GROWTH AND YIELD OF BROCCOLI AS INFLUENCED BY GIBBERELLIC ACID AND PHOSPHORUS

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CERTIFICATE

This is to certify that the thesis entitled **'Growth and Yield of Broccoli as Influenced by Gibberellic Acid and Phosphorus'** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **TAMANNA AFRIN**, Registration No. **07-02313** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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ABSTRACT

The experiment was conducted in the Horticulture Farm, Shar-e-Bangla Agricultural University, Dhaka during October 2012 to March 2013. The experiment consisted of two factors, such as Factor A: Three levels of Gibberellic acid (GA_3) i.e. G_0: 0 (control); G_1: 60 ppm GA_3 and G_2: 90 ppm GA_3, respectively and Factor B: Four levels of phosphorus i.e. P_0: 0 (control); P_1: 120; P_2: 140 and P_3: 160 kg P_2O_5/ha. The experiment was laid out in Randomized Complete Block Design with three replications. Gibberellic acid and phosphorus fertilizer influenced significantly on most of the parameters. In case of GA_3, the highest curd yield (20.64 t/ha) was found from G_1 and the lowest curd yield (18.21 t/ha) was found from G_0. For phosphorous, P_2 performed the highest curd yield (21.52 t/ha) and the lowest (16.18 t/ha) was from P_0. For combined effect, the highest curd yield (23.57 t/ha) was obtained from G_1P_2 and the lowest curd yield (16.25 t/ha) from G_0P_0. So, 60 ppm GA_3 with 140 kg P_2O_5/ha was the best for growth and yield of broccoli.

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CHAPTER I

INTRODUCTION

Sprouting Broccoli *(Brassica oleracea* var. italica) commonly known as broccoli is an important winter season vegetable crop, which resembles cauliflower. Broccoli is a member of the Brassicaceae family as a wild form of this family, which is found along the Mediterranean region (Decoteau, 2000). It originated from west Europe (Prasad and Kumar, 1999). It is one of the non-traditional and relatively new “Cole” crops in Bangladesh. Plants from Brassicaceae family are mostly native to Europe, Middle East and Asia. Cole crops are the most widely grown vegetables in the temperate zones. After the Second World War they have spread rapidly to both tropical and sub tropical areas and it has increased in Africa by 13.5% and in Asia by 8.9% from 1970 to 1980. Broccoli is a minor vegetable in Bangladesh but is one of the important cole crops in Europe and USA and it is a commercial crop in India (Tindall, 1983 and Nonnecke, 1989).

At present broccoli is widely cultivated in Europe, America and most of the Asian countries including Bangladesh. In western countries broccoli is highly popular as fresh as well as frozen vegetables. In Bangladesh broccoli was introduced about two decades ago. Unlike cauliflower, broccoli produces smaller flowering shoots (secondary curds) from the leaf axils after harvest of main apical curds which are also edible. Broccoli can be harvested for a wide period of time than cauliflower (Thompson and Kelly, 1988). Broccoli is an Italian vegetable; however, due to increase in its popularity, there is a trend to increase cultivation by farmers, as well as consumption by consumers. Broccoli is an important vegetable crop and has high nutritional and good commercial value (Yoldas *et al*., 2008). Broccoli attracted more attention due to its multifarious use and great nutritional value (Salunkhe and Kadam, 1998; Talalay and Fahey, 2001; Rangkadilok *et al*., 2004). The plants form a kind of head consisting of green buds and thick fleshy flower stalk. The terminal head rather loose, green in color and the flower stalks are longer than cauliflower (Bose *et al*., 2002).

As a newly introduced crop the average yield of broccoli is low in Bangladesh compared to other countries like and the low yield of this crop however is not an indication of low yielding potentiality of this crop. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among different factors plant growth regulators and phosphorus fertilizer can play an important role for increasing the production of broccoli in Bangladesh (Manjit Singh, *et al.*, 2011).

Plant growth regulators (PGRs) are organic compounds which are capable of modifying growth. It plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). Many reports so far been made to indicate a promising results on yield and quality of broccoli and other crops due to the use of bio-chemical substances, such as Napthaline acetic acid (NAA), Gibberelic acid (GA_3), Indole acetic acid (IAA) etc. (Voronova and Kozakov, 1983; Senthelhas *et al.*, 1987; Tadzhiryan, 1990; Tomar *et al*., 1991). In addition it is generally accepted that a biochemical processes are affected by a single chemical or a mixture of chemicals is not only different for between species but also for cultivars within the species and due to climatic regions. However, recently done preliminary trials indicate possibility of yields increase of broccoli in Bangladesh with the use of biochemical (Islam *et al*., 1993; Biswas and Mondal, 1994). Plant height, curd formation and curd size of curd can be increased with foliar application of plant growth regulators. GA_3 have a positive role on curd formation and curd size of broccoli (Sharma and Mishra, 1989). Application of GA_3 stimulates morphological characters like plant height, number of leaves, curd diameter, thickness of curd as well as the weight of the curd. The concentrations of these chemicals interacting with the environmental conditions play an important role in modifying the growth and yield components of broccoli. Application of GA_3 at 100 ppm produced the tallest plants, the largest curds and highest curd yields (Vijay and Ray, 2000).

Deficiency of soil nutrient is now considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). The cultivation of vegetable crops requires proper supply of plant nutrient. Cauliflower responds greatly to major essential elements like N, P and K for its growth and yield (Thompson and Kelly, 1988). Broccoli is a short duration crop, for that easily soluble fertilizer like as phosphorus. Phosphorus is also one of the important essential macro elements for the normal growth and development of plant. The phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Phosphorus shortage restricted the plant growth and remains immature (Hossain, 1990). Again secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al*., 2004). On the other hand nutrient availability in a soil depends on some factors, among them balance fertilizer is the important one. The optimum proportion of fertilizer enhances the growth and development of a crop as well as ensures the availability of other essential nutrients for the plant.

Under the present situation the present study was conducted to investigate the effect of GA_3 and phosphorus on broccoli with the following objectives-

- To find out the optimum concentration of GA_3 for better growth and yield of broccoli;
- To find out the optimum level of phosphorus for better growth and yield of broccoli; and
- To find out the suitable combination of GA_3 and phosphorus for ensuring the maximum growth, yield and economic return from broccoli cultivation.

CHAPTER II

REVIEW OF LITERATURE

Broccoli is one of the non-traditional and relatively new "Cole" crops in Bangladesh. The demand of vegetable is increasing day by day in our country and horizontal expansion of vegetable yield unit^{-1} area should be increased to meet this ever-increasing demand of vegetable but it will require adoption of new technology such as high management package, high yielding cultivar, higher input use etc. Management practices have considerable effects on the growth and development of any crop particularly vegetable crops. Among these, growth regulator is a modern concept as a management practices and fertilizer is a most important and common practices and both are also important factors. Numerous studies have been performed evaluating the influence of GA_3 as growth regulators and phosphorus on the performance of broccoli. But research works related to GA_3 and phosphorous on broccoli are limited in Bangladesh context. However, some of the important and informative works and research findings related to GA_3 and phosphorous on broccoli and other crops so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Influence of GA_3 on crop growth and yield

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

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

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

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

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

Nidhi-Arora *et al.* (1997) conducted an experiment with Seeds of cauliflower (Brassica oleracea var. botrytis) cultivars Snowball 16 and Hisar 1 were cultured on MS medium without growth regulators, and cotyledons of resulting 5 to 6-day-old seedlings were cultured on 6 different modified MS media. Of the BAP [benzyladenine] concentrations, 2.0 mg/litre was best for shoot regeneration. Addition of IAA (0.1 mg/litre) in combination with BAP (1.0, 2.0 and 5.0 mg/litre) showed that shoot regeneration was maximum at 0.1 mg IAA + 1.0 mg BAP/litre. The two cultivars differed significantly for percentage regeneration and Snowball 16 responded the best to in vitro culture.

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

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

Islam *et al.* (1993) determined the effective concentration of NAA and GA_3 for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and GA_3 and applied in three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days of transplanting. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm GA_3 was suitable both for higher yield and ascorbic acid content of cabbage.

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

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

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

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

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

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

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

Abdalla *et al*. (1980) conducted an experiment with cauliflower varieties and the plants were treated with different concentration of IBA (5-40 ppm), GA_3 (10-80 ppm) or NAA (120-160 ppm) 4 weeks after twice more at fortnightly intervals. NAA at 160 ppm gave the best result with regard to curd diameter, weight and color. Similar results were obtained from plants treated with GA_3 at 80 ppm and NAA at 40 ppm.

2.2 Influence of phosphorus fertilizer on crop growth and yield

Zhang *et al*. (2007) conducted an experiment at Nanjing Agricultural University in China to study the effects of balanced application of nitrogen, phosphorous and potassium fertilizers on the growth and yield of broccoli. Treatments comprised: 0:0:0. 159.13:106.46:160.04, 348.81: 99.27: 160.08 and 371.35: 102.66: 172.04 kg N, P_2O_5 and K_2O, respectively. The growth and yield of broccoli showed marked improvement with the application of 160.08 and 371.35: 102.66: 172.04 kg N, P_2O_5 and K_2O, respectively.

