EFFECT OF GIBBERELLIC ACID AND SPACING ON GROWTH AND YIELD OF LETTUCE (*Lactuca sativa* L.)

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CERTIFICATE

This is to certify that thesis entitled, ***"Effect of Gibberellic Acid and Spacing on Growth and Yield of Lettuce (Lactuca sativa L.)"*** *submitted to the,* ***Department of Horticulture****, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***Master of science in Horticulture****, embodies the result of a piece of bona fide research work carried out by* ***Taslima Akter****, Registration No.: 08-2795 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information received during the course of this investigation has been duly acknowledged.

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DEDICATED

TO

MY BELOVED

PARENTS

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The Author

EFFECT OF GIBBERELLIC ACID AND SPACING ON GROWTH AND YIELD OF LETTUCE (*Lactuca sativa* L.)

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ABSTRACT

In the present study the effect of both Gibberellic Acid (GA_3) and plant spacing on growth and yield of lettuce was examined at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2013 to January 2014. During cultivation, three levels of Gibberellic Acid (GA_3), (G_0= 0 mg/L, G_1=25 mg/L and G_2=50 mg/L) and four levels of plant spacing's as S_1= 15x20 cm, S_2=20x25 cm, S_3=25x25 cm, S_4=25x30 cm were evaluated in Randomized Complete Block Design with three replications. In case of different factors the maximum gross fresh yield (29.05 t/ha) was recorded from G_1, whereas the minimum gross fresh yield (16.27 t/ha) was recorded from G_0. The spacing of S_3 recorded the maximum gross fresh yield (23.8 t/ha) due to highest fresh weight of plants, while the minimum gross fresh yield (14.82 t/ha) was obtained from the widest spacing's S_4 due to lowest number of plants at 45 DAS. In case of combined effect the highest gross fresh yield (27.73 t/ha) was obtained from G_1S_3 where as the lowest gross fresh yield (16.27 t/ha) was recorded from G_0S_4. Cost benefit analysis indicate that the highest benefit ratio (2.04) was obtained from G_1S_3, where as the lowest benefit ratio (1.16) was obtained from G_0S_1. On the basis of overall effect and economic analysis it can be concluded that GA_3 concentration (25 mg/L) and plant spacing (25x25 cm) on growth and yield proved to be the most promising for getting optimum yield in lettuce and it is apparent that it was suitable for lettuce cultivation.

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LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
et al.	And others
BBS	Bangladesh Bureau of Statistics
BARC	Bangladesh Agriculture and Research Council
SRDI	Soil Resource Development Institute
°C	Degree Celsius
DAS	Date After Sowing
etc	Etcetera
FAO	Food and Agriculture Organization
mm	Millimeter
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
UNDP	United Nations Development Program

CHAPTER I

INTRODUCTION

Lettuce (*Lactuca Sativa L.*) is an important vegetable commodity and in demand by the local markets throughout the year. This popularity has led to an increase in lettuce production and consumption in urban areas (Maboko & Du Plooy, 2008). It is popular for its delicate, crispy texture and slightly bitter taste with milky juice as fresh condition. It is the most popular amongst the salad vegetable crops (Squire *et al*. 1987). In Bangladesh, huge quantity of lettuce is used with fast food shop and in various star hotels as fresh vegetable like salad. Lettuce production is suitable during winter season in Bangladesh. Lettuce subsector has been already identified as one of the potential value chain to intervene. The nutrient content is highest in the darker green, outer leaves. Lettuce is normally consumed raw and has a high nutrient value, being rich in calcium, iron and vitamin A. It is a good source of vitamins and often prescribed to weight conscious consumers because of its low kilojoule content (Niederwieser, 2001; Maboko, 2007). Lettuce is a cool season crop requiring growth temperatures ranging from 7 to 24^0 C, with an average of 18^0 C (Lorenz & Maynard, 1988). Optimum plant spacing ensures proper growth and development of plant resulting maximum yield of crop and economic use of land. Spacing influences average fresh weight, number of heads, and yield at harvest (Adu-Sankode, 1980; El-Shal *et al*., 1986; Eyisok *et al*., 1996). Suitable plant spacing can lead to optimum yield whereas too high or too low plant spacing could result in relatively lower yield and quality (Kobryn, 1987).

Gibberellic acid (GA_3) is a plant hormone belongs to gibberellins. Gibberllic acid is one of most important growth stimulating substance used for promoting cell elongation, cell division and thus to promote growth and development of many plant species. Among Plant Growth Regulators gibberellins play vital role in regulating developmental processes within plant bodies (Gou *et al*. 2010). A higher concentration of gibberellins increases plant growth (Bora and Sarma 2006). Yield and quality of lettuce due to stem elongation and is stimulated by both high temperatures and endogenous metabolism of gibberellic acid (GA_3) (Fukuda *et al*., 2009; Fukuda *et al*., 2012). Harrington *et al*. (1960) reported that spraying of GA_3 helps in lettuce plant growth and development as well as early harvesting. In a similar study, Lovato *et al*. (2000) reported that foliage spraying with 20 ppm. GA_3 increase lettuce yield.

GA_3 has been suggested to increase growth rate of plants and total seed yield (Passam *et al*. 2008).

Plant spacing for lettuce cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield. Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield. Yield may be increased for any crop up to 25% by using optimum spacing in leafy vegetable (Bansal, *et al*., 1995). Moniruzzaman (2006) indicated that plant population or density is among the factors that affect yield and quality of lettuce cultivated in soil. Furthermore, due to climatic and cultivar differences, the optimal plant spacing might be seasonal and cultivar dependant. Yield and quality of lettuce can be affected by various factors such as environmental condition (La Malfa and Ruggeri, 1988), nutritional management (Acar *et al*., 2008; Khah and Arvanitoyannis, 2003). In Bangladesh management practices information about plant spacing to be used in lettuce cultivation is insufficient. The farmers of Bangladesh cultivate this crop according to their own choice due to the absence or unavailability of standard production technique. As a result, they do not get satisfactory yield and return from investment.

Considering the above mentioned facts, the present research work was aimed to study with the following objectives:

a. To find out the effect of GA_3 on growth and yield of lettuce
b. To find out the effect of plant spacing on growth and yield o lettuce
c. To find out the suitable combination effect of GA_3 and plant spacing on growth and yield of lettuce

CHAPTER II

REVIEW OF LITERATURE

Very few studies on the growth and yield of lettuce have been carried out in our country as well as many other countries of the world. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to nitrogen and plant spacing on lettuce so far been done at home and abroad have been reviewed in this chapter under the following headings.

2.1 Effect of GA_3:

Shaheen *et al.* (2013) asserted that effectiveness of GA_3 applied as foliar application for enhanced vegetative and reproductive growth of okra. First foliar application of GA_3 (100 mg Kg-1) was performed after 3 weeks from sowing while next three applications with regular interval of one week. Their experiment results revealed that the increase in number of foliar application of GA_3 substantially improved the vegetative as well as reproductive growth of okra comparing to control plants. It was found that application at different growth stages of okra predominantly boosted the stem elongation, number of leaves per plant, number of pods per plant, number of seeds per pod, seed weight and seed yield. Therefore it can be concluded that foliar application of GA_3 may be an effective strategy for maximizing the growth and yield of okra.

Mohsen Kazemi (2014) carried out an experiment to investigate the effect of 2 levels of gibberellic acid (10-4 and 10-8) and 2 levels of potassium nitrate (6 and 8 mM) spray on the growth, leaf-NPK content, yield and quality parameters of tomato. He found the application of gibberellic acid and potassium alone or in combination increased plant height, number of branches, number flowers per cluster, number fruits per cluster and faster fruit growth in addition to increasing fruit number, fruit firmness, weight and yield. With regard to fruit quality, the application of GA_3 at 10-8 mM, 8 mM potassium nitrate and 10-8mM GA3+ 8 mM potassium nitrate increased fruit lycopene content, total soluble solids, vitamin C and titratable acidity compared with the control treatment. From this study, it can be concluded that spraying with gibberellic acid and potassium alone or in combination increased vegetative growth and reproductive characteristics of tomato.

Tsiakaras *et al.* (2014) carried out an experiment to find out the effect of both nitrogen application rate and gibberellic acid (GA_3) on yield and earliness of production and marketability (plant height and leaf color) of lettuce. During cultivation, four nitrogen rates (0, 150, 300 and 450 mg L-1 of N) and two foliar sprayings with two concentrations of GA_3 (0 and 50 mg L-1 for the first and second sowing and 0 and 25 mg L-1 for the third sowing) were applied. Results revealed that total fresh and dry weight significantly decreased and increased, respectively, by GA_3 application, especially in the second sowing date, whereas high nitrogen rates (300 and 450 mg L-1) resulted in higher fresh weight (by 11.2%) and lower dry weight (by 7.5%) respectively. Plant height was significantly increased by GA_3 application, except for cv. 'Adranita' in the third sowing date, whereas nitrogen application did not affect plant height for all the cultivars studied. The application of GA_3 and high nitrogen rates resulted in an increase of the total number of leaves per plant and a decrease of chlorophyll content of leaves during the first sowing date and third sowing date. In conclusion, nitrogen application could be beneficial for total yield and the total number of leaves, whereas medium GA_3 concentration (25 mg L-1) should be applied during spring (third sowing date) as it results in plants with higher number of leaves, total fresh weight (cv 'Kismy') and marketable height.

Taylor *et al,* (1975) asserted that Gibberellic acid (10 AM) causes lettuce hypocotyl cells to elongate by 400-500% more than water controls in 72 hr. Kinetic data indicate that whereas in water controls cell elongation occurs between 24 and 48 hr, in gibberellic-acid-treated material it-starts at 8 hr and continues to 72 hr. Dry weight of the cell wall shows a corresponding increase with cell elongation. The peak coincides with extensive dictyosomal activity, proliferation of endoplasmic reticulum and poly ribosomes and connections between the endoplasmic reticulum and plasmalemma in both water and gibberellic acid treated hypocotyls. At later times, the cells contain only a thin layer of cytoplasm and no special cytological features are observed. These observations indicate that, although cell growth in lettuce hypocotyls is accompanied by wall synthesis, nevertheless the cells undergo their most rapid polysaccharide and protein synthesis prior to extension growth. They also explain the earlier reported "enhanced sensitivity" of lettuce hypocotyls to gibberellic acid application at 8 hr after the beginning of the experiment.

Mahmoody *et al.* (2014) reported that exogenous GA_3 on culture medium was used to increase height of Dyckia maritima shoots to facilitate In vitro manipulation. Grapevine fruits (Thompson seedless) treated with GA_3 had increased its size and production. Results revealed that foliar application of GA_3 and nutrients had improved the productivity and quality of lily cut flowers. Stimulation of the enzyme protein synthesis by GA_3 stimulates the overall protein synthesis.

Sawhney *et al*. (1974) investigated that Lettuce (*Lactuca sativa* L.) seedlings treated with gibberellic acid produced hypocotyls 600% longer than the water acid (GA) for 72 controls. The process of elongation was accelerated by GA. Also, for hypocotyle. Short maximum elongation, presence of GA was not necessary after 20 term treatments of seedlings with GA indicated that the seedlings were h of growth in water. Colchicine most 'sensitive' to GA after 8 inhibited the GA-induced elongation. Its effect was maximal if it was GA treatment irrespective of the applied within the first 2 stage of hypocotyl development. These kinetic data are presented and lost after 36 lessened after 2 together with measurements of hypocotyl cell lengths and widths and provide a basis for correlated ultra structural studies.

Balaguera *et al.* (2011) tested with calcium and gibberellic acid to increase productivity of this crop. The objective of this study was to evaluate the effect of different levels of calcium (30, 60, and 90 kg ha^{-1} CaO) and gibberellic acid (0, 50, 100, and 150 mg L^{-1} GA_3) on the growth and yield of lettuce cv. Batavia, using a completely randomized design. Fifty percent of the calcium was applied before planting and the remaining calcium was applied 20 days after transplantation. At both times, the application was edaphic, and GA_3 was applied via foliar application at day 20. The plants were harvested at day 80, and the growth and yield variables were measured on nine plants per treatment. Significant differences were found for plant height, leaf area, fresh weight and dry mass and leaf area index. The highest production was achieved with 90 kg ha^{-1} CaO and 0 mg L^{-1} GA_3, while GA_3 applied at day 20 caused disorders in the phenotype and did not enhance the lettuce yield.

Nasiruddin *et al.* (2011) evaluated the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control (0 ppm GA3) treatment. The results revealed that the application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (45.22kg/plot and 104.66 t/ha) was found from 50 ppm GA_3.

Kumar *et al.* (2014) was conducted with the objective to determine the effects of Gibberellic acid (GA_3) on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety Golden, and six treatments with five levels of gibberellic acid (GA_3-10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm), arranged in randomized block design with three replications. They found the highest plant height, number of leaves, number of fruits, fresh fruit weight has been observed and ascorbic acid, total soluble solid (TSS) was estimated for GA 350 ppm.

Effect of gibberellic acid on the growth and yield of cabbage (Brassica oleracea var. capitata L.) was determined by Md. Hasanuzzaman Akand, *et al.* (2015) in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2013 to February 2014 to find out the effect of GA_3 on growth and yield of cabbage. The experiment was laid out in RCBD with five replications. The experiment considered four concentration of GA_3; G_0= 0 ppm, G_1= 70 ppm, G_2= 90 ppm and G_3= 110 ppm. 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). So, 90 ppm GA_3 may be used for cabbage cultivation.

Akter *et al.* (2007) conducted an experiment in pot house at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during November 2003 to February 2004 to evaluate the effects of Gibberellic Acid (GA_3) on growth, and yield of mustard var. Bina sarisha-3. Four concentrations viz., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. They found that different levels of GA_3 significantly influenced the plant height, number of fertile siliqua/plant, number of seeds/siliqua, number of flowers/plant, setting of siliqua/plant (%), and harvest index. Results also revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua/plant, number of flowers/plant, setting of siliqua/plant (%), dry matter yield, number of seeds/siliqaua, and harvest index, while the number of flowers/plant was significantly increased with the application of 75 ppm GA_3. The highest seed yield/plant was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield/plant was positively correlated with plant height, number of seeds/siliqua, number of fertile siliqua/plant and % of setting siliqua/plant.

