RESPONSE OF GIBBERELLIC ACID AND POTASH NUTRIENT ON GROWTH AND YIELD OF LATE PLANTING CABBAGE

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CERTIFICATE

This is to certify that the thesis entitled **"Response of Gibberellic Acid and Potash Nutrient on Growth and Yield of Late Planting Cabbage"** 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 **FALGUNI MAJUMDAR**, Registration No. **05-01633** 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 study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to find out response of gibberellic acid and potash nutrient on growth and yield of late planting cabbage. The experiment consisted of two factors: Factor A: Gibberellic acid (four levels) as- G_0: 0, G_1: 90, G_2: 120, G_3: 150 ppm GA_3 and Factor B: Potassium fertilizer (three levels) as- K_0: 0, K_1: 150 and K_2: 200 kg K_2O. The two factors experiment was laid out in Randomized Complete Block Design with three replications. In case of different growth regulators, the highest marketable yield (65.1 t/ha) were found from G_2, while the lowest marketable yield (40.4 t/ha) from G_0. For different levels of potassium fertilizer, the highest marketable yield (64.4 t/ha) were recorded from K_1, whereas the lowest marketable yield (44.6 t/ha) from K_0. Due to interaction effect, the highest marketable yield (75.6 t/ha) were recorded from G_2K_1, whereas the lowest marketable yield (38.4 t/ha) from G_0K_0. The highest benefit cost ratio (2.31) was noted from the combination of G_2K_1 and the lowest (1.24) from G_0K_0. From growth, yield and also economic point of view, it is apparent that the combination of G_2K_1 was suitable for late planting cabbage cultivation.

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CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) is a cole crop belongs to the family Cruciferae locally known as 'Bhadha Kopi'. It is a popular and most common winter vegetable crop grown in Bangladesh and is grown as an important vegetable in many part of the world. It is a short duration crop and grown for its compact head. It is also a well known and widely distributed crop within Asia and has been introduced successfully into parts of Central America, West Africa, America, Canada and Europe (Talekar and Selleck, 1982). It is one of the five leading vegetables in our country and ranks third in respect of production and area. At present the cultivated area of cabbage is increasing day by day with a production of 220 thousand metric tons (BBS, 2012). It is usually cultivated in Rabi season. Among the five leading vegetables of Bangladesh, the cabbage occupied an area of 11.37 thousand hectares of land (BBS, 2012).

Vegetable consumption in Bangladesh is very low with comparison to the other countries of the world and it is only 32 g per person per day against the minimum recommended quantity of 200 g per day (FAO, 1986). The total vegetable production in Bangladesh is far below the requirement and the paddy field is converted to vegetables field day after day. It is seen especially near by the town and metropolitan city because the return is nearly three times higher than that of from the paddy. Cabbage is a leafy vegetable rich in vitamin C and tryptophan, an important amino acid for our body (Rashid, 1993). It has been reported that 100 g of green edible portion of cabbage contains 92% water, 24 calories of food energy, 1.5 g of protein, 9.8 g of carbohydrate, 40 mg of Ca, 0.6 mg of Fe, 600 IU of Carotene, 0.05 mg of thiamine, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin E (Rashid, 1993). It has some medicinal value against ulcer and also prevents cancer.

According to FAO (1999) the average yield of cabbage is low in Bangladesh comparison with other countries like South Korea (61.17 t/ha), Germany (54.81 t/ha), Japan (40.31 t/ha) and India (19.10 t/ha) 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 potash fertilizer can play an important role for increasing the production of cabbage in Bangladesh (Dharmender *et al.*, 1996; Yadav *et al*., 2000).

Plant growth regulators (PGR's) are organic compounds, which in small amounts, somehow modify a given physiological plant process. It plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). These compounds has now been applied to a large variety of plant organs in several ways and it has been found to greatly enhance stem elongation as its most striking effect. This was observed in many plants after treatment with minute amount of gibberellic acid (GA_3). Reports so far been made to indicate a promising results on yield of cabbage and other vegetable crops due to the use of bio-chemical substances or hormone, such as Napthaline acetic acid (NAA), Gibberelic acid (GA_3), Indole acetic acid (IAA) etc. (Yadav *et al*., 2000; Islam *et al.*, 1993). 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 various species but also for cultivars within the species and due to climatic regions (Hardy, 1979). However, recently done preliminary trials indicate possibility of yields increase of cabbage in Bangladesh with the use of biochemical (Islam *et al*., 1993; Biswas and Mondal, 1994). Among the growth nutrients gibberellic acid stimulates cell division and cell enlargement.

Application of gibberellic acid can stimulate morphological characters of cabbage like plant height, number of leaves, head diameter, head thickness as well as weight of head.

Generally the price of winter vegetable is higher in late of rabi season, in comparison with the pick season. If growth could be enhanced by applying gibberellic acid, farmers can get higher economic return by matching up the demand of off season. On the other hand, farmers can also get more money by growing short term leafy vegetables like red amaranth, spinach, coriander leaf etc. between the two main crops. Cropping intensity as well as net income can be increased through such way in winter. When it is too cold; plant growth becomes stunt. Gibberellic acid is known to enhance plant vegetative growth. So, it can be applied to make faster the vegetative growth before head formation.

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 vegetablee crops requires proper supply of plant nutrient. Cabbage responds greatly to major essential elements like N, P and K for its growth and yield (Thompson and Kelly, 1988). Potassium as an inorganic fertilizer plays a vital role for proper growth and development of cabbage. Application of potassium in appropriate time, dose and proper method is prerequisite for any cabbage cultivation (Islam, 2003). Generally, a large amount of potassium is required for the growth of leafy vegetable (Opena *et al.*, 1988). Cabbage is a heavy feeder especially of potassium (Thompson and Kelly, 1988). For vegetative growth potassium fertilizer may effect such varied process as respiration, photosynthesis, chlorophyll development and water content of leaves.

Considering the background stated above, the present study was undertaken to investigate the effect of plant growth regulators and potash nutrients with the following objectives-

- To find out appropriate concentration of GA_3 for increasing cabbage production
- To study the effect of potassium on growth and yield of cabbage
- To find out the interaction effect of GA_3 and potassium for better plant growth, the maximum yield and economic return of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is one of the five leading vegetables in our country and it is usually cultivated in Rabi season. 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, fertilizer is a most important and common practices and growth regulator is a modern concept as a management practices and both are also important factors. Numerous studies have been performed evaluating the influence of growth regulators and potash fertilizer on the performance of cabbage. Among the above factors some of the recent past information on growth regulators and potassium fertilizer on cabbage have been reviewed under the following headings:

2.1 Effect of growth regulators on cabbage

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.

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 (63.83 t/ha) were obtained with 50 ppm GA_3.

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.

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.

The effect of foliar sprays of the growth regulators B-9 [daminozide] (2500, 2 × 2500 and 5000 ppm), Bonzi [paclobutrazol] (5, 10, 20, 40 and 80 ppm), and Sumagic [uniconazole] (2, 4, 8, 16 and 32 ppm), or soil drenches of Bonzi (1, 2, 4, 8 and 16 mg a.i./pot) and Sumagic (0.125, 0.25, 0.5, 1.0 and 2.0 mg a.i./pot), on the growth of the ornamental cabbage and kale cultivars Osaka White and Nagoya Red, growing in 8-inch pots, was investigated by Gibson and Whipker (1999). The foliar sprays and drenches were applied 22 days after potting. The growth of Osaka White decreased with increasing drench rates of Bonzi, while Nagoya Red was affected only up to a rate of 4 mg a.i/pot. All Sumagic drench rates controlled plant height of both cultivars but the response did not increase above 1 mg a.i/pot.

Foliar sprays of Bonzi did not control growth of Nagoya Red while Osaka White increased in plant height with increasing rates. Foliar sprays of Sumagic reduced plant height of both cultivars. B-9, at all rates produced plants which were 12% shorter than the control.

An experiment was conducted by Yadav *et al*. (2000) in Rajasthan, India, during the rabi season of 1996-97 to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 250, 500 and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height (28.4 cm) and plant spread (0.187 m^2) resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q/ha) was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm. Leaf area was highest in 2 sprays of 500 ppm succinic acid.

The effects of growth retardants hexaconazole (Hex) and diniconazole (Din), on the height control of cabbage plug seedling were investigated by Park *et al*. (2002) Hex at 5 mg/litre did not affect growth compared to the control. Din treatments reduced the growth of the plants compared to the control treatment, and decreased leaf number of seedlings more than Hex. Din at rates more than 100 mg/litre resulted in extreme dwarfing and unhealthy seedlings. Leaf length and width increased a little 30 days after treatment, indicating that the dwarfing effect of the compounds was temporary. Rooting rate was 92.5% in the control, and 95% in plots treated with hexaconazole at 500 mg/litre.

The in vitro propagation of shoot tips and the quality of explants of cabbage were significantly affected by the different concentrations of BA and NAA in the culture media reported by Liao *et al*. (2003). A higher rate of shoot proliferation with better quality plantlets were obtained when the medium contained more than 0.8 mg BA/litre and less than 0.5 mg NAA/litre.

The effects of kinetin and zeatin on propagation efficiency was better than the combination of both treatments when used in similar concentrations. Heat shock treatment (45^0 for 2 hour) stimulated the proliferation of shoots.

In a field experiment carried out by Wang *et al*. (2004), the effects of different growth regulators and substrates were studied. The regulators used were NAA, ABT [aminobenzotriazole] root-promoting powder, and IBA applied at 1000, 1500, and 2000 mg/litre. Water was used as control. The survival rate for cuttings and plant quality improved significantly with 1000 and 1500 mg NAA/litre. ABT treatment at 1500 mg/litre did not improve survival rate, but improved plant quality. Plant height, number of leaves, leaf area, root length, fresh leaf weight, fresh root weight, dry leaf weight, and dry root weight increased by 47.46, 35.42, 193.92, 235.79, 89.90, 40.51, 40.79, and 53.44%, respectively, as compared with the control.

