EFFECT OF GA_3 AND POTASSIUM ON GROWTH AND YIELD OF CABBAGE (*Brassica oleracea var. capitata* L.)

By

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CERTIFICATE

This is to certify that the thesis entitled, *"EFFECT OF GA_3 AND POTASSIUM ON GROWTH AND YIELD OF CABBAGE (Brassica oleracea var. capitata)"* 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 KAMRUM MOYAZZAMA, Registration No.07-02611 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated to

My Beloved Parents

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ABSTRACT

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period of October 2007 to February 2008 to study the effect of GA_3 and potassium on growth and yield of cabbage. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment considered of two factors; Factor A: three concentration of GA_3; Go= Oppm GA_3; GI= 65ppm GA_3 and G_2= 85 ppmGAs; Factor B: four levels of potassium Ko=0 kg K_2O/ha, Ki= 120 kgK_2O/ha, K_2= 135 kgK_2O/ha and K_3=150 kgK_2O/ha. Incase of GA_3 the highest yield (62.87 t/ha) was observed from G_2 and the lowest (52.64 t/ha) was found from control. The highest yield (69.57 t/ha) was recorded from K_3 and the lowest (47.75 t/ha) were observed from control. For combined effect-the highest yield (76.67 t/ha) was found from G_1K_3 and the lowest (46.94 t/ha) from control. Economic analysis revealed that G_1K_3 was the best treatment combination in respect of net return (Tk. 225022) with a benefit cost ratio 2.42. It may be concluded that 65 ppm GA_3 with 150 K_2O / ha was found suitable for growth and yield of cabbage.

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ACRONYMS

BBS	Bangladesh Bureau of Statistics
cm.	Centimeter
cv.	Cultivar
DAT	Date After Transplanting
FYM	Farm Yard Manure
m	Meter
MOC	Mustard Oil Cake
MP	Muriate of Potash
NS	Not Significant
RCBD	Randomized Completely Block Design
t/ha	Ton per hectare
TSP	Triple Super Phosphate
Viz.	Namely
Wt.	Weight

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oliracea* var. *capitata*) belongs to the family Cruciferae and is biennial harbacious in nature. It is one of the important vegetables in Bangladesh. The origin of cabbage is the Western Europe and north shores of the Mediterranean Sea (Chauhan,1986). Cabbage was reported to be grown in the Subcontinent during Mughal period, but the vegetable become popular during British rule(Bose and Som, 1986). In Bangladesh cultivation of cabbage is mainly in winter months.

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 calories 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).

Cabbage occupied an area of 11.33 thousand hectares of land during 1999-2000 growing season with a total production of 112 thousand metric tones in Bangladesh (BBS, 2000) Thus the average yield was 9.89 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) (FAO, 1999). 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. The concentrations of the chemical interacting with the environmental conditions and play important role in modifying the growth and yield components of cabbage.

Potassium deficiency may affect such varied process such as respiration, photosynthesis, chlorophyll development water content of leaves. The highest concentration of potassium is found in the meristematic regions of the plant (Nason and Mc Elory, 1963).

Considering the above facts, the present investigation was undertaken with the following objectives:

1. to find out appropriate concentration of GA_3 for maximizing cabbage production.
2. to study the effect of potassium on growth and yield of cabbage.
3. to find out the optimum doses of GA_3 and potassium for better vegetative growth, the maximum yield and economic return of cabbage.

Chapter 2
Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop of many countries of the world as well as in Bangladesh. 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. A great deal of research work has been reported on the uses of GA_3 in different vegetables including cabbage and the results already achieved are of outstanding importance. A good number of experiments on the effect of potassium on the growth and yield of cabbage were conducted in different parts of the country. But limited numbers of studies are found in this respect in Bangladesh. However, some of the research finding regarding the effects of different levels of GA_3 and potassium on the growth and yield of cabbage has been presented in this chapter.

2.1 Effect of GA_3 on the growth and yield of cabbage

Srivastava (1960, 1965, 1966) reported the beneficial effects of GA_3, NOA and other plant growth regulators as pre-sowing seed treatments of many vegetable crops. He concluded that the application of GA_3 or 2,4-D at appropriate concentration as pre sowing seed treatment may be quite beneficial in obtaining increased yield.

Chhonkar and Singh (1965) conducted an experiment in the Rabi season of 1962-63 with GA_3 at 5 and 10 ppm after two t and three weeks of transplanting. They reported that 5ppm GA_3 induced larger number of inner leaves in heads, earlier head formation by 16 days, increased head diameter, improved compactness and significantly increased the yield and quality of heads.

Chauhan and Singh (1970) found that 2 sprays of 15 ppm GA_3 at 2 and 3 weeks after cabbage transplanting increased earliness, yield and quality.

Chauhan and Bordia (1971) carried out an investigations using Drumhead variety of cabbage to assess the effects of Gibberellic acid (GA_3) at 5, 10, 15, 25, 50, 100 ppm, Beta-napthoxy-acetic acid (NOA) at 5, 10, 15, 25, 50, 100ppm and 2,4-Dicholorophenoxy-acetic acid (2,4-D) at 0.25, 0.5, 1.0, 2.0, 2.5 ppm as pre sowing seed treatment on the growth and yield of cabbage and mentioned that none of the treatments affected the height of the plants and the time taken for head formation. Maximum weight of head (1.72 kg) was obtained with 50 ppm GA_3 as against 0.81 kg under control.

Zee (1978) applied Gibberellic acid once or twice as 10 or 20 ppm spra on seedling of cabbage at transplanting or 10 or 20 days after transplanting, plants reached edible maturity 53 days after transplanting when treated with 20 ppm GA_3. Plant fresh weight and dry weight were considerably enhanced by a 20 ppm GA_3 spray applaied 10 days after transplanting. Transplanting 30 days after sowing delayed harvest and reduced plant weight, regardless of GA_3 treatment.

Badawi and Sahhar (1979) conducted an experiment at the experimental station of the faculty of Agriculture, Cairo University, Egypt. They sprayed 0, 50, 100 and 200 ppm GA_3 and 0, 10, 20 40 ppm IBA after 4 and 8 weeks of transplanting to determine the extent of stimulating effect of different concentration of GA_3 and IBA on cabbage. In the most cases, treatments showed a decline in both diameter and height of edible head. They found higher edible head weight (5.21 kg) was obtained with GA_3 (50 ppm) applied 4 weeks after transplanting.

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

Kato and Sooen (1980) observed that leaf petiole epinasty in cabbage in cabbage appeared to be controlled by the hormone balance at the epical region of the stem. They also reported that applied NAA induced a downward movement of the wrapper leaves of decapitated plants and the plants with the entire heads and in the leaves of young seedlings but GA_3 induced the upward movement of leaves.

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

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

Mishra and Singh (1986) conducted an experiment in two season trials with Snowball-16 cauliflower N and/or GA_3 were applied 15 and 45 days after transplanting found that 1% N plus 50 ppm GA_3 gave the highest yield (301.48 t/ha), whereas Bo had less effect.

Muthoo *et. al.*(1987) reported that foliar application of different concentrations of GA_3, NNA and Mo (in various combination or separately) increased the average fresh weight and dry weight of leaves and curd and yield. Among individual application, GA_3 was the best for vegetative growth and Mo followed by NNA for curd growth and yield.

Pendey and Sinha (1987) reported that photosynthetic area of the plant increased when treated with gibberellic acid and napthaline acetic acid.

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

Islam *et al*. (1993) was made in invstigation to determine the effective concentration of NNA and GA_3 for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50, 100 ppm both the NAA and GA_3 and applied at three different methods i.e. seedling soaked for 12 hours, spraying at 15 and 30 days after transplanting. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulators, 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 with growth regulators and found that GA_3 and/or NAA (both at 25, 50 or 75 ppm) 0n the yield of cabbages (ev. Pride of India) was investigated in the field at Jobner, Rajasthan, India. The highest yield was observed following treatment with 50 ppm GA_3 followed by 50 ppm NAA. Combinations and higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

Vijoy et al. (2000) observed that 30 day old Cauliflower (cv. Pant Subhra) seedling were transplanted into experimental plots and treated with 50 or 100ppm GA_3, 5 or 10ppm IBA, or 100 or 2000ppm NAA at 15 and 30 days of growth. The results clearly revealed that GA_3 produced the tallest plants, the largest curds and the highest curd yields.

2.2 Effect of different levels of potassium on growth and yield of cabbage.

Nieuwhof (1969) mentioned that on lime rich sandy clay soils in the Netherlands having 0.02 to 0.04 percent K_2O, the optimum applicational need average was 400kg K_2O per hectare for cabbage. In Germany, dressings of 80 to 220 kg of K_2O per hectare recommended.

While carrying out an experiment on the fertilizer trial with N, P and K for white cabbage at Pasviedalen, Samuelsen and Pettersen (1977) found that 200-270 kg N and 150 kg K_2O/ha gave higher growth and yield of cabbage.

Nunung-Nurtica (1980) conducted an experiment to study the effects of NPK levels on the yield of cabbage. He found that on an andasol at Margahayu, N and K_2O at the rates of 90 and 100 kg/ha respectively gave the highest yield and at Cibodasy the highest yield was obtained with 135 and 150 kg N and K_2O/ha, respectively.

In a two year trials, Samant *et. al.* (1981) studied the effects of different levelsof N, P and K on yield of cabbage in Eastern Ghat Island zone of Orissa. N, P_2O_5 and/or K_2O were applied at 75-150: 40-80: 75-150 kg/ha in 27 different combinations. They reported that the best fertilizer combination was 75:80:150 kg/ha.

An experiment was conducted at Joydebpur, Gazipur on cabbage (var.Atlas-70) during the Rabi season to find out the effect of chemical fertilizer and manure (Anon. 1985). There were five levels of nitrogen (0, 60, 120, 180 and 240 kg N/ha from urea), four levels of phosphorus (0, 60. 90 and 120 kg P_2O_5/ha from TSP) and four levels of potassium (0, 60, 120 and 180 kg K_2O/ha from MP) along with cow dung @ 5 ton/ha. The head yield was increased with the increasing rate of NPK. The highest yield (110.98) t/ha was obtained from the combined effect of 180 kg N/ha, 120kg P_2O_5/ha and 120 kg K_2O/ha with 5t/ha of cow dung.

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.

Rao and Subramaniun (1991) conducted an experiment to fiend 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_2O/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 fiendout the effects of fertilizer doses and organic manure on the yield of cabbage (Anonymous, 1991). 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. Samant *et al.* (1992) investigated the balanced fertilizer use for cabbage in clay loam soils of Orissa, India. It was reported that nitrogen (75kg/ha) and potassium (150 kg/ha) gave the highest yield (17.42 t/ha), and it was the must economic dose.

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.

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

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 225kg K2O/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.

From the above reviews, it is clear that different concentrations of GA_3 and different levels of potassium have close relation with growth and yield of cabbage. These factors both singly or combined influence plant growth and yield of cabbage but the effects of these factors on the growth and yield of cabbage have not been studied in details under Bangladesh conditions. Therefore, to ensure proper crop management and to achieve the highest possible yield and economic return, such studies under Bangladesh conditions are needed.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in the experiment. It include short description of location of the experimental plot, characteristic of soil, climate, materials of the experiment, raising of seedlings, treatments, layout and design, land preparation, manuring and fertilizing, transplanting, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

3.1 Location of the experimental plot

The research work was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from October, 2007 to January 2008. The location of the site was 23.774^0 N Latitude and 90.335^0 E Longitude with the elevation of 8.2 meter from the sea level (Anon, 1989) to study the effect of GA3 and Potassium on growth and yield of cabbage.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agro Ecological Zone 28. The analytical data of the soil, collected from the experimental area were determined in SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and presented in Appendix I.

3.3 Climate

The experimental site is situated in subtropical zone, the macro climate is characterized by heavy rainfall during the months from April to September (Kharif season) and scantly rainfall during the rest month of the year (Rabi season). Information regarding average monhly the maximum and minimum temperature, rainfall and relative humidity, soil temperature as recorded by the weather yard, Bangladesh Meteorological Department (Climate Division), Agargaon, during the period of study has been presented in Appendix II.

3.4 Planting Materials

The variety of cabbage used in the experiment was "Atlas-70". The seeds were collected from a seed trader of China seed store, Dhaka.

