ROLE OF FOLIAR APPLICATION OF SALICYLIC ACID (SA) ON THE YIELD PERFORMANCE OF BRRI dhan29

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*This is to certify that thesis entitled, **"ROLE OF FOLIAR APPLICATION OF SALICYLIC ACID (SA) ON THE YIELD PERFORMANCE OF BRRI dhan29"** submitted to the Department of Soil Science Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE,** embodies the result of a piece of bona fide research work carried out by **Shahnaz Parveen,** Registration No. **11-04248** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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TO

MY

BELOVED

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ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the Boro season (November, 2016 to May, 2017) to investigate the role of different levels of salicylic acid (SA) as foliar spray on growth and yield performance of BRRI dhan29. The experiment was laid out in a randomized complete block design with six replications. The experiment was comprised of six treatments having five levels of SA. The treatments were T_1= 0 mM SA, T_2= 0.25 mM SA, T_3= 0.5 mM SA, T_4= 0.75 mM SA, T_5= 1.0 mM SA and T_6= 2.0 mM SA. The results revealed that lower doses of SA (upto 0.75 mM) has a positive effect on biomass production including plant height, effective tiller per hill, total tiller per hill, filled grain per panicle, grain yield and straw yield of BRRI dhan29 but not in higher doses upto 2.0 mM. The highest dry matter production at both maximum tillering stage and panicle initiation stage was found in the treatment T_3 having foliar spray of 0.5 mM SA. The highest number of effective tillers per hill (14.66) was found in the treatment T_4 due to the application of 0.75 mM salicylic acid. The highest number of filled grain was found in treatment T_4. The maximum grain yield (8.13 t/ha) was found in the treatment T_4. On the other hand, minimum grain yield (7.02 t/ha) was found in the treatment T_1 (control). According to grain yield treatments can be arranged as $T_4>T_3>T_2>T_5>T_6>T_1$. Maximum straw yield (11.66 t/ha) was found in treatment T_2 due to application of 0.25 mM SA and minimum straw yield (9.84 t/ha) was found in T_6 having 2 mM SA which was statistically identical with the control, T_1. The treatments can be arranged according to straw yield as $T_2>T_4>T_3>T_5>T_6>T_1$. This experiment showed that the maximum grain yield was found in the treatment T_4 but the maximum biomass production was found in the Treatment T_2. From these results it can be concluded that some of the important growth parameters and yield contributing characters were improved due to the foliar spray of SA resulting higher yield of BRRI dhan29. No negative effect was found on BRRI dhan29 due to the foliar spray of SA upto 2.0 mM. The positive effect of low doses of SA was observed on yield and yield contributing characters of BRRI dhan29. The obtained results might be due to the increase of photosynthate, alleviation of stress tolerance mechanism by producing lignin and suberin, enhancement of insect and pathogen resistance of plants and so on. Taken together, my results suggest that foliar spray of SA can be used in BRRI dhan29 cultivation in Bangladesh.

TABLE OF CONTENTS

CONTENTS (Contd.)

CONTENTS(Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (contd.)

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
AIS	Agricultural Information Service
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV	Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
^{0}C	Degree Centigrade
et al.	And others
FAO	Food and Agriculture Organization
G	Gram (s)
HI	Harvest Index
Hr	Hour(s)
IRRI	International Rice Research Institute
i. e.	That is
Wt.	Weight
Kg	Kilogram (s)
LSD	Least Significant Difference
M	Meter
m^2	Meter squares
mm	Millimeter
MOP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
%	Percentage
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SA	Salicylic Acid
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources Development Institute
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
var.	Variety

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh and it is the staple food for more than two billion people of Asia (Hien *et al.,* 2010). Asia has the largest growing area with top producing countries including China, India, Thailand, Bangladesh and Vietnam (Xiao *et al.*, 2013). This is also the most important source of the food energy for 50% of the Global population (Zhao *et al.*, 2011). Among the most cultivated cereals in the world, rice ranks at second to wheat with over 685 million tones recorded in 2009 (Abodolereza and Racionzer, 2009). Rice is a major cereal consumed by the world population, representing about 30% of world production of grains (Yadav and Jindal, 2008; Luangmalawat *et al*. 2008). Rice is grown in more than a hundred countries with a total harvested area of nearly 160 million hectares, producing more than 700 million tons every year (IRRI, 2010). Nearly 640 million tons of rice are grown on Asia, representing 90% of global production (IRRI, 2010).

Rice is the staple food for about 156 million people of Bangladesh (Israt *et al*., 2016). In Bangladesh, rice covers about 28.49 million acres in which 34.5 million M tons of rice is produced while the average yield of rice is around 1.18 tons/acre (BBS 2016). According to BBS, 2016, Bangladesh is the 4th largest country of the world based on the rice cultivation. In case of Boro rice, it covers the largest area of 11788 (41.4% of total rice cultivation area) acre (local 195 + HYV 9968 + HYV 1625 acre) with a production of 1.86 million tons (55.5%) and the average yield is about 1177 kg/acre during the year of 2010-2011 (BBS, 2012). In Bangladesh about 82% of the total cropped land is covered by rice (Alam *et al.,* 2012). It accounts for 92% of the total food grain production in Bangladesh which provides more than 50% of the agricultural value addition employing about 48% of total rural labour forces. According to the latest estimation made by BBS, in Bangladesh per capita rice consumption is about 166 kg/year (BBS, 2015). The contribution of agriculture sector in GDP is 16.33% in 2013-14 fiscal year (Bangladesh Economic Review, 2015). In the agriculture sector, the crop sub-sector provides with 10.74 percent in GDP of which rice alone dominates with about 53 percent as well as about one-sixth of the national income comes from the rice sector (Rahman *et al.*, 2015).

The population of Bangladesh is growing by two million every year and increases by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020 (BRRI, 2011). During this time total rice area will also shrink to 10.28 million hectares. So Rice yield needs to be increased by 53.3% (Mahamud *et al*., 2013). Besides this, the increased population will require 70 percent more rice in 2025 than the present consumption (Kim and Krishnan, 2002). Food security has been and will remain a major concern in Bangladesh because food requirement is increasing at an alarming rate in order to increasing population. Rice yield, in general, is comparatively lower than that of other south East Asian countries because of severe insect infestation, drought, salinity etc. Yield loss up to 50% has been recorded in susceptible rice varieties when all the leaf sheaths and leaf blades were infected (Kumar *et al.*, 2012). 474.86 million metric tons of rice was produced through worldwide from the land of 159.64 million hectares with an average yield of 4.43 t/ha during the year of 2014-15 (USDA, 2015). USDA estimates Bangladesh has to produce around 34.51 million tons of rice from an estimated 11.7 million hectares of land in the year 2016-17.

Salicylic acid (SA), a phenolic phytohormone, which is found in plants. Salicylic acid is the first plant derivative phenolic compound to systemic acquired resistance

(Araujo *et al.*, 2005). Previous studies reported that SA can induce tolerance against high and low temperatures, drought, salinity, ultraviolet light, heavy metal toxicity, diseases and pathogens (Raskin, 1992; Yalpani *et al.*, 1994; Dat *et al.*, 1998; Metwally *et al.*, 2003; Sakhabutdinova *et al.*, 2003; Hayat & Ahmad, 2007; Horváth *et al.*, 2007, Farooq *et al.*, 2008b; Hussain *et al.*, 2008, Wang *et al.*, 2009, Thanh *et al.*, 2017). Foliar application of salicylic acid increased net photosynthetic rate and proline content in salt stressed plants and may have contributed to the enhanced growth parameters (Khoshbakht and Asgharei, 2015). Salicylic acid treated plants showed greater chlorophyll content compared to the untreated plants (Khoshbakht and Asgharei, 2015). It can affect seed germination, cell growth, stomatal opening, expretion of genes associated with senescence and fruit production (Klessing *et al.*, 2009) In addition, by detoxification of superoxideradicals SA plays an essential role in preventing oxidative damage in plants (Bowler *et al.*, 1992) and is also involved in calcium signaling (Kawano *et al.*, 2013). Plants treated with SA showed increased photosynthetic rates and water use efficiency, decreased stomatal conductance and transpiration rate (Khan *et al.*, 2003), increased vigor of early seedling growth (Farooq *et al.*, 2008b). Moreover, it was also found that exogenous application of SA can alter antioxidant capacity in plants (Rao *et al.*, 1997), providing protection against oxidative damage (Larkindale & Huang 2004). This phytohormone can directly affect pathogens as well as contribute to the establishment of SAR (Tamaoki *et al.*, 2013)

Salicylic acid is a natural compound that plays a central role in certain physiological processes and defense responses in plants (Shi and Zhu, 2008. Plants pre-treated with SA showed induced stress tolerance and protection against oxidative damage due to various stresses (Larkindale & Knight, 2002). Thus, studies that seek this information, besides aiming to learn which products can be used to stimulate grain yield and yield contributing characters, should be encouraged. Within this context, the aim of this present study was carried out with the following objectives:

- To examine the performance of BRRI dhan29 with foliar application of SA.
- To evaluate the foliar application doses of SA for the yield management of BRRI dhan29.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food crops in Bangladesh. Growth and development of rice plant are significantly influenced by the environmental factors, boitic factors, variety and cultural practices. Salicylic acid (SA) plays notable role regarding to the growth and development as well as yield contributing characters like number of effective tillers, length of panicle, number of filled grain per panicle, weight of 1000 grain etc. of rice plants. A good number of research works have been conducted at home and abroad on the effect of foliar application of SA on cultivation.

Salicylic acid is more or less unknown to the farmers in producing crops in Bangladesh. The present study deals with the effect of foliar application of SA on the productivity of rice. For aiming this point, foliar application of SA used to evaluate the different roles of morpho-physiology, yield and yield attributing characters of BRRI dhan29 at SAU campus. In this case an attempt is made to review the available literature related to the present study. Most of the research reports showed a positive effect of the foliar application of SA on yield of rice and other crops. The findings of various authors are cited below:

2.1 Application of Salicylic Acid on Rice

Issak, *et al.* (2017) showed that, biomass production, dry matter production and yield and yield contributing characters were significantly increased due to the foliar application of SA. At the maximum tillering (MT) stage, the highest biomass production (15.0 t/ha) and dry matter production was observed in 400 µM SA application. The experiment also revealed that the insect infestation was reduced with increasing level of SA to up to 1000 μM. The application of 1000 μM SA gave the maximum effective tillers/hill.

Chen, *et al.* (2017) conducted an experiment to assess the effect of SA on grain filling and other yield contributing characters of rice. The result of the experiment indicated that the mean grain-filling rate and grain weight of the inferior grains were significantly increased under the SA200 (200 mgL^{-1}) treatment and correspondingly contributed to a grain yield increase of 5.0 to 10.1% in comparison with the control. Further analysis showed that the SA200 treatment significantly increased the activity of the starch branching enzyme in inferior grains over the entire grain filling stage.

Singh, *et al.*, (2015) carried out an experiment 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 g/L) were used at three different stages (Booting stage, Heading stage and at the time of 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 per plant. The Area under Diseased Progress Curved (AUDPC) was decreased significantly for all the treatments over control. The correlation between AUDPC and yield parameters was varied. AUDPC was strongly correlated with all the yield attributes. The value of AUDPC was negatively correlated to different yield attributes proving that the pathogen had a damaging effect on the yield attributes of hybrid rice.

