EFFECT OF ZINC AND SALICYLIC ACID ON THE GROWTH AND YIELD OF BROCCOLI

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CERTIFICATE

*This is to certify that the thesis entitled, **"Effect of Zinc and Salicylic Acid on the Growth and Yield of Broccoli"** submitted to the Department of Horticulture, 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 bona fide research work carried out by **Jesmin Akter**, Registration No. **11-04353** 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 and style of this thesis have been approved and recommended for submission.

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ABSTRACT

An experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University and Dhaka, Bangladesh during the period from October 2016 to February 2017. BARI broccoli-1 was selected for experimental crop. The experiment consisted of two factors. Factor A: four levels of Zinc i.e. Z_0: control,(0 ppm), Z_1: 10 ppm, Z_2:20 ppm, Z_3: 30 ppm and Factor B:three levels of Salicylic acid i.e S_0: control (0 mM), S_1:0.3 mM, S_2: 0.6 mM. This experiment was laid out in a Randomized Complete Blocked Design with three replications. Zinc and Salicylic acid influenced significantly on most of the parameters. For Zinc treatments Z_2 performed best in case of plant height, number of leaves, leaf length, leaf breadth and also in diameter of curd (14.84 cm) and yield 15.87 t/ha and minimum in Z_0. On the other hand,for salicylic acid treatment S_1 performed best in case of plant height, number of leaves, leaf length, leaf breadth and also in diameter of curd (14.78 cm) and yield 15.37 t/ha and minimum in S_0. In combined effect, the highest yield (16.99 t/ha) was obtained from Z_2S_1 and the lowest (11.94t/ha) in Z_0S_0. So, 20 ppm zinc with 0.3 mM salicylic acid combinedly performed the best for the growth and curd formation of broccoli.

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ABBREVIATIONS AND ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	: Agro-Ecological Zone
ANOVA	: Analysis of Variance
CV%	: Percentage of Coefficient of Variation
df	: Degrees of freedom
DM	: Dry matter
et al.	: and others
FAO	: Food and Agricultural Organaization
GA_3	: Gibbrellic Acid
SAU	: Sher-e-Bangla Agricultural University
BAU	: Bangladesh Agricultural Universiry
BBS	: Bangladesh Bureau of Statistics
DAT	: Day after Transplanting
LSD	: Least Significant Difference

CHAPTER I

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica* L.) belongs to the family Brassicaceae is a biennial and herbaceous “Cole” crop. In western countries broccoli is highly popular as fresh as well as frozen vegetables. Vitamin C content in fresh broccoli is almost twice than that in cabbage and cauliflower. It is also rich in carotene and contains appreciate quantities of thiamin, riboflavin, niacin and iron (Thomson and Kelly, 1985; Rahman 1988). Broccoli helps to lower the cholesterol and lessen the impact of allergy-related substances in our body. Isothiocyanates (ITCs) are the detox-regulating molecules made from broccoli's glucosinolates and they help to control the detox process at a genetic level. The unique combination of antioxidant, anti-inflammatory and prodetoxification components in broccoli make it a unique food in terms of cancer prevention (Mateljan 2009).

In Bangladesh broccoli was introduced about two decade ago and it is planted in early September to late November (Ahmad and Shahjahan, 1991) when there is low precipitation and high evapotranspiration. It is gradually becoming popular in Bangladesh among the urban people and the Chinese restaurants together with the grand hotels are using broccoli for making soup and other delicious foods creating demand for the vegetable. There is a good scope of its cultivation in Bangladesh for increasing vegetable diversification and to meet vegetable demand of the country. This vegetable could easily be cultivated in the normal farming field. In Bangladesh broccoli is commercially cultivated in Rajshahi, Gazipur and Dhaka district. Nutritive value of the crop was more than any other winter vegetable including cabbage and cauliflower. But the price of broccoli in the markets is three to four times more than cauliflower. Vegetables were grown in 9,26,000 acres of land and the total production was approximately 33,57,000 metric tons during the year 2013-2014 with an average yield of 3,625 kg per acre (BBS, 2016).

The production of broccoli is influenced by the application of fertilizers and it is evident that balanced application of fertilizer is the prerequisite for obtaining higher yield and better quality of broccoli (Brahma *et al.* 2002). Among the micronutrients, occurrence of zinc (Zn) deficiency is quite common and widespread. Zinc is an indispensable micronutrient for proper plant growth and development. It plays an important role in different plant metabolic processes such as enzyme activity, development of cell wall, respiration, photosynthesis, chlorophyll formation and other biochemical functions. It is essential component of many enzymes such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase etc and also involved in nitrogen metabolism. The deficiency of Zn in plants disrupts these processes resulting in reduced plant growth, yield and quality. (Tisdale *et. al.*1998). In Zn deficient plants, middle leaves show development of golden yellow or orange color in the interveinal portion. The young leaves remain small in size and often termed as “little leaf” or “rosetting” (Shanmugavlu,1998).

Salicylic acid (SA) is a plant-produced phenolic compound and plant hormone. SA has being important with the discovery of different important roles of it in plant developmental processes (Horvath *et. al.* 2007). Application of SA increased biosynthesis of chlorophyll (chl) *a*, chl *b* and carotenoid, and maintained membrane integrity. SA-pretreated plants accumulated more K+ and soluble sugars in roots. Improvement of these physiological features leaded to improved plant growth (Tayeb, 2005). Using salicylic acid (SA) as an active practice to facilitate the plant growth where it can play an important role in alleviating the deleterious effects of several environmental stresses on plants and which one high temperature, drought (Singh & Usha, 2003) and salinity (Yildirim *et al.*, 2008) stresses. Many researchers clarified several beneficial effects of SA such as it can play a significant role in plant water relations (Barkosky & Einhelling, 1993), photosynthesis, growth rate and stomatal regulation (Khan *et al*., 2003; Arfan *et al*., 2007), as well as ion uptake and transport (Gunes *et al*., 2005) and membrane permeability.

But the study on the impact of different boron and salicylic acid on broccoli plant has not been done adequately. Therefore, the present experiment has been done with the following objectives:

a) To evaluate the effect of zinc on growth and yield of broccoli
b) To study the effect of salicylic acid on the growth and yield of broccoli
c) To study the combined effect of zinc and salicylic acid on growth and yield of broccoli.

CHAPTER II

REVIEW OF LITERATURE

Growth and yield of broccoli have been studied in various parts of the world, but a little study has been done on this crop under the agro-ecological condition of Bangladesh. However, available information portioning to this study was reviewed in the following headings.

2.1 Zinc related

Quratul *et.al.* (2016) reported that zinc at the rate of (0, 0.25, 0.5, and 1.0%) was applied as a foliar spray using RCBD with three replication. Maximum plant height (40.49 cm) and number of leaves plant^{-1} (13.08), were noted at 0.5 % Zn, while Zn @ 1% resulted in maximum leaf weight (9.66 g) and maximum number of curd plant^{-1}(9.17). . Among various treatments used zinc levels at the rate of 0.5%, showed better result in most of the growth and yield parameters.

Miroslav *et. at.* (2016) described that the foliar Zn spraying led to a statistically highly significant increase of sulforaphane in broccoli (about 41.1%) compared to the control. The applied N and S fertilization tended to decrease the vitamin C content in broccoli (about 9.2%) against the control. On the other hand, Zn application resulted in a return of the vitamin C content, nearly to its level in control. The results confirmed the well-known fact that nitrogen fertilization leads to nitrate accumulation in vegetables. However, the results of this research indicate that nitrogen fertilization combined with zinc application should be expressed mainly by lower nitrate accumulation in the edible parts of broccoli. The experimental data are interesting, and in terms of growing vegetables for consumption with enhanced quality, promising.

Yadav *et. al.* (2015) mentioned that foliar application of nitrogen and zinc effect the quality of cauliflower (*Brassica Oleracea* var. *Botrytis* L.) cv. Snowball-16. The experiment was laid out in RCBD with foliar application of four nitrogen levels (0, 1.0, 1.5, 2.0%) and four levels of zinc (0, 10, 15, 20 ppm). Result show that Nitrogen 1.5% significantly increased dry weight of curd, compactness of curd and colour of curd. Whereas, maximum total soluble solids in curds was recorded in nitrogen 2.0%. Zinc had also significant effect on dry weight of curd, compactness of curd and colour of curd. The double foliar spray (30 and 45 DAT) of 1.5 per cent nitrogen and 15 ppm zinc individually found to be best for yield and growth parameter.

Kant *et. al.* (2013) conducted an experiment at permanent vegetable farm, Bihar Agricultural College, Sabour, Bhagalpur during two consecutive Kharif seasons of 2007-08 and 2008-09. The treatments comprised of four basal dose of boron in form of borax (0, 5, 10 and 15 kg/ha) and Zinc in the form of zinc sulphate (0, 10, 20 and 30 kg/ ha). There were 16 treatment combinations. The experiment was laid out in Randomized Block Design, replicated thrice. The hybrid used was Himani. All the experimental plots uniformly received 200 kg N, 100 kg P_2O_5 and 80 kg K_2O per hectare. The plant height, number of leaves per plant, biological yield, curd weight and marketable yield were found highest with combined soil application of 20 kg $ZnSO_4$ + 10 kg B/ha which showed statistical equality with 30 kg $ZnSO_4$ + 10 kg B/ha.

Rathore and Chaudhary (2011) observed significant increase in protein content upto 20 kg S $ha^{-1}$and 2.5 kg ha^{-1} Zn in mustard (*Brassica juncea* L.). Babu and Singh (2001) reported that foliar application of 0.6 per cent Zn significantly increased the ascorbic acid content of the fruit in litchi.

Lashkari *et. al.* (2007) reported that foliar sprays of Fe and Zn considering three concentrations of Zn (0.0, 0.25, 0.5 and 1.0%) and three concentrations of Fe (0.0, 0.25, 0.5 and 1.0%) at 30 and 60 days after transplanting of seedlings. The results indicate that leaf area (cm^2) and marketable yield (q/ha) were found significantly highest with combined foliar sprays of zinc and iron at 0.25% concentration each. The non-significant results were obtained on minimum days taken for curd initiation and curd maturity with different combine foliar sprays of zinc and iron at 0.0, 0.25, 0.5 and 1.0% concentration each. However, the minimum days taken for curd initiation and curd maturity were recorded with individual foliar sprays of zinc and iron at 0.25%.

Zhao Yong-hou (2006) reported that foliar applications of Zn and B micronutrient fertilizers could obviously increase yield and improve quality of cabbage. The effect of the combined application of Zn and B (Zn0.25 + B3.50) on cabbage was the best. Its production-increasing ratio had reached to 32.2 per cent. It was clear that the B fertilization had better effect than the Zn fertilization on yield because the production-increasing ratio of B fertilization was 16.1 per cent higher than Zn fertilization.

The results of experiment conducted during *rabi,* 2001 and *kharif,* 2002 on response of cabbage Var Golden Acre revealed that foliar application of Zn @ 100 ppm gave maximum plant height during both the seasons (Kanujia *et al*., 2006).

Annie and Duraisami (2005) observed the significantly highest curd yield of (28.79 t ha^{-1}) with the combined application of 1.0 kg borax ha^{-1} and 2.5 kg $ZnSO_4$ ha^{-1}, which was 35.5 per cent more than the yield recorded in control. However the treatment was found to be better than individual application of various levels of borax and $ZnSO_4$ and any other combinations.

