EFFECT OF FOLIAR APPLICATION OF SALICYLIC ACID ON YIELD AND YIELD CONTRIBUTING CHARACTERS OF BARI GOM 27

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Dedicated

To

My Beloved

Parents

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CERTIFICATE

*This is to certify that thesis entitled "***EFFECT OF FOLIAR APPLICATION OF SALICYLIC ACID ON YIELD AND YIELD CONTRIBUTING CHARACTERS OF BARI GOM 27***" submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN SOIL SCIENCE****, embodies the result of a piece of bonafide research work carried out by* ***MD. NAHID HASAN,*** *Registration no.***14-06321** *under my supervision and guidance. No part of the thesis has been submitted earlier for any other degree or diploma.*

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

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Dated: December, 2014 ***The***

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ABSTRACT

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2014 to February 2015 to study effect of different levels of salicylic acid (SA) on grain yield and yield attributes of Wheat (BARI Gom 27). The experiment was included four levels of SA viz. 0 µM, 200 µM, 500 µM and 1000 µM SA. The experiment was laid out in a randomized complete block design with three replications and 7 treatment combinations as, T_1: No recommended irrigation + 0 µM salicylic acid, T_2: recommended irrigation + 0 µM salicylic acid, T_3: No recommended irrigation + 200 µM salicylic acid, T_4: recommended irrigation + 200 µM salicylic acid, T_5: No recommended irrigation + 500 µM salicylic acid, T_6: recommended irrigation + 500 µM salicylic acid and T_7: recommended irrigation + 1000 µM salicylic acid. The results revealed that yield and yield contributing characters were significantly influenced by the foliar application of different treatments. The maximum plant height (85.17 cm) was obtained from the T4 treatment and spike length (14.80 cm) was obtained from the T7 treatment. The maximum number of effective tillers per m^2 (297.67), maximum number of grains/spike (42.03), maximum filled grains/spike (39.9), lowest unfilled grains/spike (2.13), highest 1000 grain weight (56 g), highest grain yield (4.23 t/ha) and straw yield (5.20 t/ha) were obtained from the T7 treatment. On the other hand, in all cases minimum results were observed in the T1 treatment. The results showed that grain yield of wheat increased with increasing level of salicylic acid up to 1000 µM. Among the treatments having recommended irrigations (T2, T4, T6, T7), yield increasing trend was observed with increasing the level of SA. The yield increasing trend was also observed in the treatments having no recommended irrigations (T1, T3, T5) and this might be due to the foliar application of SA. The above results suggest that drought stress regulatory mechanisms could be improved in wheat through the SA. So, it can be concluded that the recommended irrigations with foliar application of SA could be applied to increase wheat yield.

CONTENTS

CONTENTS (CONTD.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS		
AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BSS	=	Bangladesh Bureau of statistics
cm	=	Centimeter
^{0}C	=	Degree Celsius
DAS	=	Days after sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	and others
FAO	=	Food and Agriculture Organization
g	=	gram (s)
HI	=	Harvest Index
kg	=	Kilogram
kg/ha	=	Kilogram/hectare
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
µM	=	Micro Mole
MoP	=	Muriate of Potash
m	=	Meter
pH	=	Hydrogen ion conc.

ppm	=	Parts Per Million
RCBD	=	Randomized Complete Block Design
RI	=	Recommended Irrigation
SA	=	Salicylic Acid
SAU	=	Sher-e-Bangla Agricultural University
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
UNDP	=	United Nations Development Programme
%	=	Percent

INTRODUCTION

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum L.*) is a major cereal crop and ranks second (after rice) in Bangladesh and first both in acreage and production in the world context (UNDP and FAO, 1999). Wheat is one of the most important cereal crops in the world, which is grown both in arid and semi-arid regions of the world (Akbar *et al*., 2001; Tunio *et al*. 2006). About one-third of the total population of the world live on wheat grain consumption. In 2013, world production of wheat was 713 million tons; making it the third most produced cereal after maize 1,016 million tons and rice 745 million tons. Globally, wheat is the leading source of vegetable protein in human food, having higher protein content than other major cereals, maize or rice. In Bangladesh, the amount of rice production is not enough for feeding a large number of its hungry people. Moreover, wheat constitutes 15-20 % of the staple cereal food of Bangladesh which stands on the second position considering the relative importance of all food crops (Rahman, 1980). Bangladesh produces 13,48,186 metric tons of wheat per annum for 4,44,805 hectares of land with an average yield of 3.031 metric tons per hectare (BBS 2016). Wheat grains have high food value. Wheat Grains contained 14.7% protein, 2.1% fat, 78.1% starch and 2.1% mineral matter (Peterson, 1965). Bangladesh is a small country with large population and its population has an increasing trend. So, cereal crop production like wheat should be increased to meet the demand of the escalating population in this country where per capita requirement of cereal food is more than 400 g. Thus wheat may solve to a considerable extent the food problem and save huge foreign currency of the country as well.

Salicylic acid (SA) is part of a signaling pathway that is induced by a number of biotic and abiotic stresses. It has been recognized as an endogenous regulatory signal in plants mediating plant defense against pathogens (Raskin, 1992). A lot of data exist on the protective effect of SA against ultraviolet light (Yalpani *et al.*, 1994), salinity (Shakirova *et al.*, 2003), drought (Singh and Usha, 2003), heavy metal toxicity (Metawally *et al.*, 2003), high temperatures (Dat *et al.*, 1998) and paraquat (Ananieva *et al.*, 2002). Salicylic acid can also play a significant role in plant water relations (Barkosky and Einhelling, 1993), photosynthesis, growth and stomatal regulation (Khan *et al.*, 2003; Arfan *et al.*, 2007; Issak *et al.*, 2013) under abiotic stress conditions. Plants produce proteins in response to abiotic and biotic stress and many of these proteins are induced by phytohormones such as ABA (Jin *et al.*, 2000) and salicylic acid (Hoyos and Zhang, 2000). SA is synthesized by many plants (Raskin *et al.*, 1990) and is accumulated in the plant tissues under the impact of unfavorable abiotic factors, contributing to the increase of plants resistance to salinization (Ding *et al*,. 2002, Kang and Saltveit, 2002).

Wheat, a major cereal crop, is subject to several biotic and abiotic stresses. These stresses affect the crop's yield globally. Drought stress is one of the most devastating environmental stresses that depress wheat yield productivity in many parts of the world. In the arid and semi-arid regions, wheat is grown under irrigation, but its production is threatened by water shortages caused by pronounced droughts or water mismanagement. Therefore, improved water use efficiency and good water management practices are needed to reduce evaporative and other losses in wheat. Plants are continuously exposed to biotic and abiotic stresses, and salt (NaCl) stress is one of the most severe abiotic stresses limiting plant productivity. If excessive amounts of salt enter the plant, it eventually rises to toxic levels in the older transpiring leaves, causing premature senescence, and reduces the photosynthetic leaf area of the plant to a level that cannot sustain growth (Munns, 2002). Several insect pests infest wheat and cause enormous damage during two important growth stages (heading and flowering) (Freier *et al*., 2007). Wheat aphids are devastating insect pests of wheat (Steffey & Grey, 2012). Management of wheat aphids is difficult due to their rapid reproduction and extremely short life cycle.

Different mechanisms have been adopted by plants to counter the wide range of biotic and abiotic stresses faced. Using plant growth regulators like cycocel and Salicylic acid is a good strategy to waves some sue effects of drought stress. Salicylic acid plays a respiratory role in plants which are under environmental stress. Plant growth regulators controls physiological and biochemical responses of plants and modify plant's internal components and perform important changes that ultimately lead to changes in nutritional and environmental impacts associated with growth and are development (Chen *et al*., 1997). In addition regulatory roles of these compounds in root growth and development, yield and yield component is well understood (Khodary, S. E. A., 2004). There are some reports that Salicylic acid could increase salt tolerance in wheat seedling (Kang *et al*., 2002) and drought stress (Janda, 1999). Different biochemical and physiological responses of plants to salicylic acid were reported (Yusuf, 2008). These effects are ion absorption, membrane permeability and mitochondrial respiration (Glass, 1974). Treated wheat cultivars with salicylic acid (SA) exhibited higher final yield under different levels of drought stress. Wheat seed priming with 0.5 mM SA resulted high germination percentage comparing to control (Janda, 1999). Attention to high rate of redistribution of photosynthetic products in stress conditions, storage of enough non structural carbohydrates in stem and other vegetative plant organs are necessary for supporting grain materials. This is especially important in severe stress conditions and at such conditions photosynthesis and correlated grain weight will decrease drastically. In addition, SA-induced increase in the resistance of wheat seedlings to salinity (Shakirova and Bezrukova, 1997). Thus the detrimental effects of high salts on the early growth of wheat seedlings may be alleiveted by treating seeds with the proper concentration of a suitable hormone (Darra *et al.,* 1973).

In recent years SA has been the focus of intensive research due to its function as systemic plant defense responses against pathogens. Salicylic acid is known to affect various physiological and bio-chemical activities of plants and may play a key role in regulating their growth and productivity (Hayat *et al*., 2010). At present, some negative impacts are appearing in wheat production due to climatic condition in our country. In this case, foliar application of SA will be helpful in wheat cultivation under drought condition. Salicylic acid is considered to be an endogenous growth regulator of phenolic nature that enhanced the leaf area and dry mass production. It enhances germination and seedling growth of wheat. Growth characteristic and photosynthetic rate is increased in wheat, when foliar application of SA is done. Significant increase in However, SA effectively protects the plants against drought stress induced oxidative stress, tissue dehydration and metabolic disturbance which improves plant and yield under drought stress.

OBJECTIVES:

1) To examine effect of foliar application of SA on the performance of wheat.
2) To evaluate the effect of foliar application of SA on the water use efficiency in wheat.
3) To evaluate the effect of foliar application of SA on the insect-pest infestation of wheat.


REVIEW
OF
LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Wheat (*Triticum aestivum L*.) is one of the most important cereal crops in Bangladesh. Growth and development of wheat plant are greatly influenced by the environmental factors, variety and cultural practices. Among these factors, irrigation and SA play notable role regarding the growth and development of wheat plants. A good number of research works have been conducted at home and abroad on the effect of foliar application of SA on wheat cultivation.