Tavares, *et al.* (2014) showed that Seed treatment with growth regulators, especially SA is a promising alternative to the seed industry because it is an important inducer of resistance to diseases and pests, as well as it acts significantly on quality and seed yield. The treatments consisted of increasing levels of 0, 50, 100, 150 and 200 mg/L SA. The physiological quality of seeds produced was treated and evaluated by tests of vigor and germination, and after harvest were evaluated seed yield. It follows that treatment of rice seeds with SA concentrations up to 130 mg/L at a solution dose of 2 ml/kg seed does not affect the germination and affects the strength, however provides substantial increases in the yield of seeds. The seed treatment with SA has no influence on seed quality produced.

Tavares, *et al.* (2014) conducted an experiment and showed the positive effect of salicylic acid concentrations via seed treatment up to a concentration of 129 mgL^{-1} on yield. The experiment showed that the most effective concentration (129 mgL^{-1}) produced approximately 18 g per plant, with about 60% higher yield than concentration zero. They concluded as, salicylic acid provided substantial increases in seed yield.

Usharani, *et al.* (2014) showed that, the effect of SA and *Pseudomonas fluoresces* on growth and yield of Paddy IR-50. Among the various treatments tested, maximum growth and yield was observed in the treatment (*Pseudomonas fluoresceces* seed application + SA applied on 30th day) and the least parameters were recorded in the Control treatment.

Ghodrat, *et al.*(2013) revealed that plant growth and development are controlled by plant growth regulators and pre-sowing seed treatments have proven beneficial to germination, seedling growth and yield of several field crops, such as rice (*Oryza sativa* L.) cultivar Sadri to soaking seeds for three days in 0.0, 50 and 100 mg/Lindole butyric acid (IBA), gibberellic acid (GA) and SA (SA) and results showed that germination rate and percent germination were significantly higher in all the hormonal treatments. Root and shoot lengths were increased significantly by nearly all the treatments. The fresh and dry weights at seedlings were positively influenced the most by IBA. Chlorophyll, carotinoids and anthocyanin contents of leaves increased significantly by soaking seeds in hormonal solutions. Number of grain per panicle increased significantly by all the treatments, whereas, 1000 grain weight was affected only by IBA and SA at 50 mg/L. IBA @ 50 mg/L had the highest impact on grain yield with 9.4 compared to 7.5 t/ha in control which is more than 25% increase in grain yield. Among the treatments, IBA @ 50 mg/L significantly affected all the yield tested components.

Sood, *et al.* (2013) showed that the effects of elicitors *viz*. benzothiadiazole (BTH) and SA on defense related enzymes *viz.* peroxides, phenylalanine ammonia lyase, superoxide dismutase, chitinase and β-1,3-glucanase, and phenols in rice (Pusa Basmati I) plants. First foliar spray of BTH (50 mg/kg) and SA (50 mg/kg) was done at the maximum tillering stage and inoculation with *Rhizoctonia solani* was carried 24 h after elicitor treatment. Elicitors were further sprayed at every growth stage. Time course analysis showed peak accumulation of defense related enzymes and phenols in the rice leaves treated with BTH and SA, and accumulation was the highest at the flowering stage. Higher enzymatic activity was observed in treated plants inoculated with *R. solani*. Compared to the untreated control plants, application of elicitors before *R. solanii* nodulation significantly elicited the defense related enzymes and phenols. Moreover, application of elicitors had a positive effect on yield and disease reduction.

Mohammed, R.A. (2011) carried out an experiment where the impacts of α-tocopherol, glycine betaine (GB) and SA applications on higher plants have been the subject of many studies, where special emphasis was given on oxidative stress tolerance under adverse conditions. However, little work has been carried out on rice responses to α-tocopherol, GB or SA under non-stress conditions, in which yield could potentially increase. This study determined the effects of α-tocopherol (2.3

kg/ha), GB (2.0 kg/ha) or SA (12.9 kg/ha) application on rice morphology, phenology and physiology under non-stress conditions. The applications did not affect production of tillers, biomass, phenology, or pollen germination; however, plant height, leaf characteristics and physiology, spikelet fertility (SF), panicle and grain characteristics and yield were affected. Plants treated with α-tocopherol, GB or SA showed 6%, 13% and 13.5%increases in grain yield as a result of decreased respiration and increased membrane integrity and SF.

Farooq, *et al.* (2009) showed that the role of salicylic acid to induce drought tolerance in aromatic fine grain rice cultivar Basmati 2000 was evaluated. SA was applied as seed and foliar treatments. For seed treatment, rice seeds were soaked in 50, 100 and150 mg/L aerated solution of SA for 48 h and then dried back. Treated and untreated seeds were sown in plastic pots in a phytotron. At four leaf stage, one set of plants was subjected to drought stress, while the other remained well watered. Drought was maintained at 50% of field capacity by watering every alternate day. For exogenous application, SA was applied 50, 100 and 150 mg/L at five leaf stage. In the control, SA was neither applied exogenously nor as seed treatment. Drought stress severely affected the seedling fresh and dry weight, photosynthesis, stomatal conductance, plant water relations and starch metabolism; however, SA application improved the performance of rice under both normal and stress conditions. Drought tolerance in rice was well associated with the accumulation of compatible solutes, maintenance of tissue water potential and enhanced potency of antioxidant system, which improved the integrity of cellular membranes and facilitated the rice plant to sustain photosynthesis and general metabolism. Foliar treatments were more effective than the seed treatments. Foliar application with 100 mg/L 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.

2.2 Application of Salicylic acid on Others Crop:

Amira, M. S. and 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).

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 salicylic acid 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 dSm^{-1} , 6.32 dSm^{-1} and 10.65 dSm^{-1} 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, protein content and yield efficiency, straw and grains N, P and K-uptake and weight of 1000 grain of wheat plants occurred with ascorbic acid 0.2% "AA_2" treatment followed by ascorbic acid 0.1% “AA_1”, SA 0.2% “SA_2”, salicylic acid 0.1% “SA_1” and untreated plants that descending order in the two seasons.

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 salicylic acid application on growth and physiological traits of maize varieties 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 stress 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. *et al.* (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 application. 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 SA_3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA_1 (SA at 10^{-2} M). The highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA_1 (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.

Ibrahim *et al.* (2014) carried out two cemented plots experiments during the winter seasons of 2012-13 and 2013-14, Soil Salinity Laboratory, Alexandria, Egypt, with a view to studying the effect of three levels of 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 per spike, number of spikes per squire m, 1000 grain weight (g), grain yield (g per plot), straw yield (g per plot), and biological yield (g per plot) in addition to grain weight per spike (g).

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 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 and 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. 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 Arv and variety on total chlorophyll and relative water content traits. It can be concluded that foliar application of wheat cultivar plants with SA 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 SA treatment improved wheat growth especially on Tabasi variety.

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/L was 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 micro nutrients. 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 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) conducted 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 weight). The obtained results revealed that salt treatments provoked oxidative stress in faba bean plants as shown by the increase in lipid per oxidation 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.

Fahad & Bano (2012) conducted a field experiment to determine the effect of exogenously applied SA on physiology 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 salicylic acid (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 dismutase (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 SA 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 Salicylic acid 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.

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 71.7-74.4% (unstressed) and 68.0-71.7% (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. & Ghaei, 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.

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 g) 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 flowering, and the third treatment was different dosage of salicylic acid (0, 0.7, 1.2 and 2.7mM). 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 0.7mMSA. 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 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.

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.

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. In parallel to increasing antioxidative activity, SA treatment decreased $H_2O_{2\ s}$content when compared to plants growing under salt stress without SA.

Amin, *et al.* (2008) conducted a field experiment for the two successive seasons of 2004-05 and 2005-06 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 SA, 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 pyruvate carboxylase (PEPC) and activities of photo respiratory enzymes glycolate oxidase (GO) and catalase (CAT), and on the activities of antioxidant enzymes superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione reeducates' (GR) and peroxidase (POX) in winter wheat (*Triticum aestivum,* cv.Dogu-88) leaves. 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 per oxidation and peroxides level. Treatment with 500 mM 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.

Gutie´rrez-Coronado, *et al. (*1998) showed that SA has a growth-stimulating effect in soybean plants. When soybean plants treated with 10 µM, 100 µM, and up to 100µM SA, shoot and root growth increase 20% and 45% respectively, at seven days after application.

CHAPTER III

MATERIALS AND METHODS

The experiments were carried out during the period from November 2015 to May 2016 at the field of Sher-e-Bangla Agricultural University, Dhaka-1207. This chapter deals with the materials and method used in the experiment. It includes a brief description on experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

3.1.1 Geographical location

The location of the experimental site was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter from the mean sea level.

3.1.2 Agro-ecological region

The soil of the experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The climate was subtropical with low temperature and minimum rainfall during November to May that was the main feature of the *rabi* season. The annual precipitation of the site was around 2200 mm and potential evapo-transpiration was 1300 mm. The average maximum temperature was 30.34^{0}C and average minimum temperature was 21.21^{0}C. The average mean temperature was 25.17^{0}C. The experiment was done during the *rab*i season. Temperature during the cropping period ranged between 12.2^{0}C to 34.5^{0}C. The humidity varies from 62% to 82% and scattered rainfall during the rest of the year.

3.1.4 Soil

The general soil type of the experimental field was Shallow Red Brown Terrace soils under Tejgaon Series. Topsoil was clay loam in texture and olive-gray with common fine to medium distinct dark yellowish brown mottles. Before the previous experiment, the initial soil pH was 6.2 and had organic carbon 0.60% and organic matter content was found 1.03%.The experimental site was flat having available irrigation and well drainage system and above flood level. Sufficient sunshine was available during the experimental period. Soil samples were collected 0-15 cm depths from experimental field. The chemical analyses of soil were done in the laboratory of the Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207. The physicochemical properties of the soil are presented below:

Table 1: Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Soil Science field,SAU, Dhaka
AEZ	Madhupur tract (28)
General soil type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Table 2: Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Clay loam
pH	6.2
Organic carbon (%)	0.60
Organic matter (%)	1.03
Total N (%)	0.03
Available P (ppm)	21.00
Exchangeable K (me/100g soil)	0.12
Available S (ppm)	48

3.2 Experiment details

3.2.1 Crop/Planting material

The experiments were conducted with BRRI dhan29 as test crops. BRRI dhan29 was developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gajipur, Bangladesh for Boro season. The pedigree line of BRRI dhan29 is BR 802-118-4-2. Average height of the plant is 95 cm. The grains are medium, slender and white in color. BRRI dhan29 is moderately resistance to leaf blight, sheath blight. The growth duration of BRRI dhan29 is about 160 days.

3.2.2 Experimental Treatments

The single factor experiment was compared with six treatments of salicylic acid.

