EFFECT OF FOLIAR APPLICATION OF GIBBERELIC ACID AND ZINC ON GROWTH AND YIELD OF CABBAGE

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EFFECT OF FOLIAR APPLICATION OF GIBBERELIC ACIDAND ZINC ON GROWTH AND YIELD OF CABBAGE

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CERTIFICATE

This is to certify that the thesis entitled,**" *Effect of foliar application of gibberelic acid and zinc on growth and yield of cabbage*"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN HORTICULTURE,** embodies the result of a piece of *bonafide* research work carried out by ***Ayesha Akhtar,*** Registration No.***14-06339*** 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 during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

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Dedicated To

My Beloved Parents

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ABSTRACT

A study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, to find out the effect of foliar application of different levels of gibberellic acid and zinc on growth and yield of cabbage. The experiment consisted of two factors such as: Factor A: three levels of gibberellic acid viz., G_0: control, G_1: 100 ppm, G_2: 150 ppm GA_3 and Factor B: three levels of zinc viz., Z_0: control, Z_1: 50 ppm, Z_2: 100 ppm Zn. The experiment was laid out in Randomized Complete Block Design with three replications. In case of different levels of GA_3, the highest head diameter (22.56 cm), head thickness (14.88 cm), fresh weight of head (1.96 kg), dry matter of head (6.33 %), yield (81.68 t/ha) were found from G_2 while the lowest head diameter (19.28 cm), head thickness (12.32 cm), fresh weight of head (1.50 kg), dry matter of head (5.45 %), yield (62.50 t/ha) from G_0. For different levels of zinc, the highest head diameter (22.42 cm), head thickness (14.87 cm), fresh weight of head (1.89 kg), dry matter of head (6.13 %), yield (78.75 t/ha) were recorded from Z_2 whereas the lowest head diameter (19.39 cm), head thickness (12.36 cm), fresh weight of head (1.57 kg), dry matter of head (5.53 %), yield (65.55 t/ha) from Z_0. Due to interaction effect, the highest head diameter (23.07 cm), head thickness (15.33 cm), fresh weight of head (2.13 kg), dry matter of head (6.66 %), yield (88.75 t/ha) were recorded from G_2Z_2 where as the lowest head diameter (18.50 cm), head thickness (12.00 cm), fresh weight of head (1.23 kg), dry matter of head (5.00 %), yield (51.25 t/ha) from G_0Z_0. The highest benefit cost ratio (2.57) was noted from the combination of G_2Z_2 and the lowest (1.57) from $G_0Z_{0.}$ From growth, yield and economic point of view, it is apparent that the combination of 150 ppm GA_3 with 100 ppm Zn was suitable for cabbage.

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ABBREVIATIONS AND ACRONYMS

@	:	At the Rate of
Abstr.	:	Abstract
AEZ	:	Agro-ecological Zone
Agric.	:	Agriculture
AVRDC	:	Asian Vegetables Research and Development Centre
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ration
cv.	:	Cultivar
DAS	:	Day After Sowing
et al.	:	et alii (and others)
FAO	:	Food and Agriculture Organization
FW	:	Fresh weight
FYM	:	Farm Yard Manure
Hort.	:	Horticulture
i.e.	:	That is
J.	:	Journal
LSD	:	Least Significant Difference
MOP	:	Muriate of Potash
NS	:	Non-significant
RCBD	:	Randomized Complete Block Design
Sci.	:	Science
Soc.	:	Society
Tk.	:	Taka
UK	:	United Kingdom
UNDP	:	United Nations Development Program
Viz.	:	Namely

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) is a member of cole crop belongs to the family Brassicaceae locally known as 'Bhadha Kopi'. It is a popular and most common winter vegetable crop grown in Bangladesh and is grown as an important vegetable in many part of the world. 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 season.

Among the vegetables grown in Bangladesh, cabbage ranks second in respect of production and area. It covers about 5% production under vegetable crops in 2013-2014 (BBS, 2015). Cabbage is a good source of β-carotene, vitamin C and fiber. 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).It has been shown to reduce the risk of some cancers, especially those in the colorectal group. Besides its nutritive value, it is a profitable cash crop for the farmers in Bangladesh.

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 also becoming very popular for obtaining higher yield in vegetable crops. They help in the synthesis of metabolites as well as translocation of nutrients and assimilation in different parts, which ultimately resulted in higher yield. Among the growth regulators, gibberellin stimulate cell division, cell enlargement or both (Nickell, 1982). Cabbage seedlings are transplanted from seedbed to the main field. The time between uprooting and establishment of young and tender seedlings in the field is very critical. Vegetables like cabbage, cauliflower and tomato respond well to plant growth regulators in minimizing the transplanting shock and being encouraged to a quick growth (Chhonkar and Singh, 1985). Application of GA_3 stimulates morpho-physiological, and yield contributing characters of cabbage.

However, the productivity of cabbage per unit area is quite low in our country as compared to the developed countries of the world (Anon. 2006). It is well documented that growth and quality of plants are greatly influenced by a wide range of nutrients. Zn is essential micronutrient and taken up by the plant in ionic form (Zn^{++}). It is evident that without use of some micronutrient viz., Zn, Cu, Fe etc., it is not possible to get the maximum benefit of N, P and K. Zinc is a cofactor of over 300 enzymes and constituent of many proteins that are involved in cell division, nucleic acid metabolism and protein synthesis. Crops yield are often limited by low level content of Zn in soils of arid and semi- arid regions (Cakmak,2000). Cakmak (2000) stated that Zn deficiency may inhibit the activities of a number of antioxidant enzymes. Zinc is essential for the synthesis of tryptophan, a precursor of IAA which is essential for normal cell division and other metabolic processes and helps in the formation of chlorophyll (Wan, 2006). Zinc deficiency leads change in leaf morphology and cell histology cause several well- known disorders such as little leaf, rosette, mottled leaf, interveinal chlorosis etc.

Therefore, an attempt is made to study the effect of Zn and GA_3levels on growth and yield of cabbage.The objectives of the research work:

1) to evaluate the effect of GA_3 on growth and yield of cabbage.
2) to study the effect of Zinc on growth and yield of cabbage.
3) to study the combined effect of zinc and GA_3 on growth and 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 zinc 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 zinc 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

Falguni (2013) conducted that the study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka to find out response of gibberellic acid and potash nutrient on growth and yield of late planting cabbage. The experiment consisted of two factors: Factor A: Gibberellic acid (four levels) as- G0: 0, G1: 90, G2: 120, G3: 150 ppm GA3 and Factor B: Potassium fertilizer (three levels) as- K0: 0, K1: 150 and K2: 200 kg K2O. The two factors experiment was laid out in Randomized Complete Block Design with three replications. In case of different growth regulators, the highest marketable yield (65.1 t/ha) were found from G2, while the lowest marketable yield (40.4 t/ha) from G0. From growth, yield and also economic point of view, it is apparent that the combination of G_2K_1 was suitable for late planting cabbage cultivation.

Juthika (2011) conducted that the 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, 90 ppm GA_3 and 200 kg N/ha may be used for cabbage cultivation.

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 50 ppm 0f GA_3 produced the tallest plants, the highest diameter of cabbage head and the highest head yields.

Yu *et al*. (2010) conducted an experiment with '8398' cabbage (*Brassica oleracea* var. captata L.) plants with 7 true leaves and 'Jingfeng No. 1' cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and 'Jingfeng No. 1' cabbage plants vernalized for 21 days were treated by high temperature of 37^0C for 12 hours to explore the changes of endogenous hormone during devernalization in cabbage. The results showed that: GA3 content had less changes, IAA content rose and ABA content decreased during devernalization. Compared with CK (vernalization period), GA3 and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower GA3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

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.

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

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).

The *invitro* propagation of shoot tips and the quality of explants of cabbage were significantly affected by the different concentrations of BA and NAA in the culture media reported by Liao *et al*. (2003). A higher rate of shoot proliferation with better quality plantlets were obtained when the medium contained more than 0.8 mg BA/litre and less than 0.5 mg NAA/litre. The effects of kinetin and zeatin on propagation efficiency was better than the combination of both treatments when used in similar concentrations. Heat shock treatment (45^0 for 2 hour) stimulated the proliferation of shoots.

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

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.

Vijoy and Kumar (2000) observed that 30 day old Cauliflower (cv. Pant Subhra) seedling were transplanted into experimental plots and treated with 50 or 100 ppm GA_3, 5 or 10 ppm IBA, or 100 or 200 ppm 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.

The effect of foliar sprays of the growth regulators B-9 [daminozide] (2500, 2 × 2500 and 5000 ppm), Bonzi [paclobutrazol] (5, 10, 20, 40 and 80 ppm), and Sumagic [uniconazole] (2, 4, 8, 16 and 32 ppm), or soil drenches of Bonzi (1, 2, 4, 8 and 16 mg a.i./pot) and Sumagic (0.125, 0.25, 0.5, 1.0 and 2.0 mg a.i./pot), on the growth of the ornamental cabbage and kale cultivars Osaka White and Nagoya Red, growing in 8-inch pots, was investigated by Chauhan and Bordia (1997). The foliar sprays and drenches were applied 22 days after potting. The growth of Osaka White decreased with increasing drench rates of Bonzi, while Nagoya Red was affected only up to a rate of 4 mg a.i/pot. All Sumagic drench rates controlled plant height of both cultivars but the response did not increase above 1 mg a.i/pot. Foliar sprays of Bonzi did not control growth of Nagoya Red while Osaka White increased in plant height with increasing rates. Foliar sprays of Sumagic reduced plant height of both cultivars. B-9, at all rates produced plants which were 12% shorter than the control.

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 50ppm 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.

Islam *et al.* (1993) was made in invstigation to determine the effective concentration of NAA 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.

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 NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Both the GA_3 and NAA increased the plant height significantly. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50 ppm followed by NAA at 50 ppm. Significant 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.

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 NAA for curd growth and 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 B had less effect.

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.

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.

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.

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 NAA (120-160ppm) 4 weeks after transplanting and twice more at fortnightly intervals. NAA 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 NAA at 40 ppm.

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.

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.

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.

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.

Srivastava (1965) 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.

2.2 Effect of zinc on the growth and yield cabbage

Zinc plays a fundamental role in several critical functions in the cell such as protein metabolism, gene expression, structural and functional integrity of biomembranes and photosynthetic carbon metabolism (Cakmak, 2000).

Some of the metabolic changes brought about by Zn deficiency could be well explained by the function of Zn as a structural component of a special enzyme or involvement in specific steps in particular metabolic pathways (Marschner, 1995). However, there are changes in the synthesis and metabolism of Zn-deficient plants that could not be explained directly by the presence of Zn in the metabolic pathway or enzyme structure. Such responses are regarded to be rather indirect effects of Zn deficiency. Concerning the central role of Zn in stability of biomembranes and proteins (Cakmak, 2000), Zn deficiency can affect the photochemical processes in the thylakoids, and thus inhibits biophysical processes of photosynthesis.