Jamal *et al.* (2012) reported that response of gibberellic acid concentrations on the growth and yield of strawberry germplasm was studied at Horticulture Farm, Sher-e-Bangla Agricultural University, and Dhaka during the period from October 2010 to April 2011. The experiment consisted of different GA_3 concentrations viz. G_0=control (fresh water) G_1=50 ppm, G_2=75 ppm and G_3=100 ppm. Tallest plant (31.4cm), the maximum number of leaves (11.1), maximum leaf area (64.5 cm2), maximum number of flower bud (30.0) and highest number of flower (28.7) was recorded from G2 treated strawberry plant. Maximum number of fruits (25.9/plant), fruit weight (13.2g) and yield (336.6g) per plant were found with 75 ppm GA_3 application, whereas the minimum was recorded in control. Foliar application with 75 ppm GA_3 showed the best performance on growth and yield of strawberry. Application of GA_3 also increased the sweetness of the berries in comparison to control.

Ndambole *et al.* (2011) examined that the effects of GA_3 on the growth, development and seed yield of cowpeas (Vigna unguiculataL. Walp). Three field trials were carried out at the Botswana College of Agriculture Not wane Farm, Botswana to evaluate the exogenous application of GA_3, 7 days after emergence at 0, 100, 200 or 300 mg L significantly increased cowpea plant height, first node height, leaf area and leaf number plant-1, nodulation, plant dry matter, pod length, pod number plant-1, seed number pod-1, 100-seed weight, harvest index and seed yield. The GA_3-induced increase in cowpea vegetative growth, nodulation, yield and yield. More research needs to be done on timing of application.

Sarma *et al.* (2006) carried out a study on the effect of Gibberellic acid (GA_3) and Cycocel [(2-Chloroethyl) trimethy lammonium chloride] singly on growth, yield and protein content of pea (cv. Aparna and Azad-P-1) was carried out in a randomized block deign with three replications. Yield attributing characters were recorded at proper time. Protein was estimated from harvested seeds. GA_3 irrespective of concentrations was most effective in promoting shoot growth while cycocel at all concentrations tried reduced shoot growth. Number of branches per plant was increased with both the hormones. In both the varieties chlorophyll contents were decreased by higher concentrations of GA_3 while cycocel increased it. Both the hormones significantly affected the yield characteristics. GA_3 at 250 μg mL-1 produced maximum number of pods per plant, seed yield, seed index and protein content in seeds in both the varieties. Their study clearly showed that judicious application of GA_3 and cycocel can increase yield and protein content in seeds of pea.

Sudip *et al.* (2014) investigated an experiment to find out the growth and yield performance of wheat to gibberellic acid concentrations which was conducted at experimental field of Sher-e-Bangla Agricultural University, Bangladesh. Experiment consisted foliar application of three concentrations of GA_3 viz. G_0: No GA_3 i.e., control condition; G_1: 100 ppm GA3 and G_2: 200 ppm GA_3. They found maximum plant height (89.9 cm), number of tiller/plant (5.0), CGR (5.8), RGR (0.04), dry matter content/plant (26.8 g), number of spikes/plant (4.1), number of spikelets/spike (19.0), ear length (17.0 cm), filled grains/spike (30.4), total grains/spike (32.6), weight of 1000-grains (45.5 g), grain yield (3.9 tha-1), straw yield (4.6 tha-1), biological yield (8.5 tha-1) and harvest index (46.1%) were found from G_2 Where as minimum from G_0.

Satyakumari and Sharma, (2012) conducted a field experiment at the Gwalior (Madhya Pradesh) during kharif-2009 to study the effect of gibberelic acid, IBA and NAA as foliar spray of cauliflower. The result indicated that growth characters like plant height (cm), diameter of the stem (cm), spread of the plant (cm) and number of leaves per plants were increased significantly under different treatments. Yield attributing characters viz., diameter of curd (cm), weight of curd per plant (kg), weight of the head per plant (kg), length of head per plant (cm), yield (q/ha) and dry weight of curd per 100 g of fresh weight were also increased significantly with different treatments. Among growth regulators GA_3 was most promising in effect followed by NAA and IBA.The growth regulator GA_3 at 150 ppm slowed significantly higher performance over the remaining treatment in all the growth characters viz., plant height etc. Growth regulator GA_3 at 150 ppm performed significantly better than the other treatments regarding the yield and yield attribute characters. Growth regulator GA_3 at 15 ppm with recommend fertilizer dose of NPK gave highest additional net profit over control followed by GA_3 at 100 ppm.

Hoque, *et al.* (2002) reported that two varieties of Mungbean were investigated for effects of seed treatment and foliar application of GA_3 at 0, 50, 100 and 200 ppm on the growth, yield and yield contributing characters. Seed treatment with GA_3 at 50 ppm increased plant height, number of leaves, fresh and dry weight. Foliar application of GA_3at 200 ppm had higher plant height and number of leaf, while that at 100 ppm greater number of pods, higher fresh and dry weight of pod, number of seeds whereas 50 ppm GA_3 resulted higher pod length and ultimately seed yield. The mungbean variety V2 performed better than V2 with foliar application of GA_3. This study indicates high potentiality to increase yield of mungbean in Bangladesh by the application of GA_3.

2.2 Effect of Plant Spacing:

Moniruzzaman (2006) conducted a field experiment from 22 June 2006 to 26 August 2006 in which he used three levels of spacing (40 x 20 cm, 40 x 30 cm and 40 x 40 cm) and two levels of mulching (mulch and non-mulch) to find out the effect of plant spacing and mulching on yield and profitability of lettuce cv. Green Wave. He found spacing showed significant effect on yield and yield components of lettuce. His experiment results also revealed that higher Gross Return (Tk. 216, 800.00) was obtained from the closest spacing in combination with mulch followed by medium spacing (40 x 30 cm) with mulch (Tk. 210, 160.00). The treatment combination of 40 x 30 cm spacing and mulching gave the highest benefit cost ratio (8.84). But the benefit cost ratio (4.22) from the treatment combination of 40 x 20 cm spacing and mulching was less due to the involvement of higher seedling cost.

Sharma *et al.* (2001) tested with twenty-four treatment combinations of six transplanting dates in lettuce cv. Alamo-1 viz., 1st Aug., 16th Aug., 1st Sept., 16th Sept., 1st Oct. and 16th October and four spacing levels viz., 30×30 cm, 45×30 cm, 45×45 cm and 60×45 cm and evaluated in a split plot design with three replications. He indicated that the widest spacing of 60×45 cm gave the maximum fresh weight and dry weight per plant (yield/plant) but lowest per hectare but the closest spacing of 30×30 cm recorded minimum yield/plant, which did not compensate optimum yield per hectare. A plant spacing of 45×30 cm was found best for getting optimum yield per plant as well as per hectare. On the basis of overall effect of dates of planting and plant spacing on yield and its attributes, the planting date of 1st September and plant spacing of 45x30 cm proved to be the most promising for getting optimum yield in lettuce cv. Alamo-1 under Kullu valley conditions of Himachal Pradesh.

Echer *et al.* (2001) evaluated the performance of 5 lettuce cultivars (Brisa, Grande Rapida, Marisa, Vera and Veronica) in 2 spacing treatments (0.20 x 0.25 m and 0.25 x 0.25 m) from September to December 1998 in Sao Paulo, Brazil. The following parameters were evaluated: fresh matter of aerial parts per plant; number of leaves per plant; leaf fresh matter per plant; average fresh matter of one leaf; relationship between leaf fresh matter per plant and fresh matter of aerial parts per plant; and average total production per area. He found the cultivars with the best performances were Vera, Marisa and Brisa. In the small spacing (0.20 x 0.25 m) treatment, there was higher production area per plant within commercial standards than in the large spacing (0.25 x 0.25 m). A higher correlation between leaf fresh matter and fresh matter of aerial parts was observed in Vera compared to other cultivars.

The effects of spacing, hoeing and mulching on the yield and quality of lettuces under integrated control were determined by Petrikova and Pokluda (2004). Marketable lettuce yields reached 82-99%. Planting density, cultivar and mulching affected the quality of lettuce heads. The quality of lettuce heads were determined by the cultivar, as well as by mulching and hand hoeing. The size of lettuce heads were positively correlated with loose spacing.

Maboko *et al.* (2009) assessed that the development and yield of four lettuce (*Lactuca sativa* L.) cultivars 'NIZ 44-675', 'Nougatine', 'Tango' and 'Natividad' at five different intra-row spacings namely: 10x20 (50 plants m^2), 10x25 (40 plants m^2), 15x20 (30 plants m^2), 20x20 (25 plants m^2) and 20x25 (20 plants m^2) cm were evaluated during May/June 2008. The experimental layout was a randomized complete block design and each treatment combination was replicated three times. He found there was a significant Interaction between spacing and cultivar regarding leaf fresh and dry mass while all cultivars reacted similarly to different spacing on other yield parameters. Plant population significantly affected plant height, fresh and dry leaf mass, leaf area and leaf number m^2, with significantly higher values of all variables at the closest spacing (50 plants m-2). His results indicate that an increase in plant population results in a significant increase in yield and yield components of leafy lettuce, with all cultivars producing the highest yield at a spacing of 50 plants m^2 during winter production.

Abubakari *et al*. (2011) carried out an experiment (Completely Randomized Design) was set up to determine the effects of Clay Pot Sub-surface Irrigation (CPSI) and spacing on the growth and fresh weight of lettuce (*Lactuca sativa*). The treatments were: CPSI with spacing; 15x15 cm, 20x20 cm and 30x30 cm. Control treatments were Watering Can Irrigation (WCI) with the same spacing as above. Treatments were replicated three times given a total of 18 experimental units. Eighteen large enamel basins of 50/20 cm (diameter/height) were filled with good topsoil and a clay pot buried neck deep in each of the basins. Seedlings were planted in all the eighteen basins. Five Hundred mL of wastewater was applied daily to plants in each container having either clay pot or watering can treatment. His experiment result revealed that fresh weight of lettuce increased almost two fold under 15x15 cm spacing compared to 20x20 and 30x30 cm.

A field study was conducted by Jordan *et al.* during 2000/2001 to study the optimum planting density, form of nitrogen and irrigation regime for lettuce cv. Amar. Seeds were sown one month before transplanting. He found effect of Plant spacing had a highly significant ($p<0.01$) effect on vegetative and yield components, but a spacing of 20 cm apart generally showed the highest values, followed by 25 cm then 15 cm. Regarding the effect of irrigation regime on vegetative and yield components, the amount of irrigation water had induced significant differences among the values of these parameters. Lettuce showed the best response under (NH4) 2SO4 + 20 cm spacing + 1 irrigation under regime 1.

Maroof Tahsin was evaluated an experiment in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2009 to January, 2010. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) N_0: 0 (Control); N_1: 50; N_2: 100 and N_3: 150 kg/ha respectively; and Factor B: Plant spacing (3 levels), S_1: 40 cm × 20 cm, S_2: 40 cm × 25 cm; S_3: 40 cm × 30 cm. The Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of ntrogen the highest yield (29.99 t/ha) was recorded from N_3 and lowest (18.65 t/ha) from N0. In case of spacing the highest yield (25.83 t/ha) was achieved from S_2 and lowest (23.0 t/ha) from S_1. For interaction effect, the highest yield (31.31 t/ha) was obtained from N_3S_2 and lowest (16.79 t/ha) from N_0S_1. The highest BCR value (3.88) was recorded from N_3S_2 and lowest (2.1) from N_0S_1. So, 150 kg/ha urea with spacing of 40 cm × 25 cm were best for growth and yield of lettuce.

Paththinige *et al.* (2008) was investigated the effect of different plant spacings on yield and fruit characteristics of okra (variety: Haritha). Treatments consisted of four plant spacings (90 x 60 cm, 60 x 45 cm, 45 x 45 cm and 45 x 30 cm) among which the spacing recommended (90 x 60 cm) by the Department of Agriculture served as the control. Treatments were arranged in a Randomized Complete Block Design with three replicates. They found from their study the total fruit yield, fruit length, fruit weight and number of fruits per plant were significantly affected by plant spacing. When compared to the control, total fruit yield increased by 35% and 160% at 45 x 45 cm spacing during the yala season and at 45x30 cm during the maha season. Their study indicated that, 45 x 45 cm spacing could be selected for the yala season while, a 45 x 30 cm spacing is appropriate for maha season for higher yields and quality fruits of okra.

An experiment was conducted during 2013-14 by Vikash *et al.* (2016) at the research farm of Department of Vegetable Science, CCS HAU, Hisar to study the effect of spacing on growth and yield of okra in summer season. Three spacing and two varieties in split-split plot design with three replications were included in the experiment. rowth parameters of okra crop were significantly affected by spacing in two varieties. They found the highest plant height was observed in wider spacing with variety HBT-49-1. However number of branches was highest in variety Hisar Unnat. Yield attributes like first fruiting node, intermodal length, fruit length, diameter etc were highest in variety HBT-49-1 leading to highest fruit yield (q/ha) in spacing 30 x 10 cm. The spacing 30 x 10 cm resulted in higher growth parameters; yield attributes and yields in variety HBT-49-1.

Nereu *et al.* (2014) find out the result of a study by analyzing the effect of different planting spacings on the growth, development and stems and roots yield in a subtropical environment of Rio Grande do Sul, Brazil. Treatments consisted of four spacings: 0.8x0.8 m, 1.0x1.0 m, 1.2x1.2 m, 1.5x1.5 m, corresponding to densities of 15,625 plants ha^{-1}, 10,000 plants ha^{-1}, 6.944,45 plants ha^{-1} and 4.444,45 plants ha^{-1}, respectively. The cultivar used was Fepagro – RS 13. The variables of growth and development analyzed were green leaf area, plant height and number of senesced leaves, internode lenght, final leaf (FLN), and number of lateral shoots, final size of leaves, phyllochron and stem and root fresh and dry weight yield. The maximum leaf area index and phyllochron increases as plant density increases. The final leaf size and number of lateral shoots increases as plant density decreases. The FLN differed only for the second sympodial branching, with the largest number of leaves in the 1.5x1.5m plant spacing. The stems yield of cultivar Fepagro–RS 13 does not vary with the planting spacing, but tuber root yield per area is higher at higher densities, while yield per plant and per root is higher in lower densities.