T_1= 0 mM Salicylic acid

T_2=0.25 mM Salicylic acid

T_3= 0.5 M Salicylic acid

T_4= 0.75 mM Salicylic acid

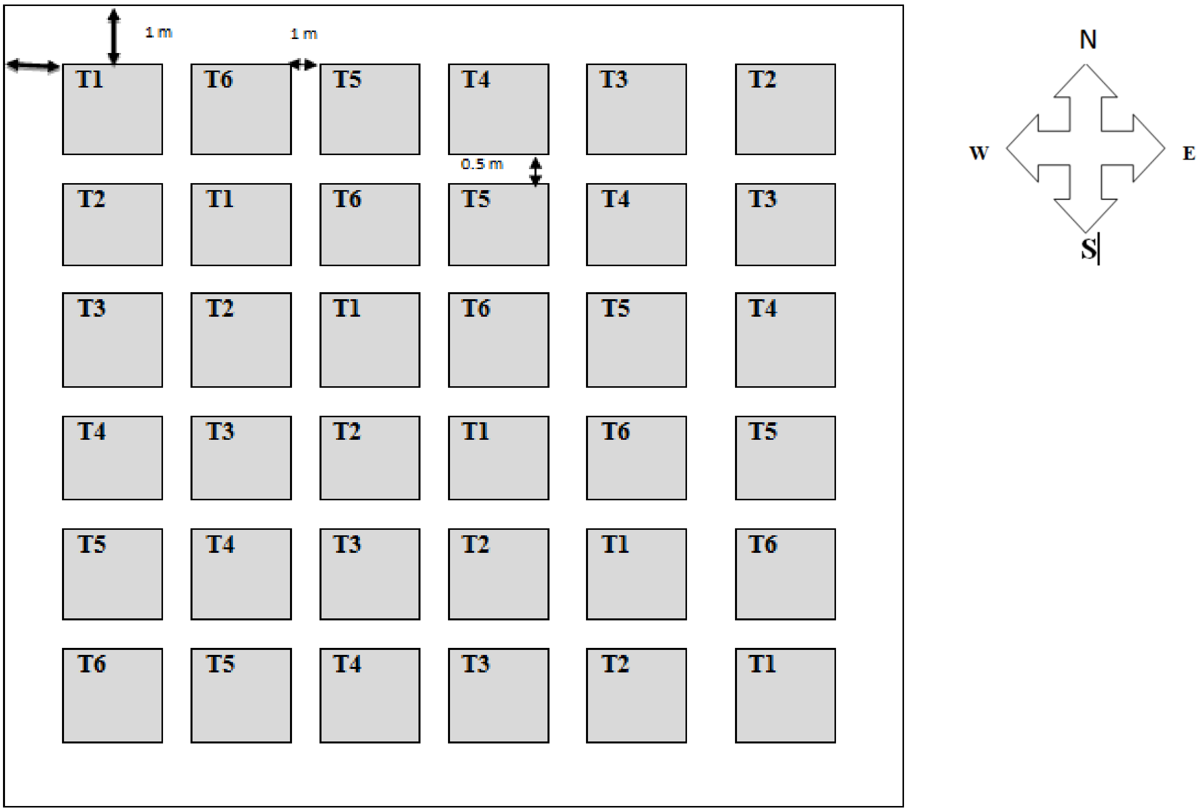
T_5=1.0 mM Salicylic acid

T_6 = 2.0 mM Salicylic acid

All the fertilizers were applied in every treatment @ Recommended dose.

3.2.3 Experimental design

The experiment was done with Randomized Complete Block Design (factorial). Each treatment in the experiment was replicated six times. The total number of unit plots was 36. The size of the unit plot was 2 m × 2 m. The treatments were randomly distributed to each block. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m, respectively. The inter block and inter row spaces were used as footpath and irrigation or drainage channel. The layout of the experiments has been shown in Figure 1.



Replications:	Treatment Combinations:
R_1: Replication 1 R_2: Replication 2 R_3: Replication 3 R_4: Replication 4 R_5: Replication 5 R_6 : Replication 6	T_1 = T_1 = 0 mM Salicylic acid T_2 = 0.25 mM Salicylic acid T_3 = 0.5 M Salicylic acid T_4 = 0.75 mM Salicylic acid T_5 = 1.0 mM Salicylic acid T_6 = 2.0 mM Salicylic acid All the fertilizers were applied in every treatment @ Recommended dose.

Figure 1: The layout of the field

3.3 Growing of crops

3.3.1 Seed collection and sprouting

BRRI dhan29 Seeds were collected from BRRI, Joydebpur, Gazipur, Bangladesh. Healthy seeds were selected by following standard method. Then seeds were immersed in water bucket for 24 hrs. These immersed seeds were taken out from water bucket and tightly kept in gunny bags. The seeds started sprouting after 48 hrs which became suitable for sowing in 72 hrs.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. Gently irrigation was provided and weeds were removed from the bed as and when required and no fertilizer was used in the nursery bed.

3.3.3 Seed sowing

The seeds were sown on the nursery bed on December 10, 2015 for raising nursery seedlings.

3.3.4 Preparation of experimental land

The soil of the experimental land was first opened on January 9, 2016 with the help of a tractor drawn disc plough; later on January 12, 2016 the land was irrigated and prepared by three successive ploughing and cross ploughing. Each ploughing was followed by laddering to have a good puddled field. After ploughing and laddering, all kinds of uprooted weeds and previous crop residues were removed from the field. After the final land preparation the field layout was made on January 14, 2016 according to experimental plan. Individual plots were cleaned and finally leveled so that no water pocket could remain in the puddle field.

3.3.5 Fertilizer dose and methods of application

The experiment unit plots of were fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate @ 150, 58, 58, 38 and 10 kg/ha respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at the time of transplanting of seedlings. No Urea was applied during land preparation. After seedling recovery, urea was applied in three splits. At first, half of the total amount of urea was applied to the soil during vegetative stage. Half of the remaining urea was applied at tillering stage and half at 7 days before panicle initiation.

3.3.6 Transplanting of seedlings

The nursery bed was made wet by application of water in one day before uprooting of the seedlings. For transplantation 37 days old seedlings were uprooted carefully from the nursery beds on 16 January, 2016 without causing much mechanical injury to the roots.

3.3.7 Intercultural operations

After transplanting the seedling, different intercultural operations were accomplished for better growth and development, which are as follows**.**

3.3.7.1 Gap filling

After one week of transplantation, a minor gap filling was done where it was necessary using the seedling from the same source.

3.3.7.2 Weeding

During the early stage of growth establishment the crop was infested with some weeds. Two hand weeding were done for each treatment; first weeding at 20 days after transplanting followed by second weeding at 15 days after first weeding.

3.3.7.3 Application of irrigation water

Irrigation water was added to each plot as and when required. All the plots were kept irrigated maintaining 3-5 cm stagnant water throughout the entire period up to 15 days before harvesting.

3.3.7.4 Plant protection measures

Plants were infested with rice leaf roller (*Cnaphalocrocis medinalis*) and rice bug (*Leptocorisa acuta*) to some extent which were successfully controlled by applying Malathion (57 EC) @ 10 ml/10 liter of water for 5 decimal lands as and when needed. Crop was protected from birds during the grain filling stage. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4 Preparation and application of Salicylic acid:

The mixture of 6.9 g SA in 100 mL ethanol is called 0.5 M stock solution of SA. 10 mL ethanol in 5 L solution was prepared to apply in T_1 (control). 2.5 mL SA solution was taken from stock solution in 5 L solution for making 0.25 mM SA solution. Similarly 5mL, 7.5 mL, 10 mL and 20 mL SA solution were taken from stock solution in 5 L solution for making 0.5 mM, 0.75 mM, 1.0 mM and 2.0 mM solution respectively. Foliar application of SA was done in rice field in three times. First step was applied on 49 DAT (tillering stage). 2^{nd} application on 84 DAT (panicle initiation stage) and 3^{rd} application on 92 DAT (flowering stage).

3.5 General observation of the experimental field

Observations were regularly made to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice hispa was observed during tillering stage that controlled properly. No bacterial and fungal diseases were observed in the field.

3.6 Harvesting and post harvest operation

When 90% of the grains became golden yellow in color maturity of crop was determined. BRRI dhan29 was harvested on May 04, 2016. Five hills per plot were preselected randomly from which different growth and yield attributes data were collected and $1m^2$ areas from middle portion. Each plot was harvested separately, bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using pedal thresher. The grains were cleaned and sun dried at moisture content of 12 % approximately. Straw was also sun dried properly. Finally grain and straw yields per plot were recorded and converted to ton per ha.

3.7 Recording of data

The followings data were recorded during the experiment.

A. Crop growth characters

i. Plant height (cm) at harvest

ii. Number of tillers/hill

B. Yield and yield components

i. Number of effective tillers/hill

ii. Number of ineffective tillers/hill

iii. Length of panicle (cm)

iv. Number of filled grains/panicle

v. Number of unfilled grains/panicle

vi. Number of total grains/panicle

vii. Weight of 1000 grains (g)

viii. Grain yield (t/ha)

ix. Straw yield (t/ha)

x. Harvest index (%)

3.8 Detailed procedures of recording data

A. Crop growth characters

i. Plant height (cm) at harvest

The height of plant was recorded in centimeter (cm) and measured from the ground level to the tip of the tallest panicle. Plants of 5 hills were measured and averaged for each plot.

ii. Number of tillers per hill

The number of tillers per hill was counted at harvest from ten randomly pre-selected hills and averaged as their number per hill. Only those tillers having three or more leaves were considered for counting.

B. Yield and other crop characters

i. Effective tillers per hill (no.)

The total number of effective tillers per hill was counted as the number of panicle which had at least one grain. The number of effective tillers per hill was recorded and finally averaged for counting effective tillers number per hill.

ii. Ineffective tillers per hill (no.)

The total number of ineffective tillers per hill was counted as the tillers which have no panicle on the head. The number of ineffective tillers per hill was recorded and finally averaged for counting ineffective tillers number per m^2.

iii. Panicle length (cm)

The length of panicle was measured from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

iv. Filled grains per panicle (no.)

If any kernel was present in grain, the grain was considered to be filled. The total number of filled grains were recorded on five panicles and finally averaged.

vi. Unfilled grains per panicle (no.)

Unfilled grains means the absence of any kernel inside and such grains present on each of five panicles were counted and finally averaged.

vii. Total grains per panicle (no.)

Total number of grains per panicle was calculated by summation of filled and unfilled grains per panicle.

viii. Weight of 1000 grains (g)

One thousand cleaned and dried grains were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained about 12% moisture and the mean weight were expressed in gram.

ix. Grain yield (t/ha)

Grain yield determined from the central $1m^2$ areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 12% moisture level. Weight of grains of each plot was converted into t/ha. Grain moisture content was measured by using a digital moisture tester.

x. Straw yield (t/ha)

Straw yield was determined from the central 1 m^2 areas of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t/ha.

xi. Biological yield (t/ha)

Grain yield together with straw yield was regarded as biological yield and calculated with the following formula:

Biological yield (t/ha) = Grain yield (t/ha) + Straw yield (t/ha)

xii. Harvest Index (%)

Harvest index denotes the ratio of economic yield to biological yield and was calculated with following formula.

$$\text{Harvest Index} = \frac{\text{Grain yield (t/ ha)}}{\text{Biological yield (t/ ha)}} \times 100$$

3.9 Statistical Analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique and the mean differences were adjudged by LSD test using the statistical computer package program, Statistix 10.