Feng *et. al.*(2005) reported that that 0.05, 5 and 10 mg/L Zn were benefit to broccoli growth, especially 10 mg/L. 0, 50, 100, 200 mg/L Zn were unfavorable for broccoli growth. The content of chlorophyll a and chlorophyll b, seedling height, leaf areas Pn and dry weight of single seedling under 10 mg/L Zn treatment of zinc solution increased 32.78 %, 39.02 %, 10.01 %, 10.85 %, 45.81 % and 13.13 %, respectively, compared with the treatment without zinc. Compared with 0.05 mg/L zinc treatment, these indexes increased 20.15 %, 27.72 %, 9.18 %, 13.10 %, 13.55 % and 5.00 %, respectively.

Ravichandran *et al*. (2005) observed that soil application of $ZnSO_4$ in combination with 0.5 percent foliar spray led to significant enhancement in the ascorbic acid content of the fruit in brinjal.

Varghese and Duraisami (2005) were conducted an experiment in farmer's holding in a sandy loam soil to study the effect of B and Zn on the yield and nutrients uptake of cauliflower. The highest curd yield of 28.79 t ha^{-1} was realized by the application of 1.0 kg B ha^{-1} and 2.5 kg Zn ha^{-1}, which was 35.5 per cent over the yield recorded in control. The combined application of these nutrients beyond these levels tended to reduce the curd yield in cauliflower. Application of 1.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1} was found to be better than individual application of various levels of B and Zn and any other combinations of these two elements in terms of nutrient uptake and soil fertility. Application of B increased the availability of all nutrients, while the application of Zn especially at higher level (5.0 kg Zn ha^{-1}) decreased the availability of Cu and Fe.

Prasad and Yadav (2003) also suggested that foliar application of borax @ 0.3 per cent for better growth (Plant height, number of leaves per plant root length, stem length, stem diameter and plant weight) and improvement in yield attributing characters (curd height, curd weight and curd diameter).

In a trial conducted with cabbage cv. pride of India, soil application of Zn as $ZnSO_4$ 10 kg ha^{-1} or two foliar application of $ZnSO_4$ (0.5 %) enhanced yields and zinc content in leaf (Iyengal *et al*., 1997).

Singh (1996) also observed marked response of Zn application and the mean per cent response was 70 per cent in Zn deficient soils at 5 ppm added Zn level.

Also noticed that application of NAA at 100 ppm with 0.2 or 0.3 per cent chelated Zn increased yield of cabbage Cv. pride of India, significantly.

Pandey *et al*. (1994) reported that cauliflower grown in Zn deficient soil responded markedly in terms of yield and quality to the applications of 20 kg $ZnSO_4$ ha^{-1}.

Singh and Thakur (1991) reported that highest curd yield of cauliflower was recorded when the plants were sprayed with zinc at 1.2%.There was increase in protein content and dry matter percentage with increasing levels of Zn, while the highest ascorbic acid content was recorded by foliar application with 0.6 to 0.9 per cent Zn.

Balyan and Dhankhar (1988) observed that application of 20 kg $ZnSO_4$ ha-1 increased the curd size index (189 cm^2) and marketable yield (201g ha-1) of cauliflower significantly.

Iyengal and Raja (1988) conducted an experiment on cabbage cv. pride of India for two years and found that fritted Zn at 5 kg ha^{-1} gave the highest cabbage yield.

Iyengal *et al*. (1997) reported that, application of $ZnSO_4$ @ 10 kg ha^{-1} increase in the carbonic andhydrase activity in cabbage.

Znic plays essential metabolic roles in plants of which the most significant is its activity as a component of a variety of enzymes, such as dehydrogenases proteinases, peptidases and phosphohydrolases. The basic zinc function in plants are related to metabolism of carbohydrates, proteins, phosphates and also of auxins, RNA and ribose formations (Shkolnik, 1974).

2.2 Salicylic acid related

Parvin and Haque (2017) reported that salicylic acid (SA), an endogenous plant growth regulator has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development. Broccoli plant was grown under saline condition with foliar application of SA as alleviating agent for salt toxicity. Plants were treated with 0, 4 and 8 dS m^{-1} concentration of NaCl solution along with three levels of foliar application of SA such as 0, 0.25 and 0.50 mM. Growth and development of broccoli was gradually decreased under increasing level of salinity and mostly hampered at 8 dS m^{-1}. Plant height, leaf size, foliage coverage as well as curd size and weight were also reduced at 8 dS m^{-1} of salinity. SA worked against the induced toxicity by salinity through improving growth behavior, yield component and yield. The improvement of plant height, leaf size (leaf length and breadth), foliage coverage, stem diameter, curd length, breadth and weight were enhanced with increasing concentration of SA where 0.25 mM of SA showed the better result. This study concludes that exogenous foliar spray of SA mitigates the salt toxicity in broccoli cultivation by improving morphology and yield contribution.

Kareem *et. al.* (2017) reported that salicylic acid and molybdenum improved the performance of both varieties of Iraqi wheat under both well watered and drought conditions. However, salicylic acid had a better general effect than molybdenum, although the difference was not significant in some of the studied parameters. The application of salicylic acid at a relatively low concentration was shown to have the most positive impact on the physiological, yield and growth parameters.

Kazemi (2014) reported that salicylic acid (0. 5 mmolL^{-1}) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 mmolL^{-1}) significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom end rot. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid. Application of salicylic acid improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Mirdad (2014) observed that that broccoli plants grown under saline water that receiving K+ at concentration 1000 mg l^{-1} as foliar application were recorded minimum the deleterious impacts of salinity stress and achieved maximum plant height, number of leaves and branches, leaf area per plant, the main, secondary and total curd yield (t ha^{-1}) and water use efficiency (WUE) over control treatment. Furthermore, the curd diameter (of main and secondary), curd weight (of main, secondary and plant) dry matter percentage of the curds and the leaf and curd mineral contents (N, P and K%) were improved with foliar application of K up to 1000 mg l^{-1}. Moreover, the vegetative growth, cruds yield and its quality, WUE and leaf and crud mineral contents of broccoli plants irrigated with saline water increased significantly and successively as the SA concentration was increased up to 200 mg l^{-1}.

Kazemi (2013) reported that salicylic acid (0.25 mM) and calcium chloride (2.5 mM) spray either alone or in combination (0.25 mM SA+2.5 mM Ca) affected on vegetative and reproductive growth, significantly. Mean comparisons indicated yield, and quality of strawberry plants was improved in low salicylic acid and calcium chloride concentration. In Finally, salicylic acid and calcium chloride application can be helpful for yield improvement and prevent of decreasing yield.

Ali and Adel (2012) reported that four salicylic acid concentrations (0, 50, 100 and 150 ppm) were assigned to the main plots. While, four foliar application concentrations of zinc (0, 300, 400 and 500 ppm) were applied to the sub-plots. The results showed that foliar application of salicylic Acid (SA) enhanced significantly ($p \leq 0.05$) plant height, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seeds weight, seed weight plant^{-1} and seed yield ha^{-1} as compared with control (untreated plants) and the superiority was due to the high SA concentration (150 ppm). Significant ($p \leq 0.05$) increases in all above mention traits were occurred with foliar application of zinc as compared with untreated plants. Furthermore, the highest values of these traits were registered at application of 500 ppm zinc which showed insignificant difference at application of 400 ppm zinc. Also, the results showed that the interaction between salicylic acid and zinc nutrient had a significant effect on all studied traits. Application of 150 ppm SA with 500 or 400 ppm zinc produced the highest significant seed yields ha^{-1}.

Javaheri *et. al.*(2012) observed that foliar application of five concentrations of salicylic acid (0, 10-2, 10-4, 10-6, 10-8 M) were used. Results showed that application of salicylic acid affected tomato yield and quality characters of tomato fruits so that tomato plants treated with salicylic acid 10-6 M significantly had higher fruit yield (3059.5 g per bush) compared to non-treated plants (2220 g per bush) due to an increase in the number of bunch per bush. Results also indicated that application of salicylic acid significantly improved the fruit quality of tomato. Application of salicylic acid increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits. Fruit of tomato plants treated with salicylic acid 10-2M significantly had higher vitamin C (32.5 mg per 100 g of fruit fresh weight) compared to non treated plants (24 mg per 100g fruit fresh weight). Salicylic acid concentration 10-2 M also increased the diameter of fruit skin (0.54 mm) more than two fold compared to control (0.26 mm). Fruit Brix index of tomato plants treated with salicylic acid 10-2M significantly increased (9.3) compared to non-treated plants (5.9). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Khandaker *et. al.* (2011) stated that salicylic acid (SA) was applied at three different concentrations (10^{-3}, 10^{-4} and 10^{-5} M), three times during the vegetation at 7-day intervals one week after sowing. Growth parameters (plant height, stem length, number and size of leaves, root length) and yield (fresh and dry matter weight) were recorded from treated and control plants on 28 days after sowing. Among bioactive compounds, betacyanins, chlorophyll, total polyphenol and antioxidant activity were the determined from the leaves of treated and control plants. All of three doses SA application enhanced the plant growth, yield and leaf's bioactive compounds compared to the control. The growth parameters and yield of red amaranth was significantly influenced by foliar SA applications. The highest yield, antioxidant activity, amount of betacyanins, chlorophyll and total polyphenol occurred in 10^{-5} M SA treatment.

Mady (2009) was conducted an experiment to study the effect of foliar application of 50 & 100 ppm of salicylic acid (SA). Results indicated that, different applied treatments significantly increased all studied growth parameters as number of branches and leaves per plant, leaf area per plant and leaves dry weight as well. Also increased photosynthetic pigments, NPK, Fe, Zn, Mn, total carbohydrates and crude protein concentrations in leaves of treated plants as compared with those of untreated ones. The highest early and total yields were obtained from salicylic acid 50ppm followed by SA 100ppm, respectively. In addition, chemical composition of minerals and some bioconstituents such as carbohydrates, vitamin C, total soluble solids in tomato fruits were also increased at the same treatments.

Dursun and Yildirim (2009) reported that tomato plants were treated with foliar SA applications at different concentrations (0.00, 0.25, 0.50 and 1.00 mM). SA was applied with spraying four times during the vegetation at 10-day intervals two weeks after planting. In the study, it was determined that foliar applications of SA showed positive effect on some fruit characteristics, plant growth, chlorophyll content in leaves, early yield and total yield. SA treatments had no effect on pH, AA and TA of tomato. Total soluble solids (TSS) increased with foliar SA applications. The greatest stem diameter, leaf dry matter and chlorophyll content were obtained from 0.50 mM SA treatment. SA treatments increased the early yield of tomato compared to the control. The yield of tomato was significantly influenced by foliar SA applications. The highest yield occurred in 0.50 mM SA treatment. According to our results, applications of 0.50 mM SA should be recommended in order to improve yield.

Hayat and Ahmad (2007) reported that salicylic acid is a plant growth regulator that increases plant bio-productivity. Experiments carried out with ornamental or horticultural plants in greenhouse conditions or in the open have clearly demonstrated that they respond to this compound. Moreover, lower quantities of SA are needed to establish positive responses in the plants. The effect on ornamental plants is expressed as the increase in plant size, the number of flowers, leaf area and the early appearance of flowers. In horticultural species, the effect reported is the increase of yield without affecting the quality of the fruits. It is proposed that the increase in bio-productivity is mainly due to the positive effect of SA on root length and its density.

Yildirim *et. al.*(2007) reported that cucumber seedlings were treated with foliar salicylic acid (SA) applications at different concentrations (0.0, 0.25, 0.50, and 1.00 mM). Salinity treatments were established by adding 0, 60, and 120 mM of sodium chloride (NaCl) to a base complete nutrient solution. The SA was applied with spraying two times as before and after transplanting.

