EFFECT OF GA_3 AND NITROGEN ON THE GROWTH AND YIELD OF CABBAGE

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EFFECT OF GA_3 AND NITROGEN ON THE GROWTH AND YIELD OF CABBAGE

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This is to certify that the thesis entitled, "*EFFECT OF GA_3 AND NITROGEN ON THE GROWTH AND YIELD OF CABBAGE*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE (M.S.) in HORTICULTURE,* embodies the result of a piece of *bona fide* research work carried out by *JUTHIKA PAUL,* Registration No.: *05-01600* 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 duly been acknowledged.

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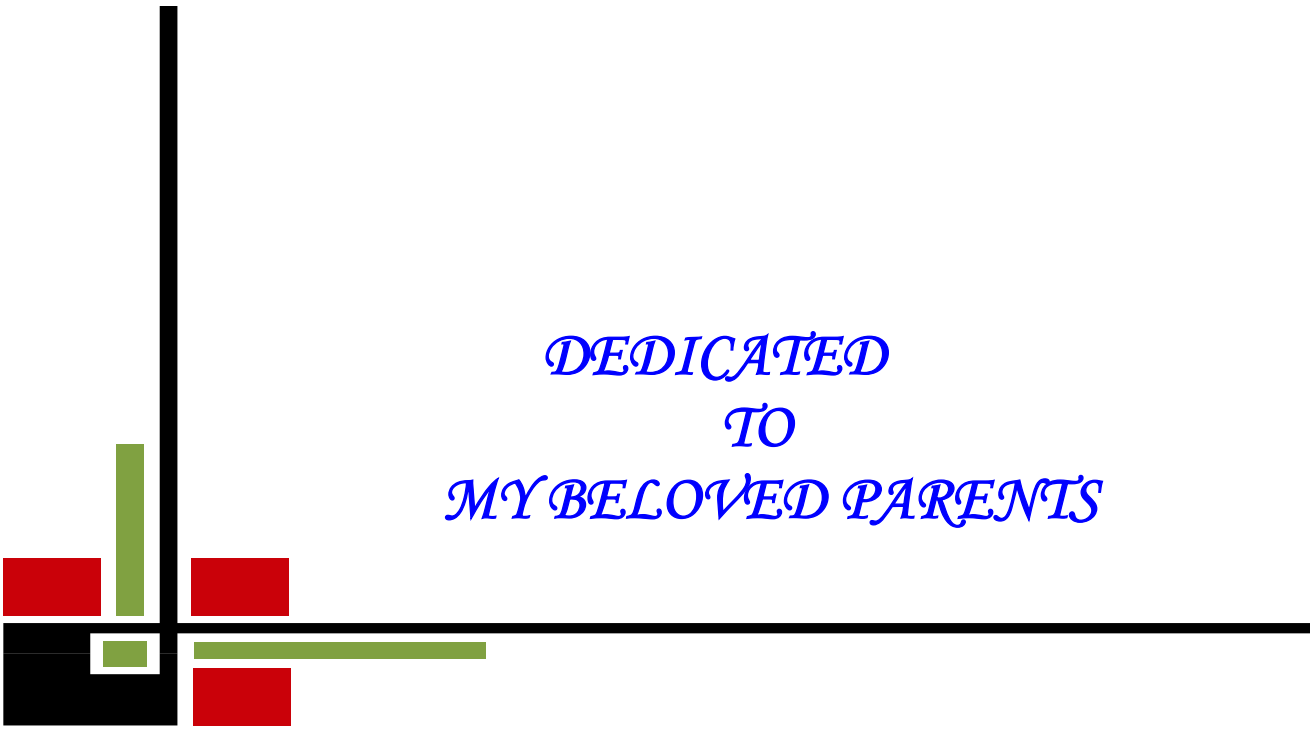

DEDICATED
TO
MY BELOVED PARENTS

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Dhaka

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ABSTRACT

An experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2010 to February 2011 to find out the effect of GA_3 and nitrogen on growth and yield of cabbage. The experiment was laid out in RCBD with three replications. The experiment considered two factors; Factor A: four concentration of GA_3 ; G_0= 0 ppm, G_1= 70 ppm, G_2= 90 ppm and G_3= 110 ppm GA_3 and Factor B: three levels of nitrogen; N_0 =0 kg , N_1 =150 kg and N_2 =200 kg N/ha. For GA_3, G_2 gave the maximum (20.11cm) thickness and highest yield (62.55 t/ha) and G_0 gave the minimum thickness (18.21cm) and lowest yield (49.16 t/ha). For nitrogen, N_2 gave the maximum thickness (20cm) and highest yield (61.57 t/ha) and N_0 gave the minimum thickness (18.66cm) and lowest yield (49.53 t/ha). For combined effect, G_2N_2 gave the highest (62.06t/ha) yield and G_0N_0 gave the lowest (49.34t/ha). So, 90ppm GA_3 and 200 kg N/ha may be used for cabbage cultivation.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
TSP	=	Triple Super Phosphate
MOP	=	Murate of Potash
RCBD	=	Randomized complete block design
DAT	=	Days after Transplanting
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
LSD	=	Least Significant Difference
NS	=	Not significant
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) belongs to the family Cruciferae and is biennial herbacious in nature. It is one of the important vegetables crop in Bangladesh. The origin of cabbage is the Western Europe and north shores of the Mediterranean Sea (Chauhan, 1986). 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 kilocalories of food energy, 1.5 g of protein, 4.8 g of carbohydrate, 40 mg of calcium, 0.6 mg of iron, 600 IU of carotene, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin C (Rashid, 1993).

Cabbage occupied an area of 11.33 thousand hectares of land during 1999-2000 growing season with a total production of 112 thousand metric tons in Bangladesh (BBS, 2000). Thus the average yield was 9.39 t/ha. This is considered as low yield compared to that of other countries of the world, viz., South Korea (61.17 t/ha), Germany (54.81 t/ha.), Japan (40.32 t/ha) and India (19.10t/ha). Such a poor yield attributed to a greater extent on the method of production technology followed by the farmers.

Growth regulators are organic compounds other than nutrients; small amount of which are capable of modifying growth (Leopold 1963). Among the growth regulators auxin causes enlargement of plant cell and gibberellins stimulate cell division, cell enlargement or both (Nickell, 1982). Due to the diversified use of productive land, it is necessary to increase the food production, and gibberellic acid (GA_3) may be a contributor in achieving the desired goal. The production of cabbage can be increased by using GA_3. Cabbage was found to show a quick growth when treated with plant growth regulators (Islam *et al.*, 1993). Application of GA_3 stimulates morphological characters like plant

height, number of leaves, head diameter, thickness of head as well as the weight of head. Therefore, it was thought that it is necessary to find out the effective dose of GA_3 in promoting growth and yield components of cabbage even in higher temperature that prevails in the later part of the growing season under Bangladesh condition.

Higher yield of cabbage is related to judicious application of fertilizer proper cultural management etc. Nitrogen can play vital role on the vegetative growth of the plant. A plant deficient in the nitrogen will tend to make little growth having usually is small leaves of yellowish in nature, frequently being rather brittle and thin. If a plant is supplied optimum amount of nitrogen, there is a tendency to increase leaf cell number and cell size with an overall increase in leaf production (Morton and Waston, 1948). Nitrogen plays an important role in the building up of protoplasm and protein which induce cell division and initiate meristematic activities when applied in optimum quantity. Low nitrogen availability causes a decrease in cell size especially cell division.

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

1) To find out appropriate concentration of GA_3 for increasing cabbage production.
2) To know the optimum dose of nitrogen on growth and yield of cabbage.
3) To find out the suitable combination of GA_3 and nitrogen for ensuring better growth and higher yield of cabbage.

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 nitrogen 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 nitrogen 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 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 applied 10 days after transplanting. Transplanting 30 days after sowing delayed harvest and reduced plant weight, regardless of GA_3 treatment.

Badawi and EL-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, NAA 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) On the yield of cabbages (ev. Pride of India) was investigated in the field at Jobner, Rajasthan, India. 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 and Kumar (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.

Nasiruddin and Roy (2011) conducted an experiment on the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. The results clearly revealed that 50ppm 0f GA_3 produced the tallest plants, the highest diameter of cabbage head and the highest head yields.

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

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

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

2.2 Effect of different levels of nitrogen on the growth and yield of cabbage

Manand Sandhu (1956) carried out an experiment on the nitrogen requirement of cabbage in India. They found the optimum dose of nitrogen is about 168 kg/ha, which gave the maximum number and larger size of outer leaves, bigger and heavier heads. The maximum sizes of marketable higher yield of head were also produced by the treatment.

Thomson and Kelly (1957) mentioned that cabbage is a heavy feeder of nitrogen. They also noted that in moist soil of California, 56-112 kg of nitrogen per hectare is considered adequate fertilization for cabbage 308 kg N/ha. The higher dose reduced proportionately bigger head weights. Similarly Vleck and Polack (1977) found that application of 140 kg N/ha was effective for raising cabbage yields, but the maximum number of outer leaves and yield were produced by 80 kg N/ha.

It was reported by Batsei *et al.* (1979) that nitrogen at the rate of 240 kg per, hectare produced the highest yield of cabbage on irrigated soil.

Csizinszky and Schyster, (1985) conducted experiments to investigate the effect of N on the yield of cabbage with 2 years trail in Florida. The experiments were conducted ill spring and autumn-winter. They observed that the high N-rate (257 kg/ha) increased head size in both seasons, but increased marketable yields in the spring.

Lawande *et al.* (1986) carried out an experiment to study the effects of spacing, nitrogen, phosphorus and potassium on yield and yield contributing characters of cabbage, cv. Golden Acre. They found 240 kg N/ha was good for cabbage yield.

Farooque and Mondol (1987) reported that the higher levels (336 kh/ha) of nitrogen increased the marketable yield of cabbage.