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

2.2 Effect of potash fertilizer on cabbage

The influence of mineral fertilizer rates on the yield and quality of cabbage cv. Eton F_1 was studied by Rutkauskiene and Poderys (1999) in the field at the Experimental station of the Lithuanian University of Agriculture. The highest harvest of cabbage was obtained at fertilizer rates (kg/ha) of $N_{240}P_{120}K_{180}$ and

$N_{300}P_{120}K_{180}$. Increasing the dose of nitrogen fertilizers decreased the quantity of vitamin C [ascorbic acid] and increased the concentration of nitrates in cabbage heads. Potassium fertilizers decreased the yield, but increased head quality.

An experiment was conducted by Liu *et al*. (1999) with 3 factors, 4 levels, and 14 treatments was carried out to study the effect of different ratios of NPK combination on yield and nitrate accumulation of cabbage. The levels of N were 0, 180, 360, and 540 kg/ha; the levels of P_2O_5 were 0, 90, 180, 270 kg/ha; the levels of K_2O were 0, 90, 180, 270 kg/ha. The plant density of cabbage was 31 500/ha. The results showed that the best results were obtained with N_{360} + P_{90} + K_{180}. The nitrate accumulation was increased with the increase of the amount of N applied.

A study was conducted by Zhou *et al*. (2001) in Tianjin, China [date not given] to determine the effect of potash application (at 0, 150, 225, 300 kg K/ha) on the time of ripening and yield of cabbage. Treatment with potash at 225 kg K/ha resulted in a more rapid heading, rapid maturation and improved cabbage quality compared to other treatments. This treatment produced the highest commercial yield increase of 17.4 t/ha and the highest profit for the farmer (9970 yuan/ha). In the Tianjin region, the rate of 225 kg K/ha, along with 225 kg N/ha and 60 kg P/ha is recommended for cabbage production on soils represented by this trial. This application should bring the farmer a net profit of 9000 to 10000 yuan/ha, depending on local market prices.

An experiment was conducted by Chaubey and Srivastava (2001) in Pantnagar, Uttar Pradesh, India, during winter to study the effect of N:P:K level (60:30:30, 120:60:60, 180:90:90, and 240:120:120 kg/ha) on the yield and yield-contributing characters (head gross and net weight, head shape index, core length, ascorbic acid, marketable head percentage, and marketability period of heads after maturity) of 23 cultivars. The analysis of variance revealed significant differences among cultivars and fertilizer levels in both seasons for all characters studied.

The yield ranged from 105.61 to 590.82 q/h. Net head weight and size increased at higher fertility levels; however, head shape index was unaffected. The percentage of marketable heads and their durability also increased at higher levels of fertilizer. Winter-spring season proved to be favourable for higher cabbage productivity.

The effects of N:P:K fertilizer rates (56.2:46.6:16.5, 75.0:62.2:22.0, and 93.7:77.8:27.5 kg/ha) and row spacing on cabbage were evaluated by Sharma (2001) in Himachal Pradesh, India,. Plant height, siliquae per plant, seeds per siliqua and seed yield increased significantly with increase in NPK rate. The effect of spacing was significant only for siliquae per plant and seed yield per ha. Wider spacing (60 x 45 cm) resulted in the highest number of siliquae per plant (54.54) and seed yield (62 kg/ha). The interaction effect between NPK fertilizer application and row spacing was significant only for seed yield; the highest value of which was obtained with NPK at 93.7:77.8:27.5.

The effect on water uptake, accumulated dry matter content, and dry matter output per litre of water in cabbage plants grown under different soil water potentials and at different fertilizer application rates was investigated by Yang *et al*. (2001). For the same range of soil water potential, an increase in N application rate increased N content in cabbage leaves and roots while P_2O_5 and K_2O contents decreased. The amount of N, P and K absorbed was maximum at 300 kg N/hm^2, medium at 0 fertilizer application rate and minimum at 1200 kg N/hm^2. N/P and N/K values increased with increases in fertilizer application rate, leading to non-equilibrium of nutrient uptake and inhibition of normal growth.

Field experiments were conducted by Bahadur *et al*. (2004) at Varanasi, Uttar Pradesh, India to evaluate the effects of organic manures and biofertilizers on the growth and yield of cabbage and they reported that NPK (120:160:180 kg/ha). Pressmud + VAM recorded the highest values for all parameters studied, i.e. number of outer leaves (13.3), fresh weight of outer leaves (476.67 g), number of inner leaves (31.7), head weight (1616.67 g), head length (16.8 cm), head diameter (15.5 cm) and head yield (602.67 q/ha).

A field trial was conducted by Guo *et al*. (2004a) in China to investigate the effects of N and K rates on the nutrient uptake and partitioning of cabbage. Sole N application increased the contents of N, B, Mn and Zn, but reduced the contents of K, Ca, Mg, Cu and Fe. Sole K increased the contents of K and other microelements in the heads, but reduced N, Ca and Mg contents. Application of N and K increased nutrient proportion in heads and leaves, which increased growth, yield, quality and nutritional value of cabbage.

Cabbage [*Brassica oleracea* var. capitata] was grown by Guo *et al*. (2004b) in two field trials in Hefei, Anhui, China. N, P_2O_5, K_2 was applied at rates of 0-60-0, 350-60-0, 450-60-0, 0-60-300, 350-60-300, and 450-60-300 kg/ha. Nitrogen and potassium and their proper combination significantly improved the yield and its nutrient use efficiency. Potassium sulfate markedly increased the content of ascorbic acid and sugars, and alleviated the unfavourable effect of irrational nitrogen application. Urea increased the content of amino acids, while nitrogen and potassium enhanced the nutritional value of the essential amino acids. Ascorbic acid and sugar contents were correlated negatively with N content in cabbage heads and positively with potassium content. It is concluded that adequate potassium supply and optimum combination of nitrogen and potassium will help to ensure high quality and yield.

The effect of fertigation and broadcast mineral fertilizer application on yield and quality of 4 cabbage (*B. oleracea* var. capitata) cultivars was studied by Marsic and Osvald (2004) in a field trial in Ljubljana, Slovenia. Five treatments were formed: K=classical fertilization with 150 kg N ha^{-1} (broadcast incorporated); F_{NPK} all nutrients (NPK) were applied via fertigation; F_{NPK} were added by classical methods and total N by fertigation. During the harvest, the height and width of the cabbage, length of stalk, weight of head with leaves and without leaves, height and width of cleaned head, firmness of head and core length were measured and the number of external trimmed leaves was counted. The highest average marketable yield was achieved by fertigation with soluble nutrients, combined with pre-plant broadcast N incorporation, with each individual cultivar as follows: Hermes F1 (38.7 t ha-1), Parel F1 (71.1 t ha-1) and Tropicana F1 (70.7 t ha-1) and the lowest by fertigation with N, where the total amount of P and K were pre-plant broadcast incorporated, with cultivars as follows: Hermes F1 (20.9 t ha-1), Parel F1 (50.4 ha-1), Tropicana F1 (63.0 t ha-1) and Fieldwinner F1 (66.1 t ha^{-1}). The firmness of cabbage heads was also affected by the method of nutrient application.

Felczynski (2004) investigated Chinese cabbage (*Brassica rapa* subsp. *pekinensis*) in a long-term, static fertilization experiment in Skierniewice (Poland). Chinese cabbage cv. Bilko F_1 (Bejo Zaden) was cultivated from potted transplants for autumn crop at density of 9 plants/m^2. The crop responded very strongly to increasing rates of organic fertilizer. The highest marketable yield (76.1 t/ha) was achieved with the highest rate of farmyard manure (FYM; 60 t/ha) plus 2nd level of mineral fertilizers (M-2), i.e. 150 kg N, 100 kg P_2O_5 and 200 kg K_2O/ha. This yield, however, did not differ statistically from the yields obtained with 40 t FYM+M-2 and with FYM at 60 t/ha alone. In the case of mineral fertilizer application without FYM, the total and marketable yields decreased along with increasing NPK rates, but the differences were not statistically proved and the yields were similar to those obtained with FYM at 40 t/ha. The lowest marketable yield (25.2 t/ha) was obtained from the control plots (without fertilizer application) and it was over 3 times lower than the best treatment. Increasing rates of FYM alone tended to increase nitrates and decreased dry matter content in heads of Chinese cabbage.

The effects of potash fertilizer on the yields of Chinese cabbage on soil P and plant P content were studied by Liu *et al*. (2005). The application of potash fertilizer at 56.25-225.00 kg/ha increased the yield of cabbage by 47.2-70.3%. A yield response was not observed when potash fertilizer was applied at more than 225.0 kg/ha to Chinese cabbage.

The total P contents of cabbage, soil total P content, and Olsen-P at the 0-20 cm soil profile increased gradually with the increase in the potash fertilizer rate. A yield response was not observed in cabbage when the rate of potash fertilizer applied was more than 450.0 kg/ha.

A field experiment was conducted by Pintu and Das (2006) in a Haplaquept soil in Gaighata, West Bengal, India, to study the effects of integrated nutrient management (INM) on the yield and uptake of nutrients by cabbage (*Brassica oleracea* var. capitata cv. Green Express). Overall, the adoption of INM practices increased the yield and nutrient uptake by cabbage. The application of recommended levels of N, P and K with 4 t organic manure ha-1 and 0.5 kg Zn ha-1 proved superior in augmenting yield and nutrient uptake. A significant positive correlation was observed between yield and uptake of N (r=0.928), P (r=0.935), K (r=0.949), Fe (r=0.758), Mn (r=0.744), Cu (r=0.598) and Zn (r=0.846). The uptake of N, P, K and cationic micronutrients (Fe, Mn, Cu and Zn) by cabbage accounted for 99% of the variability, while the uptake of Fe, Mn, Cu and Zn accounted for 80% of the variability in yield.

A field experiment was conducted by Ghuge *et al*. (2007) during 2002-03 in Parbhani, Maharashtra, India, to assess the effect of combined use of organic and inorganic nutrient sources on the growth and yield of cabbage cv. Pride of India. The treatments comprised: recommended dose of fertilizers (RDF) at 150:80:75 kg NPK/ha (T1); 50% RDF + 50% vermicompost at 2.5 t/ha (T2); 25% RDF + 75% vermicompost at 3.75 t/ha (T3); 50% RDF + 50% Terracare at 1.25 t/ha (T4); 50% RDF + 75% Terracare at 1.875 t/ha (T5); 50% RDF + 50% organic booster at 1.0 litres per plant after transplanting in 4 splits (T6); 25% RDF + 75% organic booster at 1.5 litres per plant after transplanting in 4 splits (T7); 100% vermicompost at 5 t/ha (T8); 100% Terracare at 2.5 t/ha (T9); and 100% organic booster at 2 litres per plant after transplanting in 4 splits (T10). T2 gave the maximum plant spread (18.87 cm2), head circumference (57.50 cm), head weight (1232 g per head), chlorophyll content (652.1 micro g/g of leaf), ascorbic acid (29.93 mg/100 g head) and compactness of head (79.07%).