However, foliar applications of SA resulted in greater shoot fresh weight, shoot dry weight, root fresh weight, and root dry weight as well as higher plants under salt stress. Shoot diameter and leaf number per plant increased with SA treatments under salt stress. The greatest chlorophyll content was obtained with 1.00 mM SA treatment in both saline and non-saline conditions. Leaf water relative content (LWRC) reduced in response to salt stress while SA raised LWRC of salt stressed cucumber plants. Salinity treatments induced significant increases in electrolyte leakage. Plants treated with foliar SA had lower values of electrolyte leakage than non-treated ones. In regard to nutrient content, it can be interfered that foliar SA applications increased almost all nutrient content in leaves and roots of cucumber plants under salt stress. Generally, the greatest values were obtained from 1.00 mM SA application. Based on these findings, the SA treatments may help alleviate the negative effect of salinity on the growth of cucumber.

CHAPTER III

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. It contains a short description of location of the experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc.

3.1 Location of the experimental plot

The experiment was conducted at the Central Farm of the Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2016 to February, 2017. The site is 90.2^0N and 23.5^0E Latitude and at an altitude of 8.2 m from the sea level.

3.2 Characteristics of soil

The soil of the experimental area was non- calcareous, dark gray, medium high land. The soil texture was silty loam with a pH 6.7. Soil samples of the experimental plot were collected from a depth of 0 to 30 cm before conducting the experiment. Soil was analyzed in the Soil Resources Development Institute (SRDI) Farmgate Dhaka. The experimental site was a medium high land.

3.3 Climatic condition

The experimental area was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season and scanty in the Rabi season (October to March). There was no rainfall during the month of October, November, December and January. The average maximum temperature during the period of experiment was 26.82˚C and the average minimum temperature was 17.14˚C. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the period of the experiment were collected from Weather Station of Agargaon, Dhaka.

3.4 Agro-ecological region

The experimental field belongs to the agro-ecological region of the Modhupur Tract (AEZ-28). The landscape comprises level upland, closely or broadly dissected terraces associated with either shallow or broad, deep valleys.

3.5 Experimental materials

"BARI Broccoli-1" a variety of broccoli has been used as experimental material.

3.6 Experimental treatments

Treatments were as follows:

Factor A: Zinc level

1) Z_0: control
2) Z_1: 10 ppm
3) Z_2 :20 ppm
4) Z_3: 30 ppm

Factor B: Salicylic acid level

1) S_0 – control (0 mM)
2) S_1– 0.3 mM
3) S_2 – 0.6 mM

3.7 Experimental design and layout

The experimental treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into 3 blocks with 12 unit plots of 4.8m^2 (2.4 m x 2 m) size in each block. Thus the total number of unit plots were 3x 12 = 36. The distance maintained between two unit plots was 0.5 m and that between blocks 1.0 m.

3.8 Crop husbandry

3.8.1 Raising of seedlings

For raising seedlings, the soil was ploughed and converted into loose friable and dried masses. All weeds, stubbles and dead roots were removed. Cow dung was applied to the prepared seed beds at the rate of 10 t/ha. The seeds were sown in the seed beds of 2.5m x lm size on 26 October 2016. After sowing, the seeds were covered with a thin layer of soil. When the seeds germinated, shade by bamboo mat (Chatai) was provided to protect the young seedlings from scorching sun-shine and rain. Light watering, weeding and mulching were done as and when necessary. No chemical fertilizers were applied for raising the seedlings. Seedlings were not attacked by any kind of insects or diseases. Seed germination started at 29 October 2016. The healthy 26 days old seedlings were transplanted in the experimental field on 25 November 2016.

3.8.2 Land preparation

The land was preparation was started at 18 November 2016 by ploughing and cross ploughing followed by laddering. The corner of the land was spaded and visible large clods were broken into small pieces. Weeds and stubbles were removed from the field. The layout of the experiment was done in accordance with the design adopted. Finally, individual plots were prepared by using spade before organic manure application.

3.8.3 Fertilizer application

Fertilizers like urea, MP and TSP are applied as per BARI recommendation rate. The whole amount of fertilizer MP and TSP were incorporated at the time of final land preparation. And urea was applied as in three equal doses.

3.8.4 Transplanting and after care

Healthy 26 days old seedlings were transplanted on 25 November, 2016 in the afternoon and light irrigation was given around each seedling for their better establishment. Each unit plot accommodated 12 plants. The transplanted seedlings were protected from scorching sunlight early in the morning by providing shed using banana leaf sheath and remove just before sun set daily, until the seedlings were established. A number of seedlings were planted in the border of the experimental plots for gap filling.

3.8.5 Zinc and Salicylic acid application

Four concentration of zinc (0ppm, 10ppm, 20ppm, 30ppm) were applied on the sub-plots. While, three concentration of salicylic acid (0 mM,0.3mM, 0.6mM) were assigned to the sub-plots. Zinc sulphate was used as a source for zinc. From 1 kg of zinc sulphate I was taking 0, 10ppm, 15ppm, 20ppm concentration of zinc. Salicylic acid was initially dissolved in 100µL dimethyl sulfoxide and concentration were made up with distilled water and applied to the plant. Both were applied by the hand sprayer as foliar spray to the canopy of the plant at 25DAT, 40DAT, 55DAT.

3.8.6 Gap filing

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

3.8.7 Intercultural operation

3.8.8 Weeding

Weeding was done three times in each plot to keep the plot clear.

3.8.9 Irrigation

Light irrigation was given just after transplanting of the seedlings. A week after transplanting the requirement of irrigation was envisaged. Wherever the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.8.10 Pest and Disease control

Few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Cut worms were controlled both mechanically and spraying Diazinon 60 EC @ 0.55 Kg per hectare. Some of the plants were infected by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2g /liter of water was sprayed in the field. Bird pests such as Nightingale (Common Bulbuli) visited the fields from 8 to 11 a.m. and 4 to 6 p.m. The birds were found to make puncture in the soft leaves and initiating curd and they were controlled by striking of a metallic container.

3.8.11 Harvesting

The harvesting was not possible to be done on a particular date because curd initiations as well as curd maturation period in different plants were not similar probably due to genetic characters of varieties. The compact mature curds were only harvested. After harvesting the main curd, secondary shoots were developed from the leaf axils and produced small secondary curds. Those were harvested over a period of time. The crop under investigation was harvested for the first time on 29 January, 2017 and the last harvesting was done on 9 February, 2017. The curds were harvested in compact condition before the flower buds were opened (Thompson and Kelly, 1988).

3.9 Methods of Data collection

The data pertaining to the following characters were recorded from five (5) plants randomly selected from each unit plot, except yield of curds which was recorded plot wise. Data on plant height, number of leaves, leaf length were collected at 30, 40, 50 and 60 days after transplanting. All other parameters were recorded at harvest. Data on the above mentioned crop characters were as follows:

- Plant height
- Number of leaves per plant
- Leaf length
- Leaf breadth
- Length of stem
- Diameter of stem
- Diameter of curd
- Percent dry matter of plant
- Percent dry matter of curd
- Weight of curd
- Yield per plot
- Yield per hectare

3.9.1 Plant height (cm)

The height of each sample plant was measured unit plot wise from the base to the tip of main stem of the five randomly selected plants and then averaged.

3.9.2 Number of leaves per plant

The number of leaves of each sample plant was counted unit plot wise from five randomly selected plants and then averaged.

3.9.3 Leaf length (cm)

A meter scale was used to measure the length of leaves. Leaf length of five randomly selected plants was measured in centimeter (cm) at harvest. It was measured from the base of the petiole to the tip of the leaf. All the leaves of each plant were measured separately. Only the smallest young leaves at the growing point of the plant were excluded from measuring.

3.9.4 Leaf breadth (cm)

Leaf breadth of five randomly selected plants was measured in centimeter (cm) at harvest from the widest part of the lamina with a meter scale and average breadth was recorded in centimeter (cm). All the leaves of each plant were measured separately. Only the smallest young leaves at the growing point of the plant were excluded from measuring.

3.9.5 Length of stem (cm)

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

3.9.6 Diameter of stem (cm)

The diameter of the stem was measured at the point where the central curd was cut off. Stem diameter was recorded in three dimensions with scale and the average of the three values was taken in centimeter (cm).

3.9.7 Length of root (cm)

Length of roots was considered from the base of the plant to the tip of the root. It was measured in centimeter (cm) with a meter scale after harvesting the secondary curds.

3.9.8 Diameter of primary curd

Primary curd diameter was taken by using a meter scale at the final harvest. Diameter of the curd was measured at different directions and finally the average of all directions was recorded and expressed in centimeter (cm).

3.9.9 Percent dry matter of leaf

A sample of 100 g of leaves was collected and dried under direct sunshine for 72 hours and then dried in an oven at 70 ^{0}C for 3 days. After oven drying, leaves were weighed. The dry weight was recorded in gram (g) with an electric balance. The percentage of dry matter was calculated by the following formula:

$$\text{Percent dry matter} = \frac{\text{Weight of dry matter}}{\text{Fresh weight}} \text{ x } 100$$

3.9.10 Percent dry matter of curd

A sample of 100 g of curd was collected and was dried under direct sunshine for 72 hours and then dried in an oven at 70 ^{0}C for 3 days. After oven drying, curds were weighed. The dry weight was recorded in gram (g) with an electric balance. The percentage of dry matter was calculated by the following formula:

$$\text{Percent dry matter} = \frac{\text{Weight of dry matter}}{\text{Fresh weight}} \text{ x } 100$$

3.9.11 Weight of curd (g)

Weight of the central curd was recorded excluding the weight of all secondary curds and was expressed in gram (g).

3.9.12 Yield per plant (g)

The yield per plant was calculated by accumulating weight of central curds harvested and the yield was weighed in gram (g).

3.9.13 Yield per hectare (ton)

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

3.10 Statistical analysis

The data obtained were statistically analyzed to find out the variation resulting from experimental treatments following F variance test. The difference between treatments was adjusted by Least Significant Difference Test (LSD) (Gomez and Gomez, 1984).