3.10 Collection and preparation of initial soil sample

The initial soil samples were collected from a 0-15 cm soil depth before land preparation. The sample was collected by means of an auger from different locations covering the whole experimental plot mixed thoroughly to make a composite sample. After collecting 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.

3.11 Chemical analysis of soil sample

Soil samples were analyzed for both physical and chemical properties in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.The properties studied included texture, pH, organic matter etc. The physical and chemical properties of initial soil have been presented in Table 1 and 2. The soil was analyzed following standard methods:

Particle-size analysis of soil was done by Hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the "Marshall's Textural triangular coordinate" following the USDA system.

Soil pH was measured with the help of a glass electrode pH meter using soil suspension of 1:2.5 as described by Jackson (1962).

Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). 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 in percentage.

CHAPTER IV

RESULTS AND DISCUSSION

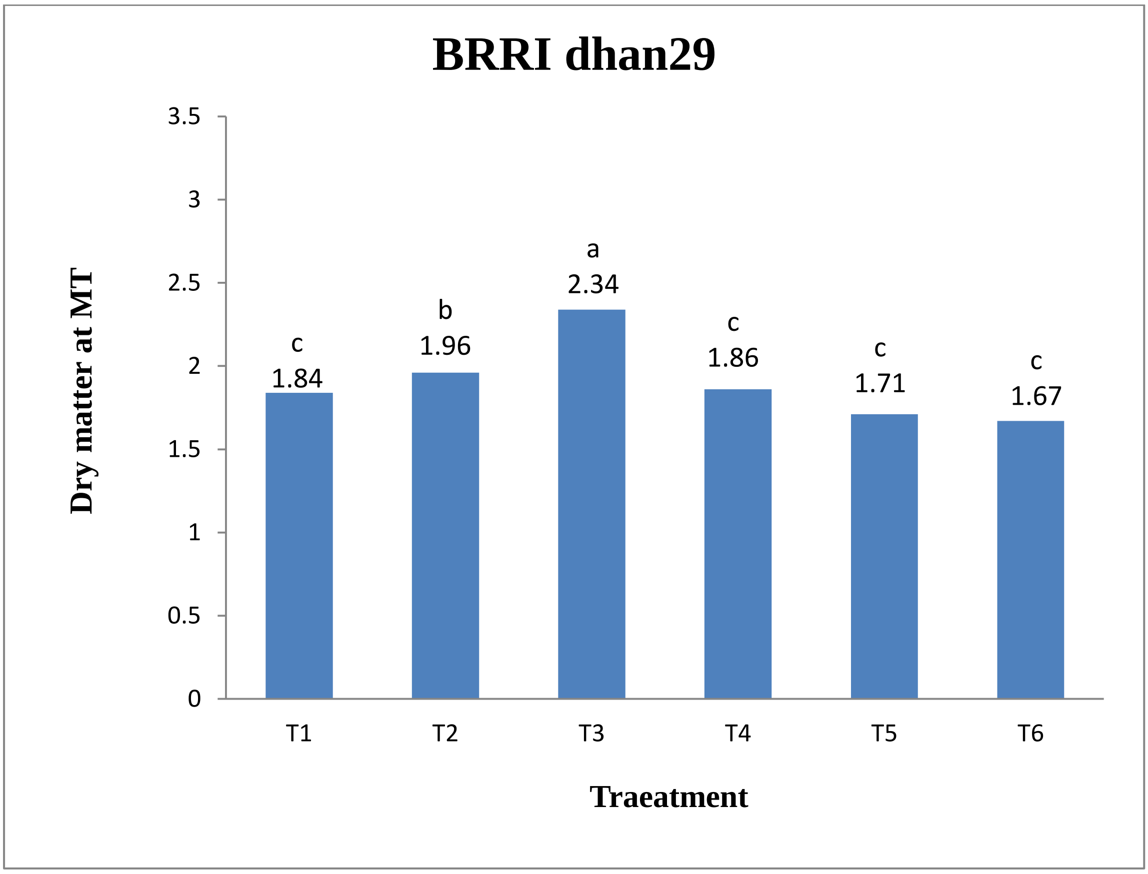
This chapter comprises of the presentation and discussion of the results obtained due to foliar application of salicylic acid on yield performance of BRRI dhan29 and chemical properties of the soil. The results of the present investigation have been presented, discussed and compared as far as available with the results of the researchers.

4.1 Role of Salicylic acid (SA) at maximum tillering stage

4.1.1 Dry matter production at maximum tillering (MT) and panicle initiation (PI) stage (t/ha)

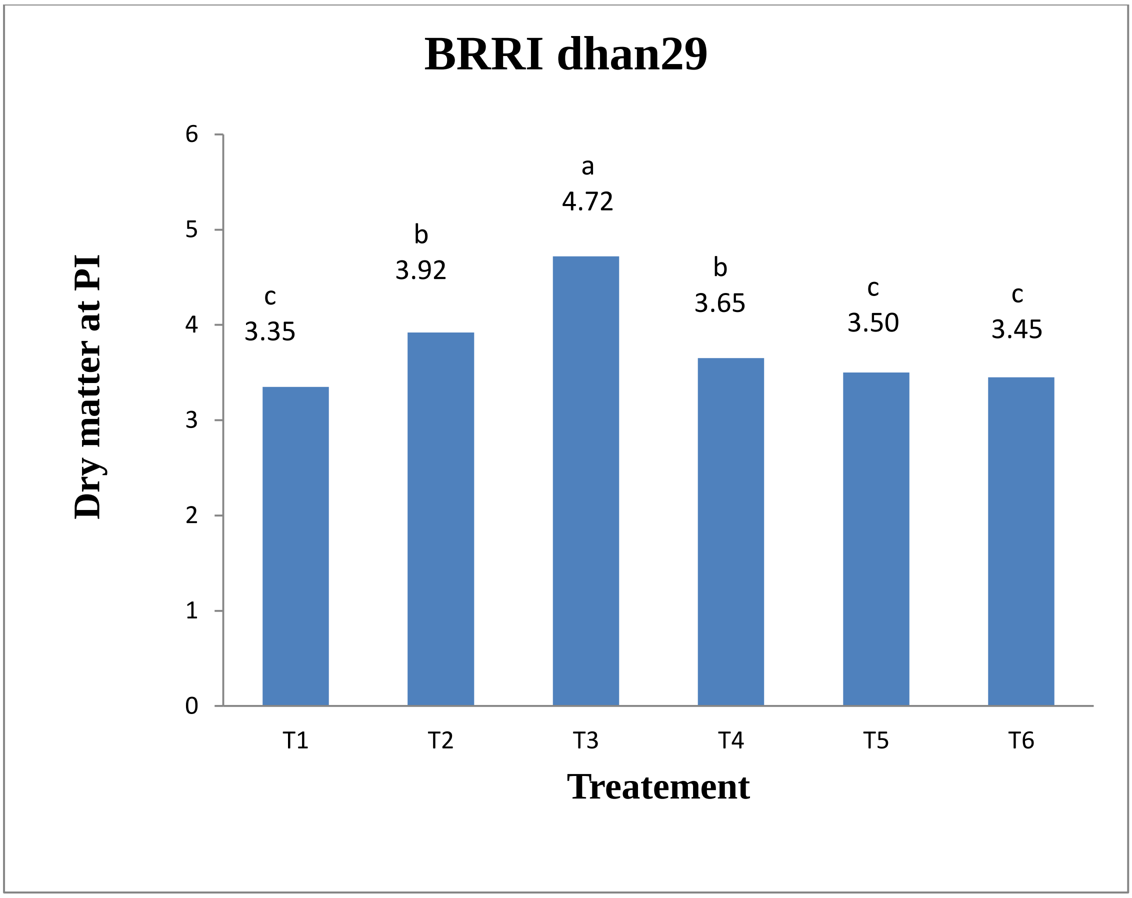
A significant variation was observed in the dry matter production of BRRI dhan29 due to the foliar application of different doses of SA at the maximum tillering (MT) and panicle initiation (PI) stages. At MT stage the highest oven dry weight (2.34 t/ha) of dry matter product was found in the T_3 treatment having foliar spray of SA @ 0.5 mM which was statistically different to all other treatments. The lowest oven dry weight (1.67 t/ha) was found in the treatment T_6 with the concentration of SA @ 2.0 mM which was statistically similar with the control T_1 having no SA. Again at PI stage the highest oven dry weight (4.72 t/ha) was found in treatment T_3 that was statistically different to all other treatments. The lowest oven dry weight was found in treatment T_6 which was statistically similar to T_1 and T_5 treatments. These results showed that foliar application of SA at lower doses have positive effect on the dry matter production of BRRI dhan29. This result also revealed that the higher doses of

SA up to 2.0 mM have no negative effect on the dry matter production (Figure 2 and 3). This was strongly supported by Usharani, *et al.* (2014) who showed that dry matter production increased due to application of SA.



T_1 = 0 mM Salicylic acid	T_4 = 0.75 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid	T_5 = 1.0 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid	T_6 = 2.0 mM Salicylic acid

Figure 2. Effect of different doses of salicylic acid on dry matter production at maximum tillering stage of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.



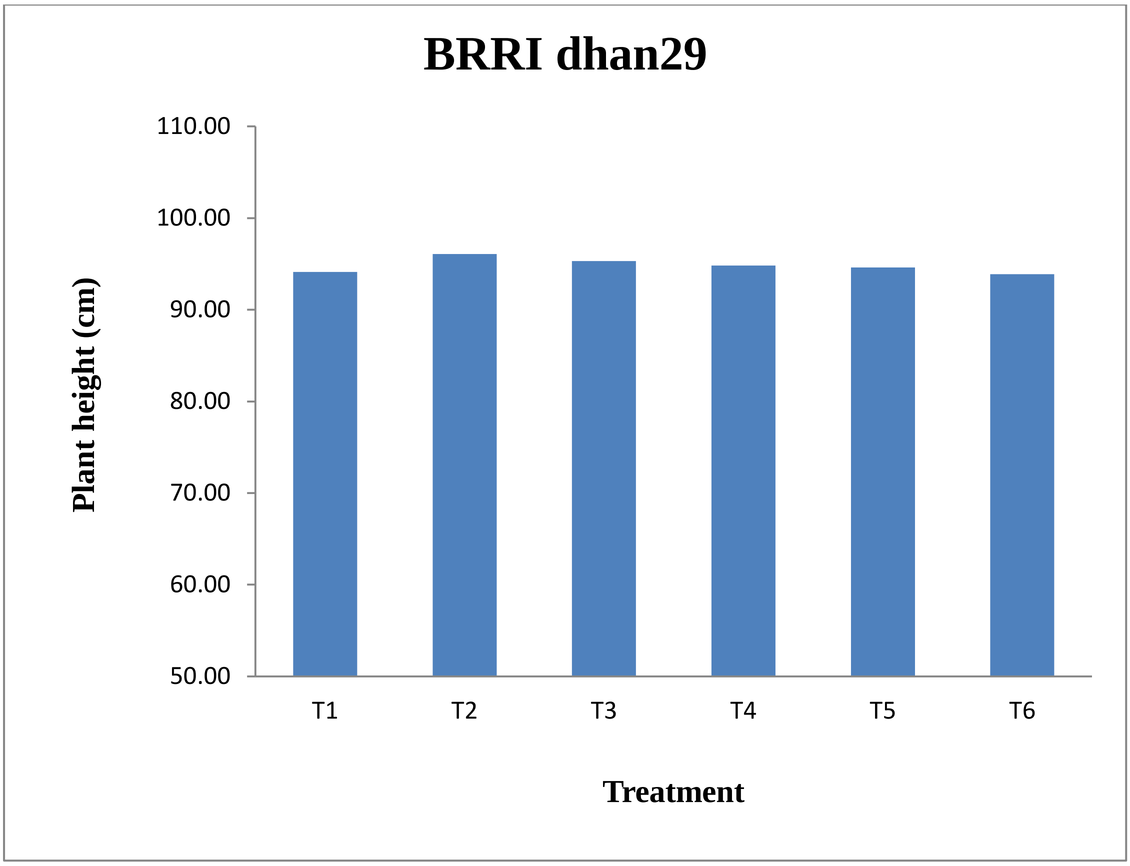
T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 3. Effect of different doses of salicylic acid on dry matter production at panicle initiation stage of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.2 Plant height (cm)