An experiment was undertaken by Brahma *et al*. (2006) at Assam Agicultural University in India during rabi season to study the effect of nitrogen, phosphorous and potassium on growth and yield of broccoli cv. Pusa Broccoli KTS-1. Treatments comprised 0:0:0, 50:30:20, 100:60:40, 150:90:60 and 200:120:80 kg NPK/ha. The growth and yield of broccoli showed marked improvement with the application of 200:120:80 kg NPK/ha.

Singh (2004) conducted a field experiment to evaluate the growth and yield of cauliflower cv. Snowball-16 under different N and P levels (0, 60, 80 and 100 kg/ha). Increasing P levels advanced curd initiation and maturity and increased plant height, leaf length, lead width, curd diameter, curd depth, net curd weight and marketable curd yield. There were no significant differences between between 80 and 100 kg P/ha. Application of 80 kg P/ha recorded the highest values for number of leaves per plant (19.44), curd diameter (16.42 cm), curd depth (10 cm), net curd weight (740.38 g), curd solidity (66.84 g/cm) and marketable curd yield (236.92 q/ha) as well as the highest net returns (Rs.101060/ha) and benefit cost ratio (6.81).

Brahma *et al.* (2002) conducted an experiment at Assam Agricultural University in India during rabi season to study the effect of nitrogen, phosphorus and potassium on growth and yield of broccoli cv. Pusa Broccoli KTS-1. Treatments comprised: 0:0:0, 50:30:20, 100:60:40, 150:90:60 and 200:120:80 kg NPK/ha. The growth and yield of broccoli showed marked improvement with the application of 200:120:80 kg NPK/ha.

Sharma *et al*. (2002) were conducted an experiment and find out the response of sprouting broccoli 'Green head' to different levels of N and P (30, 60 and 90 kg P_2O_5 /ha). They were found P are applied alone, maximum values with respects to plant height, plant frame, head size, head yield/plant and per hectare were obtained at 60 kgP_2O_5/ha respectively.

Pardeep-Kumar *et al.* (2001) conducted an experiment on performance of different broccoli cultivars (Green Head, Palam Samridhi, DPGB 12 and American Selection) under different N, P and K rates (0, 0 and 0; 60, 45 and 15 kg/ha; 90, 60 and 30 kg/ha; 120, 75 and 45 kg/ha and 150, 90 and 60 kg/ha, respectively) in India. The maximum values for growth, yield and quality characteristics were obtained at the highest N, P and K levels (150, 90 and 60 kg/ha, respectively).

Three field experiments were conducted with broccoli on clay loam to clay soils. In the first two experiments, N was applied at 0-400 kg/ha in split application (20% at planting, 40% at 30 DAT and 40 at 45 DAT) together with 80 kg P_2O_5/ha and 300 kg K_2O/ha during transplanting. In the third experiment, N and K were injected into the drip irrigation system as determined by the demand curve and P was applied at planting. In the third experiment, marketable yields were the highest (24.5 t/ha) at 400 kg N/ha. (Castellanos *et al*., 1999)

Sumiati (1998) stated that seedlings of broccoli cultivars Green King and Mikado were transplanted into Jiffy pots or into a mixture of stable manure and soil supplemented or not supplemented with NPK compound fertilizer (15:15:15) and/or Metalik. There were differences between cultivars in plant height, root length, LAI, NAR and RGR at 2, 3 or 4 weeks after transplanting. These factors were all highest at all stages in plants grown in manures + soil supplement with NPK+ Metallic and were generally lowest in plants grown in jiffy pots.

Ying *et al*. (1997) conducted a pot experiment to determine the effect of N P and K on yield and quality of broccoli. Additive effects were observed on yield and vitamin C (ascorbic acid) content when K was applied together with N or N + P. Application of N + P gave 110.8% higher yields than N alone. Significant positive correlations were found between yield and dry weight of leaves and plant size. They also suggested that N, P and K application should be balanced to obtain high yields and quality of broccoli.

Everates *et al.* (1997) stated that application of a single dose of 260 kg N/ha (minus the amount of mineral N present in the top 0.60 cm layer of soil) by row application at the time of planting gave superior results. A high-yield crop uptook 200-250 kg N, 30 kg P and up to 250 kg K/ha.

Lu *et al.* (1997) reported that nutrient absorption and dry matter accumulation of broccoli cultivars Green Valiant, Yuguan and Xinzengyanshui grown under routine fields fertilization. Amounts of N, P, K, Ca and Mg were absorbed for every 1000 kg of broccoli heads were 15.45-20.60, 1.45-2.51, 8.98-10.87, 7.32-9.48 and 1.65-2.40 kg respectively.

A close relationship existed between the texture and quality of the head and N, P and K nutrition. Rational application of nitrogen and potash fertilizers regulated the absorption of N, P and K by plants, promoted nitrate accumulation in leaves and spears, and increased spear yields. (Yang and Guan, 1995)

Steffen *et al*. (1994) observed the effect organic matter (spent mushroom compost at 64 mt/ha + rotten cattle manure at 57 mt/ha) applied in spring on growth and yield of broccoli. No fertilizer or other amendments were added to previously amended treatments, but 100% recommended NPK be added to all control treatments. Broccoli yield and head diameter were greater in the amended treatment.

Simoes *et al*. (1993) investigated the effect of container size and substrate on growth and yield of broccoli in nursery and in field. It was found that containers of 21-31 mm wide and 71-75 mm deep, in combination with rich substrates (180-210 mg N, 120-240 mg P_2O_5 and 220-270 mg K_2O litre) produced the best result.

Magnifico *et al*. (1993) conducted a field trial on a silty clay soil at Policoro with broccoli, spinach, snap beans and pickling cucumbers grown in rotation comparing 12 NPK fertilizer rates and 3 herbicides (for each crop). Trifluralin, Chlorthal [-dimethyl] and Nitrofen were used on broccoli; Lenacil, Cyclote and Chlorbufam+Cycluron were applied on spinach; Trifluralin, Alachlor and Nitrofen were applied on snap beans; and Trifuralin, chlorthal and Asulam were applied on cucumbers. Over the 5 years, 17 crops were grown: 4 of broccoli, 3 of spinach, 5 of snap beans and 5 of cucumber. An average of 94 days were needed for broccoli, 85 for spinach, 65 for beans and 58 for cucumber, a total of 302 days/year. The effects of sowing/transplanting dates and harvesting and the residual effects of herbicides were examined. Yields of each species varied widely and were mainly influenced by fertilizer rates and not herbicides. Cucumber was the only crop to show phytotoxicity from herbicides used earlier on spinach. It was concluded that this intensive system could not be recommended to farmers since it required very careful planning and yields depended on a number of contingencies.

Bracy *et al*. (1992) conducted an experiment on direct-sown broccoli cv. Early dawn and the effects of pre-planting NPK fertilizer at a rate of 45 kg N+59 kg P +112 kg P and 90 kg N + 118 kg P +224 kg K /ha plus side dressed N fertilizer at 134, 196 or 258 kg/ha, either dropped onto or knifed into the bed were determined. The marketable yield, early yield, head weight and percentage of early to total yield were unaffected by fertilizer rate or method of application.

Mitra *et al*. (1990) obtained a yield of 51.5 tones broccoli/ha by applying nitrogen, phosphorus and potassium at the rate of 100, 50 and 50 kg/ha, respectively, compared with 33.5 tones/ha with 50 kg N, 25 kg P and 25 kg K/ha. They also reported that broccoli cv. Appollo produced average individual head weight of 0.87 lb by the application of N, P and K at the rate of 300, 100 and 150 kg/ha, respectively.

Magnifico *et al*. (1989) reported the growth and accumulation of macro and microelements in various stages of the cultural cycle of 2 cultivars of broccoli in Southern Italy. Plant samples were obtained every 2 weeks beginning at the time of thinning and contenting for 112 and 126 days, respectively, for cultivars Di Gennaio and Di Marzo. Despite the different cultural cycle, the cultivars were similar in yield and element uptake. On a per hectare basis the plants removed about 460 kg N, 140 kg P_2O_5, 692 kg K_2O, 330 kg Ca, 75 kg Na, and 42 kg Mg. Microelement removal by Di Gennaio was 77 kg S, 20 kg Al, 12 kg Fe, 1 kg Mn, 479g Zn, 443 g Sr, 411 g B, 72 g Cu, 26 g Mo, 23 g Ni, and 20 g Ca. Total growth averaged 136-t/ha fresh materials, which included 14 t/ha of main heads, 28t/ha of secondary heads, and 14-t/ha dry matters. The highest removal rates were recorded from flower stem emission to main head production.

Dufault (1988) studied nitrogen and phosphorus requirements of greenhouse broccoli cv. Southern Comet and showed that increasing N rates increased head fresh weight, stem diameter, floret total chlorophyll, root and top dry weight (stem, petiole, leaf, and head), plant height, and head quality, and decreased days to heading and harvest. For quality broccoli production in greenhouse, 5.6 g N, 0.21 g P and 1.6 g K per 15-liter pot were required.

Balyan *et al.* (1988) conducted an experiment on cauliflower of five levels of N, two levels of P (0 and 50kg P_2O_5/ha) and four levels of zinc. It was found phosphorus also improved number of leaves per plant and leaf size area index at 50kg P_2O_5/ha. Interaction effect of these nutrients was found significant on marketable yield. Maximum yield was obtained at 160 kg N, 50 kg P_2O_5 and 20 kg $Znso_4$/ha.