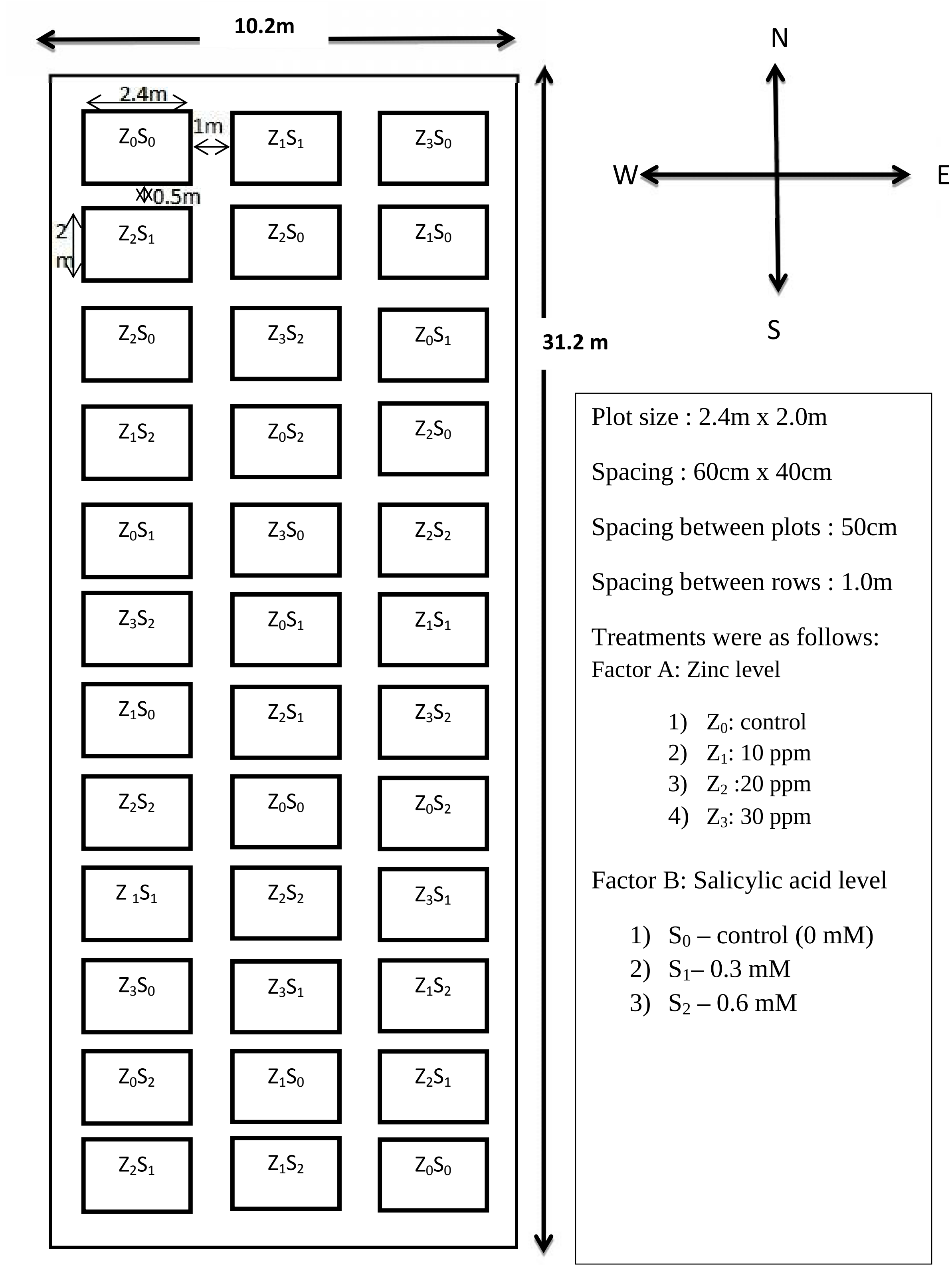


Figure 1: The layout of the experiment

CHAPTER IV

RESULTS AND DISCUSSION

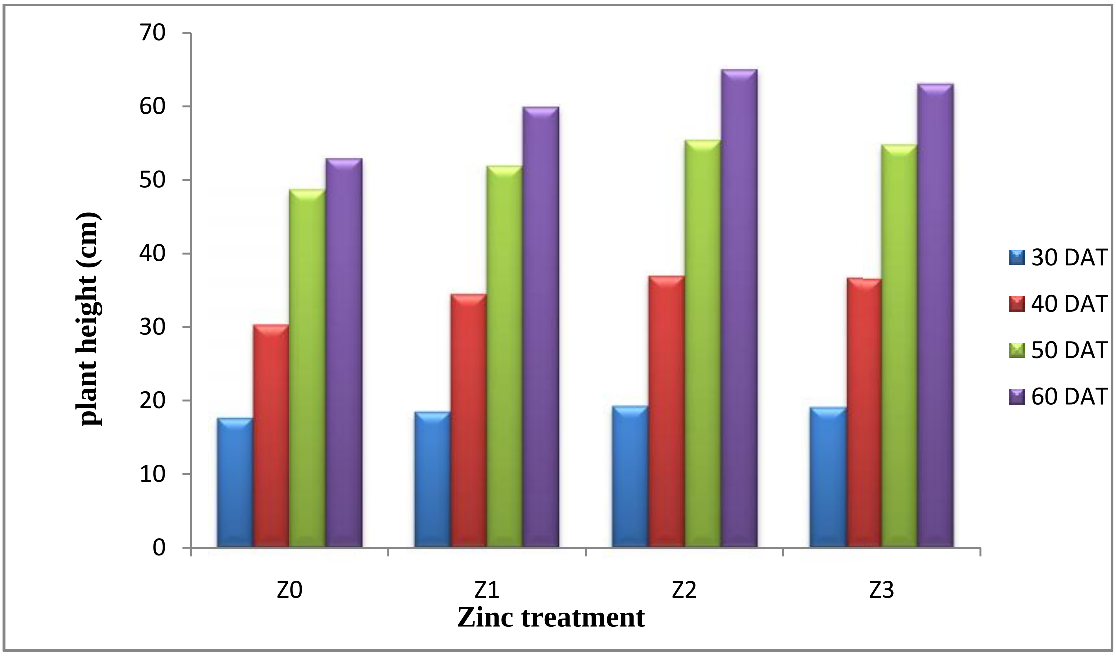
The research work was accomplished to observe the effects of zinc and salicylic acid on growth and yield of broccoli. Broccoli showed differences in terms of different growth and yield related characteristics. The analysis of variance (ANOVA) of data on different growth and yield parameters are presented in Appendices II-VII. The results of the study have been presented and discussed with the help of table and graphs and possible interpretations given under the following sub-headings.

4.1 Plant height

Application of zinc exhibited a significant influence on plant height of broccoli plant at 30, 40, 50, 60 days after transplanting (DAT) (Appendix: II). At 30 DAT, the tallest plant (19.27 cm) was measured from Z_2 (20 ppm) which was statistically similar to that of Z_3 (30 ppm) and the shortest plant (17.57 cm) was recorded from control treatment (Z_0). At 40 DAT, the tallest plant (36.95 cm) was measured from Z_2 which was statistically similar to that of Z_3 and the shortest plant (30.21 cm) was recorded from control treatment (Z_0) (figure 2). At 50 DAT, the tallest plant (55.37 cm) was measured from Z_2 which was statistically similar to that of Z_3 and the shortest plant(54.71 cm) was recorded from control treatment (Z_0). At 60 DAT, the tallest plant (64.42 cm) was measured from Z_2 which was statistically similar to that of Z_3 and the shortest (52.73 cm) was recorded from control (Z_0). Quratul *et.al.* (2016) and Prasad and Yadav (2003) also showed the same result that foliar application of zinc increase the plant height.

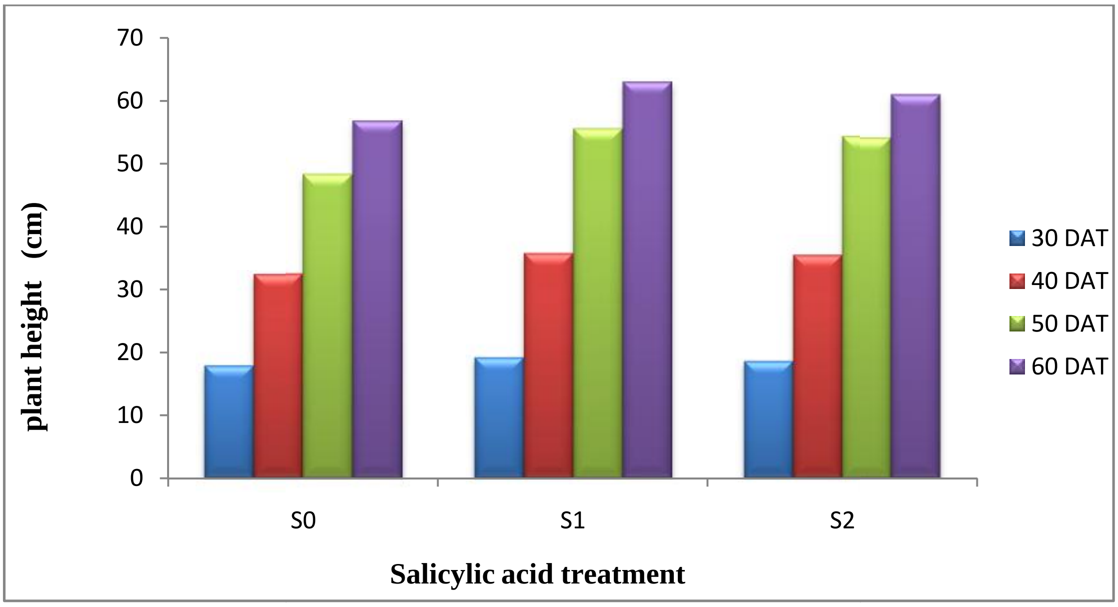
Significant variation was also found among the salicylic acid treatments (figure 3) (Appendix: II). At 30 DAT, tallest plant (19.25 cm) was obtained from S_1 (0.3 mM) and shortest plant (17.91cm) from the control (S_0). At 40 DAT, tallest plant (35.78 cm) was obtained from S_1 (0.3 mM) which was statistically identical to S_2 (0.6 mM) and the shortest plant (17.91cm) from the control(S_0). At 50 DAT, tallest plant (55.56 cm) was obtained from S_1 which was statistically identical to S_2 and the shortest (48.12 cm) from the control(S_0). At 60 DAT, tallest plant (62.31 cm) was obtained from S_1 (0.3 mM) which was statistically identical to S_3 (0.6 mM) and the shortest plant (56.57 cm) from the control(S_0). This result showed similarity with the result of Parvin and Haque (2017) and Dursun and Yildirim (2009).

Combined effects of zinc and salicylic acid on plant height also varied significantly from each other (Appendix: II). At 30 DAT, the tallest plant (20.70 cm) was obtained from Z_2S_1 treatment and the shortest (17.15 cm) from Z_0S_0 treatment. At 40 DAT, the tallest plant (39.82 cm) was obtained from Z_2S_1 treatment and the shortest (30.04 cm) from Z_0S_0 treatment (Table 1). At 50 DAT, the tallest plant (59.80 cm) was obtained from Z_2S_1 treatment and the shortest (47.05 cm) from Z_0S_0 treatment. At 60 DAT,the tallest plant (68.88 cm) was obtained from Z_2S_1 treatment and the shortest plant (51.49 cm) from Z_0S_0 treatment.