3.5 Raising of Seedlings

Cabbage seedlings were raised in two seedbeds of 5 m x 1 m size. The soil was well prepared and converted into loose friable condition to obtain good tilt. All weeds, stubbles and dead root were removed. Twenty grams of seeds were sown in two seed bed. The seeds were sown in the seed bed on 14 ,October, 2007. Seeds were then covered with finished light soil and shading was provided by polyethylene bags to protect the young seedlings from scorching sunshine and rainfall. Light watering weeding and mulching were done as and when necessary to provide seedlingsof a good condition for growth.

3.6 Treatments combination

The experiment was consisted of two factors viz. (A) three concentrations of GA_3 and (B) four levels of potassium.

The levels were as follows;

Factors A: Levels of concentration of GA_3 Solution

G_0: 0 ppm GA_3 -

G_1: 65 ppm GA_3

G_2: 85 ppm GA_3

Factors **B: Levels of potassium**

K_0 : 0 kg K_2O per hectare

K_1: 120 kg K_2O per hectare,

K_2: 135 kg K_2O per hectare

K_3 : 150 kg K_2O per hectare

The treatment combinations were 12 such as

G_0K_0, G_0K_1, G0K2, G_0K_3, G_1K_0, G_1K_1, G_1K_2, G_1K_3, G_2K_0, G2K1, G_2K_2 and G_2K_3

3.7 Layout and Design of Experiment

The two factor experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications (Fig.1) the experimental plot was divided into three blocks. Each block consisted of 12 unit plots. Different combinations of potassium and GA_3 solution were assigned randomly to each block as per design of the experiment. The size of the plot was 3 m x 1.8 m. Block to block distance was 1 m and plot to plot was o.5m.

G_2K_2	G_2K_3	G_1K_2
G_2K_3	G_0K_0	G_2K_2
G_1K_2	G_2K_1	G_0K_3
G_2K_0	G_1K_2	G_1K_3
G_1K_1	G_1K_0	G_1K_0
G_1K_0	G_1K_3	G_0K_2
G_0K_2	G_0K_0	G_2K_1
G_2K_1	G_0K_2	G_0K_0
G_0K_3	G_2K_0	G_2K_0
G_1K_3	G_1K_1	G_2K_3
G_0K_0	G_0K_3	G_0K_1
G_0K_1	G_2K_2	G_1K_1
R_1	R_2	R_3

Plot size: 3.0m x 1.8m
Block spacing: 1m
Plot spacing: 0.5m

Factors A: Levels of concentration of GA_3 Solution
G_0: 0 ppm GA_3
G_1: 65 ppm GA_3
G_2: 85 ppm GA_3

Factors B: Levels of potassium
K_0 0 kg K_2O /ha
K_1: 120 kg K_2O /ha
K_2: 135 kg K_2O /ha
K_3: 150 kg K_2O /ha
R: Replication

Fig : Field layout of the experiment following RCBD

3.8 Land Preparation

The selected plot was fallow at the time of period of land preparation. The land was opened on 02 November, 2007 with the help of the power tiller and then it was kept open to sun for seven days prior to further ploughing, cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilt for transplanting.

3.9 Application of manures and fertilizers

Well decomposed cow dung was applied to the plots at the rate of 10 tons/ha and incorporated to the soil during final land preparation. In addition, Urea and Triple super phosphate (TSP) were applied to the experimental plot @ 325 and 150 kg/ha, respectively (BARC, 1997).

The total amount of urea was applied as top dressing in ring method. 1^{st} top dressed of one third was applied 15 days after transplanting and reminder urea was top dressed in two equal installments at 30 and 45 days after transplanting. Triple Super phosphate was applied as basal dose. Muriate of potash was applied as basal dose in the plots as per treatment.

3.10 Transplanting

Thirty days old healthy and uniform sized seedlings were transplanted in the experimental plots on 16 November, 2007. The seedbed was watered one hour before uprooting the seedlings to minimize the damage to the roots of the seedlings. Healthy and 31 days old seedling were transplanted. Transplanting was done in the afternoon.

During transplanting of seedling, spacing between rows 60 cm and plant 60 cm were followed. Fifteen plants were transplanted in each unit plot. The seedlings were watered immediately after transplanting. To protect from scorching sunshine and unexpected rain, banana leaf sheath pieces were used over the transplanted seedlings. Shading and watering were continued until the seedlings were well established and it required for 6 days. A number of treated seedlings were planted on the border of the experimental plots for gap filling.

3.11 Gap filling

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. The seedlings were transplanted with a mass of root attached soil to avoid transplanting shock.

3.12 Intercultural operations

The plants were kept under careful observation. Light watering was done every morning and afternoon following transplanting and was continued for 6 days for early and well establishment of the seedlings. Weeding and other intercultural operations were done as and when required. Earthing up was done on both sides of rows after 60 days of transplanting, using the soil from the space between the rows.

3.13 Control of pest and disease

Insect attack was serious problem at the time of establishment of the seedling. Mole cricket, field cricket and cut warm attacked the young transplants. Basudin was applied for controlling the soil born insects.

Cut worms were controlled both mechanically and spraying Darsban 20 EC @ 3%. Some of the plants were attacked by aphids and were controlled by spraying Diazinon 60 EC @560 ml/ha. Few plants were infected by Alternaria leaf spot disease caused by *Alternaria brasicae*. To prevent the spread of disease copper oxychloride (50%) was sprayed in the field at the rate of 1.35 kg per 450 liters of water.

3.14 Preparation and application of GA_3

GA3 in different concentrations viz. 0, 65 and 85 ppm were prepared following the procedure mentioned below and spraying was done during the noon using hand sprayer. Spraying was done 25 days after transplanting. A 65 ppm solution of GA_3 was prepared by dissolving 65 mg of it with distilled water. Then distilled water was added to make the volume 1 liter 65ppm solution. In a similar way 85 ppm concentrations were made. An adhesive Tween-20 @ 0.1% was added to each solution according to (Roy *et al.* 1991).

Control plots were treated only with distilled water.

3.15 Harvesting

The crop was harvesting during the period from 20th to 30th January, 2008. when the plants formed compacted heads. Harvesting was done plot wise after testing the compactness of the cabbage head by thumb. The compact head showed comparatively a hard feeling. Each head was collected by cut at the base of the plant.

3.16 Data collection

When the heads were well compact, the plants were harvested at random from each unit plot. Then plants were randomly selected from each plot and data were recorded according the characters were studied. However, for gross and marketable yield per plot, all plants of each unit plot were considered.

Periodical data i. e. plant height, number of loose leaves, spread of plant length of large leaf were taken 30, 45 and 50 days after transplanting whereas the rest parameters were recorded at the time of harvest.

3.16.1 Plant height

The height of the plant was measured with meter scale from the ground level to the tip of the longest leaf and was recorded in centimeter (cm).

3.16.2 Number of leaves per plant

The number of leaves per plant was counted at 15, 30 and 45 days after transplanting.

3.16.3 Spread of plant

Horizontal space covered by the plant was measured in centimeter (cm) with a meter scale for determining spread of plant.

3.16.4 Length of large leaf

Length of large leaf was measured in cm with a meter scale from leaf base to the top and was expressed in centimeter (cm).

3.16.5 Days from transplanting to head formation

The period required to head formation from transplanting was recorded for all the plants.

3.16.6 Length of stem

The length of stem at harvest was measured in centimeter (cm) with the help of a meter scale as the distance from the ground level to the base of unfolded leaf.

3.16.7 Fresh weight of stem

The fresh weight of stem per plant was recorded from the average of 10 plants of each plot and was expressed in gram (g).

3.16.8 Diameter of stem

The diameter of stem was measured in cm with a scale as the horizontal distance from one side of upper most level of the stem to another side after sectioning the stem longitudinally at the middle portion.

3.16.9 Dry matter content stem

First the fresh weight of stem was recorded. Then one hundred grams of stem were kept in the sun for two days then after dried in the oven at 70^0C for 72 hours. The weight of dry stem was measured by electric balance.

3.16.10 Number of roots per plant

After harvest, the main root was pulled out from soil carefully and the soil was washed out by water. Then the number of roots per plant was counted.

3.16.11 Length of roots

Ten plants from each plot was selected randomly and the length of root was measured in cm with a meter scale and expressed in cm.

3.16.12 Fresh weight of roots

The fresh weight of cabbage root was recorded from the average of 10 plants in gram (g).

3.16.13 Thickness of head

Thickness of head was measured in cm with the help of a scale placed vertically along the head.

3.16.14 Diameter of head

The harvested head was placed on a table in flat position and the diameter was measured in centimeter with a meter scale.

3.16.15 Weight of loose leaves

Weight of loose leaves was collected with balance.

3.16.16 Gross weight of head

The gross weight of harvested head was measured in kilogram including loose leaves but excluding the roots.

3.16.17 Economic yield per plant

It was the weight of cabbage head excluding roots and outer leaves measured in kilogram.

1.16.18 Dry matter content of head

Four hundred and fifty gram of cabbage head was collected from the chopped head of 1o plants. The sample was dried under direct sunshine and then was dried in an oven at 70^0 C for three days before taking dry weight till it was constant. The dry weight was recorded and dry matter content was estimated.

3.16.19 Yield per plot

Yield of cabbage per unit plot was recorded by weighting all the cabbage heads from each unit plot separately excluding roots and outer leaves and it was expressed in kilogram.

3.16.20 Yield per hectare

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

3.16.21 Statistical analysis

The data obtain for different yield components and yields were statistically analyzed to find out the difference among the treatments. The analysis of variance was performed by F- test. The significance of the difference between pairs of treatment means were evaluated by the Duncan's Multiple Range Test (DMRT).

3.16.22 Economical analysis

The cost of production was analyzed in order to find out the most economic treatment of GA_3 and potassium combination. All input costs and interests on fixed (land) and running capital were considered for computing the cost of production. The interests were calculated @ 13% for 6 months.

Chapter 4

Results and Discussion

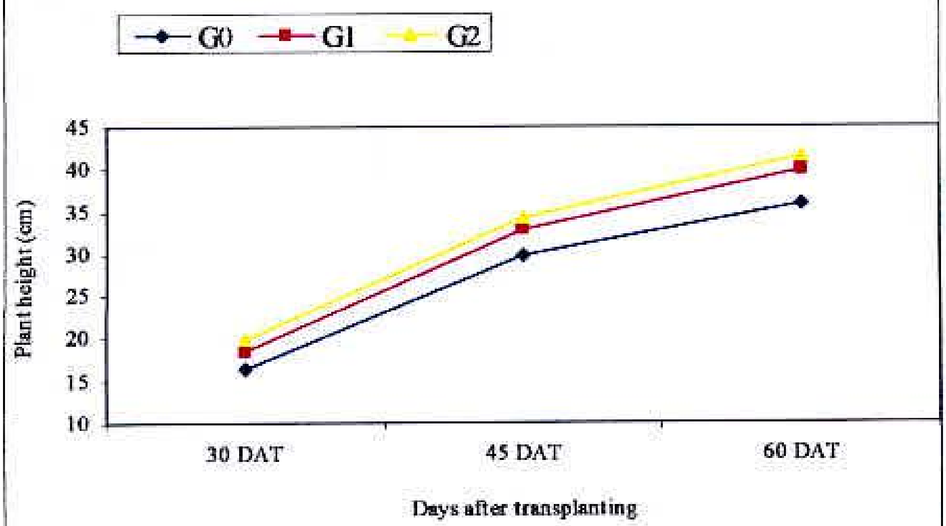
CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different concentration of GA_3 and levels of potassium on growth and yield of cabbage. Data on different yield contributing characters and yield were recorded to find out the optimum concentration of GA_3 and level of potassium for cabbage cultivation. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix III-VI. The results have been presented and discussed, and possible interpretations were given under the following headings-