An experiment was conducted by Tang *et al*. (2010) to study effect of different fertilization treatments on yield, nutrients uptake and nutrients use efficiency of Chinese cabbage and cabbage. The results showed that: yield of cabbage and Chinese cabbage of the application of manure, oil cake and special fertilizer for vegetables combined with fertilizer is higher than that of the pure chemical fertilizer treatment. The yield of application of special fertilizer for vegetables combined with fertilizer of Chinese cabbage is the highest, yield of it enhanced 25.30% compared with the pure chemical fertilizer treatment; application of oil cake and special fertilizer for vegetables combined with fertilizer are of the highest N and P nutrient use efficiency, N and P nutrient use efficiency of them enhanced 21.65%, 10.77% compared with the pure chemical fertilizer treatment, respectively. The yield of application of oil cake combined with fertilizer of cabbage is higher, yield of it enhanced 9.90% compared with the pure chemical fertilizer treatment; application of oil cake combined with fertilizer is of the highest N and P nutrient use efficiency, N and P nutrient use efficiency of it enhanced 29.23% and 14.9% compared with the pure chemical fertilizer treatment, respectively.

A field trial with a local variety of Chinese cabbage was carried out by Li *et al*. (2010) in Fuzhou, Fujian, China in 2007 to investigate effects of different NPK applied rates on its yield. Eleven treatments were designed, with N, P and K at four different levels, respectively. The average contribution rate of soil fertility to the yield of Chinese cabbage was 47.4%. The yields of Chinese cabbages treated by N, P and K were increased by 41.26, 14.90 and 25.53% on average, respectively. The effects on yield increase was ranked as N>K>P. The output/input ratios of N, P and K were 13.8, 13.2 and 9.7, respectively. The recommended applied rates of NPK fertilizers for the Chinese cabbages in Fuzhou were 232.0 kg N, 70.5 kg P_2O_5 and 209.6 kg K_2O/ha, respectively.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2011 to March 2012 to find out response of gibberellic acid and potash nutrients on growth and yield of late planting cabbage. 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 Location of the experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09^0N latitude and 90.26^0E longitudes. The altitude the location will be 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.2 Characteristics of soil

Experimental site belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and the selected plot of the land was medium high in nature with adequate irrigation facilities and remained fallow during the previous season. The soil texture of the experimental was sandy loam. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Research and Development Institute Dhaka, and result have been presented in Appendix I.

3.3 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

The test crop used in the experiment was cabbage variety Atlas-70 and the seeds were collected from Siddique Bazar, Dhaka.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Gibberellic acid (four levels) as

i G_0: 0 ppm GA_3 (control)
ii. G_1: 90 ppm GA_3
iii. G_2: 120 ppm GA_3
iv. G_3: 150 ppm GA_3

Factor B: Potassium fertilizer (three levels) as

i. K_0: 0 kg K_2O (control)
ii. K_1: 150 kg K_2O
iii. K_2: 200 kg K_2O

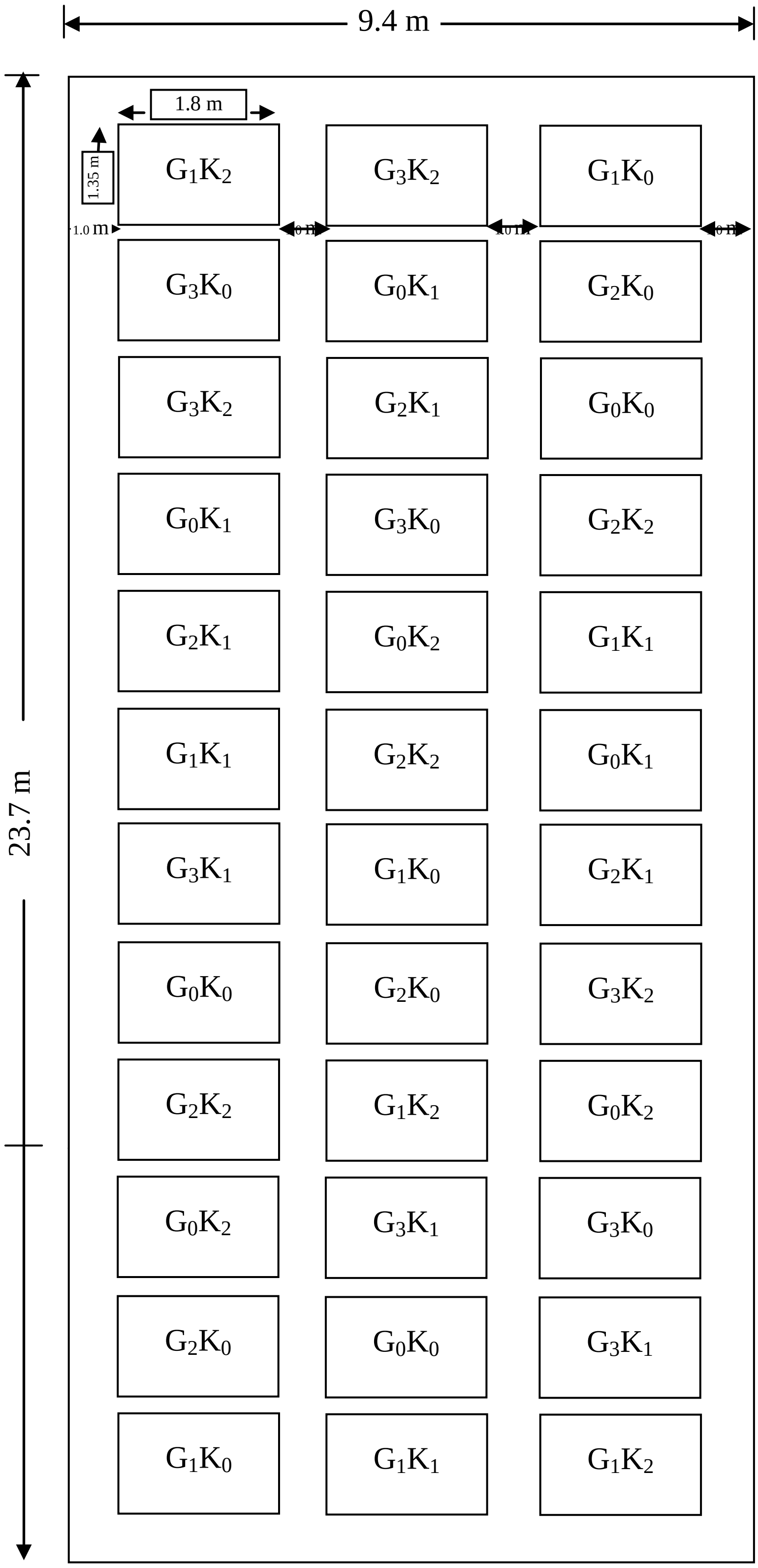
There were 12 (4 × 3) treatments combination such as G_0K_0, G_0K_1, G_0K_2, G_1K_0, G_1K_1, G_1K_2, G_2K_0, G_2K_1, G_2K_2, G_3K_0, G_3K_1 and G_3K_2.

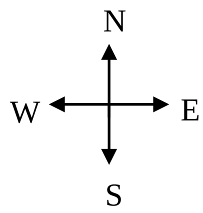
3.6 Collection of seedlings

The seedlings of cabbage variety Atlas-70 were collected from Horticulture Farm, of SAU, Dhaka.

3.7 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 222.78 m^2 with length 23.7 m and width 9.4 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 altogether in the experiment. The size of the each plot was 1.8 m × 1.35 m. The distance maintained 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.





Plot size: 1.8 m × 1.35 m
Plot spacing: 0.50 m
Between block: 1.00 m

Factor A: Gibberellic acid

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

Factor B: Potassium fertilizer

K_0: 0 kg K_2O (control)

K_1: 150 kg K_2O

K_2: 200 kg K_2O

3.8 Preparation of the main field

The selected plot of the experiment was opened in the 3rd week of November 2011 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.

3.9 Application of manure and fertilizers

Manures and fertilizers were applied according to the experimental plot considering the recommended fertilizer doses for cabbage production per hectare by BARI (2005).

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

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

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

3.10 Raising of seedlings

The seedlings were raised at the Horticultural Farm, SAU, Dhaka under special care in a 3 m × 1 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease cupravit fungicide were applied. Decomposed cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in seedbed on November 19, 2011. After sowing, the seeds were covered with 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.

3.11 Transplanting

Healthy and uniform seedlings of 25 days old seedlings were transplanting in the experimental plots on 14 December, 2011. 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 45 cm. The young transplants were shaded by banana leaf sheath during day time to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border if the experimental plots for gap filling.

3.12 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 cabbage seedlings.

3.12.1 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. Planted earlier on the border of the experimental plots same as planting time treatment. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting 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.

3.12.2 Weeding

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

3.12.3 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.

3.12.4 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.

3.12.5 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seeding 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 of plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 gm 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 cabbage field very frequently. The nightingale visited the fields in the morning and afternoon. The birds very found to puncture the soft levels and newly initiated head and were controlled by striking a kerosene tin of metallic container frequently during day time.

3.13 Harvesting

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

3.14 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of heads, 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 the experiment. Data on plant height, number of leaves and length of large leaf were collected at 20, 30, 40 and 50 days after transplanting (DAT). All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.14.1 Plant height

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

3.14.2 Number of loose leaves per plant

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

3.14.3 Plant spread

The spread of plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 10 days interval starting from 20 days after transplanting (DAT) upto 50 days and at harvest.

