = 0.53)

Effect of GA_3

Different levels of GA_3 varied significantly in terms of length of primary curd of broccoli The highest length of primary curd (12.44 cm) was attained from G_2 which was statistically similar (11.24 cm) to G_1 while the lowest length of primary curd (9.67 cm) was recorded from G_3 (Figure 16). Vijay and Ray (2000) reported that that GA_3 at 100 ppm produced the largest curds.

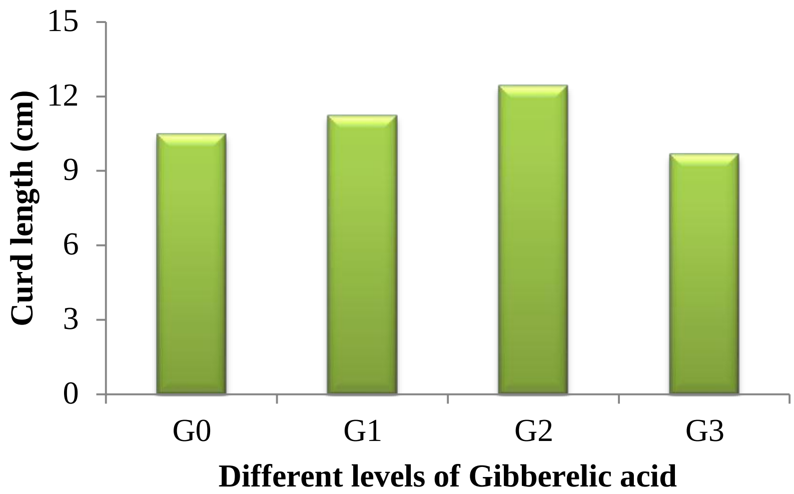


Figure 16. Effect of different levels of gibberelic acid on the curd length of broccoli (LSD $_{(0.05)}$ = 0.61)

Combined effect of different transplanting time and levels of GA_3

Statistically significant variation was recorded due to the combined effect of different different planting time and levels of GA_3 in terms of length of primary curd (Appendix VII). The highest length of primary curd (14.75 cm) was found from T_2G_2 followed by T_2G_1 (13.35 cm) which was statistically same with T_1G_2 (12.36 cm), while the lowest length of primary curd (7.90) from T_3G_3 followed by statistically same T_3G_0 (Table 5). Thus we speculate that, combined effect might be responsible for increasing curd length of broccoli. Partially similar results was reported by Ahmed (2014).

4.9 Diameter of primary curd

Effect of transplanting time

Different planting time of broccoli showed statistically significant differences in terms of diameter of primary curd .The highest diameter of primary curd (41.13cm) was found from T_2 which was statistically similar (36.2 cm) to T_1, while the lowest diameter of primary curd (26.93 cm) was found from T_3 (Figure 17) Diameter of primary curd varied for different varieties might be due to genetical and environmental influences as well as management practices. Nooprom *et al*. (2013) reported different diameter of primary curd for different variety.

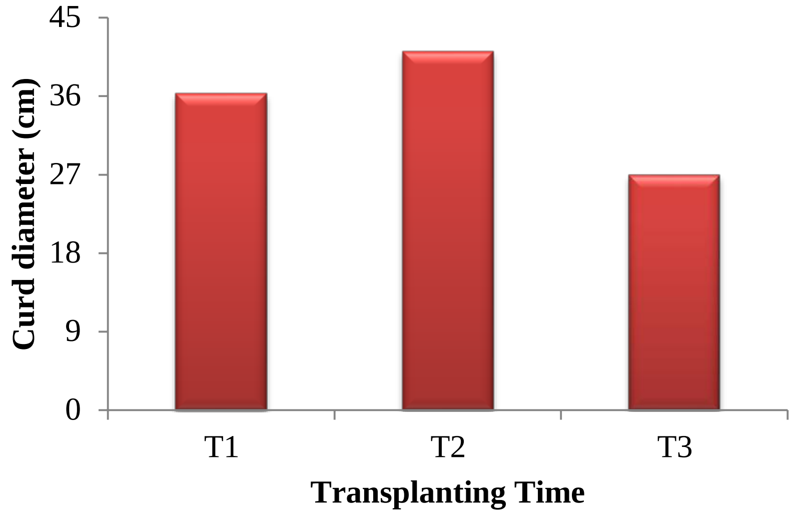


Figure 17. Effect of transplanting time on the curd diameter of broccoli (LSD $_{(0.05)}$ = 2.11)

Effect of GA_3

Diameter of primary curd of broccoli varied significantly due to different levels of GA_3. The highest diameter of primary curd 39.92 cm was found from G_2 followed by G_1 (37.24 cm) and the lowest diameter of primary curd (28.026 cm) was recorded from G_3 followed by G_0 (33.75 cm) (Figure 18). Similar results was also reported by Ahmed (2014).

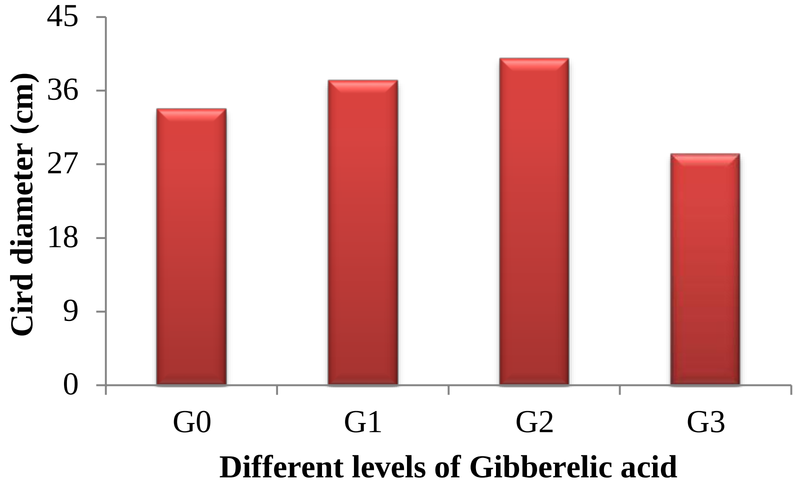


Figure 18. Effect of different levels of gibberelic acid on the curd diameter of broccoli (LSD $_{(0.05)}$ = 2.44)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different planting time and levels of GA_3 showed statistically significant variation in terms of diameter of primary curd (Appendix VII). The highest diameter of primary curd (46.24 cm) was recorded from T_2G_2 which was statistically same toT_2G_1 (42.59 cm) and the lowest diameter of primary curd (17.66 cm) from T_3G_3 followed by T_3G_0 (26.27 cm) (Table 5). Ahmed (2014) found the highest diameter of primary curd (9.55 cm) was recorded from V_1G_3 (Green magic and 100 ppm GA_3) and the lowest diameter of primary curd (7.14 cm) from V_2G_0 (Early green and 0 ppm GA_3). Thus we speculate that combined effect might be responsible for curd diameter of broccoli. This statement partially support the data Giri *et al*. (2013).