Nguyen *et al.* (2015) investigated a study which was conducted to evaluate the planting density on growth and yield of tomato fruit to determine the optimum planting density. Plant height, number of leaves per plant, fruit set, number of fruit per plant, fruit weight and fruit yield were recorded. Results indicated that treatment with 35714 plants per hectare had the highest plant height, whereas 25974 plants per hectare gave the lowest plant height. Moreover, 25974 plants per hectare had the best results in fruit set, fruit number as well as fruit weight. Planting density with 25974 plants per hectare gave the maximum fruit yield than the other treatments. It was concluded that 25974 plants per hectare significant improve fruit growth and yield of tomato fruit under field condition.

A field experiment was carried out by Monirul *et al.* (2011) at the Horticultural farm of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during September 2006 to April 2007 to investigate growth and yield of sweet pepper as influenced by spacing. There were three levels of spacing viz. 50×50 cm, 50×40 cm, 50×30 cm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were recorded on various parameters and subjected to statistical analysis. They observed the plant spacing had significant variation in almost all the growth and yield components except pericarp thickness. Number of branches per plant, number of leaves per plant, stem girth, number of fruits per plant, days to first harvest, fruit length, individual fruit weight, yield per plant were found to be significantly increased with the increasing of plant spacing but plant height at different stages, number of fruits per plot, days to 50% flowering, fruit breadth, yield per plot and yield per hectare were found to be significantly increased with the decreasing plant spacing. Considering the yield of fruits per hectare, cost of production and net return, 50×30 cm spacing appeared to be recommendable for the cultivation of sweet pepper.

Dalain *et al.* (2012) Examined that the effect of planting date and plant spacing and their interactive effects on yield, yield components and growth of Fennel under irrigation. They used three planting dates (Oct. 1st, Nov. 1st and Dec. 1st) and four plants spacing’s (10, 20, 30 and 40 cm with constant row width, 60 cm) were used. Fruit yield was significantly

($p<0.05$) influenced by plant spacing and planting date and their interaction. Their results revealed that early planting significantly increased the fruit yield combined with higher number of branches per plant, number of umbrella per plant, number of fruit per plant and plant height. The percentage of increases in Oct. 1st were 34.4 and 32.2% in fruit and biological yield respectively compared with Dec. 1st. Harvest index and thousand fruit weight was not significantly affected by planting date. Increase plant spacing to 30 cm led to more than 15% increase in fruit and biological yield. The early planting date with 30 cm plant spacing resulted in higher fruit 4136 kg ha^{-1} and biological yield 10,114 kg ha^{-1}.

Shuaibu *et al.* (2013) carried out an experiment at Kaltungo Local Government Area demonstration farm in Gombe state during the 2011 rainy season, to evaluate the effect of NPK fertilizer and spacing levels on growth and yield of Watermelon (Citrillus lanatus L). Three different spacings (1 × 1, 1 × 1.5, and 1 × 2 m) and four levels of NPK fertilizer (0, 100, 150 and 200 kg/ha) were used. All the treatments were set in a Randomized Complete Block Design (RCBD) with three replications. They indicates that the plant height, number of leaves, number of male and female flowers at 50% flowering, number of fruits per plant and weight of fruits at harvest were observed. The result of the experiment shows a significant difference (P=0.05) in plant height and number of leaves. Similarly, the result shows significant difference (P=0.05) in number of flowers, number of fruits, weight of fruits (2.96 kg) and yield per hectare (63.6 t) as compared to the control. The interaction between the treatments indicate that 150 kg/ha of NPK and a spacing of 1 × 1.5 m gave the highest number of fruit and yield per hectare. Therefore, based on the result of this findings, it is hereby recommended that the use of 150 kg NPK/ha at a spacing of 1 × 1.5 m should be adopted by the farmers for profitable watermelon production in the study area.

Rabeea *et al.* (2013) reported that planting density can be increased thrice by using different production systems. They conducted the study to see the impact of different planting densities and media on growth and yield of strawberry. The treatments were T= Control, with normal planting distance of 30 cm x 60 cm and growing media silt, sand and farm yard manure (FYM); T= 15 cm x 30 cm and silt, and FYM; T= 30 cm x 60 cm and coir; T= 15 cm x 30 cm and coir; T= 30 cm x 60 cm and peat moss; T= 15 cm x 30 cm and peat moss. Results showed that plants grown at low planting distance on all growth media showed more pronounced results as compared to high planting distance. Plants grown in peat moss at both planting densities moderately increased the plant height, canopy size, leaf area, number of fruits, fruit size, fruit weight and titratable acidity. A significant increase in fresh and dry weight of leaves, number of leaves, fruit yield in term of fruit number, fruit size and fruit weight, and fruit quality with high ascorbic acid contents were observed. While the fruit produced had more Total Soluble Solid (TSS). Plants grown in coir based growing media showed significant increase only in titratable acidity and ascorbic acid content of fruit.

Bashar *et al.* (2007) examined the effect of spacing (40 and 50cm) and stem pruning (one stem, two stem, three stem and no pruning) on the yield was evaluated on indeterminate type BARI Tomato-6 variety at Regional Agricultural Research Station, Ishurdi, Pabna during 2005-2006. Results showed that wider spacing (50cm) gave the higher marketable yield (82.39 t/ha) and closer spacing gave the lowest marketable yield (68.32 t/ha) and number of fruits/plant. Two stem pruning yielded the highest marketable yield (87.18 t/ha) and one stem pruning gave the lowest number of fruits/plant. But stem pruning also yielded the lowest marketable weight of fruits/plant. Wider spacing coupled with two stem pruning showed superior interaction (97.08 t/ha) to others.

Ogundare *et al.* (2015) investigated the effect of different spacing and urea application rates on fruit nutrient composition, growth and fruit yield of tomato. Field experiments were arranged in a randomized complete block design in factorial fashion with three replications. The row spacing were 75 × 40 cm (33,333 plant·ha-1, 75 × 50 cm (26,666 plant·ha-1) and 75 × 60 cm (22,222 plant·ha-1) while the urea rates comprised control (0 kg urea·ha-1), 54.3 and 108.6 kg urea·ha-1. The result obtained from this study indicated that urea application and spacing affected significantly growth parameters of tomato and yield per land area. It could be concluded that there was a significant increase in plant height, number of leaves, number of fruits per plant and final fruit weight of tomato as a result of urea fertilizer application at the rate of 108.6 kg urea/ha. However, this was not significantly better than plots with urea application at 54.8 kg/ha in both Ejiba and Kabba. Row spacing of 75 × 50 cm showed better performance in number of fruit and fruit yield per plots. Farmers in Ejiba and Kabba should apply urea at the rate of 54.8 kg per hectare and plant the crop at a row spacing of 75 × 50 cm for optimum yield and for a more profitable production of tomato.

Singh *et al.* (2010) assessed the effect of different spacing on growth and yield of papaya. The experiment comprised of five spacing as treatments viz. 2×2, 1×1, 1.5×1.5, 2.5×2.5 and 3×3 m us papaya cv. Coorg Honey Dew was taken for study. Vegetative growth characters like plant height, numbers of leaves and internodal length showed significant difference among all the treatments. Maximum plant height (261.7 cm), number of leaves (30), and internodal distance (2.60 cm) were observed with 1×1, 2.5×2.5, and 1×1, respectively. Flowering attributes and fruit set characters showed significant response with 2.5×2.5 m spacing. Maximum average fruit weight (120.305 g), length of fruit (22.45 cm), width of fruit (33.35 cm), and fruit yield (120.11 tonnes/ha) were recorded plants with a spacing of 2.5×2.5 m.

Mahmood *et al.* (2004) carried out a study to observe the effect of various nitrogen levels (0, 100, 150 & 200 kg ha-1) and spacing (5, 10 & 15 cm) on growth and yield of radish. The experiment was laid out according to randomized complete block design in factorial arrangement with three replications. Application of 200kg N ha.-1 planted at 10 cm plant to plant distance was found the best treatment than others in relation to growth and yield of radish.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at the Horticulture Farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2013 to January 2014. The location of the site is in 23º 74 N latitude and 90º 35 E longitude with an elevation of 8.2 meter from sea level (Anon,1989).

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The total rainfall of the experimental site was 83.6 mm during the study period. The average monthly maximum and minimum temperature were 27.17ºC and 15.6ºC respectively during the experimental period. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented (Appendix I).

3.3 Characteristics of Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in the Soil Research and Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and presented in appendix II. The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988) are given below – AEZ 28 Soil series – Tejgaon General soil- Non-calcarious dark grey.

3.4 Plant Materials

Seed of lettuce cultivar, “Grand Rapid” was collected from Kushtia seed store, Dhaka. The seed was used in the experiment and sown on 8th November, 2013. It is leafy and spreading type as well as heat tolerant in nature.

3.5 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Three levels of Giberellic Acid (GA_3) denoted as-

1. G_0=Control
2. G_1=25 ppm
3. G_2=50 ppm

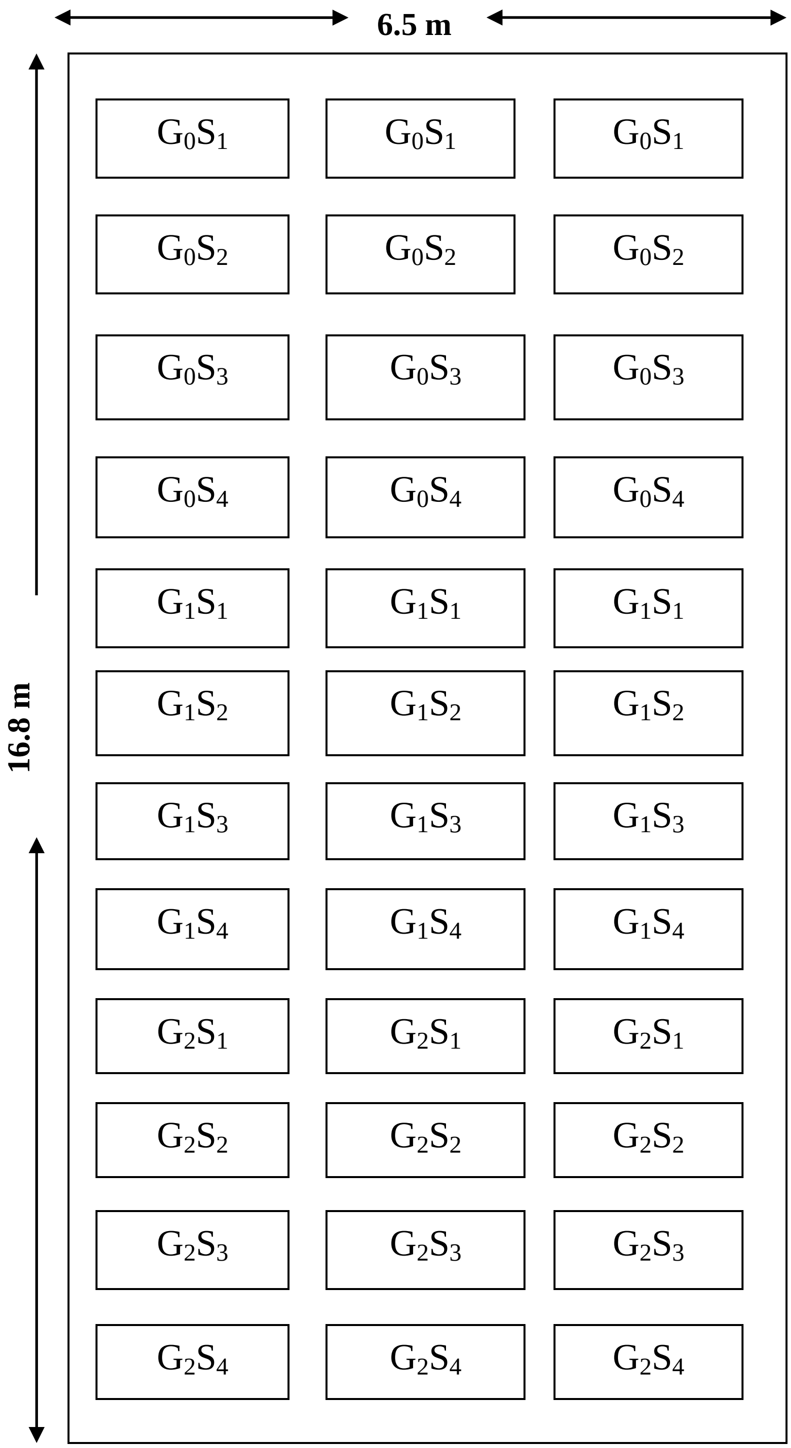
Factor B: Four levels of spacings denoted as-

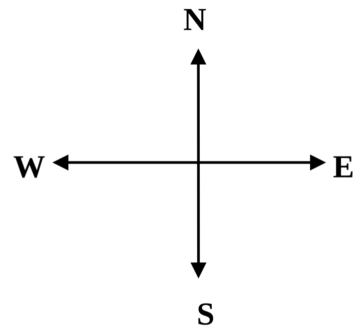
1. S_1=15 cm x 20 cm
2. S_2=20 cm x 25 cm
3. S_3=25 cm x 25 cm
4. S_4=25 cm x 30 cm

There were 12 treatment combinations such as G_0S_1, G_0S_2, G_0S_3, G_0S_4, G_1S_1, G_1S_2, G_1S_3, G_1S_4, G_2S_1, G_2S_2, G_2S_3, G_2S_4

3.6 Experimental design and layout

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 16.8 x 6.5 m^2 was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments were allotted at random. Thus there were 36 unit plots altogether in the experimental field. The size of each plot was 1.5 m × 1 m. The distance between two blocks and two plots were kept 0.5 m and 0.4 m respectively. The layout of the experiment has been shown in Figure 1.