Plant height was found to be statistically insignificant in all of the treatments used in the experiment (Figure 4). The maximum plant height was obtained in the T_2 treatment (0.5mM SA) which was statistically similar to all other treatment. According to the plant height the treatments may be arranged as $T_2>T_3>T_4>T_5>T_1>T_6$. These results indicate that lower doses of SA have a positive effect on plant height of

BRRI dhan29 and higher doses of SA up to 2.0 mM have no negative effect on plant height.



T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 4. Effect of different doses of salicylic acid on plant height of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.3 Panicle length (cm)

Panicle length was found to be statistically insignificant in all of the treatments used in the experiment (Table 3). Panicle length was not influenced significantly although there was some apparent difference in panicle length in different treatments. The maximum panicle length (27.42 cm) was obtained in the T_4 treatment (0.75 mM SA) which was statistically identical with the minimum panicle length (26.43 cm) obtained in the T_6 treatment (2.0 mM SA). According to the panicle length the treatments may be arranged as $T_4>T_3>T_2>T_5>T_1>T_6$.

Table 3. Effect of different doses of salicylic acid on panicle length on BRRI dhan29 at harvest, Boro 2016, SAU.

Treatments	Panicle length (cm)
T1	26.45a
T2	26.60a
T3	26.75a
T4	27.42a
T5	26.48a
T6	26.43a
$LSD_{0.05}$	0.9847
Level of significance	*
CV (%)	2.03

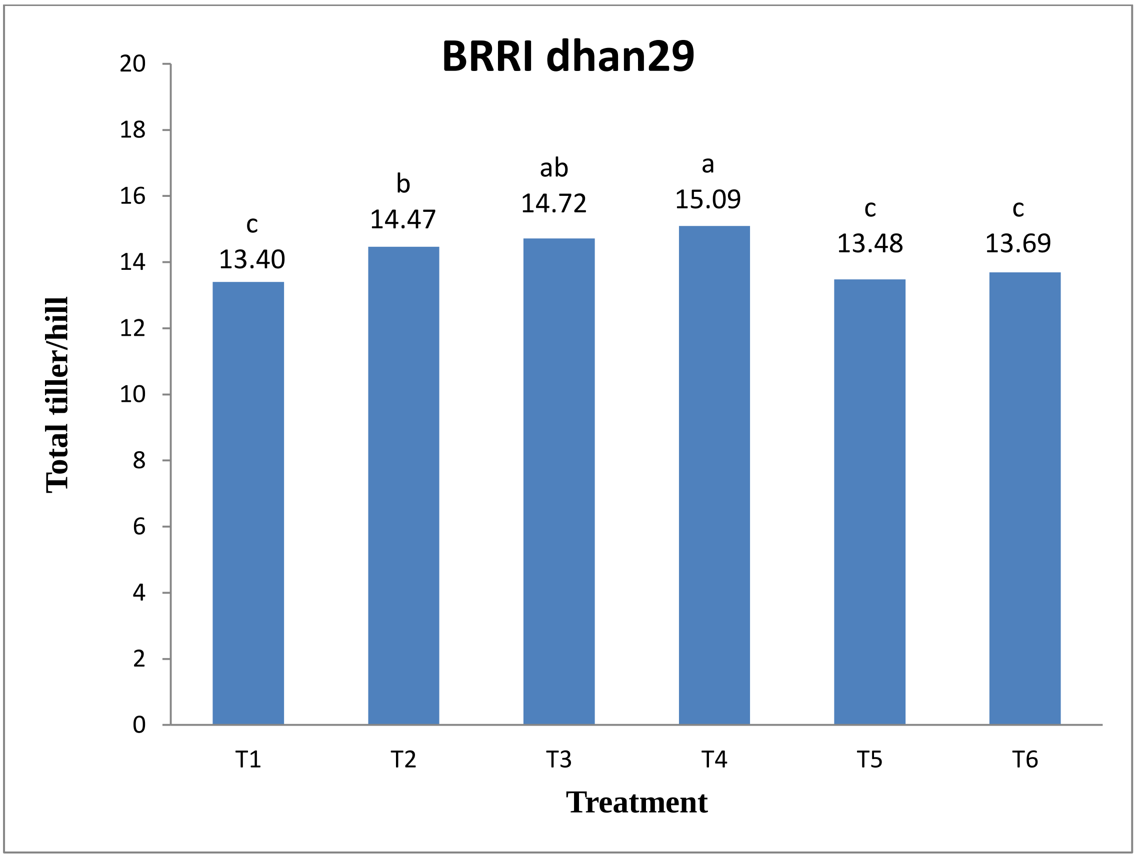
Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

*= Non significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.4 Total tillers/hill

The effect of different treatments on total tillers/hill was statistically significant (Figure 5). The maximum number of total tillers/hill (15.09) was obtained in the T_4 treatment (0.75 mM SA) and it was significantly different from the control T_1 (0 mM SA) which had the minimum number of total tillers/hill (13.4). In producing total number of tillers/hill the treatments may be arranged as $T_4>T_3>T_2>T_6>T_5>T_1$. Number of total tillers of all treatments is higher than the number of total tillers of control (treatment T_1). This is strongly supported by Sardoei, *et al.*,(2014) who reported that the exogenous spray of SA had significant effect on number of tillers.



T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 M Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 5. Effect of different doses of salicylic acid on total tillers/hill of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU,2016.

4.1.5 Number of ineffective tillers/hill

The Ineffective tillers/hill varied insignificantly due to the effects of different treatments of salicylic acid (Table 4). The highest ineffective tillers/hill was produced (1.07) by the T_1 treatment (0 mM SA) and that was statistically similar with all tillers/hill produced (0.43) by the T_4 treatments (0.75 mM SA). In producing non effective number of tillers/hill the treatments may be arranged as $T_1 > T_6 > T_2 > T_3 > T_5 > T_4$.

Table 4. Effect of different doses of salicylic acid on ineffective tillers/hill of BRRI dhan29 at harvest, Boro 2016, SAU.

Treatments	Ineffective tillers/hill
T1	1.07a
T2	0.81a
T3	0.72a
T4	0.43a
T5	0.48a
T6	1.03a
$LSD_{0.05}$	0.1023
Level of significance	*
CV (%)	7.43

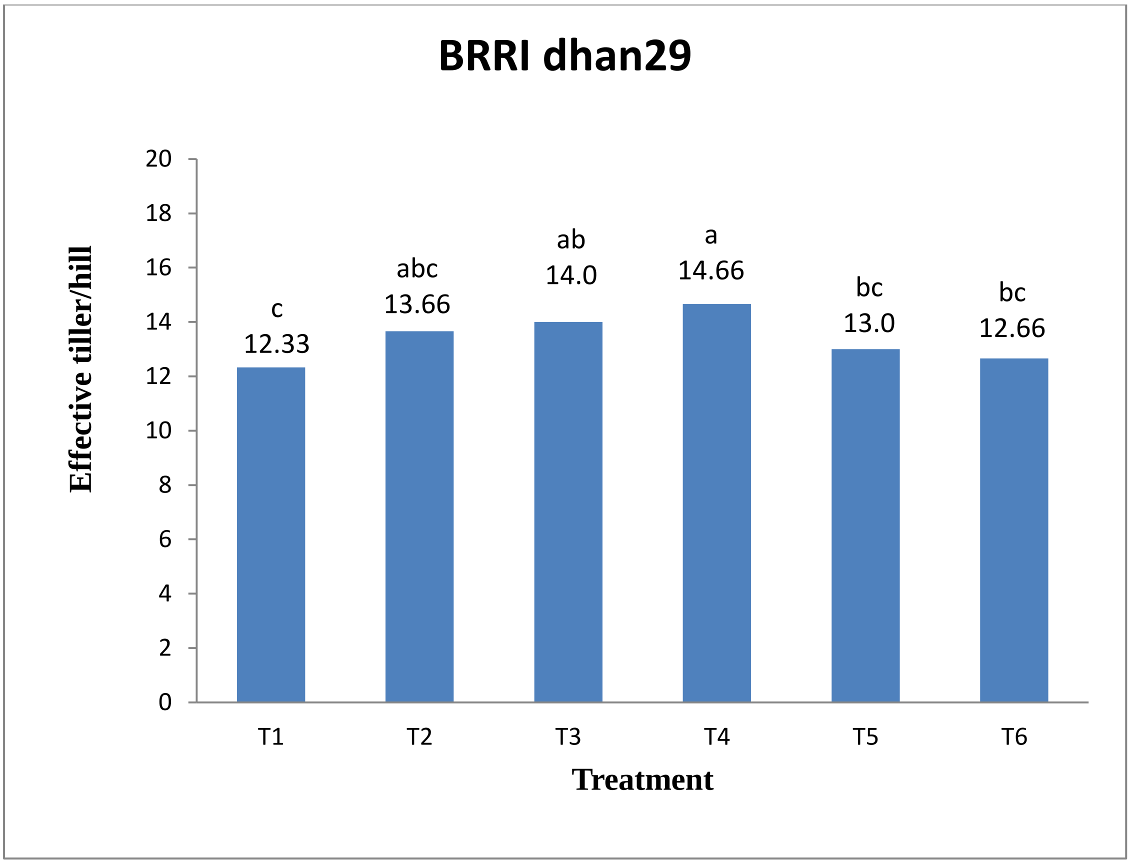
Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

*= Non significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 M Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.6 Number of effective tillers/hill

The application of different levels of salicylic acid had a significant effect on number of effective tillers per hill (Figure 6). Number of effective tillers increased with the increases of SA levels upto a certain limit. The highest number of effective tillers per hill (14.66) was found in the treatment T_4 due to the application of 0.75 mM salicylic acid which varied significantly from the control T_1 treatment (0 mM SA). The lowest number of effective tillers per hill (12.33) was found in the control T_1 treatment. In producing effective number of tillers/hill the treatments may be arranged as $T_4 > T_3 > T_2 > T_5 > T_6 > T_1$. These results might be due to the optimum use of irrigation water because foliar application of SA reduces the transpirational water losses and increases the total chlorophyll levels in the leaves. Singh *et al.* (2015) found that foliar application of salicylic acid significantly increases number of effective tillers/hill of rice. Sardoei, *et al.*, (2014) also reported that the exogenous spray of SA had significant effect on number of tillers.

