EFFECTS OF SALICYLIC ACID ON GROWTH, YIELD AND NUTRIENTS CONTENT OF OKRA (BARI Dherosh-2) UNDER DIFFERENT LEVELS OF SALINITY

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CERTIFICATE

*This is to certify that the thesis entitled "**EFFECTS OF SALICYLIC ACID ON GROWTH, YIELD AND NUTRIENTS CONTENT OF OKRA (BARI Dherosh-2) UNDER DIFFERENT LEVELS OF SALINITY**" submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bona fide research work carried out by **DHEEMAN CHANDRA DHALI**, Registration No. **18-09313** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

December, 2020
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Dedicated to
My
Beloved Parents

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celsius
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram

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Dhaka, BangladeshThe Author

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EFFECTS OF SALICYLIC ACID ON GROWTH, YIELD AND NUTRIENTS CONTENT OF OKRA (BARI Dherosh-2) UNDER DIFFERENT LEVELS OF SALINITY

ABSTRACT

A pot experiment was conducted at the net house of Agro-Environmental Chemistry Laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from March 2019 - October 2019 to find out the effects of salicylic acid on growth, yield and nutrients content of okra (BARI Dherosh-2) under different levels of salinity. The experiment comprised of two factors: Factor-1. Salinity levels: 0, 6 and 12 $dSm^{-1}$and Factor- 2. Rate of salicylic acid: 0 mM, 0.75 mM and 1.5 mM. BARI Dherosh-2 was used as the test crop. Data were taken onplant height, number of branches and leaves $plant^{-1}$, length of leaves, number of flowers $plant^{-1}$, number of fruits $plant^{-1}$, individual fruit weight as well as fruit yield $plant^{-1}$, fresh weight of shoot and dry weight of shoot, N, P and K content in fruit, shoot and root. When single effect was considered, salinity adversely affected most of the growth and yield parameters and nutrient content, but application of salicylic acid elevated all the mentioned parameters except plant height. When combined effect was considered, maximum plant height (102.33 cm) from control treatment, leaves $plant^{-1}$ (11.66) from $S_0SA_{1.5}$ at final harvest, number of branches $plant^{-1}$ (2.00), flower $plant^{-1}$ (3.33), fruit $plant^{-1}$ (14.00), single fruit weight (19.26g) and fruit yield $plant^{-1}$ (231.00g) were found from $S_6SA_{1.5}$ treatment, whereas the minimum plant height (79.33 cm) from $S_{12}SA_{1.5}$, number of branches $plant^{-1}$ (1.33), flower $plant^{-1}$ (1.33), fruit $plant^{-1}$ (8.33), single fruit weight (12.8g) and fruit yield $plant^{-1}$ (106.66 g) were found from $S_{12}SA_0$ treatment. In all the salinity levels, it was found that foliar application of salicylic acid reduce adverse effect of salt stress. Such as at S_{12} salinity level minimum fruit yield $plant^{-1}$ (106.66 g) was found when no salicylic acid was applied but when SA was applied @ 1.5 mM fruit yield was increased (191.27 g). In fruit and shoot N, P, K content was reduced due to salinity stress but in root N content increase at 12 dSm^{-1}.

CHAPTER I

INTRODUCTION

Vegetables provide a variety of health benefits being generally low in fat content and calories but rich in vitamins, protein and fiber. Almost all vegetables used world-over are free of cholesterol. Vegetables, if eaten fresh or partially cooked, can help counter of many of the common diseases such as cancer, diabetes, blood pressure, vision loss, heart diseases, and a number of intestinal disorders (Khan, 1979; Shukla and Naik, 1993).

In Bangladesh, vegetable production is not uniform round the year. Vegetables are plenty in winter but are in short in summer. The total vegetable production around 30% is produced during Kharif season and around 70% is produced in Rabi season (Anonymous, 1993). So, as a vegetable okra can get an importance in summer season production. Successful okra production may contribute partially in solving vegetable scarcity of summer season for the increasing population. To meet up our daily vegetable requirements as well as the shortage of vegetable production, okra can partially improve the vegetable production in the country. At present, a total area of 10.35 thousand hectares of land is under okra cultivation which produces about 43.21 thousand metric tons (BBS, 2011).

The pandemic COVID19, affects on global health, educations, clinical research, human civilization, and the economy. So, it has been an urgency to develop proper vaccines against corona virus. India emphasis on the most nutritious economically-important number-one-consumption-vegetable, okra, used in many human diseases, is naturally infected by different pathogens and significantly reduces production. And in near future okra may itself be a ‘Potential Biomedicine as well as Vaccine’ and world will return in normal form by defeating COVID-19 (Datta, S. C. 2020).

Okra (*Abelmoschus esculentus L. Moench*,) is a popular vegetable in Bangladesh which originated in tropical Africa (Purseglove, 1987). It belongs to the family Malvaceae and locally known as "Dherosh" or "Bhindi". It plays an important role in vegetable market during summer season when the supply of vegetables is limited. It is an annual vegetable crop in tropical and sub-tropical parts of the world but it grows year round in our country and commercially cultivated mainly in summer.

Plant growth and productivity affected by salinity as one of the major environmental factors (Misra et al., 1990). It is known that up to 20% of irrigated lands in the worlds are affected by levels of salinity (Mostafazadeh-Fard et al., 2007). High concentration of salt has adverse effect on many crop species (Zörb et al., 2004), salinity affected cell enlargement as well as photosynthesis (Misra et al., 2001; Munnus et al., 2006), it has negative effect on cell division and cell growth (Maghsoudi and Maghsoudi, 2008). Exposure of plants to salt stress increase reactive oxygen species which destroy membrane lipids (Zörb et al., 2004). Plants that exposed to salt stress produced metabolite like proline, exposure of higher plants to salt stress produced proline which is free amino acid. It is highly active, and plays an important role in membrane stability, also mitigates the effects of saline on cell membrane disruption (Parviz and Satyawat, 2008). Establishment of methods to induce stress tolerance in plants is important, and still need considerable attention. Methods used to develop stress tolerant in plants included genetic engineering, traditional breeding, in vitro selection, and the use of growth regulators (Baninasab and Ghobadi, 2011; Senaratna et al., 2000).