The flow of electrons through PSII is indicative of the overall rate of photosynthesis and is an estimation of photosynthetic performance. Chlorophyll fluorescence measurements could be used to estimate the operating quantum efficiency of electron transport through PSII in leaves (Maxwell and Johnson, 2000).

Zinc deficiency can also cause a drastic decrease in chlorophyll content as well as a severe damage to the fine structure of chloroplasts. In addition of the expected effect on photochemical processes, involvement of Zn in carbohydrate metabolism was demonstrated through its effect on net CO_2 assimilation rate via stomatal conductance (Sharma *et al.*, 1995) and sugar transformations (Marschner, 1995). Inhibition of activity of rubisco, aldolase, sucrose synthase and starch synthetase in plant tissues due to Zn starvation has been suggested (Marschner, 1995).

The effect of Zn nutritional status on stomatal conductance and starch or sucrose formation is a primary result of Zn deficiency still remains an open question. It was suggested that, Zn is involved in stomatal opening, possibly as a constituent of the enzyme carbonic anhydrase and/or as a factor in maintaining membrane integrity and K+ uptake (Sharma *et al.*, 1995).

Oxidative stress is a central factor in abiotic and biotic stress phenomena that occurs when there is a serious imbalance between the production of reactive oxygen species (ROS) and antioxidant defense capacity (Apel and Hirt, 2004).

Oxygen radicals damage nucleic acids, proteins, chlorophyll and lipids, which lead to the formation of toxic products such as malondialdehyde (MDA) (Apel and Hirt, 2004). Antioxidative enzymes such as ascorbate peroxidase (APX), catalase (CAT), peroxidase (POD), superoxide dismutase (SOD) and antioxidant compounds including ascorbate, glutathione as well as pigments such as anthocyanins and carotenoids play a key role in controlling the cellular level of these radicals and peroxides (Apel and Hirt, 2004).

Zinc is involved in the balance of ROS production and scavenging in plants because of its presence in the SOD, inhibitory effect on O_2 producing NADH oxidase and protection of biomembranes via binding of Zn to SH containing compounds (Marschner, 1995).

Knowledge of functional role of Zn is incomplete and in some instance remains controversial. Although the effects of Zn on both photochemical and dark fixation processes in photosynthesis were documented, detailed information on the fundamental processes of energy absorption, utilization and dissipation of excess excitation energy by PSII under Zn starvation is still not available. On the other hand, effects of Zn deficiency on physiological processes are unlikely to be uniform for all plant species and/or all tissues. Cruciferous vegetables act as a good source of natural antioxidants due to high levels of carotenoids, tocopherols and ascorbic acid. Red cabbage is particularly rich in anthocyanins with potent antioxidants and health promoting properties (Kaur and Kapoor, 2001).

Hajiboland and Amirazad (2010) reported that red cabbage plants subjected to Zn deficiency conditions showed stunted growth because of shortening of petioles, drastic decrease in leaf surface area (up to 72%) and number of leaves (61% reduction).

Sur *et al.* (2006) reported that the adoption of integrated nutrient management practices helped to build up of soil nutrient status with respect to N, P, K, Fe, Mn, Cu and Zn; and organic carbon content with the simultaneous increase in the yield and nutrient uptake by cabbage. They also mentioned that the adoption of integrated zinc management (IZM) practices helped to increase in the soil organic carbon content, yield and nutrient uptake especially Zn by cabbage.

Sharma *et al.* (1995) reported that Zn deficiency stress decreases leaf water potential, stomatal aperture and water saturation deficit in cabbage.

Islam (2002) to know the effect of copper and zinc on cabbage reported that both copper and zinc has an obvious inhibition effect on the growth of the studied plants and their various parts.

An experiment was conducted by Hou and Shang (2006) for determining effects of zinc and boron microelement fertilizer on yield and quality of cabbage indicated that foliar applications of Zn and B microelement fertilizers increased yield and improved quality of cabbage. In their experiment the highest production-increasing ratio had reached to 32.2% .They mentioned that B fertilization had better effect than the Zn fertilization in yield and the production-increasing ratio of B fertilization was 16.1% higher than Zn fertilization.

Hou and Shang (2006) reported that spraying Zn and B remarkably increased the total nitrogen of plant. They also indicated that Zn and B could remarkably inhibit the absorbtion of potassium. It was further mentioned that the quality of cabbage can be enhanced obviously through spraying appropriate amount of Zn and B elements on leaf.

Haiyan and Stuanes (2003) reported that plant having Zn deficiency shows strong reduction in leaf size and number of cells.

Hossain (1999) studied the effect Zn deficiency on growth, leaf pigments and photosynthesis in red cabbage (*Brassica oleracea* L. var. capitata f. rubra) plants under three different light conditions including 100, 200 and 400 µmol $m^{-2}s^{-1}$ in hydroponic medium either with adequate (725 pM free Zn activity) or low (30 pM free Zn activity)

Zn supply. Dry matter production of shoot and root was reduced by low Zn supply up to 95% and 63%, respectively, but increased with increasing light intensity. Low Zn supply caused reduction of shoot growth up to 80% under low light intensity (100 µmol m^{-2} s^{-1}), while this reduction was only 24% for plants grown under higher (400 µmol m s^{-1}) light conditions. Significantly lower Zn was allocated to shoot than roots in Zn deficient compared to Zn sufficient plants. Leaf chlorophyll and carotenoids content decreased in Zn deficient plants but anthocyanins and phenolics accumulated under these conditions. Zn deficiency did not cause any damage to PSII reaction centers but caused inhibition of both photochemical and non-photochemical quenching demonstrating reduction of electron use in dark reactions and lower heat dissipation in low Zn plants. Stomatal resistance was elevated in Zn deficient leaves that led to reduction of CO_2 assimilation rate and transpiration.

A field experiment was conducted by Kanujia *et al.* (2006) to ascertain the effect of micronutrients on growth and yield of cabbage var. 'Golden Acre' during Rabi 2001 and Kharif 2002. The study revealed that the foliar application of Zn @ 100 ppm gave maximum plant height during both the seasons, whereas maximum values for plant spread, number of non-wrapper leaves, head diameter, head weight and head yield were recorded with foliar application of mixture of all nutrients @ 100 ppm during both the seasons followed by multiplex.

CHAPTER III

MATERIALS AND METHODS

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

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, 2014 to January 2015. 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) and presented in Appendex I.

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 Soil Research and Development Institute (SRDI), Soil Testing Laboratory, Farmgate, Dhaka and presented in Appendix II.

3.3 Climate of the experimental area

The experimental site wasthe 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 III.

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 the 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, 2014. 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 three different concentration of gibberellic acid denote as G viz.,G_0= control, G_1= 100 ppm and G_2 = 150 ppm

Factor B: It consisted of three levels of zinc denote as Z viz., Z_0= control, Z_1= 50 ppm and Z_2=100 ppm

Total nine treatment combinations were as follows: G_0Z_0, G_0Z_1, G_0Z_2, G_1Z_0, G_1Z_1, G_1Z_2, G_2Z_0, G_2Z_1 and G_2Z_2.

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 19.4 m x 8.4 m was divided into three equal blocks. Each block consisted of nine (9) plots where nine (9) treatments combination of GA3 and zinc solution were assigned randomly as per design of the experiment. There were 27 unit plots altogether in the experiment. The size of the plot was 1.8 m x 1.6 m. Block to block distance was 1.0 m and plot to plot was 0.5m. Seedlings were transplanted on the plots with 60 cm x 45 cm spacing.

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, 2014 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 cowdung was applied to the plots at the rate of 10 t/ha and incorporated to the soil during final land preparation. In addition, Muriate of potash (MOP) and Triple super phosphate (TSP) were applied @ 175 and 150 kg/ha, respectively. The total amount of urea @ 225 kg/ha 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 and TSP were 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, 2014. 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. Twelve 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 itrequired 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 and Zinc

GA_3in different concentrations viz. 0, 100, 150 ppm and zinc in different concentrations viz. 0, 50, 100 ppm were prepared following the procedure mentioned below and spraying was done during the noonusing hand sprayer. Spraying was done 20 days after transplanting. 100 ppm solution of GA_3 was prepared by dissolving 100 mg of it with distilled water. Then distilled water was added to make the volume 1 liter for100 ppm solution. In a similar way 150 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. 50 ppm solution of zinc was prepared by dissolving 50 mg of it with distilled water. Then distilled water was added to make the volume 1 liter for50 ppm solution. In a similar way 100 ppm concentrations were made.

3.8.8 Harvesting

The crop was harvested during the period from 20 to 30 January, 2015 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)

>Leaf area (cm^2)

>Chlorophyll content of leaf (%)

>Days to head formation

>Days to head maturity

>Number of folded leaves per plant

>Number of outer loose leaves per plant

>Length of stem (cm)

>Diameter of stem (cm)

> Diameter of head (cm)

> Thickness of head (cm)

>Weight of loose leaves per plant (g)

>Fresh weight of total plant (g)

>Percent dry matter of loose leaves

> Fresh weight of head (g)

> Percent dry matter of head

> Yield plot (kg/plot)

> Yield per hectare (t/ha)

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, spread of plant and laef area were taken 35, 50 and 65 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 35, 50 and 65 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 Leaf area

Leaf area was measured an interval of 15 days starting from 35 DAT till 65 DAT by non-destructive method using CL-202 Leaf Area Meter (USA). Mature leaf (from 4^{th} node) were measured all time and expressed in cm^2. Three mature plant of each plot were measured and then average it after that mean was calculated.

3.10.5 Chlorophyll content of leaves (SPAD value)

Chlorophyll content of leaves was measured at an interval of 20 days starting from 20 DAP till 100 DAP. Mature leaf (fourth leaves from top) were measured all time. Three mature plant of each plot were measured by using portable Chlorophyll Meter (SPAD-502, Minolta, Japan) and then calculated an average SPAD value for each plot at each sampling time. The chlorophyll meter Soil Plant Analysis Development (SPAD-502) is a simple and portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Kariya *et al.*, 1982; Torres-netto *et al.*, 2005). It provides instantaneous and non-destructive readings on plants based on the quantification of the intensity of absorbed light by the tissue sample using a red LED (wavelength peak is ~650 nm) as a source. An infrared LED, with a central wavelength emission of approximately 940 nm, acts simultaneously with the red LED to compensate for the leaf thickness (Minolta camera Co. Ltd., 1989).

3.10.6 Days to head formation

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

3.10.7 Days to head maturity

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

3.10.8 Number of folded leaves per plant

After harvest, the folded leaves was pulled out from head carefully. Then the number of folded leaves per plant was counted.