4.10 Fresh weight of curd

Effect of transplanting time

Statistically significant difference was recorded due to different transplanting time of broccoli in terms of fresh weight of curd. The highest fresh weight of curd (517.6g) was found from T_2 which was followed (364 g) by T_1, while the lowest dry matter content of curd (240g) was obtained from T_3 (Figure 19). Nooprom *et al*. (2013) reported different weight of primary curd for different transplanting time.

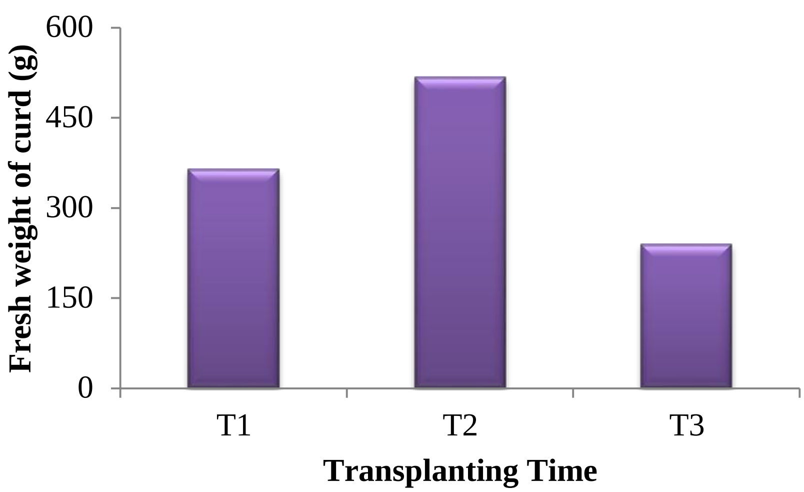
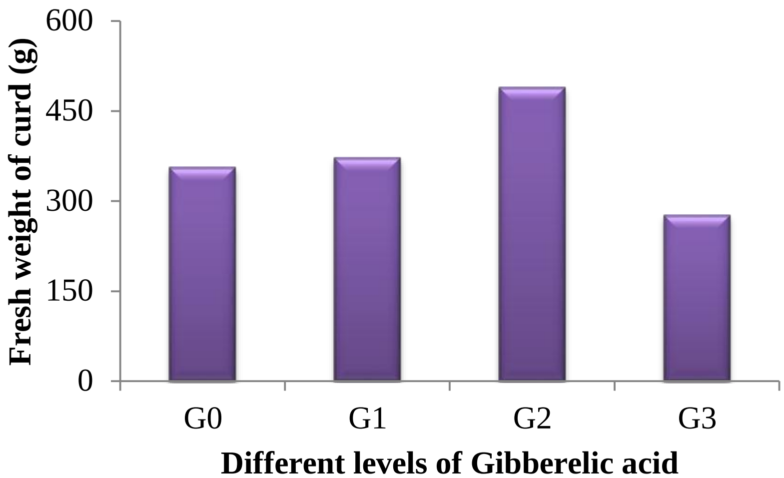


Figure 19. Effect of transplanting time on the fresh weight of curd of broccoli (LSD $_{(0.05)}$ = 25.08)

Effect of GA_3

Different levels of GA_3 varied significantly in terms of fresh weight of curd of broccoli (Appendix VIII). The highest fresh weight of curd (490.3 g) was found from G_2 which was statistically similar (372 g) to G_1 and closely followed (356 g) by G_0, and the lowest dry matter content of curd (276.9 g) was recorded from G_3 (Figure 20). Similar results was also reported by Ahmed (2014).



G_0=0 ppm GA_3, G_1= 25 ppm GA_3, G_2= 50 ppm GA_3, G_3= 75 ppm GA_3

Figure 20. Effect of different levels of gibberelic acid on the fresh weight of curd of broccoli (LSD $_{(0.05)}$ = 28.95)

Combined effect of different transplanting time and levels of GA_3

Fresh weight of curd showed statistically significant variation for the combined effect of different variety and levels of GA_3 (Appendix VIII).The highest weight of curd (674 g) was recorded from T_2G_2 followed by statistically same T_2G_1 (571 g) and T_2G_0 (493 g) the lowest weight of curd (164 g) from T_3G_3 followed by T_3G_0 (237 g) and T_3G_1 (240 g) which was statistically same. Partially similar data was found by Ahmed (2014).

4.11 Dry weight of curd (g)

Effect of transplanting time

Statistically significant difference was recorded due to different transplanting time of broccoli in terms of dry weight of curd.The highest dry matter content of curd (11.37g) was found from T_2 which was followed (9.33) by T_1 while the lowest dry matter content of curd (7.70g) was obtained from T_3 (Figure 21).With different planting time dry weight of curd varies significantly reported by Giri *et al*., (2013).