3.14.4 Length of longest leaf

The distance from the base of the petiole to the tip of longest leaf was considered length of leaf. It was measured with a meter scale and was recorded in centimeter (cm). Data were recorded as the average of 5 leaves selected at random of each plot at 10 days interval starting from 20 days after transplanting (DAT) upto 50 days and at harvest.

3.14.5 Days to 1st head formation

Each plant of the experiment plot was kept under close observation to count days to 1st head formation. Total number of days from the date of transplanting to the 1st head formation was recorded.

3.14.6 Length of stem

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

3.14.7 Diameter of stem

The diameter of the stem was measured at the point where the central head 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).

3.14.8 Fresh weight of stem per plant

The fresh weight of stem was recorded from the average of five (5) selected plants in grams (gm) with a beam balance.

3.14.9 Dry matter content of stem

At first stem of selected plant was collected, cut into pieces and was dried under sunshine for a few days and then dried in an oven at 70^0C for 72 hours before taking dry weight till it was constant. The dry weight was recorded in gram (g) with a beam balance.

3.14.10 Length of root

The length of root was considered from the base of the tip of the root. It was measured in centimeter (cm) with a meter scale after harvesting.

3.14.11 Fresh weight of roots per plant

Fresh weight of roots was recorded in weighting the total roots and was recorded in gram.

3.14.12 Thickness of head

The thickness of head was measured in centimeter (cm) with a meter scale as the vertical distance from the lower to the upper most leaves of the head after sectioning the head vertically at the middle position and mean value was calculated.

3.14.13 Diameter of head

The heads from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the head 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 head and mean value was recorded.

3.14.14 Gross weight of head

The heads from sample plants were harvested, cleaned and weighted with folding and unfolded leaves. The weight of every head were measured a weighing scale and mean values was counted.

3.14.15 Marketable yield per plant

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

3.14.16 Dry matter content of head

At first stem of selected plant was collected, cut into pieces and was dried under sunshine for a few days and then dried in an oven at 70^0C for 72 hours before taking dry weight till it was constant. The dry weight was recorded in gram (g) with a beam balance.

3.14.17 Marketable yield per plot

Marketable head yield per plot was recorded as the head weight of all the plants within a plot and was expressed in kilogram. Marketable yield included only the yield of marketable head.

3.14.18 Marketable yield per hectare

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

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for gibberellic acid and potash nutrient on yield and yield contributing characters of cabbage. 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).

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different levels of gibberellic acid and potash nutrients. 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 cabbage 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 conducted to find out response of gibberellic acid (GA_3) and potash nutrient on growth and yield of late planting cabbage. Data on different growth and yield of cabbage were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-VI. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Statistically significant variation was recorded for plant height of cabbage due to different levels of gibberellic acid at 20, 30, 40 and 50 DAT (Table 2). At 20, 30, 40 and 50 DAT, the tallest plant (13.2, 21.2, 38.5 and 46.9 cm, respectively) was recorded from G_2 which was statistically similar (13.0, 20.8, 37.0 and 45.7 cm, respectively) to G_3 and closely followed (11.8, 20.0, 36.0 and 43.1 cm, respectively) by G_1. On the other hand, the shortest plant (10.9, 19.0, 33.6 and 41.5 cm, respectively) was recorded from G_0 for 20, 30, 40 and 50 DAT, respectively. Islam (1985) reported that application of GA_3 increased the plant height of cabbage. Patil *et al.* (1987) noticed the maximum plant height with GA_3 at 50 ppm.

Different levels of potassium fertilizer showed significant variation for plant height of cabbage at 20, 30, 40 and 50 DAT (Table 3). At 20, 30, 40 and 50 DAT, the tallest plant (13.0, 21.0, 39.1 and 47.0 cm, respectively) was recorded from K_1 which was statistically similar (12.3, 20.6, 38.3 and 46.4 cm, respectively) to K_2, whereas the shortest plant (11.4, 19.2, 32.0 and 39.4 cm, respectively) was recorded from K_0. Potassium fertilizer ensures favorable condition for the growth of stem amaranth and the ultimate results was the tallest plant.

Table 2. Effect of different levels of gibberellic acid on plant height and number of leaves per plant of cabbage

Levels of GA_3	Plant height (cm) at				Number of leaves per plant at			
	20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
G_0	10.9 c	19.0 c	33.6 b	41.5 c	5.98 c	12.3 c	19.1 c	22.2 c
G_1	11.8 b	20.0 b	36.0 ab	43.1 bc	6.80 b	13.2 b	20.7 b	23.0 bc
G_2	13.2 a	21.2 a	38.5 a	46.9 a	8.49 a	14.4 a	22.6 a	25.6 a
G_3	13.0 a	20.8 ab	37.9 a	45.7 ab	8.11 a	13.8 ab	21.6 ab	24.2 b
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.02	4.88	7.87	6.79	10.84	6.63	7.60	5.18

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

Table 3. Effect of different levels of potassium on plant height and number of loose leaves per plant of cabbage

Levels of potassium	Plant height (cm) at				Number of loose leaves per plant at			
	20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
K_0	11.4 c	19.2 b	32.0 b	39.4 b	6.43 b	12.1 b	18.4 b	21.8 b
K_1	13.0 a	21.0 a	39.1 a	47.0 a	7.87 a	14.2 a	22.4 a	24.9 a
K_2	12.3 b	20.6 a	38.3 a	46.4 a	7.73 a	14.0 a	22.2 a	24.5 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.02	4.88	7.87	6.79	10.84	6.63	7.60	5.18

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

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on plant height of cabbage at 20, 30, 40 and 50 DAT (Table 4). At 20, 30, 40 and 50 DAT, the tallest plant (15.1, 22.5, 43.3 and 51.4 cm, respectively) was recorded from G_2K_1, while the shortest plant (10.5, 18.1, 29.3 and 36.4 cm, respectively) was recorded from G_0K_0.

4.2 Number of loose leaves per plant

Number of loose leaves per plant of cabbage varied significantly variation was recorded for due to different level of gibberellic acid at 20, 30, 40 and 50 DAT under the present trial (Table 2). At 20, 30, 40 and 50 DAT, the maximum number of loose leaves per plant (8.49, 14.4, 22.6 and 25.6) was found from G_2 which was statistically similar (8.11, 13.8, 21.6 and 24.2) with G_3 and closely followed (6.80, 13.2, 20.7 and 23.0) by G_1, whereas, the minimum number of loose leaves per plant (5.98, 12.3, 19.1 and 22.2) from G_0 for 20, 30, 40 and 50 DAT, respectively. Patil *et al.* (1987) reported maximum number of loose leaves with 50 ppm $GA_{3.}$

Significant variation was recorded due to different levels of potassium fertilizer in terms of number of loose leaves per plant of cabbage at 20, 30, 40 and 50 DAT (Table 3). At 20, 30, 40 and 50 DAT, the maximum number of loose leaves per plant (7.87, 14.2, 22.4 and 24.9) was attained from K_1 which was statistically similar (7.73, 14.0, 22.2 and 24.5) with K_2, while the minimum number of loose leaves per plant (6.43, 12.1, 18.4 and 21.8) was found from K_0. Bahadur *et al.* (2004) recorded number of outer leaves (13.3) with 180 kg K_2O.

Different levels of gibberellic acid and potassium fertilizer showed significant differences due to their interaction effect on number of loose leaves per plant of cabbage at 20, 30, 40 and 50 DAT (Table 4). At 20, 30, 40 and 50 DAT, the maximum number of loose leaves per plant (9.67, 15.5, 24.3 and 27.4) was recorded from G_2K_1 and the minimum number of loose leaves per plant (5.60, 10.9, 16.8 and 20.9) was found from G_0K_0.

Table 4. Interaction effect of different levels of gibberellic acid and potassium on plant height and number of loose leaves per plant of cabbage

Levels of GA_3 and potassium	Plant height (cm) at				Number of loose leaves per plant at			
	20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
G_0K_0	10.5 d	18.1 e	29.3 d	36.4 e	5.60 d	10.9 d	16.8 d	20.9 f
G_0K_1	10.5 d	18.8 de	33.0 cd	40.5 cde	5.80 cd	12.2 cd	18.8 cd	21.8 ef
G_0K_2	11.1 d	18.9 de	33.6 cd	41.5 cde	6.33 cd	12.3 cd	19.1 cd	22.2 def
G_1K_0	10.9 d	18.6 e	31.1 d	38.0 de	6.07 cd	11.6 d	17.4 cd	20.8 f
G_1K_1	12.7 bc	20.9 abc	38.9 ab	46.0 abc	7.27 bc	14.2 ab	22.5 ab	24.1 cde
G_1K_2	11.7 cd	20.5 bcd	38.0 abc	45.2 bc	7.07 bcd	13.9 ab	22.2 ab	24.2 bcd
G_2K_0	12.8 bc	20.8 abc	33.6 cd	41.0 cde	8.27 ab	13.7 bc	20.2 bc	23.1 cdef
G_2K_1	15.1 a	22.5 a	43.3 a	51.4 a	9.67 a	15.5 a	24.3 a	27.4 a
G_2K_2	13.0 bc	21.4 ab	40.6 a	49.7 ab	8.47 ab	14.6 ab	23.7 a	26.4 ab
G_3K_0	11.2 d	19.3 cde	34.1 bcd	42.4 cd	5.80 cd	12.3 cd	19.3 cd	22.5 def
G_3K_1	13.8 b	21.6 ab	41.2 a	50.1 ab	8.73 a	14.8 ab	23.9 a	26.4 ab
G_3K_2	13.5 b	21.8 ab	41.1 a	49.2 ab	9.07 a	15.1 ab	23.6 a	25.3 abc
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.02	4.88	7.87	6.79	10.84	6.63	7.60	5.18

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

4.3 Plant spread

Statistically significant variation was recorded for plant spread of cabbage due to different levels of gibberellic acid at 20, 30, 40 and 50 DAT (Figure 2). At 20, 30, 40 and 50 DAT, the maximum plant spread (16.3, 30.0, 40.8 and 51.3 cm, respectively) was recorded from G_2 which was statistically similar (16.1, 29.1, 38.9 and 50.3 cm, respectively) with G_3 and closely followed (14.4, 27.6, 37.8 and 47.4 cm, respectively) by G_1, whereas the minimum plant spread (13.0, 24.8, 35.0 and 43.8 cm, respectively) from G_0.

