GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY GIBBERELLIC ACID AND POTASSIUM

BY

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CERTIFICATE

This is to certify that thesis entitled, "**GROWTH AND YIELD OF CABBAGE AS INFLUENCED BY GIBBERELLIC ACID AND POTASSIUM**" submitted to the **Faculty of Agriculture**, 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 **SHAUKI SULTANA, Registration No. 09-03599** under my supervision and guidance. No of part of the thesis has been submitted for any other degree of diploma.

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

Dated: June, 2015

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The Author

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ABSTRACT

An experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to March 2014 to find out the effect of Gibberellic acid and Potassium on growth and yield of cabbage. The experiment was laid out in Randomized Complete Block Design with three replications. The experiment considered two factors; Factor A: different levels of $GA_{3;}$ such as G_0= 0 ppm, G_1= 105 ppm, G_2= 125 ppm and G_3= 140 ppm and Factor B: different levels of Potassium; such as K_0 = 0 kg MoP/ha, K_1 =125 kg MoP/ha and K_2 =150 kg MoP/ha. In case of $GA_{3,}$ G_2 gave the maximum (11.98 cm) thickness and highest yield (48.75 t/ha) and G_0 gave the minimum thickness (10.78 cm) and lowest yield (29.99 t/ha) of cabbage. For Potassium, K_2 gave the maximum thickness (11.63 cm) and highest yield (46.67 t/ha) and K_0 gave the minimum thickness (10.91 cm) and lowest yield (38.33 t/ha) of cabbage. Due to combined effect, G_2K_2 gave the maximum thickness (13.31 cm), yield (56.95 t/ha) and BCR (2.11) whereas G_0K_0 gave the minimum thickness (10.57 cm), yield (27.08 t/ha) and BCR (1.06). Considering the above parameters, it concluded that 125 ppm GA_3 and 150 kg MoP/ha is the best combination for cabbage production successfully.

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LIST OF ABBREVIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
Cm	=	Centimetre
CV.	=	Cultivar (s)
GA_3	=	Gibberellic Acid
DAT	=	Days after Transplanting
et al.	=	And Others
FAO	=	Food and Agriculture Organization of United Nations
Gm	=	Gram
HYV	=	High Yielding Variety
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
t/ha	=	Ton per Hectare
MOP	=	Murate of Potash
NS	=	Not significant
SRDI	=	Soil Resources and Development Institute

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) belongs to the family Brassicaceae and is biennial herbacious in nature which is locally known as Badhakopi. It is one of the important vegetables crop in Bangladesh. The origin of cabbage is the Western Europe and north shores of the Mediterranean Sea (Chauhan, 1986). It is also a well known and widely distributed crop within Asia and has been introduced successfully into part of Central America, West Africa, America, Canada and Europe. Cabbage was reported to be grown in the subcontinent during Mughal period, but the vegetable become popular during British rule (Bose and Som, 1986). The edible portion of cabbage plant is head which is formed by the fleshy leaves overlapping one another. It has been reported that 100 g of green edible portion of cabbage contains 92% water, 24 kilocalories of food energy, 1.5 g of protein, 4.8 g of carbohydrate, 40 mg of calcium, 0.6 mg of iron, 600 IU of carotene, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin C (Rashid, 1993).

Among the five leading vegetables of Bangladesh, the cabbage occupied an area of 11.37 thousand hectors of land with a production of 220 thousand metric tons (BBS, 2012). Thus the average yield was 9.39 t/ha. This is considered as low yield compared to that of other countries of the world, viz., South Korea (61.17 t/ha), Germany (54.81 t/ha.), Japan (40.32 t/ha) and India (19.10 t/ha). Such a poor yield attributed to a greater extent on the method of production technology followed by the farmers.

Growth regulators are organic compounds other than nutrients; small amount of which are capable of modifying growth (Leopold 1963). Among the growth regulators auxin causes enlargement of plant cell and gibberellins stimulate cell division, cell enlargement or both (Nickell, 1982). Due to the diversified use of productive land, it is necessary to increase the food production, and gibberellic acid (GA_3) may be a contributor in achieving the desired goal. The production of cabbage can be increased by using GA_3. Cabbage was found to show a quick growth when treated with plant growth regulators (Islam *et al.*, 1993). Application of GA_3 stimulates morphological characters like plant height, number of leaves, head diameter, thickness of head as well as the weight of head. Therefore, it was thought that it is necessary to find out the effective dose of GA_3 in promoting growth and yield components of cabbage even in higher temperature that prevails in the later part of the growing season under Bangladesh condition.

Deficiency of soil nutrient is now considered is one of the major constraints to successful upload crop production in Bangladesh (Islam and Noor, 1982). The cultivation of vegetable crops requires proper supply of plant nutrient. Cabbage responses greatly to major essential element like N, P and K for its growth and yield (Thomson and Kelly, 1988). Potassium is an inorganic fertilizer plays a vital role of proper growth and development of cabbage. Potassium (K) is essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomatal functioning, water relations and growth of meristematic tissues (Mitchell, 1970; Follett, *et al*., 1981). Potassium exerts balancing role on the effects of both nitrogen and phosphorus, consequently it is especially important in multi-nutrient fertilizer application (Brady, 1990). Mitchell (1970) describes Potassium as a major osmotic ion for the regulation of water flow in the plant. Potassium is also found in the leaves, where it acts as a catalyst for reactions involved in the activation of enzymes, synthesis of proteins, synthesis and translocation of starch and translocation of NO_3- (Archer, 1988). Plants well supplied with Potassium have strong stems that are resistant to lodging. Considering the above facts, the present investigation was undertaken with the following objectives:

1) To find out the appropriate concentration of GA_3 for increasing cabbage production.

2) To study the effect of Potassium on growth and yield of cabbage and

3) To determine the combined effect of GA_3 and Potassium for better growth, maximum yield and economic return of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop of many countries of the world as well as in Bangladesh. 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 yet until area should be increased to meet the 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. Considerable interest has been developed recently regarding the benefit from the use of GA_3 has been known to play a vital role in increasing the growth, yield and quality of cabbage. 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 heading:

2.1 Effect of GA_3 on the growth and yield of cabbage

Islam (1985) conducted an experiment at the Bangladesh Agriculture University Farm, Mymensingh with applying various growth regulators (CCC, GA_3, NAA and IBA) at 30 days after transplanting of 32 days old seedling, CCC decreased the plant height, size of loose leaves, diameter of the 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 increase 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. Signification increase in the 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 obtain 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. seeding soaked for 12 hour, spraying at 15 and 30 days of transplanting. They found that ascorbic acid content increase up to 50 ppm when sprayed twice with both the growth regulator while it 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.

Dharmendor *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. The recorded the height yield following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm (557.54 & 538.66 q/ha respectively). They also reported the combination and higher concentration of plant growth regulators proved less effect and were uneconomic in comparison to control.

The effect of foliar spray of the growth regulator B-9 (diamonized) (250, 282 and 500 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 16mg a.i./pot) and Sumagic (0.125, 0.25, 0.5, 1 and 2 mg a.i./pot), on the growth of ornamental cabbage and kale cultivators Osaka White and Nagoyra Red, growing in 8 inch pot, was investigated by Gibson and Whipker (1999). The folia sprays and drenches were applied 22 days after potting. The growth of Oska 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 rate controlled plant height of both cultivators but the response did not increase above 1 mg a.i./pot. Foliar spray of Bonzi did not control growth of Nagoya Red while Osaka White increased in plant height with increasing rates. Foliar sorays of Sunagic 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 Yadab *et al.* (2000) in Rajasthan, India, during the rabi season of 1996-97 to investigate the effects of NAA at 50,100 and 150ppm, 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.

Kar *et al.* (2003) conducted an experiment on the effect of variety and growth regulators on growth and yield of cabbage (*Brassica oleracea var. capitata*) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh, Bangladesh during October 2002 March, 2003. The highest gross and marketable yield of cabbage was obtained from the plants sprayed with 50 ppm NAA (Naphthalene Acetic Acid).

Moyazzama (2008) carried out an experiment to find out the effect of different concentration of GA_3 and potassium on the growth and yield of cabbage at sher-e-Bangla Agricultural University Farm in Dhaka. She applied GA_3 at 0, 65 and 85 ppm. The maximum plant height and diameter of head was obtained from 85 ppm of GA_3.

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

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 and ABA content decreased during devernalization. Compared with CK (vernalization period), GA_3 and ABA content decreased significantly, whereas IAA content significantly when devernalization ended. Lower GA_3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

The research work was conducted by Roy and Nasiruddin (2011) to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3 viz., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm GA_3 treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (104.66 t/ha) was found from 50 ppm GA_3.

2.2 Effect of Potassium on growth and yield of cabbage.

Farooque and Islam (1989) conducted an experiment on the effect of spacing and different management practices on the growth and yield of cabbage. They reported that the highest marketable yield produced when 8.3 t FYM, 200 kg MOC, 326 kg Urea, 125 kg TSP and 200 kg MP per hectare were applied.

Potassium is absorbed by plants in the form of the potassium ion (K^+). Soil Potassium exists in solution and in exchangeable and non-exchangeable forms, which are in dynamic equilibrium with each other (Cox *et al.,* 1999). Solution Potassium and exchangeable Potassium are replenished by non-exchangeable Potassium when they are depleted by plant removal or leaching (Gardiner and Miller, 2004).