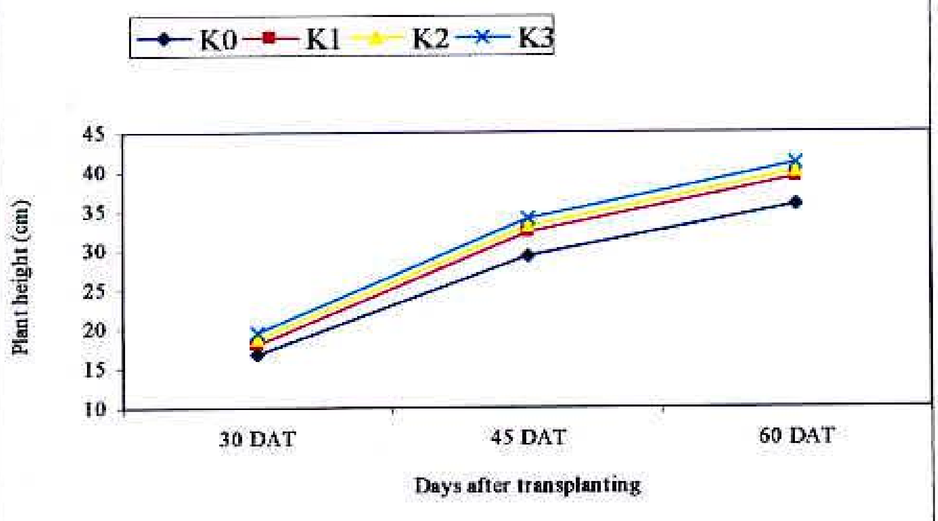
4.1 Plant height

Plant height varied significantly due to the application of different concentrations of GA_3 at the treatment days after transplanting (DAT) at 30, 45 and 60 (Appendix III). The tallest (19.78 cm) plant was recorded from the treatment G_2 (85 ppm GA_3) at 30 DAT followed by G_1 (65 ppm GA_3) and the shortest (16.24 cm) plant was obtained from G_0 (0 ppm GA_3) at 30 DAT. At 45 DAT, the tallest (34.12 cm) plant was recorded from G_2 followed by G_1, while the shortest (29.64 cm) was recorded from G_0. The tallest (41.46 cm) plant was recorded from G_2 which was closely followed (39.88 cm) by G_1 and the shortest (35.85 cm) was found from G_0 at 60 DAT (Figure 2). These results indicate that different concentrations of GA_3 create favorable condition for the growth of plant and the ultimate results the longest plant of cabbage was obtained. Badawi and Sahhar (1979) and Islam (1985) reported that the maximum height was obtained with GA_3 (50 ppm) applied 4 weeks after transplanting. Patil *et al.* (1987) reported the maximum plant height with GA_3 at 50 ppm.



GA_0: 0 ppm GA_3 GA_1: 65 ppm GA_3 GA_2: 85 ppm GA_3

Figure 2. Effect of different concentration of GA3 on plant height of cabbage



K_0: 0 kg K_2O/ha K_1 : 120 kg K_2O/ha

K_2: 135 kg K_2O/ha K_3 : 150 kg K_2O/ha

Figure 3. Effect of different level of potassium on plant height of cabbage

Different levels of potassium showed significant differences on plant height at 30, 45 and 60 DAT (Appendix III). The tallest (19.49 cm) plant was recorded from K_3 ,which was followed by K_2 and the shortest (16.64 cm) was recorded from control condition i.e. no potassium at 30 DAT. At 45 DAT the tallest (34.00 cm) plant was recorded from K_3 which was statistically similar (33.06 cm) to K_2 and the shortest (29.17 cm) plant was recorded from control condition. The tallest (41.04 cm) plant was recorded from K_3 which was statistically similar (40.10 cm) to K_2 and the shortest (35.80 cm) plant was obtained from control condition at 60 DAT (Figure 3). The results ensures maximum plant nutrients in available from potassium which help proper growth of plant and the results are the highest plant height. Rao and Subramaniun (1991) observed that the plant K concentration at all stages of growth increased significantly at the increased level of K_2O application.

The significant variation was found due to the combined effect of different concentration of GA_3 and levels of potassium in terms of plant height at 30, 45 and 60 DAT (Appendix III). The tallest (21.28 cm) plant was found at 30 DAT from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (21.14 cm) with G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha), while the shortest (14.84 cm) was recorded from G_0K_0 (no GA_3 and no potassium). At 45 DAT the tallest (36.31 cm) plant was found from G_2K_3 which was statistically identical (35.73 cm) with treatment combination of G_2K_2, while the shortest (25.80 cm) was recorded from G_0F_0. The tallest (43.69 cm) plant was obtained from G_2K_3 and the shortest (31.35 cm) plant was obtained from G_0K_0 at 60 DAT (Table 1). From the results it was revealed that both GA_3 and potassium favored in growth of cabbage and the ultimate results are the tallest plant than the control.

Table 1. Combined effect of different concentration of GA_3 and potassium on plant height, number of leaves and spread of plant of cabbage

Treatment(s)	Plant height (cm) at			Number of leaves per plant at			Spread of plant (cm) at		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
G_0K_0	14.84 f	25.80 g	31.35 f	11.33f	14.67 e	15.00 e	21.73 g	31.21 g	51.44 f
G_0K_1	16.45 e	30.69 ef	37.04 e	13.11 cd	16.33 d	20.11 d	23.83 f	35.99 f	59.58 e
G_0K_2	16.52 e	30.98 ef	37.36 e	13.33 cd	17.89 c	22.22 cd	24.65 e	36.83 e	60.03 e
G_0K_3	17.14 de	31.10 def	37.64 e	13.33 cd	17.55 cd	22.22 cd	24.98 de	37.90 d	60.58 e
G_1K_0	16.95 e	30.14 f	37.34 e	12.45 e	17.11 cd	20.11 d	24.48 e	36.93 e	60.05 e
G_1K_1	18.75 c	33.48 bc	40.56 cd	13.11 cd	18.55 c	22.56 c	25.49 cd	38.91 c	64.63 cd
G_1K_2	18.45 c	32.47 cde	39.81 d	13.56 bc	18.44 c	23.00 bc	25.21 d	38.45 c	63.60 d
G_1K_3	20.03 b	34.58 ab	41.80 bc	14.00 ab	20.56 b	25.00 ab	25.95 bc	39.71 b	66.40 bc
G_2K_0	18.12 cd	31.56 def	38.71 de	12.89 de	18.33 c	21.67 cd	25.00 de	37.78 d	62.21 de
G_2K_1	18.60 c	32.89 bcd	40.30 cd	13.22 cd	18.33 c	22.33 cd	25.35 d	38.56 c	64.18 cd
G_2K_2	21.14 a	35.73 a	43.14 ab	14.33 a	21.67 ab	25.89 a	26.42 ab	40.50 a	68.41 ab
G_2K_3	21.28 a	36.31 a	43.69 a	14.44 a	22.00 a	26.44 a	26.66 a	40.83 a	69.28 a
$LSD_{(0.05)}$	1.067	1.677	1.737	0.579	1.342	2.063	0.516	0.435	2.532
Significance Level	0.05	0.05	0.01	0.05	0.05	0.05	0.01	0.01	0.05
CV(%)	8.47	6.08	9.63	5.58	7.29	5.48	9.22	10.68	12.39

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

G_0: 0 ppm GA_3 K_0: 0 kg K_2O/ha (control)

G_1: 65 ppm GA_3 K_1: 120 kg K_2O/ha

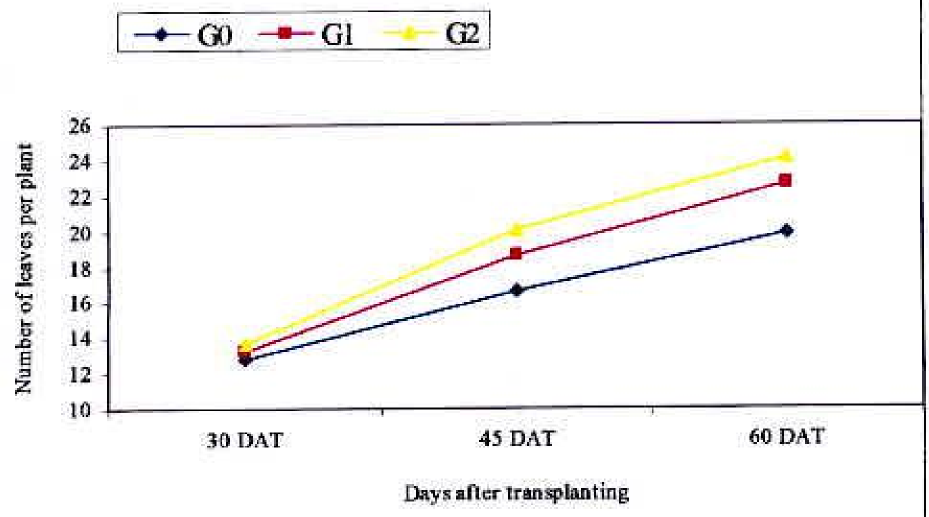
G_2: 85 ppm GA_3 K_2: 135 kg K_2O/ha

K_3: 150 kg K_2O/ha

4.2 Number of leaves per plant

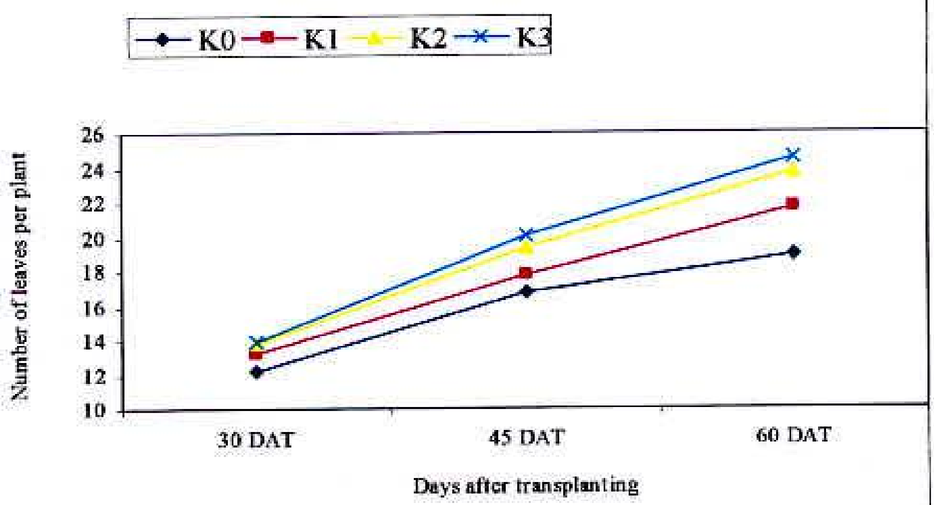
Number of leaves per plant differed significantly due to different concentrations of GA_3 at 30, 45 and 60 DAT (Appendix III). The highest (13.72) number of leaves per plant was recorded from G_2 (85 ppm GA_3) which was followed by G_1 (65 ppm GA_3), while the lowest (12.78) was obtained from G_0 (0 ppm GA_3) at 30 DAT. At 45 DAT, the highest (20.08) number of leaves per plant was observed from G_2 followed by G_1 and the lowest (16.61) was recorded from G_0. The highest (24.08) number of leaves per plant was found from G_2 which was followed by G_1 and the lowest (19.89) was recorded from G_0 at 60 DAT (Figure 4). These results indicated that different concentration of GA_3 influenced number of leaves per plant. Islam (1985) reported that GA_3 increased the number of leaves per plant. Patil *et al.* (1987) also reported maximum number of leaves with 50 ppm GA_3.

Different levels of potassium showed significant difference on number of leaves per plant at 30, 45 and 60 DAT (Appendix III). The highest (13.93) number of leaves per plant was recorded from K_3 (150 kg K_2O/ha) which was statistically identical (13.74) with K_2 (135 kg K_2O/ha), while the lowest (12.22) was found from control condition i.e. no potassium at 30 DAT. At 45 DAT the highest (20.04) number of leaves per plant was observed from K_3 which was statistically similar (19.33) with K_2 and the lowest (16.70) number of leaves per plant was found from control condition. The highest (24.55) number of leaves per plant was recorded from K_3 which was statistically similar (23.70) with K_2 and the lowest (18.93) number of leaves per plant was observed from control condition at 60 DAT (Figure 5). Potassium enhences plant growth resulting the plant produced the highest number of leaves.