Karim *et al*. (1987) studied the response of cauliflower to NPK fertilizer at different levels of irrigations. Five irrigations along with higher doses of fertilizers (N_{150}, P_{113}, K_{180}) produced the tallest plants (47.5 cm), maximum number of leaves (34.5/plant) and the heaviest curd (1070) g/plant).

Burghad and Ellering (1986) observed that under sub-optimal total nutrient suplly, a foliar fertilizer (12N: 4P: 6K) at concentrations up to 15% was tolerated, without leaf damage by dwarf beans, carrots, beetroots, endives, broccoli, leeks and white cabbages. These concentrations were equivalent to 100 kg N/ha. Plant development and leaf color improved and yields increased by 12 to 74%.

A fertilizer experiment was carried out on growth and nutrient removed by broccoli in the United States of America and found that broccoli plants removed 559 kg N, 23 kg P_2O_5, and 723 kg K_2O/ha. The total yields of broccoli were 148,400 kg/ha as a fresh materials and 16,900 kg/ha of dry matter content (Magnifico *et al.*, 1979).

Munro *et al.* (1978) conducted an experiment on broccoli and Brussels sprouts and analyzed the leaf tissue of broccoli cv. Waltham 29 and Brussels sprouts, cv. Jode Cross during the growing season. Plants were fertilized with 4 levels of N, P and K in factorial combination with and without Farm Yard Manure (FYM). Growth responses to applied N and P tended to lower tissue K levels for broccoli. FYM had little effect on tissue N and only small effects on tissue P and K. Concentrations of all three nutrients declined during the growing season. Critical N, P and K levels for plants growth were within the ranges of 5.2-6.0% N, 0.35-0.60 P and 1.7-2.2% K.

Cuteliffe and Munro (1976) conducted an experiment to see the effect of N, P and K on cauliflower cv. Snowball. They found that yields were substantially increased by the application of N and P but only slightly affected by applied K.

Maturity was slightly delayed by lack of P. Maximum yields were generally obtained where N was applied at 112-224 kg/ha, P_2O_5 at 49-98 kg/ha and K_2O at 93 kg /ha.

Borna (1976) conducted an experiment to study the effect of N, P_2O_5 and K_2O on cabbage, cauliflower broccoli, onions, leeks, carrots, parsley, celery, cucumber and tomatoes with different levels of fertilizers. He observed that fertilization and irrigation and their interactions had greater effects on marketable yield than total yield.

Kaniszewski and Jagoda (1975) conducted an experiment on the effect of increasing rates of mineral fertilizer and spacing on broccoli yields. They applied N, P_2O_5 and K_2O at the rates of 300, 600 and 900 kg/ha, respectively, and the plants were spaced at 50 × 50 cm and 50 × 70 cm. The highest NPK rates gave the best results. The highest yield per plant was obtained from wider spacing but the highest yields per hectare were obtained from closer spacing.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out growth and yield of broccoli as influenced by gibberellic acid and phosphorus. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental plot, materials used for the experiment, design of the experiment, data collection procedure and procedure of data analysis.

3.1 Description of the experimental site

3.1.1 Experimental period

The present experiment was conducted within the time period of October 2012 to March 2013.

3.1.2 Description of experimental site

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

3.1.3 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (31.4^{0}C) was recorded in the month of March 2013 while the minimum temperature (12.4^{0}C) in the month of January 2013. The highest humidity (81%) was recorded in the month of October, 2012, whereas the highest rainfall (30 mm) was recorded in the month of February 2013.

3.1.4 Characteristics of soil

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

3.2 Experimental details

3.2.1 Planting materials

The seed of broccoli (*Brassica oleracea var. italica*) cv. *Premium* crop was used as planting materials for this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

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

- i G_0: 0 ppm GA_3 (control)
- ii. G_1: 60 ppm GA_3
- iii. G_2: 90 ppm GA_3

Factor B: Phosphorus fertilizer (four levels) as

- i. P_0: 0 kg P_2O_5/ha (control)
- ii. P_1: 120 kg P_2O_5/ha
- iii. P_2: 140 kg P_2O_5/ha
- iv. P_3: 160 kg P_2O_5/ha

There were 12 (3 × 4) treatments combination such as G_0P_0, G_0P_1, G_0P_2, G_0P_3, G_1P_0, G_1P_1, G_1P_2, G_1P_3, G_2P_0, G_2P_1, G_2P_2 and G_2P_3.

3.2.3 Design and layout of the experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 299.04 m^2 with length 26.7 m and width 11.2 m. The total area was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were allotted at random. There were 36 unit plots and the size of each plot was 2.4 m × 1.6 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.2.4 Preparation of the main field

The selected plot of the experiment was opened in the 2^{nd} week of November 2012 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

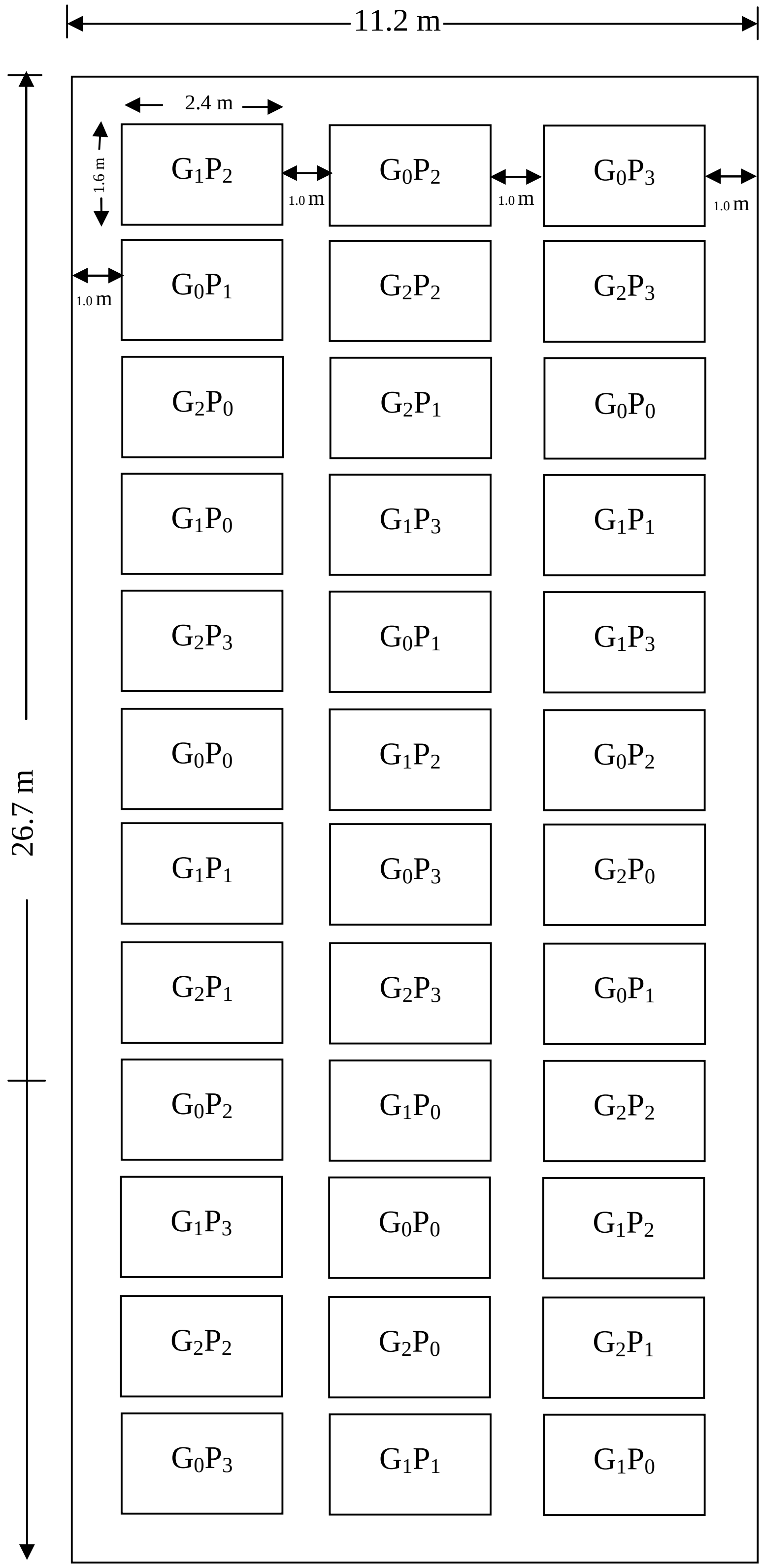
3.2.5 Application of manure and fertilizers

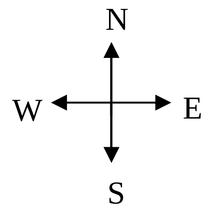
Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of broccoli.