Plot size: 1.5 m x 1 m

Plot spacing: 40 cm

Between Blocks: 50 cm

Factor A: GA_3

G_0: 0 ppm

G_1: 25 ppm

G_2: 50 ppm

Factor B: Spacing

S_1: 15 cm x 20 cm

S_2: 20 cm x 25 cm

S_3: 25 cm x 25 cm

S_4: 25 cm x 30 cm

Fig 1: Layout of the experiment

3.7 Land preparation

The land which was selected to conduct the experiment opened 15th October, 2013 with the help of a power tiller prepared by ploughing and cross ploughing followed by laddering. Deep ploughing was done to have good tilth which was necessary for getting better yield of the crop. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilth**.**

3.8 Application of manures

The recommended doses of Cowdung and N, P, K were applied on the basis of per hectare land requirement as Urea, TSP, MP. The remaining cowdung, one-third urea, the entire amount of TSP and half of MP were applied during final land preparation. The rest of MP and urea was top-dressed in two equal splits at 15 days interval after seed sowing.

Fertilizers	**Amount**
Cowdung	10 ton/ha
Urea	80 kg/ha
TSP	80 kg/ha
MP	30 kg/ha

Table 1. Cowdung, Urea, TSP, MP (Fertilizer Recommandation, BARC, 2007)

3.9 Seed sowing

Lettuce seed was directly sown by maintaining different spacing in the plot with additional light irrigation at 8th November, 2013.

3.10 Intercultural operation

When the seeds were germinated in the plot, it was always kept under careful observation. Various intercultural operations like thinning, weeding were accomplished for better growth and development of lettuce seedlings.

3.10.1 Gap filing

Dead, injured and weak seedlings were replaced by new vigorous seedlings from the stock kept on the border line of the experiment field.

3.11.2 Weeding

Weeding was done three times in these plots where it was necessary.

3.11.3 Irrigation

Light irrigation was given just after sowing of seed in the plot. A week after sowing the requirement of irrigation was envisaged through visual estimation. The plots were irrigated in every alternative day with a hosepipe until the entire plot was properly wet. Again, whenever the plants of a plot had shown the symptoms of wilting the plots were irrigated again.

3.11.4 Insects and Diseases

There was no incidence of insects and diseases.

3.12 Harvesting

Randomly selected five plants were harvested from each plot for data collection for 3 times. First harvesting was done at 25 DAS, second was 35 DAS and the third harvesting was done at 45 DAS.

3.13 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment. Five (5) plants were sampled randomly from each unit plot for the collection of data.

3.13.1 Plant height (cm)

Plant height was measured in centimeter (cm) by a meter scale at 25, 35 and 45 days after sowing (DAS) from the point of attachment of the leaves to the ground level up to the tip of the longest leaf.

3.13.2 Number of leaves per plant

Number of leaves per plant were taken from randomely selected five plants counted at 25, 35 and 45 DAS. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of five plants gave number of leaves per plant.

3.13.3 Length of leaf (cm)

The length of leaf was measured by using a meter scale. The measurement was taken from base to tip of the leaf. Average length of leaves which were matured and attained edibility was taken from five randomly selected plants. Data were recorded at 25, 35 and 45 DAS. Average was expressed in centimeter (cm).

3.13.4 Breadth of leaf (cm)

The average breadth of leaves (which were matured and attain edibility) were taken from five randomly selected plants from each plot started at 25, 35 and 45 DAS. Average was expressed in centimeter (cm).

3.14.5 Fresh weight per plant (g)

Five randomly selected plants (which were matured and attained edibility) at 25, 35 and 45 DAS were uprooted and average fresh weight of plants was recorded in gram (gm).

3.13.6 Dry matter contents (%)

After harvesting, 100g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 60°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken to get dry weight. And it was converted to percentage.

3.13.7 Chlorophyll contents

Chlorophyll contents was measured with five randomly selected leaf samples by SPAD and then average percentage was recorded.

3.13.8 Gross fresh yield (t/ha)

The yield of lettuce per hectare was calculated in ton by converting the total yield of leaves per plot.

3.14 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT C statistical package programme. The average for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

3.15 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of spacing and GA_3 application. All input cost included the cost for lease of land and interests of running capital in computing the cost of production. The interests were calculated @ 15% in simple rate. Analysis was done according to the procedure of Alam *et al*. (1989).

The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate the effect of different levels of GA_3 and spacings on the growth and yield of lettuce. The analysis of variances for different characters has been presented in Appendices IV to VIII. Data on different parameters were analyzed statistically and the results have been presented in Tables 1 to 10 and Figures 2 to 17. The results of the present study have been presented and discussed in this chapter under the following headings.

4. Effect of GA_3 and spacing on growth and yield of lettuce.

4.1 Plant height

The plant height was recorded at different stages of growth i.e. 25, 35, and 45 days after sowing (DAS). The plant height varied significantly due to the application of different levels of GA_3 (Fig.2).

During the period of plant growth the tallest (9.49 cm) plant height was observed in 50 ppm (G_2) and the shortest (6.85 cm) plant height was found from control (G_0) treatment at 25 DAS. At 35 DAS the tallest plant height (13.4 cm) was obtained from 50 ppm (G_2) and the shortest plant height (11.87 cm) was obtained from the control treatment. The tallest (18.16 cm) plant height at 45 DAS was found from 50 ppm (G_2) whereas, the shortest (15.57 cm) was obtained from the control treatment. GA is released that triggers the weakness of seed cover by stimulating gene expression involved in cell expansion and modification. GA_3 is released that stimulating gene expression involved in cell division, cell expansion, modification and also inducing hydrolytic enzymes.Mohsen Kazemi (2014) also found the application of gibberellic acid alone or in combination increased plant height.

The plant height was also varied due to different levels of spacing on growth i.e. 25, 35, and 45 days after sowing (DAS). The plant height varied significantly due to the different levels of plant spacings (Fig. 3).During the period of plant growth the tallest (9.67 cm) plant height was found from S_3 and the shortest (5.24 cm) plant height was recorded from S_1 treatment at 25 DAS. The tallest plant height (13.07cm) was obtained from S_3 and the shortest plant height (8.76 cm) was obtained from (S_1) minimum spacing was applied at 35 DAS. At 45 DAS the tallest (17.36 cm) plant height was found from (S_3) and the shortest (11.56cm) was obtained from S_1. The results indicate that due to low density the plants get proper light, nutrients and proper space for their growth.

The plant height was significantly influenced by the combined effect of different levels of GA_3 and spacing at different days after sowing (DAS). The tallest (10.07, 14.09 and 18.98 cm at 25, 35 and 45 DAS respectively) plant height was found from the treatment combination of G_2S_3 and the shortest (13.34 cm) was obtained from the treatment (G_0S_1) at 45 DAS (Table 2).

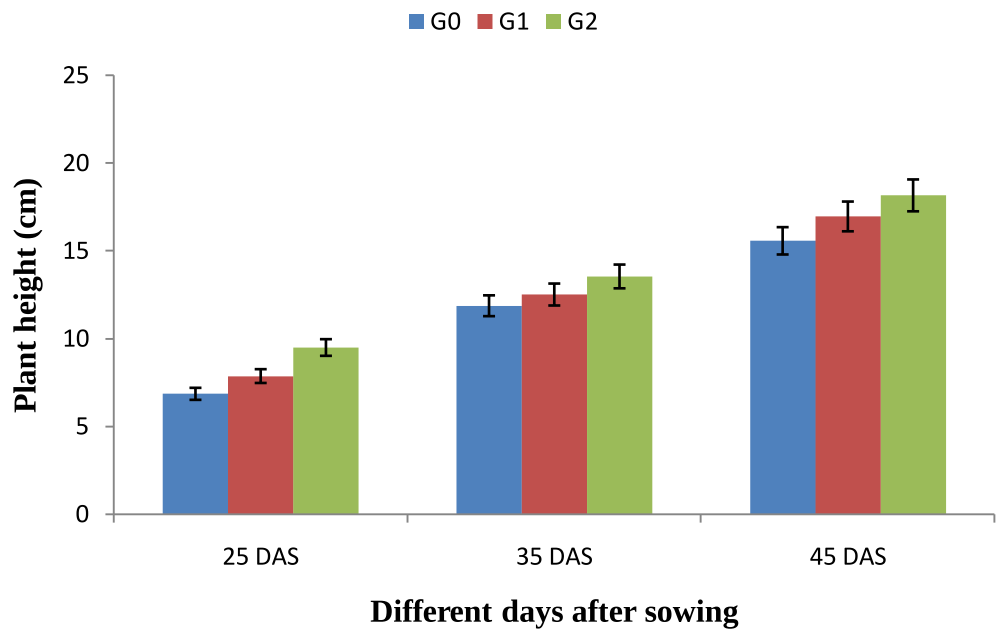


Fig 2: Effect of GA_3 on plant height of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

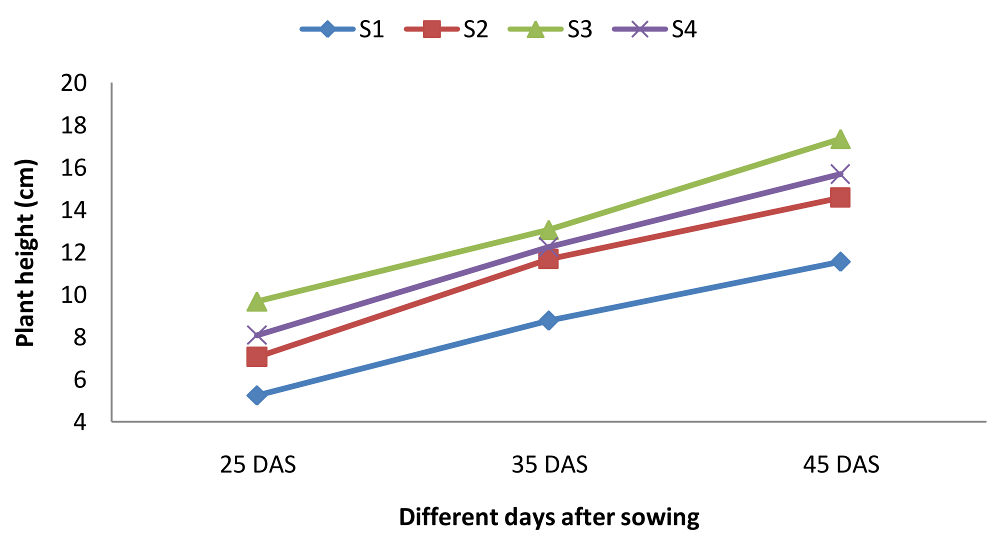


Fig 3: Effect of Spacing on plant height of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 2. Combined effect of GA_3 and spacing on plant height of lettuce

Treatment	Plant height (cm)		
	25 DAS	35 DAS	45 DAS
G_0S_1	6.27	11.18	13.97
G_0S_2	6.06	10.79	16.14
G_0S_3	7.11	12.41	16.06
G_0S_4	6.97	12.11	16.11
G_1S_1	7.71	13.74	16.63
G_1S_2	9.70	13.33	16.14
G_1S_3	7.62	13.82	17.68
G_1S_4	7.42	13.17	17.40
G_2S_1	9.51	13.33	17.63
G_2S_2	8.54	13.75	17.69
G_2S_3	10.07	14.09	18.98
G_2S_4	9.85	13.97	13.34
LSD (0.05)	1.41	1.06	1.53
CV (%)	10.35%	4.94%	5.36%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4. 2 Number of leaves per plant

Applications of GA_3 significantly increase the production of leaves per plant (Fig.4) at 25, 35 and 45 DAS. The maximum number of leaves per plant (5.28, 10.29 and 15.57 at 25, 35 and 45 DAS respectively) was produced by G_1 treatment and the minimum (4.56, 8.36 and 13.99 at 25, 35 and 45 DAS respectively) was produced by the G_0 treatment. G_1 gave the highest number of leaves per plant compare to control condition and among the different doses of GA_3, G_1 was more effective than other doses to increase the number of leaves per plant.The result is attributed for optimum dose of gibberellic acid which helps to induce shoot cell division and elongation. Shaheen *et. al.* (2013) also found the similar result.

Significant variation was found in case of number of leaves per plant due to the effect of spacing (Fig.5). The maximum number of leaves (5.74, 10.91 and 16.18 at 25, 35 and 45 DAS respectively) was obtained from S_3 treatment. The S_1 treatment gave the minimum number of leaves (4.09, 7.94 and 13.39 at 25, 35 and 45 DAS respectively) per plant showing statistically similar result with to 4.20 and 8.29 at 25 and 35 DAS from S_2 treatment. It was revealed that with the increases of spacing, number of leaves per plant also increased. Adequate space for vertical and horizontal expansion in the optimum spacing leads to the production of maximum number of leaves per plant than closer spacing. Stevens (1974) also reported similar results earlier.

The number of leaves per plant was also significantly influenced by the interaction effect of GA_3 and spacing. The number of leaves per plant was recorded to be the highest (6.73, 12.67 and 18.80 at 25, 35 and 45 DAS respectively) from the treatment combination of G_1S_3 treatment. The lowest number of leaves (3.67, 7.57 and 13.00 at 25, 35 and 45 respectively) was obtained from the G_0S_1treatment (Table 3).