GA_0: 0 ppm GA_3 GA_1: 65 ppm GA_3 GA_2: 85 ppm GA_3

Figure 4. Effect of different concentration of GA3 on number of leaves per plant of cabbage



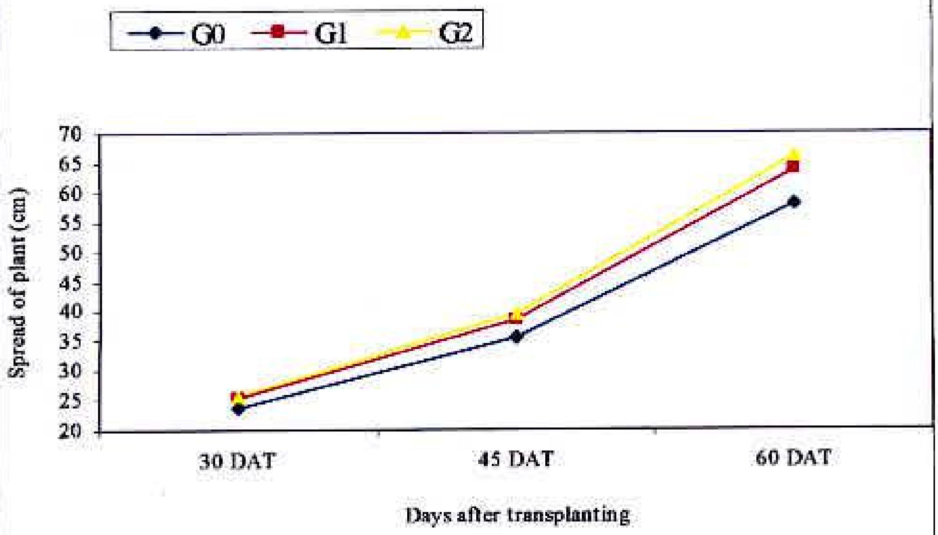
K_0: 0 kg K_2O/ha K_1: 120 kg K_2O/ha
K_2: 135 kg K_2O/ha K_3: 150 kg K_2O/ha

Figure 5. Effect of different level of potassium on number of leaves per plant of cabbage

Combined effect of different concentrations of GA_3 and levels of potassium showed significant variation in terms of number of leaves per plant at 30, 45 and 60 DAT (Appendix III). The highest (14.44) number of leaves per plant was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically identical (14.33) with G_2K_2 and the lowest (11.33) was recorded from G_0K_0 at 30 DAT. At 45 DAT the highest (22.00) numbers of leaves per plant was found from G_2K_3 which was identical (21.67) to G_2K_2, while the lowest (14.67) was observed from G_0F_0. The highest (26.44) number of leaves per plant was obtained from G_2K_3 which was statistically identical (25.89) with G_2K_2 and the lowest (15.00) number of leaves per plant was recorded from $G_0K_{0,}$ at 60 DAT (Table 1). From the results it was revealed that both GA_3 concentration and potassium stimulate the growth of cabbage and thus higher number of leaves was produced.

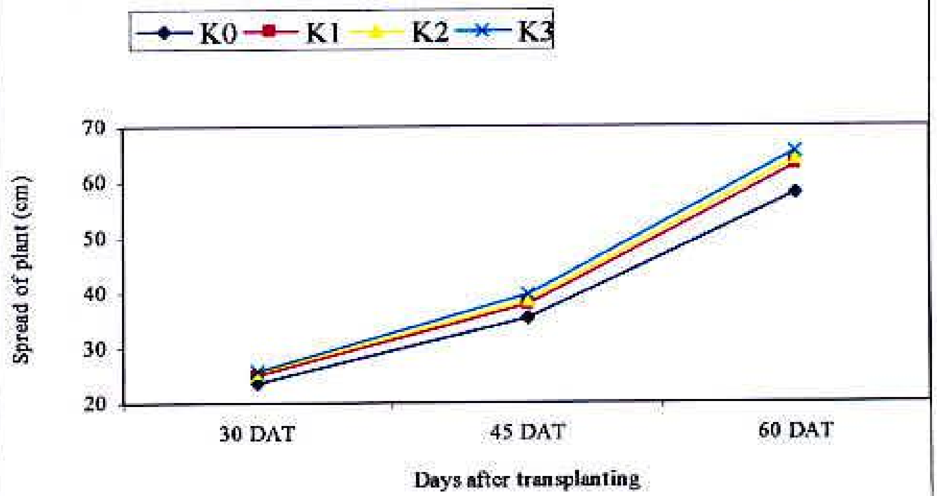
4.3 Spread of plant

Different concentrations of GA_3 showed statistically significant variation for spread of plant at 30, 45 and 60 DAT (Appendix III). The maximum (25.86 cm) plant spreading was recorded from G_2 (85 ppm GA_3) which was followed by G_1 (65 ppm GA_3) and the minimum (23.80 cm) spread of plant was found from G_0 at 30 DAT. At 45 DAT, the maximum (39.42 cm) spread of plant was recorded from G_2 followed by G_1 and the minimum (35.49 cm) was recorded from G_0. The maximum (66.02 cm) spread of plant was observed from G_2 by G_1 and the minimum (57.91 cm) was found from $G_{0,}$ at 60 DAT (Figure 6). These results indicated that different concentrations of GA_3 influenced spread of plant.



GA_0: 0 ppm GA_3 GA_1: 65 ppm GA_3 GA_2: 85 ppm GA_3

Figure 6. Effect of different concentration of GA3 on spread of plant of cabbage



K_0: 0 kg K_2O/ha K_1 : 120 kg K_2O/ha

K_2: 135 kg K_2O/ha K_3 : 150 kg K_2O/ha

Figure 7. Effect of different level of potassium on spread of plant of cabbage

Different levels of potassium showed significant differences on spread of plant at 30, 45 and 60 DAT (Appendix III). The maximum (25.86 cm) spread of plant was recorded from K_3 which was followed by K_2, while the minimum (23.74 cm) was recorded from control condition i.e. no potassium followed by K_1 at 30 DAT. At 45 DAT the maximum (39.48 cm) spread of plant was recorded from K_3 which was statistically similar (38.60 cm) to K_2 and the minimum (35.31 cm) spread of plant was recorded from control condition. The maximum (65.42 cm) spread of plant was recorded from K_3 which was statistically similar (64.01 cm) to K_2, while the minimum (57.90 cm) spread of plant was obtained from control condition i.e. no potassium which was closely (62.80 cm) followed by K_1 at 60 DAT (Figure 7). Potassium fertilizer ensures maximum plant nutrients in available from which help proper growth of plant and the results are the highest spread of plant.

The significant variation was found due to the combined effect of different concentration of GA_3 and level of potassium in terms of spread of plant at 30, 45 and 60 DAT (Appendix III). The maximum (26.66 cm) spread of plant was observed from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (26.42 cm) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha), while the minimum (21.73 cm) was recorded from G_0K_0 at 30 DAT. At 45 DAT the maximum (40.83 cm) spread of plant was found from G_2K_3 which was identical (40.50 cm) to G_2K_2 and the minimum (31.21 cm) was found from G_0F_0. The maximum (69.28 cm) spread of plant was obtained from G_2K_3 which was identical (67.41 cm) with G_2K_2, and the minimum (51.44 cm) spread of plant was obtained from G_0K_0 at 60 DAT (Table 1). From the results it was revealed that both GA_3 concentration and potassium inhenced growth of cabbage and the ultimate results are the maximum spread of plant under the trial.

4.4 Length of large leaf

Different concentrations of GA_3 showed significant variation on length of large leaf under the present trial (Appendix IV). The highest (43.22 cm) length of large leaf was found from G_2 (85 ppm GA_3). On the other hand the lowest (36.18 cm) length of large leaf was observed from G_0 (0 ppm GA_3) (Table 2).

Different levels of potassium showed significant difference on length of large leaf (Appendix IV). The highest (42.95 cm) length of large leaf was found from K_3 (150 kg K_2O/ha) which was statistically similar (42.16 cm) to K_2 (135 kg K_2O/ha) and the lowest (37.10 cm) length of large leaf was recorded from control condition (Table 2) i.e. no potassium. Potassium stimulates for optimum growth of plant with large leaf.

The significant variation was found in terms of length of large leaf due to the combined effect of different concentration of GA_3 and level of potassium (Appendix IV). The highest (45.84 cm) length of large leaf was obtained from the treatment combination of G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) which was statistically similar (45.71 cm) to G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha), while the lowest (29.67 cm) length of large leaf was found from G_0K_0 i.e. control condition (Table 3).

4.5 Days from transplanting to head initiation

Days from transplanting to head formation showed statistically significant differences for different concentration of GA_3 (Appendix IV). The lowest (31.36) days from

Table 2. Main effect of different concentrations of GA_3 and potassium on yield contributing characters of cabbage

Treatment(s)	Length of large leaf (cm)	Length of stem (cm)	Fresh weight of stem (g)	Diameter of stem (cm)	Dry matter content of stem (%)
Concentration of GA_3					
G_0	36.18 c	7.43 c	39.54 b	4.18 c	10.16 c
G_1	41.80 b	9.27 a	51.83 a	5.02 b	12.66 b
G_2	43.22 a	8.83 b	52.58 a	5.62 a	13.92 a
$LSD_{(0.05)}$	1.345	0.255	2.593	.0.178	0.505
Significance Level	0.01	0.01	0.01	0.01	0.01
Potassium					
K_0	37.10 c	8.25 c	44.57 b	4.51 d	10.38 d
K_1	39.38 b	8.68 ab	47.46 ab	4.80 c	11.71 c
K_2	42.16 a	8.71 a	49.42 a	5.09 b	13.04 b
K_3	42.95 a	8.40 bc	50.48 a	5.37 a	13.85 a
$LSD_{(0.05)}$	1.553	0.295	2.994	0.205	0.583
Significance Level	0.01	0.01	0.01	0.01	0.01
CV(%)	8.93	9.54	6.38	7.22	4.87

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

G_0: 0 ppm GA_3 K_0: 0 kg K_2O/ha (control)

G_1: 65 ppm GA_3 K_1: 120 kg K_2O/ha

G_2: 85 ppm GA_3 K_2: 135 kg K_2O/ha

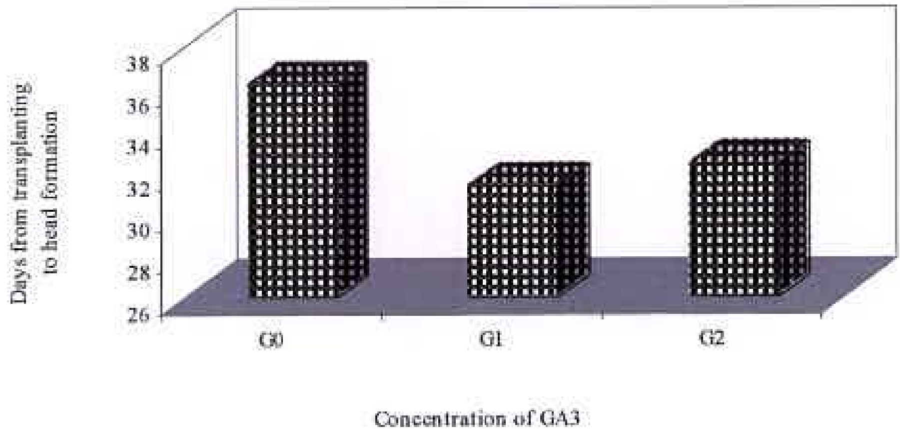
K_3: 150 kg K_2O/ha

Table 3. Combined effect of different concentrations of GA_3 and potassium on yield contributing characters of cabbage

Treatment(s)	Length of large leaf (cm)	Length of stem (cm)	Fresh weight of stem (g)	Diameter of stem (cm)	Dry matter content of stem (%)
G_0K_0	29.67 f	7.40 de	33.99 f	3.33 f	7.67 f
G_0K_1	36.66 e	7.60 d	38.22 ef	4.25 e	9.75 e
G_0K_2	39.58 cde	7.78 d	44.61 cd	4.58 de	11.31 d
G_0K_3	38.79 de	6.92 e	41.33 de	4.56 de	11.91 cd
G_1K_0	39.88 cd	8.77 c	50.65 ab	4.66 d	11.19 d
G_1K_1	41.89 bc	9.38 ab	52.98 ab	5.11 c	12.85 c
G_1K_2	41.07 cd	9.58 a	49.17 bc	4.82 cd	12.55 c
G_1K_3	44.35 ab	9.34 ab	54.54 ab	5.52 b	14.04 b
G_2K_0	41.75 bcd	8.58 c	49.08 bc	5.54 b	12.28 cd
G_2K_1	39.57 cde	9.05 abc	51.18 ab	5.03 c	12.53 c
G_2K_2	45.84 a	8.76 c	54.50 ab	5.89 ab	15.28 a
G_2K_3	45.71 a	8.92 bc	55.58 a	6.03 a	15.60 a
$LSD_{(0.05)}$	2.690	0.511	5.186	0.355	1.010
Significance Level	0.01	0.05	0.05	0.01	0.01
CV(%)	8.93	9.54	6.38	7.22	4.87