3.10.9 Number of loose leaves per plant

After harvest, the loose leaves was pulled out from head carefully. Then the number of loose leaves per plant was counted.

3.10.10 Length of stem

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

3.10.11 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.

3.10.12 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 total plant

It was the weight of total cabbage plant including roots and outer leaves measured in (g).

3.10.15 Fresh weight of head

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

3.10.16 Percent dry matter of loose leaves

The heads weighing 100g from random selected plants loose leaves 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 of loose leaves was calculated by the following formula:

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

3.10.17 Percent dry matter of head

The heads weighing 100g 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:

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

3.10.18 Yield per plot (kg/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).

3.10.19 Yield per hectare (t/ha)

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

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

3.11 Statistical analyses

The data obtained for different characters were statistically analyzed to find out the significance of the difference for gibberellic acid and zinc nutrient on yield and yield contributing characters of cabbage. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Least Significant Different Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

3.12 Economic analyses

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

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

CHAPTER IV

RESULT AND DISCUSSION

The experiment was conducted to find out the effect of foliar application of different levels of $GA_3$and zinc on growth and yield of cabbage. The results obtained from the study have been presented in this chapter through tables, figures and appendices.

4.1 Plant height (cm)

Different levels of GA_3 showed significant effect on plant height of cabbage at different days after transplanting (DAT) (Figure 1 and Appendix IV). Plant height increased with increasing level of GA_3. At 35, 50 and 65 DAT, 150 ppm of GA_3 produced the tallest plant (29.68 cm, 35.67 cm and 37.20 cm, respectively). On the other hand, the shortest plant at 35, 50 and 65 DAT were observed from the control (25.73 cm, 29.84 cm and 31.98 cm, respectively).

Different levels of zinc showed significant effect on plant height of cabbage at different DAT (Figure 2 and Appendix IV). Plant height increased with the increasing level of zinc. At 35, 50 and 65 DAT, 100 ppm of zinc produced the tallest plant (28.45 cm, 35.71 cm and 36.14 cm, respectively). In comparison, the shortest plant at 35, 50 and 65 DAT was observed from the control (26.09 cm, 31.81 cm and 32.96 cm, respectively).

Interaction of GA_3 and zinc showed significant effect on plant height (cm) of cabbage at different days after transplanting (DAT) (Table 1and Appendix IV). The tallest plant at 35 DAT (30.27 cm), 50 DAT (37.51 cm) and 65 DAT (39.29 cm) was recorded from the combination of 150 ppm GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the shortest plant at 35 DAT (25.00 cm), 50 DAT (26.80 cm) and 65 DAT (29.73 cm) was observed from control (G_0Z_0).

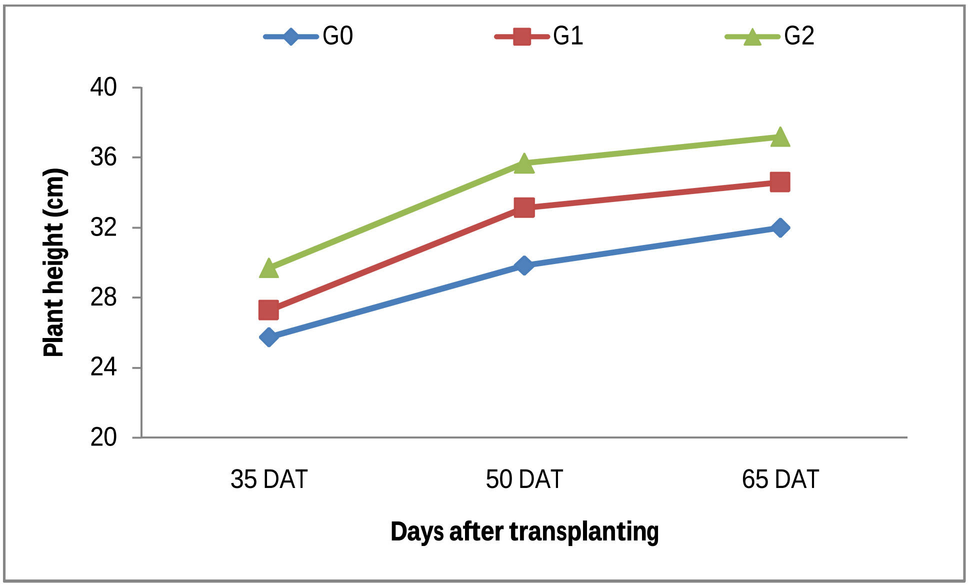

Figure 1. Effect of GA_3 on plant height of cabbage (LSD value = 1.77, 1.43 and 1.44 at 35, 50 and 65 DAT, respectively)

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

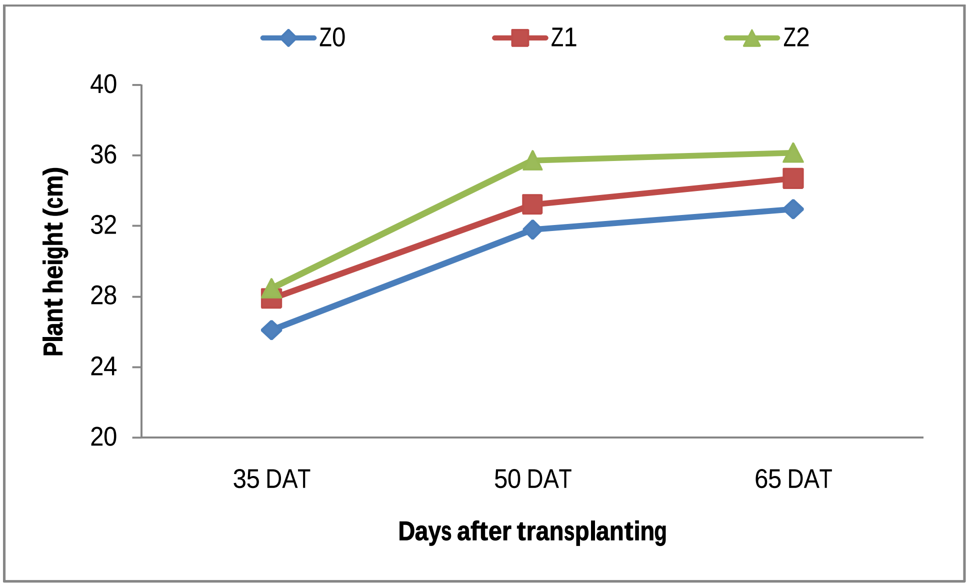

Figure 2. Effect of zinc on plant height of cabbage (LSD value = 1.77, 1.43 and 1.44 at 35, 50 and 65 DAT, respectively)

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

Table 1. Interaction effect of GA_3 and zinc on plant height of cabbage at different days after transplanting (DAT)

Treatments	Plant height (cm)		
	35 DAT	50 DAT	65 DAT
G_0Z_0	25.00	26.80	29.73
G_0Z_1	25.60	29.13	32.27
G_0Z_2	26.60	30.60	33.93
G_1Z_0	27.00	32.13	33.47
G_1Z_1	28.51	33.82	35.13
G_1Z_2	28.47	34.02	35.20
G_2Z_0	29.27	34.51	35.67
G_2Z_1	29.49	35.00	36.64
G_2Z_2	30.27	37.51	39.29
$LSD_{(0.05)}$	1.77	1.41	1.45
CV (%)	3.67	2.48	2.41

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.2 Number of leaves per plant

Different levels of GA_3 showed significant effect on number of leaves per plant of cabbage at different DAT (Figure 3and Appendix IV). Number of leaves per plant increased with increasing level of GA_3. At 35, 50 and 65 DAT, 150 ppm of GA_3 produced the maximum number of leaves per plant (12.98, 16.66 and 18.71, respectively).On the other hand, the minimum number of leaves per plant at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of GA_3 (10.78, 13.64 and 15.32, respectively).

Number of leaves per plant of cabbage was significantly influenced by different levels of zinc at different days after transplanting (DAT) (Figure 4 and Appendix IV). Number of leaves per plant increased with the increasing level of zinc. At 35, 50 and 65 DAT, 100 ppm of zinc produced the maximum number of leaves per plant (11.88, 14.51 and 16.72, respectively). On the other hand, the minimum number of leaves per plant at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of zinc (10.20, 13.67 and 15.38, respectively).

Interaction of GA_3 and zinc showed significant effect on number of leaves plant^{-1} of cabbage at different days after transplanting (DAT) (Table 2and Appendix IV). The maximum number of leaves plant^{-1} at 35 DAT (13.33), 50 DAT (17.27) and 65 DAT (19.26) was observed from the combination of 150 ppm GA_3 and 100 ppm of zinc (G_2Z_2).

In comparison, the minimum number of leaves plant^{-1} at 35 DAT (9.80), 50 DAT (13.13) and 65 DAT (15.10) was observed from control treatment (G_0Z_0).

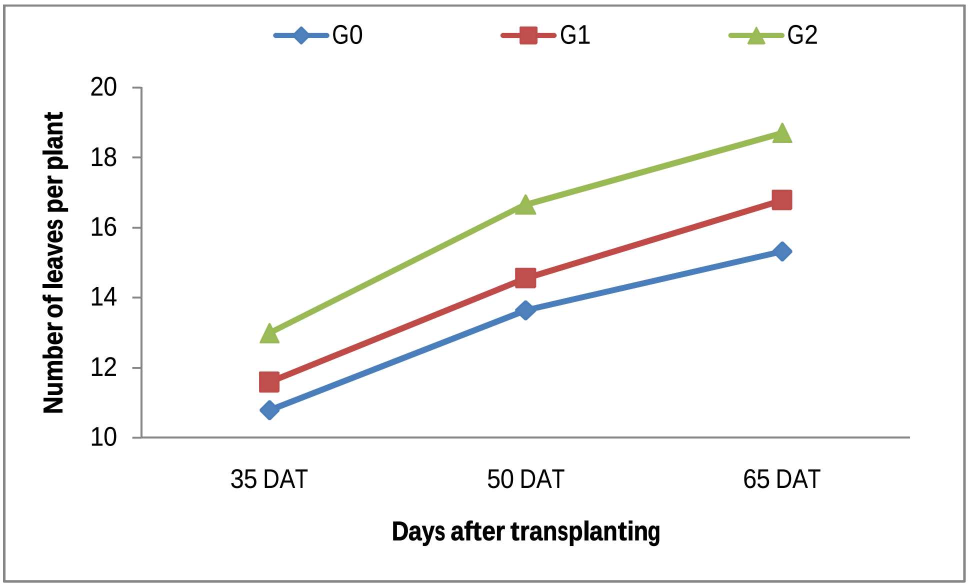

Figure 3. Effect of GA_3 on number of leaves per plant of cabbage (LSD value = 0.36, 0.49 and 0.61 at 35, 50 and 65 DAT, respectively)