Salicylic acid is more or less unknown to the farmers in producing crops in Bangladesh. Salicylic acid plays a significant role in various crops against insect pest attack. Although an extensive research have been carried out in the world on foliar application of SA, yet the work on comparative performance of SA with irrigation is very limited particularly under Bangladesh situation. In this case an attempt is made to review the available literature pertaining to the present study. Most of the research reports showed a positive effect of the foliar application of SA on yield of wheat and other crops. The findings of various authors are cited below:

2.1 Application of Salicylic Acid in Wheat:

Desoky & Merwad (2015) conducted a pot experiment to evaluate the response of wheat plants (*Triticum aestivum* L.) cv. Sakha 93 to different levels of foliar spray of some antioxidant tested substances as ascorbic and SA at a rate of 0.1 and 0.2%, with respect to vegetative criteria, some physiological properties *i.e*. phenol components, proline concentration, yield components, NPK-uptake as well as anatomical structure of flag leaf blade grown under salt stress conditions, 3.21 dS/m , 6.32 dS/m and 10.65 dS/m of soil salt. Data indicated that, all studied vegetative criteria of wheat plants, decreased under salt stress condition. Spraying antioxidant substances seemed to partially overcome the harmful effects of salt stress on vegetative criteria. The highest values of straw and grain yield, biological yield, weight of 1000 grain, protein content and yield efficiency, straw and grains N, P and K-uptake of wheat plants occurred with ascorbic acid 0.2% “AA2” treatment followed by ascorbic acid 0.1% “AA1”, SA 0.2% “SA2”, salicylic acid 0.1% “SA1” and untreated plants that descending order in the two seasons.

Ibrahim *et al.* (2014) carried out two cemented plots experiments during the winter seasons of 2012/2013 and 2013/2014, Soil Salinity Laboratory, Alexandria, Egypt, to study the effect of three levels of salicylic acid (SA) (0, 50, 100 ppm) on yield and yield components of wheat (Sakha 93). Increasing SA rates resulted in significant increase in plant height (cm), number of grain/spike, number of spikes/m2, 1000 grain weight (gm), grain yield (gm/plot), straw yield (gm/plot), and biological yield (gm/plot) in addition to grain weight/spike (gm).

Howladar & Dennett (2014) conducted a pot experiment to analyze the effect of exogenous application; seed priming or foliar spraying of SA on Yecora Rojo and Paragon wheat cv. under NaCl-salinity. Gas exchange parameters, growth parameters, yield and yield components were reduced in both cultivars under salinity stress with foliar spray and soaking seeds. Exogenous application of SA through foliar spraying or seed soaking showed a slight increases or decreases with the application method or between cultivars. SA foliar spraying exhibited a slight improvement over SA seed soaking in most parameters, particularly in Paragon. However, the low SA concentration; 0.5 mM tended to improve most parameters in both cultivars.

Morad *et al.*, (2013) showed that the effect of salt stress and SA application on growth and yield component traits of wheat, an experiment was conducted in factorial based on rcbd design with 3 replications in research farm (green house condition) of university of tehran (karaj-iran) during 2010-11. Salt stress factor including three levels (control, salt stress with NaCl 4 ds/m and NaCl 8 ds/m) and SA (application and none application). The experiment was carried out on two variety of wheat, separately. The results indicated that maximum height was achieved in Control × SA none application treatment and minimum height was achieved in NaCl 8 ds/m × SA none application treatment. also SA application increased number of grain in spike. SA application alleviated destructive effect of salt stress. The results indicated that interaction effect of salt stress × SA had significant effect ($p \leq 0.01$) on Tabasi variety but had not significant effect on Arvand variety on total chlorophyll and relative water content traits. It can be concluded that foliar application of wheat cultivar plants with salicylic acid stimulate the growth of wheat plants via the enhancement of the biosynthesis of photosynthetic pigments; improved relative water content, decreasing of organic solutes (Proline) and thus salicylic acid treatment improved wheat growth especially on Tabasi variety.

Hassanein *et al.* (2012) conducted an experiment to study the analysis of drought stress defense triggers in wheat plants grown in dry sandy lands using methods of grain-priming and/or foliar pretreatments on the preanthesis stages. Morphological, biochemical and yield components data revealed that wheat originated from grain-priming combined with foliar applications had exhibited stronger anti-drought effects. A raised tolerance level was ascertained from the up-regulation of crop production and quality in drought cultivation compared to normally irrigated wheat.

Fateh *et al.* (2012) conducted an experiment to study the effect of SA and seed weight on Wheat germination (CV. BC ROSHAN) under different levels of osmotic stress. The results showed that osmotic stress decreased seed germination of wheat cultivars in general concentration of PEG (12 bar) and 1000 Weight kernel (22 gm) decreased germination over % as compared with control. Also, the SA increased the seedling length and dry weight of seedlings. SA increased length and weight of radicle and plumule in treatments of low seed weight (1000 grain weight =22 g).The lowest germination index were also observed in the treatment of severe stress and without pre-treated with SA and minimum seed weight.

Sharafizad *et al.* (2012) conducted an experiment to investigate the effect of SA on total yield and yield component of wheat under stress condition. Treatments were drought stress at three levels (control, drought stress in mid florescence and drought stress in grain filling stage). Second treatment was application of SA as a priming agent, foliar application at beginning of tillering and foliar application of SA at beginning of flowering, and the third treatment was different dosage of salicylic acid (0, 0.7, 1.2 and 2.7 mM). Results of experiment showed that drought stress significantly decreased grain yield, efficiency of material distribution while the highest grain yield was obtained at non-stressed condition with application of 0.7 mM SA. Grain yield exhibited high and positive correlation with number of spikes in m2, number of grain in spike, biological yield and harvest index.

Anosheh *et al.* (2012) carried out a field experiment to assess the effects of SA (SA) on drought-stress induced changes in morpho-physiological and biochemical characteristics of two commonly grown wheat cultivars in Iran. Drought stress increased canopy temperature and decreased leaf area index and plant height in both cultivars; however, exogenous applications of SA (0.7 mM) reduced these harmful effects considerably. Drought stress also significantly increased the levels of total soluble proteins and free proline, the activities of antioxidant enzymes superoxide dismutase, peroxidase and catalase, and decreased the contents of chlorophyll *a* and chlorophyll *b*. Application of SA increased total soluble proteins, chlorophylls *a* and *b*, and peroxidase activity.

Erdal *et al.* (2011) performed a field experiment to study the effects of foliar-applied SA on salt sensitivity, hydrogen peroxide (H_2O_2) generation and activities of antioxidant enzymes like peroxidase (POX) and catalase (CAT) in plant tissues under salt stress. SA treatment significantly increased the fresh and dry weights in both root and shoots of wheat plants under salt stress. SA treatment significantly increased the fresh and dry weights in both root and shoots of wheat plants under salt stress. Similarly, POX and CAT activities were also augmented by SA treatment. Inparallel to increasing antioxidative activity, SA treatment decreased H_2O_2content when compared to plants growing under salt stress without SA.

Amin *et al.* (2008) conducted a field experiment for the two successive seasons of 2004/2005 and 2005/2006 at the experimental station of the National Research Centre at Shalakan, Qalubia Governorate, Egypt to study the response of wheat plants to foliar application of salicylic acid, ascorbic acid at (0.0, 100, 200 and 400 mg/L) as well as their interaction on vegetative growth, photosynthetic pigments content, yield and some biochemical constituents of wheat grains. The data indicated that, an enhancement effect of growth characters, yield, total carbohydrate as well as nitrogen, phosphorus and potassium content in wheat grains was obtained by 100 or 200 mg/L of SA. Moreover, the same preceding underwent a reverse pattern of change using the higher concentrations of SA (400 mg/L).

Yordanova and Popova (2007) carried out a field experiment to study the effects of SA) and cold on photosynthesis, activities of carboxylating enzymes ribulose-1,5-bisphosphate carboxylase (RuBPC) and phosphoenol pyruvatecarboxylase (PEPC) and activities of photorespiratory enzymesglycolate oxidase (GO) and catalase (CAT), and on the activities of antioxidant enzymes superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione reductase (GR) and peroxidase(POX) in winter wheat (*Triticum aestivum,* cv. Dogu-88) leaves. Exposure of wheat plants to a low temperature (3^{o}C) for 48 h and 72 h resulted in decreased levels of chlorophyll, CO2 assimilation and transpiration rates and increased activity of GO and CAT. Treatment with SA alone for 24 h resulted in a lower rate of photosynthesis, decreased transpiration and stomatal conductance accompanied with enhanced rate of lipid peroxidation and peroxides level. Treatment with 500 µM/L SA for 24 h before exposure to chilling provided protection on RuBPC activity and chlorophyll content. The activities of GO, CAT, POX, and APX additionally increased in SA-treated plants.

Waseem *et al.* (2006) conducted an experiment to assess whether exogenously applied SA through the rooting medium could mitigate the adverse effects of water stress on plant growth, photosynthesis and nutrient status of two wheat genotypes (S-24 & MH-97). Results showed that different levels of SA applied through the rooting medium increased photosynthetic rate in both cultivars under non-stress conditions but only in S-24 under water stress conditions. Exogenous application of 5 or 10 mg/L SA caused an increase in stomatal conductance, transpiration rate, and sub-stomatal of water stressed plants of cv. S-24 whereas it was true for droughted plants of MH-97 only when 5 mg/L SA applied. Cultivar S-24 was generally higher in N and P contents of shoot and root than that in genotype MH-97 under both normal and water stress conditions. Although, exogenously applied SA through the rooting medium had growth promoting effects under non-stress conditions, it did not mitigate the adverse effects of drought stress on growth of both cultivars, though genotype MH-97 showed some recovery under water stress conditions.

Shakirova *et al.* (2003) reported that wheat seedlings treated with 50 µM SA develop larger ears and increased the level of cell division within the apical meristem of seedling roots causing an increase in plant growth and an elevated wheat productivity. It was found that SA treatment caused accumulation of both abscisic acid (ABA) and indoleacetic acid (IAA) in the wheat seedlings but did not influence cytokinin content. SA treatment reduced the damaging action of salinity on seedling growth and accelerated reparation of the growth processes. SA-treatment diminished changes in phytohormones levels in wheat seedlings under salinity. It prevented any decrease in IAA and cytokinin contents and thus reduced stress-induced inhibition of plant growth. A high ABA level was also maintained in SA-treated wheat seedlings providing the development of antistress reactions, for example, maintenance of proline accumulation. Thus SA's protective action includes the development of antistress programs and acceleration of growth processes recovery after the removal of stress factors.

2.2 Application of Salicylic acid on Others Crop:

Amira M. S. & Qados, A. (2015) carried out an experiment to investigate the effect of salinity stress on growth, chemical constituents and yield, and to examine whether salinity stress can be offset by the exogenous application of SA on sweet pepper (*Capsicum annuum* L. cv. Orlando). Salinity stress (2000, 4000 or 6000 ppm) decreased plant growth and marketable yield but SA (250 ppm) treatment as foliar spray counteracted significantly the harmful effects of low and moderate salinity stress levels (2000 and 4000 ppm) and partially counteracted the harmful effects under the highest salinity stress level (6000 ppm).

Singh *et al.* (2015) conducted a research to assess the effect of salicylic acid along with standard fungicide on sheath infecting pathogen and yield attributes in hybrid rice. Two different concentration of SA (20 and 40 ppm) and Mancozeb (3 and 4 gm/l) were used at three different stages (Booting stage, Heading stage and at the time 50 % flowering). Results revealed significant increase for most of the yield attributes studied for all the treatments over control but found non-significant for panicle/plant.