Mitchell (1970) describes Potassium as a major osmotic ion for the regulation of water flow in the plant. Potassium is also found in the leaves, where it acts as a catalyst for reactions involved in the activation of enzymes, synthesis of proteins, synthesis and translocation of starch and translocation of NO_3^- (Archer, 1988). Plants well supplied with Potassium have strong stems that are resistant to lodging. Potassium makes plants more winter-hardy, less likely to be injured by spring or autumn frosts and it helps them to resist diseases (Mengel and Kirby, 1982). Potassium also encourages root development, but not to the same extent as P (Plaster, 2003).

Rao and Subramaniun (1991) conducted an experiment to find out the effect of potassium application on the yield and content of potassium, calcium and magnesium in cabbage at Bangalore in India. They applied K_2O at 0, 25, 50, 100, 150 and 200 kg/ha. They observed that the plant K concentration at all stages of growth increased significantly at the increasing level of K_2O application

Yetistiren and Vural (1991) studied the effects of various fertilizer applications on cabbage yield and quality. Nitrogen was applied at 10 or 20 kg/ha and K at 15 or 30 kg K_20/ha. They reported that highest yield was obtained with 20 kg N + 30 kg K_2O/ha.

An experiment was carried out at Joydebpur, Gazipur on cabbage (Var. Atlas-70) during Rabi season to find out the effects of fertilizer doses and organic manure on the yield of cabbage (Anonymous, 1991).

Samant *et al.* (1992) investigated the balanced fertilizer use for cabbage in clay loam soils of Orissa, India. It was reported that nitrogen (75 kg/ha) and potassium (150 kg/ha) gave the highest yield (17.42 t/ha), and it was the most economic dose. The application of 240 kg N/ha, 60 kg P/ha and 120 kg K/ha along with the cow dung@ 5 t/ha produced highest head yield of 75 t/ha.

Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O/ha for its higher production.

Jothi *et al.* (1993) carried out an experiment on the influence of N, P and Azospirillum on the yield of cabbage at Tamil Nadu in India. They reported that a cabbage yield of 117.2 t/ha was obtained with the application of N, P and K at 100,125 and 25 kg/ha respectively.

Halim *et al.* (1994) conducted an experiment on the effect of different doses of NPK on growth and yield of cabbage at Jamalpur in Bangladesh. Nitrogen was applied at 0, 100, 150 or 200 kg/ha, P at 0, 50, 100 or 150 kg P_2O_5 and K at 0, 75, 150 or 225 kg K_2O/ha in 12 combinations to cabbage cv. K-K cross. Gross yield and marketable head weight per plant were found the highest with 150 kg N+ 100 kg P_2O_5 + 150 kg K_2O or 200 kg N + 100 kg P_2O_5 +150 kg K_2O.

Tianxiu *et al.* (1994) studied the effect of K and Mg fertilizers applied to cabbage yield, quality and economic return and found that cabbage yield was higher with 150 kg K_2O/ha than with no potassium. The best cash return was also obtained with 150 kg K_2O/ha.

In many plants, K deficiency does not immediately result in visible hunger symptoms. At first there is only a reduction in the growth rate (hidden hunger), and only later chlorosis and necrosis may occur (Mengel and Kirby, 1982). Generally, these symptoms first occur in the older leaves, because Potassium is translocated from old to young foliage. In most plant species 16 necrosis and chlorosis first occur along the margins and tips of the leaves (Plaster, 1985, 2003)

Excess K can cause plants to first become deficient in Mg, and then in Ca, due to induced nutrient imbalances, which upset the K: Mg and K: Ca ratios, especially when Mg and Ca availability are at the low end of their sufficiency ranges (Jones, 2003). The negative response of plants to high applications of K may also be the result of an excessive salt concentration in the soil solution, which causes various types of chemical and physical stress in plants (Kuiper, 1984; Pasternak, 1987). According to Munns (1993), growth inhibition by salt stress is associated with alterations in the water relationships within the plant caused by osmotic effects.

Bishop *et al.* (2007) conducted an experiment on fertilizer treatments for cabbage, grown on sphagnum peat, consisted of an N, a P and a K series. Each nutrient was applied at four rates in combination with constant rates of the other two. Results indicated that 270 kg N/ha, the highest rate used, may not have been adequate whereas P and K at 80 and 150 kg/ha respectively were. In the N, the P, and the K series, highest head weights coincided with midribs containing 2.06% N, 0.48% P and 4.18% K, respectively.

Hossain *et al.* (2011) conducted an experiment at Bangabandhu Sheikh MujiburRahman Agricultural University, Gazipur during October 2006 to May 2007 to study the response of cabbage to fertilizer application in Salna clay loam soil. The experiment was carried out of study the response of cabbage variety Autmn Queen to added N, P, K and S nutrients in respect of growth, dry matter production and yield, nutrient contents in loose and heading leaves of the crop. Treatment receiving 240 kg N, 45 P, 180 kg K and 45 S/ ha performed the best in recording plant height, root length, number of loose and heading leaves, leaf length and breadth, thickness and diameter of head and yield.

CHAPTER III

MATERIALS AND METHODS

This experiment was conducted during the period from November 2013 to March 2014 to find out the response of Gibberellic acid and Potassium nutrients on growth and yield of 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 Farm of Sher-e-Bangla Agricultural University (SAU) Dhaka. It is located in $24^{0}9^{/}$ N latitude and $90^{0}26^{/}$ E longitudes. The altitude of the location is 8 m from the sea level as per the data of Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.2 Characteristics of soil

The 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 area 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 Resources and Development Institute (SADF) Dhaka, and result have been presented in Appendix I.

3.3 Climatic condition of the experimental site

Experimental area was 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.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Different levels of GA_3

i G_0: 0 ppm GA_3 (control)

ii. G_1: 105 ppm GA_3

iii. G_2: 125 ppm GA_3

iv. G_3: 140 ppm GA_3

Factor B: Different levels of Potassium fertilizer

i. K_0: 0 kg MoP/ha (control)

ii. K_1: 125 kg MoP/ha

iii. K_2: 150 kg MoP/ha

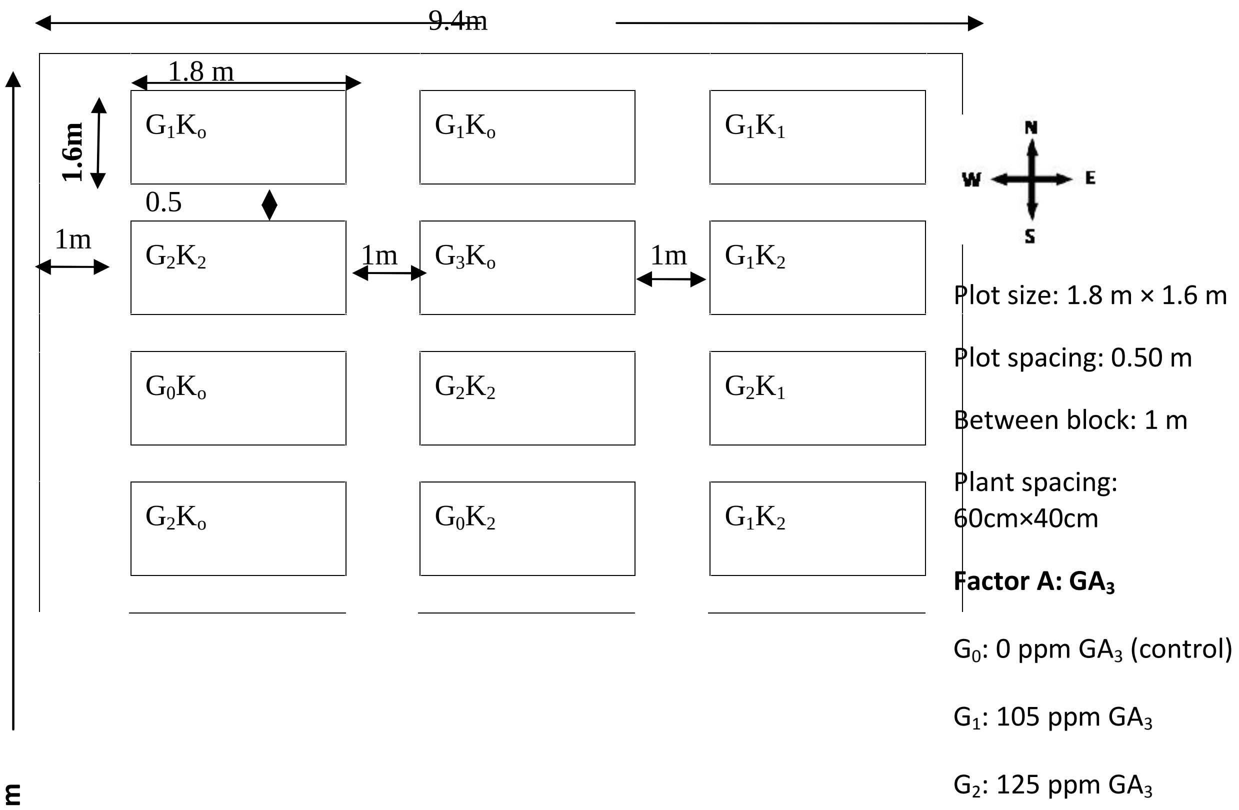
There were 12 (4×3) treatments combination such as G_0K_0, G_0K_1, G_0K_2, G_1K_0, G_1K_1, G_1K_2, G_2K_0, G_2K_1, G_2K_2, G_3K_0, G_3K_1 and G_3K_2.