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

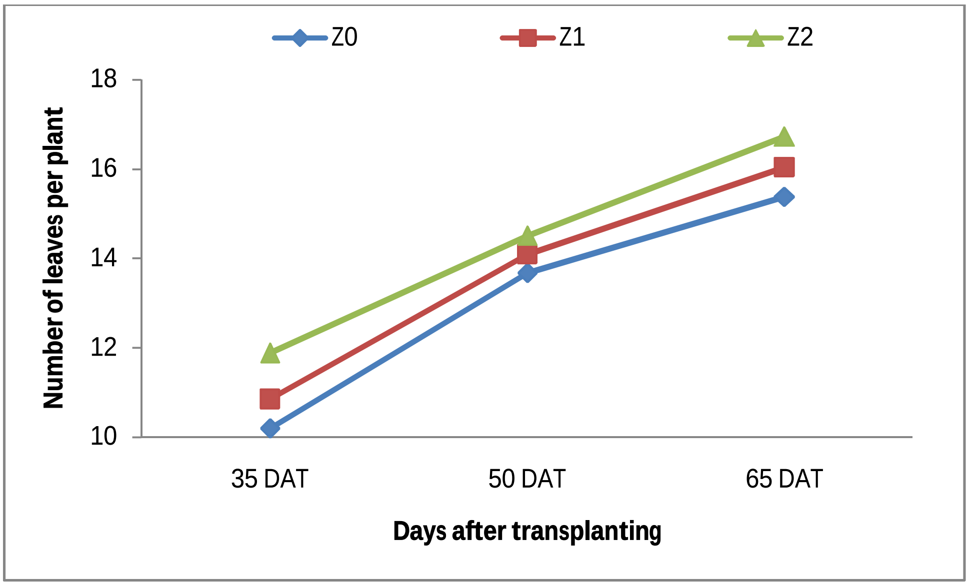

Figure 4. Effect of zinc on number of leaves per plant of cabbage (LSD value = 0.36, 0.49 and 0.61 at 35, 50 and 65 DAT, respectively)

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

Table 2. Interaction effect of GA_3 and zinc on number of leaves $plant^{-1}$ of cabbage at different days after transplanting (DAT)

Treatments	Number of leaves $plant^{-1}$		
	35 DAT	50 DAT	65 DAT
G_0Z_0	9.80	13.13	15.10
G_0Z_1	10.33	13.80	15.83
G_0Z_2	10.51	14.00	15.93
G_1Z_0	10.40	13.87	15.93
G_1Z_1	10.53	14.07	16.00
G_1Z_2	10.80	14.13	16.07
G_2Z_0	12.73	16.30	18.00
G_2Z_1	12.80	16.40	18.27
G_2Z_2	13.33	17.27	19.26
$LSD_{(0.05)}$	0.33	0.49	0.61
CV (%)	1.98	4.71	2.67

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.3 Spread of plant (cm)

Different levels of GA_3 showed significant effect on spread of cabbage at different DAT (Figure 5 and Appendix V). Spread of plant increased with increasing the level of GA_3. At 35, 50 and 65 DAT, 150 ppm of GA_3produced the maximum spread of plant (36.66 cm, 55.41 cm and 58.40 cm, respectively). In comparison, the minimum spread of plant at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of GA_3 (33.55 cm, 51.69 cm and 54.64 cm, respectively).

Different levels of zinc showed significant effect on spread of cabbage at different DAT (Figure 6 and Appendix V). Spread of plant increased with the increasing level of zinc. At 35, 50 and 65 DAT, 100 ppm of zinc produced the maximum spread of plant (36.24 cm, 55.13 cm and 58.15 cm, respectively). On the other hand, the minimum spread of plant at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of zinc (34.07 cm, 51.52 cm and 54.82 cm, respectively).

Interaction of GA_3 and zinc showed significant effect on spread of cabbage (cm) at different days after transplanting (DAT) (Table 3and Appendix V). The maximum spread of plant at 35 DAT (38.22 cm), 50 DAT (58.13 cm) and 65 DAT (60.33 cm) was observed from the combination of 150 ppm GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the minimum spread of plant at 35 DAT (32.26 cm), 50 DAT (49.73 cm) and 65 DAT (52.07 cm) was observed from control treatment (G_0Z_0).

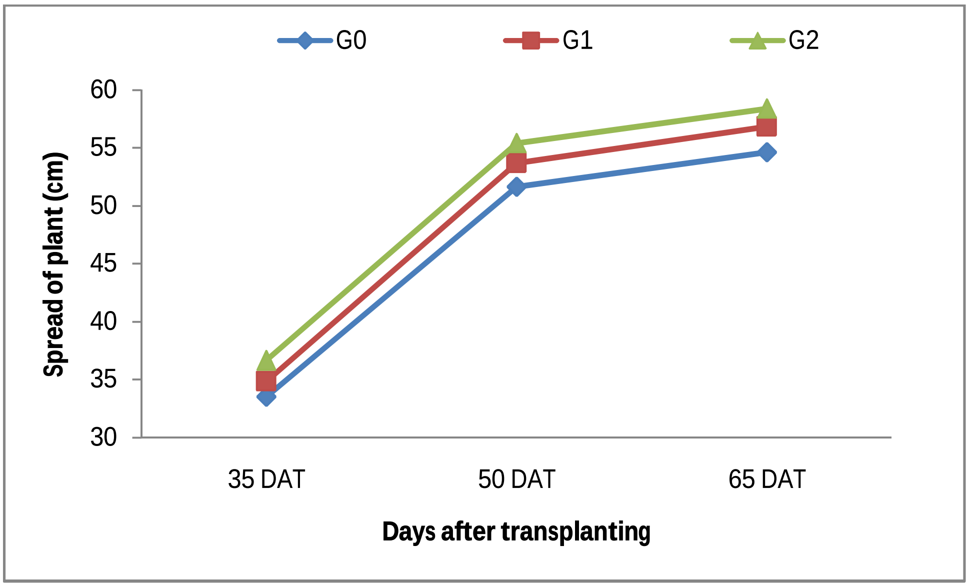

Figure 5. Effect of GA_3 on spread of plant of cabbage (LSD value = 0.63, 0.84 and 0.80 at 35, 50 and 65 DAT, respectively)

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

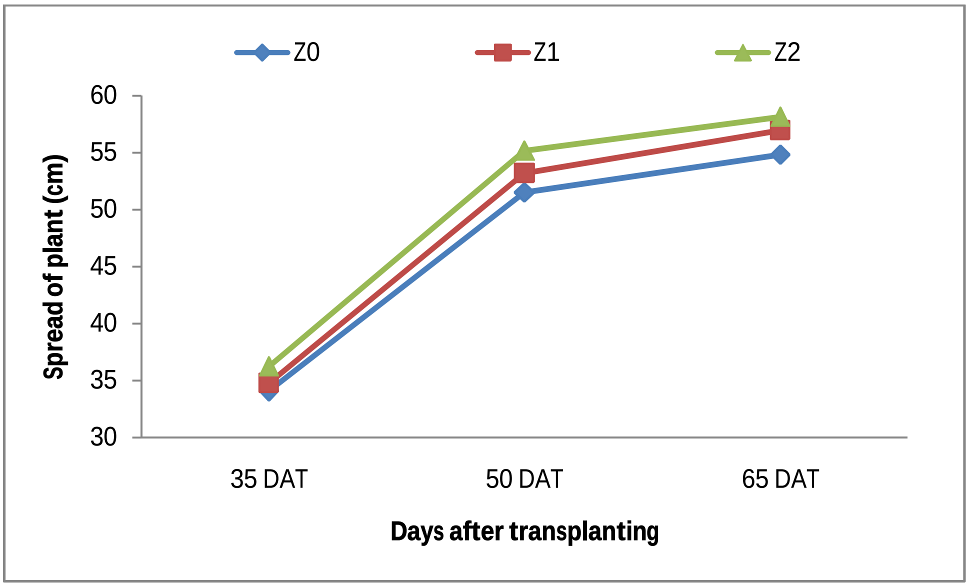

Figure 6. Effect of zinc on spread of plant of cabbage (LSD value = 0.63, 0.84 and 0.80 at 35, 50 and 65 DAT, respectively)

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

Table 3. Interaction effect of GA_3 and zinc on spread of plant of cabbage at different days after transplanting (DAT)

Treatments	Spread of plant (cm)		
	35 DAT	50 DAT	65 DAT
G_0Z_0	32.26	49.73	52.07
G_0Z_1	33.00	52.13	55.53
G_0Z_2	34.99	53.20	56.33
G_1Z_0	34.11	52.33	55.67
G_1Z_1	34.99	54.80	57.13
G_1Z_2	35.52	54.07	57.80
G_2Z_0	35.44	52.51	56.73
G_2Z_1	36.33	55.60	58.13
G_2Z_2	38.22	58.13	60.33
$LSD_{(0.05)}$	0.63	2.08	2.08
CV (%)	1.04	2.25	2.12

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.4 Leaf area (cm^2)

Leaf area of cabbage was significantly influenced by different levels of GA_3 at different days after transplanting (DAT) (Figure 7 and Appendix V). Leaf area increased with the increasing level of GA_3. At 35, 50 and 65 DAT, 150 ppm of GA_3 produced the maximum leaf area (261.70 cm^2, 783.90 cm^2 and 842.70 cm^2, respectively). In comparison, the smallest leaf area at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of GA_3 (217.7 cm^2, 694 cm^2 and 744.70 cm^2, respectively).

Leaf area of cabbage was significantly influenced by different levels of zinc at different days after transplanting (DAT) (Figure 8 and Appendix V). Leaf area increased with the increasing level of zinc. At 35, 50 and 65 DAT, 100 ppm of zinc produced the maximum leaf area (257.60 cm^2, 784.60 cm^2 and 840.7 cm^2, respectively). On the other hand, the smallest leaf area at 35, 50 and 65 DAT was observed from control treatment (0 ppm) of zinc (220.4 cm^2, 707 cm^2 and 766.60 cm^2, respectively).

Interaction of GA_3 and zinc showed significant effect on leaf area (cm^2) of cabbage at different days after transplanting (DAT) (Table 4and Appendix V). The maximum leaf area at 35 DAT (285.60 cm^2), 50 DAT (835.00 cm^2) and 65 DAT (875.00 cm^2) was recorded from the combination of 150 ppm GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the minimum leaf area at 35 DAT (199.90 cm^2), 50 DAT (652.30 cm^2) and 65 DAT (685.50 cm^2) was observed from control treatment (G_0Z_0).