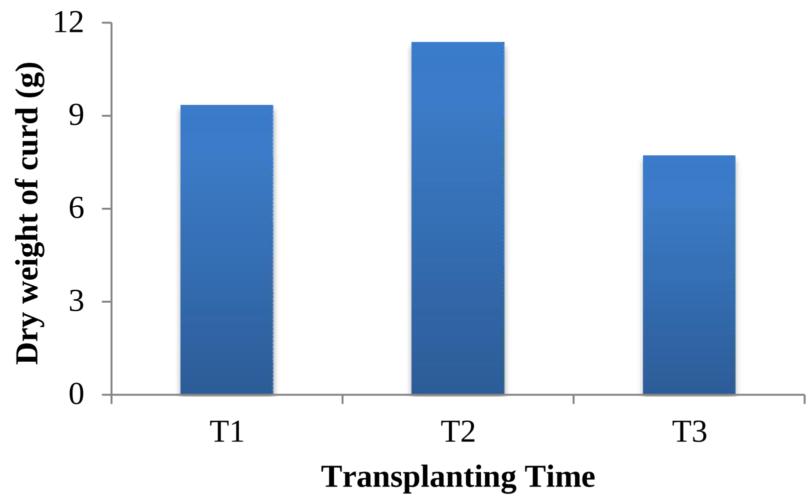


Figure 21. Effect of transplanting time on the dry weight of curd of broccoli (LSD $_{(0.05)}$ = 0.39)

Effect of GA_3

Different levels of GA_3 varied significantly in terms of dry weight of curd of broccoli .The highest dry matter content of curd (10.79 g) was found from G_2 followed by G_1 (9.81g) and G_0 (9.08 g) the lowest dry matter content of curd (8.18 g) was recorded from G_3 (Figure 22). Similar results was also reported by Ahmed (2014) and Gabal *et al.*, (1999).

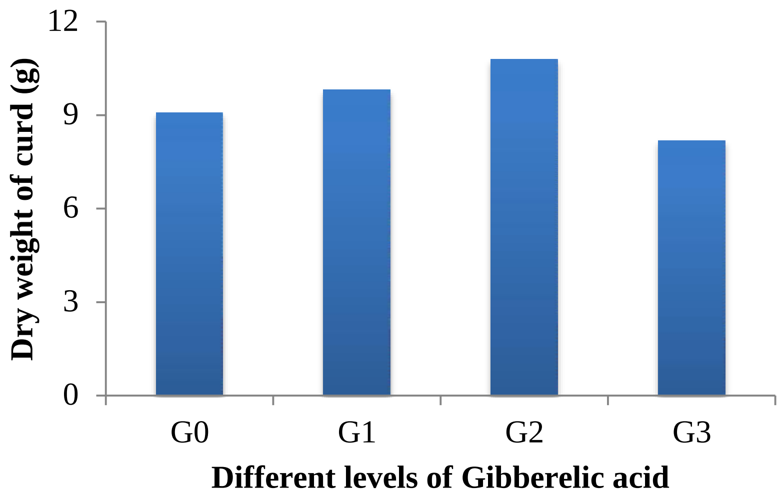


Figure 22. Effect of different levels of gibberelic acid on the dry weight of curd of broccoli (LSD $_{(0.05)}$ = 0.45)

Combined effect of different transplanting time and levels of GA_3

Dry weight of curd showed statistically significant variation for the combined effect of different variety and levels of GA_3 (Appendix VIII).The highest weight of curd (13.03g) was recorded from T_2G_2 followed by T_2G_1 (11.9 g) and the lowest weight of curd (7.03g) from T_3G_3 which was statistically same to T_3G_0 (7.33 g) (Table 5). Partially similar results was reported by Ahmed (2014) and Gulnaz *et al.*, (1999).

Table 5. Interaction effect of transplanting time and different levels of gibberelic acid on the curd length, curd diameter, fresh weight of curd and dry weight of curd of broccoli

Treatment combinations	Curd length (cm)	Curd diameter (cm)	Fresh weight of curd (g)	Dry weight of curd (g)
T_1G_0	10.57 d-f	35.89 de	339.1 cd	8.99 de
T_1G_1	11.03 de	38.44 b-d	357.7 cd	9.70 d
T_1G_2	12.36 bc	40.40 bc	480.2 b	10.73 c
T_1G_3	9.65 f-h	30.54 f	280.2 ef	7.92 fg
T_2G_0	12.18 c	39.10 b-d	493.1 b	10.93 c
T_2G_1	13.35 b	42.59 ab	517.2 b	11.90 b
T_2G_2	**14.75 a**	**46.24 a**	**674.0 a**	**13.03 a**
T_2G_3	11.48 cd	36.58 c-e	386.1 c	9.60 d
T_3G_0	8.69 hi	26.27 g	237.0 f	7.33 gh
T_3G_1	9.34 gh	30.69 f	242.0 f	7.87 fg
T_3G_2	10.22 e-g	33.11 ef	316.7 de	8.60 ef
T_3G_3	7.90 i	17.66 h	164.5 g	7.03 h
LSD $_{(0.05)}$	**1.06**	**4.22**	**50.15**	**0.78**
CV (%)	**5.7**	**7.17**	**7.92**	**4.87**

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

Number of secondary curd per plant Effect of transplanting time

Different planting time of broccoli showed statistically significant differences in terms of number of secondary curd. The highest number of secondary curd

(3.19) was recorded from T_2 which was followed (2.49) by T_1, while the lowest number of secondary curd (1.93) was found from T_3 (Figure 23). Prasad *et al*. (2010) reported different number of secondary curd for different varieties.

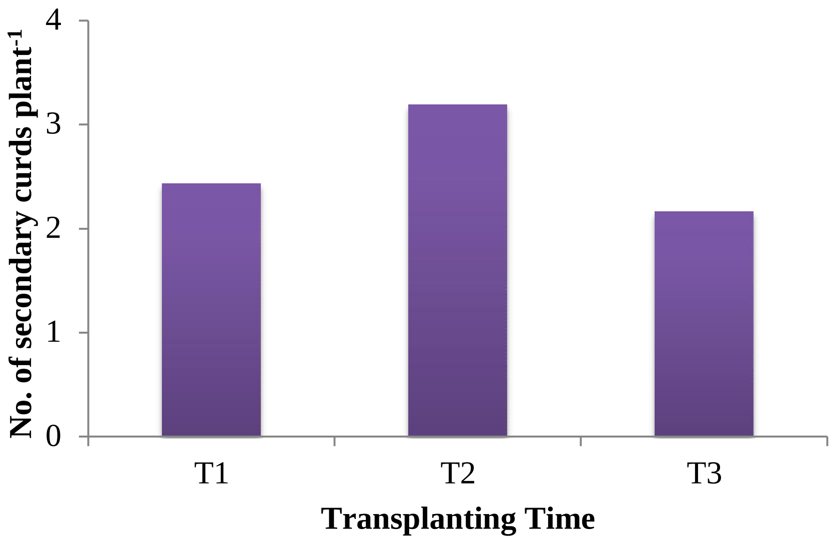


Figure 23. Effect of transplanting time on the no. of secondary curds plant^{-1} of broccoli (LSD $_{(0.05)}$ = 0.12)

Effect of GA_3

Number of secondary curd of broccoli varied significantly due to different levels of GA_3. The highest number of secondary curd (2.95) was found from G_2 which was statistically similar (2.70) to G_1, whereas the lowest number of secondary curd (2.24) was recorded from G_3 (Figure 24). Similar results was also reported by Ahmed (2014).