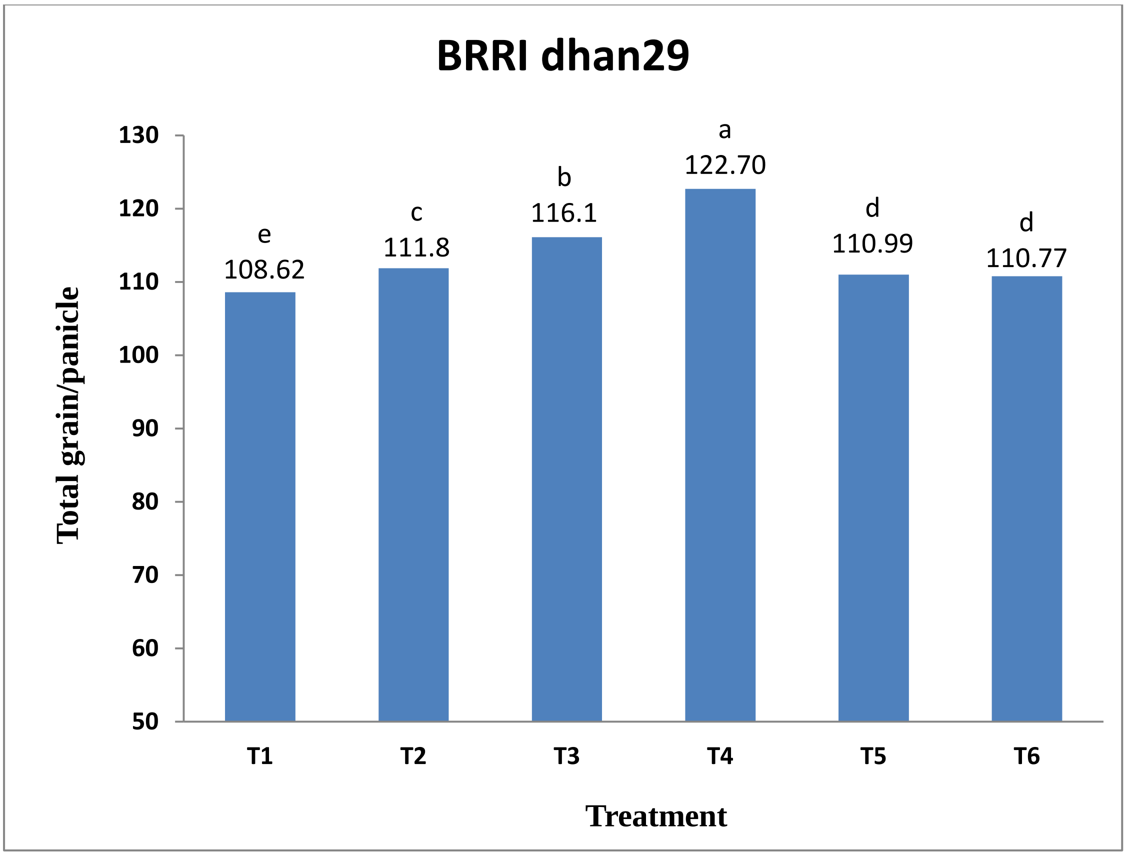


T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 6. Effect of different doses of salicylic acid on number of effective tillers/hillof BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.7 Number of total grains/panicle

The influence of salicylic acid on the number of total grain/panicle was significantly varied among the treatments (Figure 7). Number of grain/panicle was significantly influenced by the foliar application of salicylic acid at different doses. The highest number of grain (122.7) was found in T_4 treatment having 0.75 mM SA which was statistically different from all other treatments. The lowest number of grains (108.62) was found in T_1 treatment. According to the total number of grains/panicle the treatments may be arranged as $T_4>T_3>T_2>T_5>T_6>T_1$. Finally it was observed that the total number of grains/panicle of rice showed significant differences between control plants and SA foliar sprayed plants. Similar results were also found by Chen, *et al.* (2017).

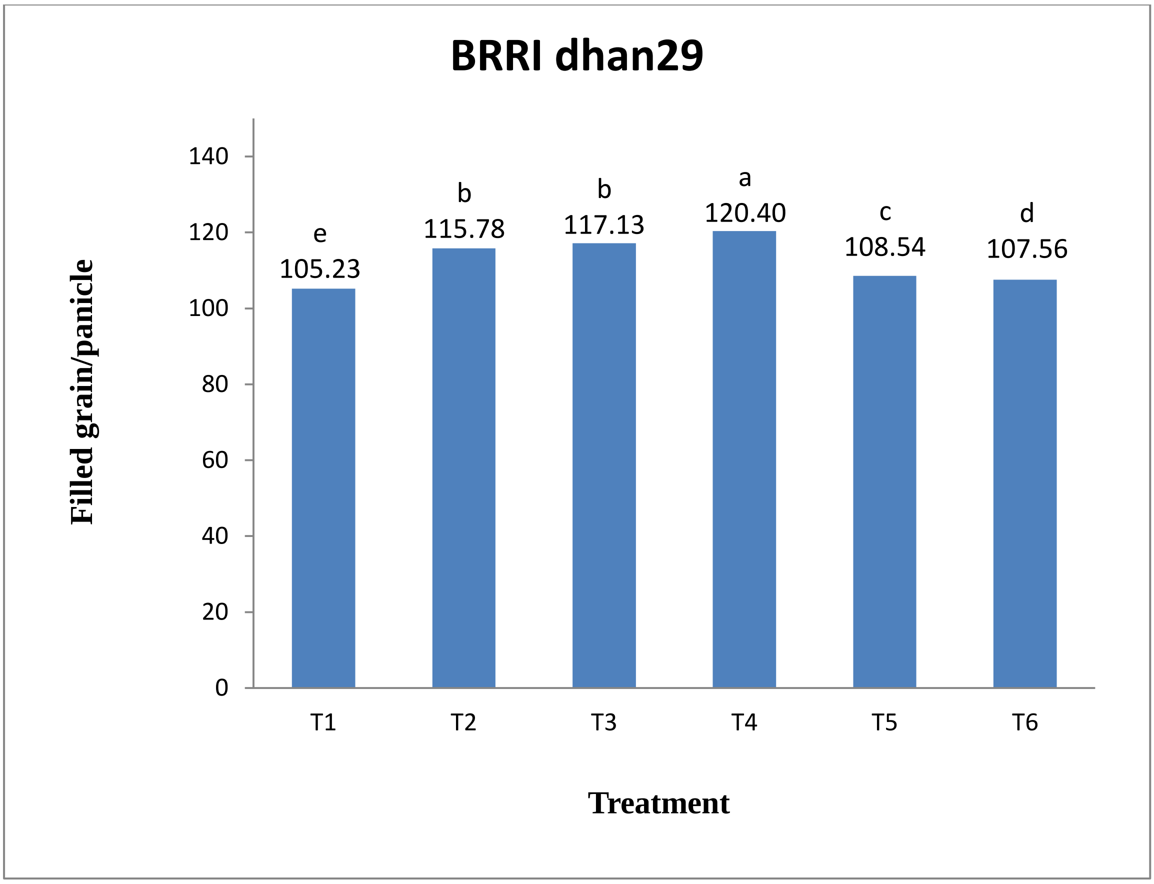


T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 7. Effect of different doses of salicylic acid on total grain per panicle of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.8 Number of filled grains/panicle

The foliar application of different levels of salicylic acid had a significant effect on filled grains per panicle (Figure 8). The highest number of grain per panicle (120.4) was found in the T_4 treatment having foliar application of 0.75 mM salicylic acid and this result was statistically different from all other treatments. The lowest number of filled grain per panicle (105.23) was found in the T_1 treatment having 0 mM salicylic acid. According to the filled grains/panicle the treatments may be arranged as $T_4>T_3>T_2>T_5>T_6>T_1$. This result suggests that foliar application of SA could help to increase the grain yield of BRRI dhan29. Singh *et al.*, (2015) and Usharani, *et al*., (2014) showed that filled grain/panicle increased significantly by the application of salicylic acid.



T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 8. Effect of different doses of salicylic acid on filled grain per panicle of BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.9 Number of unfilled grains/panicle

The application of different levels of salicylic acid had a significant effect on the unfilled grain per panicle (Table 5). The lowest number of unfilled spikelet per panicle (2.3) was found in application of 0.75mM salicylic acid under the treatment T_4 and that was statistically different from other treatments. The highest number of unfilled spikelet per panicle (3.39) was found in the control treatment T_1that was statistically different from other treatments. Sterility (%) also decreased with increases of salicylic acid level. These results showed that number of unfilled spikelet per panicle was decreased with increases of level of salicylic acid as foliar application. Mohammed, R.A. (2011) reported that number of unfilled spikelet per panicle was decreased due to foliar application of salicylic acid.

Table 5. Role of foliar application of salicylic acid on unfilled grain and 1000-grain weight of BRRI dhan29 at harvest, Boro 2016, SAU.