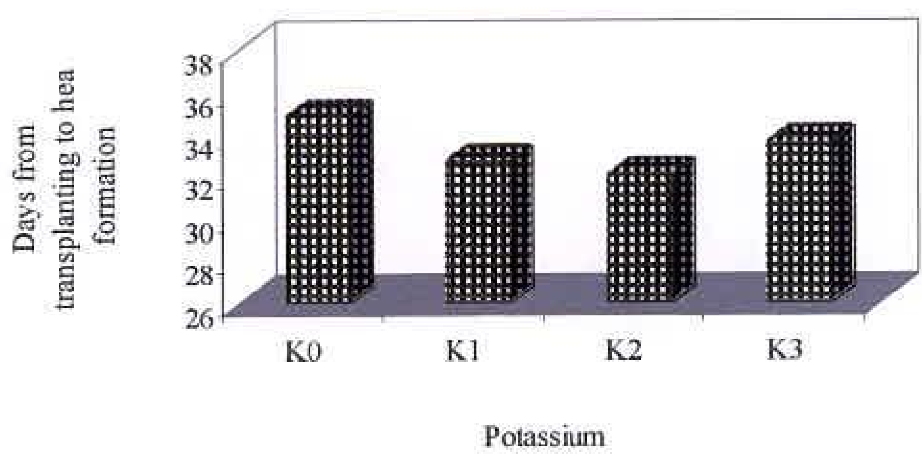
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

G_0: 0 ppm GA_3	K_0: 0 kg K_2O/ha (control)
G_1: 65 ppm GA_3	K_1: 120 kg K_2O/ha
G_2: 85 ppm GA_3	K_2: 135 kg K_2O/ha
	K_3: 150 kg K_2O/ha



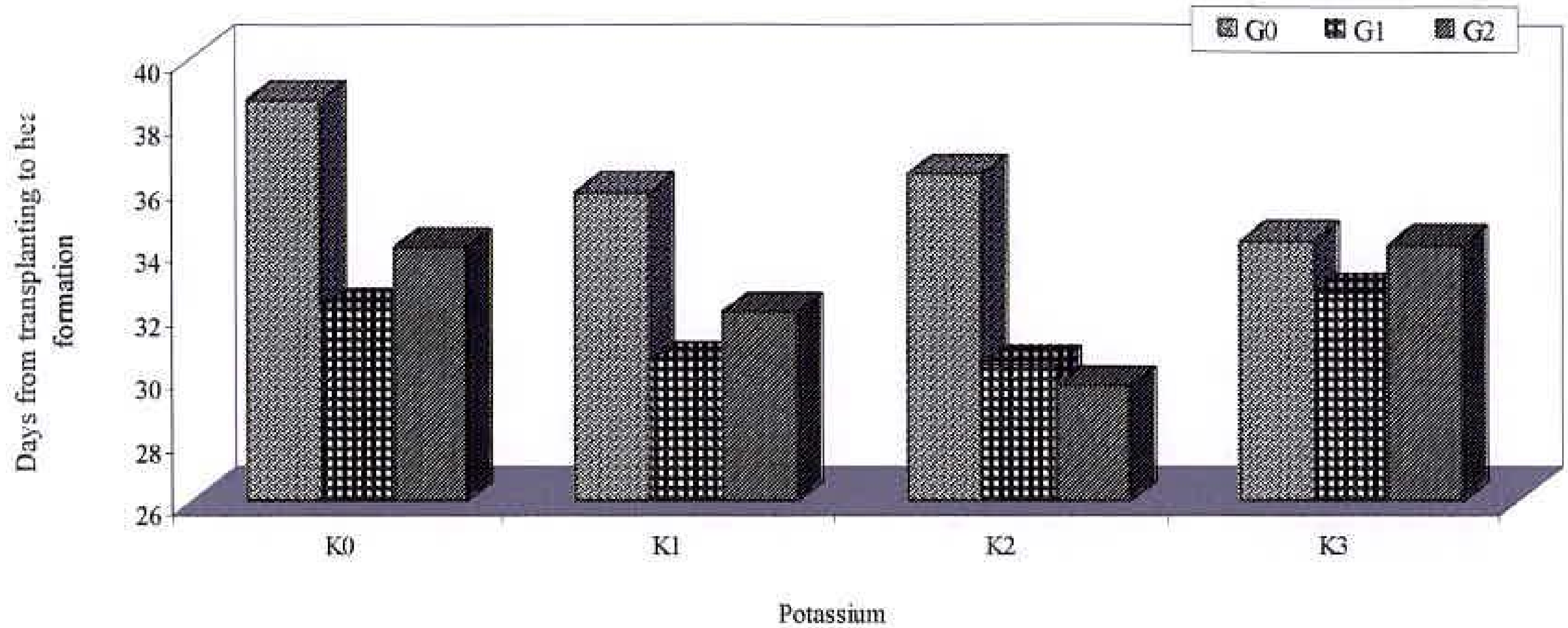
GA_0: 0 ppm GA_3 GA_1: 65 ppm GA_3 GA_2: 85 ppm GA_3

Figure 8. Effect of different concentration of GA3 on days from transplanting to head initiation of cabbage



K_0: 0 kg K_2O/ha K_1: 120 kg K_2O/ha
K_2: 135 kg K_2O/ha K_3: 150 kg K_2O/ha

Figure 9. Effect of different level of potassium on days from transplanting to head initiation of cabbage



GA₀: 0 ppm GA₃ GA₁: 65 ppm GA₃ GA₂: 85 ppm GA₃

K₀: 0 kg K₂O/ha K₁ : 120 kg K₂O/ha
K₂: 135 kg K₂O/ha K₃ : 1□□ kg K₂O/ha

Figure 10. Combined effect of different concentration of GA3 and level of potassium on days from transplanting to head initiation of cabbage

transplanting to head initiation was recorded from G_1 (65 ppm GA_3) which was statistically identical (32.44) to G_2 (85 ppm GA_3) and the highest (36.25) days from transplanting to head initiation was obtained from G_0 (0 ppm GA_3) under the trial (Figure 8). Patil *et al.* (1987) reported head formation was 13 days earlier with 50 ppm GA_3.

Different level of potassium showed significant variation for days from transplanting to head formation (Appendix IV). The lowest (32.11) days from transplanting to head initiation was recorded from K_2 (135 kg K_2O/ha) which was statistically similar (32.74) to K_1 (120 kg K_2O/ha), while the highest (34.92) days from transplanting to head formation was recorded from control condition i.e. no potassium which was closely (33.63) followed by K_3 (150 kg K_2O/ha (Figure 9)).

Combined effect of different concentration of GA_3 and level of potassium showed significant differences in terms of days from transplanting to head formation (Appendix IV). The lowest (30.33) days from transplanting to head formation was recorded from the treatment combination of G_1K_2 (65 ppm GA_3 and 135 kg K_2O/ha) which was statistically similar (30.44) to G_1K_1 (65 ppm GA_3 and 120 kg K_2O/ha) and the highest (38.67) days from transplanting to head formation was recorded from G_0K_0 i.e. control condition (Figure 10).

4.6 Length of stem

Different concentration of GA_3 showed statistically significant differences for length of stem (Appendix IV). The highest (9.27 cm) length of stem was recorded from G_1 (65 ppm GA_3) and the lowest (7.43 cm) length of stem was found from G_0 (0 ppm GA_3) under the trial (Table 2).

Different levels of potassium showed significant differences on length of stem (Appendix IV). The highest (8.71 cm) length of stem was found from K_2 (135 kg K_2O/ha) which was statistically similar (8.68 cm) to K_1 (120 kg K_2O/ha), while the lowest (8.25 cm) length of stem was recorded from control condition (Table 2) i.e. no potassium.

The significant variation was found due to the combined effect of different concentration of GA_3 and level of potassium in terms of length of stem (Appendix IV). The highest (9.58 cm) length of stem was observed from the treatment combination of G_1K_2 (65 ppm GA_3 and 135 kg K_2O/ha) which was statistically similar (9.38 cm) to G_1K_1 (65 ppm GA_3 and 120 kg K_2O/ha), and the lowest (6.92 cm) length of stem was recorded from G_0K_3 (Table 3).

4.7 Fresh weight of stem

Different concentration of GA_3 showed statistically significant differences on fresh weight of stem (Appendix IV). The maximum (52.58 g) fresh weight of stem was found from G_2 (85 ppm GA_3) which was statistically similar (51.83 g) to G_1 (65 ppm GA_3). On the other hand, the minimum (39.54 g) fresh weight of stem was obtained from G_0 (0 ppm GA_3) under the trial (Table 2).

Different level of potassium showed significant differences for fresh weight of stem (Appendix IV). The maximum (50.48 g) fresh weight of stem was observed from K_3 (150 kg K_2O/ha) which was statistically similar (49.42 g) to K_1 (47.46g) and K_2 (135 kg K_2O/ha), while the minimum (44.57 g) fresh weight of stem was recorded from control condition (Table 2)

Significant difference was found due to the combined effect of different concentrations of GA_3 and levels of potassium in terms of fresh weight of stem (Appendix IV). The maximum (55.58 g) fresh weight of stem was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) and the minimum (33.99 g) fresh weight of stem was recorded from G_0K_0 i.e. control condition (Table 3).

4.8 Diameter of stem

Different concentration of GA_3 showed statistically significant differences for diameter of stem (Appendix IV). The maximum (5.62 cm) diameter of stem was recorded from G_2 (85 ppm GA_3), while the minimum (4.18 cm) diameter of stem was found from G_0 (0 ppm GA_3) under the trial (Table 2).

Different level of potassium showed significant differences for diameter of stem (Appendix IV). The maximum (5.37 cm) diameter of stem was observed from K_3 (150 kg K_2O/ha) and the minimum (4.51 cm) diameter of stem was recorded from control condition (Table 2).

Statistically significant variation was found due to the combined effect of different concentrations of GA_3 and level of potassium in terms of diameter of stem (Appendix IV). The maximum (6.03 cm) diameter of stem was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (5.03 cm) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the minimum (3.33 cm) diameter of stem was observed from G_0K_0 (Table 3).

4.9 Dry matter content stem

Different concentration of GA_3 showed statistically significant differences for dry matter content of stem (Appendix IV). The highest (13.92%) dry matter content of stem was recorded from G_2 (85 ppm GA_3) and the lowest (10.16%) dry matter content of stem was found from G_0 (0 ppm GA_3) under the trial (Table 2).

Different level of potassium showed significant variation for dry matter content of stem (Appendix IV). The highest (13.85%) dry matter content of stem was observed from K_3 (150 kg K_2O/ha) while the lowest (10.38%) dry matter content of stem was recorded from control condition (Table 2) i.e. no potassium.

In terms of dry matter content of stem was found significant variation was found due to the combined effect of different concentration of GA_3 and levels of potassium (Appendix IV). The highest (15.60%) dry matter content of stem was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (15.28%) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (7.67%) dry matter content of stem was recorded from G_0K_0 (Table 3).

4.10 Number of roots per plant

Number of roots per plant showed statistically significant differences for different concentration of GA_3 (Appendix V). The highest (23.81) number of roots per plant was observed from G_2 (85 ppm GA_3) and the lowest (18.77) number of roots per plant was obtained from G_0 (Table 4).

Different levels of potassium showed significant differences on number of roots per plant (Appendix V). The highest (23.41) number of roots per plant was recorded from K_3 (150 kg K_2O/ha) while the lowest (19.99) number of roots per plant was found from control condition (Table 4).

Statistically significant variation was found due to the combined effect of different concentrations of GA_3 and levels of potassium on number of roots per plant (Appendix V). The highest (25.47) number of roots per plant was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (24.87) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (15.40) number of roots per plant was recorded from G_0K_0 (Table 5).

4.11 Length of root

Different concentration of GA_3 showed statistically significant differences for length of roots under the trial (Appendix V). The highest (26.83 cm) length of roots was observed from G_2 (85 ppm GA_3) and the lowest (21.27 cm) length of roots was obtained from G_0 (0 ppm GA_3) under the trial (Table 4).

Different level of potassium showed significant differences for length of roots (Appendix V). The highest (26.50 cm) length of roots was recorded from K_3 (150 kg K_2O/ha) .On the other hand the lowest (22.14 cm) length of roots was obtained from control condition i.e. no potassium (Table 4).