In a 3 years replicated trials was conducted by Khurana *et al.* (1987) to investigate the effect of nitrogen 'and spacing on cabbage cv. Pride of India and found that the highest head yield and the average head weight were produced by 60 kg nitrogen per hectare in four splits.

An experiment, Prabhakar and Srinivas (1987) used three nitrogen levels (0, 75 and 150 kg/ha) and found that individual head yield was increased with increasing nitrogen up to 150 kg/ha (1,76 t/ha), compared with 1.04 t/ha with 75 kg N/ha and 0.23 t/ha in the control.

Singh and Naik (1988) studied the response of cabbage to plant spacing, nitrogen and phosphorus levels, at Rachi, India. It was found that the thickness of marketable head and head weight of cabbage were the maximum at the rate of 180 kg N/ha.

Khadir *et al*. (1989) carried out an experiment to study the effect of different levels of urea fertilizer and plant spacing on growth and yield of cabbage. The different nitrogen levels were 0, 138 and 276 kg/ha. They found that the mean head weight, diameter and yield were greater at the maximum nitrogen level. They obtained increased leaf number/plant, vegetative growth and maximum yield from 276 kg N/ha.

An experiment was conducted by Hill (1990) in Australia to study the effect of plant spacing and nitrogenous fertilizer on the yield and plant conformation of Chinese cabbage. There were 6 levels of N (0, 50, 100,200,300 or 400 kg n/ha) in the experiment. He found the maximum marketable yield of 126.6 and 123.6 t/ha with the N-rates of 200 and 300 kg/ha, respectively and the yield decreased when the N-rate was increased to 400kg/ha. He also noted damage due to soft rot which was severe at the highest N- rate and contributed to the reduced yield.

Jiaswal *et al.* (1992) carried out an experiment on effect of nitrogen levels, method of application and spacing on growth and productivity of cabbage. N was applied at the rate of 125, 250 or 375 g/ha. Highest yield (770.77g/ha) was obtained with 375 kg N/ha applied under foliar application at 4, 5, 6 or 7 weeks after transplanting at spacing 30x20 cm.

Malik *et al.* (1996) studied the effect of nitrogen and spacing on growth and yield of cabbage cv. Pussa Drum Head at Mohanpur in India. They applied N fertilizer at the rate 0, 40, 80 or 120 kg/ha on a sandy loam soil during the winter season. Yield increased with increasing rate of N application

(57.76 and 331.46 g/ha with 0 and 120 kg/ha, respectively). Highest net profit and cost: benefit ratio were obtained at 120 kg N/ha and at the closer spacing.

An experiment was conducted by Gopal and Lal (1996) to find out the effect of nitrogen and spacing on yield and quality of cabbage cv. Golden Acre, in India. They used different levels of nitrogen 0, 50, 75 or 100 kg/ha. Growth (number of leaves, height of plant and weight of head) increased with increasing rates of N. The highest yield (254.85 q/ha) was observed at the rate of 100 kg N/ha compared with 168.73 q/ha in control.

Bhuiyan (1996) carried out an experiment to find out the effect of different levels of nitrogen and their time of application on the growth and yield of cabbage at horticulture farm, Bangladesh Agricultural University, Mymenshing in Bangladesh. There were 6 levels of nitrogen (0, 75, 150, 225 and 300 kg N/ha). He found that different levels of nitrogen had significantly influenced on growth and yield of cabbage. Yield contributing characters and yield such as plant height, diameter and thickness of the head were maximum at a rate 150 kg N/ha. The highest gross yield (79.62 ton/ha) was achieved by the application of 150 kg N/ha compared to the lowest yield at 28.88 ton/ha case of 0 kg N/ha.

According to Dixit (1997) the effects on N (0, 40, 80, 120 or 160 kg/ha) on the growth of cabbages, cv. Pride of India was investigated in Himachal Pradesh, India. Yield increasing with increasing N rate (from 136.8 to 175.1 q/ha after, addition of 0 and 160 kg N/ha respectively).

Hossain (1998) studied the effect of different planting time, spacing and nitrogen level on the growth and yield of cabbage at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh. The experiment consisted four levels nitrogen viz.0, 50 150 and 250 kg/ha. The maximum plant height, diameter of head, thickness of head, number of lateral roots, gross yield (108.60 ton/ha), marketable yield (79.33 ton/ha) were obtained from 250 kg/ N/ha.

Wang and Li (2004) carried out an experiment on a vegetable field with Peking cabbage (*Brassica pekinensis* lour. rupr.), cabbage (*Brassica chinensis var. oleifera makino and nemoto*), green cabbage (*Brassica chinensis* L.), spinach *(Spinacia oleracea* L.), and rape (*Brassica campestris* L.) to study the effects of nitrogen (N) forms and rates, and phosphorus (P) fertilization on their growth and nitrate accumulation. The results indicated that application of ammonium chloride, ammonium nitrate, sodium nitrate, and urea significantly increased the yields and nitrate concentrations of Peking cabbage and spinach.

Khan *et al.* (2002) conducted an experiment to evaluate the influence of N_2, P_2O_5 on the growth and marketable yield of cabbage. All three nutrients were given in five different combinations with or without FYM. Results showed that N_2, P_2O_5 and K_2O @ 160:90:60 kg ha^{-1} alone with FYM @ 15-20 t ha^{-1} gave the maximum total weight of 1641 g in T_5 followed of T_4 as 1459 g given N_2, P_2O_5, K_2O @ 120:90:O kg ha^{-1} with FYM @ 15-20 t ha^{-1}, whereas in the control treatment, no fertilizer it was found 1004. As far as weight of edible portion is concern it was significant amount all treatments, in T_5 it was found as 1099 g followed by T_4 as 929 g, the minimum weight of edible portion was obtained in control treatment,

With no fertilizers as 597 g. Although, plant with maximum height was found in T_5, but it was found non-significant among all treatments. Data on the girth indicates that it was significant among all treatments. Maximum girth was obtained in T_5 as 41.69, followed as 39.46 in T_3. On the whole it was observed that application of N, P_2O_5 and K_2 O @ 160:90:60 along with FYM @ 15-20 t ha^{-1} gave the desirable results in term of growth and marketable yield of cabbage.

Pramanik (2007)) carried out an experiment to find out the effect of different levels of nitrogen and phosphorus on the growth and yield of cabbage at Sher-e-Bangla Agricultural University Farm in Dhaka. Nitrogen was applied at 0, 200, 260 and 320 kg/ha.the maximum plant height and diameter of head was obtained from 260 kg of nitrogen per hectare.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in the experiment. It includes 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 field

The research work was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from October, 2010 to January 2011. The location of the site was 23.714°N Latitude and 90.335°E Longitude with the elevation of 8.2 meter from the sea level (Anon, 1989).

3.2 Soil of the experimental field

The experimental plot belongs to the Modhupur Tract which was under the 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 of the experimental area

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 monthly the maximum and minimum temperature, rainfall and relative humidity and sunshine hour 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 Plant materials used

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 the seedbed of 3 m x 1 m size. The soil was well prepared and converted into loose friable condition to obtain good tilth. 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 25 October, 2010. 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 seedlings of a good condition for growth.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:-

Factor A : It included four different concentration of GA_3 (Gibberellic Acid) which are mentioned below with alphabetic symbol.

Doses of GA_3	**Alphabetic symbol**
0 ppm	G_0
70 ppm	G_1
90 ppm	G_2
110 ppm	G_3

Factor B : It consisted of three levels of nitrogen which are mentioned below with alphabetic symbol.

Levels of nitrogen	Alphabetic symbol
0 kg/ha	N_0
150 kg/ha	N_1
200 kg/ha	N_2

Total 12 treatment combinations were as follows:

G_0N_0 G_0N_1 G_0N_2

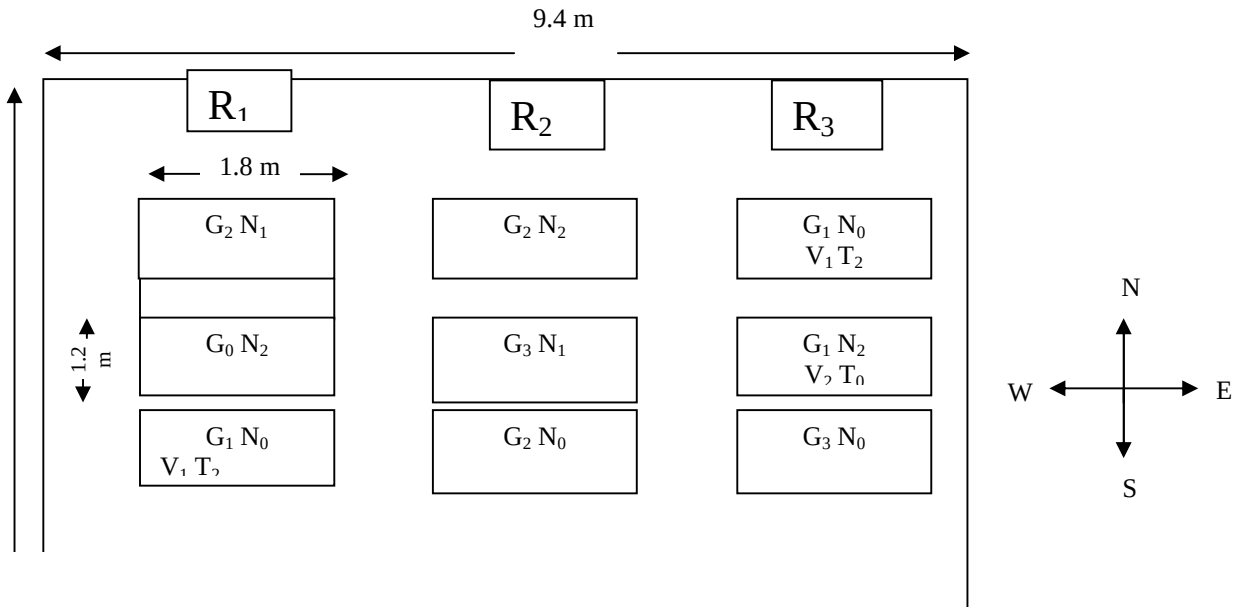
G_1N_0 G_1N_1 G_1N_2

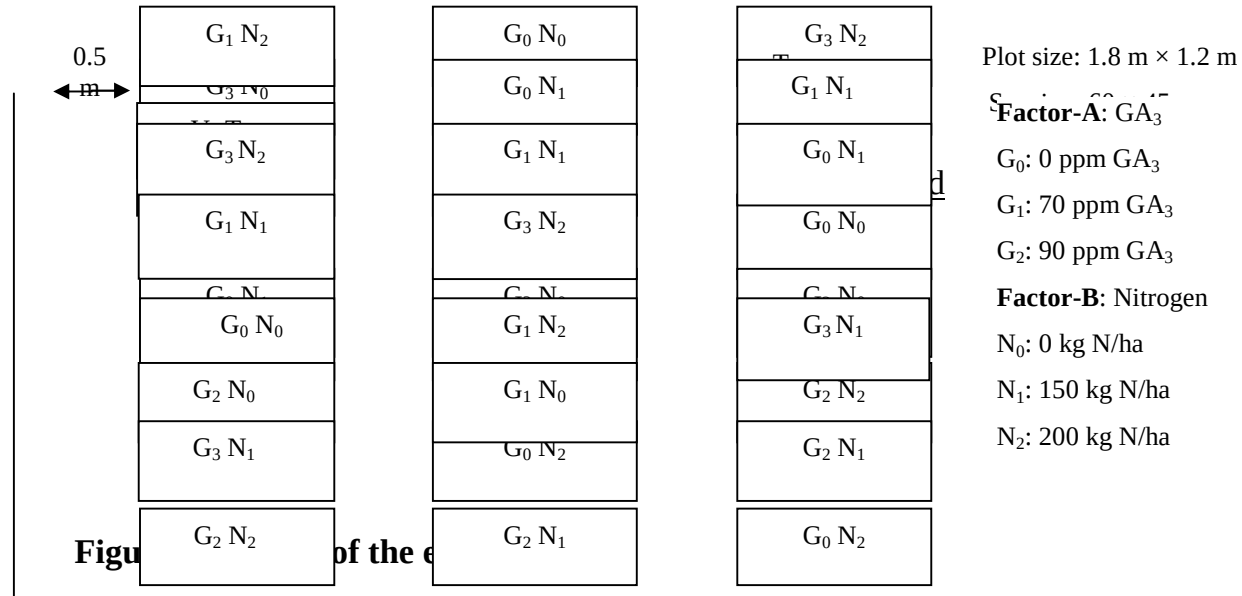
G_2N_0 G_2N_1 G_2N_2

G_3N_0 G_3N_1 G_3N_2p

3.7 Layout and design of the experiment

The two factor experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. An area of 20.9m x 9.4m was divided into three equal blocks. Each block consisted of 12 plots where 12 treatments combination of nitrogen and GA_3 solution were assigned randomly as per design of the experiment. There were 36 unit plots altogether in the experiment. The size of the plot was 1.8 m x 1.2 m. Block to block distance was 1 m and plot to plot was o.5m. Seedlings were transplanted on the plots with 60 cm x 45 cm spacing.





Figu of the e

3.8 Cultivation procedure:

3.8.1 Land preparation

The selected plot was fallow at the time of period of land preparation. The land was opened on 02 November, 2010 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 tilth for transplanting.

3.8.2 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, Muriate of potash (MOP) and Triple super phosphate (TSP) were applied to the experimental plot @ 175 and 150 kg/ha, respectively. The total amount of urea (as per treatment) was applied as top dressing around the base of the plant. Top dressing of one third of urea was applied at 15 days after transplanting and remaining urea was top dressed in two equal installments at 30 and 45 days after transplanting (DAT). MOP was applied as basal dose and top dressing at 45 DAT in equal split. TSP was applied as basal dose in the plots.

3.8.3 Transplanting of seedlings

Thirty days old healthy and uniform sized seedlings were transplanted in the experimental plots on 25 November, 2010. The seedbed was watered one hour before uprooting the seedlings to minimize the damage to the roots of the seedlings. Transplanting was done in the afternoon. During transplanting of seedling, 60 cm x 45 cm spacing were followed. Eight 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.

3.8.4 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 with soil ball to avoid transplanting shock.

3.8.5 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.

3.8.6 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 transplanted seedlings. Basudin was applied for controlling the soil born insects. Cut worms were controlled both mechanically and spraying by Dursban 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 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.

3.8.7 Preparation and application of GA_3

GA_3 in different concentrations viz. 0, 70, 90 and 110 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. 70 ppm solution of GA3 was prepared by dissolving 70 mg of it with distilled water. Then distilled water was added to make the volume 1 liter 70 ppm solution. In a similar way 90 and 110 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.

3.8.8 Harvesting

The crop was harvested during the period from 20 to 30 January, 2011 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 cutting at the base of the plant.

3.9 Parameters assessed:

Five plants were selected at random at the time of collecting data from each plot and mean data on the following parameters were recorded:-

- Plant height (cm)
- Number of leaves per plant
- Spread of plant (cm)
- Stem length (cm)
- Stem diameter (cm)
- Fresh weight of stem (g)
- Number of roots per plant
- Root length (cm)
- Fresh weight of root (g)
- Length of large leaf (cm)
- Width of large leaf (cm)
- Diameter of head (cm)
- Thickness of head (cm)

- Fresh weight of head (g)
- Percent dry matter of head
- Yield per plot (kg)
- Yield per hectare (ton)

3.10 Data collection:

When the heads were well compact, the plants were harvested at random from each unit plot. Plants were randomly selected from each plot and data were recorded according to 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 and spread of plant were taken 30 and 60 days after transplanting whereas the rest parameters were recorded at the time of harvest.

3.10.1 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).

3.10.2 Number of leaves per plant

The number of leaves per plant was counted at 30 and 60 days after transplanting.

3.10.3 Spread of plant

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

3.10.4 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).

3.10.5 Width of large leaf

Width of large leaf was measured in cm with a meter scale and was expressed in centimeter (cm).

3.10.6 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.

3.10.7 Fresh weight of stem

T he fresh weight of stem per plant was recorded from the average of 5 plants of each plot and was expressed in gram (g).

3.10.8 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.

3.10.9 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.

3.10.10 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).

3.10.11 Fresh weight of roots

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

3.10.12 Thickness of head

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

3.10.13 Diameter of head

'The harvested head was placed on a table in flat position and the diameter was measured in (cm) with a meter scale.

3.10.14 Fresh weight of head

It was the weight of cabbage head excluding roots and outer leaves measured in (g).

3.10.15 Percent dry matter of head

The heads weighing 200g from random selected plants were cut into very small pieces after well mixing and then sun dried for two days, sun dried samples were then put into envelopes and oven dried for 72 hours at 68 to 72^0 C in an oven. After oven drying, samples were weighted. An electric balance was used to

record the dry weight of sample and it was calculated on percentage basis. The percentage of dry matter was calculated by the following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of the sample}}{\text{Fresh weight of the sample}} \text{ X } 100$$

3.10.16 Yield per plot

The yield per plot was measured by totalling the head yield of each unit plot separately during the period from first to final harvest and was recorded in kilogram (kg).

3.10.17 Yield per hectare

The yield per hectare was calculated out from per plot yield data and their average was taken. It was measured by the following formula,

$$\text{Yield per hectare (ton)} = \frac{\text{Yield per plot (kg) x 10000}}{\text{Area of plot in square meter x 1000}}$$

3.11 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 Least Significant Different test at 5% level of probality.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted to find out the effect of GA_3 and nitrogen on growth and yield of cabbage. Data on different growth and yield contributing

characters were recorded to find out the optimum dose of GA_3 and nitrogen for cabbage. The analysis of variance (ANOVA) of the data on different growth and yield components are given in Appendix III-IV. The results have been presented and discussed, and possible interpretations have been drawn under the following headings.

4.1 Plant height

Plant height varied significantly at different days after transplanting (DAT) due to application of different concentrations of GA_3 (Appendix III). At 30 DAT the maximum plant height (30.42 cm) was obtained from G_2 (90 ppm GA_3), while the minimum (27.61s cm) was recorded from G_0 (0 ppm GA_3). The maximum plant height (36.76 cm) was observed in G_2 and the minimum (31.43 cm) was found from G_0 at 60 DAT. The effect of GA_3 application on plant height was best at the concentration of 90 ppm (Figure 1). Moyazzama (2008) reported that the maximum plant height was obtained from 85 ppm GA_3. Nasiruddin and Roy (2011) reported that the tallest plant was obtained from 50 ppm GA_3.

Different levels of nitrogen showed significant variation on plant height at different days after transplanting (DAT) (Appendix III). The maximum plant height (29.79 cm) was observed in N_2 (200 kg/ha) and the minimum (28.44 cm) was found from N_0 (control) at 30 DAT. At 60 DAT the maximum plant height (36.82 cm) was obtained from N_2, while the minimum (33.30 cm) was recorded from N_0. Nitrogen upto 200 kg/ha gradually increase the growth of cabbage plant (Figure 2). Hossain (1998) obtained the maximum plant height from 250 kg N/ha. Pramanik (2007) reported that the maximum plant height was obtained with 260 kg N/ha.

The variation was found due to combined effect of GA_3 and nitrogen on plant height at different DAT. The maximum plant height (30.10 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (control) gave the minimum (28.02 cm) plant height (table 1) at 30 DAT. At 60 DAT the treatment combination G_2N_2 gave the maximum (36.79 cm) plant height, where as the minimum plant height (32.36 cm) was observed in the combination of G_0N_0.