Treatment (dose)	Unfilled grains/ panicle	1000-grain weight
T1	3.39a	29.18a
T2	3.1bc	30a
T3	2.97c	32a
T4	2.3d	32.9a
T5	2.45d	29.71a
T6	3.21b	29.53a
$LSD_{0.05}$	0.1503	1.5824
Level of significance	**	*
CV (%)	2.85	2.85

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

*= Nonsignificant at 1% level of probability

** = Significant at 1% level of probability

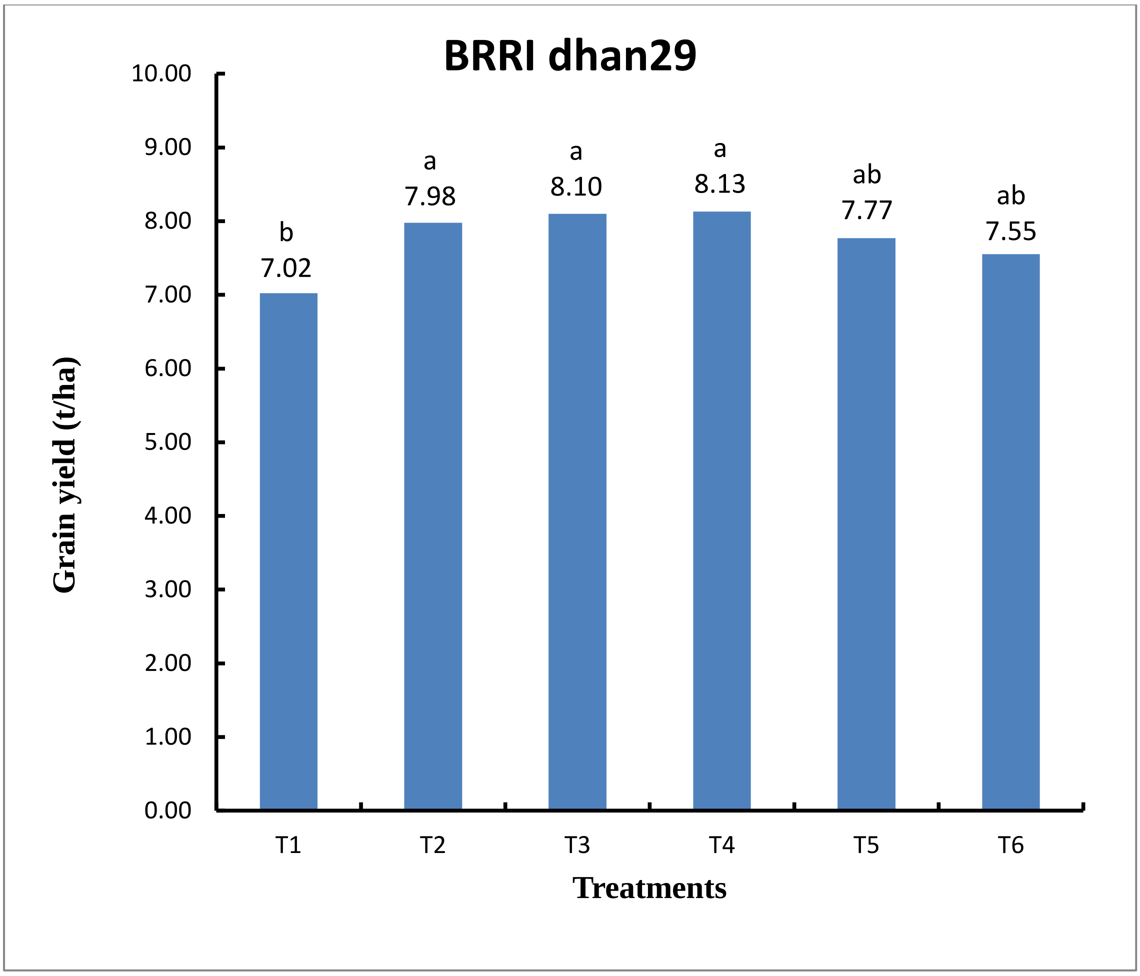
T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.10 1000 grain weight (g)

Table 5 shows the effects of different treatments on 1000-grain weight. It was found that 1000-grain weight was statistically insignificant with compare to the T_1 treatment (control). The maximum 1000 grain weight (32.9 g) was found in the treatment T_4 having 0.75 mM salicylic acid which was statistically similar to all other treatments. The lowest 1000 grain weight (29.18 g) was found in the control treatment T_1. Though there was no statistical difference among the treatments, there were increase results due to foliar spray of SA. In case of 1000-grain weight the treatments may be arranged as $T_4>T_3>T_2>T_5>T_6>T_1$. It was observed that, as the level of salicylic acid foliar application increases the 1000-grain weight increases insignificantly. Ibrahim, *et al.*, (2014) showed 1000 grain weight increased due to the application of salicylic acid.

4.1.11 Grain yield (t/ha)

The influence of salicylic acid on grain yield was significantly varied among the treatments. Figure 9 shows the effects of different level of salicylic acid on grain yield of BRRI dhan29. The maximum grain yield (8.13 t/ha) was found in the treatment T_4 having 0.75 mM salicylic acid which differed statically from all other treatments and this result revealed that the grain yield of treatment T_4 had 15.84% higher yield over control (Treatment T_1). Here Treatment T_1 (control) shows the lowest yield (7.02 t/ha). Treatment T_2, T_3 and T_4 did not differ significantly but they differ significantly with control (Treatment T_1). Treatment T_5 and T_6 are statistically identical to the treatment T_2 having the highest yield. According to grain yield treatments can be arranged as $T_4>T_3>T_2>T_5>T_6>T_1$. This result is strongly supported by Mohammed, A. R. (2011). He showed that SA treated plants gave 13.5% higher grain yield compared to controlled plants. The increasing result may cause due to the increased tiller per hill, increased filled grain per panicle, increased amount of chlorophyll content which helps the plant to produce more food. Ultimately the grain yield increases. Saranraj, P. (2014) also showed that the application of SA can increase grain yield. Sharafizad *et al.*, (2012) showed that dosage of SA significantly affected total grain yield.

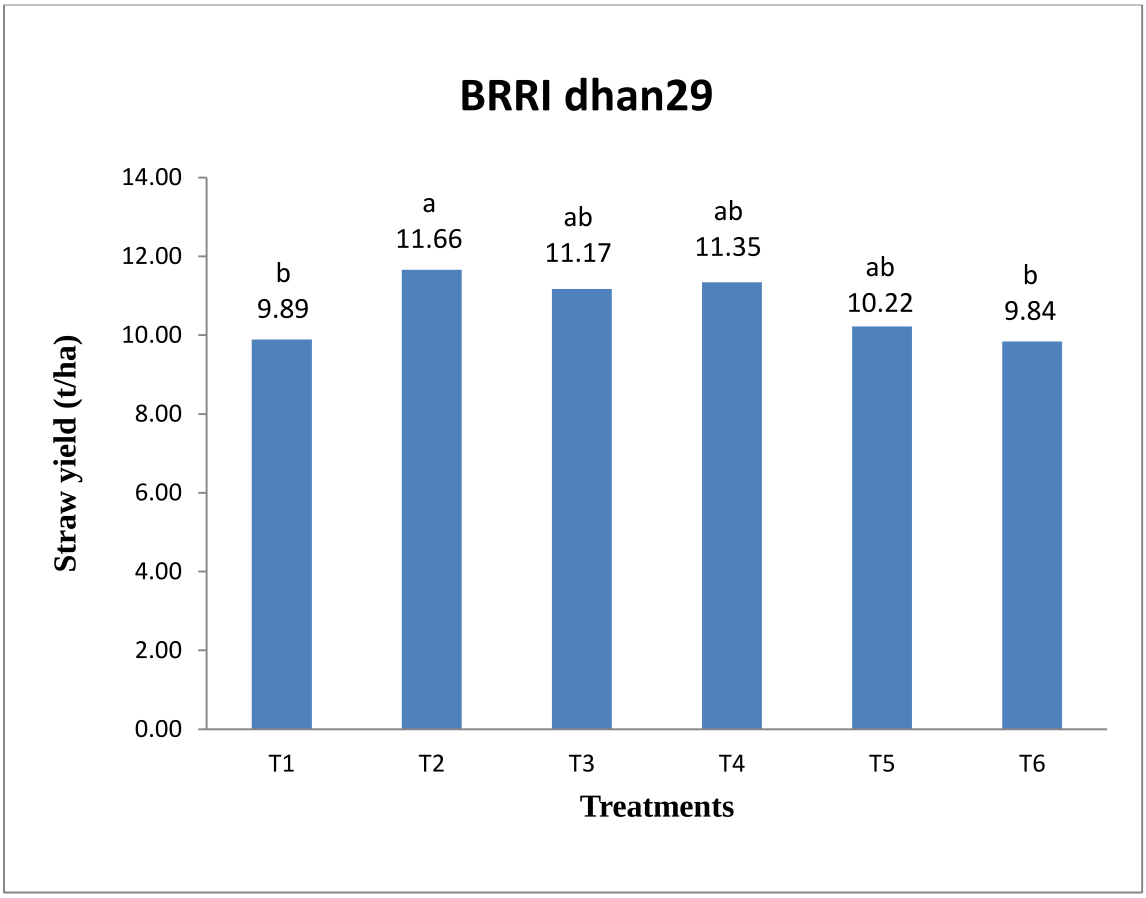


T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 M Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 9. Effect of different doses of salicylic acid on grain yieldof BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.12 Straw yield (t /ha)

The foliar application of different levels of salicylic acid had a significant effect on straw yield. Figure 10 shows that the foliar application of salicylic acid on BRRI dhan29 gave higher straw yield compared to control (Treatment T_1). Here the lowest straw yield (9.84 t/ha) was found in treatment T_6 (2 mM SA) which was statistically identical to control (T_1) having 9.89 t/ha yield. Treatment T_6 had the lowest result may be due to the higher dose of salicylic acid. The highest yield (11.66 t/ha) was found in treatment T_2 which differs significantly to control (T_1). Treatments T_3, T_4 and T_5 was statistically identical to the control (treatment T_1) but they had higher yield compared to control. The treatments can be arranged according to straw yield as $T_2>T_4>T_3>T_5>T_6>T_1$. This increased result caused may be due to the increased level of chlorophyll content as well as increased dry matter content. This result is strongly supported by Saranraj, P. (2014) who showed that application of SA can increase straw yield even upto 74.53% over control. Usharani *et al.*, (2014) also showed highest straw yield was achieved by the application of salicylic acid.



T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 M Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Figure 10. Effect of different doses of salicylic acid on straw yieldof BRRI dhan29 at harvest, Boro 2016, SAU. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.13 Biological Yield

Significant response was observed in the biological yield of BRRI dhan29 due to foliar application of different level of salicylic acid (Table 6). The biological yield was varied from 16.91 - 19.64 t/ha. The highest biological yield (19.64 t/ha) was obtained in the T_2 treatment. On the other hand, lowest biological yield (16.91 t/ha) was obtained from the T_1 treatment. In terms of biological yield the treatments may be arranged as $T_2>T_4>T_3>T_6>T_5>T_1$. It was observed that, as the rate of foliar application of salicylic acid increases biological yield also increases.

4.1.14 Harvest Index

Harvest index (HI) is the ratio of seed yield to total above ground plant yield. Significant response was not observed in the harvest index due to the foliar application of different levels of salicylic acid on BRRI dhan29 (Table 6). From the results, it was found that the highest harvest index (43.42%) was obtained from the treatment T_6 and the lowest index (40.63%) was obtained in the T_2 treatment whereas, treatment T_1 having the harvest index 41.51%.

Table 6. Effect of different doses of salicylic acid on grain, straw, biological yield and harvest index of BRRI dhan29, Boro 2016, SAU.

Treatments	Grain yield (t/ha)	Straw (t/ha)	Biological yield (t/ha)	Harvest index (%)
T1	7.02 b	9.89 b	16.91	41.51
T2	7.98 a	11.66 a	19.64	40.63
T3	8.10 a	11.17ab	19.27	42.03
T4	8.13 a	11.35ab	19.48	41.74
T5	7.77ab	10.22ab	17.99	43.19
T6	7.55ab	9.84 b	17.39	43.42
$LSD_{0.05}$	0.9003	1.62		
SE (±)	0.3091	0.556		
Level of significance	**	**		
CV (%)	9.76	12.75		

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

** = Significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

Table 7. Grain yield and straw increase over control of BRRI dhan29, Boro 2016, SAU.