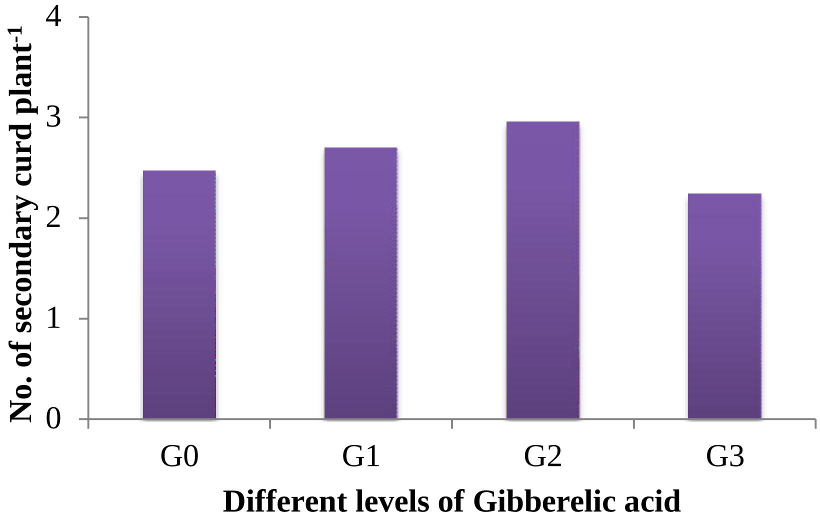


Figure 24. Effect of different levels of gibberelic acid on the no. of secondary curds plant^{-1} of broccoli (LSD $_{(0.05)}$ = 0.13)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different transplanting time and levels of GA_3 showed statistically significant variation in terms of number of secondary curd (Appendix IX).The highest number of secondary curd (3.73) was recorded from T_2G_2 followed by T_2G_1 (3.37), T_2G_0 (3.01) and the lowest number of secondary curd (1.93) from T_3G_3 which was statistically same to T_3G_0 (2.10) and T_1G_3 (2.75) (Table 6). Partially similar results was also reported by Ahmed (2014).). The highest number of secondary curd (3.47) was recorded from V_1G_3 (Green magic and 100 ppm GA_3) and the lowest number of secondary curd (2.27) from V_2G_0 (Early green and 0 ppm GA_3) Gautam *et. al*., (2001).

4.12 Weight of secondary curd per plant

Effect of transplanting time

Different transplanting time of broccoli showed statistically significant differences in terms of weight of secondary curd .The highest weight of secondary curd (85.51 g) was found from T_2 which was followed (76.71 g) by T_1, while the lowest weight of secondary curd (59.26 g) was found from T_3 (Figure 25). Dhengle and Bhosale (2008) stated the effect of yield in variation of fresh weight of secondary curd.

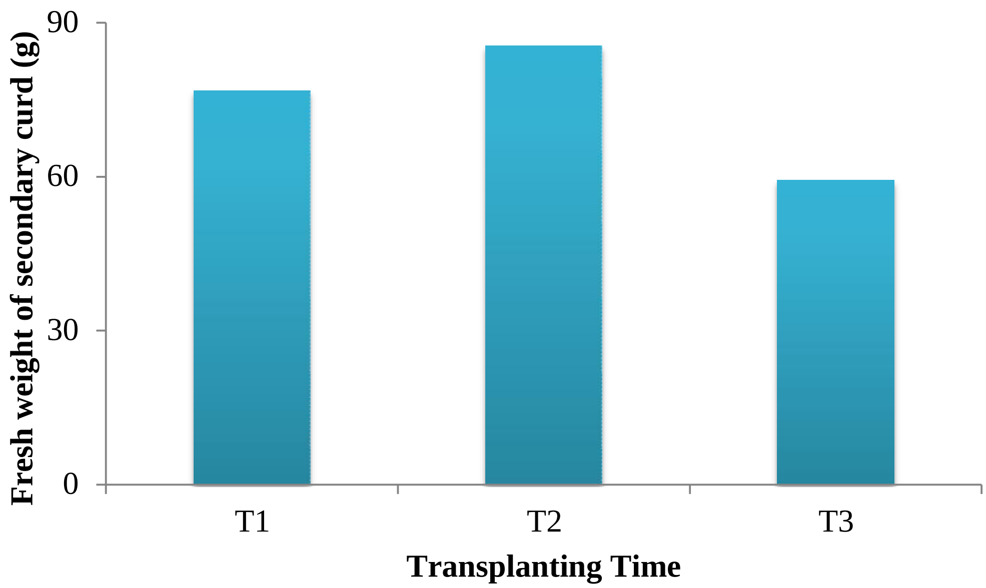


Figure 25. Effect of transplanting time on the fresh weight of secondary curd of broccoli (LSD $_{(0.05)}$ = 2.57)

Effect of GA_3

Weight of secondary curd of broccoli varied significantly due to different levels of GA_3 .The highest weight of secondary curd (78.28 g) was recorded from G_2 which was statistically similar (75.54 g) to G_1,while the lowest weight of secondary curd (68.53 g) was recorded from G_3 (Figure 26). Similar results was also reported by Ahmed (2014).