From the results it was found that both GA_3 and nitrogen favored plant growth which ensured the maximum plant height.

4.2 Number of leaves per plant

Number of leaves per plant varied significantly at different days after transplanting (DAT) due to application of different concentrations of GA_3 (Appendix III). At 30 DAT the maximum number of leaves per plant (12.28) was obtained from G_2 (90 ppm GA_3), while the minimum (10.59) was recorded from G_0 (control). The maximum leaves per plant (15.05) was observed in G_2 and the minimum (11.47) was found from G_0 at 60 DAT (Figure 3). Chhonkar and Singh (1965) reported that 5 ppm GA_3 induce larger number of leaves. Patil *et al.* (1987) reported that 50 ppm GA_3 induce larger number of leaves.

Different levels of nitrogen showed significant variation on number of leaves per plant at different days after transplanting (DAT) (Appendix III). The highest number of leaves per plant (12.10) was observed in N_2 (200 kg/ha) and the lowest number (10.72) was counted from N_0 (control) at 30 DAT. At 60 DAT the maximum leaves per plant (14.30) was obtained from N_2, while the minimum (12.73) was recorded from N_0. Nitrogen upto 200 kg/ha gradually increase the growth of cabbage plant (Figure 4). Man and Sandhu (1956) reported maximum number of leaves by 168 kg/ha N application. Khadir et al. (1989) obtained increased number of leaves per plant from 276 kg N/ha. Hossain (1998) obtained maximum number of leaves per plant from 250 kg N/ha.

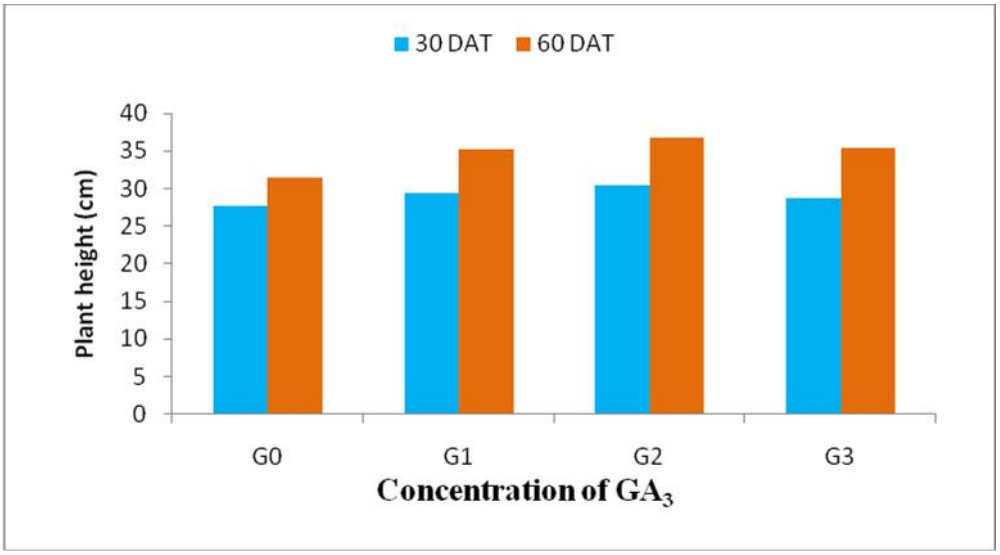


Figure 2. Effect of GA_3 on the height of cabbage plant

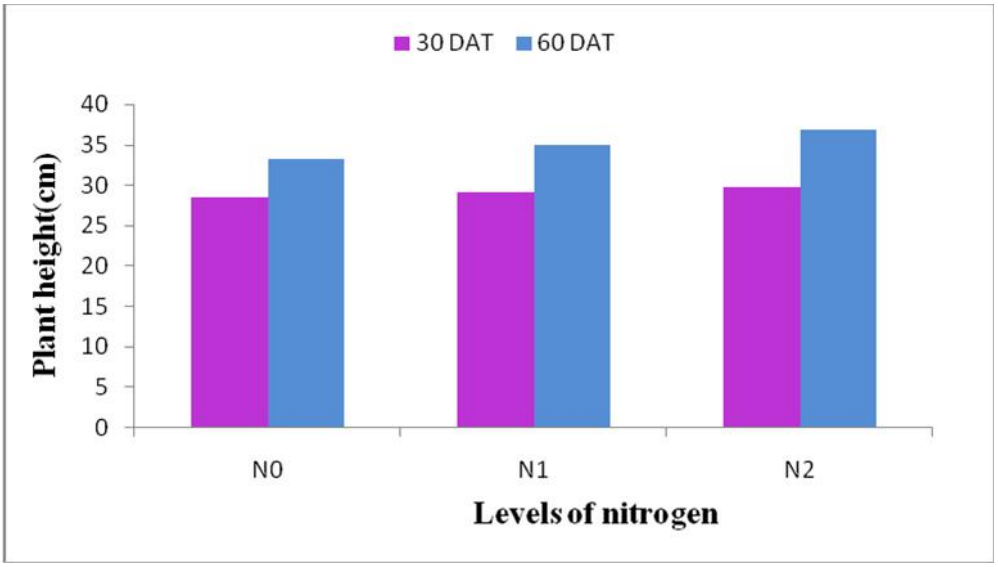


Figure 3. Effect of nitrogen on the height of cabbage plant

Where,

G_0 = 0 ppm GA_3

G_1 = 70 ppm GA_3

G_2 = 90 ppm GA_3

G_3 = 110 ppm GA_3

N_0 = No nitrogen (control)

N_1 = 150 kg N/ha

N_2 = 200 kg N/ha

The variation was found due to combined effect of GA_3 and nitrogen on number of leaves per plant at different DAT. The maximum number of leaves per plant (12.19) was counted from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (control) gave the minimum (10.65) number of leaves per plant (Table 1) at 30 DAT. At 60 DAT the treatment combination of G_2N_2 gave the maximum (14.67) leaves per plant, where as the minimum number of leaves per plant (12.10) was observed in the combination of G_0N_0. From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured highest number of leaves per plant.

4.3 Spread of plant

Spread of plant varied significantly at different days after transplanting (DAT) due to application of different concentrations of GA_3 (Appendix III). At 30 DAT the maximum plant spreading (44.81 cm) was obtained from G_2 (90 ppm GA_3), while the minimum (41.32 cm) was recorded from G_0 (0 ppm GA_3). The maximum plant spreading (58.46 cm) was observed in G_2 and the minimum (53.15 cm) was found from G_0 at 60 DAT (Table 2). The effect of GA_3 application on spread of plant was best at the concentration of 90 ppm. Moyazzama (2008) reported that the maximum spread of plant was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on plant spreading at different days after transplanting (DAT) (Appendix III). The maximum plant spreading (44.48 cm) was observed in N_2 (200 kg/ha) and the minimum (41.96 cm) was found from N_0 (control) at 30 DAT (Table 2). At 60 DAT, the maximum plant spreading (57.14 cm) was obtained from N_2 , while the minimum (54.99 cm) was recorded from N_0. Nitrogen upto 200 kg/ha gradually increase the growth of cabbage plant. Khadir et al. (1989) obtained increased plant growth from 276 kg N/ha. Pramanik (2007) reported that the maximum spread of plant was obtained from 260 kg N/ha.