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 factorial experiments were laid out in the Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 241.58 m^2 with length 25.7 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 × 1.6 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.



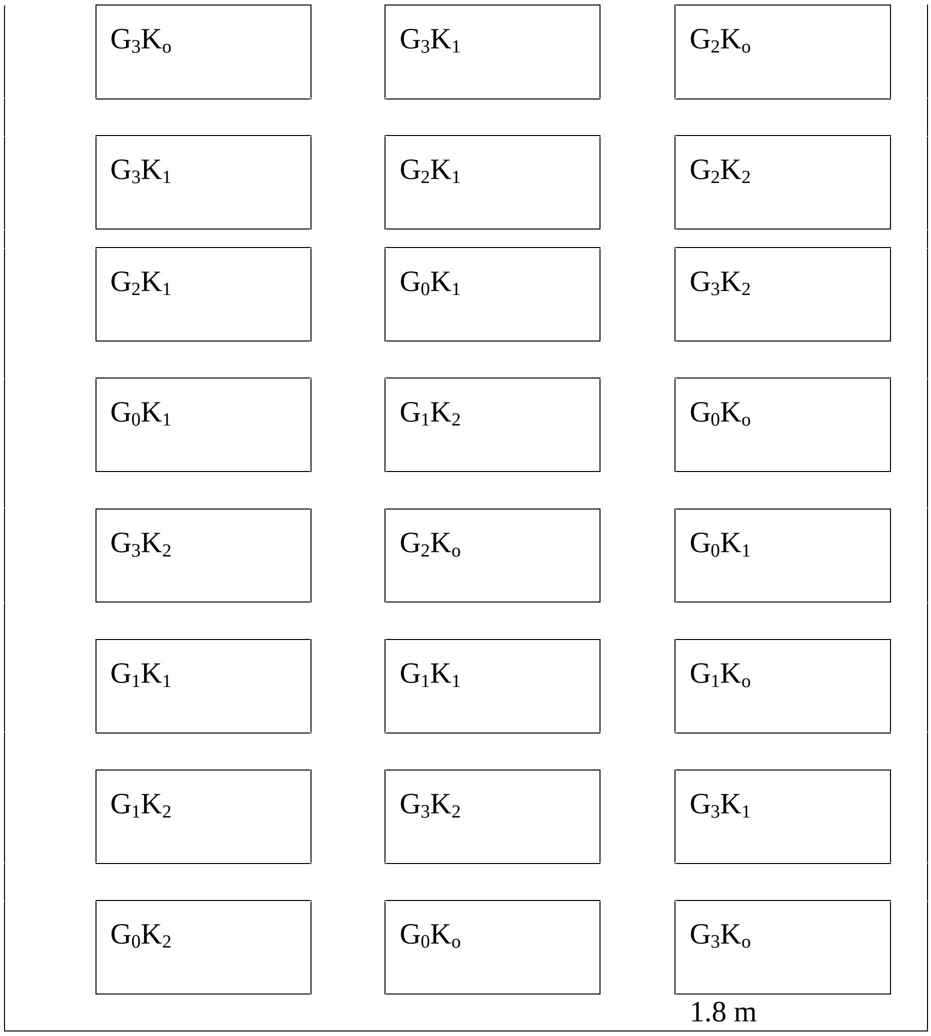


Figure1. Layout of the experimental plot

3.8 Preparation of the main field

The selected plot of the experiment was opened in the 1st week of November 2013 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 to the experimental plot considering the recommended fertilizer doses of BARI (2005).

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

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	20DAT	30 DAT	40 DAT
Cow dung	20 tones	100	--	--	--
Urea	250 kg	--	33.33	33.33	33.33
TSP	150 kg	100	--	--	--
MoP	As per treatment	--	--	--	--

The total amount of cow dung, 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 20, 30 and 40 day after transplanting.

3.10 Collection, preparation and application of growth regulator

Plant growth regulator Gibberellic Acid (GA_3) was collected from Hatkhola Road, Dhaka. A 1000 ppm stock solution of GA_3 was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 70 ml of this stock solution was diluted in 1 liter of distilled water to get 70 ppm GA_3 solution. In a similar way, 90 ml stock solutions were diluted to 1 litre of distilled water to get 90 ppm solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. GA_3 as per treatment were applied at four times 15, 30, 45 and 60 days after transplanting by a mini hand sprayer.

3.11 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 cow dung was applied to the prepared seedbed at the rate of 10 t/ha. Ten (10) grams of seeds were sown in seedbed on 1st November, 2013. 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.

3.12 Transplanting

Healthy and uniform at 30 days old seedlings were transplanting in the experimental plots on 1st December 2013. The seedlings were uploaded carefully from the seed bed to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon.

The seedlings were watered immediately after transplanting. Seedlings were sown in the plot with maintaining distance between row to row was 60 cm and plant to plant was 40 cm. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. The field was kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.13 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.

3.13.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock. Replacement was done with healthy seedling having a bowl 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.

3.13.2 Weeding

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

3.13.3 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.

3.13.4 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 three days intervals.

3.13.5 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 plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. Birds pest such as nightingales (common

Bulbuli) were seen visiting the cabbage field very frequently. The nightingale visited the fields in the morning and afternoon. The birds found to puncture the newly initiated head and were controlled by striking a kerosene tin of metallic container frequently during day time.

3.14 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.

3.15 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 30, 45 and 60 days after transplanting (DAT) and at harvest. All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.15.1 Plant height

Plant height was measured from sample plants by using meter scale in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 15 days interval starting from 30 days after transplanting (DAT) up to harvest to observe the growth rate of plants.

3.15.2 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 15 days interval starting from 30 days after transplanting (DAT) up to harvest.

3.15.3 Plant spread

The spread of plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from each plot at 15 days interval starting from 30 days after transplanting (DAT) up to harvest.

3.15.4 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.

3.15.5 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 in centimeter (cm).

3.15.6 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).

3.15.7 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 during harvest after detached from head of cabbage and roots.

3.15.8 Dry matter content of stem

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

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

3.15.9 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.

3.15.10 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.

3.15.11 Dry matter content of head

At first head from selected plant were 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. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of head were computed by simple calculation from the weight recorded by the following formula:

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

Fresh weight of head

3.15.12 Gross weight of head per plant

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

3.15.13 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.

3.15.14 Gross yield per plot

Gross yield per plot was recorded by multiplying average gross weight of head per plant with total number of plant within a plot and was expressed in kilogram. Gross yield included yield with folded and unfolded leaves of cabbage.

3.15.15 Marketable yield per plot

Marketable yield per plot was recorded by multiplying average marketable yield weight of head per plant with total number of plant within a plot and was expressed in kilogram. Marketable yield included only the yield of marketable head.

3.15.16 Gross yield per hectare

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

3.15.17 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.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different level of GA_3 and potassium fertilizers on growth 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).

3.17 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different levels of GA_3 and potassium. 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 the growth and yield of cabbage as influenced by GA_3 and potassium fertilizer. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices III-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub-headings:

4.1 Plant height

Significant variation was recorded on plant height of cabbage due to different concentrations of gibberellic acid at 30, 45, 60 DAT and at harvest (Figure.2 and Appendix III). At 30, 45, 60 DAT and at harvest, the tallest plant (21.60, 25.60, 29.57 and 35.05 cm, respectively) was recorded from G_2 (125 ppm GA_3) which was statistically similar (20.13, 25.17, 28.56 and 31.26 cm, respectively) to G_3 (140 ppm GA_3) and the shortest plant (17.30, 23.70, 27.84 And 28.90 cm, respectively) was recorded from G_0 (control, i.e. 0 ppm GA_3) for 30, 45, 60 DAT and at harvest, respectively (Figure 2). 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 125 ppm.

Different levels of potassium fertilizer showed significant variation for plant height of cabbage at 30, 45, 60 DAT and at harvest (Figure.3 and Appendix III). At 30, 45, 60 DAT and at harvest, the tallest plant (20.42, 25.23, 29.11and 33.94 cm, respectively) was recorded from K_2 (150 kg MoP/ha) which was statistically similar (19.82, 24.95, 28.73 and 31.32cm, respectively) to K_1 (125 kg MoP/ha), whereas the shortest plant (18.30, 24.15, 27.90 and 28.88 cm, respectively) was by K_0 (0 kg MoP/ha).

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on plant height of cabbage at 30, 45, 60 DAT and at harvest (Appendix III and Table.2). At 30, 45, 60 DAT and at harvest, the tallest plant (22.47, 25.85, 30.10 and 40.33 cm, respectively) was obtained from G_2K_2 (125 ppm GA_3 +150 kg MoP/ha), while the shortest plant (15.20, 22.33, 27.10 and 28.20 cm, respectively) was recorded from G_0K_0 (0 ppm GA_3 + 0 kg MoP/ha).