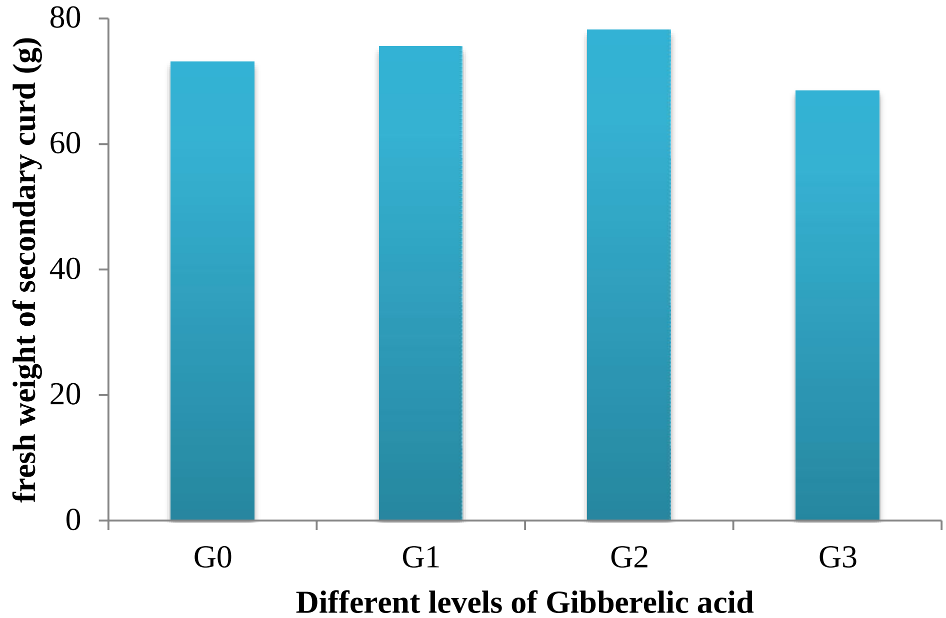


Figure 26. Effect of different levels of gibberelic acid on the fresh weight of secondary curd of broccoli (LSD $_{(0.05)}$ = 2.97)

Combined effect of different transplanting time and levels of GA_3

Combined effect of different planting time and levels of GA_3 showed statistically significant variation in terms weight of secondary curd (Appendix X). The highest weight of secondary curd (90.59 g) was recorded from T_2G_2 which was statistically same to T_2G_1 (87.68 g) and the lowest weight of secondary curd (13.62 g) from T_3G_3 which was statistically same to T_3G_0 (58.70 g) (Table 6). Partially similar results was reported by Ahmed (2014). He found that the highest weight of secondary curd (89.1 g) from V_1G_3 (Green magic and 100ppm GA_3) and the lowest weight of secondary curd (57.4 g) from V_2G_0 (Early green and 0 ppm GA_3).

4. 14 Curd yield per hectare

Effect of transplanting time

Curd yield per hectare of broccoli showed statistically significant differences due to transplanting time. The highest curd yield per hectare (21.81 ton) was recorded from T_2 which was followed (19.68 ton) by T_1, while the lowest curd yield per hectare (16.34 ton) was found from T_3 (Figure 27). Similar results also found by Ahmed and Wajid (2004).

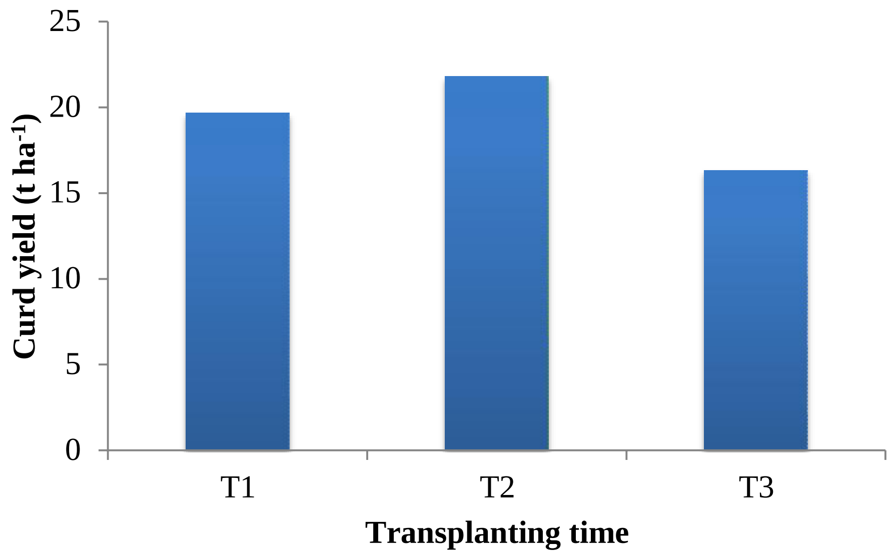
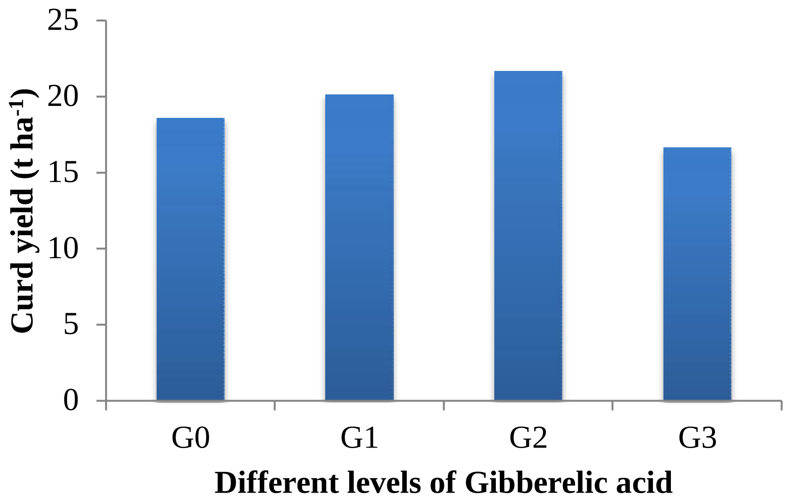


Figure 27. Effect of transplanting time on the curd yield of broccoli (LSD $_{(0.05)}$ = 0.75)

Effect of GA_3

Different levels of GA_3 varied significantly in terms of curd yield per hectare of broccoli .The highest curd yield per hectare (21.69 ton) was found from G_2 which was statistically similar (20.14 ton) to G_1 , while and the lowest curd yield per hectare (16.65 ton) was recorded from G_3 (Table 6). Vijay and Ray (2000) reported that GA_3 at 100 ppm produced the largest curds.