Z_0: Control (0 ppm), Z_1: 10 ppm, Z_2: 20 ppm, Z_3: 30 ppm

Figure 2. Effect of zinc on plant height at different days after transplanting (DAT)



S_0: Control (0 mM), S_1: 0.3 mM, S_2: 0.6 mM

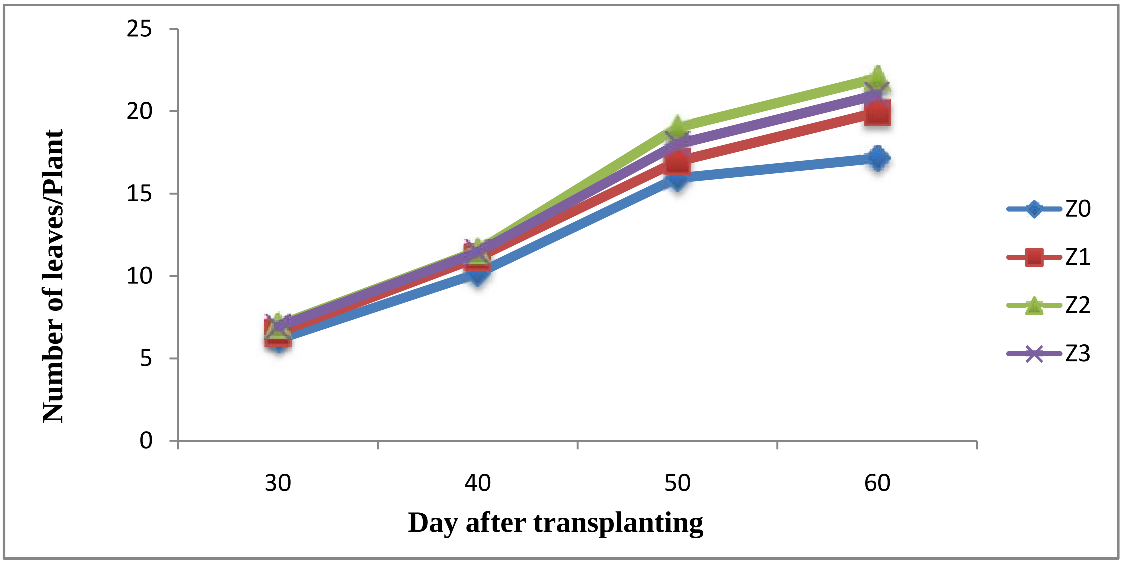
Figure 3. Effect of salicylic acid on plant height at different days after transplanting (DAT)

4.2 Number of leaves per plant

Broccoli plants with different zinc treatments also showed significant variation in case of number of leaves per plant (Appendix: III). Maximum leaf number at 30 DAT was observed in treatment Z_2 (6.76) (20 ppm) which was statistically identical to Z_3 (30 ppm) and minimum in control (Z_o) (6.16) (figure 4). Maximum leaf number at 40 DAT was observed in treatment Z_2 (11.51) and minimum in control (Z_0) (10.16). Maximum leaf number at 50 DAT was observed in treatment Z_2 (18.80) and minimum in control (Z_0) (15.93). Maximum leaf number at 60 DAT observed in treatment Z_2 (21.22) which was statistically identical to Z_3 and minimum in control (Z_0) (17.14). Varghese and Duraisami (2005) and Feng *et. al.*(2005) results also support the findings of this research results.

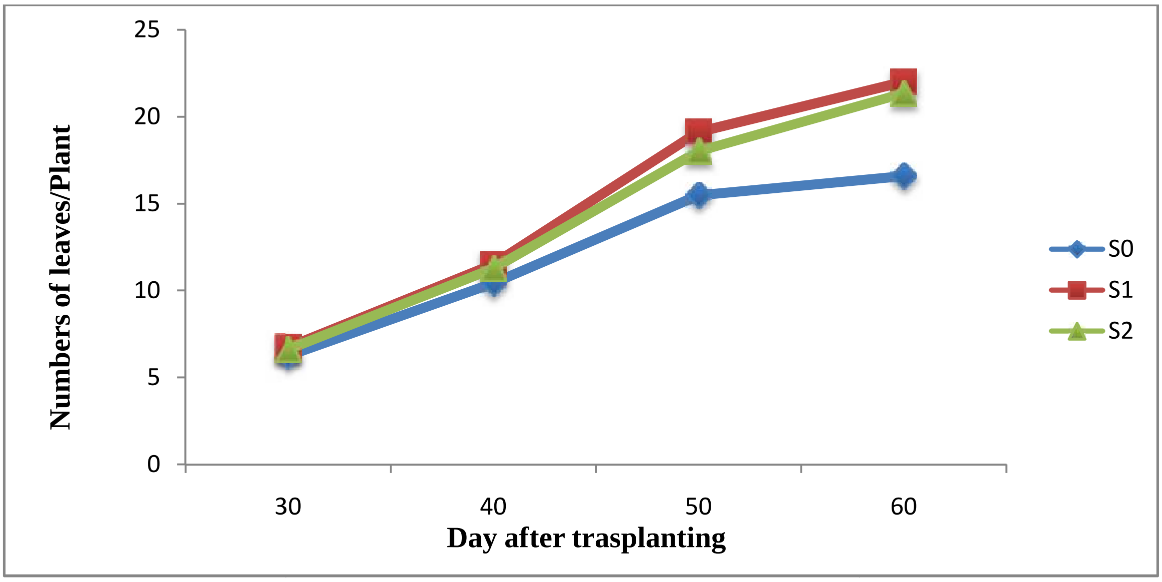
Leaf number per plant was significantly affected by salicylic acid treatments (figure 5) (Appendix: III). At 30 DAT, maximum leaf number (6.75) was obtained from S_1 (0.3 mM) treatment and minimum (6.25) from control (S_0) .At 40 DAT, maximum leaf number (11.50) was obtained from S_1 treatment followed by treatment S_2 and minimum (10.42) from control (S_0).At 50 DAT, maximum leaf number (19.12) was obtained from S_1 (0.3 mM) treatment and minimum (15.48) from control (S_0) . At 60 DAT, maximum leaf number (21.55) was obtained from S_1 treatment followed by treatment S_2 and minimum (16.58) from control (S_0). Similar result was obtained by Mady (2009) and Kazemi (2014). That means foliar application of salicylic acid increase the leaf number of plants.

The number of leaves was significantly influenced by the combined effect of zinc and salicylic acid at 30, 40, 50 and 60 DAT (Appendix: III). Maximum leaf number at 30 DAT was observed in treatment Z_2S_1 (7.13) and minimum in control (Z_0S_0) (6.07) (Table 1). Maximum leaf number at 40 DAT observed in treatment Z_2S_1 (12.13) and minimum in control treatment Z_0S_0 (10.07). Maximum leaf number at 50 DAT observed in treatment Z_2S_1 (21.07) which and minimum in control(Z_0S_0) (13.87). And at 60 DAT, maximum leaf number (23.60) was found from the treatment Z_3S_2 and minimum (15.90) from Z_0S_0.



Z_0: Control (0 ppm), Z_1: 10 ppm, Z_2: 20 ppm, Z_3: 30 ppm

Figure 4. Effect of zinc on number of leaf/plant at different days after transplanting (DAT)



S_0: Control (0 mM), S_1: 0.3 mM, S_2: 0.6 mM

Figure 5. Effect of salicylic acid on number of leaves/plant at different days after transplanting (DAT)

4.3 Leaf length

Leaf length of broccoli plant significantly varied due to the zinc treatment (Appendix: IV) . At 30 DAT, the longest leaf (15.79cm) was found from the Z_2 (20 ppm) treatment followed by the treatment Z_3 (30 ppm) and the shortest (14.29cm) from the treatment Z_0 (table 2). At 40 DAT, the longest leaf length (34.29cm) was found from the Z_2 treatment which was statistically identical to treatment Z_3 and the shortest (26.06 cm) from the control (Z_0). At 50 DAT, the longest leaf (41.65cm) was found from the Z_2 treatment which was statistically identical to treatment Z_3 and the shortest (35.34cm) from the(Z_0). At 60 DAT, the longest leaf (46.00cm) was found from the Z_2 (20 ppm) treatment which was statistically similar with treatment Z_3 (30 ppm) and the shortest (39.01cm) from the (Z_0). Zinc is an essential micronutrient which helps in the growth of plant leaves also. The result supports the findings of Lashkari *et. al.* (2007).

Salicylic acid had a significant influence on leaf length of broccoli plants at 30, 40, 50 and 60 DAT (Table 2) (Appendix: IV). The longest leaf (15.61 cm) was found from S_1 (0.3 mM) treatment followed by the treatment S_3 (0.6 mM) and the lowest (14.56cm) from the S_0 at 30 DAT. At 40 DAT, longest leaf (32.74 cm) was found from S_1 treatment followed by the treatment S_3 and the lowest (28.80cm) from the control (S_0). At 50 DAT, longest leaf (42.47 cm) was found from S_1 (0.3 mM) treatment followed by the treatment S_3 and the lowest (33.77 cm) from the control (S_0). The longest leaf length (45.95 cm) was found from S_1 treatment which was statically similar with treatment S_3 and the lowest (38.79 cm) from the control (S_0) at 60 DAT. Yildirim *et. al.*(2007) and Dursun and Yildirim (2009) reported the same results in case of leaf length.

The combinations of zinc and salicylic acid treatments also showed statistically significant variation in case of leaf length at 30, 40, 50 and 60 DAT(Appendix: IV). At 30DAT, the longest leaf (16.60cm) was found from Z_2S_1 treatment whereas the lowest (13.50cm) from Z_0S_0 (Table 3). At 40DAT, the longest leaf (36.48cm) was found from Z_2S_1 treatment whereas the lowest (25.46 cm) from Z_0S_0. At 50DAT, the longest leaf (45.67cm) was found from Z_2S_1 treatment and lowest (25.46 cm) from Z_0S_0 treatment. At 60DAT, the longest leaf (49.84cm) was found from Z_2S_1 treatment and the lowest (37.50 cm) from $Z_0S_{0.}$

Table 1. Combined effect of zinc and salicylic acid on plant height and number of leaves/plant at different days after transplanting (DAT) and at harvest of broccoli

Treatments	Plant height (cm) at				Number of leaves/plant at			
	30 DAT	40 DAT	50 DAT	Harvest	30 DAT	40DAT	50 DAT	Harvest
Z_0S_0	17.15 b	30.04 g	47.05 c	51.49 e	6.07 c	10.07 c	13.87 e	15.90 d
Z_0S_1	17.71 b	29.54 g	48.81 c	51.04 e	6.13 c	10.13 c	16.20 cd	17.40 cd
Z_0S_2	17.85 b	31.05 fg	49.65 c	55.66 de	6.27 bc	10.27 c	17.73 bc	18.13 c
Z_1S_0	19.30 ab	31.90 efg	46.35 c	55.82 de	6.27 bc	10.33 c	15.13 de	16.20 d
Z_1S_1	17.99 b	35.74 bcd	54.73 b	61.65 bc	6.67 abc	11.67 ab	18.47 b	21.80 b
Z_1S_2	18.15 b	35.68 bcd	54.59 b	62.29 bc	6.73 abc	11.40 b	17.27 bcd	21.80 b
Z_2S_0	17.73 b	34.13 cde	50.28 c	60.06 bcd	6.40 abc	10.67 c	16.67 bcd	17.40 cd
Z_2S_1	20.70 a	39.82 a	59.80 a	68.88 a	7.13 a	12.13 a	21.07 a	23.60 a
Z_2S_2	19.39 ab	36.89 abc	56.04 ab	64.32 ab	6.73 abc	11.73 ab	18.67 b	22.67 ab
Z_3S_0	17.47 b	33.63 def	48.82 c	58.92 cd	6.27 bc	10.60 c	16.27 cd	16.80 cd
Z_3S_1	19.81 ab	37.99 ab	58.90 ab	65.77 ab	7.07 ab	11.57 ab	19.73 ab	23.40 ab
Z_3S_2	19.01 ab	37.94 ab	56.40 ab	64.95 ab	6.73 abc	11.67 ab	18.47 b	22.80 ab
$LSD_{(0.05)}$	1.957	2.752	4.190	4.428	0.740	0.587	1.946	1.508
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
CV(%)	6.22	4.71	5.70	4.34	6.69	5.14	6.55	4.49

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

Z_0: Control
Z_1: 10 ppm
Z_2: 20 ppm
Z_3: 30 ppm

S_0: control (0 mM)
S_1: 0.3 mM
S_2: 0.6 mM

4.4 Leaf breadth

Zinc had a significant influence on leaf breadth of broccoli plants at 30, 40, 50 and 60 DAT (Appendix: V). At 30 DAT, the maximum leaf breadth (7.87cm) was found from the Z_2 treatment which was statistically identical to treatment Z_3 and the minimum (6.85 cm) from the treatment Z_0 (Table 2). At 40 DAT, the maximum leaf breadth (13.96cm) was found from the Z_2 treatment which was statistically similar with treatment Z_3 and the minimum (11.54 cm) from the treatment Z_0. At 50 DAT, the maximum leaf breadth (15.57cm) was found from the Z_2 treatment and the minimum (14.38 cm) from the treatment Z_0. At 60 DAT, the maximum leaf breadth (18.90 cm) was found from the Z_2 and the minimum (16.65 cm) from the treatment Z_0. Yadav *et. al.* (2015) reported this kind of result also that micronutrients increase the leaf breadth.