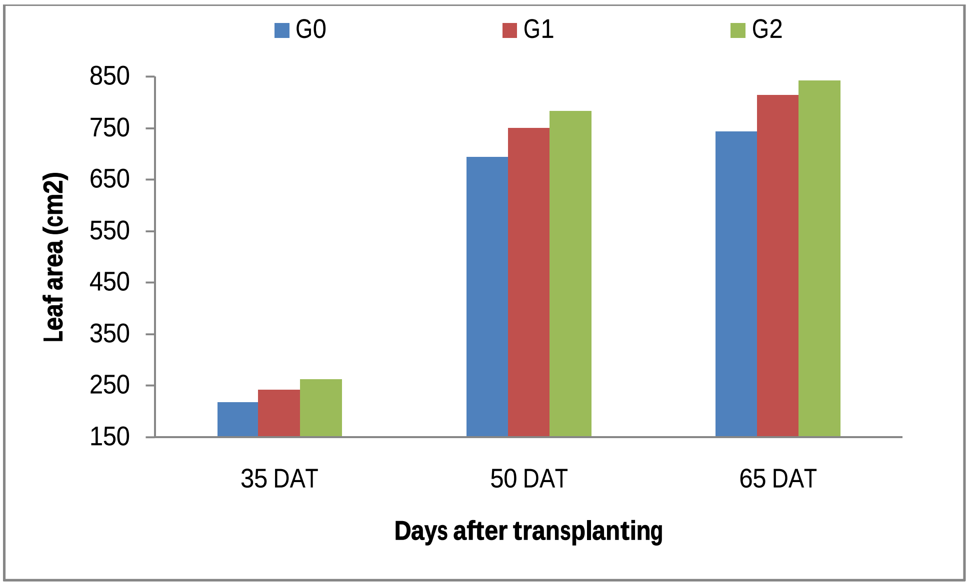

Figure 7. Effect of GA_3 on leaf area of cabbage (LSD value = 7.60, 10.78 and 12.84 at 35, 50 and 65 DAT, respectively)

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

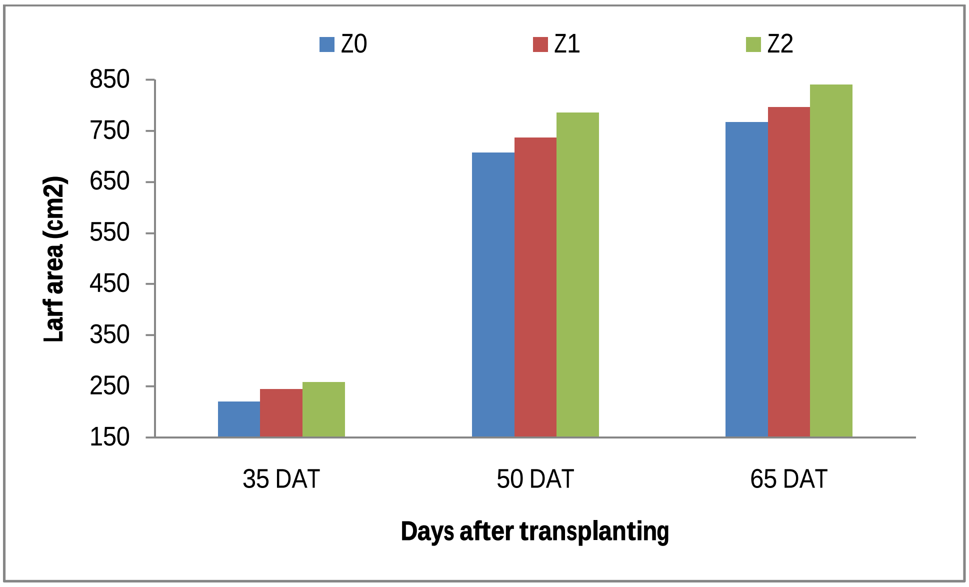

Figure 8. Effect of zinc on leaf area of cabbage (LSD value = 7.60, 10.78 and 12.84 at 35, 50 and 65 DAT, respectively)

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

Table 4. Interaction effect of GA_3 and zinc on leaf area of cabbage at different days after transplanting (DAT)

Treatments	Leaf area (cm^2)		
	35 DAT	50 DAT	65 DAT
G_0Z_0	199.90	652.30	685.50
G_0Z_1	222.90	681.20	731.40
G_0Z_2	230.30	748.70	817.30
G_1Z_0	224.90	730.10	806.10
G_1Z_1	245.20	750.10	811.20
G_1Z_2	256.90	770.00	829.70
G_2Z_0	236.40	738.70	808.10
G_2Z_1	263.10	778.00	845.00
G_2Z_2	285.60	835.00	875.00
$LSD_{(0.05)}$	7.60	10.78	12.84
CV (%)	1.83	4.84	3.96

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.5 Chlorophyll content of leaf (%)

Different levels of GA_3 application had significant effect on chlorophyll content of leaf (Table 5and Appendix VI). The maximum chlorophyll content of leaf (58.21) was recorded from 150 ppm of GA_3. In comparison, the minimum chlorophyll content of leaf (53.32) was recorded from control treatment (0 ppm) of GA_3.

Different levels of zinc application had significant effect on chlorophyll content of leaf (Table 6and Appendix VI). The maximum chlorophyll content of leaf (58.26) was recorded from 100 ppm of zinc. In comparison, the minimum chlorophyll content of leaf (53.27) was recorded from control treatment (0 ppm) of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on chlorophyll content of leaf of cabbage (Table 7and Appendix VI). The maximum chlorophyll content of leaf (60.60), was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the minimum chlorophyll content of leaf (51.61) was recorded from control treatment combination (G_0Z_0).

4.6 Days to head formation

Different levels of GA_3 application had significant effect on days to head formation, of cabbage (Table 5and Appendix VI). The maximum days to head formation (43.74) were recorded from control (0 ppm) application. In comparison, the minimum days to head formation (38.83) were recorded from 150 ppm of GA_3.

Different levels of zinc application had significant effect on days to head formation, of cabbage (Table 6and Appendix VI). The maximum days required to head formation (42.73) was recorded from control (0 ppm) application. In comparison, the minimum days required to head formation (39.84) was recorded from 100 ppm of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on days to head formation of cabbage (Table 7and Appendix VI). The maximum days required to head formation (45.00) was recorded from control (G_0Z_0) treatment. On the other hand, the minimum days required to head formation (37.30) was recorded from 150 ppm of GA_3 with 100 ppm (G_2Z_2) application.

4.7 Days to head maturity

Different levels of GA_3 application had significant effect on days to head maturity of cabbage (Table 5and Appendix VI). The maximum days to head maturity (74.60) was recorded from control (0 ppm) application. In comparison, the minimum days to head maturity (67.03) was recorded from 150 ppm of GA_3.

Different levels of zinc application had significant effect on days to head maturity of cabbage (Table 6and Appendix VI). The maximum days to head maturity (74.70) was recorded from control (0 ppm) zinc application. In comparison, the minimum days to head maturity (67.77) was recorded from 100 ppm of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on days to head maturity of cabbage (Table 7and Appendix VI). The maximum days required to head maturity (76.50) was recorded from control (G_0Z_0) treatment. On the other hand, minimum days required to head maturity (64.00) was recorded from 150 ppm of GA_3 with 100 ppm (G_2Z_2) application.

Table 5. Effect of GA_3 on chlorophyll content of leaf, days to head formation, days to head maturity, number of folded leaves plant^{-1} and number of outer loose leaves plant^{-1} of cabbage

GA_3	Chlorophyll content of leaf (%)	Days to head formation	Days to head maturity	Number of folded leaves plant^{-1}	Number of outer loose leaves plant^{-1}
G_0	53.32	43.74	74.60	37.45	13.67
G_1	55.82	41.20	71.59	39.33	14.89
G_2	58.21	38.83	67.03	41.11	15.96
$LSD_{(0.05)}$	1.03	0.69	2.80	1.51	1.04
CV (%)	2.10	2.96	2.27	2.21	4.09

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

Table 6. Effect of zinc on chlorophyll content of leaf, days to head formation, days to head maturity, number of folded leaves plant^{-1} and number of outer loose leaves plant^{-1} of cabbage

Zinc	Chlorophyll content of leaf(%)	Days to head formation	Days to head maturity	Number of folded leaves plant^{-1}	Number of outer loose leaves plant^{-1}
Z_0	53.27	42.73	74.70	37.09	13.00
Z_1	55.83	41.20	71.76	39.22	14.56
Z_2	58.26	39.84	67.77	40.78	15.65
$LSD_{(0.05)}$	1.03	0.69	2.80	1.51	1.04
CV (%)	2.10	2.96	2.27	2.21	4.09

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

4.8 Number of folded leaves plant^{-1}

Different levels of GA_3 application had significant effect on number of folded leaves plant^{-1} of cabbage (Table 5and Appendix VI). The highest number of folded leaves plant^{-1} (41.11) was recorded from G_2treatment. In comparison, the lowest number of folded leaves plant^{-1} (37.45) was recorded from G_0 treatment (0 ppm) of GA_3.

Different levels of zinc application had significant effect on number of folded leaves plant^{-1} of cabbage (Table 6and Appendix VI). The highest number of folded leaves plant^{-1} (40.78) was recorded from Z_2 treatment. In comparison, the lowest number of folded leaves plant^{-1} (37.09) was recorded from Z_0 treatment (0 ppm) of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on number of folded leaves plant^{-1} of cabbage (Table 7and Appendix VI). The highest number of folded leaves plant^{-1} (42.67) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the lowest number of folded leaves plant^{-1} (35.67) was recorded from control treatment combination (G_0Z_0).

Table 7. Interaction effect of GA_3 and zinc on chlorophyll content of leaf, days to head formation, days to head maturity, number of folded leaves plant^{-1} and number of outer loose leaves plant^{-1} of cabbage

Treatments	Chlorophyll content of leaf(%)	Days to head formation	Days to head maturity	Number of folded leaves plant^{-1}	Number of outer loose leaves plant^{-1}
G_0Z_0	51.61	45.00	76.50	35.67	12.60
G_0Z_1	53.77	43.70	72.70	37.67	13.67
G_0Z_2	54.17	42.53	72.60	39.00	14.67
G_1Z_0	54.93	42.90	72.60	38.33	14.67
G_1Z_1	55.53	41.00	73.47	39.00	15.00
G_1Z_2	57.01	39.70	68.70	40.67	15.00
G_2Z_0	55.86	40.30	69.00	39.67	14.67
G_2Z_1	58.18	38.90	67.10	41.00	15.00
G_2Z_2	60.60	37.30	64.00	42.67	17.00
$LSD_{(0.05)}$	1.03	0.69	2.80	1.51	1.04
CV (%)	2.10	2.96	2.27	2.21	4.09

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.9 Number of outer loose leaves plant^{-1}

Different levels of GA_3 application had significant effect on number of outer loose leaves plant^{-1} of cabbage (Table 5and Appendix VI). The highest number of outer loose leaves plant^{-1} (15.96) was recorded from G_2(150 ppm) treatment. In comparison, the lowest number of outer loose leaves plant^{-1} (13.67) was recorded from G_0 treatment (0 ppm) of GA_3.