Ahmad *et al.* (2014) conducted an experiment in pots and field to investigate the effect of exogenous application of ascorbic acid (AsA), SA and H_2O_2 to improve the maize performance at sub-optimum temperatures. In pot experiment, foliar application of AsA, SA and H_2O_2 at each concentration improved seedling growth, leaf relative water, chlorophyll *b* contents, membrane stability and enzymatic antioxidant activities in maize. In field experiment, application of these substances either through seed priming or foliar spray improved the morphological, yield related attributes and grain yield of spring maize; however, seed priming was more effective than foliar application.

Molazem, D. & Bashirzadeh, A. (2014) conducted an experiment to evaluate the effect of salt stress and SA application on growth and physiological traits of maize varieties, in factorial split plot based on RCBD design with 3 replications in research farm of Islamic Azad University of Ardebil branch during 2012-13.Salt stress factor including three levels (control, 50 mM and 100 mM NaCl) and SA (control, 1 mM and 2 mM). Results from the experiment showed that, between different salinity in carotenoid, chlorophyll a+b, chlorophyll content and proline were significantly different. Effect of SA except for stem diameter was not significant for all traits. Between leaves length with chlorophyll content, total chlorophyll (a+b) and carotenoid was observed significant positive correlation. There was a significant positive correlation between chlorophyll content with total chlorophyll, carotenoids and stem diameter.

Mahdi, J. (2014) revealed that the effects of SA on some quality characters of tomato different concentration of SA (10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} molar and control) was done in seedling stage as foliar replication. Measured characters was including (number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter). Obtained results of this study show that SA significantly affected number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter. Among foliar application, the highest rate of tomato yield with mean of 3059.5 g obtained in SA3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA1 (SA at 10^{-2} M). Highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control treatment and the highest amount of fruit weight and also fruit diameter was measured in control treatment with mean of 61.50 g and 51.75 mm, respectively.

Mohsen, K. (2014) conducted an experiment to study the effect of SA and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. These factors included SA in 2 levels (0.5 and 0.75 mM/L) and methyl jasmonate in 3 levels (0.25, 0.5 and 0.75 mM/L) applied on tomato. Results indicated that SA (0. 5 mM/L) and methyl jasmonate (0.25 mM/L) either alone or in combination (0.5 mM/L SA+ 0.25 mM/L MJ) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 mM/L) alone significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom end rot, but methyl jasmonate application alone or in combination had not significant effect on blossom end rot and leaves -NK content. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of SA and methyl jasmonate either alone or in combination (0.5 mM/L SA+ 0.25 mM/L MJ). Application of SA with methyl jasmonate improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Usharani *et al.* (2014) investigated the effect of SA and *Pseudomonas fluorescens* on growth and yield of Paddy IR-50. Among the various treatments tested, maximum growth and yield was observed in the treatment T_6 (*Pseudomonas fluorescens* seed application + SA applied on 30^{th} day) and the least parameters were recorded in the Control treatment (T_1).

Javed *et al.* (2013) Showed that the effect of SA on growth and nitrogen metabolism in mungbean grown under saline conditions, an experiment was conducted in wire house in plastic pots containing soil + sand at NIAB Faisalabd. Mungbean (*Vigna radiate* L.) varieties, two salt tolerant (NM-98 and NM-92) and two salt sensitive

(NM-54 and NM-13-1), identified in laboratory experiments, were grown under four salinity levels, i.e., 1.2, 4, 8 and 12 Ds/m. Salicylic acid @ 0, 100, 200 and 300 mg /L was applied as foliar spray at vegetative and flowering stages. Results indicated that salinity reduced the growth by decreasing plant height and fresh biomass of all the cultivars, however, the salt tolerant cultivars performed better than sensitive ones. Foliar application of SA @ 100 mg/L significantly improved all the growth parameters in all the cultivars under saline conditions. The SA levels of 200 and 300 mg/L did not show appreciable performance regarding growth attributes under normal and saline conditions. Application of SA @ 100 mg/Lwas helpful in reducing the adverse effects of salinity on all the above mentioned parameters while other levels of SA did not perform better under all salinity treatments.

Ghasemi-Fasaei, R. (2013) showed that foliar application of SA decreased mean dry weight of cucumber by 31%, while its effect on mean dry weight of chickpea was negligible. Foliar application of SA decreased mean uptake of Zn, Mn, Cu and Fe in cucumber shoot by 29, 34, 22 and 31%, respectively. Decrease in dry matter yield of cucumber following foliar application of SA was, therefore, attributed to the significant decrease in the uptakes of metal micronutrrients. Foliar application of SA decreased mean uptake of Cu and Fe in chickpea shoot by 31 and 18%, respectively. The effect of SA on mean Zn uptake in chickpea shoot was negligible. Foliar application of SA caused an increase in mean Mn uptake of chickpea shoot by about 7%.The influence of HA levels on mean dry matter weight in chickpea was uncertain. Soil application of 2 and 4 mg HA kg-1 caused negligible decrease in mean dry matter weight of chickpea shoot by 5 and 8%, respectively. The effects of HA levels on the uptakes of Mn was insignificant. Application of 4 mg HA kg-1 increased mean uptakes of Fe, Cu and Zn by 7.1, 8.5 and 9.6%, respectively. Application of 4 mg

HA/kg increased mean uptakes of metal micronutrients compared to the control although the increase for Fe uptake was negligible. Application of 4 mg HA/kg increased mean uptakes of Mn, Cu and Zn by 18.7, 100, and 18.6%, respectively. Shoot dry weight of chickpea was significantly correlated with the uptakes of Zn, Fe and Mn but was not correlated with the uptake of Cu. Shoot dry weight of cucumber was significantly correlated with the uptakes of Zn, Fe, Cu and Mn. In cucumber shoot, the uptakes of all metal micronutrients were significantly correlated with each other. In chickpea shoot, the uptakes of all metal micronutrients other than Fe were significantly correlated with each other. According to the results of present study it appears that neither SA nor HA was efficient to be recommendable for correcting metal micronutrients deficiency under micronutrients deficient conditions.

Salwa *et al.* (2013) The work concerned to study the effect of SA on growth criteria (shoot height and shoot dry weight), soluble sugars and protein, antioxidant enzymes (SOD, APX and GR) activities and specific activities, lipid peroxidation, electrolyte leakage and yield criteria (Pod weight, seed weight, seed number and 100-seed wieght). The obtained results revealed that salt treatments provoked oxidative stress in faba bean plants as shown by the increase in lipid peroxidation and electrolyte leakage and consequently negatively affected growth and yield criteria. Foliar spray with SA at the concentration of 2mM followed by 1mM mitigated the harmful effects of salt stress through the enhancement of the protective parameters, such as antioxidant enzymes, soluble sugars and proteins and consequently improved growth and yield criteria.

Sood *et al*. (2013) undertook a field study to ascertain the effects of elicitors *viz.* benzothiadiazole (BTH) and SA on defense related enzymes *viz.* peroxidase, phenylalanine ammonia lyase, superoxide dismutase, chitinase and β-1,3-glucanase, and phenols in rice (Pusa Basmati I) plants. Higher enzymatic activity was observed in elicitor treated plants inoculated with *R. solani*. Compared to the untreated control plants, application of elicitors before *R. solani* inoculation significantly elicited the defense related enzymes and phenols. Moreover, application of elicitors had a positive effect on yield and disease reduction.

Zamaninejad *et al.* (2013) conducted an experiment in order to investigate foliar spraying of different concentrations of SA on corn (KSC400 var.) yield and yield components under drought condition, based on Randomized Complete Block Design (RCBD) as Split Plot with three replications during 2011-2012 growing season at Sabzevar region, Iran. Means comparison revealed that the effect of SA spraying on the growth of morphological traits and increasing in the corn yield was considerable and significantly inhibited of decreasing in plant height, ear height, leaf area of the main ear, row no/ear, kernel no/ row and ear length 1 Mm concentration of SA at 10-12 leaf stage had the greatest impact on the relieving of drought stress.

Fahad, S. & Asgharibano (2012) conducted a field experiment to determine the effect of exogenously applied SA onphysiology of maize (*Zea mays* L.) hybrid cv. 3025 grown in saline field (pH 8.4 and EC 4.2 ds/m) as well as on the nutrient status of saline soil. The SA (10^{-5} M) was applied as foliar spray, 40 days after sowing (DAS) at vegetative stage of maize plants. Foliar application of SA to salt stressed plants further augmented the sugar, protein, proline, superoxide dismutase (SOD), peroxidase (POD) ascorbate peroxidase (APOX) activities, endogenous abscisic acid (ABA) , indole acetic acid (IAA) content, and root length, fresh and dry weights of roots whereas, the chlorophyll a/b and ABA/IAA ratio were decreased. The exogenous application of SA significantly decreased the Na^{+}, Ni^{+3}, Pb^{+4}, Zn^{+2}, and Na^{+}/K^{+} content of soil and roots while increased the Co^{+3}, Mn^{+2}, Cu^{+3}, Fe^{+2}, K^{+} and Mg^{+2} content under salinity stress. It can be inferred that exogenous application of SA (10^{-5}M) was effective in ameliorating the adverse effects of salinity on nutrient status of soil. SA (10^{-5}M) can be implicated to mitigate the adverse effects of salinity on maize plants.

Rao *et al.* (2012) conducted a pot experiment to determine drought mitigating effect of Salicylic acid and L-Tryptophan. Salicylic acid and L Tryptophan were sprayed at 3-4 leaves stage @ 100, 150, 200 ppm and 5, 10, 15 ppm, respectively. Drought stress was induced by withholding water after five days of SA and L-Tryptophan application. Significantly higher relative water content, leaf membrane stability index, chlorophyll and potassium content were found in plants treated with 100 ppm SA and 15 ppm L-Tryptophan compared with other treatments and control plants. Results suggest that foliar application of SA and L-Tryptophan can play a role to reduce the effect of drought in maize.

Javaheri *et al.* (2012) carried out an experiment to study the effects of SA on yield quantity and quality of tomato. Foliar application of five concentrations of SA (0, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} M) were used. Results showed that application of SA affected tomato yield and quality characters of tomato fruits so that tomato plants treated with SA 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, significantly improved the fruit quality of tomato, increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits.