Different levels of potassium fertilizer showed significant variation plant spread of cabbage at 20, 30, 40 and 50 DAT (Figure 3). At 20, 30, 40 and 50 DAT, the maximum plant spread (15.6, 29.8, 40.7 and 50.6 cm, respectively) was recorded from K_2 which was statistically similar (15.3, 29.5, 40.4 and 50.6 cm, respectively) with K_1 and the minimum plant spread (13.9, 24.4, 33.3 and 42.6 cm, respectively) was found from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on plant spread of cabbage at 20, 30, 40 and 50 DAT (Table 5). At 20, 30, 40 and 50 DAT, the maximum plant spread (18.4, 33.6, 44.5 and 57.1 cm, respectively) was recorded from G_3K_2, whereas the minimum (12.9, 21.2, 29.4 and 40.1 cm, respectively) from G_0K_0.

4.4 Length of largest leaf

Statistically significant variation was recorded for length of largest leaf of cabbage due to different levels of gibberellic acid at 20, 30, 40 and 50 DAT under the present trial (Figure 4). At 20, 30, 40 and 50 DAT, the maximum length of largest leaf (14.3, 24.5, 31.6 and 37.8 cm, respectively) was found from G_2 which was statistically similar (14.1, 23.9, 30.7 and 36.9 cm, respectively) with G_3 and closely followed (12.2, 22.7, 28.8 and 35.4 cm, respectively) by G_1, while the minimum length of largest leaf (11.7, 20.4, 26.7 and 33.1 cm, respectively) was recorded from G_0 for 20, 30, 40 and 50 DAT, respectively. Islam (1985) reported that GA_3 increased the size of cabbage leaf.

Table 5. Interaction effect of different levels of gibberellic acid and potassium on plant spread and length of largest leaf of cabbage

Levels of GA_3 and potassium	Plant spread (cm) at				Length of largest leaf (cm)			
	20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
G_0K_0	12.9 fg	21.2 d	29.4 d	40.1 d	11.2 e	19.9 c	23.7 f	30.8 ef
G_0K_1	13.1 fg	25.2 cd	35.6 bc	44.5 cd	11.8 e	20.3 c	26.4 def	33.8 cde
G_0K_2	12.7 g	24.4 cd	34.1 cd	42.1 d	11.3 e	20.0 c	25.3 ef	32.2 def
G_1K_0	13.6 efg	23.1 d	32.7 cd	42.5 d	11.5 e	20.8 c	25.3 ef	28.2 f
G_1K_1	14.7 def	29.7 ab	40.2 ab	50.2 bc	12.3 de	23.6 b	30.7 abcd	39.8 ab
G_1K_2	15.0 cde	30.1 ab	40.5 ab	49.5 bc	12.8 cde	23.7 b	30.4 bcd	38.2 abc
G_2K_0	15.9 bcd	28.4 bc	35.9 bc	43.3 d	14.4 abc	23.9 ab	26.3 def	34.5 bcde
G_2K_1	16.3 bcd	30.5 ab	43.0 a	53.8 ab	13.9 bcd	24.6 ab	33.3 ab	39.0 abc
G_2K_2	16.5 bc	31.2 ab	43.4 a	56.7 a	14.5 abc	25.0 ab	35.2 a	39.8 ab
G_3K_0	13.3 efg	24.9 cd	35.3 bc	44.7 cd	12.1 de	20.8 c	28.4 cde	33.4 cdef
G_3K_1	17.1 ab	32.5 ab	42.7 a	53.8 ab	15.1 ab	25.3 ab	33.0 abc	37.6 abcd
G_3K_2	18.4 a	33.6 a	44.5 a	57.1 a	16.1 a	26.4 a	35.3 a	42.3 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.54	8.59	7.50	6.74	8.28	5.93	8.49	8.31

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

G_0: 0 ppm GA_3 (control)
G_1: 90 ppm GA_3
G_2: 120 ppm GA_3
G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)
K_1: 150 kg K_2O/ha
K_2: 200 kg K_2O/ha

Different levels of potassium fertilizer showed significant variation length of largest leaf of cabbage at 20, 30, 40 and 50 DAT (Figure 5). At 20, 30, 40 and 50 DAT, the maximum length of largest leaf (13.7, 23.8, 31.6 and 38.1 cm, respectively) was obtained from K_2 which was statistically similar (13.3, 23.4, 30.8 and 37.6 cm, respectively) with K_1, whereas the minimum length of largest leaf (12.3, 21.4, 25.9 and 31.7 cm, respectively) was found from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on length of largest leaf of cabbage at 20, 30, 40 and 50 DAT (Table 5). At 20, 30, 40 and 50 DAT, the maximum length of largest leaf (16.1, 26.4, 35.3 and 42.3 cm, respectively) was recorded from G_3K_2, while the minimum length of largest leaf (11.2, 19.9, 23.7 and 30.8 cm, respectively) was recorded from G_0K_0.

4.5 Days to 1st head formation

Statistically significant variation was recorded for days to 1st head formation of cabbage due to different levels of gibberellic acid under the present trial (Figure 6). The highest days to 1st head formation (38.0) was found from G_0, while the lowest days (34.9) was recorded from G_2 which was statistically similar (36.0 and 36.2) with G_1 and G_3. Patil *et al.* (1987) reported that head formation was 13 days earlier with 50 ppm GA_3.

Different levels of potassium fertilizer showed significant variation for days to 1st head formation of cabbage (Figure 7). The highest days to 1st head formation (37.4) was attained from K_0 whereas the lowest days to 1st head formation (35.7) was recorded from K_1 which was statistically similar (35.8) with K_2.

Interaction effect of different levels of gibberellic acid and potassium fertilizer varied significantly on days to 1st head formation of cabbage (Figure 8). The highest days to 1st head formation (43.0) was recorded from G_0K_0 and the lowest days(33.3)fromG_2K_1.

4.6 Length of stem

Statistically significant variation was recorded for length of stem of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest length of stem (8.74 cm) was recorded from G_2 which was statistically similar (8.63 cm and 8.06 cm) with G_3 and G_1, whereas the lowest length of stem (7.18 cm) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for length of stem of cabbage (Table 7). The highest length of stem (8.64 cm) was found from K_1 which was statistically similar (8.48 cm) with K_2, while the lowest length of stem (7.34 cm) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on length of stem of cabbage (Table 8). The highest length of stem (9.87 cm) was recorded from G_3K_1, again the lowest length of stem (6.74 cm) was found from $G_3K_{0.}$

4.7 Diameter of stem

Statistically significant variation was recorded for diameter of stem of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest diameter of stem (3.57 cm) was found from G_3 which was statistically similar (3.51 cm and 3.19 cm) with G_2 and G_1, while the lowest diameter of stem (2.68 cm) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for diameter of stem of cabbage (Table 7). The highest diameter of stem (3.59 cm) was recorded from K_1 which was statistically similar (3.48 cm) with K_2, whereas the lowest diameter of stem (2.65 cm) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on diameter of stem of cabbage (Table 8). The highest diameter of stem (4.45) was recorded from G_3K_1 and the lowest diameter of stem (2.21 cm) was found from G_0K_0.

Table 6. Effect of different levels of gibberellic acid on yield contributing characters of cabbage

Levels of GA_3	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of stem (g)	Dry matter content of stem (%)	Length of roots (cm)	Fresh weight of roots (g)
G_0	7.18 b	2.68 b	46.3 b	11.2 b	19.7 b	18.5 c
G_1	8.06 a	3.19 a	53.5 a	12.1 a	21.9 ab	21.2 b
G_2	8.63 a	3.51 a	57.0 a	12.6 a	23.9 a	23.7 a
G_3	8.74 a	3.57 a	55.4 a	12.8 a	24.1 a	22.2 ab
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	9.61	10.59	10.37	6.50	11.53	9.88

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

Table 7. Effect of different levels of potassium on yield contributing characters of cabbage

Levels of potassium	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of stem (g)	Dry matter content of stem (%)	Length of roots (cm)	Fresh weight of roots (g)
K_0	7.34 b	2.65 b	46.4 b	11.0 b	20.17 b	17.73 b
K_1	8.64 a	3.59 a	57.3 a	12.8 a	24.10 a	23.41 a
K_2	8.48 a	3.48 a	55.3 a	12.6 a	23.02 a	23.03 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	9.61	10.59	10.37	6.50	11.53	9.88

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

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

Table 8. Interaction effect of different levels of gibberellic acid and potassium on yield contributing characters of cabbage

Levels of GA_3 and potassium	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of stem (g)	Dry matter content of stem (%)	Length of roots (cm)	Fresh weight of roots (g)
G_0K_0	7.46 cde	2.21 e	41.2 d	12.2 bc	17.1 d	15.2 b
G_0K_1	7.00 de	2.44 e	42.2 cd	10.6 d	19.3 cd	17.6 b
G_0K_2	7.08 de	2.54 e	44.3 cd	10.7 d	19.8 cd	19.0 b
G_1K_0	6.84 e	2.35 e	45.3 cd	10.5 d	19.2 cd	17.7 b
G_1K_1	8.76 abc	3.65 abcd	57.2 ab	13.0 ab	24.1 bc	22.9 a
G_1K_2	8.58 abc	3.57 bcd	57.9 ab	12.8 ab	22.5 bc	23.0 a
G_2K_0	8.32 bcd	2.95 de	47.1 cd	10.7 d	24.3 bc	19.1 b
G_2K_1	8.92 abc	3.81 abc	64.2 a	13.7 a	24.2 bc	26.6 a
G_2K_2	8.66 abc	3.76 abcd	59.7 ab	13.5 ab	23.4 bc	25.3 a
G_3K_0	6.74 e	3.06 cde	52.2 bc	10.9 cd	20.1 cd	19.0 b
G_3K_1	9.87 a	4.45 a	65.6 a	14.0 a	28.9 a	26.6 a
G_3K_2	9.62 ab	4.04 ab	59.3 ab	13.5 ab	26.4 ab	24.8 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	9.61	10.59	10.37	6.50	11.53	9.88