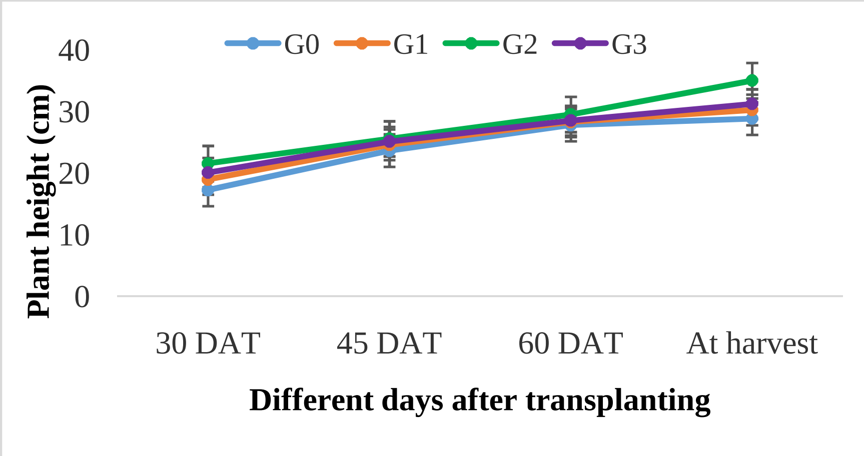


Figure 2. Effect of GA_3 at different days after transplanting on plant height of cabbage

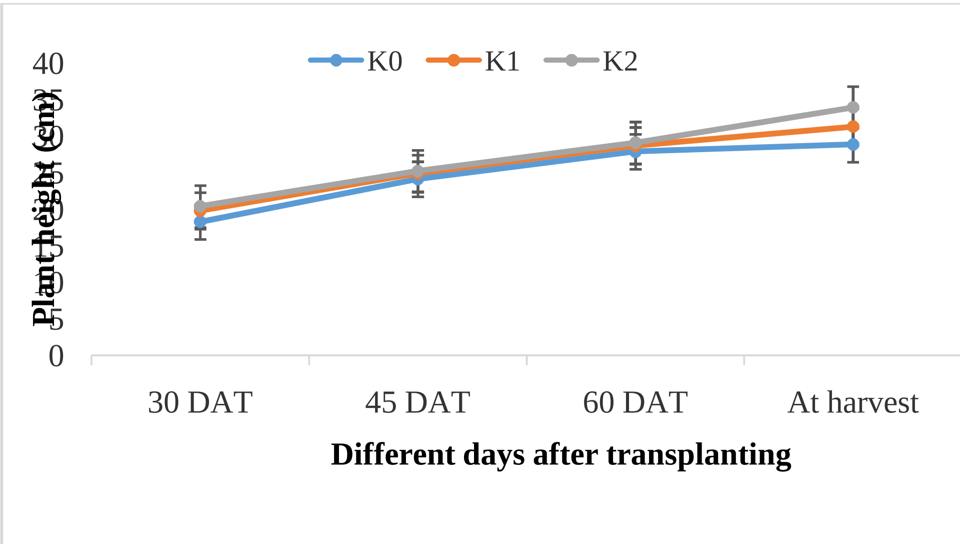


Figure 3. Effect of potassium fertilizer at different days after transplanting on plant height of cabbage

Table 2. Combined effects of potassium doses and levels of GA_3 on plant height at different days after transplant of cabbage

Treatment Combination	Plant height (cm)			
	Days after transplanting (DAT)			
	30	45	60	At harvest
K_0G_0	15.20 g	22.33c	27.10b	28.20 f
K_0G_1	17.87 f	24.25b	27.83b	28.33 f
K_0G_2	21.07 b	25.40a	28.87ab	30.33 de
K_0G_3	19.07 ef	24.63b	27.80b	28.64 f
K_1G_0	17.93 f	24.20b	27.93b	28.83 f
K_1G_1	19.47 de	24.77b	28.37ab	30.25 de
K_1G_2	21.27 b	25.55a	29.73a	34.50 b
K_1G_3	20.60 bc	25.30a	28.90ab	31.70 cd
K_2G_0	18.77 ef	24.58b	28.50ab	29.67 ef
K_2G_1	19.73 cd	24.92b	28.87ab	32.33 bc
K_2G_2	22.47 a	25.85a	30.10a	40.33 a
K_2G_3	20.73 bc	25.58a	28.97	33.43 bc
LSD0.05	1.13	1.30	1.62	2.16
Level of significance	*	NS	NS	**
CV (%)	3.43	3.10	3.35	4.09

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

** = Significant at 1% level of probability,

* = Significant at 5% level of probability, NS = Not significant

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

4.2 Number of leaves per plant

Significant variation was recorded on number of leaves per plant due to application of different concentrations of GA_3 at 30, 45, 60 DAT and at harvest (Figure.4 and Appendix IV). At 30, 45, 60 DAT and at harvest, the maximum number of leaves per plant (10.54, 14.08, 16.70 and 18.80) was found from G_2 which was statistically similar (88.90, 12.78, 15.36 and 17.18) to G_1, whereas, the minimum number (8.22, 12.10, 14.66 and 16.59) was obtained from G_0 at 30, 45, 60 DAT and at harvest, respectively. Patil *et al.* (1987) reported maximum number of leaves with 125 ppm GA_3.

Significant variation was recorded due to different levels of potassium fertilizer in terms of number of leaves per plant of cabbage at 30, 45, 60 DAT and at harvest (Figure.5 and Appendix IV). At 30, 45, 60 DAT and harvest, the maximum number of leaves per plant (9.90, 13.55, 16.29 and 18.16) was counted from K_2 which was statistically similar (9.220, 13.07, 15.68 and 17.72) to K_1 and while the minimum number (8.82, 12.57, 15.12 and 17.16) was found from K_0.

Different concentrations of gibberellic acid and potassium fertilizer showed significant differences due to their combined effect on number of leaves per plant of cabbage at 30, 45, 60 DAT and at harvest (Table.3). At 30, 45, 60 DAT and at harvest, the maximum number of leaves per plant (11.27, 14.62, 17.83 and 19.31) was recorded from G_2K_2 and the minimum number of leaves per plant (7.80, 11.72, 14.33 and 16.17) was found from G_0K_0 at the same date of observations (Appendix IV)

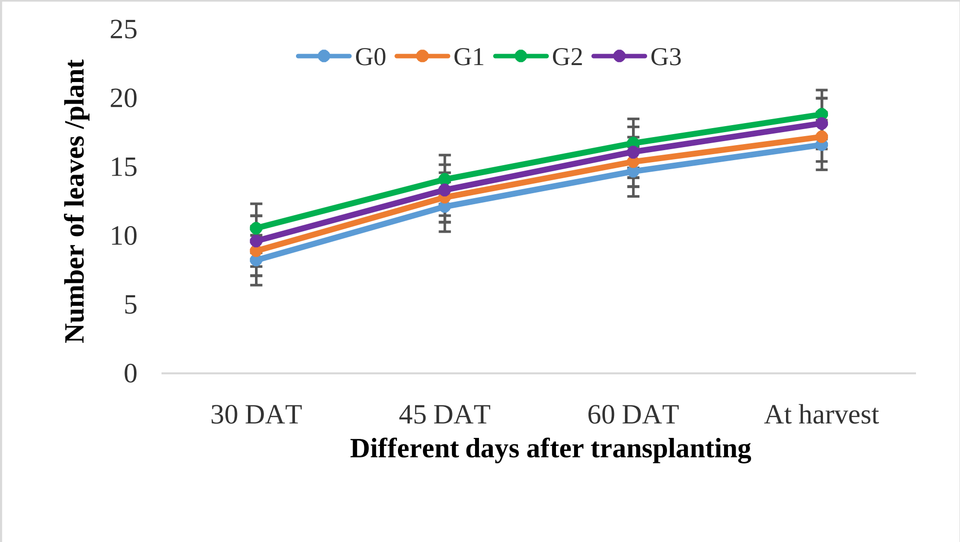


Figure 4. Effect of GA_3 at different days after transplanting on number of leaves/plant

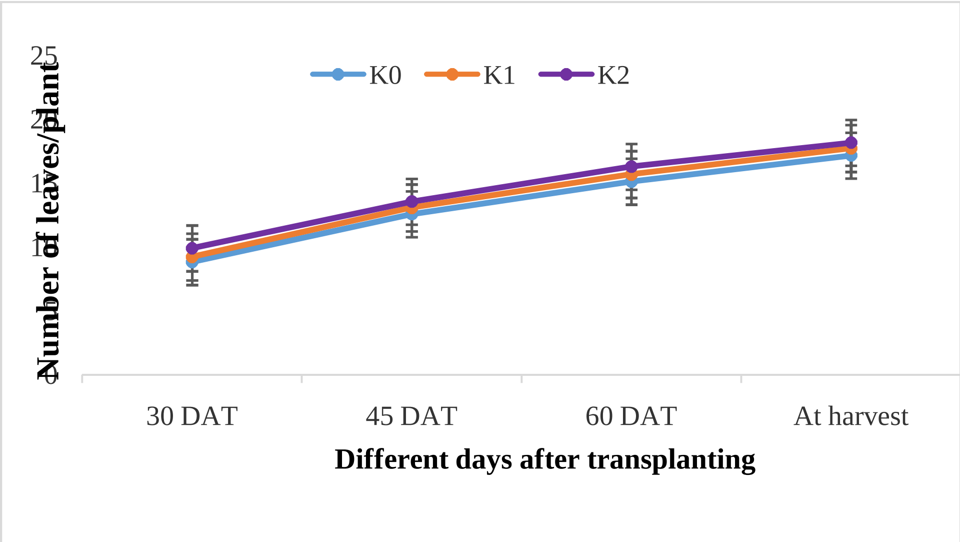


Figure 5. Effect of potassium fertilizer at different days after transplanting on number of leaves/plant

Table 3. Combined effects of potassium doses and levels of GA_3 on number of leaves/plant at different days after transplant of cabbage