Significant variation was found among the salicylic acid treatment in case of leaf breadth (Table 2) (Appendix: V). At 30 DAT, the maximum leaf breadth (7.80cm) was observed from the treatment S_1 (0.3 mM) and minimum (7.05cm) from the treatment S_0. At 40 DAT, maximum leaf breadth (13.67 cm) was found from S_1 treatment followed by the treatment S_3 and the lowest (12.06cm) from the S_0. At 50 DAT, maximum leaf breadth (15.37 cm) was found from S_1 treatment which was statically similar with treatment S_3 and lowest (14.60cm) was found from the S_0. At 60 DAT, maximum leaf breadth (18.30 cm) was found from S_1 treatment which was statistically identical to treatment S_3 and lowest (17.05 cm) was found from the S_0. Salicylic acid may cause for the increase of the cell number and that's helps in maximum leaf breadth stated by Kazemi (2013) and Khandaker *et. al.* (2011).

Leaf breadth was significantly differed among the plants with different treatment combination at 30, 40, 50 and 60 DAT (Table 3) (Appendix: V). Maximum leaf breadth at 30 DAT was observed in treatment Z_2S_1 (8.40 cm) and minimum in control (Z_0S_0) (6.60cm). Maximum leaf breadth (14.72cm) at 40 DAT was observed in treatment Z_2S_1 and minimum in control (Z_0S_0) (11.14cm). At 50 DAT, maximum leaf breadth (15.99 cm) was found from the treatment Z_2S_1 and minimum (14.14cm) form the Z_0S_1. Maximum leaf breadth (19.45cm) at 60 DAT was observed in treatment Z_2S_1 and minimum(16.28cm). in control (Z_0S_0).

4.5 Length of stem

Length of stem of the broccoli plants from different zinc treatments varied significantly (Appendix: VI). The longest stem (25.30 cm) was obtained from treatment Z_2 (20ppm) followed by treatment Z_3 (30ppm) and shortest (20.68cm) from the Z_0 (Table 4). Quratul *et.al.* (2016) reported that foliar spray of zinc increase the crop growth.

The application of salicylic acid significantly influenced on the stem length of broccoli plant (Appendix: VI).The longest stem (24.59 cm) was found from the treatment S_1 (0.03mM) which was statistically identical to S_2 (0.06 mM) and the shortest (22.02cm) from the control treatment S_0 (Table 4). Foliar spray increase the broccoli stem length and growth reported by Parvin and Haque (2017) and Dursun and Yildirim (2009).

Combined effect of zinc and salicylic acid showed significant difference in case of stem length (Table 5) (Appendix: VI). The longest stem length (27.42 cm) was obtained from the treatment Z_2S_1 and the shortest stem (20.07 cm) from Z_0S_0.

Table 2. Effect of zinc and salicylic acid on leaf length and leaf breadth of broccoli at different days after transplanting (DAT)

Treatments	Leaf length (cm) at				Leaf breadth (cm) at			
	30 DAT	40 DAT	50 DAT	60 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Levels of zinc								
Z_0	14.29 b	26.06 c	35.34 c	39.01 c	6.85 b	11.54 c	14.38 c	16.65 d
Z_1	15.13 ab	30.95 b	39.56 b	42.99 b	7.49 ab	12.95 b	14.92 b	17.42 c
Z_2	15.79 a	34.29 a	41.65 a	46.00 a	7.87 a	13.96 a	15.57 a	18.90 a
Z_3	15.65 a	33.67 a	41.28 a	44.82 a	7.68 a	13.74 a	15.34 ab	18.36 b
$LSD_{(0.05)}$	1.018	1.408	1.679	1.514	0.664	0.634	0.417	0.514
Level of significance	0.05	0.01	0.01	0.01	0.05	0.01	0.01	0.01
Levels of salicylic acid								
S_0	14.56 b	28.80 b	33.77 b	38.79 b	7.05 b	12.06 b	14.60 b	17.05 b
S_1	15.61 a	32.74 a	42.47 a	45.95 a	7.80 a	13.67 a	15.37 a	18.30 a
S_2	15.48 a	32.19 a	42.13 a	44.87 a	7.57 ab	13.40 a	15.19 a	18.14 a
$LSD_{(0.05)}$	0.882	1.219	1.454	1.311	0.575	0.549	0.361	0.445
Level of significance	0.05	0.01	0.01	0.01	0.05	0.01	0.01	0.01
CV(%)	6.85	4.61	6.35	5.58	9.09	4.97	5.83	6.95

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

Z_0: Control
Z_1: 10 ppm
Z_2: 20 ppm
Z_3: 30 ppm

S_0: control (0 mM)
S_1: 0.3 mM
S_2: 0.6 mM

Table 3. Combined effect of zinc and salicylic acid on leaf length and leaf breadth of broccoli at different days after transplanting (DAT)

Treatments	Leaf length (cm) at				Leaf breadth (cm) at			
	30 DAT	40 DAT	50 DAT	Harvest	30 DAT	40 DAT	50 DAT	Harvest
Z_0S_0	13.50 c	25.46 e	32.33 d	37.50 e	6.60 b	11.14 e	14.19 e	16.28 d
Z_0S_1	13.87 bc	25.53 e	36.16 bc	39.32 de	6.75 b	11.42 e	14.14 e	16.46 d
Z_0S_2	15.50 abc	27.20 e	37.52 b	40.20 de	7.20 ab	12.05 de	14.81 cde	17.21 cd
Z_1S_0	14.17 bc	28.02 e	33.34 cd	37.99 de	6.85 b	11.21 e	14.35 de	16.92 d
Z_1S_1	15.73 ab	32.77 bcd	42.67 ab	45.80 c	7.75 ab	14.04 ab	15.66 ab	18.07 bc
Z_1S_2	15.49 abc	32.08 cd	42.67 ab	45.16 c	7.86 ab	13.59 abc	14.75 cde	17.25 cd
Z_2S_0	15.36 abc	31.16 d	35.22 bcd	40.58 d	7.48 ab	13.10 bcd	15.02 bcd	17.91 bc
Z_2S_1	16.60 a	36.48 a	45.67 a	49.84 a	8.40 a	14.72 a	15.99 a	19.45 a
Z_2S_2	15.40 abc	35.23 ab	43.06 ab	47.58 abc	7.73 ab	14.05 ab	15.71 ab	19.03 ab
Z_3S_0	15.20 abc	30.56 d	34.17 cd	39.09 de	7.27 ab	12.79 cd	14.82 cde	17.10 cd
Z_3S_1	15.84 ab	35.37 ab	43.39 ab	48.84 ab	8.01 ab	14.11 ab	15.71 ab	19.02 ab
Z_3S_2	15.52 abc	34.27 abc	43.28 ab	46.54 bc	7.47 ab	13.91 abc	15.48 abc	18.76 ab
$LSD_{(0.05)}$	1.764	2.438	2.908	2.623	1.150	1.097	0.722	0.890
Level of significance	0.05	0.05	0.05	0.01	0.05	0.05	0.05	0.05
CV(%)	6.85	4.61	6.35	5.58	9.09	4.97	5.83	6.95

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

Z_0: Control
Z_1: 10 ppm
Z_2: 20 ppm
Z3: 30 ppm

S_0: control (0 mM)
S_1: 0.3 mM
S_2: 0.6 mM

4.6 Diameter of stem

Application of zinc exhibited a significant influence on the diameter of stem (Appendix: VI). The maximum diameter of stem (2.64cm) was obtained from the treatment Z_2 (20ppm) followed by the treatment Z_3. And the minimum (2.13cm) from the treatment Z_0 (Table 4). Zhao Yong-hou (2006) reported that foliar application of zinc enhance the growth of broccoli stem.

Foliar application of salicylic acid treatment also had significant influence on broccoli stem diameter (table 4) (Appendix: VI). The maximum stem diameter (2.66 cm) was found from the treatment S_1 and the minimum (2.14 cm) from the treatment S_0. Yildirim *et. al.*(2007) and Kazemi (2014) reported that the application of salicylic acid increase the vegetative growth of the broccoli plant.

Significant difference was found during the combined application of zinc and salicylic acid application on broccoli stem diameter (Table 5) (Appendix: VI). The maximum stem diameter (2.97 cm) was found from the treatment combination of Z_2S_1 and minimum (2.06 cm) from the Z_0S_0 treatment.

4.7 Length of root

Length of root was significantly influenced by the zinc application (Appendix: VI). The longest root (22.83cm) was obtained from the treatment Z_2 (20ppm) which was statically identical to Z_3 (30ppm) treatment. And the shortest root length (18.53cm) was found from the treatment Z_0(table 4). Feng *et. al.*(2005) reported the same result.

Length of root of broccoli plant showed significant difference in case of salicylic acid (Appendix: VI). The longest root (22.27 cm) was obtained from the treatment S_1 (0.3 mM) followed by the treatment S_2 (0.6mM). And the shortest root (19.38cm) from the S_0 (table 4). Mady (2009) and Khandaker *et. al.* (2011) observed the same result as salicylic acid helps to the growth of roots to uptake more nutrients from the surroundings.

The length of root was significantly influenced by the combined effect of zinc and salicylic acid treatment application (table 5) (Appendix: VI). The longest root was (24.51cm) obtained from the treatment combination Z_2S_1 while the shortest (18.06cm) from the treatment combination of Z_0S_0.

4.8 Diameter of curd

Significant variation was found among the zinc treatments in case of curd diameter (tale 4) (Appendix: VI). The maximum curd diameter (14.84cm) was obtained from the Z_2 (20ppm) and the minimum (13.15cm) from the Z_0 treatment.

Application of salicylic acid significantly affect the diameter of broccoli curd (table 4) (Appendix: VI). The maximum curd diameter (17.78cm) was found from the S_1 (0.3 mM) treatment and minimum (13.77cm) from the S_0 treatment which was statistically similar with S_2 (0.6mM). Dursun and Yildirim (2009) reported the same findings in case of curd diameter as salicylic acid increase cell number and ultimate results in curd growth.

Combined application of zinc and salicylic acid significantly influenced the curd diameter (table 5) (Appendix: VI). The maximum curd diameter (15.31 cm) was found from the Z_2S_1 treatment and minimum (12.44cm) from the Z_0S_0 treatment.