Pradeep *et. al.* (2012) showed that four chickpea genotypes (Tyson, ICC 4958, JG 315 and DCP 92-3) were treated with 1.0 mM and 1.5 mM SA and subjected to pre- and post flowering drought stress to analyse its influence on nitrate reductase (NR) activity, relative water content (RWC), proline and antioxidant enzymes activity (superoxide dismutase and peroxidase). Leaf RWC significantly reduced during stress at both the growth stages and ranged between 71.67-74.43% (unstressed) and 67.96-71.67% (stressed), whereas in 1.5 mM SA treated plants leaf RWC increased comparable to the control (unstressed plant). NR activity significantly reduced under stress at the post anthesis stage of growth but was maintained higher in 1.5 mM SA treated plants in all the four genotypes studied. On the other hand, activities of antioxidant enzymes superoxide dismutase (SOD) and peroxidase (POX) were up regulated by drought stress and interestingly further enhanced by 1.5 mM SA treatment. The response of SA (1.5 mM) was relatively more in ICC 4958 and Tyson cultivars of chickpea. Hence, results signify the role of SA in protecting metabolic activity along with regulating the drought response of plants.

Sadeghipour, O. & Aghaei, P. (2012) conducted an experiment to evaluate the influence of exogenous SA application on some traits of common bean under water stress conditions in Iran during 2011. Results showed that drought decreased plant height, leaf area index (LAI) and protein yield but increased seed protein content. Nevertheless, seeds soaking in SA (especially 0.5 mM) diminished drought damages and increased plant height, LAI and protein yield in both water stress and optimum conditions. SA application also decreased seed protein content. Results indicate that exogenous application of this phytohormone can act as an effective tool in improving the growth and production of common bean under water stress conditions.

El-Yazied, A.A. (2011) conducted a field experiment to study the effect of foliar application with 50 & 100 ppm of SA and 50 & 100 ppm chelated zinc (Zn) and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, fruiting and fruit quality of sweet pepper cv. California Wonder during autumn 2009 and 2010 seasons. Results indicated that different applied treatments significantly increased all studied growth parameters, namely, number of branches and leaves per plant, leaf area per plant and leaf dry weight. Furthermore, the highest early, marketable and total yields as well as physical characters of sweet pepper fruits were obtained with 100 ppm SA plus chelated 50 ppm zinc followed by 50 ppm SA plus 100 ppm Zn.

Farooq *et al.* (2009) conducted a pot experiment to evaluate the role of SA to induce drought tolerance in aromatic fine grain rice cultivar Basmati 2000. Foliar treatments were more effective than the seed treatments. Foliar application with 100 mg/L (FA 100) was the best treatment to induce the drought tolerance and improve the performance under normal and stress conditions compared with the control or other treatments used in this study.

Jeyakumar *et al*. (2008) reported that application of SA (125 ppm) in black gram increased the seed yield (85 kg/ha).

Nagasubramaniam *et al*. (2007) revealed that the cob yield of baby corn was the highest (7703.4 kg/ ha) by the foliar application of SA (100 ppm).

Chandra *et al.* (2007) showed that the effects of SA on seed germination, seedling growth, flowering and biochemical activities were studied out in four cowpea (Vigna unguiculata) genotypes in control environments. The results revealed that both germination and seedling growth were negatively affected by 0.02%. SA application, however did not affect the size of full expanded buds, time of 50 % flowering and date of flower initiation. A maximum increase in peroxidase (EC1.11.1.7) activity was observed in UPC 4200 over other genotypes. No significant change in the content of total soluble and intercellular fluid proteins was observed except in UPC 4200 genotype. SA induced accumulation of total soluble sugars more at flowering stage than at seed setting stage. It is evident from the present study that UPC 4200 genotype was more responsive to salicylic acid both in terms of increased peroxidase activity and less negative effect on morphological attributes, thus suggesting its wider use without negative impact on environment as SA has been reported in plants.

Sujatha, (2001) reported that foliar application of SA (100 ppm) on green gram at 75 DAS increased number of pods/ plant, number of seeds/ pod, seed weight/ plant, 100 seed weight and grain yield (840 kg/ ha).

Hare *et al.* (1998) have expressed that proline content increase when there is an injury in plant tissue. Possibly in plants treated with SA 200 mg/L and subjected to saline stress, where growth is greater and plant status better, damage is less therefore proline level are decreased.

Gutie´rrez-Coronado *et al. (*1998) showed that SA has growth-stimulating effects in soybean plants. When soybean plants treated with 10 nM, 100 µM, and up to 10 mM SA, shoot and root growth increase; 20% and 45%, respectively, 7 d after application.

Singh and Kaur (1981) revealed that SA sprayed on mungbean significantly increased the pod number/ plant and yield.

Singh *et al*. (1980) reported that, foliar application of SA in green gram at branching, flower bud initiation stages increased the number of flowers, pods & seeds/ plant and seed yield.

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methods used in the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate and materials used for the experiment. The details of the experiment are given below.

3.1 Location Of The Experiment

The research work was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period fromNovember2014 to March 2015. The field was located at the south part of the main academic building. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28).

3.2 Soil

The experiment was carried out in typical wheat growing soil of Sher e Bangla Agricultural University (SAU) Farm, Dhaka, during rabi season of 2014.The farm belongs to the General soil type, Deep Red Brown Terrace Soil" under Tejgaon series. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of initial soil are presented in Table 1 and 3.

3.3 Climate

The experimental area is under the subtropical climate. Usually the rainfall was heavy during Kharif season and scanty in Rabi season. The atmospheric temperatures increased at the growing period proceeded towards Kharif season. The weather conditions of crop growth period such as monthly mean rainfall (mm), mean temperature (°C), sunshine hours and humidity (%) in appendix 3.

3.4 Planting materials

Wheat (*Triticum aestivum L.*) variety BARI GOM 27 was used as plant material. BARI developed this variety and released in 2012. It is most popular variety now due to its high yielding potentials suitable for early and late planting (up to the second week of December). This variety attains a height of 95-100 cm and it is resistant to leaf spot, leaf and stem rust disease. The numbers of tillers/plant are 4-5 and the leaves are wide and deep green in color. It requires 60-65 days to heading. Grains yield is 3.5 to 5.4 t/ha and 1000 grain weight is 35-40g. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Seeds contain 60-65% carbohydrate.

Table 1.Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e Bangla agricultural University Farm, Dhaka
AEZ	Madhupur tract
General soil type	Deep Red brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds are removed. The first ploughing and final land preparation were done on 10November and 16November 2014, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before seed sowing and basal dose of fertilizers was incorporated thoroughly before seed sowing.

3.6 Fertilizer application

Fertilizer was applied based on BARC fertilizer recommendation guide-2014. The rate of N-P-K-S-Zn-B were 120-30-90-15-1.6-1.0 kg/ha respectively. The unit plots were fertilized with 208.70 g Urea, 120g TSP, 144g MP,75g Gypsum, 5O g $MgSO_4$, 2.6 g ZnO and 4.71 g H_3BO_3 respectively. Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) Zinc sulphate, Boric acid were used as nitrogen, phosphorus and potassium, Zinc and Boron respectively. The whole amount of TSP, MP, Gypsum, Zinc sulphate and Boric acid and two thirds of the Urea were applied at the time of final land preparation prior to sowing. The remaining one-third of urea was top-dressed on 20 days after sowing (DAS) the seed.

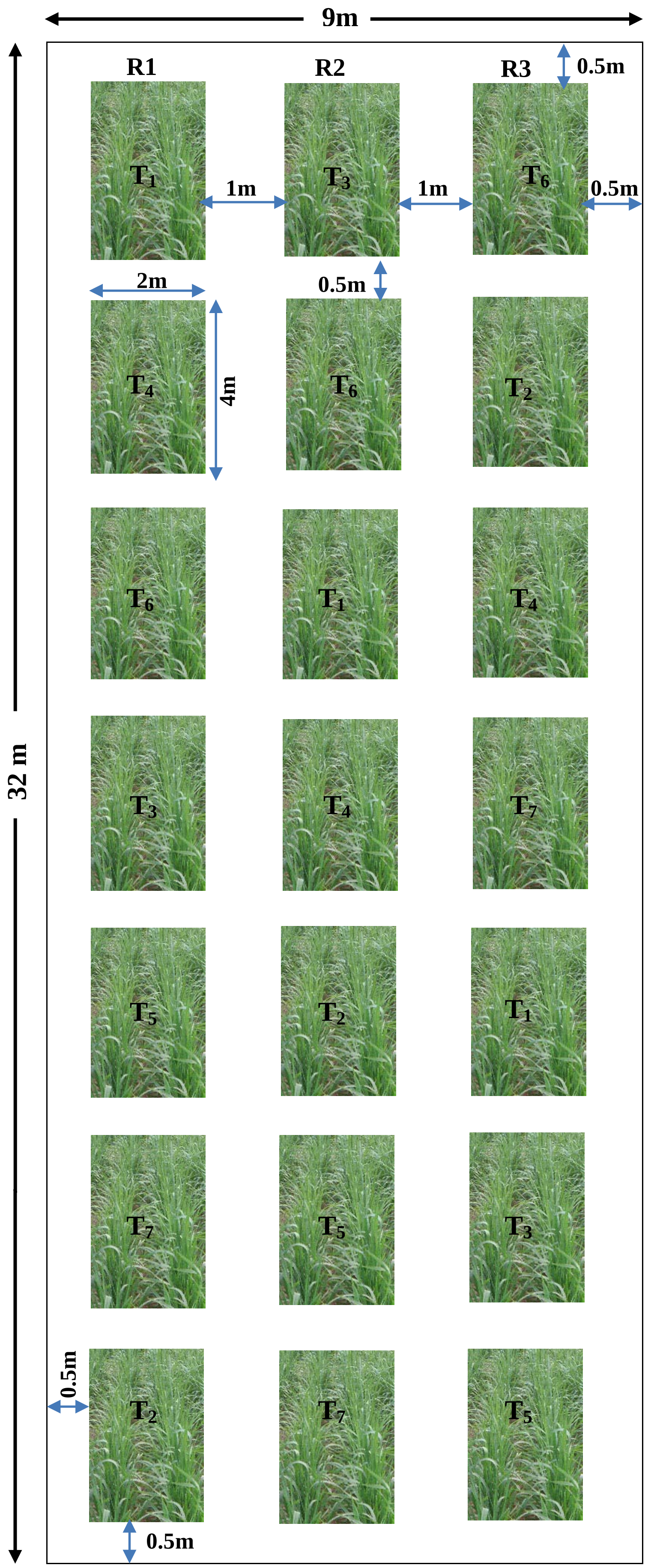
3.7 Treatments of the experiment

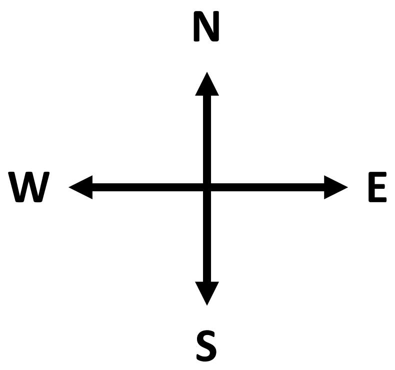
The experiment was single factorial with seven levels of Salicylic acid. Therefore seven treatment combinations of this experiment will be as follows:

T_1 = Without Irrigation+0 µM SA
T_2 = With Irrigation+ 0µM SA
T_3 = Without Irrigation+ 200 µM SA
T_4 = With Irrigation+ 200 µM SA
T_5 =Without Irrigation+ 500 µM SA
T_6 = With Irrigation+ 500 µM SA
T_7 = With Irrigation+ 1000 µM SA

3.8 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (factorial). Each treatment was replicated three times. The size of a unit plot was 4 m × 2 m. The distance between two adjacent replications (block) was 1m and row to row distance was 0.5 m. The inter block and inter row spaces were used as foot path and irrigation/drainage channels.