Table 4. Main effect of different concentrations of GA_3 and potassium on yield contributing characters of cabbage

Treatment(s)	Number of roots per plant	Length of roots (cm)	Fresh weight of roots (g)	Thickness of head (cm)	Diameter of head (cm)
Concentration of GA_3					
G_0	18.77 c	21.27 c	21.75 b	11.33 b	15.68 b
G_1	22.41 b	25.27 b	25.60 a	13.56 a	18.47 a
G_2	23.81 a	26.83 a	25.69 a	14.39 a	18.88 a
$LSD_{(0.05)}$	0.571	0.904	0.855	1.014	0.938
Significance Level	0.01	0.01	0.01	0.01	0.01
Potassium					
K_0	19.99 d	22.14 d	23.05 b	11.48 b	15.46 c
K_1	20.94 c	24.01 c	24.80 a	13.07 a	17.55 b
K_2	22.30 b	25.18 b	25.22 a	13.79 a	18.67 a
K_3	23.41 a	26.50 a	24.32 a	14.03 a	19.01 a
$LSD_{(0.05)}$	0.659	1.043	0.987	1.170	1.083
Significance Level	0.01	0.01	0.01	0.01	0.01
CV(%)	8.11	10.36	4.15	9.14	6.27

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

G_0: 0 ppm GA_3 K_0: 0 kg K_2O/ha (control)
G_1: 65 ppm GA_3 K_1: 120 kg K_2O/ha
G_2: 85 ppm GA_3 K_2: 135 kg K_2O/ha
K_3: 150 kg K_2O/ha

Table 5. Combined effect of different concentration of GA_3 and potassium on yield contributing characters of cabbage

Treatment(s)	Number of roots per plant	Length of roots (cm)	Fresh weight of roots (g)	Thickness of head (cm)	Diameter of head (cm)
G_0K_0	15.40 g	17.13 f	21.60 d	10.59 d	13.81 d
G_0K_1	18.23 f	21.27 e	21.53 d	10.86 d	15.31 cd
G_0K_2	20.30 e	22.53 de	23.60 c	11.74 d	16.71 bc
G_0K_3	21.13 de	24.17 cd	20.27 d	12.14 cd	16.88 bc
G_1K_0	21.80 cd	23.67 cd	23.53 c	11.39 d	16.29 c
G_1K_1	22.47 bc	25.63 bc	26.49 a	14.13 abc	18.70 ab
G_1K_2	21.73 cd	24.97 bc	26.79 a	14.29 abc	19.10 a
G_1K_3	23.63 b	26.83 ab	25.59 ab	14.42 ab	19.77 a
G_2K_0	22.77 bc	25.63 bc	24.03 bc	12.47 bcd	16.29 c
G_2K_1	22.13 cd	25.13 bc	26.39 a	14.23 abc	18.64 ab
G_2K_2	24.87 a	28.03 a	25.26 abc	15.34 a	20.18 a
G_2K_3	25.47 a	28.50 a	27.09 a	15.51 a	20.39 a
$LSD_{(0.05)}$	1.142	1.807	1.710	2.027	1.876
Significance Level	0.01	0.01	0.01	0.01	0.01
CV(%)	8.11	10.36	4.15	9.14	6.27

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

G_0: 0 ppm GA_3 — K_0: 0 kg K_2O/ha (control)

G_1: 65 ppm GA_3 — K_1: 120 kg K_2O/ha

G_2: 85 ppm GA_3 — K_2: 135 kg K_2O/ha

K_3: 150 kg K_2O/ha

The significant variation was found due to the combined effect of different concentration of GA_3 and level of potassium in terms of length of root (Appendix V). The highest (28.50 cm) length of roots was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (28.03 cm) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (17.13 cm) length of root was recorded from G_0K_0 (Table 5).

4.12 Fresh weight of roots

Different concentrations of GA_3 showed statistically significant differences for fresh weight of roots (Appendix V). The highest (25.69 g) fresh weight of roots was recorded from G_2 (85 ppm GA_3) which was statistically similar (25.60 g) to G_1 (65 ppm GA_3) and the lowest (21.75 g) fresh weight of roots was observed from G_0 (0 ppm GA_3) under the trial (Table 4).

Different levels of potassium showed significant differences on fresh weight of roots (Appendix V). The highest (24.32 g) fresh weight of roots was recorded from K_3 (150 kg K_2O/ha) which was statistically identical (25.22 g and 24.80 g) to K_2 (135 kg K_2O/ha) and K_1 (120 kg K_2O/ha), respectively and the lowest (23.05 g) fresh weight of roots was found from control condition i.e. no potassium (Table 4).

Combined effect of different concentration of GA_3 and level of potassium in terms of fresh weight of root showed statistically significant differences (Appendix V). The highest (27.09 g) fresh weight of roots was observed from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (26.39 g) to G_2K_1 (85 ppm GA_3 and 120 kg K_2O/ha) and the lowest (21.60 g) fresh weight of roots was recorded from G_0K_0 (Table 5).

4.13 Thickness of head (cm)

Different concentrations of GA_3 showed statistically significant differences on thickness of head (Appendix V). The highest (14.39 cm) thickness of head was recorded from G_2 (85 ppm GA_3) which statistically identical (13.56 cm) to G_1 (65 ppm GA_3) and the lowest (11.33 cm) thickness of head was found from G_0 (0 ppm GA_3) under the trial (Table 4). Dharmender *et al.* (1996) reported that combinations and higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

Different levels of potassium showed significant differences for thickness of head (Appendix V). The highest (14.03 cm) thickness of head was recorded from K_3 (150 kg K_2O/ha) which statistically similar (13.79 cm and 13.07 cm) to K_2 (135 kg K_2O/ha) and K_1 (120 kg K_2O/ha), and the lowest (11.48 cm) thickness of head was found from control condition i.e. no potassium (Table 4). Rao and Subramaniun (1991) observed that the plant K concentration at all stages of growth increased significantly at the level of K_2O application dose.

Statistically significant variation was found due to the combined effect of different concentrations of GA_3 and levels of potassium in terms of thickness of head (Appendix V). The highest (15.51 cm) thickness of head was recorded from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (15.34 cm) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (10.59 cm) thickness of head was recorded from G_0K_0 (Table 5).

4.14 Diameter of head

Statistically significant difference was recorded for different concentrations of GA_3 due to the diameter of cabbage head (Appendix V). The highest (18.88 cm) diameter of head was recorded from G_2 (85 ppm GA_3) which statistically identical (18.47 cm) to G_1 (65 ppm GA_3) and the lowest (15.68 cm) diameter of head was obtained from G_0 (0 ppm GA_3) under the trial (Table 4). Patil *et al.* (1987) reported the maximum head diameter with GA_3 at 50 ppm.

Different levels of potassium showed significant differences for diameter of head (Appendix V). The highest (19.01 cm) diameter of head was found from K_3 (150 kg K_2O/ha) which statistically similar (18.67 cm) to K_2 (135 kg K_2O/ha), while the lowest (15.46 cm) diameter of head was recorded from control condition i.e. no potassium (Table 4). Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O /ha for its higher production.

Combined effect of different concentrations of GA_3 and levels of potassium in terms of diameter of head showed significant differences (Appendix V). The highest (20.39 cm) diameter of head was observed from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (20.18 cm) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (13.81 cm) diameter of head was recorded from G_0K_0 (Table 5).

4.15 Weight of loose leaves

Different concentrations of GA_3 showed statistically significant variation for weight of loose leaves (Appendix VI). The minimum (302.19 g) weight of loose leaves was recorded from G_1 (65 ppm GA_3) and the maximum (345.95 g) weight of loose leaves was observed from G_0 (0 ppm GA_3) under the trial (Table 6).

Different levels of potassium showed significant differences for weight of loose leaves (Appendix VI). The minimum (308.93 g) weight of loose leaves was recorded from K_3

(150 kg K_2O/ha) and the maximum (326.05 g) weight of loose leaves was found from K_2 (135 kg K_2O/ha) (Table 6).

The significant variation was found due to the combined effect of different concentrations of GA_3 and levels of potassium in terms of weight of loose leaves (Appendix VI). The minimum (296.17 g) weight of loose leaves was found from the treatment combination of G_1K_0 (65 ppm GA_3 and 0 kg K_2O/ha) and 150 kg K_2O/ha) and the maximum (367.21 g) weight of loose leaves was recorded from G_0K_2 (Table 7).

4.16 Gross weight of head

Different concentrations of GA_3 showed statistically significant variation on gross weight of head (Appendix VI). The highest (2.76 kg) gross weight of head was observed from G_2 (85 ppm GA_3) and the lowest (2.12 kg) gross weight of head was obtained from G_0 (0 ppm GA_3) under the trial (Table 6).

Different levels of potassium showed significant differences for gross weight of head (Appendix VI). The highest (2.97 kg) gross weight of head was found from K_3 (150 kg K_2O/ha) and the lowest (2.05 kg) gross weight of head was recorded from K_0 (control) which was statistically similar (2.07 kg) to K_1 (Table 6). Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O /ha for its higher production.

Combined effect of different concentrations of GA_3 and levels of potassium in terms of gross weight of head showed significant variation (Appendix VI). The highest (3.48 kg) gross weight of head was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (3.43 kg) to G_3K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (1.89 kg) gross weight of head was recorded from G_0K_1 (Table 7).

Table 6. Main effect of different concentration of GA_3 and potassium on yield contributing characters and yield of cabbage

Treatment(s)	Weight of loose leaves (g)	Gross weight of head (kg)	Economic yield per plant (kg)	Dry matter content of head (%)	Yield per plot (kg)	Yield per hectare (ton)
Concentration of GA_3						
G_0	345.95 a	2.12 c	1.89 b	9.91 c	28.42 b	52.64 b
G_1	302.19 c	2.60 b	2.23 a	11.81 b	33.42 a	61.90 a
G_2	312.27 b	2.76 a	2.26 a	12.41 a	33.95 a	62.87 a
$LSD_{(0.05)}$	8.775	0.060	0.085	0.274	1.261	2.336
Significance Level	0.01	0.01	0.01	0.01	0.01	0.01
Potassium						
K_0	319.88 a	2.05 c	1.72 c	10.10 d	25.78 c	47.75 c
K_1	325.68 a	2.07 c	1.86 b	11.04 c	27.95 b	51.76 b
K_2	326.05 a	2.89 b	2.43 a	11.95 b	36.43 a	67.47 a
K_3	308.93 b	2.97 a	2.50 a	12.42 a	37.57 a	69.57 a
$LSD_{(0.05)}$	10.13	0.069	0.098	0.317	1.456	2.697
Significance Level	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.24	5.73	4.67	7.85	4.67	4.67

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

G_0: 0 ppm GA_3 | K_0: 0 kg K_2O/ha (control)
G_1: 65 ppm GA_3 | K_1: 120 kg K_2O/ha
G_2: 85 ppm GA_3 | K_2: 135 kg K_2O/ha
K_3: 150 kg K_2O/ha

Table 7. Combined effect of different concentrations of GA_3 and potassium on yield contributing characters and yield of cabbage

Treatment(s)	Weight of loose leaves (g)	Gross weight of head (kg)	Economic yield per plant (kg)	Dry matter content of head (%)	Yield per plot (kg)	Yield per hectare (ton)
G_0K_0	353.20 a	1.95 g	1.69 e	7.78 g	25.35 e	46.94 e
G_0K_1	353.01 a	1.89 g	1.74 e	9.63 f	26.05 e	48.24 e
G_0K_2	367.21 a	2.28 de	2.07 c	10.94 e	31.00 c	57.41 c
G_0K_3	310.38 bc	2.36 d	2.09 c	11.29 de	31.30 c	57.96 c
G_1K_0	296.17 c	2.18 ef	1.74 e	11.01 e	26.15 e	48.43 e
G_1K_1	303.83 bc	2.17 ef	1.85 de	11.98 c	27.70 de	51.30 de
G_1K_2	306.01 bc	2.96 c	2.56 b	11.66 cd	38.45 b	71.20 b
G_1K_3	302.73 bc	3.09 b	2.76 a	12.59 b	41.40 a	76.67 a
G_2K_0	310.27 bc	2.01 g	1.72 e	11.50 cde	25.85 e	47.87 e
G_2K_1	320.22 b	2.13 f	2.01 cd	11.52 cde	30.10 cd	55.74 cd
G_2K_2	304.92 bc	3.43 a	2.66 ab	13.23 a	39.85 ab	73.80 ab
G_2K_3	313.66 bc	3.48 a	2.67 ab	13.39 a	40.00 ab	74.07 ab
$LSD_{(0.05)}$	17.55	0.120	0.169	0.549	2.522	4.672
Significance Level	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.24	5.73	4.67	7.85	4.67	4.67

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

G_0: 0 ppm GA_3 — K_0: 0 kg K_2O/ha (control)

G_1: 65 ppm GA_3 — K_1: 120 kg K_2O/ha

G_2: 85 ppm GA_3 — K_2: 135 kg K_2O/ha

K_3: 150 kg K_2O/ha

4.17 Economic yield per plant

Statistically significant variation for economic yield per plant was recorded for different concentration of GA_3 (Appendix VI). The highest (2.26 kg) economic yield per plant was recorded from G_2 (85 ppm GA_3) which was statistically similar (2.23 kg) to G_1 (65 ppm GA_3) and the lowest (1.89 kg) economic yield per plant was observed from G_0 (0 ppm GA_3) under the trial (Table 6). Chauhan and Bordia (1971) reported maximum weight of head (1.72 kg) was obtained with 50ppm GA_3 as against 0.81 kg under control.