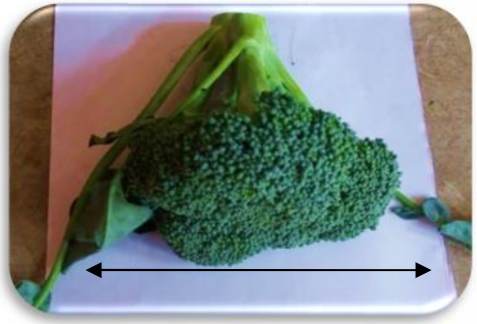
12.44 cm
Z_0S_0

13.20 cm
Z_0S_1

13.80 cm
Z_0S_2

13.91 cm
Z_1S_0

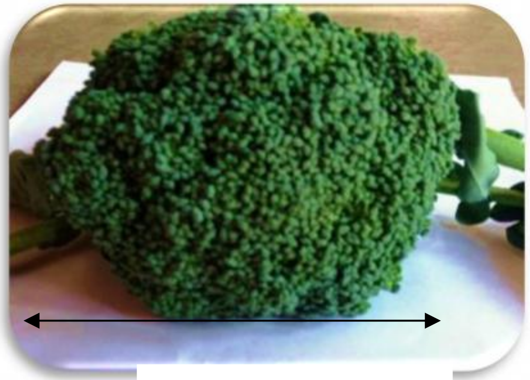
14.91 cm
Z_1S_1



14.25 cm
Z_1S_2

Plate 1: Showing diameter of curds of different treatment combination

14.50 cm
Z_2S_0

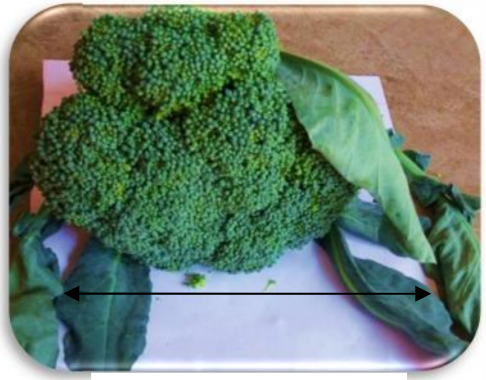


15.31 cm
Z_2S_1

14.69 cm
Z_2S_2

14.23 cm
Z_3S_0

15.10 cm
Z_3S_1



14.46 cm
Z_3S_2

Plate 2: Showing diameter of curds of different treatment combination

4.9 Percent dry matter of plant

Application of zinc exhibited a significant influence on the dry matter content of plant (Appendix: VII). The highest dry matter content (19.08) was obtained from the Z_2 (20ppm) treatment followed by the treatment Z_3 (30ppm) and lowest (16.01) was found from the Z_0 treatment (Table 6). By increasing micronutrients concentration plant weight in broccoli significantly increased, may be due to higher accumulation of the micronutrients in plants, which can cause better photosynthesis, which ultimately results in better growth of plants. Zinc application significantly increased plant weight reported by Feng *et. al.*(2005).

Application of salicylic acid significantly affect the percent of dry matter content of plant(Appendix: VII). The highest dry matter content (18.92) was obtained from the treatment S_1 (0.3 mM) which was statistacilly identical to S_2 (0.6mM) and the lowest (16.40) from the treatment S_0 (table 6). This may be happened due to increase in the accumulation of different nutrients in the plant reported by Khan *et. al.*(2010).

Significant difference was found during the combined application of zinc and salicylic acid application on percent of dry matter content of broccoli plant (table 7). The highest dry matter content (20.68) obtained from Z_2S_1 treatment and lowest (15.38) from the Z_0S_0 treatment.

Table 4. Effect of zinc and salicylic acid on yield contributing characters

Treatments	Length of Stem (cm)	Diameter of stem (cm)	Length of root (cm)	Diameter of curd (cm)
Levels of zinc				
Z_0	20.68 c	2.13 c	18.53 c	13.15 c
Z_1	23.53 b	2.39 b	20.79 b	14.36 b
Z_2	25.30 a	2.64 a	22.83 a	14.84 a
Z_3	24.93 a	2.56 a	22.40 a	14.60 ab
$LSD_{(0.05)}$	0.995	0.148	0.898	0.414
Level of significance	0.01	0.01	0.01	0.01
Levels of salicylic acid				
S_0	22.02 b	2.14 c	19.38 b	13.77 b
S_1	24.59 a	2.66 a	22.27 a	14.78 a
S_2	24.22 a	2.50 b	21.76 a	14.15 b
$LSD_{(0.05)}$	0.862	0.128	0.777	0.447
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.34	6.20	4.31	8.23

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

Z_0: Control

Z_1: 10 ppm

Z_2: 20 ppm

Z_3: 30 ppm

S_0: control (0 mM)

S_1: 0.3 mM

S_2: 0.6 mM

Table 5. Combined effect of zinc and salicylic acid on yield contributing characters

Treatments	Length of Stem (cm)	Diameter of stem (cm)	Length of root (cm)	Diameter of curd (cm)
Z_0S_0	20.07 g	2.06 e	18.06 h	12.44 g
Z_0S_1	20.08 g	2.10 e	18.21 h	13.20 f
Z_0S_2	21.88 efg	2.23 de	19.33 fgh	13.80 e
Z_1S_0	21.46 fg	2.08 e	18.60 gh	13.91 e
Z_1S_1	24.61 bcd	2.66 bc	22.09 cd	14.91 abc
Z_1S_2	24.52 bcd	2.44 cd	21.67 cde	14.25 de
Z_2S_0	23.48 cde	2.32 de	20.65 def	14.50 cd
Z_2S_1	27.42 a	2.97 a	24.51 a	15.31 a
Z_2S_2	25.01 bc	2.65 bc	23.35 abc	14.69 bcd
Z_3S_0	23.05 def	2.13 e	20.21 efg	14.23 de
Z_3S_1	26.27 ab	2.89 ab	24.27 ab	15.10 ab
Z_3S_2	25.46 b	2.67 bc	22.70 bc	14.46 cd
$LSD_{(0.05)}$	1.724	0.257	1.555	0.476
Level of significance	0.05	0.01	0.05	0.05
CV(%)	4.31	6.20	4.34	8.23

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

Z_0: Control

Z_1: 10 ppm

Z_2: 20 ppm

Z_3: 30 ppm

S_0: control (0 mM)

S_1: 0.3 mM

S_2: 0.6 mM

4.10 Percent dry matter content of curd

Significant variation was found among the zinc treatments in case of percent dry matter content of curd (Appendix: VI). The highest dry matter content of curd (20.58%) was obtained from the Z_2 (20ppm) treatment which was statistically similar with treatment Z_3 (30ppm) and the lowest (17.08%) was found from the Z_0 treatment(Table 6). Lashkari *et. al.*(2007) reported the same findings about dry matter content.

Treatments of salicylic acid application also significantly influenced on the curd dry matter content (Appendix: VII). The highest curd dry matter content (20.25%) was obtained from the treatment S_1 (0.3 mM) which was statically identical to S_2 (0.6mM) and the lowest (17.64%) from the treatment S_0 (Table 6). This may be happened due to increase in the accumulation of different nutrients in the plant reported by Khan *et. al.*(2010).

Combined application of zinc and salicylic acid significantly influenced on percent of dry matter content of broccoli curd (table 7) (Appendix: VII). The highest dry matter content (22.11%) obtained from Z_2S_1 treatment and the lowest (16.62%) from the Z_0S_0 treatment.

4.11 Weight of curd (g)/plant

The foliar application of zinc significantly influenced on curd weight of broccoli (Appendix: VII). The highest curd weight (415.90g) was obtained from the Z_2 (20ppm) treatment and the lowest curd weight (366.16g) from the treatment of Z_0(Table 6). Zinc play important role in synthesis of auxin and pollen formation .Sufficient supply of zinc improve the curd yield in crucifers reported by Hafeez *et. al.*(2013).

Salicylic acid treatment application had a significant influence on the curd weight (Appendix: VII). The highest curd weight (411.78 g) was found from the treatment S_1 (0.3 mM) which was statistically similar with the treatment S_2 (0.6mM) and the lowest (374.17 g) from the treatment S_0 (Table 6). Jeyakumar *et. al.* (2008) and Dursun and Yildirim (2009) reported the same findings that salicylic acid increase the flower production rate by enhancing the growth regulators.

The curd weight was significantly influenced by the combined effect of zinc and salicylic acid treatment application (table 7) (Appendix: VII). The highest weight (441.02g) was obtained from the treatment Z_2S_1 and the lowest (358.85 g) from the treatment Z_0S_0.

4.12 Yield per plot (kg)

Significant variation was found among the zinc treatments in case of yield per plot (Appendix: VII). The highest yield per plot (4.57 kg) was obtained from the treatment Z_2 (20ppm) and the lowest from yield per plot (3.65 kg) from the Z_0 treatment (Table 6). Quratul *et.al.* (2016) and Yadav *et. al.* (2015) reported that as zinc helps in the vegetative growth which causes highest yield of the crop.

Application of salicylic acid exhibited a significant influence on the yield per plot (Appendix: VII). The highest yield per plot (4.43 kg) was found from the treatment S_1 (0.3 mM) which was statistically similar with the treatment S_2 (0.6mM) and the lowest (3.83 kg) from the treatment S_0(Table 6). Parvin and Haque (2017), Kareem *et. al.* (2017) and Yildirim *et. al.*(2007) reported that increasing all the vegetative characteristics salicylic acid increase the yield of the broccoli.

Combined application of zinc and salicylic acid significantly influenced on the yield per plot (Table 7). The highest weight (4.89 kg) was obtained from the treatment Z_2S_1 and the lowest (3.44 kg) from the treatment Z_0S_0.

4.13 Yield per hectare (ton)

The foliar application of zinc significantly influenced on curd yield per hectare of broccoli (Appendix: VII). The highest yield per hectare (15.87 ton) was obtained from the treatment Z_2 (20ppm) and the lowest from yield per hectare (12.67 ton) from the Z_0 treatment(Table 6). Quratul *et.al.* (2016), Yadav *et. al.*(2015), Feng *et. al.*(2005) and Lashkari *et. al.* (2007) reported that the micronutrient zinc increase the yield of the broccoli curd yield.

Application of salicylic acid exhibited a significant influence on the yield per hectare (Appendix: VII). The highest yield per plot (15.37 ton) was found from the treatment S_1 (0.3 mM) which was statistically similar with the treatment S_2 (0.6mM) and the lowest (13.31 ton) from the treatment S_0(Table 6). These results are in agreement with that obtained by Parvin and Haque (2017), Kareem *et. al.* (2017), Yildirim *et. al.*(2007) and Kazemi (2013).

Combined application of zinc and salicylic acid significantly influenced on the yield per hectare (Table 7) (Appendix: VII). The highest yield (16.99 ton) was obtained from the treatment Z_2S_1 and the lowest (11.94 ton) from the treatment Z_0S_0.