G_0=0 ppm GA_3, G_1= 25 ppm GA_3, G_2= 50 ppm GA_3, G_3= 75 ppm GA_3

Figure 28. Effect of different levels of gibberelic acid on the curd yield of broccoli ($LSD_{(0.05)}$ = 0.86)

Combined effect of different transplanting time and levels of GA_3

Statistically significant variation was recorded due to the combined effect of different transplanting time and levels of GA_3 in terms of curd yield per hectare (Appendix X). The highest curd yield per hectare (24.52 ton) was recorded from T_2G_2 followed by T_2G_1 (22.17 ton) and T_2G_0 (20.88 ton) which was statistically same.The lowest curd yield per hectare (13.62 ton) from T_3G_3 (Table 6).This finding is partially supported by data reported by Ahmed (2014); Giri *et al*. (2013) and Nooprom *et. al*., (

Table 6. Interaction effect of transplanting time and different levels of gibberelic acid on the curd no. of secondary curds plant^{-1}, weight of secondary curd and curd yield of broccoli

Treatment combinations	No. of secondary curds plant^{-1}		Weight of secondary curd (g)		\urd yield (t	
T_1G_0	2.30	e-g	75.01	de	19.31	de
T_1G_1	2.53	de	78.46	cd	20.62	cd
T_1G_2	2.75	d	81.02	bc	22.13	b
T_1G_3	2.13	gh	72.73	e	16.67	gh
T_2G_0	3.01	c	85.65	ab	20.88	bc
T_2G_1	3.37	b	87.68	a	22.17	b
T_2G_2	**3.73**	**a**	**90.59**	**a**	**24.52**	**a**
T_2G_3	2.67	d	78.10	cd	19.65	c-e
T_3G_0	2.10	gh	58.70	fg	15.67	h
T_3G_1	2.21	fg	60.47	f	17.63	fg
T_3G_2	2.39	ef	63.12	f	18.43	ef
T_3G_3	1.93	h	54.75	g	13.62	i
LSD $_{(0.05)}$	**0.23**		**5.14**		**1.50**	
CV (%)	**5.37**		**4.11**		**4.59**	

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Central Farm of the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh The experiment was carried out during the Rabi season from October 2016 to May 2017. Seedlings were transplanted on 01 November, 2016, 15 November 2016 and 30 November 2016, transplanted to main field at 25 days seedling and were harvested up to 30 May, 2017 to study the effect of optimum planting time and appropriate concentration of GA_3 on growth and yield of broccoli. The experiment consisted of two factors (optimum planting time and appropriate concentration of GA_3). There were three planting times as T_1= 1 November, T_2= 15 November and T_3= 30 November while Gibberellic acid-GA_3 (four levels) as G_0: 0 ppm GA_3, G_1: 25 ppm GA_3, G_2: 50 ppm GA_3 and G_3: 75 ppm GA_3. This two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Collected data were statistically analyzed for the evaluation of the treatments for the detection of the optimum time of transplanting time and best concentration of GA_3 and the best combination. The summary of the results has been presented in this chapter.

At harvesting for different planting times, the tallest plant was recorded from T_2 (15 November), at 20, 40 DAT and at harvest gave 39.56, 48.19cm and 57.94 cm respectively while the shortest plant from T_3 (30 November) at same DAT gave 26.84, 38.47 and 44.26 respectively. On the other hand, level of GA_3 G_2:50 ppm showed the tallest plant (38.71, 47.93 and 57.25 cm) but G_3:75 and G_0:0 ppm gave similar type of the lowest result at 20, 40 DAT and at harvest respectively. Combined effect of different planting time and levels of GA_3 showed statistically significant variation in terms of plant height of broccoli at 20, 40 DAT and at harvest. At 20, 40 DAT and at harvest, the tallest plant (43.61, 53.33 and 63.41 cm, respectively) was recorded from T_2G_2 (15 November with 50ppm GA_3) and the shortest plant 20.26, 34.69 and 39.71 respectively) by T_3G_3 (30 November with 75ppm GA_3).

The maximum number of leaves per plant was obtained from T_2 (15 November), at 20, 40 DAT and at harvest gave result as 11.05, 13.64 and 17.80 respectively, whereas the minimum number from T_3 (30 November) at same DAT gave result as 7.776, 9.633 and 13.50 respectively. On the other hand, level of GA_3 G_2:50 ppm achieved highest number 10.24, 13.71 and 17.72 while the lowest number was found in the level of G_3:75 ppm as 8.013, 9.890 and 13.59 at same DAT. In case of combined effect, the maximum number of leaves per plant (12.44, 16.64 and 20.30 respectively) was found from T_2G_2 (15 N0vember with 50ppm GA_3), whereas the minimum number (7.12, 8.82 and 11.89 respectively) from T_3G_3 (30 November with 75ppm GA_3) at 20, 40 DAT and at harvest.

The longest leaf was recorded from T_2 (15 November) at 20, 40 DAT and at harvest gave result as 7.668, 17.38 and 24.22 cm respectively again the lowest length from T_3 (30 November) at same DAT gave result as 5.004, 10.23 and 15.53 cm. Besides, the level of GA_3 G_2:50 ppm achieved highest value 6.524, 15.67 and 21.96 cm while the lowest was given by G_0: 0 ppm as 5.779, 12.94 and 18.88 cm at same DAT. In combination the highest length of leaf (8.04, 19.30 and 25.34 cm, respectively) was found from T_2G_2 and the lowest length (4.54, 8.93 and 13.83 cm, respectively) from T_3G_0.

The minimum days required from transplanting to first visible curd was recorded (near about 46 days) from T_2 (15 November) while the maximum days (54) from T_3 (30 November). In case of GA_3 G_2:50 ppm achieved minimum date (49 DAT) and maximum days was found in G_3:75 ppm GA_3. In combined effect, minimum days required from transplanting to first visible curd (44 DAT) was recorded from T_2G_2 and the maximum days (58 DAT) from T_3G_3.

The highest stem diameter (12.19 cm) was found from T_2 (15 November), while the lowest length (7.973 cm) from T_3 (30 November). While highest (11.89 cm) found in level of GA_3 G_2:50 ppm and the lowest (9.074 cm) at G_3:75 ppm. The combined effect was found best (13.70 cm) at T_2G_2 while the lowest (9.240 cm) was found from T_3G_3 combination.

The highest length of stem (24.17 cm) was found from T_2 (15 November), while the lowest length (16.04 cm) from T_3 (30 November). In case of GA_3 the best (21.42 cm) result is found at G_2:50 ppm and the lowest (19.85 cm) at G_0:0ppm. In amalgamation it was found the best (25.36 cm) combination was T_2G_2 and the lowest (15.41 cm) was found T_3G_0 combination.