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

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

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





Plot size: 2.4 m × 1.6 m

Plot spacing: 0.50 m

Between block: 1.00 m

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

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

Factor B: Phosphorus fertilizer (four levels) as

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_3: 160 kg P_2O_5/ha

3.2.6 Collection, preparation and application of growth regulator

Plant growth regulator Gibberellic Acid (GA_3) was collected from Hatkhola Road, Dhaka. A 1000 ppm stock solution of GA_3 was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 60 ml of this stock solution was diluted in 1 litre of distilled water to get 60 ppm GA_3 solution. In a similar way, 90 ppm stock solutions were diluted to 1 litre of distilled water to get 90 ppm solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. GA_3 as per treatment were applied at four times 15, 30 and 45, 60 days after transplanting by a mini hand sprayer.

3.3 Growing of crops

3.3.1 Collection of seeds

The seed of broccoli *Brassica oleracea* var. *italica* cv. *Premium* crop was collected from Siddique Bazar market, Dhaka.

3.3.2 Raising of seedlings

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 3 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in seedbed on October 25, 2012. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth.

3.3.3 Transplanting

Healthy and uniform seedlings of 30 days old seedlings were transplanting in the experimental plots on 24 November, 2012. The seedlings were uploaded carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row was 60 cm and plant to plant was 40 cm. As a result there are 16 seedlings were accommodated in each plot according to the design of the plot size at 2.4 m × 1.6 m. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.3.4 Intercultural operation

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

3.3.4.1 Gap filling

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

3.3.4.2 Weeding

The hand weeding was done 15, 30 and 45, 60 days after transplanting to keep the plots free from weeds.

3.3.4.3 Earthing up

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

3.3.4.4 Irrigation

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

3.3.4.5 Pest and disease control

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

3.4 Harvesting

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

3.5 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth; yield attributes and yields as affected by different treatments of this experiment. Data on plant height, number of leaves and length of largest leaf were collected at 25, 35, 45 and 55 days after transplanting (DAT) and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.5.1 Plant height

Plant height was measured from sample plants by using meter scale in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 10 days interval starting from 25 days after transplanting (DAT) and continued upto 55 DAT to observe the growth rate of plants.

3.15.2 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 25 DAT and continued upto 55 DAT.

3.15.3 Length of largest leaf

The length of largest leaf was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 25 DAT and continued upto 55 DAT.

3.15.4 Days required from transplanting to harvest

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

3.5.5 Length of stem

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

3.5.6 Diameter of stem

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

3.5.7 Fresh weight of leaves per plant

The fresh weight of leaves per plant was recorded from the average of five (5) selected plants in grams (gm) with a beam balance during harvest after detached from curd of broccoli and roots.

3.15.8 Dry matter content of leaves

At first leaf of selected plant were collected, cut into pieces and was dried under sunshine for a 3 days and then dried in an oven at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of leaves were computed by simple calculation from the weight recorded by the following formula:

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

3.5.9 Weight of primary curd

The curds from sample plants were harvested, cleaned and weighted. The weight of every primary curd were weighted by weighing machine and mean values was counted.

3.5.10 Diameter of primary curd

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

3.5.11 Number of secondary curd per plant

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

3.5.12 Weight of secondary curd

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

3.5.13 Curd yield per plant

After harvest primary and secondary curd from selected plants from each unit plot the leaves were removed from the curd and weighted by a weighing machine and recorded the weight of curd as per plant. The average weight was calculated per plant and recorded.

3.5.14 Curd yield per plot

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

3.5.15 Curd yield per hectare

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

3.6 Statistical analysis

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

3.7 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different levels of GA_3 and phosphorus. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. The market price of broccoli was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to study the growth and yield of broccoli as influenced by different level of GA_3 and phosphorus. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices III-VII. The findings of the experiment 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

Plant height of broccoli showed statistically significant variation due to different levels of GA_3 at 25, 35, 45, 55 DAT and at harvest (Appendix III). At 25, 35, 45, 55 DAT and at harvest, the tallest plant (20.46, 40.20, 57.47, 72.50 and 75.78 cm, respectively) was recorded from G_1 (60 ppm GA_3) which was statistically similar (20.22, 38.74, 57.19, 71.21 and 75.05 cm, respectively) to G_2 (90 ppm GA_3) and the shortest plant (19.33, 37.58, 55.12, 67.95 and 71.79 cm, respectively) was recorded from G_0 (control, i.e. 0 ppm GA_3) at 25, 35, 45, 55 DAT and at harvest, respectively (Figure 2). Sharma and Mishra (1989) reported that plant height increased with foliar application of GA_3.

Statistically significant variation was recorded for different levels of phosphorus in terms of plant height of broccoli at 25, 35, 45, 55 DAT and at harvest (Appendix III). At 25, 35, 45, 55 DAT and at harvest, the tallest plant (20.76, 39.65, 58.65, 72.80 and 76.54 cm, respectively) was recorded from P_2 (140 kg P_2O_5) which was statistically similar (20.13, 39.51, 57.37, 71.06 and 75.92 cm, respectively) to P_3 (160 kg P_2O_5), whereas the shortest plant (19.22, 37.16, 53.64, 67.67 and 69.56 cm, respectively) was recorded from P_0 (0 kg P_2O_5 i.e. control) (Figure 3). Bose and Som, 1986 reported that optimum level of phosphorus ensured the longest plant. Singh (2004) also reported that application of phosphetic fertilizers increase the plant height.

Due to combined effect of different concentrations of GA_3 and phosphorus significant variation was recorded on plant height of broccoli at 25, 35, 45, 55 DAT and at harvest (Appendix III). At 25, 35, 45, 55 DAT and at harvest, the tallest plant (23.98, 44.46, 64.77, 78.57 and 82.76 cm, respectively) was obtained from G_1P_2 (60 ppm GA_3 + 140 kg P_2O_5), while the shortest plant (19.89, 38.68, 56.27, 65.70 and 68.37 cm, respectively) from G_0P_0 (0 ppm GA_3 + 0 kg P_2O_5/ha) treatment combination (Table 2)

4.2 Number of leaves per plant

Significant variation was recorded on number of leaves per plant due to different concentrations of GA_3 at 25, 35, 45, 55 DAT and at harvest (Appendix IV). At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (8.66, 13.58, 18.00, 23.03 and 23.54) was found from G_1 which was closely followed (7.23, 13.05, 16.42, 20.47 and 21.52) by G_2, whereas, the minimum number (7.70, 12.23, 14.83, 17.20 and 19.70) from G_0 at 25, 35, 45, 55 DAT and at harvest, respectively (Table 3). Lendve *et al*. (2010) found that application of GA_3 50 ppm was found significantly superior in terms of number of the leaves.

Different levels of phosphorus showed significant variation on number of leaves per plant of broccoli at 25, 35, 45, 55 DAT and at harvest (Appendix IV). At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (7.47, 14.04, 17.22, 22.11 and 22.90) was counted from P_2 which was statistically similar (7.40, 13.56, 16.73, 21.67 and 22.43) to P_3 and closely followed (6.93, 13.27, 16.38, 19.22 and 21.22) by P_1, while the minimum number (6.46, 11.09, 15.33, 17.93 and 19.28) from P_0 (Table 3). Brahma *et al*. (2006) growth of broccoli showed marked improvement with the application of 120 kg P/ha. Singh (2004) also found similar trend of results of his study.

Due to the combined effect of GA_3 and phosphorus significant differences was recorded on number of leaves per plant of broccoli at 25, 35, 45, 55 DAT and at harvest (Appendix IV). At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (8.88, 15.40, 19.93, 26.13 and 26.89) was recorded from G_1P_2 and the minimum number (7.08, 10.60, 13.47, 14.93 and 19.49) from G_0P_0 at the same date of observations (Table 4).

Table 2. Combined effect of different levels of GA_3 and phosphorus on plant height of broccoli

Treatment	Plant height (cm) at				
	25 DAT	35 DAT	45 DAT	55 DAT	Harvest
G_0P_0	19.89 d	38.68 c	56.29 d	65.70 c	68.37 c
G_0P_1	21.53 bc	39.67 bc	58.67 bcd	71.40 bc	76.80 ab
G_0P_2	20.72 cd	39.65 bc	58.71 bcd	70.59 bc	76.06 ab
G_0P_3	21.84 bc	39.88 bc	59.91 bcd	72.21 abc	78.69 ab
G_1P_0	21.34 bcd	39.97 bc	57.12 cd	72.58 ab	75.86 ab
G_1P_1	21.70 bc	42.38 ab	61.00 abc	73.51 ab	78.55 ab
G_1P_2	23.98 a	44.46 a	64.77 a	78.57 a	82.76 a
G_1P_3	21.49 bc	41.56 abc	60.09 bcd	73.45 ab	78.67 ab
G_2P_0	21.45 bc	38.51 c	57.33 cd	70.83 bc	73.98 bc
G_2P_1	21.47 bc	40.77 bc	60.33 bcd	73.19 ab	78.63 ab
G_2P_2	22.60 b	40.49 bc	62.28 ab	75.35 ab	80.33 ab
G_2P_3	22.07 bc	42.75 ab	61.94 ab	73.60 ab	79.99 ab
$LSD_{(0.05)}$	1.386	2.784	3.850	5.923	6.182
Level of significance	*	*	*	*	**
CV(%)	8.48	9.01	9.20	8.38	7.90

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance; * 5% level of significance

Table 3. Effect of different levels of GA_3 and phosphorus on number of leaves per plant of broccoli