Treatments	Grain yield (t/ha)	% Increase over control	Straw yield (t/ha)	% Increase over control
T1	7.02 b	-	9.89 b	--
T2	7.98 a	13.65	11.66 a	17.9
T3	8.10 a	15.36	11.17ab	12.94
T4	8.13 a	15.84	11.35ab	14.76
T5	7.77ab	10.66	10.22ab	3.34
T6	7.55ab	7.6	9.837 b	-0.54
$LSD_{0.05}$	0.9003	-	1.6207	-
SE (±)	0.3091	-	0.556	-
Level of significance	**		**	
CV (%)	9.76		12.75	

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

** = Significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.15 pH of Post-Harvest Soils

The pH value of the post-harvest soils did not differ significantly due to the foliar application of SA. The pH remains almost similar among all the six treatments. The ranges of pH value of those treatments are shown at the table 8.

Table 8: Effect of different doses of salicylic acid on pH of post harvest soils of BRRI dhan29, Boro 2016, SAU.

Treatments	pH of Post-Harvest Soils
T_1	6.3a
T_2	6.3a
T_3	6.2a
T_4	6.2a
T_5	6.4a
T_6	6.2a
Initial soil pH	**6.2**
$LSD_{0.05}$	0.0920
Level of significance	*
CV%	0.81

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

*= Non significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.16 Organic carbon of post harvest soil

The value of organic carbon of the post-harvest soils was not differ significantly due to the foliar application of SA. The organic carbon remains almost similar among all the six treatments. The ranges of organic carbon of those treatments are shown at the table 9.

Table 9: Effect of different doses of salicylic acid on organic carbon of post harvest soils of BRRI dhan29, Boro 2016, SAU.

Treatments	Organic carbon of Post-Harvest Soils
T_1	0.61a
T_2	0.62a
T_3	0.62a
T_4	0.63a
T_5	0.60a
T_6	0.61a
Initial soil organic carbon	**0.60**
$LSD_{0.05}$	0.0380
Level of significance	*
CV%	3.41

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

*= Non significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 mM Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

4.1.17 Organic matter of post harvest soil

Table 9 is showing the effects of different levels of SA on organic matter status of post harvest soils. It was found that organic matter status of post harvest soil statistically insignificant. The organic matter remains almost similar among all the six treatments. The ranges of organic matter of those treatments are shown at the table 10.

Table 10: Effect of doses of salicylic acid on organic carbon of post harvest soils of BRRI dhan29, Boro 2016, SAU.

Treatments	Organic matter of Post-Harvest Soils
T_1	1.05a
T_2	1.07a
T_3	1.07a
T_4	1.07a
T_5	1.03a
T_6	1.04a
Initial soil organic matter	**1.03**
$LSD_{0.05}$	0.0663
Level of significance	*
CV%	3.46

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

* = Non significant at 1% level of probability

T_1 = 0 mM Salicylic acid
T_2 = 0.25 mM Salicylic acid
T_3 = 0.5 M Salicylic acid
T_4 = 0.75 mM Salicylic acid
T_5 = 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2015 to May 2016.The study was aimed to determine the role of foliar application of salicylic acid in yield performance of BRRI dhan29 at Boro season under the Modhupur Tract (AEZ-28).

The single factor experiment was compared with six treatments of salicylic acid.

T_1= 0 mM Salicylic acid
T_2= 0.25 mM Salicylic acid
T_3= 0.5 M Salicylic acid
T_4= 0.75 mM Salicylic acid
T_5= 1.0 mM Salicylic acid
T_6 = 2.0 mM Salicylic acid

All the fertilizers were applied in every treatment @ recommended dose.

The experiment was laid out in a randomized complete block design with three replications. There were 18 unit plots and the size of the plot was 2m × 2m. There were 6 treatment combinations. BRRI dhan29 was sown as test crop. Data on different growth and yield parameters were recorded and **a**nalyzed statistically. Foliar application of salicylic acid was done in rice field in three times. First step was applied on 49DAT (tillering stage), 2nd application on 84 DAT (panicle initiation stage) and 3rd application on 92 DAT (flowering stage). Weeding, irrigation and pest managements were done if and when necessary. Plant height, panicle length, number of effective tillers/hill, number of filled grain/panicle, unfilled grain/panicle, 1000 grain weight, grain yield, straw yield, biological yield and harvest index were taken.

The tallest plant (96.08 cm) was found in the T_4 treatment having 0.75 mM of salicylic acid and it was statistically identical with the treatments $T_{3,}$ T_2 and T_5. The shortest plant (93.87 cm) was found in the treatment T_1. The highest number of effective tillers per hill (14.66) was found in the treatment T_4 due to the application of 0.75mM salicylic acid which was statistically similar with the treatments T_3, T_2 and T_5. The lowest number of effective tillers per hill (12.33) was found in the treatment T_1. The highest number of grain per panicle (120.4) was found in the T_4 treatment having foliar application of 0.75 mM salicylic acid and it was statistically similar with the treatments T_3 and T_2. Similarly, the lowest number of unfilled grain per panicle (2.3) was found with the same treatment. The maximum 1000 grain weight (32.9 g) was found in the treatment T_4 having 0.75 mM salicylic acid which was statistically similar to the treatment T_3, T_2 and T_5. The maximum grain yield (8.13 t/ha) was found in the treatment T_4 having 0.75 mM salicylic acid and it was statistically identical with the treatment T_3 having 0.5 mM salicylic acid where the control treatment T_1 (7.02 t/ha) has the lowest grain yield. The highest straw yield (11.66 t/ha) was found in T_2 treatment where the control treatment T_1 was (9.89 t/ha).

The present study was conducted to improve our understanding of rice responses to salicylic acid application. Our results indicated beneficial effects of salicylic acid application. Application of salicylic acid has a profound effect on effective tillers/hills, 1000 grain weight, filled grain/panicle, unfilled grain/panicle, grain yield, straw yield & biological yield. Decreased respiration rates and increased membrane integrity as a result of salicylic acid application might have increased the amount of photo synthates transported to the grains, thereby increasing the number of filled grains per panicle, hence increased spikelet fertility. Besides that, our results indicate that primary tillers become earlier, effective tillers become higher, flowering and maturity time become earlier resulting more yield.

Based on the experimental results, it might be concluded that,

i. Lower doses (Treatment T_4) of the salicylic acid (0.75 mM) influenced morphological characters, yield attributes, grain and straw yield of rice cv. BRRI dhan29 compared to the control treatment T_1; and

ii. Treatment T_4 showed the statistically higher result compared to the control T_1 with the application of 0.75 mM SA.

Recommendations

From the above experimental findings, it is apparent that the foliar application of salicylic acid performed better on yield and yield parameters of rice cv. BRRI dhan29. In order to recommend the practices for the rice growers, the following aspects would be considered in future:

i) Similar experiments need to be conducted in different locations and seasons of Bangladesh to draw a final conclusion regarding the foliar application of salicylic acid on rice.

ii) Varietal trials need to be investigated.

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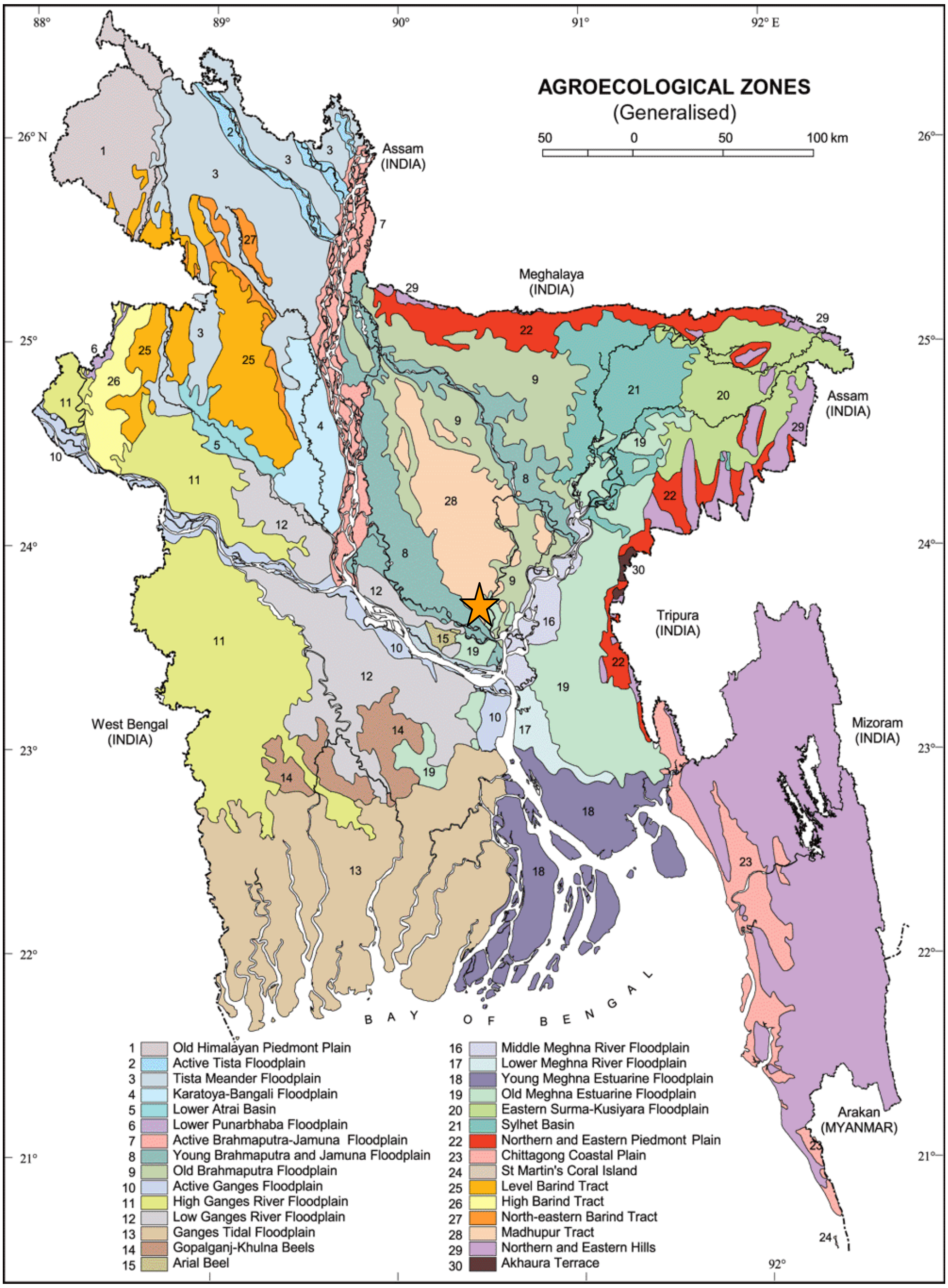
APPENDICES

Appendix I. Map showing the experimental sites under study



Appendix II. Monthly record of air temperature, relative humidity and rainfall (average) of the experimental site during the period from November 2015 to May 2016, SAU.

Month (2016)	Air temperature(^0C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November	26.5	19.4	81	22
December	25.8	16.0	78	00
January	25.8	12.2	72	6
February	28.4	14.7	64	21
March	32.3	19.3	62	57
April	34.5	23.5	66	138
May	33.4	24.8	78	272

Source: Bangladesh Meteorological Department (Climate and weather division) Agargoan, Dhaka-1