The highest Length of primary curd (12.94 cm) was recorded from T_2 (15 November) while the lowest length (9.035 cm) from T_3 (30 November). In case of GA_3 the best (12.44 cm) result is found at G_2:50 ppm and the lowest (9.677 cm) at G_3:75ppm. In amalgamation it was found the best (14.75 cm) combination was T_2G_2 and the lowest (7.897 cm) was found T_3G_3 combination.

The highest diameter of primary curd (41.13 cm) was found from T_2 (15 November), while the lowest diameter (26.93 cm) from T_3 (30 November). On the other hand application of GA_3 the best (39.92 cm) result is found at G_2:50 ppm and the lowest (28.26 cm) at G_3:75ppm. In amalgamation it was found the best (46.24 cm) combination was T_2G_2 and the lowest (17.66 cm) was found T_3G_0 combination.

The maximum weight of primary curd (517.6 g) was found from T_2 (15 November), while the lowest weight (240.0 g) from T_3 (30 November). On the other hand application of GA_3 the best (490.3 g) result is found at G_2:50 ppm and the lowest (276.9 g) at G_3:75ppm. In amalgamation it was found the best (674.0 g) combination was T_2G_2 and the lowest (164.5 g) was found T_3G_3 combination.

The highest number of secondary curd (3.192) was recorded from T_2 (15 November), while the lowest number (2.158) from T_3 (30 November). In case of GA_3 the best (2.957) result is found at G_2:50 ppm and the lowest (2.243) at G_3:75ppm. Besides, in amalgamation it was found the best (3.727) combination was T_2G_2 and the lowest (1.930) was found T_3G_3 combination.

The maximum weight of secondary curd (85.51g) was found from T_2 (15 November), while the lowest weight (59.26 g) from T_3 (30 November). On the other hand application of GA_3 the best (78.24 g) result is found at G_2:50 ppm and the lowest (68.53 g) at G_3:75ppm. In amalgamation it was found the best (90.59 g) combination was T_2G_2 and the lowest (54.75 g) was found T_3G_3 combination.

The highest dry matter content of leaves (9.986%) was recorded from T_2 (15 November) while the lowest (7.750%) from T_3 (30 November). In case of GA_3 the best (9.822%) result is found at G_2:50 ppm and the lowest (8.078%) at G_3:75ppm. In amalgamate effect it was found the best (11.13%) combination was T_2G_2 and the lowest (7.133%) was found T_3G_3combination.

The highest dry matter content of curd (11.37%) was found from T_2 (15 November), while the lowest (7.708%) from (30 November). Whereas foliar application of GA_3 the best (10.79%) result is found at G_2:50 ppm and the lowest (8.186 %) at G_3:75ppm. In amalgamate effect it was found the best (13.03%) combination was T_2G_2 and the lowest (7.033%) was found T_3G_3 combination.

The maximum curd yield (21.81 t ha^{-1}) was found from T_2 (15 November), while the lowest (16.34ton) from T_3 (30 November) per ha. Whereas foliar application of GA_3 the best (21.69 t ha^{-1}) result is found at G_2:50 ppm and the lowest (16.65 ton) at G_3:75ppm. In amalgamate effect it was found the best (24.52 t ha^{-1}) combination was T_2G_2 and the lowest (13.62 t ha^{-1}) was found T_3G_3 combination.

Conclusion

Based on the result of the present research the following conclusion might be drawn:

- The transplanting time (25 DAT) T_2 (15 November) was found the most optimum time to transplant "Broccoli" seedlings which gave the maximum plant height, number of leaves per plant, leaf length, stem length, diameter of stem, percent dry matter of leaf, percent dry matter of curd, number of primary curd per plant, number of secondary curd per plant, weight of primary and secondary curd, and yield.

- The foliar application of GA_3 (Gibberellic acid) gave the best result at G_2 (50ppm) to the morpho-physiological and yield contributing characters of “Broccoli”.

- The transplanting time T_2 (15 November) and the foliar application of GA_3 (Gibberellic acid) at G_2 (50ppm) independently as well as in combination produced the highest yield of “Broccoli”.

Future perspective

Further research in the following areas may be carried out:

- The findings obtained from the present investigation should be confirmed by conducting similar type of research in different agro-ecological zones (AEZ) of Bangladesh.

- It needs to conduct related research work with other GA_3 (Gibberellic acid) concentrations and different transplanting date.

- Information about foliar application of GA_3 (Gibberellic acid) needs to be disseminated to the farmer’s level and adopt in their field for more production of “Broccoli”.