Treatment	Number of leaves/plant at				
	25 DAT	35 DAT	45 DAT	55 DAT	Harvest
Levels of GA_3					
G_0	7.70 c	12.23 c	14.83 c	17.20 c	19.70 c
G_1	8.66 a	13.58 a	18.00 a	23.03 a	23.54 a
G_2	8.46 b	13.05 b	16.42 b	20.47 b	21.52 b
$LSD_{(0.05)}$	0.186	0.445	0.933	1.137	1.434
Level of significance	**	**	**	**	**
Levels of phosphorous					
P_0	6.46 c	11.09 c	15.33 b	17.93 b	19.28 b
P_1	6.93 b	13.27 b	16.38 ab	19.22 b	21.22 b
P_2	7.47 a	14.04 a	17.22 a	22.11 a	22.90 a
P_3	7.40 a	13.56 a	16.73 a	21.67 a	22.43 a
$LSD_{(0.05)}$	0.214	0.514	1.077	1.313	1.656
Level of significance	**	**	**	**	**
CV(%)	6.03	4.06	6.71	6.64	9.93

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance;

Table 4. Combined effect of different levels of GA_3 and phosphorus on number of leaves per plant of broccoli

Treatment	Number of leaves/plant at				
	25 DAT	35 DAT	45 DAT	55 DAT	Harvest
G_0P_0	7.08 d	10.60 h	13.47 e	14.93 h	19.49 d
G_0P_1	7.35 cd	13.13 cde	15.67 cd	17.07 gh	21.09 cd
G_0P_2	7.62 c	12.20 ef	14.73 de	17.53 fg	21.02 cd
G_0P_3	7.63 c	13.00 de	15.47cd	19.27 efg	22.89 bcd
G_1P_0	7.75 c	11.73 fg	16.87 bc	21.27 cde	22.62 bcd
G_1P_1	8.15 b	13.20 cd	17.07 bc	21.00 cde	24.82 ab
G_1P_2	8.88 a	15.40 a	19.93 a	26.13 a	26.89 a
G_1P_3	8.75 a	14.00 bc	18.13 ab	23.73 b	25.29 ab
G_2P_0	7.38 cd	10.93 gh	15.67 cd	17.60 fg	19.89 d
G_2P_1	8.15 b	13.47 cd	16.40 bcd	19.60 def	23.22 bc
G_2P_2	8.76 a	14.53 ab	17.00 bc	22.67 bc	24.96 ab
G_2P_3	8.68 a	13.27 cd	16.60 bcd	22.00 bcd	23.49 bc
$LSD_{(0.05)}$	0.371	0.890	1.865	2.275	2.868
Level of significance	*	**	*	*	**
CV(%)	6.03	4.06	6.71	6.64	9.93

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance; * 5% level of significance

4.3 Length of largest leaf

Significant variation was recorded on length of largest leaf of broccoli due to use of different levels of GA_3 at 25, 35, 45, 55 DAT and at harvest (Appendix V). At 25, 35, 45, 55 DAT and at harvest, the longest leaf (23.70, 38.12, 45.83, 54.28 and 58.70 cm, respectively) was recorded from G_1 which was statistically similar (22.59, 37.37, 43.79, 53.85 and 55.93 cm, respectively) to G_2, whereas the shortest leaf (19.60, 30.55, 35.70, 46.29 and 51.82 cm, respectively) was obtained from G_0 (Figure 4).

Different levels of phosphorus varied significantly on length of largest leaf at 25, 35, 45, 55 DAT and at harvest (Appendix V). At 20, 30, 40, 50 DAT and at harvest, the longest leaf (23.98, 38.66, 45.49, 54.81 and 59.47 cm, respectively) was found from P_2 which was statistically similar (23.20, 37.44, 44.35, 53.46 and 57.97 cm, respectively) with P_3 and the shortest leaf (19.52, 30.59, 33.55, 46.60 and 49.31 cm, respectively) from P_0 (Figure 5). Phosphorus is one of the important essential macro elements for growth and development of plant (Bose and Som, 1986). Dufault (1988) got same trends of results of his study.

Combined effect of different levels of GA_3 and phosphorus showed significant differences on length of largest leaf of broccoli at 25, 35, 45, 55 DAT and at harvest (Table 4 and Appendix V). At 25, 35, 45, 55 DAT and at harvest, the longest leaf (27.17, 46.83, 56.00, 61.03 and 67.03 cm, respectively) was obtained from G_1P_2 and the shortest leaf (18.67, 27.14, 32.62, 40.58 and 45.74 cm, respectively) from G_0P_0 i.e. control treatment combination (Table 5).

4.4 Days required from transplanting to harvest

Significant variation was recorded for days required from transplanting to harvest of broccoli due to different levels of GA_3 (Appendix VI). The control treatment (G_0) took the highest (62.80 days) from transplanting to harvest which was statistically similar (61.47 days) to G_2, while the lowest (59.55 days) was required from transplanting to harvest from G_1 (Table 6). Lendve *et al*. (2010) reported that 75 ppm GA_3, which gave better results for days required for head initiation.

Table 5. Combined effect of different levels of GA_3 and phosphorus on length of largest leaf of broccoli

Treatment	Length of largest leaf (cm) at				
	25 DAT	35 DAT	45 DAT	55 DAT	Harvest
G_0P_0	18.67 f	27.14 ef	32.62 f	40.58 e	45.74 e
G_0P_1	19.58 ef	34.09 d	38.96 de	51.54 bc	56.27 bcd
G_0P_2	18.72 f	26.63 f	29.51 f	43.59 de	48.91 de
G_0P_3	21.42 de	34.35 d	41.72 cd	49.44 cd	56.37 bcd
G_1P_0	20.56 def	32.11 de	34.76 ef	51.73 bc	52.89 cde
G_1P_1	22.82 cd	35.94 cd	47.48 bc	51.60 bc	56.19 bcd
G_1P_2	27.17 a	46.83 a	56.00 a	61.03 a	67.03 a
G_1P_3	24.26 bc	37.58 bcd	45.09 bcd	52.76 bc	58.69 bc
G_2P_0	19.33 ef	32.51 de	33.29 ef	47.50 cde	49.30 de
G_2P_1	21.09 de	34.06 d	44.71 bcd	49.91 cd	53.12 cde
G_2P_2	26.04 ab	42.52 ab	50.94 ab	59.81 a	62.46 ab
G_2P_3	23.91 bc	40.40 bc	46.23 bc	58.17 ab	58.85 bc
$LSD_{(0.05)}$	2.095	5.136	5.695	6.688	7.734
Level of significance	**	**	**	**	**
CV(%)	9.68	8.99	9.26	8.66	9.06

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance;

Table 6. Effect of different levels of GA_3 and phosphorus on yield contributing characters of broccoli

Treatment	Days required from transplanting to harvest	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of leaves/ plant (g)	Dry matter content of leaves (%)
Levels of GA_3					
G_0	62.80 a	21.49 b	3.23 b	220.42 c	8.32 b
G_1	59.55 b	25.77 a	3.56 a	264.75 a	9.14 a
G_2	61.47 ab	24.84 a	3.46 a	252.40 b	8.95 a
$LSD_{(0.05)}$	2.460	2.690	0.192	12.14	0.556
Level of significance	*	**	**	**	**
Levels of phosphorous					
P_0	64.70 a	22.17 b	2.97 b	225.38 c	8.00 b
P_1	61.25 b	23.84 a	3.18 a	243.96 b	8.87 a
P_2	58.92 b	24.87 a	3.29 a	260.00 a	9.23 a
P_3	60.03 b	24.47 a	3.27 a	254.09 ab	9.12 a
$LSD_{(0.05)}$	2.821	1.429	0.152	14.02	0.713
Level of significance	**	**	**	**	**
CV(%)	7.76	6.93	8.85	7.09	9.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance; * 5% level of significance

Different levels of phosphorus showed significant variation on days required from transplanting to harvest of broccoli (Table 5 and Appendix VI). The highest (64.70 days) was required from transplanting to harvest for P_0, which was followed (61.25 days) by P_1, whereas the lowest (58.92 days) to harvest was needed from P_2 (Table 6).

Combined effect of different levels of GA_3 and phosphorus varied significantly on days required from transplanting to harvest of broccoli (Table 6 and Appendix VI). The maximum duration (66.60 days) was required from transplanting to harvest by the control treatment combination (G_0P_0), while the minimum (54.26 days) took the G_1P_2 treatment (Table 7).

4.5 Length of stem

Significant variation was recorded on length of stem of broccoli due to different levels of GA_3 under the present trial (Appendix VI). The highest length of stem (25.77 cm) was recorded from G_1 which was statistically similar (24.84 cm) by G_2, whereas the lowest length of stem (21.49 cm) was recorded from G_0 (Table 6). Manjit Singh (2011) showed that GA_3 increase the length of stem upto a certain limit of GA_3 concentration.

Different levels of phosphorus showed significant variation on length of stem of broccoli (Appendix VI). The highest length of stem (24.87 cm) was found from P_2 which was statistically similar (24.47 cm and 23.84 cm) with P_3 and P_1, while the lowest length of stem (22.17 cm) was recorded from P_0 (Table 6). Brahma *et al.* (2006) growth broccoli showed marked improvement with the application of 120 kg P/ha.