Treatment Combination	Number of leaves/plant			
	Days after transplanting (DAT)			
	30	45	60	At harvest
K_0G_0	7.800d	11.72c	14.33 f	16.17c
K_0G_1	8.470c	12.63b	15.27 cde	16.77c
K_0G_2	9.870b	13.20ab	15.53 cd	17.93b
K_0G_3	9.130b	12.75b	15.33 cde	17.76b
K_1G_0	8.070c	12.12b	14.53 ef	16.29c
K_1G_1	9.070b	12.67b	15.33 cde	17.27b
K_1G_2	10.47ab	14.41a	16.73 b	19.15a
K_1G_3	9.270b	13.08ab	16.13 bc	18.17ab
K_2G_0	8.800c	12.45b	15.13 def	17.32b
K_2G_1	9.130b	13.05ab	15.47 cd	17.50b
K_2G_2	11.27a	14.62a	17.83 a	19.31a
K_2G_3	10.40ab	14.09	16.73 b	18.50
LSD0.05	0.889	0.722	0.819	1.10
Level of significance	NS	NS	*	NS
CV (%)	5.64	3.26	3.08	3.66

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

* = Significant at 5% level of probability, NS = Not significant

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

4.3 Days to 1st head formation

Significant variation was recorded for days to 1st head formation of cabbage due to different concentrations of gibberellic acid under the present trial (Table 4). The control treatment (G_0) took the highest (16.62) days to first head formation which was statistically similar (16.31 days) to G_1, while the lowest days (15.13) was required to 1st head formation from G_2. 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 on days to 1st head formation of cabbage (Table 4). The highest (16.40) days was required to 1st head formation for K_0, which was statistically similar (15.97 days) to K_1, whereas the lowest days (15.67) to K_2.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer varied significantly on days to 1st head formation of cabbage (Table 4). The maximum (17.07) days was required to 1st head formation by the control treatment combination G_0K_0, while the minimum (14.80) days period took the G_2K_2 treatment.

Table 4. Main effect of different levels of GA_3 and Potassium fertilizer on days at head formation of cabbage

Effect of GA_3

Levels of GA_3	Days at head formation
G_0	16.62 a
G_1	16.31 ab
G_2	15.13 c
G_3	15.98 b
LSD0.05	0.50
Level of significance	**
CV (%)	3.19
Effect of Potassium fertilizer	
Potassium fertilizer	Days at head formation
K_0	16.40 a
K_1	15.97 b
K_2	15.67 b
LSD0.05	0.43
Level of significance	**
CV (%)	3.19
Combined effect of GA_3	
Potassium x levels of GA_3	Days at head formation
K_0G_0	17.07a
K_0G_1	16.60ab
K_0G_2	15.40b
K_0G_3	16.53ab
K_1G_0	16.60ab
K_1G_1	16.27ab
K_1G_2	15.20b
K_1G_3	15.80b
K_2G_0	16.20ab
K_2G_1	16.07ab

K_2G_2	14.80c
K_2G_3	15.60b
$LSD_{0.05}$	0.863
Level of significance	NS
CV (%)	3.19

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

** = Significant at 1% level of probability

NS = Not significant

4.4 Length of stem

Significant variation was recorded on length of stem of cabbage due to different concentrations of gibberellic acid under the present trial (Table.5 and Appendix VI). The highest length of stem (44.97 cm) was recorded from G_2 which was closely followed (43.94 cm) by G_3, whereas the lowest length of stem (42.04 cm) was recorded from G_0. Lendve *et al.* (2010) reported similar findings from their earlier experiment.

Different levels of potassium fertilizer showed significant variation on length of stem of cabbage (Table.6 and Appendix VI). The highest length of stem (44.83 cm) was found from K_2 which was closely followed (43.47 cm) by K_1, while the lowest length of stem (42.11 cm) was recorded from K_0. Marsic and Osvald (2004) reported significant variation regarding length of stalk for different level of potassium fertilizers.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on length of stem of cabbage (Table 7 and Appendix VI). The highest length of stem (46.40 cm) was recorded from G_2K_2, again the lowest length of stem (41.40 cm) was found from G_0K_0.

Table 5. Main effect of levels of GA_3 on yield and yield contributing characters of cabbage

Levels of GA_3	Leaf length (cm)	Leaf breadth (cm)	Length of stem (cm)	Dry weight (g)	No. of roots/ plant	Width of root (cm)	Length of root (cm)	Fresh wt. of roots (g)
G_0	24.1b	16.30c	42.0c	32.7c	16.72d	1.42 c	14.67c	19.03d
G_1	25.44 b	17.1b	42.92bc	34.7b	17.36c	1.48 bc	15.53bc	19.79 c
G_2	27.02 a	17.94a	44.97a	39.2a	19.98a	1.71a	17.44 a	22.43a
G_3	26.70 a	17.51b	43.94ab	38.7a	18.70b	1.53 b	16.56ab	20.82b
$LS_{0.05}$	1.26	0.72	1.34	1.28	0.59	0.08	1.19	0.66
Level of significance	**	**	**	**	**	**	**	**
CV (%)	**5.00**	**4.22**	**3.17**	**3.61**	**3.34**	**5.43**	**7.62**	**3.29**

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

** = Significant at 1% level of probability

LS = Level of significance

Table 6. Main effect of potassium doses on yield and yield contributing characters of cabbage

Potassium fertilizer	Leaf length (cm)	Leaf breadth (cm)	Length of stem (cm)	Dry weight (g)	No. of roots/ plant	Width of root (cm)	Length of root (cm)	Fresh wt. of roots (g)
K_0	24.3c	16.65b	42.11c	32.58c	17.60b	1.462b	14.93 b	18.55 c
K_1	26.0b	17.22ab	43.47b	35.08b	17.98b	1.51 b	16.20 a	20.66 b
K_2	27.16a	17.83 a	44.83a	41.50a	18.99a	1.64 a	17.02 a	22.35 a
$LSD_{0.05}$	1.09	0.62	1.16	1.11	0.51	0.07	1.03	0.57
Level of significance	**	**	**	**	**	**	**	**
CV (%)	**5.00**	**4.22**	**3.17**	**3.61**	**3.34**	**5.43**	**7.62**	**3.29**

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

** = Significant at 1% level of probability

LS = Level of significance

Table 7. Combined effects of potassium doses and levels of GA_3 on yield and yield contributing characters of cabbage

Treatment combination	Leaf length (cm)	Leaf breadth (cm)	Length of stem (cm)	Dry weight (g)	No. of roots /plant	Width of root (cm)	Length of root (cm)	Fresh Weight of roots (g)
K_0G_0	21.90e	15.53c	41.40c	27.00 f	15.64 e	1.38 d	12.78d	17.94 f
K_0G_1	24.87d	16.73b	41.70c	31.67 e	16.72 d	1.41 cd	14.72c	18.08 f
K_0G_2	25.43c	17.23ab	43.33b	36.33c	19.52a	1.57 bc	16.13b	19.48d
K_0G_3	25.13c	17.10ab	42.00b	35.33 d	18.54b	1.47bc	16.08b	18.69ef
K_1G_0	24.50c	16.23b	41.50c	32.00 e	16.22d	1.39d	15.18b	18.47ef
K_1G_1	25.27c	17.27ab	43.47b	32.67 e	16.88 d	1.49bc	15.45b	20.27c
K_1G_2	27.43ab	17.90ab	45.17ab	37.6 bc	20.08 a	1.59 b	17.86ab	22.90 b
K_1G_3	26.83b	17.47ab	43.73b	38.0bc	18.74b	1.54bc	16.33b	20.99 c
K_2G_0	26.13b	17.13ab	43.23b	39.33 b	18.31c	1.46 cd	16.04b	20.68 c
K_2G_1	26.17b	17.50ab	43.60b	40.00b	18.48b	1.53bc	16.43b	21.02 c
K_2G_2	28.20a	18.70a	46.40a	43.67 a	20.33 a	1.97 a	18.33a	24.92 a
K_2G_3	28.13a	17.97ab	46.10a	43.00 a	18.82c	1.59 b	17.28	22.79 b
$LSD_{0.05}$	2.18	1.24	2.33	2.23	1.03	0.14	2.06	1.14
Level of significance	NS	NS	NS	*	*	**	NS	**
CV (%)	**5.00**	**4.22**	**3.17**	**3.61**	**3.34**	**5.43**	**7.62**	**3.29**

** = Significant at 1% level of probability

* = Significant at 5% level of probability

NS = Not significant

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

4.5 Diameter of stem

Significant variation was recorded on diameter of stem of cabbage for different concentrations of gibberellic acid (Table.8 and Appendix VI). The highest diameter of stem (1.97 cm) was found from G_2 which was statistically similar (1.86 cm) to G_3, while the lowest diameter (1.64 cm) was found from G_0 (Table 8).

Different levels of potassium fertilizer showed significant variation for diameter of stem of cabbage (Table.9 and Appendix VI). The highest diameter of stem (1.92 cm) was found from K_2 which was statistically similar 1.80 cm) with K_1 and whereas the lowest diameter of stem (1.70 cm) was obtained from K_0 (Table 9).