Distance between replications:

1m

Distance between treatments:

0.5m

Total length of the field:

(7×4m) +(8×0.5m) = 32m

Total width of the field:

(3×2m)+(0.5m+1m+1m+0.5m)= 9m

Total area of the field:

L×B = 32m × 9m = 288m^2

<u>Replications:</u>

R_1: Replication 1

R_2: Replication 2

R_3:Replication 3

<u>Treatment Combinations:</u>

T1: 0 µM Salicylic acid

T2: 200 µM Salicylic acid

T3: 500 µM Salicylic acid

T4: 0 µM Salicylic acid

T5: 200 µM Salicylic acid

T6: 500 µM Salicylic acid

T7: 1000 µM salicylic acid

Figure 1: Layout of Experimental Plot

3.9 Sowing of seeds in the field

The seeds of wheat were sown in rows made by hand plough on November 16, 2014. The seeds were sown in rows in the furrows having a depth of 2-3 cm from soil surface. Row to row distance was 50 cm.

3.10 Intercultural operations

3.10.1 Irrigation

Two irrigations were applied; first irrigation was applied at 20 DAS (Days after sowing) and second irrigation was applied at 52 DAS.

3.10.2 Weeding

The crop field was weeded twice; first weeding was done at 20 DAS (Days after sowing) and second weeding at 40 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.10.3 Protection against insect and pest

A huge number of aphids were attacked on wheat field from vegetative stage to ripening stage especially in treatment 1, 2, 3 & 5. No control measures were taken during aphid attack because I want to examine the effects of Salicylic Acid on insect pest management.

3.10.4 Preparation and application of Salicylic acid

Four levels of SA concentration were applied in experimental field. The mixture of 13.812 g SA in 100 ml ethanol is called 1M Stock solution of SA. 0.4 ml SA solution was taken from stock solution in 2 L spray bottle for making 200 µM SA solutions. Similarly 1 ml and 2 ml SA solution were taken from stock solution in 2 L spray bottle for making 500 µM and 1000 µM SA solution respectively. Foliar application of SA was done in wheat field.

3.11 Crop sampling and data collection

The crop sampling was done at the time of harvest. Harvesting date was 01/03/2015. At each harvest, ten plants were selected randomly from each plot. The selected plants of each plot were cut carefully at the soil surface level. The plant heights, spike length, no of grain per spike, filled grain per spike, unfilled grain per spike, 1000 grain weight, grain yield and straw yield were recorded separately.

3.12 Harvesting and postharvest operations

Harvesting was done when 90% of the crops become brown in color. The matured crops were cut and collected manually from a pre demarcated area of $1m^2$ at the center of each plot. After harvesting, the samples were sun dried.

Table2. Dates of different operations done during the field study

Operations	**Working Dates**
First ploughing of the field	10 November 2014
Final land preparation	16 November 2014
Application of fertilizers (2/3rd Urea, TSP, MP, Gypsum, $MgSO_4$, ZnO, Boric acid)	16 November 2014
Seed sowing	16 November 2014
Intercultural Operations	**Working Dates**
Thinning and gap filling	28 November 2014
First weeding	05 December 2014
First irrigation and rest 1/3rd urea application	05 December 2014
Mulching	09 December 2014
Thinning and 2nd irrigation	06 January 2015
Harvesting and threshing	01 March 2015

3.13 Data collection

The data on the following parameters of ten plants were recorded at each harvest.

1) Plant height (cm)
2) Spike length (cm)
3) Number of grain per spike
4) Filled grain per spike
5) Unfilled grain per spike
6) 1000 grain weight (g)
7) Grain yield (t/ha)
8) Straw yield (t/ha)

3.14 Procedure of data collection

3.14.1 No. of tiller/m^2

Total number of plants from 1m^2 area from each plot was counted at the time of harvest.

3.14.2 Plant height

The height of ten plants were measured with a meter scale from the ground level to top of the plants and the mean heights were expressed in cm.

3.14.3 Spike length

Spike length were measured from ten plants and then averaged. This was taken at the time of harvest and it is expressed in cm.

3.14.4 Number of grain/spike

Total grain numbers were counted from total spike that was obtained from pre-selected ten plants. After that it was averaged and expressed as number of grain per spike.

3.14.5 Number of filled grain/spike

Filled grain per spike were counted from ten plants and then averaged.

3.14.6 Number of unfilled grain/spike

Unfilled grain per spike were counted from ten plants and then averaged.

3.14.7 Weight of 1000 grain

One thousands cleaned dried seeds were counted randomly from each harvest sample and weighted by using a digital electric balance and mean weight was expressed in gram.

3.14.8 Grain yield (t/ha)

Weight of grain of the demarcated area ($1m^2$) of each plot was taken and then converted to the yield in t/ha.

3.14.9 Straw yield (t/ha)

Straw obtained from each plot were sun dried and weighed carefully. The dry weight was taken carefully. The dry weighed straw of central $1m^2$ area and ten sample plants were added to the respective unit plot yield to record the final straw yield/plot and finally converted to t/ha.

3.14.10 Biological Yield (t/ha)

Biological yield was calculated from addition of grain yield and straw yield.

3.14.11 Harvest Index (%)

The harvest index (HI) was calculated by dividing the actual yield of seeds by the biological yield of the crop. It was expressed as percentage.

$$\text{Harvest Index} = \frac{\text{Seed Yield (t ha}^{-1}\text{)}}{\text{Biological Yield(t ha}^{-1}\text{)}} \times 100$$

3.15 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-computer package program. 5% level of significance was used to compare the mean differences among the treatments.

3.16 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

Table 3.Physical and chemical properties of the of the initial soil sample

Characteristics	Value
Particle size analysis	
% sand	8
% silt	50
% clay	42
Textural class	Silty clay
Consistency	Granular and friable when dry
pH	6.27
Bulk density (g/cc)	1.45
Particle density (g/cc)	2.25
Organic carbon (%)	0.66
Organic matter (%)	1.14
Total N (%)	0.06
Available P (ppm)	19.85
Exchangeable K (meq/100g of soil)	0.12

3.17 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil science department, Sher-e-Bangla Agricultural University, Dhaka. The properties studied included soil texture, p^H, organic matter, total N, available P, exchangeable k, and available S. The physical and chemical properties of postharvest soil was analyzed by standard methods:

3.17.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method and then textural class was determined by plotting the values for % sand, % silt and % clay to the "Marshall's Textural Triangular Coordinate" according to the USDA system.

3.17.2 Soil P^H

Soil p^H was measured with the help of a Glass electrode p^H meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

3.17.3 Organic C

Organic carbon in soil was determined by Walkley and Black (1934) Wet Oxidation Method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed as percentage.

3.17.4 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1

gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination. Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

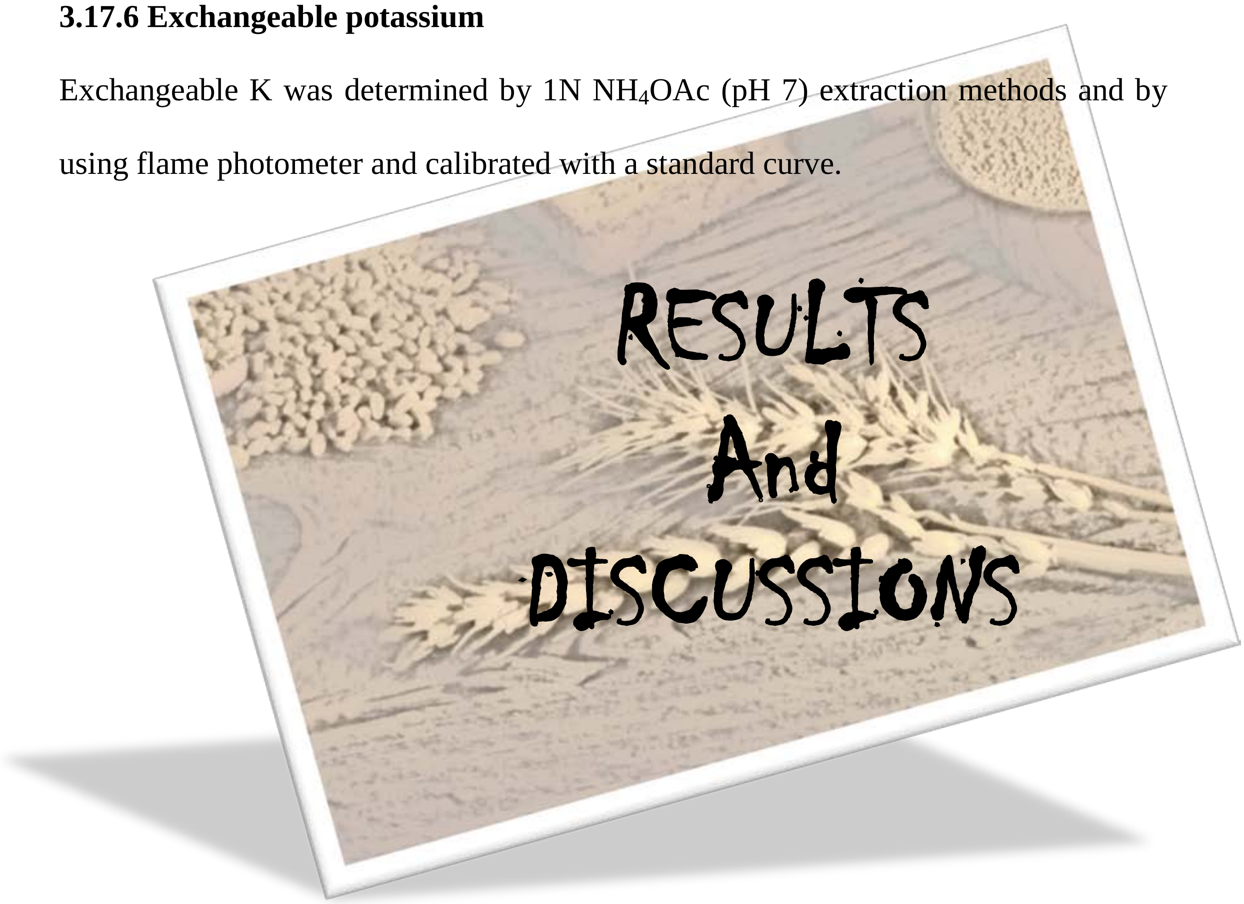
S = Sample weight in gram

3.17.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve.