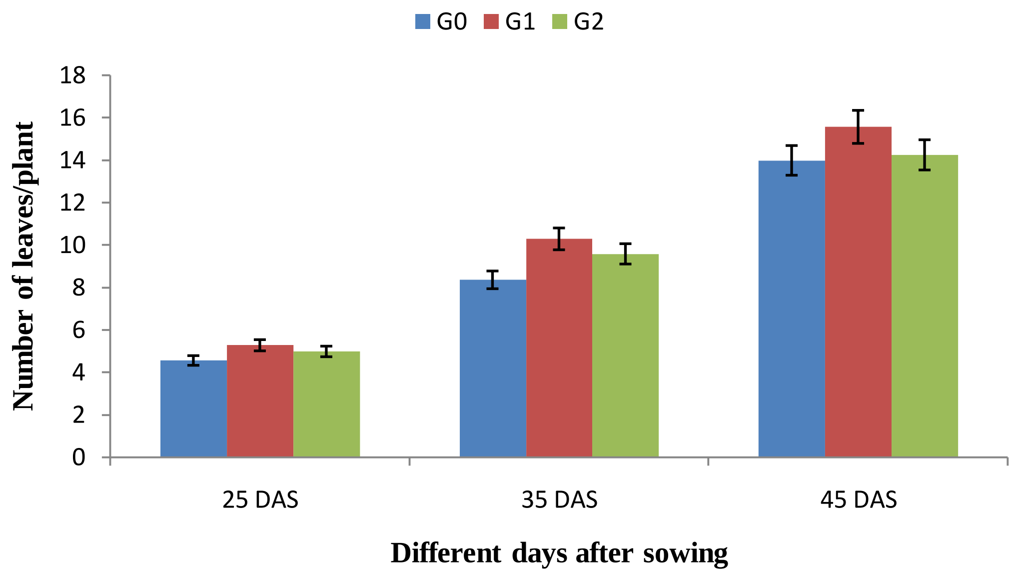


Fig 4: Effect of GA_3 on number of leaves/plant at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

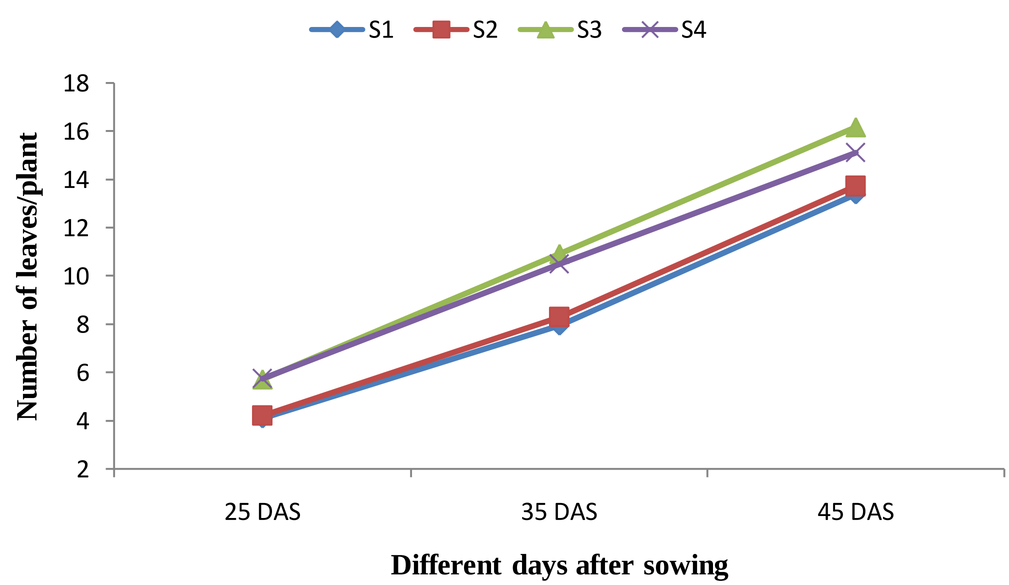


Fig 5: Effect of Spacing on number of leaves/plant at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 3. Combined effect of GA_3 and spacing on number of leaves/lettuce plant

Treatment	Number of leaves/plant		
	25 DAS	**35 DAS**	**45 DAS**
G_0S_1	3.67	7.57	13.00
G_0S_2	3.80	7.53	13.40
G_0S_3	4.43	9.10	14.67
G_0S_4	6.33	9.23	14.53
G_1S_1	4.33	8.63	13.80
G_1S_2	4.47	8.967	14.37
G_1S_3	6.73	12.67	18.80
G_1S_4	5.57	10.90	15.30
G_2S_1	4.27	7.63	13.37
G_2S_2	4.33	8.37	13.40
G_2S_3	6.00	10.97	15.07
G_2S_4	5.33	11.37	15.53
LSD (0.05)	1.23	1.88	1.72
CV (%)	14.68%	11.78%	6.96%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4. 3 Length of leaf

During the period of plant growth the highest (9.49 cm) length of leaf was observed in 50 ppm (G_2) and the shortest (6.85 cm) length of leaf was found from control (G_0) treatment at 25 DAS. At 35 DAS the largest length of leaf (13.4 cm) was obtained from 50 ppm (G_2) and the minimum length of leaf (11.87 cm) was obtained from the G_0. The longest (18.16 cm) length of leaf at 45 DAS was found from 50 ppm (G_2) whereas, the shortest (15.57 cm) was obtained from the control treatment (Fig. 6)

The length of leaf was also varied due to different levels of spacing on growth i.e. 25, 35, and 45 days after sowing (DAS). The length of leaf varied significantly due to the different levels of plant spacing (Fig.7).During the period of plant growth the highest (8.27 cm) leaf length was found from S_3 and the shortest (7.83 cm) leaf length was recorded from S_1treatment at 25 DAS. The highest leaf length (13.1cm) was obtained from S_3 and the shortest leaf length (12.08 cm) was obtained from 15x20 cm (S_1) minimum spacing was applied at 35 DAS. At 45 DAS the highest (17.40 cm) leaf length was found from S_3 and the shortest (16.08 cm) was obtained from S_1. Michel *et. al*. (2014) found the leaf size increases as plant density decreases.

The leaf length significantly influenced by the combined effect of different levels of GA_3 and spacing at different days after sowing (DAS). The longest (10.07, 13.98 and 19.34 cm at 25, 35 and 45 DAS respectively) leaf length was found from the treatment combination of G_2S_3 and the shortest (13.97 cm) was obtained from the treatment (G_0S_1) at 45 DAS (Table 4).

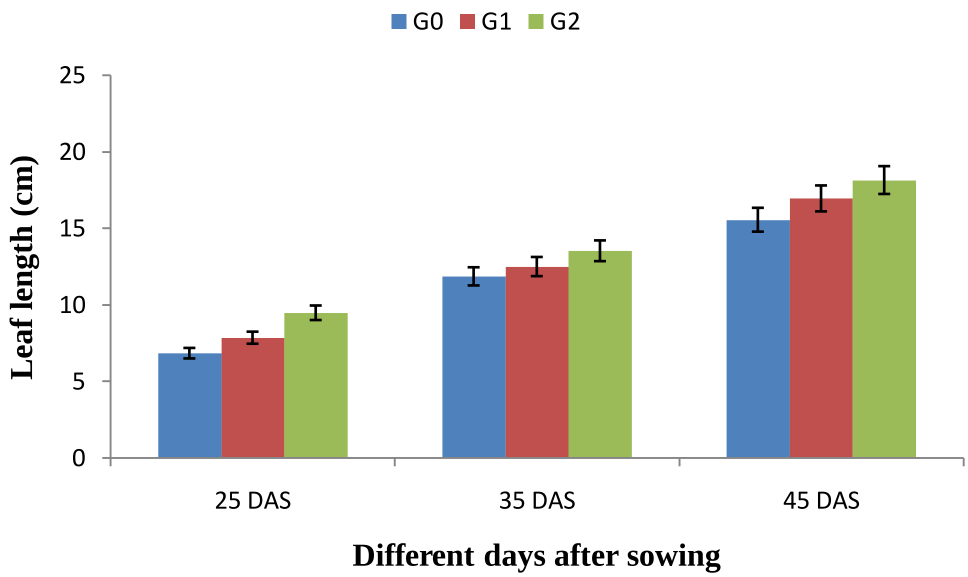


Fig 6: Effect of GA_3 on leaf length of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

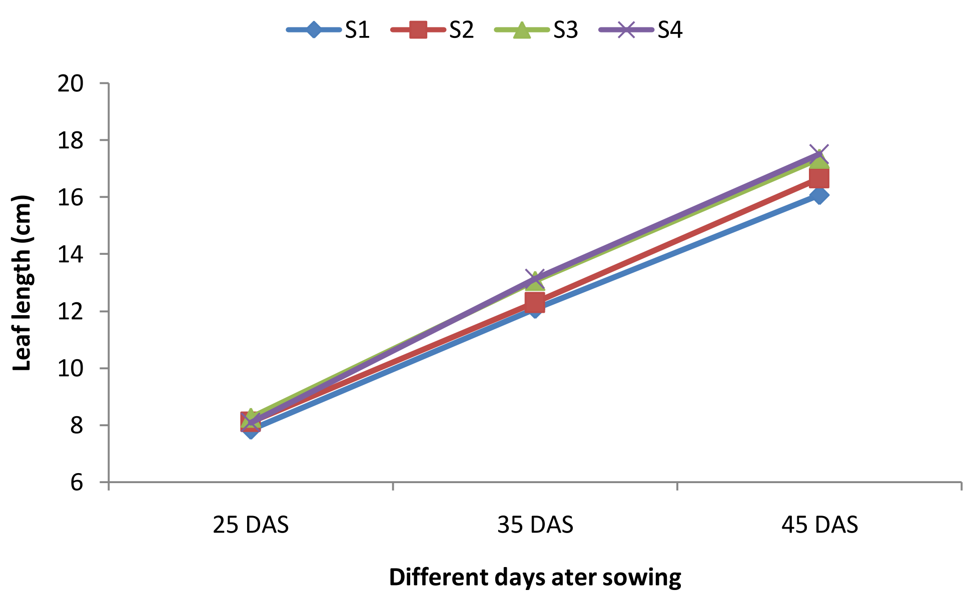


Fig 7: Effect of Spacing on leaf length of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 4. Combined effect of GA_3 and spacing on leaf length of lettuce

Treatment	Leaf length (cm)		
	25 DAS	**35 DAS**	**45 DAS**
G_0S_1	6.07	11.18	13.97
G_0S_2	6.06	10.79	16.14
G_0S_3	7.01	12.41	16.06
G_0S_4	6.97	13.11	16.11
G_1S_1	7.71	11.74	16.63
G_1S_2	9.70	13.33	16.14
G_1S_3	7.62	12.82	17.68
G_1S_4	7.42	12.17	17.40
G_2S_1	9.51	13.33	17.63
G_2S_2	8.54	12.75	17.69
G_2S_3	10.07	13.98	19.34
G_2S_4	9.85	14.09	18.98
LSD (0.05)	1.41	1.06	1.53
CV (%)	10.35%	4.94%	5.36%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.4 Breadth of leaf per plant

The effect of GA_3 was significant in case of breadth of leaf per plant (Appendix IV). The widest (7.45 cm, 12.31 cm and 15.88 cm from G_1 treatment. G_0 treatment produced narrowest leaf (5.22 cm, 9.42 cm and 12.55 cm at 25, 35 and 45 DAS respectively) (Fig.8).

The Breadth of leaf counted at different DAS was significantly influenced by spacing. Treatment S_3 produced maximum Breadth of leaf (8.16 cm, 12.73 cm and 16.04 cm at 25, 35 and 45 DAS respectively) and the minimum (4.88 cm, 8.47 cm and 12.08 cm at 25, 35 and 45 DAS respectively) Breadth of leaf was recorded in S1 treatment (Fig. 9). It was revealed that with the increases of spacing leaf breath showed increasing trend. In case of closer spacing plant compete for light and with the time being leaf breath decreases.

Due to combined effects of GA_3 and spacing were significant in respect of breadth of leaf. Pebam *et. al*. (2010) found length of fruit and width of fruit were increased with optimum spacing. Numerically the highest breadth of leaf (8.67 cm, 13.30 cm and 17.53 cm at 30 and 40 DAS respectively) was obtained from the treatment combination of G_1S_3 and the minimum breadth of leaf (4.80 cm, 8.70 and 14.17 cm at 25, 35 and 45 DAS respectively) was measured in the treatment combination of G_0S_1 treatment (Table 5).

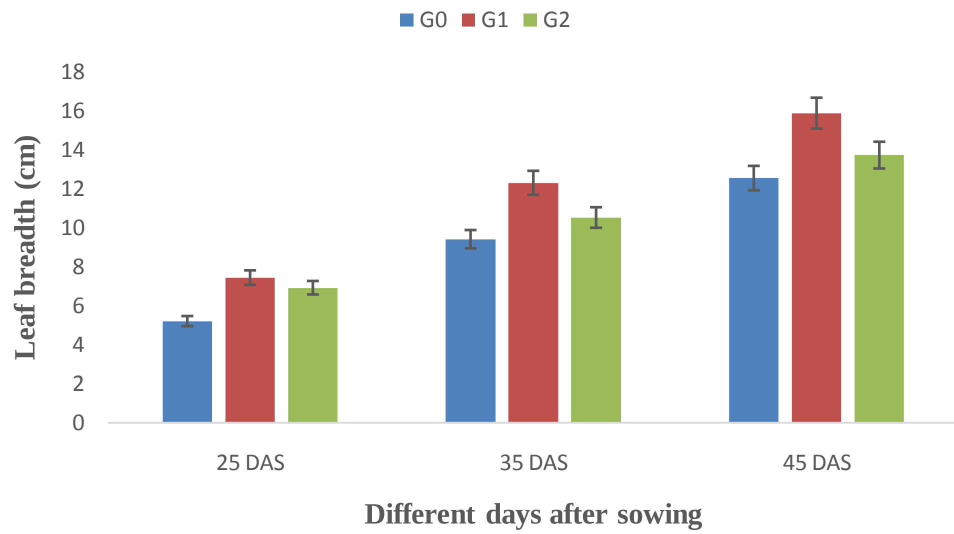


Fig 8: Effect of GA_3 on leaf breadth of lettuce at different days after sowing

G0= 0 ppm G1= 25 ppm G2= 50 ppm

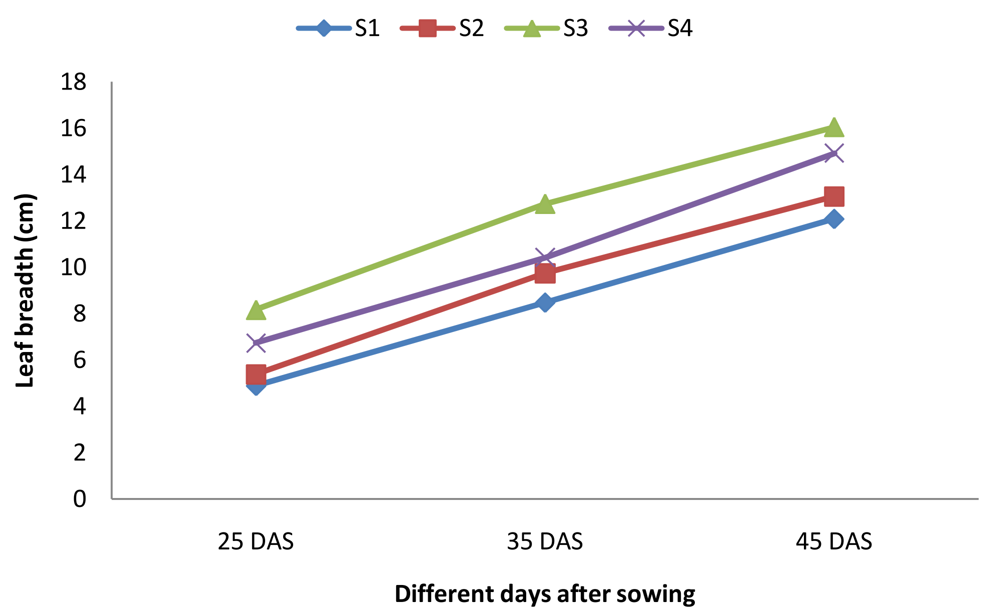


Fig 9: Effect of Spacing on leaf breadth of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 5. Combined effect of GA_3 and spacing on leaf breadth of lettuce