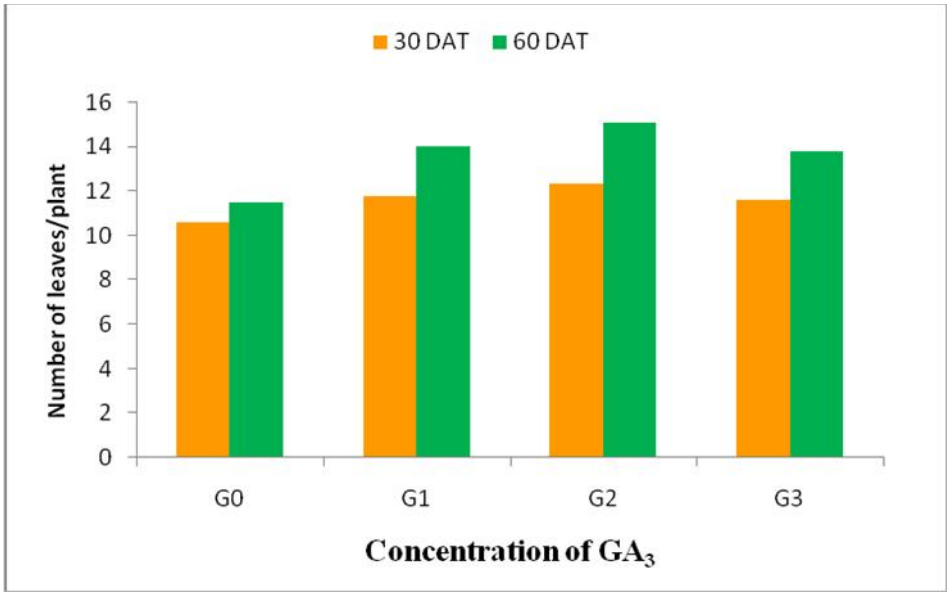


Figure 4. Effect of GA_3 on the number of leaves per cabbage plant

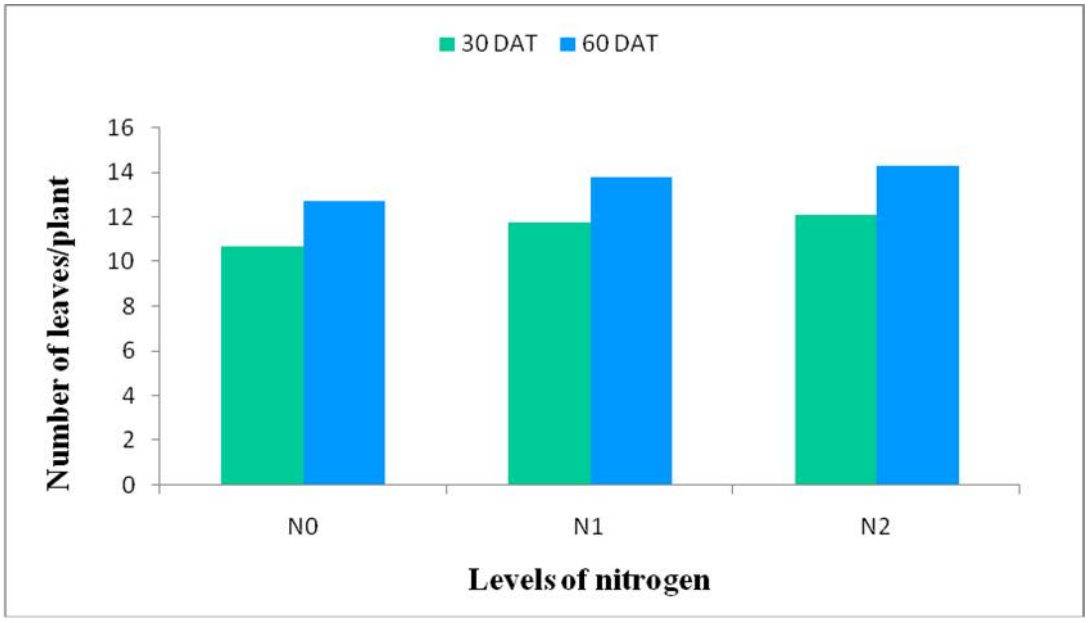


Figure 5. Effect of nitrogen on the number of leaves per cabbage plant

Table 1. Combined effect of GA_3 and Nitrogen on plant height and number of leaves per plant of cabbage

Treatments	Plant height (cm) at		Number of Leaves/plant at	
	30 DAT	60 DAT	30 DAT	60 DAT
G_0N_0	28.02	32.36	10.65	12.10
G_0N_1	28.39	33.16	11.19	12.64
G_0N_2	28.70	34.12	11.34	12.88
G_1N_0	28.95	34.25	11.23	13.36
G_1N_1	29.32	35.05	11.77	13.91
G_1N_2	29.63	36.01	11.92	14.15
G_2N_0	29.43	35.03	11.50	13.89
G_2N_1	29.80	35.83	12.04	14.43
G_2N_2	30.10	36.79	12.19	14.67
G_3N_0	28.61	34.30	11.15	13.25
G_3N_1	29.98	35.10	11.69	13.78
G_3N_2	29.28	36.06	11.84	14.02
$LSD_{(0.05)}$	0.106	0.213	1.107	0.016
CV (%)	6.13	5.57	6.01	4.49

Where,

G_0 = 0 ppm GA_3 N_0 = No nitrogen (control)

G_1 = 70 ppm GA_3 N_1 = 150 kg N/ha

G_2 = 90 ppm GA_3 N_2 = 200 kg N/ha

G_3 = 110 ppm GA_3

The variation was found due to combined effect of GA_3 application and nitrogen on plant height at different DAT. The maximum plant spreading (44.64 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) , while the treatment combination of G_0N_0 (control) gave the minimum (41.64 cm) plant spreading (table 3) at 30 DAT. At 60 DAT, the treatment combination of G_2N_2 gave the maximum (57.80 cm) plant height, where as the minimum plant spreading (54.07 cm) was observed in the combination of G_0N_0. From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured maximum plant spreading.

4.4 Length of stem

Length of stem varied significantly due to application of different concentrations of GA_3 (Appendix III). The maximum length of stem (7.93 cm) was obtained from G_2 (90 ppm GA_3) which was statistically similar to G_1 (70 ppm GA_3), while the minimum (6.69 cm) was recorded from G_0 (0 ppm GA_3) (Table 2). Moyazzama (2008) reported that the maximum length of stem was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on stem length (Appendix III). The maximum stem length (7.79 cm) was observed in N_2 (200 kg/ha) and the minimum (6.90 cm) was found from N_0 (control) (Table 2). Nitrogen upto 200kg /ha gradually increase the growth of cabbage plant. Pramanik (2007) reported that the maximum length of stem was obtained from 260 kg N/ha.

Table 2. Effect of GA_3 and nitrogen on spread of plant, stem and root characteristics of cabbage

Effect of GA_3								
Treatments	Spread of plant (cm) at		Stem characteristics			Root characteristics		
	30 DAT	60 DAT	Length (cm)	Diameter (cm)	Fresh weight (g)	Number of roots/plant	Root length (cm)	Fresh weight (g)
G_0	41.32	53.15	6.69	3.21	47.87	36.07	19.43	24.07
G_1	43.24	58.20	7.74	3.97	55.86	39.44	22.89	30.11
G_2	44.81	58.46	7.93	4.21	57.02	45.20	22.50	31.37
G_3	42.94	56.32	7.24	3.87	53.56	41.22	20.61	28.61
LSD $_{(0.05)}$	1.203	1.401	0.229	0.193	2.56	2.712	2.104	2.213
Effect of nitrogen								
N_0	41.96	54.99	6.90	3.51	50.30	36.78	19.39	26.44
N_1	43.27	56.08	7.52	3.90	54.40	41.42	21.71	28.79
N_2	44.48	57.14	7.79	4.03	56.03	43.26	22.97	30.39
LSD $_{(0.05)}$	1.001	1.026	0.199	0.167	2.22	2.349	1.822	1.917
CV(%)	8.86	9.21	3.16	5.17	4.89	6.85	10.08	7.93

The variation was found due to combined effect of GA_3 application and nitrogen on stem length. The maximum stem length (8.47 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (control) gave the minimum (6.23 cm) stem length (table 3). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured maximum length of stem.

4.5 Diameter of stem

Diameter of stem varied significantly due to application of different concentrations of GA_3 (Appendix III). The maximum diameter of stem (4.21 cm) was obtained from G_2 (90 ppm GA_3), while the minimum (3.21 cm) was recorded from G_0 (0 ppm GA_3) (Table 2). Moyazzama (2008) reported that the maximum diameter of stem was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on stem diameter (Appendix III). The maximum stem diameter (4.03 cm) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (3.90 cm) and the minimum (3.51 cm) was obtained from N_0 (control) (Table 2). The increasing level of Nitrogen (200 kg/ha) increase the growth of cabbage plant. Pramanik (2007) reported that the maximum diameter of stem was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on stem diameter. The maximum stem diameter (4.47 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_2N_1 (4.33 cm), while the treatment combination of G_0N_0 (control) gave the minimum (2.82 cm) stem diameter (table 3). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured the maximum diameter of stem.

4.6 Fresh weight of stem

Fresh weight of stem varied significantly due to application of different concentrations of GA_3 (Appendix III). The maximum weight of stem (57.02 g) was obtained from G_2 (90 ppm GA_3) which was followed by G_1 and G_3 (70 and 110 ppm GA_3 respectively), while the minimum (47.87 g) was recorded from G_0 (0 ppm GA_3) (Table 2). Moyazzama (2008) reported that the maximum fresh weight of stem was obtained from 85 ppm GA_3.

Table 3. Combined effect of GA_3 and Nitrogen on stem and root characteristics of cabbage

Treatments	Spread of plant (cm) at		Stem characteristics			Root characteristics		
	30 DAT	60 DAT	Length (cm)	Diameter (cm)	Fresh weight (g)	Number of roots/plant	Root length (cm)	Fresh weight (g)
G_0N_0	41.64	54.07	6.23	2.82	44.67	31.33	17.33	22.00
G_0N_1	42.29	54.61	6.83	3.40	48.83	37.33	19.83	24.67
G_0N_2	42.90	55.14	7.00	3.40	50.11	39.55	21.11	25.55
G_1N_0	42.60	56.54	7.27	3.73	51.97	36.33	21.50	27.33
G_1N_1	43.25	57.14	7.93	4.00	56.60	40.00	23.33	30.00
G_1N_2	43.86	57.67	8.03	4.17	59.00	42.00	23.83	32.98
G_2N_0	43.38	56.72	7.37	3.83	52.72	40.44	20.05	29.44
G_2N_1	44.04	57.27	7.97	4.33	58.33	46.50	22.83	31.67
G_2N_2	44.64	57.80	8.47	4.47	60.00	48.67	24.60	33.00
G_3N_0	42.45	55.16	6.73	3.67	51.83	39.00	18.67	27.00
G_3N_1	43.13	56.20	7.33	3.88	53.83	41.83	20.83	28.83
G_3N_2	43.71	56.73	7.67	4.07	55.00	42.83	22.33	30.00
$LSD_{(0.05)}$	0.103	0.110	0.397	0.334	4.440	4.698	3.645	3.833
CV (%)	8.86	8.21	3.16	5.17	4.89	6.85	10.08	7.93

Different levels of nitrogen showed significant variation on fresh weight of stem (Appendix III). The maximum stem weight (56.03 g) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (54.40 g) and the minimum (50.30 g) was recorded from N_0 (control) (Table 2). Nitrogen upto 200 kg/ha gradually

increase the growth of cabbage plant. Pramanik (2007) reported that the maximum fresh weight of stem was obtained from 260 kg N/ha.

Due to combined effect of different concentration of GA_3 and different levels of nitrogen showed significant variation on fresh weight of stem. The maximum stem weight (60 g) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_2N_1 (58.33 g) and G_1N_2 (59.00 g), while the treatment combination of G_0N_0 gave the minimum (44.67 g) fresh weight of stem which was statistically similar to G_0N_1 (48.83 g) (table 3). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured the maximum fresh weight of stem.