3.17.6 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve.



CHAPTER 4

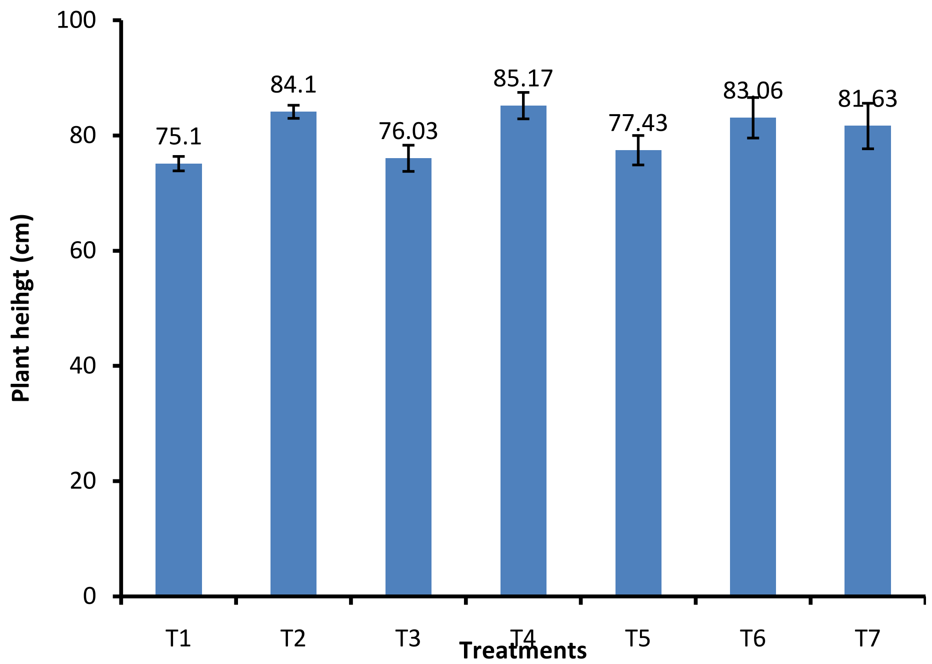
RESULTS AND DISCUSSION

The results obtained from the present study for different characters, yields and other analyses have been presented and discussed in this chapter.

4.1 Role of salicylic acid on growth, yield attributing characters and yield of wheat

4.1.1 Plant height

Under the present study, the plant height was significantly influenced by the different treatment combinations (Fig.2). The results revealed that the maximum plant height (85.17 cm) was observed from the treatment T4 (with irrigation with 200 µM SA) whereas the minimum plant height (75.10 cm) was obtained from the treatment T1 (without irrigation with no SA). However, foliar application of SA did not influence the plant height of wheat. There were no significant differences among the plant height obtained from the treatments T2, T4, T6 and T7. Here, it was also observed that lower dose of SA had a positive effect on plant height in the T4 (200 µM SA) and T6 (500 µM SA) treatments but not at higher dose in the treatment T7 (1000 µM SA). Higher dose reduced plant height but not at significant level up to 1000 µM SA. Plant height increased due to application of SA (Ibrahim *et al.,* 2014 & Amin *et al.* 2008).

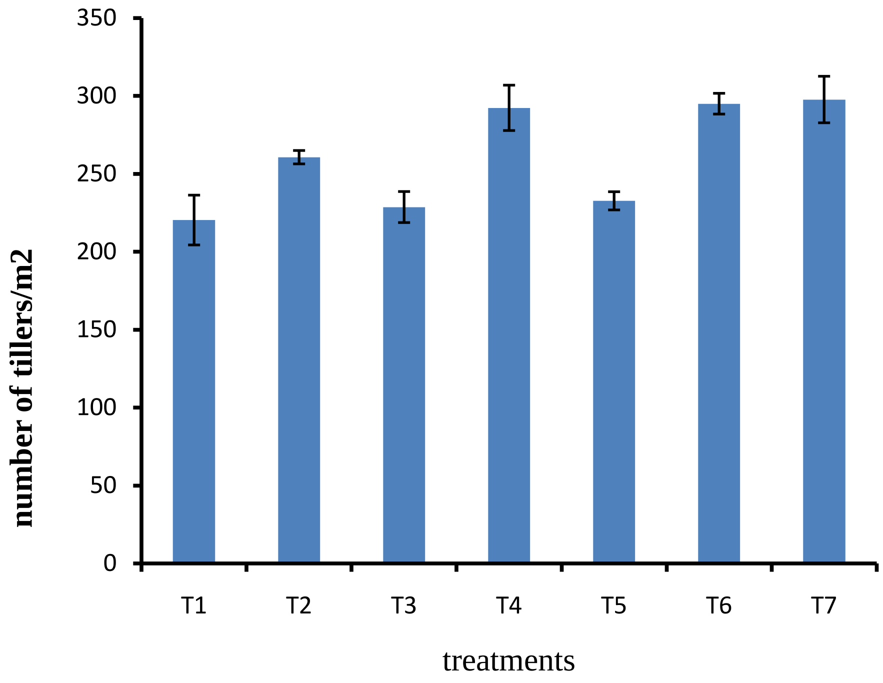


T_1 = Without Irrigation+0 µM SA
T_2 = With Irrigation+0 µM SA
T_3 = Without Irrigation+200 µMSA
T_4 =With Irrigation+200 µM SA
T_5 = Without Irrigation+500 µMSA
T_6 = With Irrigation+500 µM SA
T_7 = With Irrigation+1000 µM SA

Fig. 2 Effect of different levels of SA on plant height of wheat (BARI GOM 27)

4.1.2 Total number of effective tillers per square meter

Statistically significant variation was recorded in the total number of effective tillers per square meter of BARI GOM 27 due to the different treatments. The maximum effective tillers per square meter (297.7) were recorded from the treatment T7 and the minimum effective tillers per square meter (220.3) were observed from the T1 treatment. The tiller numbers were increased with increasing the level of SA in the treatments T4, T6 and T7 compare with T2, with irrigations, but no significant differences were observed. The increasing trend of tiller numbers were also observed with increasing the level of SA in the treatments T3 and T5 compare with T1, having without irrigations. However, no significant differences were also observed among the treatments without irrigations. These results suggest that SA could play a vital role as a stress reducing component in wheat cultivation. Total number of effective tillers increased significantly due to application of SA (Amin *et al.* 2008).

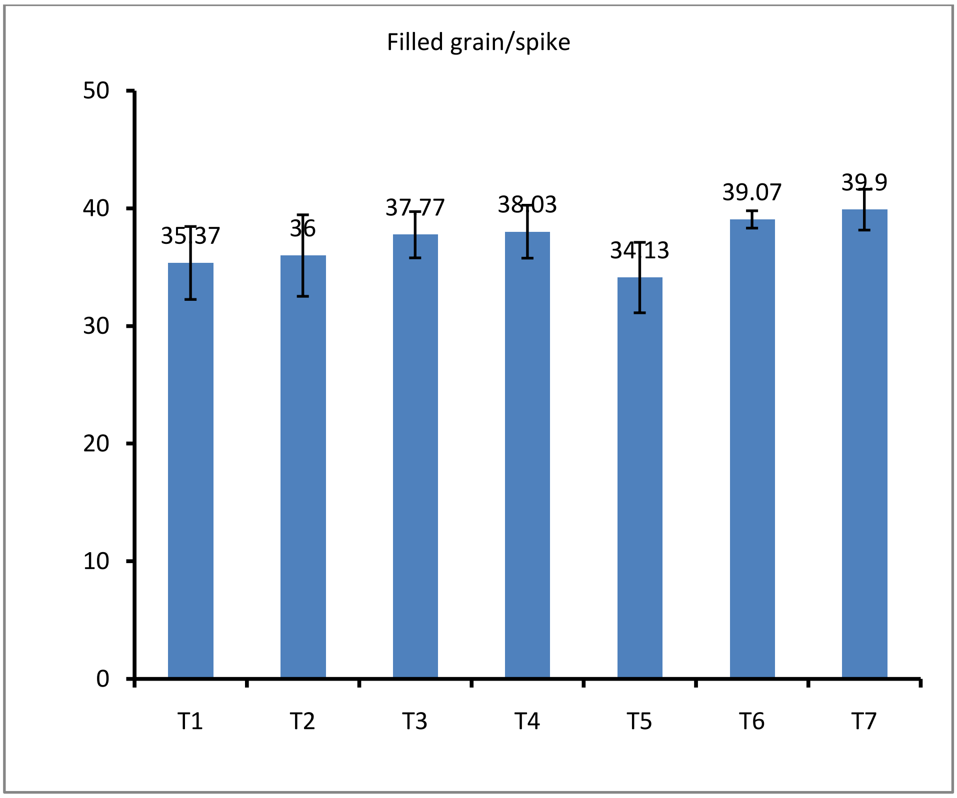


T1 = Without Irrigation+0µM SA
T2 = With Irrigation+0µM SA
T3 = WithoutIrrigation+200µM SA
T4 = With Irrigation+200µM SA
T5 = Without Irrigation+500µM SA
T6 = With Irrigation+500µM SA
T7 = With Irrigation+1000µM SA

Fig. 3 Effect of different levels of SA on the number of tillers of wheat

4.1.3 Number of filled grain/spike

Filled grains per spike were varied significantly due to different treatment combinations. SA at 200 µM increased the filled grains (37.77) per spike in the T3 treatment compare to T1 and T5 (Fig.4) treatments with irrigations. With irrigation condition, filled grains per spike were significantly increased with increasing the level of SA in the treatments T4, T6, and T7 compare to T2 treatments. The maximum number of field grains per panicle were observed in the treatment T7 (39.90) and the minimum number of field grains were recorded in the T5 (34.13) treatment. Results indicate that foliar application of SA with irrigations condition could increase the yield potentiality through increasing the number of field grains per spike in wheat (Table 4).