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on diameter of stem of cabbage (Table.10 and Appendix VI). The highest diameter of stem (2.05 cm) was recorded from G_2K_2 and the lowest diameter of stem (1.50 cm) was found from G_0K_0**.**

Table 8 Main effects of levels of GA_3 on yield and yield contributing characters of cabbage

Levels of GA_3	Length of stem (cm)	Diameter of stem (cm)	Thickness of head (cm)	Diameter of head (cm)	Length of large leaves (cm)	Width of large leaves (cm)	Weight of leaves (g)
G_0	8.47 c	1.64 c	10.78 b	16.90 c	23.77 c	19.40 c	388.9 c
G_1	8.86 c	1.56 bc	11.01 b	17.33 bc	24.19 bc	19.69 bc	408.6 b
G_2	10.38 a	1.97 a	11.98 a	18.43 a	25.71 a	20.59 a	444.9 a
G_3	9.58 b	1.86 ab	11.12 b	17.75 b	24.70 b	20.13 ab	435.7 a
$LSD_{0.05}$	0.65	0.17	0.57	0.57	0.82	0.68	14.00
Level of significance	**	**	**	**	**	**	**
CV (%)	**7.16**	**9.88**	**5.23**	**3.32**	**3.43**	**3.48**	**3.41**

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

Table 9. Main effect of potassium fertilizer on yield and yield contributing characters of cabbage

Potassium fertilizer	Length of stem (cm)	Diameter of stem (cm)	Thickness of head (cm)	Diameter of head (cm)	Length of large leaves (cm)	Width of large leaves (cm)	Weight of leaves (gm)
K_0	8.70 c	1.70 b	10.91 b	17.27 b	24.00 b	19.15 b	390.6 c
K_1	9.28 b	1.80 ab	11.13 b	17.52 ab	24.51 b	20.12 a	456.8 a
K_2	9.99 a	1.92 a	11.63 a	18.01 a	25.26 a	20.59 a	411.2 b
$LSD_{0.05}$	0.57	0.15	0.50	0.495	0.71	0.59	12.13
Level of significance	**	*	*	**	**	**	**
CV (%)	**7.16**	**9.88**	**5.23**	**3.32**	**3.43**	**3.48**	**3.41**

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

Table 10. Combined effects of potassium doses and levels of GA_3 on yield and yield contributing characters of cabbage

Treatment combination	Length of stem (cm)	Diameter of stem (cm)	Thickness of head (cm)	Diameter of head (cm)	Length of large leaves (cm)	Width of large leaves (cm)	Weight of leaves (gm)
K_0G_0	8.10c	1.50e	10.57 b	16.71b	23.67c	18.33 e	373.4c
K_0G_1	8.19c	1.63d	10.96 b	17.15b	23.62c	18.69 de	380.7c
K_0G_2	9.43ab	1.90b	11.10 b	17.65b	24.82b	19.93bcd	412.1b
K_0G_3	9.07ab	1.77c	11.02 b	17.57b	23.90c	19.65bcd	396.1c
K_1G_0	8.56c	1.61d	10.86 b	16.94b	23.40c	19.33cde	417.1b
K_1G_1	8.96c	1.77c	10.97 b	17.40b	23.86c	19.60bcd	444.9b
K_1G_2	10.13b	1.95b	11.52 b	18.09b	25.83ab	21.63a	485.2c
K_1G_3	9.48ab	1.85c	11.15 b	17.66b	24.94b	19.91bcd	479.9a
K_2G_0	8.74c	1.82c	10.90 b	17.04b	24.23b	20.53abc	376.1c
K_2G_1	9.44ab	1.83c	11.11 b	17.44b	25.08ab	20.77ab	400.2c
K_2G_2	11.58a	2.05a	13.31 a	19.55a	26.48a	20.22 bc	437.4a
K_2G_3	10.20b	1.97b	11.18 b	18.02b	25.27ab	20.82 ab	431.1b
$LSD_{0.05}$	1.13	0.30	0.99	0.99	1.42	1.17	24.25
Level of significance	NS	NS	*	NS	NS	*	NS
CV (%)	7.16	9.88	5.23	3.32	3.43	3.48	3.41

* = Significant at 5% level of probability; NS = Not significant

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

4.6 Thickness of head

Significance variation was recorded on thickness of head of cabbage due to different concentrations gibberellic acid (Table 8 and Appendix VI). The highest thickness of head (11.98 cm) was found from G_2 which was closely followed (11.12 cm) by G_3, while the lowest (10.78 cm) from G_0. Lendve *et al*. (2010) stated that the thickness of head on cabbage increase with the application of certain levels of GA_3.

Different levels of potassium fertilizer showed significant variation for thickness of head of cabbage (Table 9 and Appendix VI). The maximum thickness of head (11.63 cm) was attained from K_2 which was closely followed (11.13 cm) with K_1, whereas the minimum thickness of head (10.91cm) was recorded from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on thickness of head of cabbage (Table 10 and Appendix VI). The highest thickness of head (13.31cm) was recorded from G_2K_2 and the lowest thickness of head (10.57 cm) was found from $G_0K_{0.}$

4.7 Diameter of head

Significance variation was recorded for diameter of head of cabbage due to different concentrations of gibberellic acid under the present trial (Table.8 and Appendix VI). The highest diameter of head (18.43 cm) was obtained from G_2 which was closely followed (17.75 cm) by G_3, while the lowest diameter of head (16.90 cm) was found from G_0. But in earlier another experiment, Patil *et al.* (1987) was 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.9 and Appendix VI). The highest diameter of head (18.01 cm) was found from K_2 which was statistically similar (17.52 cm) to K_1, whereas the lowest diameter of head (17.27 cm) was recorded from K_0. Chaubey and Srivastava (2001) also found similar trends of results in their study.

Due to combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on diameter of head of cabbage (Table.10 and Appendix VI). The highest diameter of head (19.55 cm) was obtained from G_2K_2 and the lowest diameter of head (16.71 cm) was found from $G_0K_{0.}$

4.8 Gross weight of head per plant

Significant variation was recorded on gross weight of head of cabbage per plant due to different concentrations of gibberellic acid under the present trial (Table 11 and Appendix VII). The highest gross weight of head (1.67 kg) was recorded from G_2 which was statistically similar (1.55 kg) by G_3, while the lowest gross weight of head (1.22 kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation on gross weight of head of cabbage (Table 12 and Appendix VII). The highest gross weight of head (1.63 kg) was recorded from K_2 which was closely followed (1.45 kg) with K_1, whereas the lowest gross weight of head (1.38 kg) was recorded from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on gross weight of head of cabbage (Table 13 and Appendix VII). The highest gross weight of head (1.89 kg) was found from G_2K_2 and the lowest gross weight of head (1.07 kg) was found from $G_0K_{0.}$

4.9 Marketable yield per plant

Significant variation was recorded for marketable yield per plant of cabbage due to different concentrations of gibberellic acid under the present trial (Table 11 and Appendix VII). The highest marketable yield per plant (1.17 kg) was found from G_2 which was statistically similar (1.08 kg) with G_3, while the lowest marketable yield per plant (0.72 kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for marketable yield per plant of cabbage (Table 12 and Appendix VII). The highest marketable yield per plant (1.12 kg) was found from K_2, whereas the lowest marketable yield per plant (0.92 kg) was recorded from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per plant of cabbage (Table 13 and Appendix VII). The highest marketable yield per plant (1.37 kg) was recorded from G_2K_2 and the lowest marketable yield per plant (0.65 kg) was found from $G_0K_{0.}$

4.10 Gross yield per plot

Significant variation was recorded for gross yield per plot of cabbage due to different concentrations of gibberellic acid under the present trial (Table.11 and Appendix VII). The highest gross yield per plot (20.04 kg) was attained from G_2 which was statistically similar (18.55 kg) to G_3, while the lowest gross yield per plot (14.60 kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for gross yield per plot of cabbage (Table.12 and Appendix VII). The highest gross yield per plot (19.56 kg) was recorded from K_2 which was closely followed (17.40 kg) by K_1, whereas the lowest gross yield per plot (16.56kg) was found from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on gross yield per plot of cabbage (Table.13 and Appendix VII). The highest gross yield per plot (22.64 kg) was recorded from G_2K_2 and the lowest gross yield per plot (12.88 kg) was found from $G_0K_{0.}$

4.11 Marketable yield per plot

Significant variation was recorded for marketable yield per plot of cabbage due to different concentrations of gibberellic acid under the present trial (Table.11 and Appendix VII). The highest marketable yield per plot (14.04 kg) was attained from G_2 which was statistically similar (13.01 kg) to G_3, while the lowest marketable yield per plot (8.64kg) was recorded from G_0.

Different levels of potassium fertilizer showed significant variation for marketable yield per plot of cabbage (Table.12 and Appendix VII). The highest marketable yield per plot (13.44 kg) was recorded from K_2 which was closely followed (11.57 kg) by K_1, whereas the lowest marketable yield per plot (11.04 kg) was recorded from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per plot of cabbage (Table.13 and Appendix VII). The highest marketable yield per plot (16.40 kg) was recorded from G_2K_2 and the lowest marketable yield per plot (7.80 kg) was found from $G_0K_{0.}$

4.12 Gross yield per hectare

Significant variation was recorded for gross yield per hectare of cabbage due to different concentrations of gibberellic acid under the present trial (Table 11 and Appendix VII). The highest gross yield per hectare (69.58 t/ha) was recorded from G_2 which was statistically similar (64.41 t/ha) with G_3, while the lowest gross yield (50.70 t/ha) from G_0.

Different levels of potassium fertilizer showed significant variation for gross yield per hectare of cabbage (Table 12 and Appendix VII). The highest gross yield per hectare (67.91 t/ha) was found from K_2 which was closely followed (60.413 t/ha) by K_1, whereas the lowest gross yield (57.49 t/ha) from K_0.