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

4.8 Fresh weight of stem

Statistically significant variation was recorded for fresh weight of stem of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest fresh weight of stem (57.0 g) was recorded from G_2 which was statistically similar (55.4 g and 53.5 g) with G_3 and G_1, whereas the lowest fresh weight of stem (46.3 g) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for fresh weight of stem of cabbage (Table 7). The highest fresh weight of stem (57.3 g) was recorded from K_1 which was statistically similar (55.3 g) with K_2, while the lowest fresh weight of stem (46.4 g) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on fresh weight of stem of cabbage (Table 8). The highest fresh weight of stem (65.6 g) was recorded from G_3K_1 and the lowest fresh weight of stem (41.2 g) was found from $G_0K_{0.}$

4.9 Dry matter content of stem

Statistically significant variation was recorded for dry matter content of stem of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest dry matter content of stem (12.8 g) was found from G_3 which was statistically similar (12.6 g and 12.1 g) with G_2 and G_1, while the lowest dry matter content of stem (11.0 g) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for dry matter content of stem of cabbage (Table 7). The highest dry matter content of stem (12.8 g) was found from K_1 which was statistically similar (12.6 g) with K_2, whereas the lowest dry matter content of stem (11.0 g) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on dry matter content of stem of cabbage (Table 8). The highest dry matter content of stem (14.0 g) was recorded from G_3K_1 and the lowest dry matter content of stem (10.5 g) was found from $G_1K_{0.}$

4.10 Length of roots

Statistically significant variation was recorded for length of roots of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest length of roots (24.1 cm) was attained from G_3 which was statistically similar (23.9 cm and 21.9 cm) with G_2 and G_1, while the lowest length of roots (19.7 cm) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for length of roots of cabbage (Table 7). The highest length of roots (24.1 cm) was attained from K_1 which was statistically similar (23.0 cm) with K_2, whereas the lowest length of roots (20.2 cm) was found from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on length of roots of cabbage (Table 8). The highest length of roots (28.9 cm) was recorded from G_3K_1 and the lowest length of roots (17.1 cm) was found from $G_0K_{0.}$

4.11 Fresh weight of roots

Statistically significant variation was recorded for fresh weight of roots of cabbage due to different levels of gibberellic acid under the present trial (Table 6). The highest fresh weight of roots (23.7 g) was recorded from G_2 which was statistically similar (22.2 g) with G_3 and closely followed (21.2 g) by G_1, while the lowest fresh weight of roots (18.5 g) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for fresh weight of roots of cabbage (Table 7). The highest fresh weight of roots (23.4 g) was found from K_1 which was statistically similar (23.0 g) with K_2, whereas the lowest fresh weight of roots (17.7 g) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on fresh weight of roots of cabbage (Table 8). The highest fresh weight of roots (26.6 g) was recorded from G_3K_1 and the lowest fresh weight of roots (15.2 g) was found from $G_0K_{0.}$

4.12 Thickness of head

Significant variation was recorded for thickness of head of cabbage due to different levels gibberellic acid under the present trial (Table 9). The highest thickness of head (13.4 cm) was found from G_3 which was statistically similar (12.9 cm and 12.7 cm) with G_2 and G_1, while the lowest (11.8 cm) from G_0.

Different levels of potassium fertilizer showed significant variation for thickness of head of cabbage (Table 10). The highest thickness of head (13.5 cm) was attained from K_1 which was statistically similar (13.2 cm) with K_2, whereas the lowest thickness of head (11.4 cm) was recorded from K_0. Bahadur *et al.* (2004) recorded head length (16.8 cm) with 180 kg K_2O.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on thickness of head of cabbage (Table 11). The highest thickness of head (15.5 cm) was recorded from G_2K_1 and the lowest thickness of head (10.8 cm) was found from G_0K_0.

4.13 Diameter of head

Statistically significant variation was recorded for diameter of head of cabbage due to different levels of gibberellic acid under the present trial (Table 9). The highest diameter of head (14.7 cm) was recorded from G_2 which was closely followed (13.9 cm) by G_3, while the lowest diameter of head (11.5 cm) was recorded from G_0. Patil *et al.* (1987) were noticed the maximum head diameter with GA_3 at 50 ppm.

Different levels of potassium fertilizer showed significant variation for diameter of head of cabbage (Table 10). The highest diameter of head (14.0 cm) was found from K_1 which was statistically similar (13.7 cm) with K_2, whereas the lowest diameter of head (12.0 cm) was recorded from K_0. Bahadur *et al.* (2004) recorded head diameter (15.5 cm) with 180 kg K_2O.

Table 9. Effect of different levels of gibberellic acid on yield contributing characters and yield of cabbage

Levels of GA_3	Thickness of head (cm)	Diameter of head (cm)	Gross weight of head (kg)	Marketable yield per plant (kg)	Dry matter content of head (%)	Marketable yield per hectare (ton)
G_0	11.8 b	11.5 d	1.42 c	1.09 c	10.5 c	40.4 c
G_1	12.7 ab	12.9 c	1.88 b	1.56 b	11.6 b	57.8 b
G_2	12.9 a	14.7 a	2.14 a	1.76 a	13.0 a	65.1 a
G_3	13.4 a	13.9 b	2.02 a	1.71 a	12.4 ab	63.2 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	7.35	4.96	7.06	6.47	4.72	6.47

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

Table 10. Effect of different levels of potassium on yield contributing characters and yield of cabbage

Levels of potassium	Thickness of head (cm)	Diameter of head (cm)	Gross weight of head (kg)	Marketable yield per plant (kg)	Dry matter content of head (%)	Marketable yield per hectare (ton)
K_0	11.4 b	12.0 b	1.41 b	1.20 c	10.7 b	44.6 c
K_1	13.5 a	14.0 a	2.14 a	1.74 a	12.6 a	64.4 a
K_2	13.2 a	13.7 a	2.04 a	1.64 b	12.4 a	60.8 b
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	7.35	4.96	7.06	6.47	4.72	6.47

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

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

Table 11. Interaction effect of different levels of gibberellic acid and potassium on yield contributing characters and yield of cabbage

Levels of GA_3 and potassium	Thickness of head (cm)	Diameter of head (cm)	Gross weight of head (kg)	Marketable yield per plant (kg)	Dry matter content of head (%)	Marketable yield per hectare (ton)
G_0K_0	10.8 e	10.3 c	1.24 e	1.04 e	10.1 d	38.4 e
G_0K_1	11.5 de	10.6 c	1.61 cd	1.16 e	10.3 d	43.0 e
G_0K_2	12.0 cde	11.2 c	1.40 de	1.07 e	10.6 cd	39.8 e
G_1K_0	10.7 e	11.3 c	1.36 e	1.17 e	10.2 d	43.2 e
G_1K_1	13.7 bc	13.8 b	2.18 ab	1.81 bc	12.4 abc	66.9 bc
G_1K_2	13.7 bc	13.5 b	2.08 b	1.71 c	12.3 abc	63.3 c
G_2K_0	12.3 bcde	13.5 b	1.69 c	1.41 d	11.7 bcd	52.2 d
G_2K_1	15.5 a	16.2 a	2.42 a	2.04 a	14.0 a	75.6 a
G_2K_2	13.1 bcd	15.1 a	2.30 ab	1.82 bc	13.4 ab	67.4 bc
G_3K_0	12.0 cde	12.7 b	1.34 e	1.20 e	10.7 cd	44.6 e
G_3K_1	13.4 bc	15.4 a	2.34 a	1.95 ab	13.8 a	72.1 ab
G_3K_2	14.1 ab	15.1 a	2.37 a	1.97 ab	13.3 ab	72.8 ab
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	7.35	4.96	7.06	6.47	4.72	6.47

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

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on diameter of head of cabbage (Table 11). The highest diameter of head (16.2 cm) was obtained from G_2K_1 and the lowest diameter of head (10.3 cm) was found from $G_0K_{0.}$

4.14 Gross weight of head

Statistically significant variation was recorded for gross weight of head of cabbage due to different levels of gibberellic acid under the present trial (Table 9). The highest gross weight of head (2.14 kg) was recorded from G_2 which was statistically similar (2.02 kg) with G_3 and closely followed (1.88 kg) by G_1, while the lowest gross weight of head (1.42 kg) was recorded from G_0. Patil *et al.* (1987) were noticed the maximum head weight with GA_3 at 50 ppm.

Different levels of potassium fertilizer showed significant variation for gross weight of head of cabbage (Table 10). The highest gross weight of head (2.14 kg) was recorded from K_1 which was statistically similar (2.03 kg) with K_2, whereas the lowest gross weight of head (1.41 kg) was recorded from K_0. Bahadur *et al.* (2004) recorded head weight (1.62 kg) with 180 kg K_2O.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on gross weight of head of cabbage (Table 11). The highest gross weight of head (2.42 kg) was found from G_2K_1 and the lowest gross weight of head (1.24 kg) was found from $G_0K_{0.}$

4.15 Marketable yield per plant

Statistically significant variation was recorded for marketable yield per plant of cabbage due to different levels of gibberellic acid under the present trial (Table 9). The highest marketable yield per plant (1.76 kg) was found from G_2 which was statistically similar (1.71 kg) with G_3 and closely followed (1.56 kg) by G_1, while the lowest marketable yield per plant (1.09 kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for marketable yield per plant of cabbage (Table 10). The highest marketable yield per plant

(1.74 kg) was found from K_1 which was closely followed (1.64 kg) with K_2, whereas the lowest marketable yield per plant (1.20 kg) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per plant of cabbage (Table 11). The highest marketable yield per plant (2.04 kg) was recorded from G_2K_1 and the lowest marketable yield per plant (1.04 kg) was found from G_0K_0.

4.16 Dry matter content of head

Statistically significant variation was recorded for dry matter content of head of stem of cabbage due to different levels of gibberellic acid under the present trial (Table 9). The highest dry matter content of head (13.0 g) was recorded from G_2 which was statistically similar (12.4 g) with G_3 and closely followed (11.6 g) by G_1, while the lowest dry matter content of head (10.5 g) was found from G_0.

Different levels of potassium fertilizer showed significant variation for dry matter content of head of cabbage (Table 10). The highest dry matter content of head (12.6 g) was found from K_1 which was statistically similar (12.4 g) with K_2, whereas the lowest dry matter content of head (10.7 g) from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on dry matter content of head of cabbage (Table 11). The highest dry matter content of head (14.0 g) was recorded from G_2K_1 and the lowest dry matter content of head (10.1 g) was found from G_0K_0.