Different levels of potassium showed significant differences for economic yield per plant (Appendix VI). The highest (2.50 kg) economic yield per plant was recorded from K_3 (150 kg K_2O/ha) which was statistically identical (2.43 kg) to K_2 (135 kg K_2O/ha) and the lowest (1.72 kg) economic yield per plant was found from K_0 (control) which was closely (1.86 kg) followed by K_1 (Table 6). Rao and Subramaniun (1991) observed that the plant K concentration at all stages of growth increased significantly at the level of K_2O application dose.

Statistically significant variation was found due to the combined effect of different concentrations of GA_3 and level of potassium in terms of economic yield per plant (Appendix VI). The highest (2.76 kg) economic yield per plant was observed from the treatment combination of G_1K_3 (65 ppm GA_3 and 150 kg K_2O/ha) and the lowest (1.69 kg) economic yield per plant was recorded from G_0K_0 (Table 7). Dharmender *et al.* (1996) reported that combinations and higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

4.18 Dry matter content of head

Different concentration of GA_3 showed statistically significant variation on dry matter content of head (Appendix VI). The highest (12.41%) dry matter content of head was found from G_2 (85 ppm GA_3) and the lowest (9.91%) dry matter content of head was obtained from G_0 (0 ppm GA_3) under the trial (Table 6). Chauhan and Bordia (1971) reported maximum dry matter content for the application of growth regulators.

Dry matter content of head showed significant differences for different level of potassium (Appendix VI). The highest (12.42%) dry matter content of head was observed from K_3 (150 kg K_2O/ha) which was closely (11.95%) followed by K_2 (135 kg K_2O/ha) and the lowest (10.10%) dry matter content of head was recorded from K_0 .(Table 6). Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O /ha for its higher dry matter production.

The significant variation was found due to the combined effect of different concentrations of GA_3 and levels of potassium in terms of dry matter content of head (Appendix VI). The highest (13.39%) dry matter content of head was found from the treatment combination of G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (13.23%) to G_2K_2 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (7.78%g) dry matter content of head was recorded from G_0K_0 (Table 7).

4.19 Yield per plot

Different concentrations of GA_3 showed statistically significant variation on yield per plot (Appendix VI). The highest (33.95 kg) yield per plot was found from G_2 (85 ppm GA_3) which was statistically similar (33.42 kg) to G_1 (65 ppm GA_3) and the lowest (28.42 kg) yield per plot was obtained from G_0 (0 ppm GA_3) under the trial (Table 6). Dharmender *et al.* (1996) reported that combinations and higher concentration of plant growth regulators proved less effective and were uneconomic in comparison to the control.

Different levels of potassium showed significant differences for yield per plot (Appendix VI). The highest (37.57 kg) yield per plot was observed from K_3 (150 kg K_2O/ha) which was statistically identical (36.43 kg) to K_2 (135 kg K_2O/ha) and the lowest (25.78 kg) yield per plot was recorded from K_0 (Table 6). Aditiya (1993) reported that the Rabi season cabbage (Var.Atlas-70) required 225 kg K_2O /ha for its higher production.

The significant variation was found due to the combined effect of different concentration of GA_3 and level of potassium in terms of yield per plot (Appendix VI). The highest (41.40 kg) yield per plot was found from the treatment combination of G_1K_3 (65 ppm GA_3 and 150 kg K_2O/ha) and the lowest (25.35 kg) yield per plot was recorded from G_0K_0 (Table 7).

4.20 Yield per hectare

Yield per hectare showed statistically significant differences for different concentrations of GA_3 (Appendix VI). The highest (62.87 ton) yield per hectare was observed from G_2 (85 ppm GA_3) which was statistically similar (61.90 ton) to G_1 (65 ppm GA_3) and the lowest (52.64 ton) yield per hectare was found from G_0 (0 ppm GA_3) under the trial

(Table 6). Islam *et al.* (1993) reported that two sprays with 50 ppm GA_3 was suitable for higher yield.

A significant difference on yield per hectare was recorded for different level of potassium (Appendix VI). The highest (69.57 ton) yield per hectare was recorded from K_3 (150 kg K_2O/ha) which was statistically identical (67.47 ton) to K_2 (135kg K_2O/ha) and the lowest (47.75 ton) yield per hectare was observed from K_0 (Table 6). Rao and Subramaniun (1991) observed that the plant K concentration at all stages of growth increased significantly at the level of K_2O application dose. Tianxiu *et al.*(1994) found that cabbage yield was higher with 150 kg K_2O/ha than with no potassium.

Combined effect of different concentrations of GA_3 and levels of potassium showed significant variation in terms of yield per hectare (Appendix VI). The highest (76.67 ton) yield per hectare was found from the treatment combination of G_1K_3 (65 ppm GA_3 and 150 kg K_2O/ha) which was statistically similar (74.07 ton) to G_2K_3 (85 ppm GA_3 and 135 kg K_2O/ha) and the lowest (46.94 ton) yield per hectare was recorded from G_0K_0 (Table 7).

4.21 Economic analysis

Input costs for land preparation, seed cost, GA_3, fertilizer, thinning, irrigation and man power required for all the operations from sowing to harvesting of cabbage were recorded for unit plot and converted into hectare. Prices of cabbage were considered on the basis of Farmgate market rate. The economic analysis was done to find out the gross rturn, net return and the benefit cost ratio in the present experiment in the table 8.

Table 8. Cost and return of cabbage cultivation as influenced by different concentration of GA_3 and level of potassium

Treatment(s)	Cost of production (Tk./ha)	Yield of cabbage	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0K_0	146139	46.94	234700	88561	1.61
G_0K_1	150165	48.24	241200	91035	1.61
G_0K_2	150668	57.41	287050	136382	1.91
G_0K_3	151171	57.96	289800	138629	1.92
G_1K_0	153296	48.43	242150	88854	1.58
G_1K_1	157322	51.30	256500	99178	1.63
G_1K_2	157825	71.20	356000	198175	2.26
G_1K_3	158328	76.67	383350	225022	2.42
G_2K_0	155980	47.87	239350	83370	1.53
G_2K_1	160006	55.74	278700	118694	1.74
G_2K_2	160509	73.80	369000	208491	2.29
G_2K_3	161012	74.07	370350	209338	2.30

G_0: 0 ppm GA_3
G_1: 65 ppm GA_3
G_2: 85 ppm GA_3

K_0: 0 kg K_2O/ha (control)
K_1: 120 kg K_2O/ha
K_2: 135 kg K_2O/ha
K_3: 150 kg K_2O/ha

Market price of cabbage @ Tk. 5,000/ton
Gross return = Total yield (t/ha) × Tk. 5,000
Net return = Gross return - Total cost of production
Benefit Cost Ratio (BCR) = Gross return/Total cost of production

4.21.1 Gross return

In the combination of GA_3 and potassium showed different gross return in present study. (Table 8). The highest gross return (Tk. 383,350/ha) was recorded from G_1K_3 (65 ppm GA_3 and 150 kg K_2O/ha) and the second the highest gross return (Tk. 370,350/ha) was obtained from G_2K_3 (85 ppm GA_3 and 150 kg K_2O/ha). The lowest gross return (Tk. 234,700/ha) was recorded from G_0K_0 (0 ppm GA_3 and 0 kg K_2O/ha).

4.21.2 Net return

In case of net return different treatment combination showed various amount of net return. The highest net return (Tk. 225,022/ha) was recorded from G_1K_3 and the second highest net return (Tk. 209,338/ha) was recorded from G_2K_3. The lowest net return (Tk. 88,561/ha) was recorded from G_0K_0 (Table 8).

4.21.3 Benefit cost ratio

A wide range of difference in respect of benefit cost ratio was obtained from different treatment combinations (Table 8). The highest (2.42) benefit cost ratio was recorded of G_1K_3 and the second highest (2.30) was recorded from G_2K_3. The lowest befit cost ratio (1.53) was recorded from G_2K_0. From economic point of view, it is apparent that the treatment combination of G_1K_3 was more profitable compare to other treatments combination.

Chapter 5

Summary, Conclusion and Recommendation

CHAPTER IV

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from October, 2007 to January 2008 to study the effect of different concentrations of GA_3 and levels of potassium on growth and yield of cabbage. The experiment consisted of two factors i.e. (A): concentration of GA_3 (3 levels) i.e. 0 ppm (G_0), 65 ppm (G_1), 85 ppm (G_2) and (B) level of potassium (4 levels) i.e. 0 kg K_2O/ha (K_0), 120 kg K_2O/ha (K_1), 135 kg K_2O/ha (K_2), 150 kg K_2O/ha (K_3). The number of treatment combinations was 12. The data obtained for different characters were statistically analyzed to find out the significance of the different concentrations of GA_3 and levels of potassium on growth and yield of cabbage.

The tallest (41.46 cm) plant was recorded from G_2 and the shortest (35.85 cm) was found from G_0 at 60 DAT. The highest (24.08) number of leaves per plant was found from G_2 and the lowest (19.89) was recorded from G_0 at 60 DAT. The maximum (66.02 cm) spread of plant was observed from G_2, while the minimum (57.91 cm) was found from G_0 at 60 DAT. The highest (43.22 cm) length of large leaf was found from G_2 and the lowest (36.18 cm) was observed from G_0. The lowest (31.36) days from transplanting to head initiation was recorded from G_1 and the highest (36.25) was obserded from G_0. The highest (8.83 cm) stem length was recorded from G_1, while the lowest (7.43 cm) was observed from G_0. The maximum (52.58 g) fresh weight of stem was found from G_2 and the minimum (39.54 g) was obtained from G_0. The maximum (5.62 cm) diameter of stem was recorded from G_2 and the minimum (4.18 cm) was found from G_0. The highest (23.81) number of roots per plant was observed from G_2 and the lowest (18.77) was obtained from G_0. The highest (26.83 cm) length of roots was observed from G_2 and the lowest (21.27 cm) was obtained from G_0. The highest (14.39 cm) thickness of head was recorded from G_2 and the lowest (11.33 cm) was found from G_0. The highest (18.88 cm) diameter of head was recorded from G_2 and the lowest (15.68 cm) was obtained from G_0. The minimum (302.19 g) weight of loose leaves was estimated from G_1 and the maximum (345.95 g) was observed from G_0. The highest (2.76 kg) gross weight of head was observed from G_2 and the lowest (2.12 kg) was obtained from G_0. The highest (2.26 kg) economic yield per plant was recorded from G_2 and the lowest (1.89 kg) was found from G_0. The highest (12.41%) dry matter content of head was found from G_2 and the lowest (9.91%) was from G_0. The highest (62.87 ton) yield per hectare was observed from G_2 and the lowest (52.64 ton) was found from G_0.