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on gross yield per hectare of cabbage (Table 13 and Appendix VII). The highest gross yield per hectare (78.62 t/ha) was recorded from G_2K_2 and the lowest gross yield per hectare (44.71 t/ha) was found from $G_0K_{0.}$

4.13 Marketable yield per hectare

Significant variation was recorded for marketable yield per hectare of cabbage due to different concentrations of gibberellic acid (Figure 6. and Appendix VII). The highest marketable yield per hectare (48.75 t/ha) was recorded from G_2 which was statistically similar (45.16 t/ha) with G_3, while the lowest marketable yield per hectare (29.99 t/ha) from G_0. Generally, GA_3 increased yield contributing characters and finally the yield of cabbage (Islam 1985). 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 (Figure 7 and Appendix VII). The highest marketable yield per hectare (46.67 t/ha) was found from K_2 which was closely followed (40.17 t/ha) with K_1, whereas the lowest marketable yield per hectare (38.33 t/ha) from K_0. Potassium is also one of the important essential macro elements for the normal growth and development of plant as well as yield (Bose and Som, 1986).

Combined effect of different concentrations of gibberellic acid and potassium fertilizer showed significant differences on marketable yield per hectare of cabbage (Table 13 and Appendix VII). The highest marketable yield (56.95 t/ha) was recorded from G_2K_2 and the lowest marketable yield (27.08 t/ha) was found from G_0K_0.

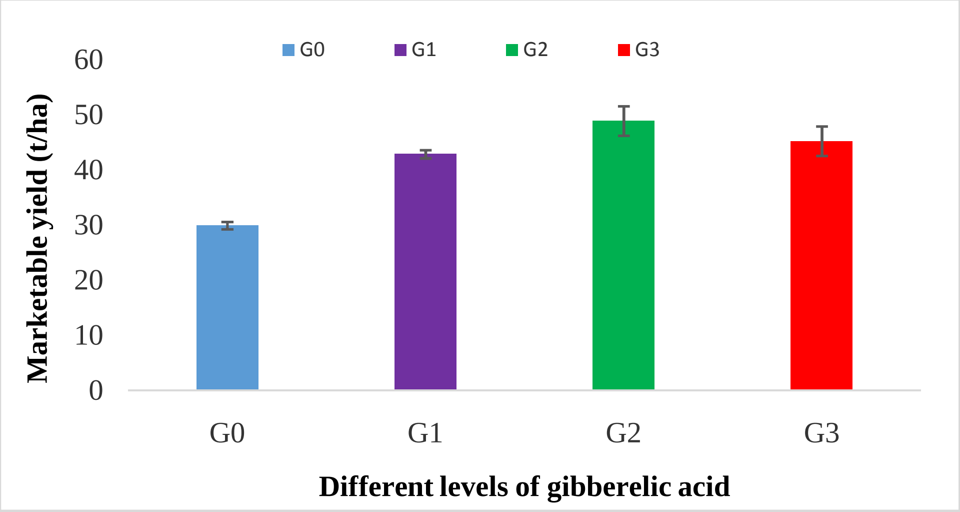


Figure 6. Effect of different levels of GA_3 on marketable yield of cabbage

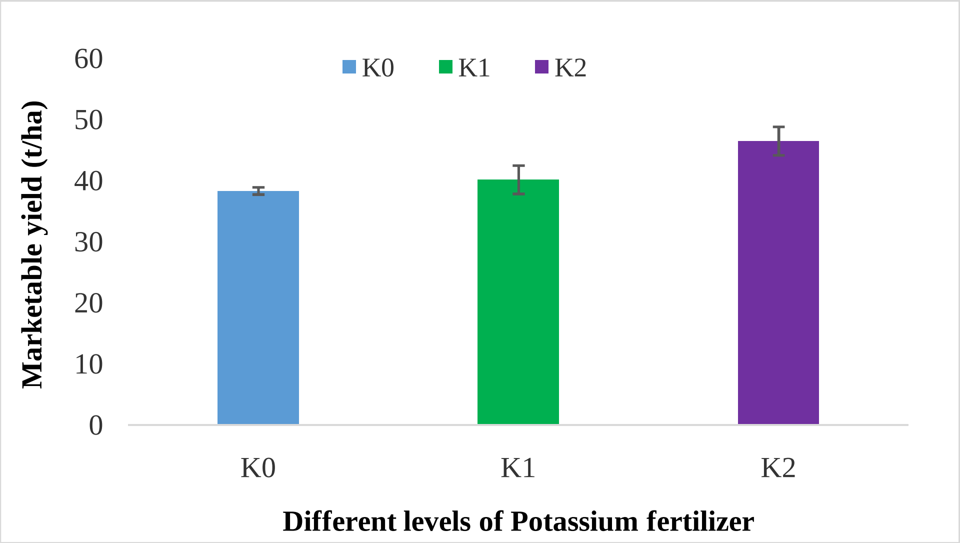


Figure 7. Effect of different levels of potassium fertilizer on marketable yield of cabbage

Table 11. Main effect of levels of GA_3 on yield and yield contributing characters of cabbage

Levels of GA_3	Gross wt of head (kg/ plant)	Marketable yield (kg/plant)	Gross yield (kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Marketable yield (t/ha)
G_0	1.22 c	0.72 d	14.60 c	8.64 d	50.70 c	29.99 d
G_1	1.52 b	1.03 c	18.24 b	12.36 c	63.32 b	42.91 c
G_2	1.67 a	1.17 a	20.04 a	14.04 a	69.58 a	48.75 a
G_3	1.55 b	1.08 b	18.6 b	12.96 b	64.58 b	44.99 b
$LSD_{0.05}$	0.053	0.044	0.738	0.682	2.67	2.68
Level of significance	**	**	**	**	**	**
CV (%)	**3.67**	**4.73**	**3.39**	**4.66**	**3.54**	**5.28**

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

Table12. Main effect of potassium doses on yield and yield contributing characters of cabbage

Potassium doses	Gross wt of head (kg/ plant)	Marketable yield (kg/plant)	Gross yield (kg/ plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Marketable yield (t/ha)
K_0	1.38 c	0.92 c	16.56 c	11.04 c	57.49 c	38.33 c
K_1	1.45 b	0.96 b	17.4 b	11.52 b	60.41 b	39.99 b
K_2	1.63 a	1.12 a	19.56 a	13.44 a	67.91 a	46.67 a
$LSD_{0.05}$	0.046	0.038	0.639	0.590	2.32	2.33

Level of significance	**	**	**	**	**	**
CV (%)	**3.67**	**4.73**	**3.39**	**4.66**	**3.54**	**5.28**

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

Table 13. Combined effects of potassium doses and levels of GA_3 on yield and yield contributing characters of cabbage

Treatment combination	Gross wt of head (kg/plant)	Marketable yield (kg/plant)	Gross yield (kg/plot)	Marketable yield (kg/plot)	Gross yield (t/ha)	Marketable yield (t/ha)
K_0G_0	1.07 h	0.65 h	12.88 h	7.80 h	44.71 h	27.08 g
K_0G_1	1.45 ef	0.96 f	17.40 ef	11.52 f	60.41 ef	39.99 e
K_0G_2	1.55 bcde	1.05 cde	18.60 cd	12.60 cde	64.58 bd	43.75 cde
K_0G_3	1.46 ef	1.02 def	17.48 ef	12.24 def	60.70def	42.50 de
K_1G_0	1.21 g	0.72 gh	14.52 g	8.60 gh	50.41 g	29.86 fg
K_1G_1	1.48 de	0.99ef	17.76 de	11.88 ef	61.66 de	41.25 e
K_1G_2	1.58 bcd	1.10 cd	18.96 bc	13.20 cd	65.83 bc	45.83 bcd
K_1G_3	1.53 cde	1.05 de	18.36 cde	12.60 cde	63.75 cd	43.75 cde
K_2G_0	1.37 f	0.78 g	16.40 f	9.40 g	56.95 f	32.64 f
K_2G_1	1.62 bc	1.13 bc	19.44 bc	13.56 bc	67.50 bc	47.08 bc
K_2G_2	1.89 a	1.37 a	22.64 a	16.40 a	78.62 a	56.95 a
K_2G_3	1.65 b	1.18 b	19.80 b	14.19 b	68.75 b	49.29 b
$LSD_{0.05}$	0.09	0.08	1.28	1.18	4.64	4.65
Level of significance	*	*	*	**	*	*
CV (%)	3.67	4.73	3.39	4.66	3.54	5.28

** = Significant at 1% level of probability

* = Significant at 5% level of probability

K_0 = 0 kg MoP/ha K_1 = 125 kg MoP/ha K_2 = 150 kg MoP/ha

G_0 = 0 ppm GA_3 G_1 =105 ppm GA_3 G_2 =125 ppm GA_3

G_3 =140 ppm GA_3

4.14 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 plot and converted into cost per hectare. Price of cabbage was considered as per market rate. The economic analysis presented under the following headings-

4.14.1 Gross return

The combination of different concentrations of gibberellic acid and potassium fertilizer showed different value in terms of gross return under the trial (Table 14 & Appendix VIII). The highest gross return (Tk. 341,700) was obtained from the treatment combination G_2K_2 and the second highest gross return (Tk. 295,740) was found in G_3K_2. The lowest gross return (Tk. 162,480) was obtained from G_0K_0.