T_1 = Without Irrigation+0µM SA

T_2 =With Irrigation+0µM SA

T_3 = Without Irrigation+200µM SA

T_4 = With Irrigation+200µM SA

T_5 = Without Irrigation+500µM SA

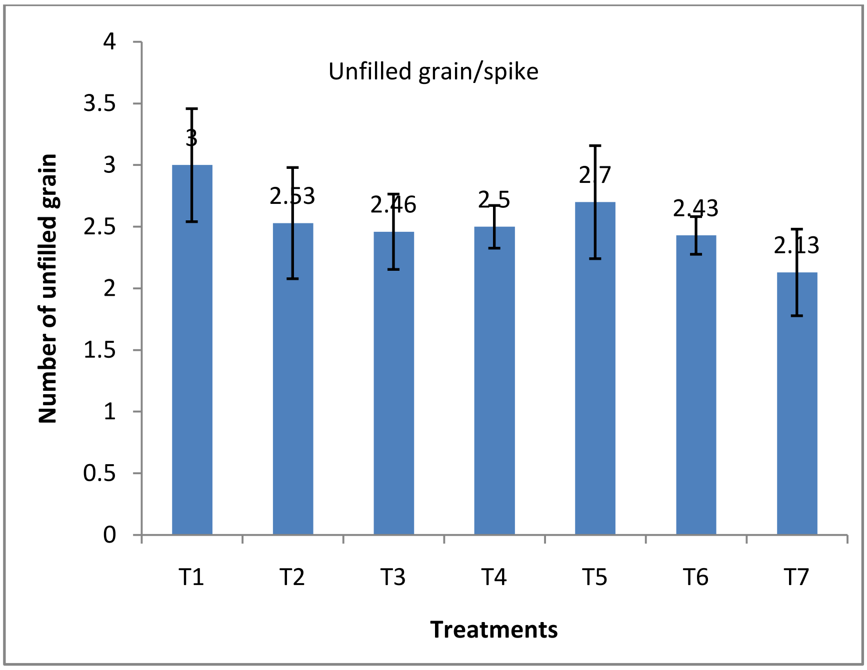
T_6 = With Irrigation+500µM SA

T_7 = With Irrigation+1000µM SA

Fig. 4 Effect of different levels of SA on filled grains per spike of wheat

4.1.4 Number of unfilled grain/spike

Number of unfilled grain per spike of BARI GOM 27 was differ significantly among the treatments. The maximum number of unfilled grains per spike (3.0) was recorded from T1 treatment which was statistically similar with T5 (2.7) treatments without irrigations. With irrigations condition with SA as foliar applications reduced the number of unfilled grains per panicle in the treatments T4, T6, and T7 compare to T2 treatments. The minimum number of unfilled grain per spike was recorded in the treatment T7 having 1000 µM of SA with recommended irrigations. This result suggests that SA could play important role in the reduction of spikelet sterility of wheat (Table 4).



T_1 = Without Irrigation+0µM SA

T_2 = With Irrigation+0µM SA

T_3 = Without Irrigation+200µM SA

T_4 = With Irrigation+200µM SA

T_5 = Without Irrigation+500µM SA

T_6 = With Irrigation+500µM SA

T_7 = With Irrigation+1000µM SA

Fig. 5 Effect of different levels of SA on unfilled grains per spike of wheat

4.1.5 Spike length

The spike length was significantly influenced by the treatments. Results revealed that the longest spike length (14.80 cm) was recorded from the T7 treatment having 1000 µM SA with recommend irrigations and the shortest spike length (12.93 cm) was recorded from the T1 treatment without irrigations (Table 5). Spike length was increased with increasing the level of SA in both conditions with or without recommended irrigations. Spike length up was differ significantly in the treatments T3 and T5 compare to T1 treatment without Irrigation. Here, it can be suggested that SA had a contribution to longer spike length and it was clearer in the without irrigation condition. Amin *et. al.* (2008) observed that foliar application of salicylic at 100 ppm (724 µM) and 200 ppm (1448 µM) promoted spike length of wheat plants.

4.1.6 Weight of 1000 grain

Foliar application of different levels of SA to the different growth stages of wheat showed significant differences on 1000 grain weight (Table 5). The highest 1000 grain weight (56 g) was observed in the treatment T7 which was statistically identical with the treatments T2, T4, T6 having recommended irrigations. On the other hand, 1000 grain weight was also statistically identical in the treatments T1, T3 and T5 without irrigations. However, in both condition with or without irrigations, increasing trend of the 1000 grain weight was observed due to the foliar application of SA. (Fig. 7). Ibrahim *et al.* (2014) found that exogenous application of 0 ppm (362 µM) and 100 ppm (724 µM) SA resulted in significant increase in 1000 grain weight. Weight of 1000 grain increased significantly due to application of SA (Sharafizad et al., 2012)

Table 4. Effect of treatments on thousand grain weight and spike length of wheat

Treatments	Spike length (cm)	1000 grain weight (g)
T1= Without Irrigation + 0 µM SA	12.93 e	45.00 d
T2= With Irrigation + 0µM SA	14.17 bc	53.67 abc
T3= Without Irrigation + 200 µM SA	13.47 de	47.87 cd
T4= With Irrigation + 200 µM SA	14.50 ab	54.87 ab
T5= Without Irrigation + 500 µM SA	13.57 cd	49.33 bcd
T6= With Irrigation + 500 µM SA	14.73 ab	55.00 ab
T7= With Irrigation + 1000 µM SA	14.80 a	56.00 a
$LSD_{0.05}$	0.632	5.91
SE (±)	0.29	1.92
Level of significance	*	**
CV (%)	2.53	6.44

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

4.1.7 Grain Yield (t/ha)

The grain yield of wheat was increased significantly due to the foliar application of SA at different growth stages. The highest grain yield (4.24 t/ha) was found from the treatment T7 having 1000 µM SA (Table 6) with recommend irrigations which was statistically identical with the treatment T6 having 500 µM SA with recommend irrigations. The lowest grain yield (1.84 t/ha) was obtained from the treatment T1 having no SA without recommended irrigations, which was significantly differ with the treatments T3 and T5 without recommended irrigations. In the recommended irrigation condition, foliar application of SA increased grain yield 19.60%, 31.80%, and 35.98% in the treatments T4, T6, and T7 compare to the treatment T2 respectively (Table 7.2). On the other hand, without irrigation condition, foliar application of SA also increased grain yield 25.38% and 32.45% in the treatments T3 and T5 compare to the treatment T1, respectively (Table 7.1). It was also found that foliar application of SA @ 1000 µM was more effective than other doses to increase the wheat grain yield. These results suggested that foliar application of SA has a significant role on the increment of wheat grain yield, even though in the drought stressed conditions (T3, T5). It is suggested that salicylic acid with decreasing evapotranspiration and increasing root development and let root to absorb more nutrients under drought stress, using this treatment resulted in increased grain production compare to control. Ibrahim *et al.* (2014) found that exogenous application of 50 ppm (362 µM) and 100 ppm (724 µM) SA resulted in significant increasing grain yield, straw yield. Sharafiza, M. *et.al.* (2012) was also found that application of 0.7 mM and 2.7 mM of SA increased the grain yield of wheat.

Table 5. Effect of treatments on grain yield, straw yield, biological yield and harvest index of wheat

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T1= Without Irrigation + 0 µM SA	1.84 e	2.87 d	4.713 c	39.27 c
T2= With Irrigation + 0µM SA	3.11 c	4.08 bc	7.193 b	43.31 ab
T3= Without Irrigation + 200 µM SA	2.31 d	3.46 cd	5.767 c	40.51 bc
T4= With Irrigation + 200 µM SA	3.72 b	5.02ab	8.740 a	42.58 abc
T5= Without Irrigation + 500 µM SA	2.44 d	3.26 cd	5.703 c	43.19 ab
T6= With Irrigation + 500 µM SA	4.11 ab	5.16a	9.273 a	44.30 ab
T7= With Irrigation + 1000 µM SA	4.24a	5.20a	9.443 a	44.88 a
$LSD_{0.05}$	0.413	0.982	1.17	3.54
SE (±)	0.134	0.319	0.382	1.15
Level of significance	**	**	**	*
CV (%)	7.49	13.30	9.12	4.68

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Figures in a column having common letter (s) do not differ significantly at 5% level of significance by DMRT

Table 6.1 Role of SA on grain yield increment of BARI Gom27 under no recommended irrigation condition

Treatments	Grain yield (t/ha)	% Grain yield Increased over T1
T1= Without Irrigation + 0 µM SA	1.840	---
T3= Without Irrigation + 200 µM SA	2.307	25.38
T5= Without Irrigation + 500 µM SA	2.437	32.45

Table 6.2 Role of SA on grain yield increment of BARI Gom27 under recommended irrigation condition

Treatments	Grain yield (t/ha)	% Grain yield Increased over T2
T2= With Irrigation + 0µM SA	3.113	---
T4= With Irrigation + 200 µM SA	3.720	19.60
T6= With Irrigation + 500 µM SA	4.107	31.80
T7= With Irrigation + 1000 µM SA	4.237	35.98

Table 7.1 Role of SA on straw yield increment of BARI Gom27 under no recommended irrigation condition

Treatments	Straw yield (t/ha)	% Straw yield Increased over T1
T1= Without Irrigation + 0 µM SA	2.87 d	-
T3= Without Irrigation + 200 µM SA	3.46 cd	20.56
T5= Without Irrigation + 500 µM SA	3.26 cd	13.59

Table 7.2 Role of SA on grain yield increment of BARI Gom27 under recommended irrigation condition

Treatments	Straw yield (t/ha)	% Straw yield Increased over T1
T2= With Irrigation + 0µM SA	4.08 bc	----
T4= With Irrigation + 200 µM SA	5.02ab	23.04
T6= With Irrigation + 500 µM SA	5.16a	26.47
T7= With Irrigation + 1000 µM SA	5.20a	27.45

4.1.8 Straw yield (t/ha)

The straw yield of wheat increased significantly due to addition of SA up to the 1000 µM SA**.** The highest straw yield (5.20 t/ha) was observed from the treatment T7 having 1000 µM SA with recommended irrigations. The highest straw yield was statistically identical with the treatments T6 (5.16 t/ha) and T4 (5.02 t/ha) having SA levels 500 µM and 200 µM with recommended irrigations (Table 6). The lowest straw yield (2.87 t/ha) was obtained from the treatment T1 having no SA without recommended irrigations, which was statistically identical with the treatments T3 and T5. With irrigation condition, foliar application of SA increased straw yield 23.04%, 26.47%, and 27.45% under the treatments T4, T6, and T7 compare to the treatment T2, respectively (Table 8.2). On the other hand, without irrigation condition, foliar application of SA also increased grain yield 20.56% and 13.59% under the treatments T3 and T5 compare to the treatment T1, respectively (Table 8.1). Here, it can be stated that foliar application of SA @ 1000 μM was more effective to increase the straw yield of wheat than other doses (Fig. 9). Ibrahim *et al.* (2014) found that exogenous application of 50 ppm (362 μM) and 100 ppm (724 μM) SA resulted in significant increment of straw yield.

4.1.9 Biological Yield (t/ha)

Significant response was observed in biological yield due to foliar application of different levels of SA on BARI GOM 27. The biological yield was varied from 4.713 to 9.443 t/ha. The highest biological yield (9.443 t/ha) was obtained from the treatment T7 which was statistically identical with the treatments T4 and T6 (Table 6). The lowest biological yield (4.71 t/ha) was obtained in the T1 treatment which was statistically identical with the treatments T3 and T5. Biological yield was significantly increased in the treatments T4, T6, and T7 (with irrigations with SA) compare to the treatment T2 (having recommended irrigations with no SA). Ibrahim *et al.* (2014) found that exogenous application of 50 ppm (362 µM) and 100 ppm (724 µM) SA resulted in the significant increment of biological yield. (Sharafizad *et al.*, 2012) Biological yield increased significantly due to application of SA.