4.7 Number of roots per plant

Number of roots per plant showed significant variation due to application of different concentrations of GA_3 (Appendix IV). The maximum number of roots per plant (45.20) was obtained from G_2 (90 ppm GA_3), while the minimum (36.07) was recorded from G_0 (0 ppm GA_3) (Table 2). The effect of GA_3 application on roots per plant was most effective at the concentration of 90 ppm. Moyazzama (2008) reported that the maximum number of roots per plant was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on roots per plant (Appendix IV). The highest number of roots per plant (43.26) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (41.42) and the lowest number (36.78) was found from N_0 (Table 2). Nitrogen upto 200 kg/ha gradually increase the number of roots per cabbage plant. Hossain (1998) obtained the maximum number of lateral roots from 250 kg N/ha. Pramanik (2007) reported that the maximum number of roots per plant was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on roots per plant (Appendix IV). The maximum roots per plant (48.67) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_2N_1 (46.50), while the treatment combination of G_0N_0 (control) gave the minimum (31.33) number of roots per plant (table 3). From the results it was found that both GA_3 application and nitrogen favored roots per plant which ensured maximum plant growth.

4.8 Length of root

Length of root varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum length of root (22.89 cm) was obtained from G_1 (70 ppm GA_3) which was statistically similar to G_2 (90 ppm GA_3), while the minimum (19.43 cm) was recorded from G_0 (0 ppm GA_3) which was statistically similar to G_3 (Table 2). Moyazzama (2008) reported that the maximum length of root was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on root length (Appendix IV). The longest root (22.97 cm) was obtained from N_2 (200 kg/ha) which was statistically similar to N_1 (21.71 cm) and the minimum (19.39 cm) was found for N_0 (control) (Table 2). Nitrogen upto 200 kg/ha gradually increase the root length of cabbage plant. Pramanik (2007) reported that the maximum length of root was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on root length. The maximum length of root (24.60 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_1N_2, G_1N_1, G_2N_1, G_3N_2, G_1N_0 and G_0N_2 while the treatment combination of G_0N_0 (control) gave the minimum (17.33 cm) root length (table 3). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured the maximum length of root.

4.9 Fresh weight of root

Fresh weight of root varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum fresh weight of root (31.37 g) was obtained from G_2 (90 ppm GA_3) which was statistically similar to G_1 (70 ppm GA_3), while the minimum (24.07 g) was recorded from G_0 (0 ppm GA_3) (Table 2). The effect of GA_3 application on fresh weight of root was best at the concentration of 90 ppm which was followed by 70, 110 and 0 ppm. Moyazzama (2008) reported that the maximum fresh weight of root was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on fresh weight of root (Appendix IV). The maximum fresh weight of root (30.39 g) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (28.79 g) and the minimum

(26.44 g) was found from N_0 (control) (Table 2). Nitrogen upto 200 kg/ha gradually increase the root growth of cabbage plant. Pramanik (2007) reported that the maximum fresh weight of root was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on fresh weight of root. The maximum fresh weight of root (33.00 g) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_1N_2, G_2N_1, G_3N_2, G_2N_0 and G_1N_1, while the treatment combination of G_0N_0 (control) gave the minimum (22.00 g) fresh weight of root (table 3). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured maximum fresh weight of root.

4.10 Length of large leaf

Length of large leaf varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum length (36.14 cm) was obtained from G_2 (90 ppm GA_3) which was followed by G_1 and G_3 (70 and 110 ppm GA_3) and the minimum (32.36 cm) was recorded from G_0 (0 ppm GA_3) (Table 4). Moyazzama (2008) reported that the maximum length of large leaf was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on length of large leaf (Appendix IV). The maximum leaf length (35.44 cm) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (34.58 cm) and the minimum (33.10 cm) was found in N_0 (control) (Table 4). Nitrogen upto 200 kg/ha gradually increase the leaf length of cabbage plant. Man and Sandhu (1956) reported that the largest leaf size was obtained from 168 kg/ha N application. Pramanik (2007) reported that the maximum length of large leaf was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on leaf length. The maximum leaf length (37.33 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_1N_2 and G_2N_1, while the treatment combination of G_0N_0 (control) gave the minimum (31.00 cm) leaf length (table

5). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured maximum length of large leaf.

4.11 Width of large leaf

Width of large leaf varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum width (30.46 cm) was obtained from G_2 (90 ppm GA_3) which was followed by G_1 and G_3 (70 and 110 ppm GA_3) and the minimum (26.39 cm) was recorded from G_0 (0 ppm GA_3) (Table 4).

Different levels of nitrogen showed significant variation on width of large leaf (Appendix IV). The maximum leaf width (30.04 cm) was observed in N_2 (200 kg/ha) which was followed by N_1 (28.25 cm) and the minimum (26.39 cm) was recorded from N_0 (control) (Table 4). Nitrogen upto 200 kg/ha gradually increase the leaf width of cabbage plant.

Table 4. Effect of GA_3 and nitrogen on leaf and head characteristics of cabbage

Effect of GA_3							
Treatments	Characteristics of large leaf		Head characteristics			Dry matter of head(%)	Yield/plot (kg)
	Length (cm)	Width (cm)	Diameter (cm)	Thickness (cm)	Fresh Weight (g)		
G_0	32.36	26.39	10.17	18.21	1328	7.82	10.62
G_1	34.72	27.50	11.72	19.94	1504	8.12	12.03
G_2	36.14	30.46	12.90	20.11	1689	9.74	13.51
G_3	34.28	28.56	11.69	19.17	1514	8.52	12.11
LSD $_{(0.05)}$	1.066	1.477	0.694	1.021	138.5	0.063	1.23
Effect of nitrogen							
N_0	33.10	26.39	10.73	18.66	1337	7.02	10.70
N_1	34.58	28.25	11.71	19.42	1527	7.93	12.22
N_2	35.44	30.04	12.43	20.00	1663	8.97	13.30
LSD $_{(0.05)}$	0.923	1.279	0.601	0.884	119.9	0.017	1.08
CV(%)	3.17	5.35	6.11	5.40	9.39	8.44	9.93

The variation was found due to combined effect of GA_3 application and nitrogen on leaf width. The maximum leaf width (32.33 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_1N_2 and G_2N_1, while the treatment combination of G_0N_0 (control) gave the minimum (24.17 cm) leaf width which was statistically similar to G_0N_1 and G_1N_0 (table 5). From the results it was found that both GA_3 application and nitrogen favored plant growth which ensured maximum width of large leaf.

Table 5. Combined effect of GA_3 and Nitrogen on leaf and head characteristics of cabbage

Treatments	Characteristics of large leaf		Head characteristics			Dry matter of head(%)	Yield/plot (kg)	Yield/ha (ton)
	Length (cm)	Width (cm)	Diameter (cm)	Thickness (cm)	Fresh weight (g)			
G_0N_0	31.00	24.17	9.50	17.30	1217	8.42	10.66	49.34
G_0N_1	32.83	26.67	10.50	18.33	1367	8.87	11.42	52.87
G_0N_2	33.25	28.33	10.50	19.00	1400	7.90	11.96	56.36
G_1N_0	33.50	25.50	10.83	19.33	1347	7.55	11.36	52.61
G_1N_1	34.67	27.00	10.67	19.83	1483	8.02	12.12	56.18
G_1N_2	36.00	30.00	12.67	20.65	1683	8.55	12.66	58.63
G_2N_0	34.92	28.72	11.73	19.50	1433	8.24	12.10	56.04
G_2N_1	36.17	30.33	13.17	20.17	1733	8.70	12.86	59.56
G_2N_2	37.33	32.33	13.80	20.67	1900	9.22	13.40	62.06
G_3N_0	33.00	27.17	10.83	18.50	1350	7.77	11.40	52.80
G_3N_1	34.67	29.00	11.50	19.33	1525	8.24	12.16	56.32
G_3N_2	35.17	29.50	12.73	19.67	1667	8.22	12.70	58.82
$LSD_{(0.05)}$	1.85	2.56	1.20	1.769	239.9	0.016	0.736	2.07
CV (%)	3.17	5.35	6.11	5.40	9.39	8.44	9.93	8.42

4.12 Diameter of head

Diameter of head varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum diameter of head (12.90 cm) was obtained from G_2 (90 ppm GA_3) which was followed by G_1 and G_3 (70 and 110 ppm GA_3 respectively), while the minimum (10.17 cm) was recorded from G_0 (0 ppm GA_3) (Table 4). The effect of GA_3 application on head diameter was the best at the concentration of 90 ppm which was followed by 70, 110 and 0 ppm. Chhonkar and Singh (1985) reported that 5 ppm GA_3 induce increased head diameter, compactness and yield. Nasiruddin and Roy (2011) reported that the maximum diameter of head was obtained from 50 ppm GA_3.

Different levels of nitrogen showed significant variation on head diameter (Appendix IV). The maximum head diameter (12.43 cm) was observed in N_2 (200 kg/ha) which was followed by N_1 (11.71 cm) and the minimum (10.73 cm) was found in N_0 (control) (Table 4). Nitrogen upto 200 kg/ha gradually increase the head size of cabbage plant. Man and Sandhu (1956) reported bigger heads by

168 kg/ha N application. Hossain (1998) obtained maximum head diameter from 250 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on head diameter. The maximum head diameter (13.80 cm) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_2N_1 (13.17 cm) and G_1N_2 (12.67 cm), while the treatment combination of G_0N_0 (control) gave the minimum (9.50cm) head diameter which was statistically similar to G_0N_1 (10.50 cm) and G_0N_2 (10.50 cm) (Table 5). From the results it was found that both GA_3 application and nitrogen favored yield which was ensured by the maximum diameter of head.