Different levels of zinc application had significant effect on number of outer loose leaves plant^{-1} of cabbage (Table 6and Appendix VI). The highest number of outer loose leaves plant^{-1} (15.65) was recorded from Z_2(100 ppm) treatment. In comparison, the lowest number of outer loose leaves plant^{-1} (13.00) was recorded from Z_0 treatment (0 ppm) of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on number of outer loose leaves plant^{-1} of cabbage (Table 7and Appendix VI). The highest number of outer loose leaves plant^{-1} (17.00) was recorded from treatment combination of G_2Z_2(150 ppm of

$GA_3$and 100 ppm of zinc) treatment. In comparison, the lowest number of outer loose leaves plant^{-1} (12.60) was recorded from control (G_0Z_0) treatment combination.

4.10 Stem length (cm)

Different levels of GA_3 application had significant effect on stem length (cm) of cabbage (Table 8and Appendix VII). The longest stem (8.16 cm) was recorded from 150 ppm of GA_3. In comparison, the shortest stem (7.36 cm) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on stem length (cm) of cabbage (Table 9and Appendix VII). The longest stem (8.07 cm) was recorded from 100 ppm of zinc. In comparison, the shortest stem (7.37 cm) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on stem length of cabbage(Table 10and Appendix VII). The longest stem (8.52 cm) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the shortest stem (7.00 cm) was recorded from control treatment combination (G_0Z_0).

4.11 Stem diameter (cm)

Different levels of GA_3 application had significant effect on stem diameter of cabbage (Table 8and Appendix VII). The largest stem diameter (2.91 cm) was recorded from 150 ppm of GA_3(G_2). In comparison, shortest stem diameter (2.45 cm) was recorded from G_0 (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on stem diameter of cabbage (Table 9and Appendix VII). The highest stem diameter (2.85 cm) was recorded from 100 ppm of zinc(Z_2). In comparison, the lowest stem diameter (2.49 cm) was recorded from Z_0 (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on stem diameter of cabbage(Table 10and Appendix VII). The maximum stem diameter (3.28 cm) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). On the other hand, the minimum stem diameter (2.17 cm) was recorded from control treatment combination (G_0Z_0).

Table 8. Effect of GA_3 on stem length, stem diameter, head diameter, head thickness and weight of loose leaves plant^{-1} of cabbage

GA_3	Stem length (cm)	Stem diameter (cm)	Head diameter (cm)	Head thickness (cm)	Weight of loose leaves plant^{-1} (kg)
G_0	7.36	2.45	19.28	12.32	0.70
G_1	7.73	2.62	19.97	12.59	0.77
G_2	8.16	2.91	22.56	14.88	0.87
$LSD_{(0.05)}$	0.31	0.12	0.50	0.20	0.05
CV (%)	2.35	2.60	1.47	1.91	3.49

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

Table 9. Effect of zinc on stem length, stem diameter, head diameter, head thickness and weight of loose leaves plant^{-1} of cabbage

Zinc	Stem length (cm)	Stem diameter (cm)	Head diameter (cm)	Head thickness (cm)	Weight of loose leaves plant^{-1} (kg)
Z_0	7.37	2.49	19.39	12.36	0.71
Z_1	7.71	2.64	19.91	12.57	0.79
Z_2	8.07	2.85	22.42	14.87	0.85
$LSD_{(0.05)}$	0.31	0.12	0.50	0.20	0.05
CV (%)	2.35	2.60	1.47	1.91	3.49

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

4.12 Head diameter (cm)

Different levels of GA_3 application had significant effect on head diameter of cabbage (Table 8and Appendix VII). The largest head diameter (22.56 cm) was recorded from 150 ppm of GA_3. In comparison, the shortest head diameter (19.28 cm) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on head diameter of cabbage (Table 9and Appendix VII). The highest head diameter (22.42 cm) was recorded from 100 ppm of zinc. In comparison, the lowest head diameter (19.39 cm) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on head diameter of cabbage(Table 10and Appendix VII). The maximum head diameter (23.07 cm) was recorded from the treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the minimum head diameter (18.50 cm) was recorded from control treatment combination (G_0Z_0).

4.13 Head thickness (cm)

Different levels of GA_3 application had significant effect on head thickness of cabbage (Table 8and Appendix VII). The maximum head thickness (14.88 cm) was recorded from 150 ppm of GA_3. In comparison, the minimum head thickness (12.32 cm) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on head thickness of cabbage (Table 9and Appendix VII). The highest head thickness (14.87 cm) was recorded from 100 ppm of zinc. In comparison, the lowest head thickness (12.36 cm) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect onhead thickness of cabbage(Table 10and Appendix VII). The maximum head thickness (15.33 cm) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the minimum head thickness (12.00 cm) was recorded from control treatment combination (G_0Z_0).

4.14 Weight of loose leaves plant^{-1} (kg)

Different levels of GA_3 application had significant effect on weight of loose leaves plant^{-1}of cabbage (Table 8and Appendix VII). The maximum weight of loose leaves plant^{-1} (0.87 kg) was recorded from 150 ppm of GA_3. In comparison, the minimum weight of loose leaves plant^{-1} (0.70 kg) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on weight of loose leaves plant^{-1} of cabbage (Table 9and Appendix VII). The maximum weight of loose leaves plant^{-1} (0.85 kg) was recorded from 100 ppm of zinc. In comparison, the minimum weight of loose leaves plant^{-1} (0.71 kg) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on weight of loose leaves plant^{-1} of cabbage(Table 10and Appendix VII). The highest weight of loose leaves plant^{-1} (0.95 kg) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). In comparison, the lowest weight of loose leaves plant^{-1} (0.60 kg) was recorded from control treatment combination (G_0Z_0).

Table 10. Interaction effect of GA_3 and zinc on stem length, stem diameter, head diameter, head thickness and weight of loose leaves $plant^{-1}$ of cabbage

Treatments	Stem length (cm)	Stem diameter (cm)	Head diameter (cm)	Head thickness (cm)	Weight of loose leaves $plant^{-1}$ (kg)
G_0Z_0	7.00	2.17	18.50	12.00	0.60
G_0Z_1	7.32	2.59	19.50	12.37	0.73
G_0Z_2	7.67	2.60	19.83	12.60	0.78
G_1Z_0	7.38	2.59	19.67	12.50	0.73
G_1Z_1	7.79	2.60	19.90	12.60	0.78
G_1Z_2	8.01	2.66	20.33	12.67	0.81
G_2Z_0	7.92	2.71	22.27	14.57	0.80
G_2Z_1	8.03	2.74	22.33	14.73	0.85
G_2Z_2	8.52	3.28	23.07	15.33	0.95
$LSD_{(0.05)}$	0.31	0.12	0.50	0.20	0.05
CV (%)	2.35	2.60	1.47	1.91	3.49

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm

4.15 Fresh weight of total plant (kg)

Different levels of GA_3 application had significant effect on fresh total plant weight of cabbage (Table 11and Appendix VIII). The maximum fresh weight of total plant (2.82 kg) was recorded from 150 ppm of GA_3 treatment. In comparison, the minimum fresh weight of total plant (2.36 kg) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on fresh total plant weight of cabbage (Table 12and Appendix VIII). The maximum fresh weight of total plant (2.77 kg) was recorded from 100 ppm of zinc treatment. In comparison, the minimum fresh weight of total plant (2.43 kg) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on fresh total plant weight of cabbage (Table 13and Appendix VIII). The maximum fresh weight of total plant (3.01 kg), was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). On the other hand, the minimum fresh weight of total plant (2.11 kg) was recorded from control treatment combination (G_0Z_0).

4.16 Fresh weight of head (kg)

Different levels of GA_3 application had significant effect on fresh head weight of cabbage (Table 11and Appendix VIII). The maximum fresh head weight (1.96 kg) was recorded from 150 ppm of GA_3 treatment whereas, the minimum (1.50 kg) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on fresh head weight of cabbage (Table 12and Appendix VIII). The maximum fresh head weight (1.89 kg) was recorded from 100 ppm of zinc treatment which, the minimum fresh head weight (1.57 kg) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on fresh head weight of cabbage (Table 13and Appendix VIII). The highest fresh head weight (2.13 kg) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). On the other hand, the minimum fresh head weigt (1.23 kg) was recorded from control treatment combination (G_0Z_0).

4.17 Dry matter of loose leaves (%)

Different levels of GA_3 application had significant effect on dry matter of cabbage loose leaves (Table 11and Appendix VIII). The highest dry matter of loose leaves (9.56 %) was recorded from 150 ppm of GA_3 treatment. In comparison, the lowest dry matter of loose leaves (8.33 %) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on dry matter of cabbage loose leaves (Table 12and Appendix VIII). The highest dry matter of loose leaves (9.33 %) was recorded from 100 ppm of zinc treatment. In comparison, the lowest dry matter of loose leaves (8.33 %) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on dry matter of cabbage loose leaves (Table 13and Appendix VIII). The highest dry matter of loose leaves (10.00 %) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2) whereas, the lowest (8.00 %) was recorded from control treatment combination (G_0Z_0).

Table 11. Effect of GA_3 on fresh weight of total plant, fresh weight of head, dry matter of loose leaves, dry matter of head, yield $plot^{-1}$ and yield ha^{-1} of cabbage

GA_3	Fresh weight of total plant (kg)	Fresh weight of head (kg)	Dry matter of loose leaves (%)	Dry matter of head (%)	Yield $plot^{-1}$ (kg)	Yield ha^{-1} (ton)
G_0	2.36	1.50	8.33	5.45	18.00	62.50
G_1	2.60	1.78	8.78	5.89	21.32	74.03
G_2	2.82	1.96	9.56	6.33	23.51	81.68
$LSD_{(0.05)}$	0.06	0.05	0.64	0.08	0.42	0.61
CV (%)	1.38	1.27	4.14	2.71	4.01	3.97

Note: G_0 – 0 ppm, G_1 –100 ppm and G_2 – 150 ppm

Table 12. Effect of zinc on fresh weight of total plant, fresh weight of head, dry matter of loose leaves, dry matter of head,yield $plot^{-1}$ and yield ha^{-1} of cabbage

Zinc	Fresh weight of total plant (kg)	Fresh weight of head (kg)	Dry matter of loose leaves (%)	Dry matter of head (%)	Yield $plot^{-1}$ (kg)	Yield ha^{-1} (ton)
Z_0	2.43	1.57	8.33	5.53	18.88	65.55
Z_1	2.59	1.77	9.00	6.00	21.28	73.91
Z_2	2.77	1.89	9.33	6.13	22.66	78.75
$LSD_{(0.05)}$	0.06	0.05	0.64	0.08	0.42	0.61
CV (%)	1.38	1.27	4.14	2.71	4.01	3.97

Note: Z_0 – 0 ppm, Z_1 – 50 ppm and Z_2 – 100 ppm

4.18 Dry matter of head (%)

Different levels of GA_3 application had significant effect on dry matter of cabbage head (Table 11and Appendix VIII). The highest dry matter of head (6.33 %) was recorded from 150 ppm of GA_3 treatment. In comparison, the lowest dry matter of head (5.45 %) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on dry matter of cabbage head (Table 12and Appendix VIII). The maximum dry matter of head (6.13 %) was recorded from 100 ppm of zinc treatment whereas, the minimum (5.53 %) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on dry matter of cabbage head (Table 13and Appendix VIII). The highest dry matter of head (6.66 %) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). On the other hand, the lowest dry matter of head (5.00 %) was recorded from control treatment combination (G_0Z_0).