Combined effect of different levels of GA_3 and phosphorus showed significant differences on length of stem of broccoli (Appendix VI). The highest length of stem (27.38 cm) was recorded from G_1P_2, again the lowest length of stem (19.12 cm) was found from G_0P_0 (Table 7).

Table 7. Combined effect of different levels of GA_3 and phosphorus on yield contributing characters of broccoli

Treatment	Days required from transplanting to harvest	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of leaves (g)	Dry matter content of leaves (%)
G_0P_0	66.60 a	19.12 e	3.10 e	210.60 f	7.32 e
G_0P_1	65.60 ab	22.45 d	3.28 de	224.53 def	8.79 bcd
G_0P_2	57.93 de	20.12 e	3.16 e	214.40 ef	7.89 de
G_0P_3	60.93 bcd	22.48 d	3.31 cde	232.13 def	8.88 bcd
G_1P_0	64.93 abc	23.72 cd	3.30 cde	238.47 cde	8.07 cde
G_1P_1	58.26 de	25.08 bc	3.54 abcd	263.80 bc	9.03 abc
G_1P_2	54.26 e	27.38 a	3.73 a	291.67 a	9.99 a
G_1P_3	60.60 bcd	25.12 bc	3.59 abc	265.07 bc	9.09 abc
G_2P_0	62.60 abcd	22.92 cd	3.16 e	227.07 def	8.31 cde
G_2P_1	59.93 cd	23.65 cd	3.36 bcde	243.53 cd	8.49 bcd
G_2P_2	58.26 de	26.35 ab	3.65 ab	273.93 ab	9.52 ab
G_2P_3	64.93 abc	25.05 bc	3.58 abc	265.07 bc	9.10 abc
$LSD_{(0.05)}$	4.620	2.133	0.262	24.280	0.958
Level of significance	**	*	*	*	*
CV(%)	7.76	6.93	8.85	7.09	9.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)
G_1: 60 ppm GA_3
G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)
P_1: 120 kg P_2O_5/ha
P_2: 140 kg P_2O_5/ha
P_2: 160 kg P_2O_5/ha

** 1% level of significance; * 5% level of significance

4.6 Diameter of stem

Significant variation was recorded on diameter of stem of broccoli for different levels of GA_3 (Appendix VI). The highest diameter of stem (3.56 cm) was found from G_1 which was statistically similar (3.46 cm) to G_2, while the lowest diameter (3.23 cm) was found from G_0 (Table 6). Sharma and Mishra, 1989 reported that curd size increased with foliar application of GA_3.

Different levels of phosphorus showed significant variation for diameter of stem of broccoli (Appendix VI). The highest diameter of stem (3.29 cm) was obtained from P_2 which was statistically similar (3.27 cm and 3.18 cm) with P_3 and P_1, whereas the lowest diameter of stem (2.97 cm) was recorded from P_0 (Table 6).

Combined effect of different levels of GA3 and phosphorus showed significant differences on diameter of stem of broccoli (Appendix VI). The highest diameter of stem (3.73) was recorded from G_1P_2 and the lowest diameter of stem (3.10 cm) was found from G_0P_0 (Table 7)**.**

4.7 Fresh weight of leaves per plant

Significant variation was recorded for fresh weight of leaves of broccoli due to different levels of GA_3 (Appendix VI). The maximum fresh weight of leaves (264.75 g) was recorded from G_1 which was followed (252.40 g) by G_2, whereas the minimum fresh weight of leaves (220.42 g) was recorded from G_0 (Table 6). Lendve *et al*. (2010) found that application of GA_3 50 ppm was found significantly superior in terms of fresh weight leaves.

Different levels of phosphorus showed significant variation on fresh weight of stem of broccoli under the present trial (Appendix VI). The maximum fresh weight of leaves (260.00 g) was recorded from P_2 which was statistically identical (254.09 g) to P_3, while the minimum fresh weight of leaves (225.38 g) was found from P_0 (Table 6). Brahma *et al*. (2006) growth of broccoli showed marked improvement with the application of 120 kg P/ha.

Due to the combined effect of different levels of GA_3 and phosphorus showed significant differences on fresh weight of leaves of broccoli (Appendix VI). The maximum fresh weight of leaves (291.67 g) was recorded from G_1P_2 and the minimum fresh weight (210.60 g) was found from G_0P_0 (Table 7).

4.8 Dry matter content of leaves

Significant variation was found on dry matter content of leaves of broccoli due to different levels of GA_3 under the present trial (Appendix VI). The highest dry matter content of leaves (9.14%) was found from G_1 which was statistically similar (8.95%) to G_2 and the lowest dry matter (8.32%) was found from G_0 (Table 6). 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.

Different levels of phosphorus showed significant variation for dry matter content of leaves of broccoli (Appendix VI). The highest dry matter content of leaves (9.23%) was found from P_2 which was statistically similar (9.12% and 8.87%) with P_3 and P_1, whereas the lowest dry matter (8.00%) from P_0 (Table 6).

Combined effect of different levels of GA_3 and phosphorus showed significant differences on dry matter content of leaves of broccoli (Appendix VI). The highest dry matter content of leaves (9.99%) was recorded from G_1P_2 and the lowest dry matter content of leaves (7.32%) was found from G_0P_0 (Table 7).

4.9 Diameter of primary curd

Significant variation was recorded for diameter of primary curd of broccoli due to different concentrations of GA_3 under the present study (Appendix VII). The highest diameter of primary curd (12.15 cm) was obtained from G_1 which was closely followed (11.27 cm) by G_2, while the lowest diameter of primary curd (10.27 cm) was found from G_0 (Figure 6).

Different levels of phosphorus showed significant variation diameter of primary curd of broccoli (Appendix VII). The highest diameter of primary curd (11.56 cm) was found from P_2 which was statistically similar (11.20 cm and 10.56 cm) to P_1 and P_3, whereas the lowest diameter of primary curd (9.89 cm) was recorded from P_0 (Figure 7). Sharma *et al*. (2002) agreed to the findings of the present study.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on diameter of primary curd of broccoli (Appendix VII). The highest diameter of primary curd (13.39 cm) was obtained from G_1P_2 and the lowest diameter of primary curd (9.44 cm) was found from G_0P_0 (Figure 8).

4.10 Weight of primary curd

Significant variation was recorded for weight of primary curd of broccoli due to different levels of GA_3 (Appendix VII). The highest weight of primary curd (381.00 g) was obtained from G_1 which was statistically similar (374.20 g) to G_2, while the lowest weight of primary curd (335.55 g) was found from G_0 (Table 8). Vijay and Ray (2000) reported that that GA_3 at 100 ppm produced the largest curds.

Different levels of phosphorus showed significant variation for weight of primary curd of broccoli (Appendix VII). The highest weight of primary curd (396.69 g) was found from P_2 which was statistically similar (387.24 g) to P_3 and closely followed (353.78 g) by P_1, whereas the lowest weight of primary curd (316.62 g) was recorded from P_0 (Table 8). Brahma *et al*. (2006) yield of broccoli showed marked improvement with the application of 120 kg P/ha.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on weight of primary curd of broccoli (Appendix VII). The highest weight of primary curd (437.67 g) was obtained from G_1P_2 and the lowest weight of primary curd (308.53 g) was found from G_0P_0 (Table 9).

4.11 Number of secondary curd

Significant variation was recorded for number of secondary curd of broccoli due to different levels of GA_3 (Appendix VII). The highest number of secondary curd (3.50) was counted from G_1 which was statically similar (3.45) to G_2, while the lowest number of secondary curd (3.01) was found from G_0 (Table 8).

Table 8. Effect of different levels of GA_3 and phosphorus on yield contributing characters and yield of broccoli

Treatment	Weight of primary curd (g)	Number of secondary curd	Weight of secondary curd (g/plant)	Curd yield (g/plant)	Curd yield (t/ha)
Levels of GA_3					
G_0	335.55 b	3.01 b	101.40 b	436.95 b	18.21b
G_1	381.00 a	3.50 a	114.25 a	495.25 a	20.64 a
G_2	374.20 a	3.45 a	108.27 ab	482.48 a	20.10 a
$LSD_{(0.05)}$	22.25	0.209	6.906	24.62	1.026
Level of significance	**	**	**	**	**
Levels of phosphorous					
P_0	316.62 c	2.80 c	86.01 c	402.63 c	16.78 c
P_1	353.78 b	3.22 b	109.69 b	463.46 b	19.31 b
P_2	396.69 a	3.73 a	119.89 a	516.58 a	21.52 a
P_3	387.24 a	3.69 a	116.31 ab	503.55 a	20.98 a
$LSD_{(0.05)}$	25.69	0.242	7.975	28.43	1.185
Level of significance	**	**	**	**	**
CV(%)	7.23	9.92	7.55	6.17	6.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)

G_1: 60 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)

P_1: 120 kg P_2O_5/ha

G_2: 90 ppm GA_3 P_2: 140 kg P_2O_5/ha

P_2: 160 kg P_2O_5/ha

** 1% level of significance;

Table 9. Combined effect of different levels of GA_3 and phosphorus on yield contributing characters and yield of broccoli