Treatment	Leaf breadth (cm)		
	25 DAS	35 DAS	45 DAS
G_0S_1	4.80	8.70	14.17
G_0S_2	5.23	8.80	14.87
G_0S_3	5.47	10.13	14.90
G_0S_4	5.37	10.03	14.27
G_1S_1	6.00	10.70	15.33
G_1S_2	6.33	11.03	15.57
G_1S_3	8.67	13.30	17.53
G_1S_4	6.73	11.10	15.10
G_2S_1	6.83	12.00	15.73
G_2S_2	7.57	12.37	16.07
G_2S_3	7.33	11.77	15.70
G_2S_4	8.07	13.10	15.40
LSD (0.05)	1.06	1.14	1.51
CV (%)	9.56%	6.05%	5.80%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.5 Fresh weight of leaves per plant (g)

GA_3 significantly influenced the fresh weight of leaves per plant at 25, 35 and 45 DAS. The maximum weight of fresh leaves per plant (30.35, 89.61 and 181.55 g at 25, 35 and 45 DAS respectively) was recorded from G_1 and the minimum weight (17.74, 45.84 and 101.7 g at 25, 35 and 45 DAS respectively) was measured in the G_0 treatment (Fig. 10). Among the different $GA_{3,}$ G_1 was more effective than those of other doses. Total fresh and dry weight significantly increased, by GA_3 application. Ebrahim *et. al*. (2014) showed similar result as two foliar sprayings with two concentrations of GA_3 (0 and 50 mg L-1 for the first and second sowing and 0 and 25 mg L-1 for the third sowing) were applied which increased fresh weight of plant.

The fresh weight of leaves per plant was significantly influenced by plant spacing. Treatment S_3 produced maximum fresh weight of leaves per plant (22.98, 71.01, 138.97 g at 25, 35 and 45 DAS respectively) and the minimum fresh weight of leaves per plant (15.5, 37.61 and 98.54 g at 25, 35 and 45 DAS respectively) was recorded from S_1 treatment (Fig. 11). It was revealed that with the increases of spacing fresh weight of leaves per plant showed increasing trend. In case of wider spacing plant receive enough light and nutrients which leads to attain the maximum fresh weight of leaves per plant. Similar trends of result was also observed by Echer *et al.* (2001)

The interaction effects of GA_3 and plant spacing were significant in respect of fresh weight of leaves per plant. The highest (30.97, 85.43 and 182.5 g 25, 35 and 45 DAS respectively) from $G_1S_3$and the lowest (14.43, 27.87 and 83.87 g at 25, 35 and 45 DAS respectively) fresh weight of leaves per plant were recorded from the treatment combination of G_0S_1 (Table 6).

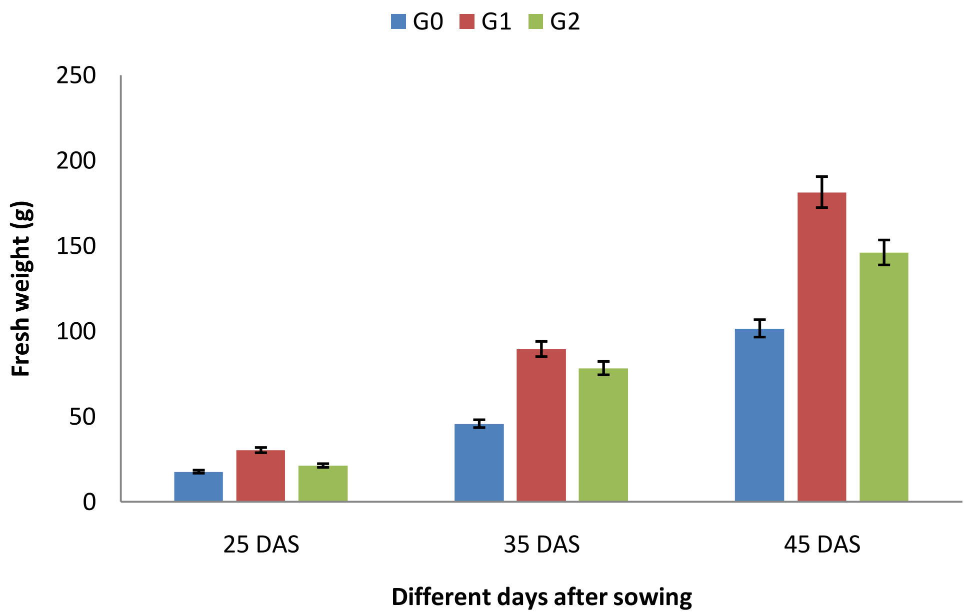


Fig 10: Effect of GA_3 on fresh weight of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

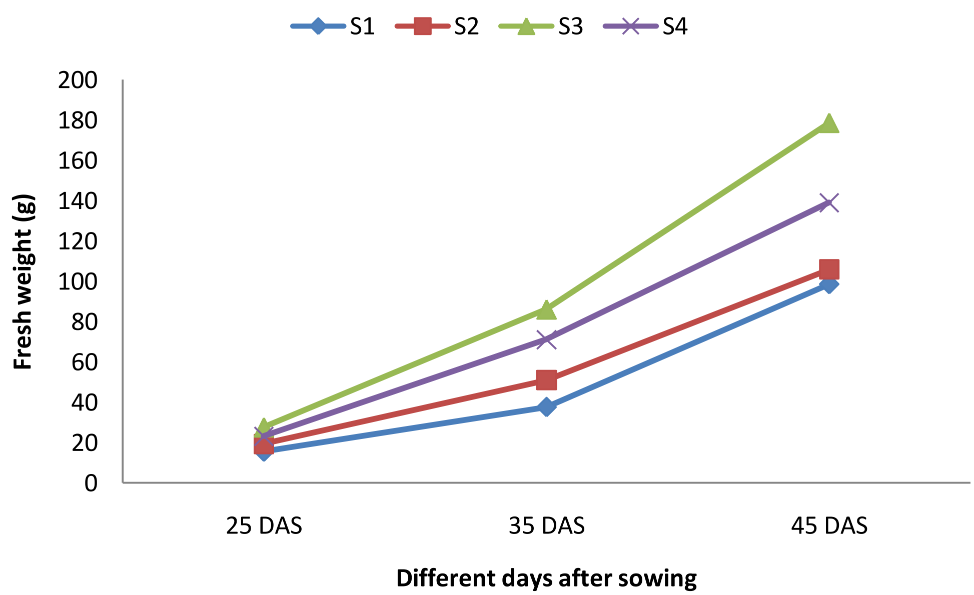


Fig 11: Effect of Spacing on fresh weight of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 6. Combined effect of GA_3 and spacing on fresh weight of lettuce

Treatment	Fresh weight (g)		
	25 DAS	35 DAS	45 DAS
G_0S_1	14.43	27.87	83.87
G_0S_2	15.80	29.13	91.93
G_0S_3	15.83	38.30	114.03
G_0S_4	16.90	32.07	106.97
G_1S_1	24.33	78.67	105.13
G_1S_2	26.20	79.63	113.60
G_1S_3	30.97	85.43	182.5
G_1S_4	28.90	80.70	130.0
G_2S_1	22.73	64.30	106.63
G_2S_2	22.87	67.93	117.03
G_2S_3	21.47	79.07	172.53
G_2S_4	19.13	72.27	140.43
LSD (0.05)	1.32	3.47	13.28
CV (%)	11.49%	10.45%	9.51%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.6 Dry matter content (%)

GA_3 significantly influenced the dry matter content (%) at 25, 35 and 45 DAS. The maximum dry matter content (9.71%, 11.43% and 11.82%) at 25, 35 and 45 DAS respectively) was recorded from G_1 and the minimum dry matter content (8.41%, 9.09% and 9.11%) at 25, 35 and 45 DAS respectively) was recorded from G_1 (Fig. 12).

The dry matter content (%)was not significantly influenced by plant spacing (Appendix V). Treatment S_3(10.11%, 10.76% and 11.6%) at 25, 35 and 45 DAS respectively) and the minimum dry matter content (%)(8.62 %, 9.12 % and 8.84 % at 25, 35 and 45 DAS respectively) was recorded in S_1 treatment (Fig. 13). It was revealed that with the increase of spacing dry matter content (%)showed increasing trend because of less competition for nutrients among the plants during growth stages. Similar result was also observed by Sharma *et al*. (2001).

The interaction effects of GA_3 and plant spacing were significant in respect of dry matter content (%). The highest (11.83%, 12.47% and 14.37% at 25, 35 and 45 DAS respectively) from G_1S_3. The lowest (8.70%, 8.70% and 8.63% at 25, 35 and 45 DAS respectively) dry matter content (%) were obtained from the treatment combination G_0S_1 treatment (Table 7).

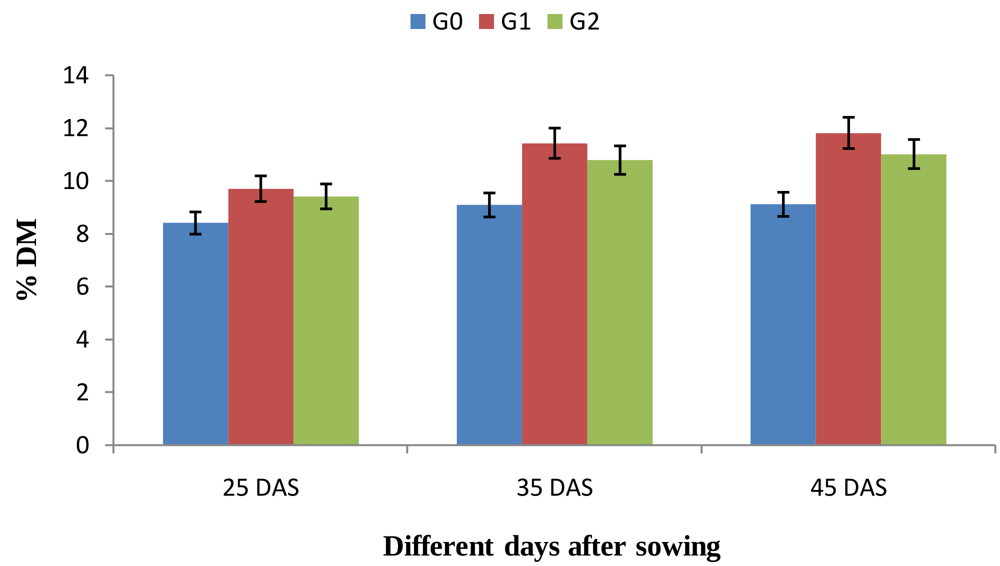


Fig 12: Effect of GA_3 on dry matter content (%) of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

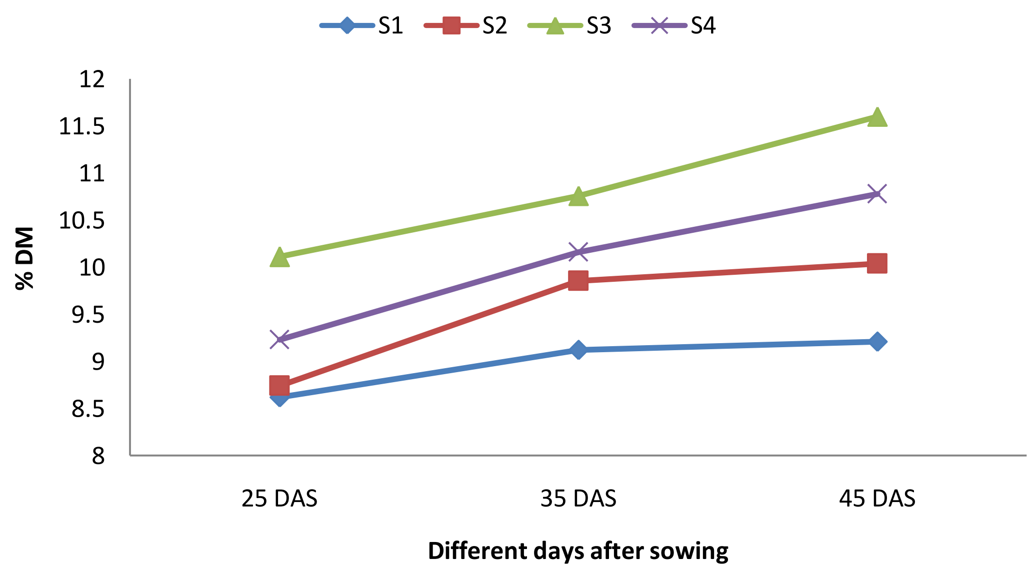


Fig 13: Effect of Spacing on dry matter content (%) of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 7. Combined effect of GA_3 and spacing on dry matter content (%)of lettuce

Treatment	Dry matter content (%)		
	25 DAS	35 DAS	45 DAS
G_0S_1	8.20	8.53	8.47
G_0S_2	8.70	8.70	8.63
G_0S_3	8.03	9.13	9.43
G_0S_4	8.70	10.00	9.63
G_1S_1	9.30	9.30	10.87
G_1S_2	9.33	11.60	10.90
G_1S_3	11.83	12.47	14.37
G_1S_4	9.37	13.70	13.17
G_2S_1	9.37	9.37	9.80
G_2S_2	9.20	9.43	10.70
G_2S_3	10.47	10.67	12.20
G_2S_4	9.63	12.33	12.40
LSD (0.05)	1.65	2.44	2.35
CV (%)	10.61%	13.82%	12.94%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.7 Chlorophyll contents (%)

GA_3 significantly decrease the chlorophyll contents (%) at 25, 35 and 45 DAS. The maximum chlorophyll contents (%) per plant (0.41, 0.59 and 0.79 at 25, 35 and 45 DAS respectively) was recorded from G_0 and the minimum chlorophyll contents (%) per plant (0.24, 0.35 and 0.50 at 25, 35 and 45 DAS respectively) was recorded from G_2 (Fig. 14). Tsiakaras *et. al*. (2014) found the application of GA_3 resulted in decrease of chlorophyll content of leaves during the first sowing date and third sowing date.