4.1.10 Harvest Index (t/ha):

Significant response was observed in harvest index due to foliar application of different level of SA on BARI GOM 27. From the result, it was evident that the highest index (44.88%) was obtained from T7 treatment and the lowest index (39.27%) was obtained in the T1 treatment (Table 6).


SUMMARY
And
CONCLUSION

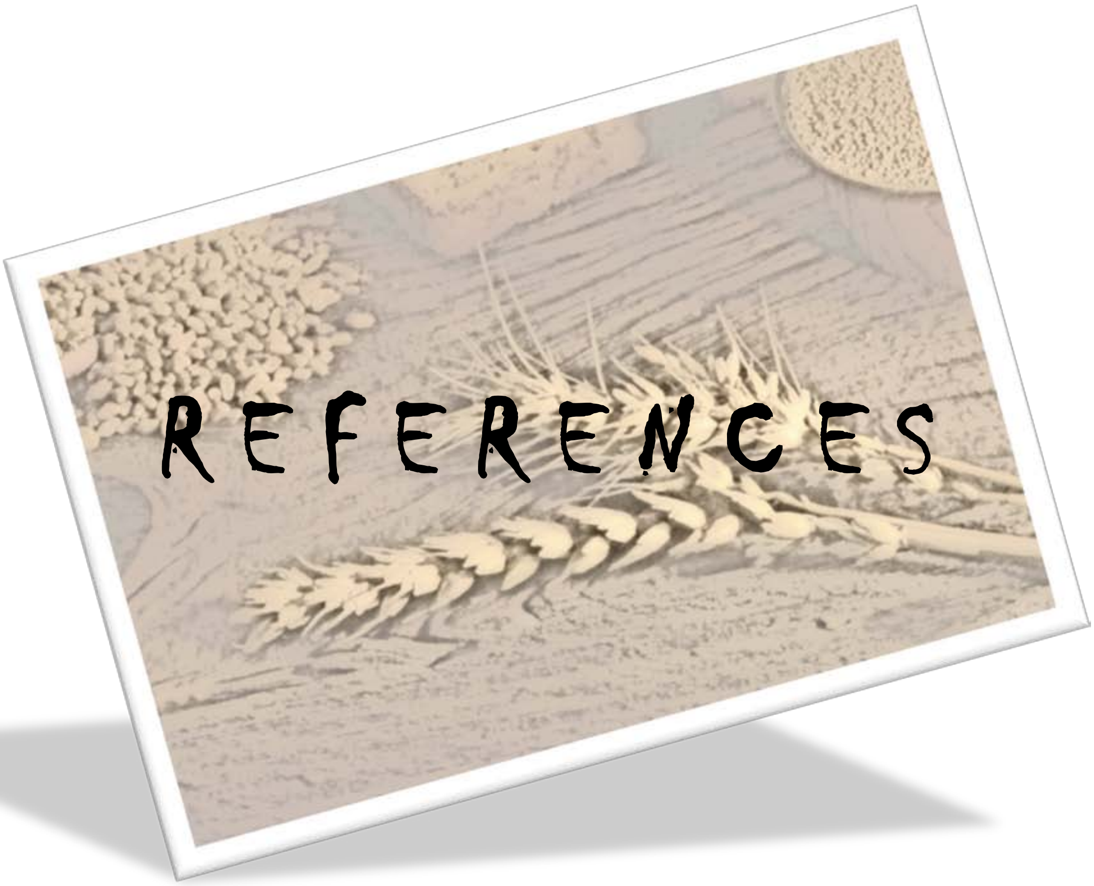
CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2014 to February 2015 to evaluate the effect of four levels of SA viz. 0 µM, 200 µM, 500 µM and 1000 µM SA on grain yield and yield attributes of Wheat (BARI GOM 27). The soil of the experimental field belongs to Madhupur tract representing Tejgaon series.

The experiment was laid out in a randomized complete block design with three replications. There were 21 unit plots and the size of the plot was 4 m × 2 m i.e. 8 m2. There were 7 treatments combination. Wheat seed of cv. BARI GOM 27 was sown as test crop. Data on different growth and yield parameters were recorded and analyzed statistically. The results showed that plant height, number of tillers, spike length, number of grains/spike, 1000-grain weight , grain yield, straw yield, biological yield and harvest index were significantly affected by different levels of SA application in relation to yield. The maximum plant height (85.17 cm) was obtained from the T4 treatment and longest spike length (14.80 cm) was obtained from the T7 treatment. The maximum number of effective tillers per m^2 (297.67), maximum number of grains/spike (42.03), maximum filled grains/spike (39.9), lowest unfilled grains/spike (2.13), highest 1000 grain weight (56 g), highest grain yield (4.23 t/ha) and straw yield (5.20 t/ha) were obtained from the T7 treatment. On the other hand, in all cases minimum results were observed in the T1 treatment. The results showed that grain yield of wheat increased with increasing level of salicylic acid up to 1000 µM.

The overall results of the present study demonstrated that wheat might be grown successfully to get maximum yield with the foliar application of 1000 µM SA. Treatment T7 showed the maximum grain yield of wheat it might be due to the strong management of wheat aphids in the treatment T7 having 1000 µM of SA as foliar application at different stages of wheat. Wheat aphids are devastating insect pest of wheat (Steffey & Grey, 2012) and a very clear picture was found in the wheat aphid management with the 1000 µM SA. No aphids were found in the treatment T7 whereas; all the treatments were affected by wheat aphid and maximum aphids were observed in the control treatment T1. However, before making conclusion concerning the appropriate dose of salicylic acid, the study needs further investigation in other Agro Ecological Zones (AEZs) of Bangladesh for country-wide recommendation which will be useful.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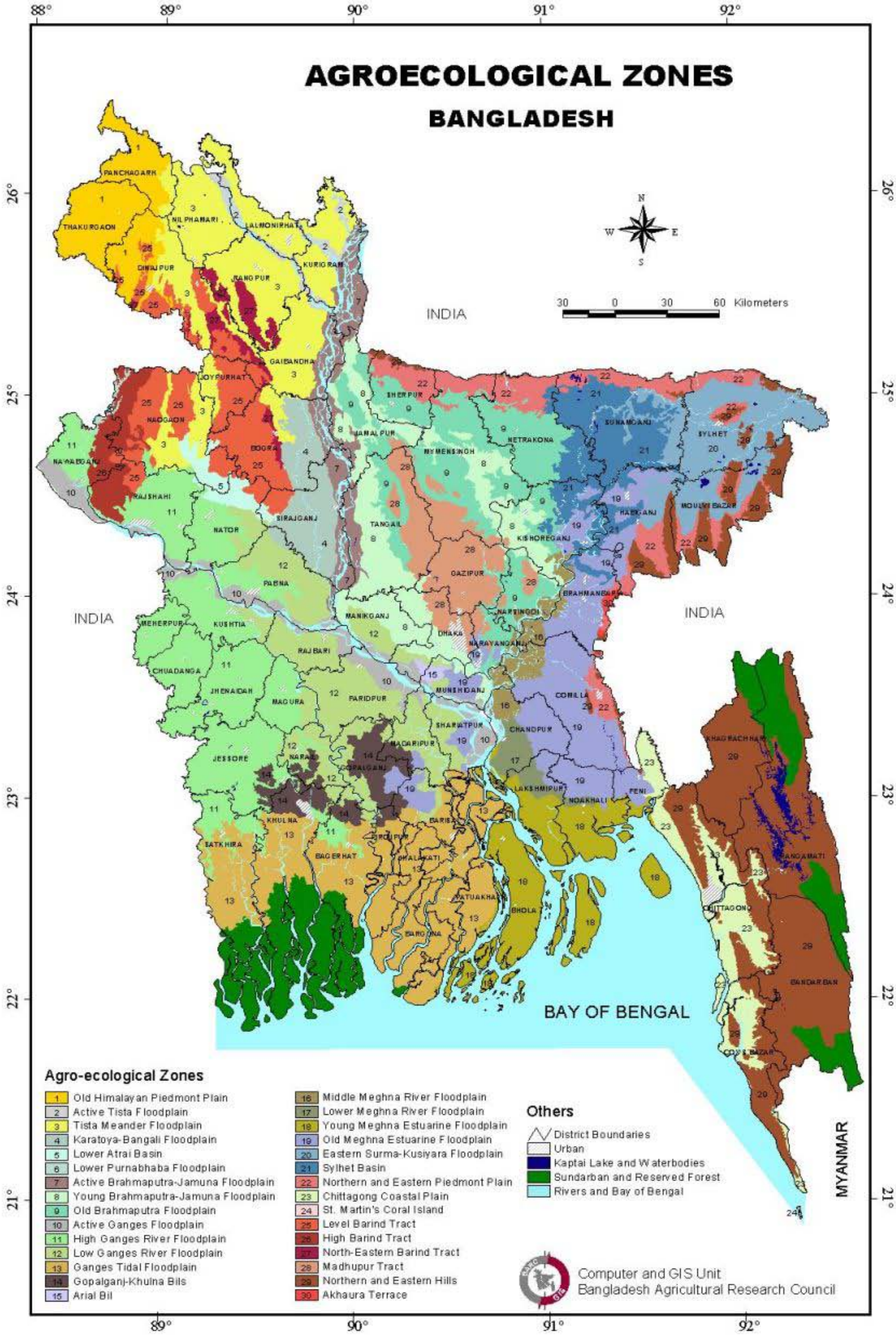
APPENDICES

APPENDICES

Appendix I. Agro-Ecological Zones of Bangladesh



Appendix II.Chemical properties of post-harvest soil

Treatments	% Organic Carbon	% Organic matter	pH
T1= Without Irrigation+0 µM Salicylic Acid	0.67	1.15	5.77
T2=With Irrigation+ 0µM SA	0.66	1.14	5.76
T3=Without Irrigation+ 200 µM SA	0.67	1.15	5.77
T4=With Irrigation+ 200 µM SA	0.66	1.14	5.78
T5=Without irrigation+ 500 µM SA	0.68	1.16	5.77
T6=With Irrigation+ 500 µM SA	0.68	1.16	5.81
T7=With Irrigation+ 1000 µM SA	0.66	1.14	5.78
SE (±)	0.037	0.024	0.056
Level of significance	NS	NS	NS
CV (%)	8.88	3.30	1.69

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2014 to March 2015

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2014	25.8	16.0	78	00	6.8
December, 2014	22.4	13.5	74	00	6.3
January, 2015	24.5	12.4	68	00	5.7
February, 2015	27.1	16.7	67	30	6.7
March, 2015	28.1	19.5	68	00	6.8

* Monthly average,

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

Picture showing different stages of wheat in experimental plot