4.17 Marketable yield per plot

Statistically significant variation was recorded for marketable yield per plot of cabbage due to different levels of gibberellic acid under the present trial (Figure 9). The highest marketable yield per plot (15.8 kg) was attained from G_2 which was statistically similar (15.4 kg) to G_3 and closely followed (14.1 kg) by G_1, while the lowest marketable yield per plot (9.81 kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for marketable yield per plot of cabbage (Figure 10). The highest marketable yield per plot (15.7 kg) was recorded from K_1 which was closely followed (14.8 kg) by K_2, whereas the lowest marketable yield per plot (10.8 kg) was recorded from K_0.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per plot of cabbage (Figure 11). The highest marketable yield per plot (18.4 kg) was recorded from G_2K_1 and the lowest marketable yield per plot (9.33 kg) was found from $G_0K_{0.}$

4.18 Marketable yield per hectare

Statistically significant variation was recorded for marketable yield per hectare of cabbage due to different levels of gibberellic acid under the present trial (Table 9). The highest marketable yield per hectare (65.1 ton) was recorded from G_2 which was statistically similar (63.2 ton) with G_3 and closely followed (57.8 ton) by G_1, while the lowest marketable yield per hectare (40.4 ton) from G_0. Islam (1985) reported that GA_3 increased yield contributing characters and finally the yield of cabbage. Patil *et al.* (1987) reported maximum yield (63.83 t/ha) with 50 ppm $GA_{3.}$ Islam *et al.* (1993) also reported that two sprays with 50 ppm GA_3 was suitable for higher yield of cabbage.

Different levels of potassium fertilizer showed significant variation for marketable yield per hectare of cabbage (Table 10). The highest marketable yield per hectare (64.4 ton) was found from K_1 which was closely followed (60.8 ton) by K_2, whereas the lowest marketable yield per hectare (44.6 ton) from K_0. Bahadur *et al*. (2004) recorded head yield (602.67 q/ha) with 180 kg K_2O.

Interaction effect of different levels of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per hectare of cabbage (Table 11). The highest marketable yield per hectare (75.6 ton) was recorded from G_2K_1 and the lowest marketable yield per hectare (38.4 ton) was found from $G_0K_{0.}$

4.19 Economic analysis

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

4.19.1 Gross return

The combination of different levels of gibberellic acid and potassium fertilizer showed different value in terms of gross return under the trial (Table 12). The highest gross return (Tk. 453,600) was obtained from the treatment combination G_2K_1 and the second highest gross return (Tk. 436,800) was found in G_3K_2. The lowest gross return (Tk. 230,400) was obtained from G_0K_0.

4.19.2 Net return

In case of net return, different levels of gibberellic acid and potassium fertilizer showed different levels of net return under the present trial (Table 12). The highest net return (Tk. 257,437) was found from the treatment combination G_2K_1 and the second highest net return (Tk. 237,379) was obtained from the combination G_3K_2. The lowest (Tk. 44,011) net return was obtained G_0K_0.

4.19.3 Benefit cost ratio

In the different levels of gibberellic acid and potassium fertilizer the highest benefit cost ratio (2.31) was noted from the combination of G_2K_1 and the second highest benefit cost ratio (2.19) was estimated from the combination of G_3K_2. The lowest benefit cost ratio (1.24) was obtained from G_0K_0 (Table 12). From economic point of view, it is apparent from the above results that the combination of G_2K_1 was better than rest of the combination.

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Table 12. Cost and return of cabbage cultivation as influenced by different levels of gibberellic acid and potassium

Levels of GA_3 and potassium	Cost of production (Tk./ha)	Yield of cabbage (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0K_0	186,389	38.4	230,400	44,011	1.24
G_0K_1	189,422	43.0	258,000	68,578	1.36
G_0K_2	190,433	39.8	238,800	48,367	1.25
G_1K_0	190,883	43.2	259,200	68,317	1.36
G_1K_1	193,916	66.9	401,400	207,484	2.07
G_1K_2	194,927	63.3	379,800	184,873	1.95
G_2K_0	193,130	52.2	313,200	120,070	1.62
G_2K_1	196,163	75.6	453,600	257,437	2.31
G_2K_2	197,174	67.4	404,400	207,226	2.05
G_3K_0	195,377	44.6	267,600	72,223	1.37
G_3K_1	198,410	72.1	432,600	234,190	2.18
G_3K_2	199,421	72.8	436,800	237,379	2.19

Price of cabbage @ Tk. 6000/ton

G_0: 0 ppm GA_3 (control)
G_1: 90 ppm GA_3
G_2: 120 ppm GA_3
G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)
K_1: 150 kg K_2O/ha
K_2: 200 kg K_2O/ha

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka to find out response of gibberellic acid and potash nutrient on growth and yield of late planting cabbage. Data on different growth and yield of cabbage were recorded. The test crop used in the experiment was cabbage variety Atlas-70. The experiment consisted of two factors: Factor A: gibberellic acid (four levels) as- G_0: 0 ppm GA_3, G_1: 90 ppm GA_3, G_2: 120 ppm GA_3, G_3: 150 ppm GA_3 and Factor B: Potassium fertilizer (three levels) as-K_0: 0 kg K_2O, K_1: 150 kg K_2O and K_2: 200 kg K_2O. The two factors experiment was laid out in Randomized Complete Block Design with three replications.

In case of different levels of gibberellic acid, at 20, 30, 40 and 50 DAT, the tallest plant (13.2, 21.2 38.5 and 46.9 cm, respectively), the maximum number of loose leaves per plant (8.49, 14.4, 22.6 and 25.6, respectively), the maximum plant spread (16.3, 30.0, 40.8 and 51.3 cm, respectively), the maximum length of largest leaf (14.3, 24.5, 31.6 and 37.8 cm, respectively), the lowest days to 1st head formation (34.9), the highest length of stem (8.74 cm), the highest diameter of stem (3.57 cm), the highest fresh weight of stem (57.0 g), the highest dry matter content of stem (12.8 g), the highest length of roots (24.1 cm), the highest fresh weight of roots (23.7 g), the highest thickness of head (13.4 cm), the highest diameter of head (14.7 cm), the highest gross weight of head (2.14 kg), the highest marketable yield per plant (1.78 kg), the highest dry matter content of head (13.0 g), the highest marketable yield per plot (15.8 kg) and the highest marketable yield per hectare (65.1 ton) was recorded from $G_{2,}$ whereas the shortest plant (10.9, 19.0, 33.6 and 41.5 cm, respectively), minimum number of loose leaves (5.98, 12.3, 19.1 and 22.2, respectively), the minimum plant spread (13.0, 24.8, 35.0 and

43.8 cm, respectively), the minimum length of largest leaf (11.7, 20.4, 26.7 and 33.1 cm, respectively), the highest days to 1st head formation (38.0), the lowest length of stem (7.18 cm), lowest diameter of stem (2.68 cm), the lowest fresh weight of stem (46.3 g), the lowest dry matter content of stem (11.0 g), the lowest length of root (19.7 cm), the lowest fresh weight of roots (18.5 g), the lowest thickness of head (11.8 cm), the lowest diameter of head (11.5 cm), the lowest gross weight of head (1.42 kg), the lowest marketable yield per plant (1.09 kg), the lowest dry matter content of head (10.5 g), the lowest marketable yield per plot (9.81 kg) and the lowest marketable yield per hectare (40.4 ton) was recorded from G_0.

For different levels of potash nutrients, at 20, 30, 40 and 50 DAT, the tallest plant (13.0, 21.0 39.1 and 47.0 cm, respectively), the maximum number of loose leaves per plant (7.87, 14.2, 22.4 and 24.9, respectively), the maximum plant spread (15.6, 29.8, 40.7 and 50.6 cm, respectively), the maximum length of largest leaf (13.7, 23.8, 31.6 and 38.1 cm, respectively), the lowest days to 1st head formation (35.7), the highest length of stem (8.64 cm), the highest diameter of stem (3.59 cm), the highest fresh weight of stem (57.3 g), the highest dry matter content of stem (12.8 g), the highest length of roots (24.1 cm), the highest fresh weight of roots (23.4 g), the highest thickness of head (13.5 cm), the highest diameter of head (14.0 cm), the highest gross weight of head (2.14 kg), the highest marketable yield per plant (1.74 kg), the highest dry matter content of head (12.6 g), the highest marketable yield per plot (15.7 kg) and the highest marketable yield per hectare (64.4 ton) was recorded from $K_{1,}$ while the shortest plant (11.4, 19.2, 32.0 and 39.4 cm, respectively), minimum number of loose leaves (6.43, 12.1, 18.4 and 21.8, respectively), the minimum plant spread (13.9, 24.4, 33.3 and 42.6 cm, respectively), the minimum length of largest leaf (12.3, 21.4, 25.9 and 31.7 cm, respectively), the highest days to 1st head formation (37.4), the lowest length of stem (7.34 cm), lowest diameter of stem (2.65 cm), the lowest fresh weight of stem (46.4 g), the lowest dry matter content of stem (11.0 g), the lowest length of root (20.2 cm), the lowest fresh weight of roots (17.7 g), the lowest thickness of head (11.4 cm), the lowest diameter of head (12.0 cm), the lowest gross weight of head (1.40 kg), the lowest marketable yield per plant (1.20 kg), the lowest dry matter content of head (10.7 g), the lowest marketable yield per plot (10.8 kg) and the lowest marketable yield per hectare (44.6 ton) was recorded from K_0.