The chlorophyll contents (%) per plant was not significantly influenced by plant spacing (Appendix VI). Treatment S_3 produced maximum chlorophyll contents (%)per plant (0.68, 0.81 and 0.98 at 25, 35 and 45 DAS respectively) and the minimum chlorophyll contents (%) per plant (0.34, 0.43 and 0.49 at 25, 35 and 45 DAS respectively) was recorded in S_1 treatment (Fig. 15).

The interaction effects of GA_3 and plant spacing were significant in respect of chlorophyll contents (%) per plant (Appendix VI). The highest (1.01, 1.10 and 1.08 at 25, 35 and 45 DAS respectively) from G_0S_4. The lowest (0.20, 0.22, 0.19 at 25, 35 and 45 DAS respectively) chlorophyll contents (%) per plant were obtained from the treatment combination G_2S_4 (Table 8).

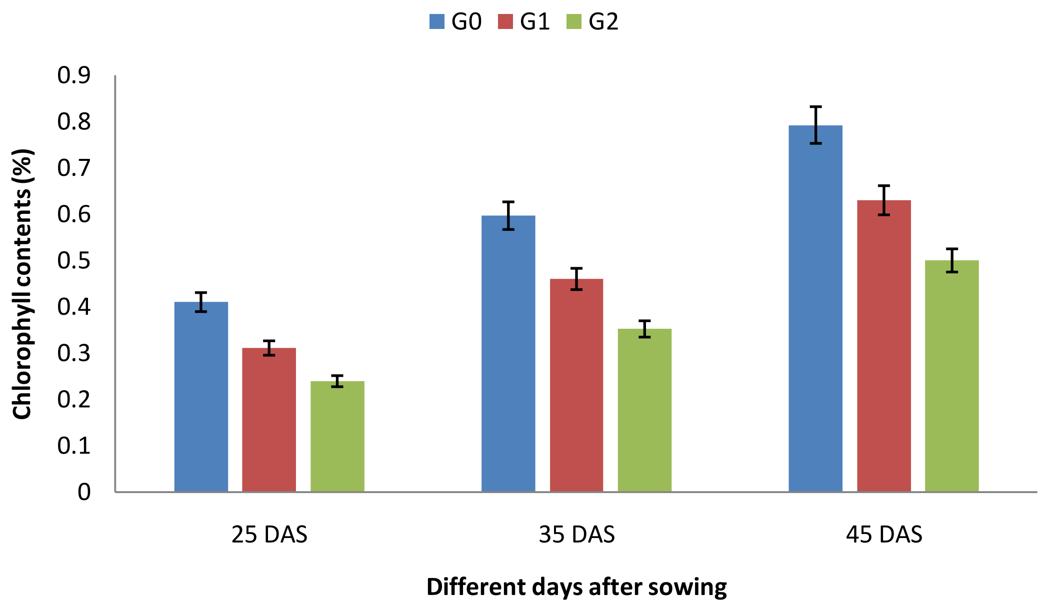


Fig 14: Effect of GA_3 on chlorophyll contents (%) of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

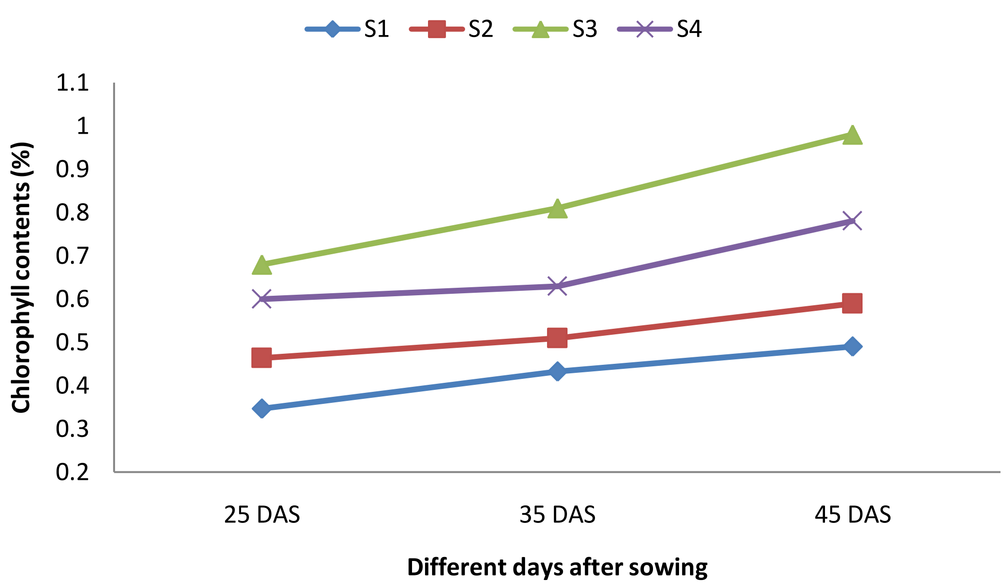


Fig 15: Effect of spacing on chlorophyll contents (%) of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 8. Combined effect of GA_3 and spacing on chlorophyll contents (%) of lettuce

Treatment	Chlorophyll contents (%)		
	25 DAS	35 DAS	45 DAS
G_0S_1	0.85	0.76	0.73
G_0S_2	0.73	0.68	0.64
G_0S_3	0.71	0.65	0.72
G_0S_4	1.01	1.09	1.08
G_1S_1	0.53	0.46	0.46
G_1S_2	0.41	0.39	0.39
G_1S_3	0.36	0.33	0.37
G_1S_4	0.35	0.39	0.36
G_2S_1	0.26	0.29	0.26
G_2S_2	0.27	0.25	0.31
G_2S_3	0.22	0.22	0.21
G_2S_4	0.20	0.22	0.19
LSD (0.05)	0.14	0.13	0.15
CV (%)	16.65%	16.66%	18.50%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.8 Gross yield of lettuce leaves (t/ha)

Gross yield of lettuce leaves was significantly influenced by the effect of GA_3 and plant spacing. The maximum yield (4.86 t/ha, 14.33 t/ha and 29.05 t/ha at 25, 35 and 45 DAS respectively) was recorded from G_1 treatment and the lowest (2.83 t/ha, 7.33 t/ha and 16.27 t/ha at 25, 35 and 45 DAS respectively) was from the G_0 treatment (Fig. 16).

The yield of lettuce leaves per hectare was found to be statistically significant due to spacing (Fig. 17). The highest gross yield (3.66 t/ha, 11.45 t/ha and 23.8 t/ha at 25, 35 and 45 DAS respectively) was obtained from S_1 and the lowest (2.45 t/ha, 7.50 t/ha and 14.82 t/ha at 25, 35 and 45 DAS respectively) was from S_4. It was revealed that in case of higher fresh weight the gross yield (t/ha) was increased by optimum spacing. C.P. Du Plooy (2009) found the similar result.

Due to combined effect of GA_3 and spacing showed significant variation on yield of lettuce leaves per hectare (Appendix VI). The highest yield of lettuce (4.99 t/ha, 12.71 t/ha and 27.73 t/ha at 25, 35 and 45 DAS respectively) was measured from G_1S_3 and the lowest yield (2.83 t/ha, 7.33 t/ha and 16.27 t/ha at 25, 35 and 45 DAS respectively) was from G_0S_4 (table 10).

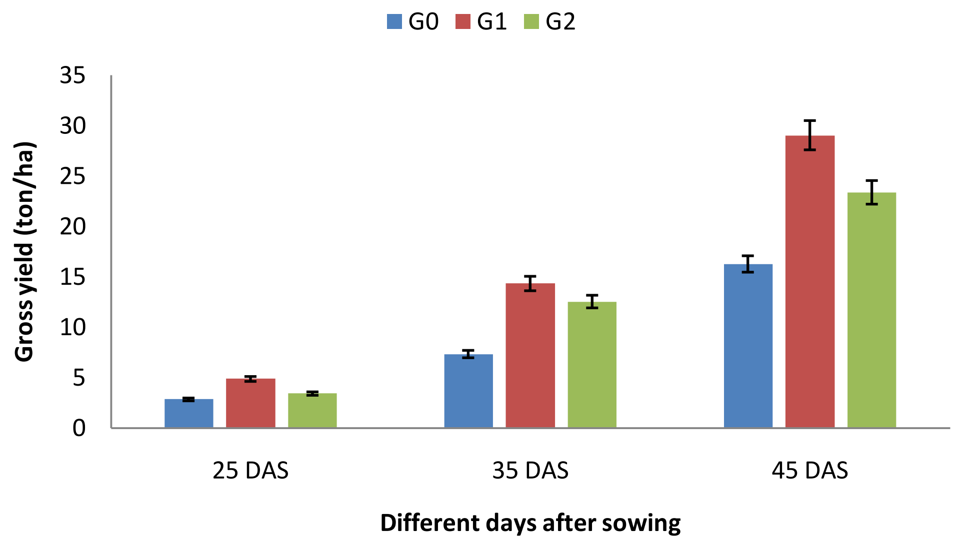


Fig 16: Effect of GA_3 on gross yield (t/ha) of lettuce at different days after sowing

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

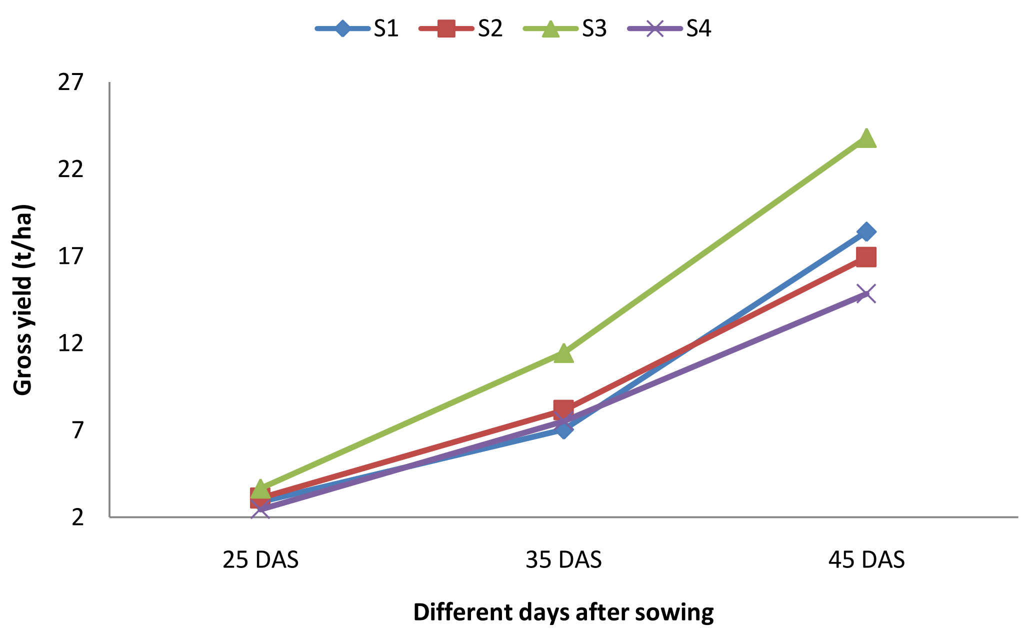


Fig 17: Effect of spacing on gross yield (t/ha) of lettuce at different days after sowing

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

Table 9. Combined effect of GA_3 and spacing on gross yield (t/ha)of lettuce

Treatment	Gross yield (t/ha)		
	25 DAS	**35 DAS**	**45 DAS**
G_0S_1	2.93	7.29	15.92
G_0S_2	2.73	7.06	12.91
G_0S_3	2.62	6.95	13.96
G_0S_4	2.06	6.34	11.80
G_1S_1	3.28	9.48	19.83
G_1S_2	3.79	9.14	22.78
G_1S_3	4.99	12.71	27.73
G_1S_4	2.59	10.51	18.50
G_2S_1	2.61	8.91	16.71
G_2S_2	2.10	8.87	17.33
G_2S_3	2.80	8.03	19.87
G_2S_4	2.54	8.35	15.50
LSD (0.05)	0.19	0.48	1.92
CV (%)	12.37%	10.37%	10.41%

LSD test at 5% level of significance

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

4.10 Cost and benefit analysis

The cost and return analysis were done and have been presented in table 10 and appendix VII. Materials (1A), non materials (1B) and over head costs were recorded for all the treatments of unit plot and calculated on per hectare basis.

The total cost of production ranges between Tk. 131750 and 125870 per hectare among the different treatment combinations. The highest cost of production Tk. 131750 per ha was involved in different types of lettuce cost and price of GA_3, while the lowest cost of production Tk. 125870 per ha was involved in the combination of no GA_3 and low cost of lettuce. Gross net return from the different treatment combinations ranged between Tk. 268800 and Tk. 146420 per ha. Among the different treatment combinations G_1S_3 gave the highest net return Tk. 137050 per ha while the lowest net return Tk. 20550 was obtained from the treatment combination G_0S_1. The benefit cost ratio (BCR) was found to be the highest (2.04) in the treatment combination G_1S_3. The lowest BCR (1.16) was recorded from G_0S_1. Thus it was apparent that G_1S_3 treatment gave the highest gross return (Tk. 137050).