4.19 Yield plot^{-1} (kg)

Different levels of GA_3 application had significant effect on yield plot^{-1}of cabbage (Table 11and Appendix VIII). The highest yield plot^{-1} (23.51 kg) was recorded from 150 ppm of GA_3 treatment. In comparison, the lowest yield plot^{-1} (18.00 kg) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on yield plot^{-1}of cabbage (Table 12and Appendix VIII). The highest yield plot^{-1} (22.66 kg) was recorded from 100 ppm of zinc treatment. In comparison, the lowest yield plot^{-1} (18.88 kg) was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on yield plot^{-1}of cabbage (Table 13and Appendix VIII). The highest yield plot^{-1} (25.52 kg) was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2). On the other hand, the lowest yield plot^{-1} (14.76 kg) was recorded from control treatment combination (G_0Z_0).

4.20 Yield ha^{-1} (ton)

Different levels of GA_3 application had significant effect on yield ha^{-1} of cabbage (Table 11and Appendix VIII). The highest yield ha^{-1} (81.68 ton)was recorded from 150 ppm of GA_3 treatment. In comparison, the lowest yield ha^{-1} (62.50 ton)was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc application had significant effect on yield ha^{-1}of cabbage (Table 12and Appendix VIII). The highest yield ha^{-1} (78.75 ton)was recorded from 100 ppm of zinc treatment. In comparison, the lowest yield ha^{-1} (65.55 ton)was recorded from control (0 ppm) treatment of zinc.

Interaction of GA_3 and zinc treatment showed significant effect on yield ha^{-1}of cabbage (Table 13and Appendix VIII). The maximum yield ha^{-1} (88.75 ton)was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2) whereas, the minimum(51.25 ton)was recorded from control treatment combination (G_0Z_0).

Table 13. Interaction effect of GA_3 and zinc on fresh weight of total plant, fresh weight of head, dry matter of loose leaves, dry matter of head, yield plot^{-1} and yield ha^{-1} of cabbage

Treatments	Fresh weight of total plant (kg)	Fresh weight of head (kg)	Dry matter of loose leaves (%)	Dry matter of head (%)	Yield plot^{-1} (kg)	Yield ha^{-1} (ton)
G_0Z_0	2.11	1.23	8.00	5.00	14.76	51.25
G_0Z_1	2.41	1.56	8.33	5.67	18.72	65.00
G_0Z_2	2.57	1.71	8.67	5.67	20.51	71.25
G_1Z_0	2.51	1.67	8.00	5.60	20.04	69.58
G_1Z_1	2.58	1.83	9.00	6.00	21.96	76.25
G_1Z_2	2.72	1.83	9.33	6.07	21.96	76.25
G_2Z_0	2.68	1.82	9.00	6.00	21.84	75.83
G_2Z_1	2.78	1.93	9.67	6.33	23.16	80.47
G_2Z_2	3.01	2.13	10.00	6.66	25.52	88.75
$LSD_{(0.05)}$	0.06	0.05	0.64	0.08	0.42	0.61
CV (%)	1.38	1.27	4.14	2.71	4.01	3.97

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm.

4.21 Economic analyses

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

4.21.1 Gross return

The combination of different levels of gibberellic acid and zinc showed different value in terms of gross return under the trial (Table 14). The highest gross return (Tk. 5,32,500.00) was obtained from the treatment combination G_2Z_2 and the second highest gross return (Tk. 4,82,500.00) was found in G_2Z_1. The lowest gross return (Tk. 3,07,500.00) was obtained from G_0Z_0.

4.21.2 Net return

In case of net return, different levels of gibberellic acid and zinc showed different levels of net return under the present trial (Table 14). The highest net return (Tk. 3,25,326.00) was found from the treatment combination G_2Z_2 and the second highest net return (Tk. 2,76,337.00) was obtained from the combination G_2Z_1. The lowest (Tk. 1,11,111.00) net return was obtained G_0Z_0.

4.21.3 Benefit cost ratio

In the different levels of gibberellic acid and zinc the highest benefit cost ratio (2.57) was noted from the combination of G_2Z_2 and the second highest benefit cost ratio (2.34) was estimated from the combination of G_2Z_1. The lowest benefit cost ratio (1.57) was obtained from G_0Z_0 (Table 14). From economic point of view, it is apparent from the above results that the combination of G_2Z_2 was better than rest of the combination.

Table 14. Cost and return of cabbage cultivation as influenced by different levels of gibberellic acid and zinc

Levels of GA_3 and zinc	Cost of production (Tk./ha)	Yield of cabbage (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0Z_0	1,96,389.00	51.25	3,07,500.00	1,11,111.00	1.57
G_0Z_1	1,99,422.00	65.00	3,90,000.00	1,90,578.00	1.96
G_0Z_2	2,00,433.00	71.25	4,27,500.00	2,27,067.00	2.13
G_1Z_0	2,00,883.00	69.58	4,17,500.00	2,16,617.00	2.08
G_1Z_1	2,03,916.00	76.25	4,57,500.00	2,53,584.00	2.24
G_1Z_2	2,04,927.00	76.25	4,57,500.00	2,52,573.00	2.23
G_2Z_0	2,03,130.00	75.83	4,55,000.00	2,51,870.00	2.24
G_2Z_1	2,06,163.00	80.42	4,82,500.00	2,76,337.00	2.34
G_2Z_2	2,07,174.00	88.75	5,32,500.00	3,25,326.00	2.57

Price of cabbage @ Tk. 6000/ton

Note: G_0 – 0 ppm, G_1 –100 ppm, G_2 – 150 ppm and Z_0 – 0 ppm, Z_1 – 50 ppm, Z_2 – 100 ppm.

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 2014 to January 2015 to find out the effect of GA_3 and zinc on the growth and yield of cabbage. The experiment consisted of two factors Factor A: Different doses of GA3 such as G_0: Control, G_1: 100 ppm and G_2: 150 ppm; Factor B: Different doses of zinc such as Z_0: control, Z_1: 50 ppm and Z_2: 100 ppm. Data on different growth and yield contributing characters were recorded.

Different levels of GA_3 showed significant effect on plant height, number of leaves per plant, spread of plant and leaf area of cabbage at different days after transplanting (DAT). At 65 DAT, the highest plant height (37.20 cm), number of leaves per plant (18.71), spread of plant (58.40 cm) and leaf area (842.70 cm^2) were recorded from 150 ppm GA_3 treatment. On the other hand, the lowest plant height (31.98 cm), number of leaves per plant (15.32), spread of plant (54.64 cm) and leaf area (744.70 cm^2) were observed from control treatment (0 ppm) of GA_3. The maximum chlorophyll content of leaf (58.21),days to head formation (43.74), days to head maturity (74.60), number of folded leaves $plant^{-1}$ (41.11), number of outer loose leaves $plant^{-1}$ (15.96), stem length (8.16 cm), stem diameter (2.91 cm), head diameter (22.56 cm), head thickness (14.88 cm), weight of loose leaves $plant^{-1}$ (0.87 kg), fresh weight of total plant (2.82 kg), fresh weight of head (1.96 kg), dry matter of loose leaves (9.56 %), dry matter of head (6.33 %), yield $plot^{-1}$ (19.74 kg), yield ha^{-1} (81.86 ton)were recorded from 150 ppm of GA_3. On the other hand, minimum chlorophyll content of leaf (53.32), days to head formation (38.83), days to head maturity (67.03), number of folded leaves $plant^{-1}$ (37.45), number of outer loose leaves $plant^{-1}$ (13.67), stem length (7.36 cm),stem diameter (2.45 cm), head diameter (19.28 cm), head thickness (12.32 cm), weight of loose leaves $plant^{-1}$ (0.70 kg), fresh weight of total plant (2.36 kg), fresh weight of head (1.50 kg),dry matter of loose leaves (8.33 %), dry matter of head (5.45 %), yield $plot^{-1}$ (17.83 kg) and yield ha^{-1} (62.05 ton) was recorded from control (0 ppm) treatment of GA_3.

Different levels of zinc showed significant effect on plant height, number of leaves per plant, spread of plant and leaf area of cabbage at different days after transplanting (DAT). At 65 DAT, the highest plant height (36.45 cm), number of leaves per plant (16.72), spread of plant (58.15 cm) and leaf area (840.70 cm^2) were recorded from 150 ppm GA_3 treatment. On the other hand, the lowest plant height (32.96 cm), number of leaves per plant (16.72), spread of plant (54.15 cm) and leaf area (766.60 cm^2) were observed from control treatment (0 ppm) of GA_3.The maximum chlorophyll content of leaf (58.26), days required to head formation (42.73), days to head maturity (74.70), number of folded leaves $plant^{-1}$ (40.78), number of outer loose leaves $plant^{-1}$ (15.65), stem length (8.07 cm), stem diameter (2.85 cm), head diameter (22.42 cm), head thickness (14.87 cm), weight of loose leaves $plant^{-1}$ (0.85 kg), fresh weight of total plant (2.77 kg),fresh weight of head (1.89 kg), dry matter of loose leaves (9.33 %),dry matter of head (6.13 %),yield $plot^{-1}$ (19.78 kg) and yield ha^{-1} (78.75 ton) whereas, the minimum chlorophyll content of leaf (53.27), days required to head formation (39.84), days to head maturity (67.77),number of folded leaves $plant^{-1}$ (37.09), number of outer loose leaves $plant^{-1}$ (13.00), stem length (7.37 cm), stem diameter (2.49 cm), head diameter (19.39 cm), head thickness (12.36 cm), weight of loose leaves $plant^{-1}$ (0.71 kg), fresh weight of total plant (2.43 kg),fresh weight of head (1.57 kg), dry matter of loose leaves (8.33 %),dry matter of head (5.53 %),yield $plot^{-1}$ (18.08 kg) and yield ha^{-1} (65.55 ton)were recorded from control (0 ppm) treatment of zinc.