Treatment	Weight of primary curd (g)	Number of secondary curd	Weight of secondary curd (g/plant)	Curd yield (g/plant)	Curd yield (t/ha)
G_0P_0	308.53 f	2.95 e	81.56 e	390.09 g	16.25 g
G_0P_1	333.87 cdef	3.29 cde	102.94 cd	436.81 defg	18.20 defg
G_0P_2	323.00 def	3.13 de	109.46 bc	432.46 efg	18.02 efg
G_0P_3	376.80 bc	3.82 b	111.62 bc	488.42 cd	20.35 cd
G_1P_0	325.60 def	3.15 de	90.30 de	415.90 fg	17.33 fg
G_1P_1	367.73 bcd	3.69 bc	116.84 abc	484.57 cde	20.19 cde
G_1P_2	437.67 a	4.35 a	127.90 a	565.57 a	23.57 a
G_1P_3	393.00 ab	3.95 ab	121.94 ab	514.94 abc	21.46 abc
G_2P_0	315.73 ef	3.14 de	86.16 e	401.89 g	16.75 g
G_2P_1	359.73 bcde	3.55 bcd	109.28 bc	469.01 cdef	19.54 cdef
G_2P_2	429.40 a	4.29 a	122.30 ab	551.70 ab	22.99 ab
G_2P_3	391.93 ab	3.96 ab	115.36 abc	507.29 bc	21.14bc
$LSD_{(0.05)}$	44.50	0.416	13.81	49.24	2.052
Level of significance	*	**	*	*	*
CV(%)	7.23	9.92	7.55	6.17	6.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability

G_0: 0 ppm GA_3 (control)	P_0: 0 kg P_2O_5/ha (control)
G_1: 60 ppm GA_3	P_1: 120 kg P_2O_5/ha
G_2: 90 ppm GA_3	P_2: 140 kg P_2O_5/ha
	P_2: 160 kg P_2O_5/ha

** 1% level of significance; * 5% level of significance

Different levels of phosphorus showed significant variation on number of secondary curd of broccoli (Appendix VII). The highest number of secondary curd (3.73) was found from P_2 which was statistically similar (3.62) to P_3 and closely followed (3.22) by P_1, whereas the lowest number of secondary curd (2.80) was counted from P_0 (Table 8). Bracy *et al*. (1992) observed the similar trends of results in their study.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on number of secondary curd of broccoli (Appendix VII). The highest number of secondary curd (4.35) was obtained from G_1P_2 and the lowest number of secondary curd (2.95) was found from G_0P_0 (Table 9).

4.12 Weight of secondary curd

Significant variation was recorded for weight of secondary curd of broccoli due to different levels of GA_3 (Appendix VII). The highest weight of secondary curd (114.25 g) was obtained from G_1 which was statistically similar (108.27 g) to G_2, while the lowest weight of secondary curd (101.40 g) from G_0 (Table 8).

Different levels of phosphorus showed significant variation for weight of secondary curd of broccoli (Appendix VII). The highest weight of secondary curd (119.89 g) was found from P_2 which was statistically similar (116.31 g) to P_3 and closely followed (109.69 g) by P_1, whereas the lowest weight of secondary curd (86.01 g) was recorded from P_0 (Table 8). Mitra *et al*. (1990) agreed to the present findings of their study.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on weight of secondary curd of broccoli (Appendix VII). The highest weight of secondary curd (127.90 g) was obtained from G_1P_2 and the lowest weight of secondary curd (81.56 g) was found from G_0P_0 (Table 9).

4.13 Curd yield per plant

Significant variation was recorded on curd yield per plant due to different levels of GA_3 (Appendix VII). The highest curd yield per plant (495.25 g) was obtained from G_1 which was statistically similar (482.48 g) to G_2, while the lowest curd yield per plant (436.95 g) was found from G_0 (Table 8).

Different levels of phosphorus showed significant variation for curd yield per plant of broccoli (Appendix VII). The highest curd yield per plant (516.58 g) was found from P_2 which was statistically similar (503.55 g) to P_3 and closely followed (463.46 g) by P_1, whereas the lowest yield (402.63 g) from P_0 (Table 8).

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on curd yield per plant of broccoli (Appendix VII). The highest curd yield per plant (565.57 g) was obtained from G_1P_2 and the lowest curd yield per plant (390.09 g) was found from G_0P_0 (Table 9).

4.14 Curd yield per plot

Significant variation was recorded for curd yield per plot of broccoli due to different levels of GA_3 (Appendix VII). The highest curd yield per plot (7.92 kg) was obtained from G_1 which was statistically similar (7.72 kg) to G_2, while the lowest curd yield per plot (6.99 kg) was found from G_0 (Figure 9). Dhengle and Bhosale (2008) reported that higher concentrations of plant growth regulators proved less effective for curd yield per plot.

Different levels of phosphorus showed significant variation for curd yield per plot of broccoli (Appendix VII). The highest curd yield per plot (8.27 kg) was found from P_2 which was statistically similar (8.06 kg) to P_3 and closely followed (7.42 kg) by P_1, whereas the lowest curd yield per plot (6.44 kg) from P_0 (Figure 10). Reddy *et al*. (2005) reported curd yield was also highest with 100 kg P.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on curd yield per plot of broccoli (Appendix VII). The highest curd yield per plot (9.05 kg) was obtained from G_1P_2 and the lowest curd yield per plot (6.24 kg) was found from G_0P_0 (Figure 11).

4.15 Curd yield per hectare

Significant variation was recorded for curd yield per hectare of broccoli due to different levels of GA_3 (Appendix VII). The highest curd yield (20.64 t/ha) was obtained from G_1 which was statistically similar (20.10 t/ha) to G_2, while the lowest curd yield (18.21 t/ha) was found from G_0 (Table 8). GA_3 have a positive role on curd formation and curd size of broccoli (Sharma and Mishra, 1989). Vijay and Ray (2000) reported that GA_3 at 100 ppm produced the largest curds.

Different levels of phosphorus showed significant variation for curd yield per hectare of broccoli (Appendix VII). The highest curd yield (21.52 t/ha) was found from P_2 which was statistically similar (20.98 t/ha) to P_3 and closely followed (19.31 t/ha) by P_1, whereas the lowest curd yield (16.78 t/ha) was recorded from P_0 (Table 8). Brahma *et al*. (2006) yield of broccoli showed marked improvement with the application of 120 kg P/ha. Mitra (1990) and Bracy *et al*. (1992) observed the similar trends of results in their study.

Due to combined effect of different levels of GA_3 and phosphorus showed significant differences on curd yield per hectare of broccoli (Appendix VII). The highest curd yield (23.57 t/ha) was obtained from G_1P_2 and the lowest curd yield (16.25 t/ha) was found from G_0P_0 (Table 9).

4.16 Economic analysis

Input costs for land preparation, fertilizer, irrigation and manpower required for all the operations from seed sowing to harvesting of broccoli were recorded as per plot and converted into cost per hectare. Price of broccoli was considered as per market rate. The economic analysis presented under the following headings-

4.16.1 Gross return

The combination of different levels of GA_3 and phosphorus showed different value in terms of gross return under the trial (Table 10). The highest gross return (Tk. 471,400/ha) was obtained from the treatment combination G_1P_2 and the second highest gross return (Tk. 459,800/ha) was found in G_2P_2. The lowest gross return (Tk. 325,000/ha) was obtained from G_0P_0.

Table 10. Cost and return of broccoli cultivation as influenced by different levels of GA_3 and phosphorus

Treatment Combination	Cost of production (Tk./ha)	Yield of broccoli (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0P_0	222,341	16.25	325,000	102,659	1.46
G_0P_1	224,363	18.20	364,000	139,637	1.62
G_0P_2	225,374	18.02	360,400	135,026	1.60
G_0P_3	226,385	20.35	407,000	180,615	1.80
G_1P_0	226,835	17.33	346,600	119,765	1.53
G_1P_1	228,857	20.19	403,800	174,943	1.76
G_1P_2	229,868	23.57	471,400	241,532	2.05
G_1P_3	230,879	21.46	429,200	198,321	1.86
G_2P_0	229,082	16.75	335,000	105,918	1.46
G_2P_1	231,104	19.54	390,800	159,696	1.69
G_2P_2	232,115	22.99	459,800	227,685	1.98
G_2P_3	233,126	21.14	422,800	189,674	1.81

Price of broccoli @ Tk. 20,000/ton (Rate of Kawran Bazar, Dhaka)

G_0: 0 ppm GA_3 (control)
G_1: 60 ppm GA_3
G_2: 90 ppm GA_3

P_0: 0 kg P_2O_5/ha (control)
P_1: 120 kg P_2O_5/ha
P_2: 140 kg P_2O_5/ha
P_2: 160 kg P_2O_5/ha

4.16.2 Net return

In case of net return, different levels of GA3 and phosphorus showed different levels of net return under the present trial (Table 10). The highest net return (Tk. 241,532/ha) was found from the treatment combination G_1P_2 and the second highest net return (Tk. 227,685/ha) was obtained from the combination G_2P_2. The lowest (Tk. 102,659/ha) net return was obtained G_0P_0.