Table 10. Cost and benefit of lettuce due to GA_3 and spacing treatments

Treatment combinations	Gross return (Tk./ha)	Total cost of production (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio (BCR)
G_0S_1	146420	125870	20550	1.16
G_0S_2	149760	125870	23890	1.19
G_0S_3	153600	125870	27730	1.22
G_0S_4	192000	131750	60250	1.46
G_1S_1	207350	131750	75600	1.57
G_1S_2	184320	131750	52570	1.40
G_1S_3	268800	131750	137050	2.04
G_1S_4	216000	131750	84250	1.64
G_2S_1	207360	131750	75610	1.57
G_2S_2	185840	131750	54090	1.41
G_2S_3	182000	131750	50250	1.38
G_2S_4	168000	131750	36250	1.28

GA_3= 6000tk/lit.

Lettuce=10 tk/kg

Cowdung= 10 tk/kg

Urea= 16 tk/kg

TSP= 40tk/kg

MP= 70 tk/kg

G_0= 0 ppm G_1= 25 ppm G_2= 50 ppm

S_1= 15x20 cm S_2= 20x25 cm S_3= 25x25 cm S_4= 25x30 cm

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of November, 2013 to January, 2014. The experiment consisted of two factors. Factor A: GA_3 (3 levels) GA_0: ppm (Control); GA_1: 25 ppm; GA_2: 50 ppm; Factor B: Plant spacing (4 levels), S_1: 15 cm × 20 cm, S_2: 20 cm × 25 cm; S_3: 25 cm × 25 cm and S4: 25 cm × 30 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded.

GA_3 effect was considered significant under the present study. On the growth parameters; plant height was highest with higher GA_2 (50 ppm), Number of leaves/plant, leaf length and leaf breadth were highest with optimum dose of GA_1 (25 ppm). GA_3 application increased the yield of production. At 25, 35 and 45 DAS the highest plant height (9.49 cm, 13.54 cm and 18.16 cm respectively), highest number of leaf (5.28, 10.29 and 15.57 respectively), highest length of leaf (9.49 cm, 13.54 cm and 18.16 cm respectively), highest leaf breadth (7.45 cm, 12.31 cm and 15.88 cm respectively), highest fresh weight per plant (30.35, 89.61 and 181.55 g), highest dry matter content (9.71%, 11.43% and 11.82%), highest chlorophyll percentage (0.41, 0.59 and 0.79) and gross yield (4.86 t/ha, 14.33 t/ha and 29.05 t/ha respectively) were found from GA_1 (25 ppm) whereas the lowest plant height (6.85, 11.87 and 15.57 cm), lowest number of leaves (4.56, 8.36 and 13.99), minimum leaf length (6.85, 11.87 and 15.57 cm), minimum leaf breadth (5.22 cm, 9.42 cm and 12.55 cm), minimum fresh weight (17.74, 45.84 and 101.7 g), minimum dry matter content (8.41%, 9.09% and 9.11%), minimum chlorophyll percentage (0.24, 0.35 and 0.50) and lowest gross yield (2.83 t/ha, 7.33 t/ha and 16.27 t/ha respectively) was recorded from G_0 (control) treatment.

Different plant spacing had significant effect on growth, yield and yield parameters of lettuce crop under the present study. At 25, 35 and 45 DAS the tallest plant (9.67, 13.07 and 17.36 cm respectively) was recorded from spacing; S_3 (25 cm × 25 cm) where the shortest plant (5.24, 8.76 and 11.56 cm respectively) was found from closer spacing, S_1 (15 cm × 20 cm). Again, at 25, 35 and 45 DAS, the maximum number of leaves/plant (5.74, 10.91 and

16.18respectively) was obtained from S_3 and the minimum (4.09, 7.94 and 13.39) was recorded from S_1, and at the same condition, the highest leaf length (8.27 cm, 13.12 cm and 17.50 cm respectively), leaf breadth (8.16 cm, 12.73 cm and 16.04 cm respectively), fresh weight/plant (22.98, 71.01, 138.97 g respectively) and dry matter content (10.11%, 10.76% and 11.6% respectively), highest chlorophyll percentage (0.68, 0.81 and 0.98) highest gross yield (3.66 t/ha, 11.45 t/ha and 23.8 t/ha)were observed from $S_{3.}$Whereas the leaf length (7.83 cm, 12.08 cm and 16.08 cm, respectively), leaf breadth (4.88 cm, 8.47 cm and 12.08 cm respectively), chlorophyll percentage (0.52, 0.57 and 0.55 respectively), lowest fresh weight (15.5, 37.61 and 98.54 g respectively) and dry matter content (8.62 %, 9.12 % and 8.84 % respectively) chlorophyll percentage (0.34, 0.43 and 0.49) were recorded from S_1. In terms of yield of lettuce, the lowest gross yield of lettuce observed at 25, 35 and 45 DAS (2.45 t/ha, 7.50 t/ha and 14.82 t/ha respectively) was observed from $S_{1.}$

Interaction of GA_3 and spacing had significant effect on growth, yield and yield contributing characters of lettuce crop. Results showed that at 25, 35 and 45 DAS, the tallest plant (9.67, 13.07 and 18.98 cm respectively) was recorded from G_2S_3 where the shortest plant (7.267 cm, 11.18 cm and 13.97 cm, respectively) was found from G_0S_1. Again, at 25, 35 and 45 DAS, the maximum number of leaves/plant (6.73, 12.67 and 18.80 respectively), highest leaf length (10.07 cm, 14.09 cm and 18.98 cm respectively) was found from $G_2S_{3,}$ highest yield/plot (3.09, 3.56, 4.0 and 4.39 kg, respectively) and yield/ha (6.44, 7.41, 8.31 and 9.15 t, respectively), was found from G_2S_3, but the highest leaf breadth (8.67 cm, 13.30 cm and 17.53 cm, respectively), highest chlorophyll percentage (1.01, 1.09 and 1.08 respectively from G_0S_4 treatment) fresh weight/plant (30.97, 85.43 and 182.5 g), and dry matter content (11.83%, 12.47% and 14.37% respectively), chlorophyll percentage (1.01, 1.10 and 1.08), the highest gross yield (4.99 t/ha, 12.71 t/ha and 27.73 t/ha) were obtained from $G_1S_{3.}$ On the other hand, at 25, 35 and 45 DAS, the lowest plant height (5.34, 8.76 and 11.56 cm), lowest number of leaves/plant (3.67, 7.57 and 13.00, respectively), leaf length (3.67, 7.57 and 13.00 respectively), leaf breadth (4.80 cm, 8.70 and 14.17 cm, respectively), fresh weight/plant (14.43, 27.87 and 83.87 g respectively), dry matter content (8.70%, 8.70% and 8.63% respectively), chlorophyll percentage (0.20, 0.22 and 0.19 respectively from G_2S_4), gross yield (2.83 t/ha, 7.33 t/ha and 16.27 t/ha respectively), was found from G_0S_1.

Under the present study, the ultimate goal was to achieve highest return with lettuce cultivation applying different treatment combinations and from this point of view the highest net return (Tk. 137050/ha) and BCR (2.04) were achieved from G_1S_3 where the lowest net return (Tk. 20550/ha) and BCR (1.16) were from G_0S_1.

From economic point of view, it is apparent from the above results that G_1S_3 was the most profitable than rest of the treatment combinations. For lettuce production 25 ppm GA_3 with spacing S_3 (25 × 25cm) need to be used for optimum yield and bigger economic return.

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CHAPTER VII
APPENDICES

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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2013 to January 2014

Month	***Air temperature (^{0}C)**		***Relative humidity (%)**	***Rainfall (mm) (total)**
	Maximum	Minimum		
November, 2013	25.82	16.04	78	00
December, 2013	22.4	13.5	74	00
January, 2014	24.5	12.4	68	00

* Monthly average,

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

Appendix III. Analysis of variance of the data on plant height and number of leaves of lettuce as influenced by different levels of gibberellic acid and spacing

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at			Number of leaves per plant at		
		25 DAS	35 DAS	45 DAS	25 DAS	35 DAS	45 DAS
Replication	2	0.47	0.13	0.45	0.42	1.33	0.70
Level of GA3 (A)	2	21.29*	8.46*	20.18*	1.56*	11.48*	8.56*
Level of spacing (B)	3	0.29^{NS}	2.55*	3.89*	7.59*	20.54*	14.99*
Interaction (A×B)	6	3.46*	1.78*	1.11*	1.39*	1.49*	3.90*
Error	22	0.70	0.39	0.82	0.53	1.23	1.03

*Significant at 0.05 level of probability
* NS= Non Significant

Appendix IV. Analysis of variance of the data on leaf length and leaf breadth of lettuce influenced by different levels of gibberellic acid and spacing

Source of variation	Degrees of freedom	Mean square					
		leaf length (cm) at			leaf breadth (cm) at		
		25 DAS	35 DAS	45 DAS	25 DAS	35 DAS	45 DAS
Replication	2	0.47	0.13	0.45	2.01	3.30	1.07
Level of GA3 (A)	2	21.29*	8.46*	20.18*	16.40*	26.89*	6.37*
Level of spacing (B)	3	0.29^{NS}	2.55*	3.89*	2.63*	3.10*	2.27*
Interaction (A×B)	6	3.46*	1.78*	1.11*	1.35*	1.98*	1.07*
Error	22	0.70	0.39	0.82	0.39	0.45	0.80

*Significant at 0.05 level of probability
* NS= Non Significant

Appendix V. Analysis of variance of the data on fresh weight and dry weight of lettuce influenced by different levels of gibberellic acid and spacing

Source of variation	Degrees of freedom	Mean square					
		fresh weight (g) at			dry weight (g) at		
		25 DAS	35 DAS	45 DAS	25 DAS	35 DAS	45 DAS
Replication	2	0.58	6.17	23.29	0.62	0.17	0.20
Level of GA3 (A)	2	10.04*	36.41*	1207.74*	5.58*	17.47*	23.23*
Level of spacing (B)	3	11.18*	24.64*	2695.29*	4.11*	13.94*	20.19*
Interaction (A×B)	6	1.76*	7.56*	85.18*	2.62*	3.08*	3.39*
Error	22	0.61	4.20	61.52	0.95	2.08	1.90

*Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on chlorophyll percentage and gross yield (ton/ha)of lettuce influenced by different levels of gibberellic acid and spacing

Source of variation	Degrees of freedom	Mean square					
		chlorophyll percentage(%) at			gross yield (ton/ha) at		
		25 DAS	35 DAS	45 DAS	25 DAS	35 DAS	45 DAS
Replication	2	0.003	0.004	0.003	0.02	0.12	0.78
Level of GA3 (A)	2	1.088*	0.980*	0.960*	0.18*	0.56*	21.47*
Level of spacing (B)	3	0.025*	0.048*	0.022*	1.04*	13.01*	120.81*
Interaction (A×B)	6	0.027*	0.430*	0.053*	0.05*	0.10*	2.11*
Error	22	0.007	0.006	0.008	0.01	0.08	1.29

*Significant at 0.05 level of probability

Appendix VII. Production cost of lettuce per hectare

(A) Material cost (Tk.)

Treatment Combination	Seed (Kg/ha)	GA_3	Fertilizer				Sub total 1 (A)
			Cowdung	Urea	TSP	MP	
G_0S_1	6140	0	13200	6000	8600	9700	43640
G_0S_2	6140	0	13200	6000	8600	9700	43640
G_0S_3	6140	0	13200	6000	8600	9700	43640
G_0S_4	6140	4900	13200	6000	8600	9700	48540
G_1S_1	6140	4900	13200	6000	8600	9700	48540
G_1S_2	6140	4900	13200	6000	8600	9700	48540
G_1S_3	6140	4900	13200	6000	8600	9700	48540
G_1S_4	6140	4900	13200	6000	8600	9700	48540
G_2S_1	6140	4900	13200	6000	8600	9700	48540
G_2S_2	6140	4900	13200	6000	8600	9700	48540
G_2S_3	6140	4900	13200	6000	8600	9700	48540
G_2S_4	6140	4900	13200	6000	8600	9700	48540

(B) Non-material cost (Tk./ha)

Treatment combination	Land preparation	Seed sowing	Intercultural operation	Harvesting	Sub total (B)	Total input cost 1 (A) + 1 (B)
G_0S_1	13500	8300	8250	8700	38750	82390
G_0S_2	13500	8300	8250	8700	38750	82390
G_0S_3	13500	8300	8250	8700	38750	82390
G_0S_4	13500	8300	8250	8700	38750	87290
G_1S_1	13500	8300	8250	8700	38750	87290
G_1S_2	13500	8300	8250	8700	38750	87290
G_1S_3	13500	8300	8250	8700	38750	87290
G_1S_4	13500	8300	8250	8700	38750	87290
G_2S_1	13500	8300	8250	8700	38750	87290
G_2S_2	13500	8300	8250	8700	38750	87290
G_2S_3	13500	8300	8250	8700	38750	87290
G_2S_4	13500	8300	8250	8700	38750	87290

Appendix VII. Contd.

(C) Overhead cost and total cost of production (Tk.)

Treatment combinations	Cost of lease of land	Miscellaneous cost (5% of input cost)	Interest on running capital for 6 months (15% of the total input cost)	Total	Total cost of production (input cost + interest on running capital, Tk/ha)
G_0S_1	27000	4120	12360	43480	125870
G_0S_2	27000	4120	12360	43480	125870
G_0S_3	27000	4120	12360	43480	125870
G_0S_4	27000	4365	13095	44460	131750
G_1S_1	27000	4365	13095	44460	131750
G_1S_2	27000	4365	13095	44460	131750
G_1S_3	27000	4365	13095	44460	131750
G_1S_4	27000	4365	13095	44460	131750
G_2S_1	27000	4365	13095	44460	131750
G_2S_2	27000	4365	13095	44460	131750
G_2S_3	27000	4365	13095	44460	131750
G_2S_4	27000	4365	13095	44460	131750