Interaction effect of GA_3 and zinc application showed significant effect on plant height, number of leaves per plant, spread of plant and leaf area of cabbage at different days after transplanting (DAT). At 65 DAT, the highest plant height (39.29 cm), number of leaves per plant (19.26), spread of plant (60.33 cm) and leaf area (875.00 cm^2) were recorded from 150 ppm GA_3 treatment. On the other hand, the lowest plant height (29.73 cm), number of leaves per plant (15.10), spread of plant (52.07 cm) and leaf area (685.50 cm^2) were observed from control treatment (0 ppm) of GA_3.The maximum chlorophyll content of leaf (60.60),days required to head formation (45.00),days required to head maturity (76.50), number of folded leaves $plant^{-1}$ (42.67), number of outer loose leaves $plant^{-1}$ (17.00),stem length (8.52 cm), stem diameter (3.28 cm), head diameter (23.07 cm), head thickness (15.33 cm), weight of loose leaves $plant^{-1}$ (0.95 kg), fresh weight of total plant (3.01 kg), fresh weight of head (2.13 kg),dry matter of loose leaves (10.00 %), dry matter of head (6.66 %), yield $plot^{-1}$ (20.89 kg) and yield ha^{-1} (88.75 ton)was recorded from treatment combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2)whereas, the minimum chlorophyll content of leaf (51.61), days required to head formation (37.30),days required to head maturity (64.00), number of folded leaves plant^{-1} (35.67),number of outer loose leaves plant^{-1} (12.60), stem length (7.00 cm), stem diameter (2.17 cm), head diameter (18.50 cm), head thickness (12.00 cm), weight of loose leaves plant^{-1} (0.60 kg),fresh weight of total plant (2.11 kg), fresh weight of head (1.23 kg), dry matter of loose leaves (8.00 %), dry matter of head (5.00 %), yield plot^{-1} (16.79 kg) and yield ha^{-1} (51.25 ton)was recorded from control treatment combination (G_0Z_0).

The highest gross return (Tk. 5,32,500.00), net return (Tk. 3,25,326.00) and cost benefit ratio (2.57) were found in G_2Z_2 treatment while, the lowest gross return (Tk. 53,07,500.00), net return (Tk. 1,11,111.00) and cost benefit ratio (1.57) were found in G_0Z_0 treatment.

Conclusion

The present study revealed that the growth, yield and economic point of view, the combination of 150 ppm of GA_3 and 100 ppm of zinc (G_2Z_2) is suitable for cabbage cultivation.

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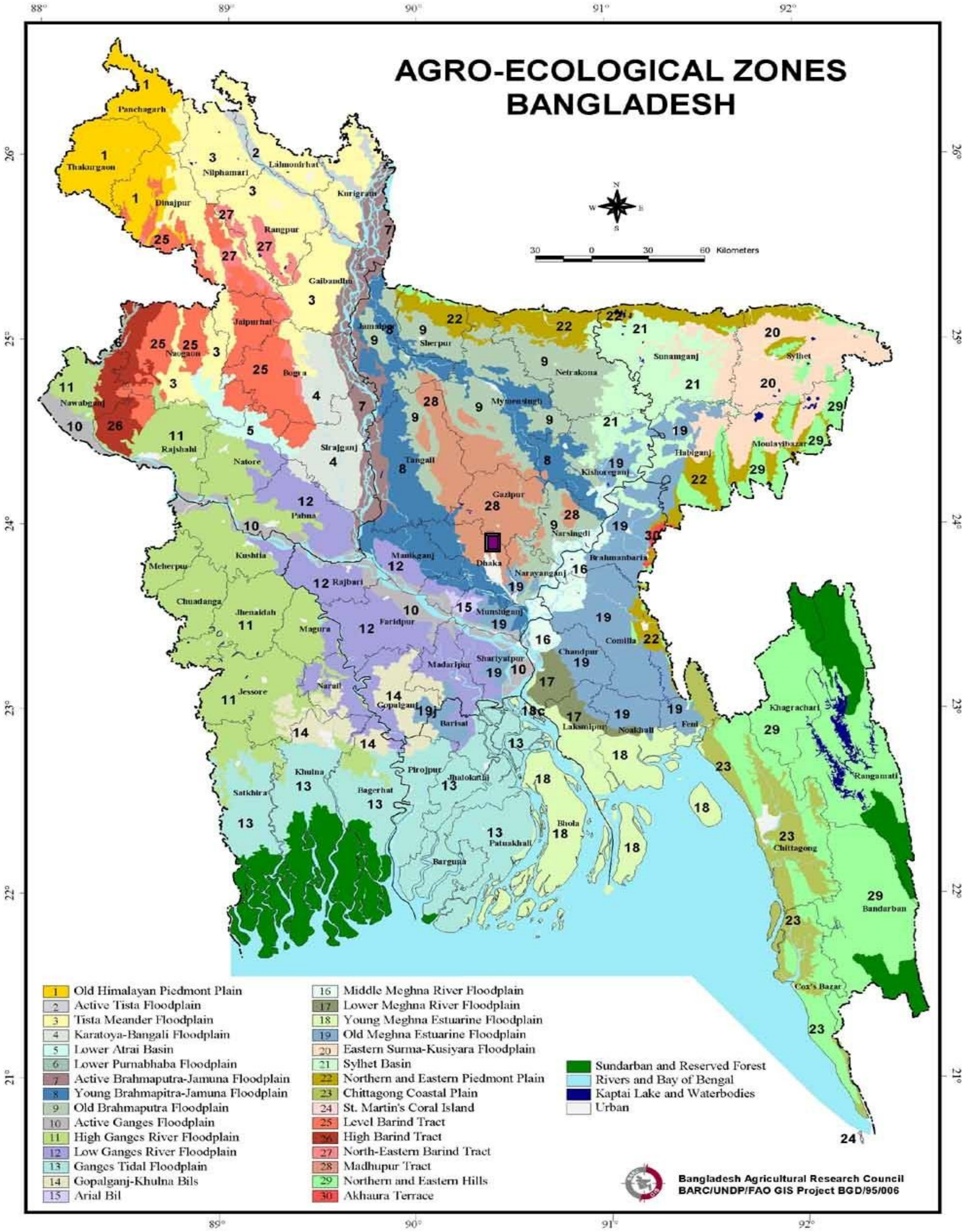
APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

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

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
PH	6.45
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. Monthly average record of air temperature, rainfall, relative humidity and Sunshine of the experimental site during the period from October 2014 to January 2015.

Month	Air temperature (°c)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2014	31.6	23.8	78	172.3	5.2
November, 2014	29.6	19.2	77	34.4	5.7
December, 2014	26.4	14.1	69	12.8	5.5
January, 2015	25.4	12.7	68	7.7	5.6

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

Appendix IV: Error mean square values for plant height and number of leaves per plant of cabbage at different days after transplanting

Source of variation	Degrees of freedom	Plant height			Number of leaves per plant		
		35 DAT	50 DAT	65 DAT	35 DAT	50 DAT	65 DAT
Replication	2	0.512	6.929	6.929	70.355	146.980	146.980
GA_3 (A)	2	61.214*	258.021*	258.021*	262.010*	150.568*	111.634*
Zinc (B)	2	5.027*	121.587*	55.037**	79.470*	84.468*	84.468**
A × B	4	0.716**	6.669**	6.669*	3.795*	5.685**	5.685*
Error	16	1.949	15.077	15.077	36.725	11.934	11.934

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix V: Error mean square values for spread of plant and leaf area of cabbage at different days after treansplanting

Source of variation	Degrees of freedom	Spread of plant			Laef area		
		35 DAT	50 DAT	65 DAT	35 DAT	50 DAT	65 DAT
Replication	2	0.008	0.612	0.401	0.737	0.136	0.138
GA_3 (A)	2	3.909**	8.810*	12.801*	6.418**	8.048**	3.923**
Zinc (B)	2	0.268*	13.934**	9.808*	7.435*	10.310*	0.328**
A × B	4	0.087*	0.679*	0.368**	0.081*	0.252**	1.247*
Error	16	0.185	0.350	0.481	0.522	0.591	0.245

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VI: Error mean square values for chlorophyll content of leaf, days to head formation, days to head maturity, number of folded leaves plant^{-1} and number of outer loose leaves plant^{-1} of cabbage

Source of variation	Degrees of freedom	Chlorophyll content of leaf	Days to head formation	Days to head maturity	Number of folded leaves plant^{-1}	Number of outer loose leaves plant^{-1}
Replication	2	0.020	0.433	0.001	0.001	0.07
GA_3 (A)	2	0.305*	0.135*	0.082*	0.041*	0.012*
Zinc (B)	2	0.081*	0.395*	0.034*	0.026*	0.33*
A × B	4	0.003*	0.641*	0.008*	0.007*	0.103*
Error	16	0.006	2.839	0.003	0.002	6.720

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VII: Error mean square values for stem length (cm), stem diameter (cm), head diameter (cm), head thickness (cm) and and weight of loose leavse plant^{-1} of cabbage

Source of variation	Degrees of freedom	Stem length (cm)	Stem diameter (cm)	Head diameter (cm)	Head thickness (cm)	Weight of loose leaves plant^{-1} (kg)
Replication	2	1.863	2.164	4.224	0.302	0.264
GA_3 (A)	2	3.346*	6.761**	5.643**	5.362*	2.794*
Zinc (B)	2	4.086**	1.107**	8.127**	1.901*	3.655*
A × B	4	3.407**	1.26**	5.03**	1.60*	3.660*
Error	16	0.452	1.61	3.35	4.23	2.752

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VIII: Error mean square values for fresh weight of total plant (kg), fresh weight of head (kg), dry matter of loose leaves (%), dry matter of head (%), yield $plot^{-1}$ (kg) and yield ha^{-1} (ton) of cabbage

Source of variation	Degrees of freedom	Fresh weight of total plant (kg)	Fresh weight of head (kg)	Dry matter of loose leaves (%)	Dry matter of head (%)	Yield $plot^{-1}$ (kg)	Yield ha^{-1} (ton)
Replication	2	0.934	0.042	0.147	0.0001	0.000	0.143
GA_3 (A)	2	0.883**	0.491*	0.952*	0.017**	0.054*	0.398**
Zinc (B)	2	0.933*	0.832*	0.892*	0.001*	0.880*	0.212**
A × B	4	0.518**	0.981*	0.50**	0.001*	0.515*	0.758*
Error	16	8.306	5.173	5.38	0.001	3.412	2.421

*Significant at 5% level of probability

** Significant at 1% level of probability