4.16.3 Benefit cost ratio

In the different levels of GA_3 and phosphorus the highest benefit cost ratio (2.05) was noted from the combination of G_1P_2 and the second highest benefit cost ratio (1.98) was estimated from the combination of G_2P_2. The lowest benefit cost ratio (1.46) was obtained from G_0P_0 (Table 10). From economic point of view, it is apparent from the above results that the combination of G_1P_2 was better than rest of the combination.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm, Shar-e-Bangla Agricultural University, Dhaka during the period from October 2012 to March 2013 to find out growth and yield of broccoli as influenced by GA_3 and phosphorus. The test crop used in the experiment was broccoli cv. Premium crop. The experiment consisted of two factors: Factor A: Gibberellic acid-GA_3 (three levels) as- G_0: 0 ppm GA_3 (control); G_1: 60 ppm $GA_{3;}$ G_2: 90 ppm GA_3 and Factor B: Phosphorus (four levels) as- P_0: 0 kg P_2O_5 (control); P_1: 120 kg $P_2O_{5;}$ P_2: 140 kg P_2O_5 and P_3: 160 kg P_2O_5. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield parameters and yield were recorded.

In case of GA_3 at 25, 35, 45, 55 DAT and at harvest, the tallest plant (20.46, 40.20, 57.47, 72.50 and 75.78 cm, respectively) was recorded from G_1 and the shortest plant (19.33, 37.58, 55.12, 67.95 and 71.79 cm, respectively) was recorded from G_0. At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (7.43, 13.58, 18.00, 23.03 and 24.62) was obtained from G_1, whereas the minimum number (6.47, 12.23, 14.83, 17.20 and 20.78) from G_0. At 25, 35, 45, 55 DAT and at harvest, the longest leaf (23.70, 38.12, 45.83, 54.28 and 58.70 cm, respectively) was recorded from G_1, whereas the shortest leaf (19.60, 30.55, 35.70, 46.29 and 51.82 cm, respectively) was obtained from G_0. The control treatment (G_0) took the highest (62.80 days) from transplanting to harvest, while the lowest (59.55 days) was required from transplanting to harvest from G_1. The highest length of stem (25.77 cm) was recorded from G_1, whereas the lowest (21.49 cm) from G_0. The highest diameter of stem (3.56 cm) was found from G_1, while the lowest (3.23 cm) from G_0. The maximum fresh weight of leaves (264.75 g) was recorded from G_1, whereas the minimum (220.42 g) was recorded from G_0. The highest dry matter content of leaves (9.14%) was found from G_1, while the lowest (8.32%) from G_0.

The highest diameter of primary curd (12.15 cm) was obtained from G_1, while the lowest (10.27 cm) from G_0. The highest weight of primary curd (381.00 g) was obtained from G_1, while the lowest (335.55 g) was found from G_0. The highest number of secondary curd (3.50) was obtained from G_1, while the lowest (3.01) from G_0. The highest weight of secondary curd (114.25 g) was obtained from G_1, while the lowest (101.40 g) from G_0. The highest curd yield per plant (495.25 g) was obtained from G_1, while the lowest (436.95 g) from G_0. The highest curd yield per plot (7.92 kg) was obtained from G_1, while the lowest (6.99 kg) from G_0. The highest curd yield (20.64 t/ha) was obtained from G_1, while the lowest (18.21 t/ha) was found from G_0.

At 25, 35, 45, 55 DAT and at harvest, the tallest plant (20.76, 39.65, 58.65, 72.80 and 76.54 cm, respectively) was recorded from P_2, whereas the shortest plant (19.22, 37.16, 53.64, 67.67 and 69.56 cm, respectively) was recorded from P_0. At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (7.47, 14.04, 17.22, 22.11 and 22.90) was counted from P_2, while the minimum number (6.46, 11.09, 15.33, 17.93 and 19.28) was found from P_0. At 20, 30, 40, 50 DAT and at harvest, the longest leaf (23.98, 38.66, 45.49, 54.81 and 59.47 cm, respectively) was recorded from P_2 and the shortest leaf (19.52, 30.59, 33.55, 46.60 and 49.31 cm, respectively) was observed in P_0. The highest duration (64.70 days) was required from transplanting to harvest for P_0, whereas the lowest duration (58.92 days) to harvest was needed in P_2. The highest length of stem (24.87 cm) was found from P_2, while the lowest length of stem (22.17 cm) was recorded from P_0. The highest diameter of stem (3.29 cm) was found from P_2, whereas the lowest diameter of stem (2.97 cm) was obtained from P_0. The maximum fresh weight of leaves (260.00 g) was recorded from P_2, while the minimum fresh weight of leaves (225.38 g) was found from P_0. The highest dry matter content of leaves (9.23%) was found from P_2, whereas the lowest dry matter content of leaves (8.00%) was recorded from P_0. The highest diameter of primary curd (11.56 cm) was found from P_2, whereas the lowest diameter of primary curd (9.89 cm) was recorded from P_0. The highest weight of primary curd (396.69 g) was found from P_2, whereas the lowest weight of primary curd (316.62 g) was recorded from P_0. The highest number of secondary curd (3.51) was found from P_2, whereas the lowest number of secondary curd (2.67) was recorded from P_0. The highest weight of secondary curd (119.89 g) was found from P_2, whereas the lowest weight of secondary curd (86.01 g) was recorded from P_0. The highest curd yield per plant (516.58 g) was found from P_2, whereas the lowest curd yield per plant (402.63 g) was recorded from P_0. The highest curd yield per plot (8.27 kg) was found from P_2, whereas the lowest curd yield per plot (6.44 kg) was recorded from P_0. The highest curd yield (21.52 t/ha) was found from P_2, whereas the lowest curd yield per hectare (16.78 t/ha) was recorded from P_0.

Due to combined effect of GA_3 and phosphorous, at 25, 35, 45, 55 DAT and at harvest, the tallest plant (23.98, 44.46, 64.77, 78.57 and 82.76 cm, respectively) was obtained from G_1P_2, while the shortest plant (19.89, 38.68, 56.29, 65.70 and 68.37 cm, respectively) was recorded from G_0P_0. At 25, 35, 45, 55 DAT and at harvest, the maximum number of leaves per plant (8.88, 15.40, 19.93, 26.13 and 26.89) was counted from G_1P_2 and the minimum number of leaves per plant (7.08, 10.60, 13.47, 14.93 and 19.49) was found from G_0P_0 at the same date of observations. At 25, 35, 45, 55 DAT and at harvest, the longest leaf (27.17, 46.83, 56.00, 61.03 and 67.03 cm, respectively) was obtained from G_1P_2 and the shortest leaf (18.67, 27.14, 32.62, 40.58 and 45.74 cm, respectively) from G_0P_0. The maximum duration (66.60 days) was required from transplanting to harvest by the control treatment combination (G_0P_0), while the minimum duration (54.26 days) took the G_1P_3 treatment. The highest length of stem (27.38 cm) was recorded from G_1P_2, again the lowest length of stem (19.12 cm) was found from G_0P_0. The highest diameter of stem (3.73) was recorded from G_1P_2 and the lowest diameter of stem (3.10 cm) was found from G_0P_0**.** The maximum fresh weight of leaves (291.67 g) was recorded from G_1P_2 and the minimum fresh weight (210.60 g) was found from G_0P_0. The highest dry matter content of leaves (9.99%) was recorded from G_1P_2 and the lowest dry matter content of leaves (7.32%) was found from G_0P_0. The highest diameter of primary curd (13.39 cm) was obtained from G_1P_2 and the lowest diameter (9.44 cm) from G_0P_0. The highest weight of primary curd (437.67 g) was obtained from G_1P_2 and the lowest weight (308.53 g) from G_0P_0. The highest number of secondary curd (4.35) was obtained from G_1P_2 and the lowest number (2.95) from G_0P_0. The highest weight of secondary curd (127.90 g) was obtained from G_1P_2 and the lowest weight (81.56 g) from G_0P_0. The highest curd yield per plant (565.57 g) was obtained from G_1P_2 and the lowest (390.09 g) from G_0P_0. The highest curd yield per plot (9.05 kg) was obtained from G_1P_2 and the lowest curd yield per plot (6.24 kg) from G_0P_0. The highest curd yield (23.57 t/ha) was obtained from G_1P_2 and the lowest yield (16.25 t/ha) found from G_0P_0.

The combination of different levels of GA_3 and phosphorus, the highest gross return (Tk. 471,400/ha) was obtained from the treatment combination G_1P_2 and the lowest gross return (Tk. 325,000/ha) was obtained from G_0P_0.In case of net return, the highest net return (Tk. 241,532/ha) was found from the treatment combination G_1P_2 and the lowest (Tk. 102,659/ha) net return was obtained G_0P_0. In the different levels of GA_3 and phosphorus the highest benefit cost ratio (2.05) was noted from the combination of G_1P_2 and the lowest benefit cost ratio (1.46) was obtained from G_0P_0. From economic point of view, it is apparent from the above results that the combination of G_1P_2 was better than rest of the combination.

Conclusion

Among the combination of different levels of gibberellic acid and phosphorus fertilizer 60 ppm GA_3 and 140 kg P_2O_5/ha induced superior growth, yield contributing characters and yield of broccoli as well as highest economic return.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Another plant growth regulators with different concentration need to be considered in different agro-ecological zones of Bangladesh for regional trial before final recommendation.
2. Another levels of phosphorus and other fertilizer may be used in future study.

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