Table 6. Effect of zinc and salicylic acid on yield contributing characters and yield of broccoli

Treatments	Percent dry matter content of plant (%)	Percent dry matter content of curd (%)	Weight of curd (g)	Curd yield/plot (kg)	Curd yield/hectare (ton)
Levels of zinc					
Z_0	16.01 c	17.08 c	366.16 c	3.65 c	12.67 c
Z_1	17.92 b	18.99 b	397.64 b	4.17 b	14.50 b
Z_2	19.08 a	20.58 a	415.90 a	4.57 a	15.87 a
Z_3	18.83 a	20.26 a	406.04 ab	4.38 ab	15.21 ab
$LSD_{(0.05)}$	0.769	1.040	14.75	0.210	0.730
Level of significance	0.01	0.01	0.01	0.01	0.01
Levels of salicylic acid					
S_0	16.40 b	17.64 b	374.17 b	3.83 b	13.31 b
S_1	18.92 a	20.25 a	411.78 a	4.43 a	15.37 a
S_2	18.56 a	19.80 a	403.35 a	4.32 a	15.00 a
$LSD_{(0.05)}$	0.666	0.901	12.77	0.182	0.632
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	4.38	5.53	6.38	5.13	5.13

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

Z_0: Control

Z_1: 10 ppm

Z_2: 20 ppm

Z_3: 30 ppm

S_0: control (0 mM)

S_1: 0.3 mM

S_2: 0.6 mM

Table 7. Combined effect of zinc and salicylic acid on yield contributing characters and yield of broccoli

Treatments	Percent dry matter content of plant (%)	Percent dry matter content of curd (%)	Weight of curd (g)	Curd yield/plot (kg)	Curd yield/hectare (ton)
Z_0S_0	15.38 d	16.62 f	358.85 d	3.44 e	11.94 e
Z_0S_1	15.93 cd	16.99 ef	364.34 d	3.46 e	12.02 e
Z_0S_2	16.73 cd	17.63 ef	375.28 d	4.04 cd	14.04 cd
Z_1S_0	16.31 cd	17.06 ef	377.31 d	3.76 de	13.05 de
Z_1S_1	18.77 b	20.07 bcd	408.83 bc	4.51 ab	15.65 ab
Z_1S_2	18.67 b	19.84 cd	406.78 bc	4.26 bc	14.79 bc
Z_2S_0	17.16 c	18.66 de	384.08 cd	4.28 bc	14.87 bc
Z_2S_1	20.68 a	22.11 a	441.02 a	4.89 a	16.99 a
Z_2S_2	19.40 ab	20.98 abc	422.59 ab	4.54 ab	15.76 ab
Z_3S_0	16.77 cd	18.20 def	376.46 d	3.86 d	13.40 d
Z_3S_1	20.08 ab	21.84 ab	432.91 ab	4.84 ab	16.82 ab
Z_3S_2	19.42 ab	20.74 abc	408.75 bc	4.44 b	15.42 b
$LSD_{(0.05)}$	1.331	1.802	25.55	0.363	1.265
Level of significance	0.05	0.05	0.05	0.01	0.01
CV(%)	4.38	5.53	6.38	5.13	5.13

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

Z_0: Control — S_0: control (0 mM)

Z_1: 10 ppm — S_1: 0.3 mM

Z_2: 20 ppm — S_2: 0.6 mM

Z_3: 30 ppm

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

In order to observe the effects of zinc and salicylic acid on broccoli, an experiment was conducted to inspect the growth and yield of broccoli at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2016 to February 2017. Two factor experiment included application of zinc viz. Z_0 :control, Z_1: 10 ppm, Z_2:20 ppm, Z_3: 30 ppm as factor A and salicylic acid viz. S_0 – control (0 mM), S_1– 0.3 mM, S_2 – 0.6 mM included as factor B. The experiment was setup in randomized complete block design (RCBD) with three replications.

Collected data were statistically analyzed for the evaluation of treatments for the detection of the best treatment of zinc, salicylic acid and the best amalgamation. Summary of the results and conclusion have been described in this chapter.

In case of zinc, at 60 DAT, the longest plant (64.42cm), the maximum number of leaves/plant (21.22), the longest leaf (46.00cm) and maximum leaf breadth (18.90cm) were recorded from Z_2 (20 ppm) treatment. On the other hand, the shortest plant (52.73cm), minimum number of leaves (17.14), the shortest leaf (39.01cm) and minimum leaf breadth (16.65cm) were recorded from the Z_0 treatment.

In case of salicylic acid, at 60 DAT, the longest plant (35.78cm), the maximum number of leaves (21.55), the longest leaf (45.95cm) and maximum leaf breadth (18.30cm) were recorded from S_1 (0.3 mM) treatment. On the other hand, the shortest plant (56.57cm), minimum number of /plant (16.58), the shortest leaf (38.79cm) and minimum leaf breadth (17.05cm) were recorded from the S_0 treatment.

Considering the combined effect of zinc and salicylic acid, at 60 DAT, the longest plant (68.88cm), the maximum number of leaves/plant (23.60), the longest leaf (49.84cm) and maximum leaf breadth (19.45cm) were recorded from Z_2S_1 treatment. On the other hand, shortest plant (51.49cm), minimum number of leaves/plant (15.90), the shortest leaf (37.50cm) and minimum leaf breadth (16.28cm) were recorded from the Z_0S_0 treatment.

In case of length of stem, zinc treatment Z_2 (20 ppm) produced the longest stem (25.30cm) and the shortest (20.68cm) from Z_0 treatment. Regarding the effect of salicylic acid, the longest leaf (24.59cm) and the shortest (22.02cm) from S_0 treatment. **In amalgamation, Z_2S_1 provided** longest leaf (27.42cm) and the shortest (20.07cm) from Z_0S_0 treatment.

Z_2 (20 ppm) showed the maximum diameter of stem (2.64cm) and Z_0 showed the minimum diameter of stem (2.13cm) in case of zinc treatments. S_1 (0.3 mM) showed the maximum diameter of stem (2.66cm) and S_0 showed the minimum diameter of stem (2.14cm) in case of salicylic acid treatments. In case of combined effects, Z_2S_1 produce maximum diameter of stem (2.97cm) and Z_0S_0 produce the minimum (2.06cm).

In case of length of root, longest root (22.83cm) obtained from the Z_2 (20 ppm) treatment and the shortest (18.53cm) from the Z_0 treatment. Among salicylic acid treatment, longest root (22.27cm) obtained from the S_1 (0.3 mM)) treatment and the shortest (19.38cm) from the S_0. In amalgamation, longest root (24.51cm) obtained from the Z_2S_1 treatment and shortest (18.06cm) from the Z_0S_0 treatment.

In case of diameter of curd, among zinc treatments Z_2 (20 ppm) produce the maximum curd diameter (14.84cm) whereas minimum (13.15cm) in Z_0 treatment. Regarding the effect of salicylic acid, S_1 (0.3 mM) produced the maximum curd diameter (14.84cm) whereas minimum (13.77cm) in S_0 treatment. In case of combined effect Z_2S_1 produce maximum curd diameter (15.31cm) and minimum (12.44cm) in Z_0S_0 treatment combination. Z_0S_0.

In case of percent of dry matter content of plant and curd, highest percentage of dry matter content obtained from Z_2 (19.08 and 20.58) and lowest from the Z_0 (16.01 and 17.08) treatment. Regarding salicylic acid, highest percentage of dry matter content obtained from S_1 (18.92 and 20.25) and lowest from the S_0 (16.40 and 17.64) treatment. Combination of zinc with salicylic acid, highest percentage of dry matter content obtained from Z_2S_1 (20.68 and 22.11) and lowest from the Z_0S_0 (15.38 and 16.62) treatment combination.

Weight of curd (415.90g) was found highest in Z_2 (20 ppm) and lowest curd weight (366.16g) was found from the control Z_0 treatment. In case of salicylic acid, weight of curd (411.78g) was found highest in S_1 (0.3 mM) and lowest curd weight (374.17g) was found from the control S_0 treatment. In amalgamation effect, highest curd weight (441.02g) was obtained from the Z_2S_1 treatment and lowest (358.85g) from the Z_0S_0 treatment.

In case of curd yield per plot and per hectare, among zinc treatments Z_2 (20 ppm) produced the highest yield (4.57kg and 15.87 ton) and lowest yield (3.65kg and 12.67 ton) from the control Z_0 treatment. On the other hand, in case of salicylic acid, S_1 (0.3 mM) produced highest yield per plot and per hectare (4.43 kg and 15.37 ton) and lowest (3.83kg and 13.31 ton) in S_0 treatment. In combined effects, Z_2S_1 produce the highest yield (4.89 kg and 16.99 ton) and Z_0S_0 produce the lowest yield (3.44kg and 11.94 ton) per plot and per hectare respectively.

5.2 Conclusion

Based on the results of the present study, it can be concluded that among zinc treatments Z_2 (20 ppm) produced the biggest curd and gave the highest yield. On the other hand, S_1 (0.3 mM) salicylic acid treatment performed excellent in term of all parameters. Z_2S_1 treatment combination is 15ppm zinc with 0.3 mM salicylic acid performed best in term of all parameters and produced the highest yield and therefore, could be recommended to be followed by the farmer after another year trial at least.

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I. Results of morphological, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	**Characteristics**
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	**Percentage (%)**
Sand	28.78
Silt	42.12
Clay	29.1

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.95
Organic matter (%)	0.77
Total nitrogen (%)	0.075
Available P (ppm)	15.07
Exchangeable K (%)	0.32
Available S (ppm)	16.17

Source: Soil Resource Development Institute (SRDI)

Appendix-II. Analysis of variance of data on plant height at different days after transplanting of broccoli

Source of variation	Degrees of freedom (df)	Mean square of plant height at			
		30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.11	0.58	0.68	0.14
Factor A (Zinc)	2	5.14**	85.37**	88.21**	260.99**
Factor B (Salicylic acid)	3	5.37**	40.33**	187.51**	121.04**
Interaction (A X B)	6	3.53**	6.37*	29.49**	18.34**
Error	22	1.34	2.64	6.12	6.83
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-III. Analysis of variance of data on number of leaves at different days after transplanting of broccoli

Source of variation	Degrees of freedom (df)	Mean square of number of leaves at			
		30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.041	0.008	0.701	0.351
Factor A (Zinc)	2	0.650**	3.525**	16.233**	31.590**
Factor B (Salicylic acid)	3	0.804**	3.902**	41.754**	95.183**
Interaction (A X B)	6	0.602**	0.358**	5.898**	4.517**
Error	22	0.191	0.120	1.321	0.793
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-IV. Analysis of variance of data on leaf length at different days after transplanting of broccoli

Source of variation	Degrees of freedom (df)	Mean square of leaf length at			
		30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.015	1.102	0.182	2.116
Factor A (Zinc)	2	4.142**	126.172**	75.339**	84.323**
Factor B (Salicylic acid)	3	3.951**	54.691**	291.581**	178.982**
Interaction (A X B)	6	4.640**	5.212*	8.850**	10.417*
Error	22	1.085	2.073	2.950	2.399
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-V. Analysis of variance of data on leaf breadth at different days after transplanting of broccoli

Source of variation	Degrees of freedom (df)	Mean square of leaf breadth at			
		30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.014	0.196	0.004	0.168
Factor A (Zinc)	2	1.768**	10.768**	2.466**	8.965**
Factor B (Salicylic acid)	3	1.777**	8.936**	1.977**	5.497**
Interaction (A X B)	6	2.009**	2.650**	1.390**	0.730*
Error	22	0.461	0.420	0.182	0.276
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-VI. Analysis of variance of data on yield contributing characters of broccoli

Source of variation	Degrees of freedom (df)	Mean square of			
		Length of stem	Diameter of stem	Length of root	Diameter of primary curd
Replication	2	0.073	0.009	0.044	0.035
Factor A (Zinc)	2	39.634**	0.465**	34.098**	2.938**
Factor B (Salicylic acid)	3	23.264**	0.826**	28.545**	4.537**
Interaction (A X B)	6	3.276**	0.082**	2.698**	1.370**
Error	22	1.036	0.023	0.843	0.201
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-VII. Analysis of variance of data on yield contributing characters of broccoli

Source of variation	Degrees of freedom (df)	Mean square of			
		Percent dry matter content of curd	Weight of curd	Curd yield per plot	Curd yield per hectare
Replication	2	0.079	144.451	0.007	0.081
Factor A (Zinc)	2	22.760**	4167.760**	1.427**	17.215**
Factor B (Salicylic acid)	3	23.433**	4672.400**	1.193**	14.390**
Interaction (A X B)	6	5.153*	470.049*	0.205**	2.467**
Error	22	1.132	227.616	0.046	0.558

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

Plate 3: Experimental plot and seedbed