4.13 Thickness of head

Thickness of head varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum thickness of head (20.11cm) was obtained from G_2 (90 ppm GA_3) which was statistically similar to G_1 and G_3 (70 and 110 ppm GA_3 respectively), while the minimum (18.21 cm) was recorded for G_0 (0 ppm GA_3) (Table 4). The effect of GA_3 application on head thickness was optimum at the concentration of 90 ppm which was followed by 70, 110 and 0 ppm. Moyazzama (2008) reported that the maximum thickness of head was obtained from 85 ppm GA_3.

Different levels of nitrogen showed significant variation on head thickness (Appendix IV). The maximum head thickness (20.00 cm) was observed in N_2 (200 kg/ha) which was statistically similar to N_1 (19.42 cm) and the minimum (18.66 cm) was found from control treatment (Table 4). Nitrogen upto 200 kg/ha gradually increase the head size of cabbage plant. Man and Sandhu (1956) reported heavier heads by 168 kg/ha N application. Batsei *et al.* (1979) reported highest head weight at 240 kg N/ha. Csizinszky and Schyster (1985) observed that the high N rate (257 kg/ha) increased head size. Hossain (1998) obtained the maximum head thickness from 250 kg N/ha.

Head thickness varied due to combined effect of application of different concentration of GA_3 and different levels of nitrogen (Appendix IV). The

maximum head thickness (20.67 cm) was recorded from the treatment combination of G_2N_2 which was statistically similar to G_1N_2, G_2N_1, G_3N_1, G_3N_2, G_2N_0, G_1N_1, G_1N_0 and G_0N_2, while the treatment combination of G_0N_0 (control) gave the minimum (17.30 cm) head thickness (Table 5). the results it was found that both GA_3 application and nitrogen favored yield which was ensured by maximum thickness of head.

4.14 Fresh weight of head

Fresh weight of head varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum fresh weight of head (1689 g) was obtained from G_2 (90 ppm GA_3) which was followed by G_1 (1504 g) and G_3 (1514 g), while the minimum (1328 g) was recorded from G_0 (0 ppm GA_3) (Table 4). The effect of GA_3 application on fresh weight of head was optimum at the concentration of 90 ppm which was followed by 70, 110 and 0 ppm. Chauhan and Bordia (1971), and Badawi and Sahhar (1979) found maximum yield for 50 ppm GA_3..

Different levels of nitrogen showed significant variation on fresh weight of head (Appendix IV). The maximum head weight (1663 g) was observed from N_2 (200 kg/ha) which was followed by N_1 (1527 g) and the minimum (1337 g) was found in N_0 (control) (Table 4). Nitrogen upto 200 kg/ha gradually increase the head weight of cabbage plant. Singh and Naik (1988) found that 180 kg N/ha performed the highest yield.

The variation was found due to combined effect of GA_3 application and nitrogen on fresh weight of head. The maximum head weight (1900 g) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm) which was statistically similar to G_1N_2, G_2N_1 and G_3N_2, while the treatment combination G_0N_0 (control) gave the minimum (1217 g) fresh weight of head which was statistically similar to G_0N_1, G_0N_2, G_1N_0, G_2N_0 and G_3N_0 (table 5). From the results it was found that both GA_3 application and nitrogen favored cabbage yield which was ensured by maximum fresh weight of head. Zee (1978) reported that plant fresh weight was considerably enhanced with the application of 20 ppm GA_3.

4.15 Percent dry matter of head

Percent dry matter of head varied significantly due to application of different concentrations of GA_3 (Appendix IV). The maximum dry matter content (9.74 %) was obtained from G_2 (90 ppm GA_3), while the minimum (7.82 %) was recorded from G_0 (0 ppm GA_3) (Table 4). The effect of GA_3 application on dry matter content of head was optimum at the concentration of 90 ppm which was followed by 70, 110 and 0 ppm. Zee (1978) reported that plant dry weight was considerably enhanced with the application of 20 ppm GA_3.

Different levels of nitrogen showed significant variation on dry matter content of head (Appendix IV). The maximum dry matter content (8.97 %) was observed from N_2 (200 kg/ha) which was followed by N_1 (7.93 %) and the minimum (7.02 %) was found from N_0 (control) (Table 4). Nitrogen up to 200 kg/ha gradually increase the dry matter content of head. Lawande *et al*. (1986) found 240 kg N/ha was good for cabbage yield. Hill (1990) reported that the maximum marketable yield of 126.6 t/ha and 123.6 t/ha with the N-rates of 200 and 300 kg/ha, respectively and the yield decreased when the N-rate was increased to 400 kg/ha. Hossain (1998) obtained maximum marketable yield from 250 kg N/ha. Pramanik (2007) reported that the maximum dry matter content of head was obtained from 260 kg N/ha.

The variation was found due to combined effect of GA_3 application and nitrogen on dry matter content of head. The maximum dry matter content (9.22%) was recorded from the treatment combination of G_2N_2 (200 kg/ha N with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (control) gave the minimum (8.42 %). (table 5). From the results it was found that both GA_3 and nitrogen favored cabbage yield which was censured by maximum gross weight of head.

4.16. Yield per plot

Yield per plot varied significantly due to application of different concentrations of GA_3 (Appendix IV). The highest yield per plot (13.51 kg) was obtained from G_2 (90 ppm GA_3), while the lowest (10.62 kg) was recorded from G_0 (Table 4). The best effect of GA_3 application on yield per plot was obtained from the

concentration of 90 ppm which was followed by 110, 70 and 0 ppm. Badawi and Sahhar(1979) found that plants treated with GA_3 (50 ppm) showed significantly greater yield per plot than untreated controls. Chauhan and Bordia (1971)) found a gradual increase in the yield per plot with 50 ppm of GA_3.

Different levels of nitrogen showed significant variation on yield per plot (Appendix IV). The highest yield per plot (13.30 kg) was observed in N_2 (200 kg/ha) and the lowest (10.70 kg) was found in N_0 (control) (Table 4). The best effect of nitrogen application on yield per plot was obtained from the dose of 200kg/ha. Singh and Naik (1988) found that 180 kg N/ha performed the highest yield.

The variation was found due to combined effect of GA_3 application and nitrogen on yield per plot. The maximum yield per plot (13.40 kg) was recorded from the treatment combination of G_2N_2 (200 kg/ha with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (control) gave the minimum (10.66 kg) yield per plot (Table 5). From the results it was found that both GA_3 application and nitrogen favored yield per plot which ensured the highest yield.

4.17. Yield per ha

Yield (ton/ha) varied significantly due to application of different concentrations of GA_3 (Appendix IV). The highest yield (62.55 t/ha) was obtained from G_2 (90 ppm GA_3), while the lowest (49.16 t/ha) was recorded from G_0 (control) Fig.(5). Patil *et al*.(1987) found that plants treated with 50 ppm GA_3 showed the maximum yield per ha. Chauhan and Bordia (1971)) found a gradual increase in the yield per plot with 50 ppm of GA_3.

Different levels of nitrogen showed significant variation on yield per ha (Appendix IV). The highest yield (61.57 t/ha) was observed from N_2 (200 kg/ha) and the lowest (49.53 t/ha) was found in N_0 (Control) Fig.(6). Singh and Naik (1988) found that 180 kg N/ha performed the highest yield.

The variation was found due to combined effect of GA_3 and nitrogen on yield. The maximum yield (62.06 t/ha) was noted from the treatment combination of G_2N_2 (200 kg/ha of N with GA_3 application at 90 ppm), while the treatment combination of G_0N_0 (Control) gave the minimum (49.34 t/ha) yield (Table 5).

From the results it was found that both 90 ppm GA_3 and 200 kg N/ha favored for ensuring higher yield of cabbage.