The tallest (41.04 cm) plant was recorded from K_3 and the shortest (35.80 cm) plant was obtained from control condition at 60 DAT. The highest (24.55) number of leaves per plant was recorded from K_3 and the lowest (18.93) was observed from control condition at 60 DAT. The maximum (65.42 cm) spread of plant was recorded from K_3 and the minimum (57.90 cm) was obtained from control condition at 60 DAT. The highest (42.95 cm) length of large leaf was found from K_3, while the lowest (37.10 cm) was recorded from control condition. For head formation, K2 treatment required the lowest days (32.11) from transplanting, while the highest (34.92) was required for control condition. The highest (8.71 cm) length of stem was found from K_2, while the lowest (8.25 cm) was recorded from control condition. The maximum (50.48 g) fresh weight of stem was observed from K_3, while the minimum (44.57 g) was recorded from control condition. The maximum (5.37 cm) diameter of stem was observed from K_3, while the minimum (4.51 cm) was recorded from control condition. The highest (23.41) number of roots per plant was recorded from K_3, while the lowest (19.99) was found from control condition. The highest (26.50 cm) length of roots was recorded from K_3 and the lowest (22.14 cm) was obtained from control condition. The highest (14.03 cm) thickness of head was recorded from K_3 and the lowest (11.48 cm) was found from control condition. The highest (19.01 cm) diameter of head was found from K_3 and the lowest (15.46 cm) was recorded from control condition. The minimum (308.93 g) weight of loose leaves was recorded from K_3 and the maximum (326.05 g) was found from K_2. The highest (2.97 kg) gross weight of head was found from K_3 and the lowest (2.05 kg) was recorded from K_0. The highest (2.50 kg) economic yield per plant was recorded from K_3 and the lowest (1.72 kg) was found from K_0. The highest (12.42%) dry matter content of head was observed from K_3 and the lowest (10.10%) was recorded from K_0. The highest (69.57 ton) yield per hectare was recorded from K_3 and the lowest (47.75 ton) was observed from K_0.

In combined effect the tallest (43.69 cm) plant was obtained from the treatment combination G_2K_3, and the shortest (31.35 cm) was obtained from G_0K_0 at 60 DAT. The highest (26.44) number of leaves per plant was obtained from G_2K_3 and the lowest (15.00) was recorded from G_0K_0 at 60 DAT. The maximum (69.28 cm) spread of plant was obtained from G_2K_3 and the minimum (51.44 cm) was obtained from G_0K_0 at 60 DAT. The highest (45.84 cm) length of large leaf was observed from G_2K_2 and the lowest (29.67 cm) was found from G_0K_0. The lowest (30.33) days from transplanting to head formation was recorded from G_1K_2 and the highest (38.67) was recorded from G_0K_0. The highest (9.58 cm) length of stem was observed from the treatment combination of G_1K_2 and the lowest (6.92 cm) was recorded from G_0K_3. The maximum (55.58 g) fresh weight of stem was found from the treatment combination of G_2K_3 and the minimum (33.99 g) was recorded from G_0K_0. The maximum (6.03 cm) diameter of stem was found from the treatment combination of G_2K_3 and the minimum (3.33 cm) was observed from G_0K_0. The highest (25.47) number of roots per plant was found from G_2K_3 and the lowest (15.40) was recorded from G_0K_0. The highest (28.50 cm) length of roots was found from G_2K_3 and the lowest (17.13 cm) was recorded from G_0K_0. The highest (15.51 cm) thickness of head was recorded from the treatment combination of G_2K_3 and the lowest (10.59 cm) was recorded from G_0K_0. The highest (20.39 cm) diameter of head was observed from G_2K_3 and the lowest (13.81 cm) was recorded from G_0K_0. The minimum (296.17 g) weight of loose leaves was found from G_1K_0, while the maximum (367.21 g) was recorded from G_0K_2. The highest (3.48 kg) gross weight of head was found from G_2K_3 and the lowest (1.89 kg) was recorded from G_0K_1. The highest (2.76 kg) economic yield per plant was observed from G_1K_3 and the lowest (1.69 kg) was recorded from G_0K_0. The highest (13.39%) dry matter content of head was found from G_2K_3 and the lowest (7.78%g) was recorded from G_0K_0. The highest (76.67 ton) yield per hectare was found from G_1K_3 and the lowest (46.94 ton) was recorded from G_0K_0. The highest gross return (Tk. 383,350/ha) was recorded from G_1K_3 and the lowest gross return (Tk. 234,700/ha) was recorded from G_0K_0. The highest (2.42) benefit cost ratio was recorded of G_1K_3 and the lowest benefit cost ratio (1.53) was recorded from G_2K_0. From economic point of view, it is apparent that the treatment combination of G_1K_3 was more profitable compare to other treatment.

Therefore, it may be suggested that 85 ppm concentrations of GA_3 and 150 kg K_2O/ha can be used to obtain maximum growth and higher yield of cabbage production For ensuring the higher yield and economic return further such studies should be carried out in other agro-ecological zones of the country before final recommendation.

Chapter 6
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Appendix I. Physical & Chemical properties of soil in the experimental field

Physical properties of soil in the experimental field

Soil physical properties	Analytical data
Soil texture	Sandy loam
Sand (%)	30.65
Silt (%)	38.19
Clay (%)	31.16
Soil Type	Shallow Red Brown Terrace soil
Soil Series	Tejgoan

Chemical properties of soil in the experimental field

Soil chemical properties	Analytical data
Soil pH	5.6
Total N (%)	0.078
Available P (ppm)	0.0015
Available K (ppm)	0.0053
Organic matter (%)	0.88
C : N ratio	12:1

Source: SRDI, Framgate, Dhaka.

Appendix II. Monthly Air temperature, Rainfall, Relative humidity and Sunshine of the Experimental site during the study (October, 2007 to February, 2008)

Year	Month	Average* air temperature (°C)			Total** Rainfall (mm)	Average* Relative humidity (%)	Total** Sunshine hours
		Maximum	Minimum	Mean			
2007	October	30.5	24.3	27.4	417	80	142
	November	29.7	20.1	24.9	5	65	192.2
	December	26.9	15.8	21.35	0	68	217.03
2008	January	24.6	12.5	18.7	0	66	171.01
	February	27.1	16.8	21.95	0	64	158.68
	March	31.5	19.6	25.55	160	47	255.01

* Monthly Average

** Monthly Total

Source: The Meteorological Department (Weather division) of Bangladesh, Agargaon, Dhaka.

Source: Bangladesh The Meteorological Department (Climate division), Agargaon, Dhaka-1207

Appendix III. Analysis of variance of the data on plant height, number of leaves and spread of plant of cabbage as influenced by different concentration of GA_3 and potassium

Source of variation	Degrees of freedom	Mean square								
		Plant height (cm) at			Number of leaves per plant at			Spread of plant (cm) at		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
Replication	2	0.044	2.072	0.539	0.197	0.003	0.486	0.346	0.015	1.930
Conc. of GA_3 (A)	2	38.828**	62.696**	100.543**	2.673**	36.581**	54.653**	13.599**	50.784**	208.997**
Potassium (B)	3	13.274**	39.491**	47.115**	5.289**	20.558**	56.418**	7.567**	28.995**	96.172**
Interaction (A×B)	6	1.352*	3.221*	3.660*	0.340*	2.093*	4.115*	0.939**	3.923**	7.876**
Error	22	0.397	0.981	1.052	0.117	0.628	1.484	0.093	0.066	2.236

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

Appendix IV. Analysis of variance of the data on yield contributing characters of cabbage as influenced by different concentration of GA_3 and potassium

Source of variation	Degrees of freedom	Mean square					
		Length of large leaf (cm)	Days from transplanting to head formation	Length of stem (cm)	Fresh weight of stem (g)	Diameter of stem (cm)	Dry matter content of stem (%)
Replication	2	0.916	0.131	0.119	4.460	0.024	0.022
Conc. of GA_3 (A)	2	166.381**	79.133**	11.118**	644.137**	6.300**	43.989**
Potassium (B)	3	64.591**	13.393**	0.443**	60.682**	1.235**	20.917**
Interaction (A×B)	6	17.795**	6.886*	0.230*	22.400*	0.404**	1.606**
Error	22	2.524	2.548	0.091	9.378	0.044	0.356

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

Appendix V. Analysis of variance of the data on yield contributing characters of cabbage as influenced by different concentration of GA_3 and potassium

Source of variation	Degrees of freedom	Mean square				
		Number of roots per plant	Length of roots (cm)	Fresh weight of roots (g)	Thickness of head (cm)	Diameter of head (cm)
Replication	2	1.419	1.021	0.375	3.210	0.109
Conc. of GA_3 (A)	2	81.280**	98.410**	60.725**	29.916**	36.332**
Potassium (B)	3	20.342**	30.720**	7.923**	11.852**	23.047**
Interaction (A×B)	6	4.660**	5.082**	4.832**	2.977*	2.366*
Error	22	0.455	1.139	1.020	1.433	1.228

** 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 concentration of GA_3 and potassium

Source of variation	Degrees of freedom	Mean square					
		Weight of loose leaves (g)	Gross weight of head (kg)	Economic yield per plant (kg)	Dry matter content of head (%)	Yield per plot (kg)	Yield per hectare (ton)
Replication	2	41.020	0.005	0.004	0.064	0.908	3.114
Conc. of GA_3 (A)	2	6303.060**	1.344**	0.496**	20.411**	111.603**	382.725**
Potassium (B)	3	574.375**	2.304**	1.409**	9.523**	317.022**	1087.180**
Interaction (A×B)	6	711.026**	0.245**	0.087**	1.320**	19.684**	67.504**
Error	22	107.417	0.005	0.010	0.105	2.219	7.611

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

Appendix VII. Production cost of cabbage per hectare

A. Input cost

Treatment(s)	Labour cost	Ploughing cost	Seed Cost	Water for plant Establishment	Cost of GA3	Manure and fertilizers				Insecticide/ pesticides	Sub Total (A)
						Cowdung	Urea	TSP	MP		
G_0K_0	16000.00	6000.00	3000.00	2500.00	0.00	20000.00	1200.00	2700.00	0.00	5000.00	56400.00
G_0K_1	16000.00	6000.00	3000.00	2500.00	0.00	20000.00	1200.00	2700.00	3600.00	5000.00	60000.00
G_0K_2	16000.00	6000.00	3000.00	2500.00	0.00	20000.00	1200.00	2700.00	4050.00	5000.00	60450.00
G_0K_3	16000.00	6000.00	3000.00	2500.00	0.00	20000.00	1200.00	2700.00	4500.00	5000.00	60900.00
G_1K_0	17000.00	6000.00	3000.00	2500.00	5400.00	20000.00	1200.00	2700.00	0.00	5000.00	62800.00
G_1K_1	17000.00	6000.00	3000.00	2500.00	5400.00	20000.00	1200.00	2700.00	3600.00	5000.00	66400.00
G_1K_2	17000.00	6000.00	3000.00	2500.00	5400.00	20000.00	1200.00	2700.00	4050.00	5000.00	66850.00
G_1K_3	17000.00	6000.00	3000.00	2500.00	5400.00	20000.00	1200.00	2700.00	4500.00	5000.00	67300.00
G_2K_0	18000.00	6000.00	3000.00	2500.00	6800.00	20000.00	1200.00	2700.00	0.00	5000.00	65200.00
G_2K_1	18000.00	6000.00	3000.00	2500.00	6800.00	20000.00	1200.00	2700.00	3600.00	5000.00	68800.00
G_2K_2	18000.00	6000.00	3000.00	2500.00	6800.00	20000.00	1200.00	2700.00	4050.00	5000.00	69250.00
G_2K_3	18000.00	6000.00	3000.00	2500.00	6800.00	20000.00	1200.00	2700.00	4500.00	5000.00	69700.00

G_0: 0 ppm GA_3

G_1: 65 ppm GA_3

G_2: 85 ppm GA_3

K_0: 0 kg K_2O/ha (control)

K_1: 120 kg K_2O/ha

K_2: 135 kg K_2O/ha

K_3: 150 kg K_2O/ha

Appendix VII. Contd.

B. Overhead cost (Tk./ha)

Treatment(s)	Cost of lease of land for 6 months (13% of value of land Tk. 6,00000/year	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
G_0K_0	78000	2820	8919	89739	146139
G_0K_1	78000	3000	9165	90165	150165
G_0K_2	78000	3023	9196	90218	150668
G_0K_3	78000	3045	9226	90271	151171
G_1K_0	78000	3140	9356	90496	153296
G_1K_1	78000	3320	9602	90922	157322
G_1K_2	78000	3343	9633	90975	157825
G_1K_3	78000	3365	9663	91028	158328
G_2K_0	78000	3260	9520	90780	155980
G_2K_1	78000	3440	9766	91206	160006
G_2K_2	78000	3463	9796	91259	160509
G_2K_3	78000	3485	9827	91312	161012

G_0: 0 ppm GA_3
G_1: 65 ppm GA_3
G_2: 85 ppm GA_3

K_0: 0 kg K_2O/ha (control)
K_1: 120 kg K_2O/ha
K_2: 135 kg K_2O/ha
K_3: 150 kg K_2O/ha