Due to interaction effect of different levels of gibberellic acid and potassium fertilizer, at 20, 30, 40 and 50 DAT, the tallest plant (15.1, 22.5, 43.3 and 51.4 cm, respectively) was observed from G_2K_1, while the shortest plant (10.5, 18.1, 29.3 cm and 36.4 cm, respectively) from G_0K_0. At 20, 30, 40 and 50 DAT, the maximum number of leaves per plant (9.67, 15.5, 24.3 and 26.4, respectively) was observed from G_3K_3 and the minimum number (5.60, 10.9, 16.8 and 20.9, respectively) from G_0K_0. At 20, 30, 40 and 50 DAT, the maximum plant spread (18.4, 33.6, 44.5 and 57.1 cm, respectively) was observed from G_2K_1, whereas the minimum (12.9, 21.2, 29.4 and 40.1 cm, respectively) from G_0K_0. At 20, 30, 40 and 50 DAT, the maximum length of longest leaf (16.1, 26.4, 35.3 and 42.3 cm, respectively) from G_3K_1, while the minimum length of longest leaf (11.2, 19.9, 23.7 and 30.8 cm, respectively) from G_0K_0. The highest days to 1st head formation (43.0) was recorded from G_0K_0 and the lowest days (33.3) from G_2K_1. The highest length of stem (9.87 cm) was recorded from G_3K_1, again the lowest (6.74 cm) from $G_3K_{0.}$ The highest diameter of stem (4.45) was recorded from G_3K_1 and the lowest (2.21 cm) from $G_0K_{0.}$ The highest fresh weight of stem (65.6 g) was recorded from G_3K_1 and the lowest (41.2 g) from $G_0K_{0.}$ The highest dry matter content of stem (14.0 g) was observed from G_3K_3 and the lowest (10.5 g) from $G_1K_{0.}$ The highest length of roots (28.9 cm) was observed from G_3K_1 and the lowest (17.1 cm) from $G_0K_{0.}$ The highest fresh weight of roots (26.6 g) was recorded from G_3K_1 and the lowest (15.2 g) from $G_0K_{0.}$ The highest thickness of head (15.5 cm) was recorded from G_3K_1 and the lowest (10.8 cm) from $G_0K_{0.}$ The highest diameter of head (16.2 cm) was obtained from G_3K_1 and the lowest (10.3 cm) from $G_0K_{0.}$ The highest gross weight of head (2.42 kg) was found from G_2K_1

and the lowest (1.24 kg) from $G_0K_{0.}$ The highest marketable yield per plant (2.04 kg) was recorded from G_2K_1 and the lowest (1.04 kg) from $G_0K_{0.}$ The highest dry matter content of head (14.0 g) was observed from G_2K_1 and the lowest (10.1 g) from $G_0K_{0.}$ The highest marketable yield per plot (18.4 kg) was recorded from G_2K_1 and the lowest (9.33 kg) from $G_0K_{0.}$ The highest marketable yield per hectare (75.6 ton) was observed from G_2K_1 and the lowest (38.4 ton) from $G_0K_{0.}$ In the different level of gibberellic acid and potash nutrients the highest benefit cost ratio (2.31) was noted from the combination of G_2K_1 and the lowest benefit cost ratio (1.24) from G_0K_0.

Conclusion

Among the combination of different levels of gibberellic acid and potassium 120 ppm GA_3 and 150 kg K_2O performed superior in growth, yield contributing characters and yield of cabbage as well as highest economic return.

Recommendations

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

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Another plant growth regulator with different concentration need to be consider before final recommendation.
3. Another level of potassium fertilizer may be used in future study.

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APPENDICES

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2011 to March 2012

Month	*Air temperature (^oC)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2011	25.82	16.04	78	00
December, 2011	22.4	13.5	74	00
January, 2012	24.5	12.4	68	00
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	11

* Monthly average,

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

Appendix III. **Analysis of variance of the data on plant height and number of loose leaves of cabbage as influenced by different levels of gibberellic acid and potassium**

Source of variation	Degrees of freedom	Mean square							
		Plant height (cm) at				Number of loose leaves per plant at			
		20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
Replication	2	0.071	0.379	2.022	3.494	0.148	0.132	0.122	0.554
Level of GA_3 (A)	3	10.637**	8.825**	43.973**	54.816**	12.185**	7.242**	20.181**	20.150**
Level of potassium (B)	2	8.549**	10.711**	180.135**	211.974**	7.524**	15.237**	59.417**	33.875**
Interaction (A×B)	6	3.934**	3.856**	32.792**	41.651**	2.874**	3.872**	9.981**	6.073**
Error	22	0.542	0.978	8.231	9.033	0.634	0.793	2.542	1.513

** Significant at 0.01 level of probability;

Appendix IV. **Analysis of variance of the data on plant spread and length of largest leaf of cabbage as influenced by different levels of gibberellic acid and potassium**

Source of variation	Degrees of freedom	Mean square							
		Plant spread (cm) at				Length of largest leaf (cm)			
		20 DAT	30 DAT	40 DAT	50 DAT	20 DAT	30 DAT	40 DAT	50 DAT
Replication	2	0.232	0.567	1.274	13.575	0.269	1.272	1.424	0.201
Level of GA_3 (A)	3	21.475**	46.525**	51.879**	102.770**	15.383**	29.459**	42.357**	36.983**
Level of potassium (B)	2	9.671**	110.186**	206.964**	278.846**	6.076**	20.521**	112.541**	150.949**
Interaction (A×B)	6	5.535**	28.176**	37.347**	58.780**	5.575**	8.440**	34.249**	31.793**
Error	22	0.956	5.737	8.171	10.541	1.173	1.835	6.254	8.853

** Significant at 0.01 level of probability;

Appendix V. **Analysis of variance of the data on yield contributing characters of cabbage as influenced by different levels of gibberellic acid and potassium**

Source of variation	Degrees of freedom	Mean square							
		Days to 1st head formation	Length of stem (cm)	Diameter of stem (cm)	Fresh weight of stem (g)	Dry matter content of stem (%)	Number of roots per plant	Length of roots (cm)	Fresh weight of roots (g)
Replication	2	0.111	0.201	0.141	7.786	0.227	0.288	0.220	2.761
Level of GA_3 (A)	3	16.102**	4.618**	1.481**	201.644**	4.843**	3.759**	38.764**	42.497**
Level of potassium (B)	2	11.194*	6.047**	3.183**	401.196**	11.639**	9.591**	49.453**	120.751**
Interaction (A×B)	6	28.713**	2.296**	1.229**	182.882**	4.646**	3.137*	28.407**	22.995**
Error	22	2.566	0.614	0.201	30.223	0.625	0.973	6.693	4.464

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. **Analysis of variance of the data on yield contributing characters and yield of cabbage as influenced by different levels of gibberellic acid and potassium**

Source of variation	Degrees of freedom	Mean square						
		Thickness of head (cm)	Diameter of head (cm)	Gross weight of head (kg)	Marketable yield per plant (kg)	Dry matter content of head (%)	Marketable yield per plot (kg)	Marketable yield per hectare (ton)
Replication	2	0.003	0.368	0.005	0.003	0.080	0.272	4.607
Level of GA_3 (A)	3	4.195**	16.750**	0.890**	0.830**	10.108**	67.251**	1138.907**
Level of potassium (B)	2	15.042**	14.673**	1.874**	0.973**	13.595**	78.838**	1335.128**
Interaction (A×B)	6	4.094**	9.083**	0.104**	0.090**	2.626**	7.298**	123.600**
Error	22	0.874	0.431	0.017	0.010	0.104	0.792	13.415

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Per hectare production cost of cabbage

A. Input cost

Levels of GA_3 and potassium	Labour cost	Ploughing cost	Seed Cost	Water for plant Establishment	GA_3 cost	Manure and fertilizers				Insecticide/ pesticides	Sub total (A)
						Cowdung	Urea	TSP	MP		
G_0K_0	24,000	14,000	6,000	10,000	0	20,000	1,200	2,700	0	8,000	85,900
G_0K_1	24,000	14,000	6,000	10,000	0	20,000	1,200	2,700	2,700	8,000	88,600
G_0K_2	24,000	14,000	6,000	10,000	0	20,000	1,200	2,700	3,600	8,000	89,500
G_1K_0	24,000	14,000	6,000	10,000	4,000	20,000	1,200	2,700	0	8,000	89,900
G_1K_1	24,000	14,000	6,000	10,000	4,000	20,000	1,200	2,700	2,700	8,000	92,600
G_1K_2	24,000	14,000	6,000	10,000	4,000	20,000	1,200	2,700	3,600	8,000	93,500
G_2K_0	24,000	14,000	6,000	10,000	6,000	20,000	1,200	2,700	0	8,000	91,900
G_2K_1	24,000	14,000	6,000	10,000	6,000	20,000	1,200	2,700	2,700	8,000	94,600
G_2K_2	24,000	14,000	6,000	10,000	6,000	20,000	1,200	2,700	3,600	8,000	95,500
G_3K_0	24,000	14,000	6,000	10,000	8,000	20,000	1,200	2,700	0	8,000	93,900
G_3K_1	24,000	14,000	6,000	10,000	8,000	20,000	1,200	2,700	2,700	8,000	96,600
G_3K_2	24,000	14,000	6,000	10,000	8,000	20,000	1,200	2,700	3,600	8,000	97,500

G_0: 0 ppm GA_3 (control)

G_1: 90 ppm GA_3

G_2: 120 ppm GA_3

G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)

K_1: 150 kg K_2O/ha

K_2: 200 kg K_2O/ha

Appendix VII. (Cont'd)

B. Overhead cost (Tk./ha)

Levels of GA_3 and potassium	Cost of lease of land for 6 month (14% of value of land Tk. 12,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
G_0K_0	84,000	4,295	12,194	100,489	186,389
G_0K_1	84,000	4,430	12,392	100,822	189,422
G_0K_2	84,000	4,475	12,458	100,933	190,433
G_1K_0	84,000	4,495	12,488	100,983	190,883
G_1K_1	84,000	4,630	12,686	101,316	193,916
G_1K_2	84,000	4,675	12,752	101,427	194,927
G_2K_0	84,000	4,595	12,635	101,230	193,130
G_2K_1	84,000	4,730	12,833	101,563	196,163
G_2K_2	84,000	4,775	12,899	101,674	197,174
G_3K_0	84,000	4,695	12,782	101,477	195,377
G_3K_1	84,000	4,830	12,980	101,810	198,410
G_3K_2	84,000	4,875	13,046	101,921	199,421

G_0: 0 ppm GA_3 (control)
G_1: 90 ppm GA_3
G_2: 120 ppm GA_3
G_3: 150 ppm GA_3

K_0: 0 kg K_2O/ha (control)
K_1: 150 kg K_2O/ha
K_2: 200 kg K_2O/ha