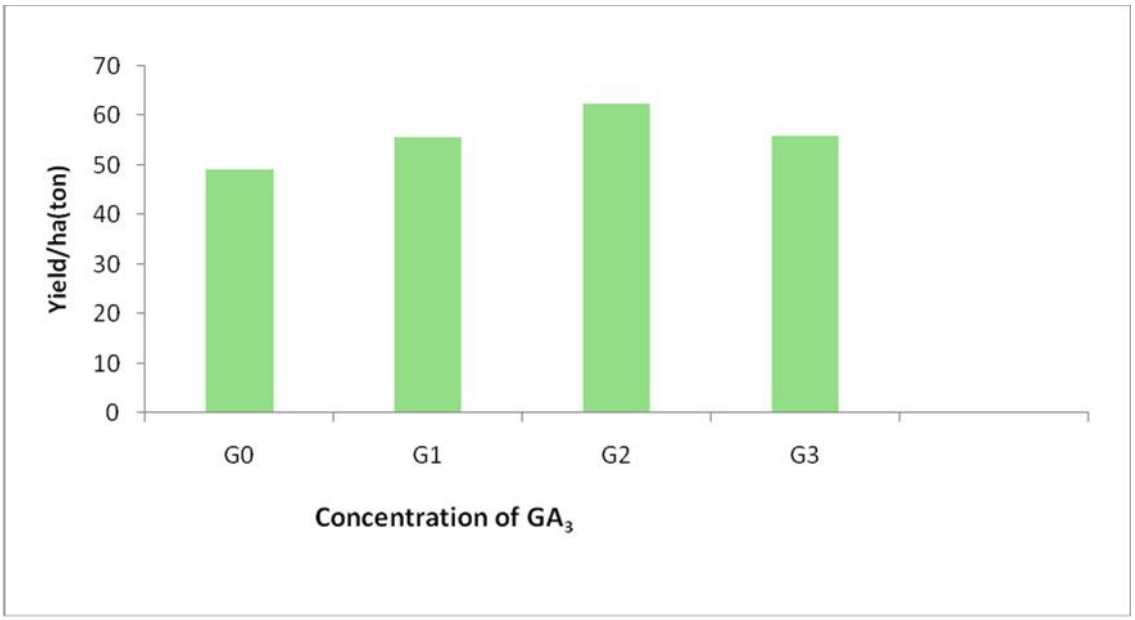


Figure 6. Effect of GA_3 on yield of cabbage

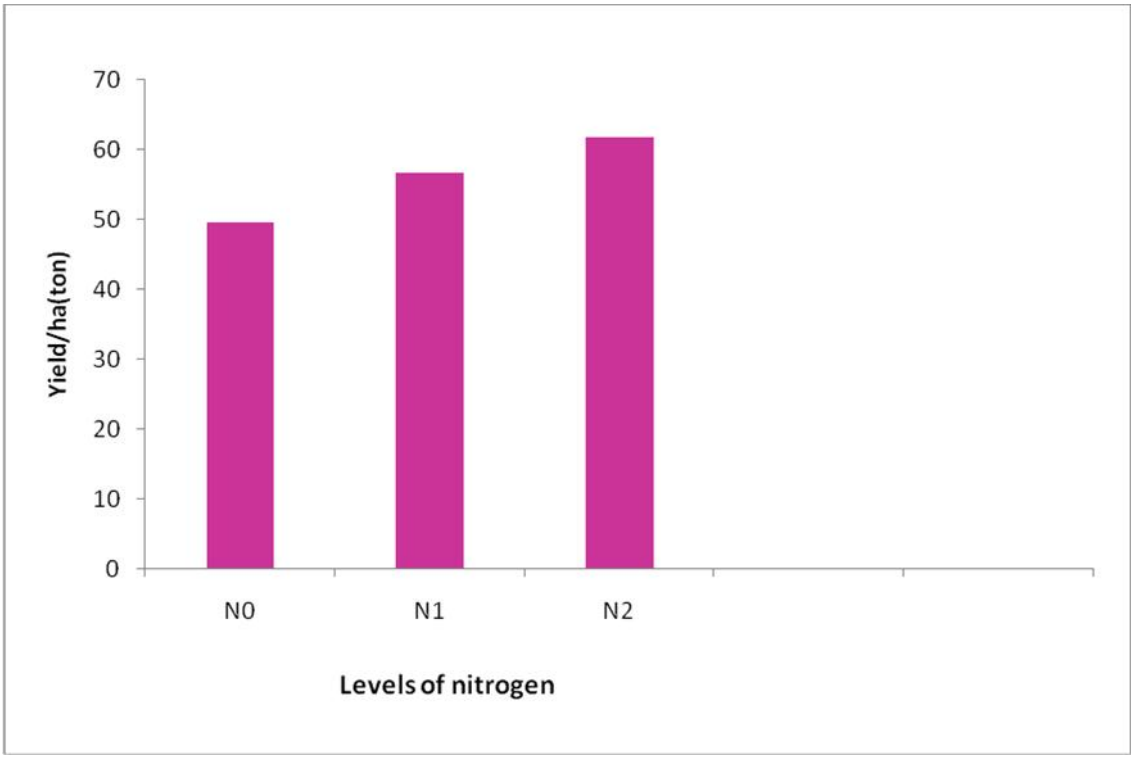


Figure 7. Effect of nitrogen on yield of cabbage

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted in the Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2010 to January 2011 to find out the effect of GA_3 and nitrogen on the growth and yield of cabbage. The experiment consisted of two factors Factor A: Different doses of GA_3 such as G_0: Control, G_1: 70 ppm G_2: 90 ppm and G_3: 110 ppm; Factor B: Different doses of nitrogen such as N_0: control, N_1: 150 kg/ha and N_2: 200 kg/ha. Data on different growth and yield contributing characters were recorded.

The maximum (36.76 cm) plant height was recorded from G_2 and the minimum (31.43 cm) was recorded from G_0 at 60 DAT. At 60 DAT the maximum (15.05) number of leaves per plant was recorded from G_2 and the minimum (11.47) was recorded from G_0. from G_0. The maximum (4.21 cm) stem diameter was recorded from G_2 and the minimum (3.21cm) was recorded from $G_{0.}$ The maximum (57.02 g) fresh weight of stem was recorded from G_2 and the minimum (47.87 g) was recorded from $G_{0.}$ The maximum (12.90 cm) head diameter was recorded from G_2 and the minimum (10.17 cm) was recorded from G_0. The maximum (20.11 cm) head thickness was recorded from G_2 and the minimum (18.21 cm) was recorded from G_0. The maximum (1689 g) fresh weight of head was recorded from G_2 and the minimum (1328 g) was recorded from G_0 at 60 DAT. The maximum (9.74%) dry matter content was recorded from G_2 and the minimum (7.82%) was recorded from G_0 at 60 DAT. The maximum (13.51 kg) yield per plot was recorded from G_2 and the minimum (10.62 kg) was recorded from G_0 at 60 DAT .The maximum (62.55 ton) yield per ha was recorded from G_2 and the minimum (49.16 ton) was recorded from G_0 at 60 DAT

The maximum (36.82 cm) plant height was recorded from N_2 and the minimum (33.30 cm) was recorded from N_0 at 60 DAT. At 60 DAT the maximum (14.30) number of leaves per plant was recorded from N_2 and the minimum (12.73) was recorded from N_0. The maximum (4.03 cm) stem

diameter was recorded from N_2 and the minimum (3.51 cm) was recorded from N_0. The maximum (12.43 cm) head diameter was recorded from N_2 and the minimum (10.73 cm) was recorded from N_0. The maximum (20.00 cm) head thickness was recorded from N_2 and the minimum (18.66 cm) was recorded from N_0. The maximum (1663 g) fresh weight of head was recorded from N_2 and the minimum (1337 g) was recorded from N_0. The maximum (8.97%) dry matter content was recorded from N_2 and the minimum (7.02 %) was recorded from N_0 at 60 DAT. The maximum (13.30 kg) yield per plot was recorded from N_2 and the minimum (10.70 kg) was recorded from N_0 at 60 DAT .The maximum (61.57 ton) yield per ha was recorded from N_2 and the minimum (49.53 ton) was recorded from N_0 at 60 DAT

The maximum (36.79 cm) plant height was recorded from the treatment combination of G_2N_2 and the minimum (32.36 cm) was recorded from the treatment combination of G_0N_0 at 60 DAT. At 60 DAT the maximum (14.67) number of leaves per plant was recorded from G_2N_2 and the minimum (12.10) was recorded from the treatment combination of G_0N_0. The maximum (4.47 cm) stem diameter was recorded from G_2N_2 and the minimum (2.82 cm) was recorded from the treatment combination of G_0N_0. The maximum (60.00 g) fresh weight of stem was recorded from G_2N_2 and the minimum (44.67 g) was recorded from the treatment combination of G_0N_0. The maximum (13.80 cm) head diameter was recorded from G_2N_2 and the minimum (9.50 cm) was recorded from the treatment combination of G_0N_0. The maximum (20.67 cm) head thickness was recorded G_2N_2 and the minimum (17.30 cm) was recorded from the treatment combination of G_0N_0. The maximum (1900 g) weight of head was recorded from G_2N_2 and the minimum (1217 g) was recorded from the treatment combination of G_0N_0. The maximum (9.22 %) percent dry matter content of head was recorded from G_2N_2 and the minimum (8.42 %) was recorded from the treatment combination of G_0N_0. The maximum (13.40 kg) yield per plot was recorded from G_2N_2 and the minimum (10.66 kg) was recorded from the treatment combination of G_0N_0. The maximum (62.06 ton) yield per ha was recorded

from G_2N_2 and the minimum (49.34 ton) was recorded from the treatment combination of G_0N_0.

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

1. Such study may be conducted in different agro-ecological zones (AEZ) and seasons of Bangladesh for exploitation of regional adaptability and other performances;

2. Some higher levels of GA_3 and nitrogen may be included in future program for more confirmation of the results.

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APPENDICES

Appendix I. Monthly average record of air temperature, rainfall, relative humidity and Sunshine of the experimental site during the period from October 2010 to April 2011.

Month	Air temperature (°c)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2010	31.6	23.8	78	172.3	5.2
November, 2010	29.6	19.2	77	34.4	5.7
December, 2010	26.4	14.1	69	12.8	5.5
January, 2011	25.4	12.7	68	7.7	5.6
February, 2011	28.1	15.5	68	28.9	5.5
March, 2011	32.5	20.4	64	65.8	5.2
April, 2011	33.7	23.6	69	165.3	4.9

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka - 1212

Appendix II. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix III. Analysis of variance of the data for different plant characteristics of cabbage

Sources of variation	Degrees of freedom	Mean square					
		Plant height (cm) at		Leaves/ plant at		Spread of plant (c	
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DA
Replication	2	3.462	5.612	2.113	1.936	3.041	1.7
GA_3 (A)	3	10.123*	28.246*	5.316*	18.324*	4.351*	1.92
Nitrogen (B)	2	6.101**	16.724**	4.281*	11.653*	6.716**	7.81
Interaction (A X B)	6	1.721*	1.936*	0.169**	1.157*	0.013*	0.27
Error	22	1.613	0.929	0.866	1.761	0.885	4.1

Appendix IV. Analysis of variance of the data for root, leaf and head characteristics of cabbage

Sources of variation	Degrees of freedom	Mean square							
		Root characteristics			Characteristics of large leaf		Head characteristi		
		Roots/plant (no.)	Root length (cm)	Fresh weight (g)	Length (cm)	Width (cm)	Diameter (cm)	Thicknes s (cm)	v
Replication	2	4.252	30.007	53.623	6.396	15.620	4.230	5.431	
GA_3 (A)	3	130.055**	23.789**	91.300**	21.891**	27.034**	11.297**	6.789**	
Nitrogen (B)	2	133.996**	39.589**	47.233**	16.724**	40.045**	8.741**	5.431*	
Interaction (AXB)	6	3.797	0.655	1.229	0.171	1.085	0.313	0.081	1
Error	22	7.698	4.633	5.125	1.188	2.282	0.504	1.091	

**- Significant at 1% level and *- Significant at 5% level
NS= Non- Significant