CHAPTER VI

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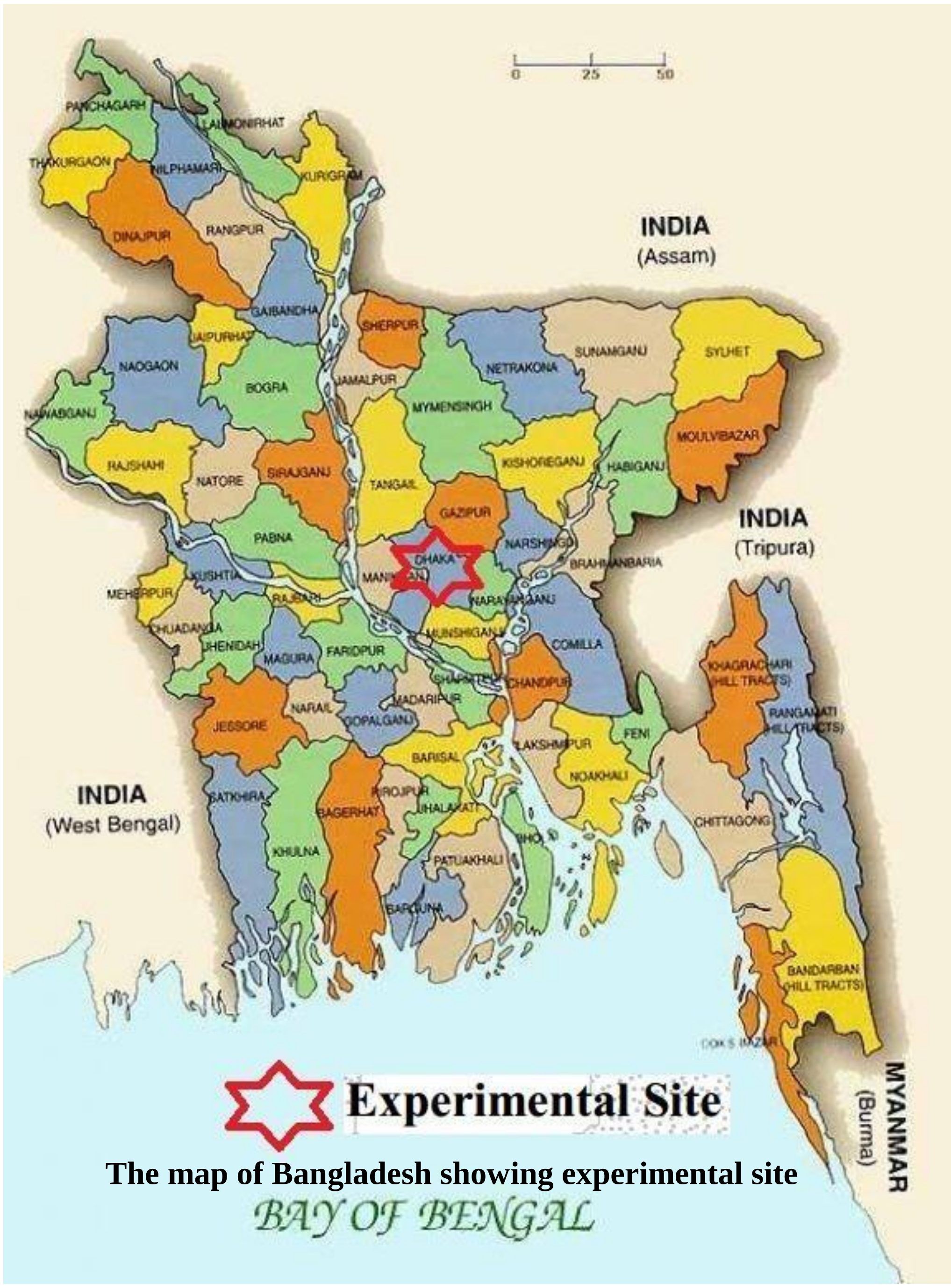
APPENDICES

Appendix I: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207



The map of Bangladesh showing experimental site

Appendix II: Monthly records of meteorological observation at the period of experiment (September, 2016 to June, 2017)

Name of months	Temperature (^0C)		Relative humidity (%)
	Maximum	Minimum	
September, 2016	35	26	82
October, 2016	36	24	73
November, 2016	34	19	71
December, 2016	30	16	68
January, 2017	29	14	59
February, 2016	32	15	51
March, 2016	32	17	64
April, 2016	36	20	72
May, 2016	36	21	71
June, 2016			

Source: Timeanddate.com/weather/bangladesh/dhaka

Appendix III: Morphological characteristics of soil of the experimental plot

Morphological features	Characteristics
Location	Research farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained

Appendix IV. Analysis of variance of the data on plant height of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square of value of plant height at different days after sowing		
		20	40	At harvest
Replication	2	1.019	10.279	9.655
Transplanting time (A)	2	519.06*	287.227*	571.379*
Gibberelic acid (B)	3	129.51*	130.905*	204.851*
Transplanting time (A) X Gibberelic acid (B)	6	1.47*	2.144*	1.597*
Error	22	7.31	9.154	7.482

*Significant at 5% level of significance

Appendix V. Analysis of variance of the data on number of leaf per plants of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square of value number of leaf per plants at different days after sowing		
		20	40	At harvest
Replication	2	1.019	10.279	19.311
Transplanting time (A)	2	519.06*	287.227*	1142.758*
Gibberelic acid (B)	3	129.51*	130.905*	614.552*
Transplanting time (A) X Gibberelic acid (B)	6	1.47*	2.144*	9.583*
Error	22	7.31	9.154	164.595

*Significant at 5% level of significance

Appendix VI. Analysis of variance of the data of longest leaf length of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square of value of longest leaf length (cm)at different days after sowing		
		20	40	At harvest
Replication	2	0.437	0.448	2.547
Transplanting time (A)	2	21.978*	160.398*	233.711*
Gibberelic acid (B)	3	0.992*	12.286*	15.257*
Transplanting time (A) X Gibberelic acid (B)	6	0.036 *	1.305*	0.685*
Error	22	0.158	0.554	0.754

*Significant at 5% level of significance

Appendix VII. Analysis of variance of the data of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square		
		Stem diameter (cm)	Curd diameter (cm)	Curd length (cm)
Replication	2	1.822	0.845	0.521
Transplanting time (A)	2	57.234*	625.455*	45.736*
Gibberelic acid (B)	3	12.982*	228.122*	12.456*
Transplanting time (A) X Gibberelic acid (B)	6	0.477*	9.236*	0.206*
Error	22	0.398	6.224	0.391

*Significant at 5% level of significance

Appendix VIII. Analysis of variance of the data of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square		
		Fresh weight of curd (g))	Dry weight of curd (g)	Dry weight of leaf (g)
Replication	2	1375.262	0.391	0.028
Transplanting time (A)	2	231963.98*	40.294*	15.104*
Gibberelic acid (B)	3	69768.717*	10.984*	5.073*
Transplanting time (A) X Gibberelic acid (B)	6	2678.406*	0.502*	0.131*
Error	22	877.164*	0.213	0.244

*Significant at 5% level of significance

Appendix IX. Analysis of variance of the data of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square		
		Stem length (cm)	Days to 1st visible curd	No. of secondary curds $plant^{-1}$
Replication	2	0.233	6.887	0.007
Transplanting time (A)	2	407.958*	448.887*	3.449*
Gibberelic acid (B)	3	12.266*	117.852*	0.846*
Transplanting time (A) X Gibberelic acid (B)	6	0.504*	13.771*	0.056*
Error	22	10.681	59.353	0.019

*Significant at 5% level of significance

Appendix X. Analysis of variance of the data of broccoli as affected by transplanting time and different levels of gibberelic acid

Source of variation	df	Mean square	
		Weight of secondary curd (g)	Curd yield (t ha^{-1})
Replication	2	10.898	1.543
Transplanting time (A)	2	2145.159*	91.226*
Gibberelic acid (B)	3	153.021*	41.846*
Transplanting time (A) X Gibberelic acid (B)	6	4.867*	0.581*
Error	22	9.228	0.782

*Significant at 5% level of significance