4.14.2 Net return

In case of net return, different concentrations of gibberellic acid and potassium fertilizer were showed different levels of net return under the present trial (Table 14 and Appendix VIII). The highest net return (Tk. 179,641) was found from the treatment combination G_2K_2 and the second highest net return (Tk. 130,349) was obtained from the combination G_3K_2. The lowest (Tk.9,703) net return was obtained G_0K_0.

4.14.3 Benefit cost ratio

In the different concentrations of gibberellic acid and potassium fertilizer the highest benefit cost ratio (2.11) was noted from the combination of G_2K_2 and the second highest benefit cost ratio (1.79) was estimated from the combination of G_3K_2. The lowest benefit cost ratio (1.06) was obtained from G_0K_0 (Table 14 & Appendix VIII)

Table 14. Cost and return of cabbage cultivation as influenced by different levels of GA_3 and potassium

Treatment Combination	Cost of production (Tk./ha)	Yield of cabbage (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0K_0	152,777	27.08	162,480	9,703	1.06
G_0K_1	157,299	29.86	179,160	21,861	1.14
G_0K_2	158,370	32.64	195,840	37,470	1.24
G_1K_0	158,727	39.99	239,940	81,213	1.51
G_1K_1	161,011	41.25	247,500	84,489	1.52
G_1K_2	160,869	47.08	282,480	121,611	1.76
G_2K_0	159,917	43.75	262,500	102,583	1.64
G_2K_1	160,201	45.83	274,980	110,779	1.67
G_2K_2	162,059	56.95	341,700	179,641	2.11
G_3 K_0	161,107	42.5	255,000	93,893	1.58
G_3K_1	164,320	43.75	262,500	98,180	1.60
G_3K_2	165,391	49.29	295,740	130,349	1.79

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm, Shar-e-Bangla Agricultural University, Dhaka during the period from November 2013 to March 2014 to find out the growth and yield of cabbage as influenced by Gibberellic acid and potassium fertilizer. The test crop used in the experiment was cabbage variety Atlas-70. The experiment consisted of two factors: Factor A: Gibberellic acid-GA_3 different levels as- G_0: 0 ppm GA_3 (control); G_1: 105 ppm GA_3; G_2: 125 ppm GA_3 and G_3: 140 ppm GA_3; Factor B: Potassium fertilizer different levels as- K_0: 0 kg MoP/ha (control); K_1: 125 kg MoP/ha and K_2: 150 kg MoP/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield parameters and yield was recorded.

At 30, 45, 60 DAT and at harvest, the tallest plant (21.60, 25.60, 29.57and 35.05 cm respectively) was recorded from G_2 and the shortest plant (17.30, 23.70, 27.84 and 28.90 cm respectively) was recorded from G_0. At 30, 45, 60 DAT and at harvest, the maximum number of leaves per plant (10.54, 14.08, 16.70 and 18.80) were found from G_2, whereas, the minimum number (8.22, 12.10, 14.66 and 16.59) from G_0. The highest days to 1^{st} head formation (16.62) was found from G_0, while the lowest days (15.13) were recorded from G_2.

The highest length of stem (44.97 cm) was recorded from G_2, whereas the lowest (42.04 cm) was recorded from G_0. The highest diameter of stem (1.97 cm) was found from G_2, while the lowest diameter of stem (1.64 cm) was recorded from G_0. The highest thickness of head (11.98 cm) was found from G_2, while the lowest (10.78 cm) from G_0. The highest diameter of head (18.43 cm) was recorded from G_2, while the lowest (16.90 cm) was recorded from G_0.

The highest gross weight of head (1.67 kg) was recorded from G_2, while the lowest gross weight of head (1.22 kg) was recorded from G_0. The highest marketable yield per plant (1.17 kg) was found from G_2, while the lowest marketable yield per plant (0.72 kg) was recorded from G_0. The highest gross yield per plot (20.04 kg) was attained from G_2, while the lowest gross yield per plot (14,60 kg) was recorded from G_0. The highest marketable yield per plot (14.04 kg) was attained from G_2, while the lowest marketable yield per plot (8.64 kg) was recorded from G_0. The highest gross yield per hector (69.58 t/ha) was recorded from G_2, while the lowest gross yield per hector (50.70 t/ha) from G_0. The highest marketable yield per hector (48.75 t/ha) was recorded from G_2, while the lowest marketable yield per hector (29.99 t/ha) from G_0.

At 30, 45, 60 DAT and harvest, the tallest plant (20.42, 25.23, 29.11 and 33.94 cm, respectively) was recorded from K_2, whereas the shortest plant (18.30, 24.15, 27.90 and 28.88 cm, respectively) was recorded from K_0. At 30, 45, 60 DAT and at harvest, the maximum number of leaves per plant (9.90, 13.55, 16.29 and 18.16) was attained from K_2, while the minimum number of leaves per plant (8.81, 12.57, 15.12 and 17.16) was found from K_0.

The highest days to 1^{st} head formation (16.40) was attained from K_0, whereas the lowest days to 1^{st} head formation (15.67) was recorded from K_2. The highest length of stem (44.83 cm) was found from K_2, while the lowest length of stem (42.11 cm) was recorded from K_0. The highest diameter of stem (1.92 cm) was recorded from K_2, whereas the lowest (1.70 cm) was recorded from K_0. The highest thickness of head (11.63 cm) was attained from K_2, whereas the lowest thickness of head (10.91 cm) was recorded from K_0.

The highest diameter of head (18.01 cm) was found from K_2, whereas the lowest diameter of head (17.27 cm) was recorded from K_0. The highest gross weight of head per plant (1.63 kg) was recorded from K_2, whereas the lowest gross weight of head (1.38 kg) was recorded from K_0. The highest marketable yield per plant (1.12 kg) was found from K_2, whereas the lowest marketable yield per plant (0.92 kg) was recorded from K_0.

The highest gross yield per plot (19.57 kg) was recorded from K_2, whereas the lowest gross yield per plot (16.56 kg) was found from K_0. The highest marketable yield per plot (13.39 kg) was recorded from K_2, whereas the lowest marketable yield per plot (11.04 kg) was recorded from K_0. The highest gross yield per hectare (67.91 t/ha) was found from K_2, whereas the lowest gross yield (57.49 t/ha) from K_0. The highest marketable yield per hectare (46.67 t/ha) was found from K_2, whereas the lowest marketable yield per hectare (38.33 t/ha) from K_0.

At 30, 45, 60 DAT and at harvest, the tallest plant (22.47, 25.85, 30.10 and 40.33cm respectively) was recorded from G_2K_2, while the shortest plant 15.20, 22.33, 27.10 and 28.20cm respectively) was recorded from G_0K_0. At 30, 45, 60 DAT and at harvest, the maximum number of leaves per plant (11.27, 14.62, 17.83 and 19.31) was recorded from G_2K_2 and the minimum number of leaves per plant (7.80, 11.72, 14.33 and 16.17) was found from G_0K_0.

The highest days to 1st head formation (17.07) was recorded from G_0K_0 and the lowest days (14.80) from G_2K_2. The highest length of stem (46.40 cm) was recorded from G_2k_2, again the lowest length of stem (41.40 cm) was found from $G_0K_{0.}$ The highest diameter of stem (2.05 cm) was recorded from G_2K_2 and the lowest diameter of stem (1.50 cm) was found from $G_0k_{2.}$ The highest thickness of head (13.31cm) was recorded from G_2K_2 and the lowest thickness of head (10.57 cm) was found from $G_0K_{0.}$

The highest diameter of head (19.55 cm) was obtained from G_2K_2 and the lowest diameter of head (16.71 cm) was found from $G_0K_{0.}$ The highest gross weight of head (1.89 kg) was found from G_2K_2 and the lowest gross weight of head (1.07 kg) was found from $G_0K_{0.}$ The highest marketable yield per plant (1.37 kg) was recorded from G_2K_2 and the lowest marketable yield per plant (0.65 kg) was found from $G_0K_{0.}$ The highest gross yield per plot (22.64 kg) was recorded from G_2K_2 and the lowest gross yield per plot (12.88 kg) was found from $G_0K_{0.}$

The highest marketable yield per plot (16.40 kg) was recorded from G_2K_2 and the lowest marketable yield per plot (7.80 kg) was found from $G_0K_{0.}$ The highest gross yield per hector (78.62 t/ha) was recorded from G_2K_2 and the lowest gross yield (44.71 t/ha) was found from $G_0K_{0.}$ The highest marketable yield per hector (56.95 t/ha) was recorded from G_2K_2 and the lowest marketable yield (27.08 t/ha) was found from $G_0K_{0.}$

Considering the combination of different levels of gibberellic acid and potassium fertilizer, the highest gross return (Tk. 341,700) was obtained from the treatment combination G_2K_2 and the lowest gross return (Tk. 162,480) was obtained from G_0K_0. The highest net return (Tk. 179,641) was found from the treatment combination G_2K_2 and the lowest (Tk. 9,703) net return was obtained G_0K_0. The highest benefit cost ratio (2.11) was noted from the combination of G_2K_2 and the lowest benefit cost ratio (1.06) was obtained from G_0K_0. From economic point of view, it is apparent from the above results that the combination of G_2K_2 (125 ppm GA_3 and 150 kg MoP/ha) was better than rest of the combination. Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Another plant growth regulator with different concentration need to be considered in different agro-ecological zones of Bangladesh for regional trial before final recommendation.
2. Another level of potassium fertilizer may be used in future study.

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