One viable strategy of overcoming the salt-induced injurious effects on plant growth is the exogenous application of growth regulators, osmo-protectants and stress signaling molecules (Farooq et al., 2010). Application of salicylic acid (SA) effectively alleviates the salt-induced damage in plant (Farooq et al., 2010).

Salicylic acid is a growth regulator with phenolic nature (Sakhabutdinova et al., 2003), it acts as non-enzymatic antioxidant, also plays a vital role in regulating some plant physiological processes (Noreen et al., 2009), such as stimulating adventitious organ, development, herbicidal effect and providing resistant to environmental stress (Hussein et al., 2007).

Salicylic acid (SA) is a phenolic compound. It is one kind of plant growth regulator, non-enzymatic antioxidant and acts as an important signal molecule for modifying plant responses to environmental stresses. Salicylic Acid protects plant growth and induces antioxidant defense system under salt stress (Nazar et al., 2011).SA plays important role in flowering induction, plant growth and development, synthesis of ethylene, opening and closure of stomata and respiration of plants (Raskin, 1992). Plants undergoes damages caused by oxidative stresses through increasing

antioxidants enzymes activities, are diminished by SA application (El-Tayeb; 2005, Idrees et al., 2011). SA has received much attention due to its function in plant's responses to environmental stresses. Exogenous SA alters the activities of antioxidant enzymes and increases plant tolerance to abiotic stress by decreasing generation of ROS.

Salicylic acid (SA) is regarded as one of the most effective growth regulator. SA not only acts as an antioxidant but the cellular levels of SA are correlated with the activation of complex biological defense 3 mechanisms. It has also been used to counteract the adverse effects of salt stress in many crop plants (Beltagi et al. 2008). It has proposed functions in whole plant metabolism.Treatment with exogenous salicylic acid has been shown to decrease the harmful effect of abotic stresss, such as high salinity (Tari et al. 2002). The effect of salicylic acid not only depend on not only concentration but also plant species, developmental stage or mode of application (Horvath et al. 2007).

Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan et al. 2010). Endogenous salicylic acid is said to act like a growth regulator and functions as an indirect signal stimulating many physiological, biochemical and molecular processes and therefore it affects the plant growth and development (Klessig and Malamy, 1994). Numerous studies have documented the influence of endo and exogenous salicylic acid on the content of photosynthetic pigments in leaves (Yildirim et al. 2008), on plant photosynthesis (Fariduddin et al. 2003) and on nitrogen metabolism owing to salicylic acid producing a positive impact on the activity of nitrate reductase (Fariduddin et al. 2003; Miguel et al. 2002), synthesis of secondary plant metabolites (Eraslan et al. 2007). Salicylic acid increased fruit number and yield also facilitate transferring sugar to the fruit from leaves (Elvwan and Hamahyomy, 2009). Thus, application of salicylic acid affected yield and quality characters of tomato (Javaheri et al. 2012). In most of the cases, hardening with SA to a subsequent abiotic stress was investigate in short term experiments (Wang et al. 2005). However, our knowledge about oxidative stress and antioxidant response during salt stress after a long term SA pre-treatment is incomplete.

To withstand different environmental factors, plants alter their metabolic pathways to adjust to changes in environments (Rathinasabapathi, 2000), compatible solutes made up of a wide range of organic compounds, such as: simple sugars (fructose and glucose), sugar alcohols (glycerol and methylated inositols), complex sugars (trehalose, raffinose and fructans), polyols, quaternary ammonium compounds (proline, glycine betaine, alpha-alanine betaine, proline betaine) and tertiary sulfonium compounds that are hydrophilic, they can replace water at the surface of proteins, complex protein structures and membranes which explains their action as osmoprotectants and as low molecular weight chaperones (Hasegawa et al., 2000; Nuccio et al., 1999). The metabolic pathways such as proline, glycine betaine, polyols, antioxidant components are responsible to keep the plant survive under stress conditions. Proline is the most common organic compatible solute in the cytoplasm and organelles to keep stability of osmotic pressure of ions in the vacuole, high level of proline may improve the osmotic adaptation and protect the plants against the salt or drought induced injuries. Under salt stress, proline is significantly accumulated and performs the positive role in the adaptation of cells to salt and water stress (Kaviani, 2008). Proline plays a major role in protein accumulation and in cell adaptation to salinity stress (El-Enany, 1995) thus, accumulation of proline in plant may be related to osmotic and saline stress tolerance (Watanabe et al., 2000). Therefore, this present study was designed with the objective to investigate the effect of salicylic acid on negative effects of saline, as well as on accumulations of compatible solutes, and also to determine the best concentration of salicylic acid that accumulates more of these metabolic constituents in stressed okra plant. This study will help us to evaluate the salinity tolerance level of okra in the perspective of Bangladesh and make opportunities for further study in relevant field.

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken to find out the following objectives:

1. To determine the effect of salicylic acid (SA) on growth rate and yield contributing parameters of okra (BARI Dherosh-2) under different level of salinity.

2. To assess the effect of salicylic acid (SA) on nutrient content (N, P, K) of okra (BARI Dherosh-2).

CHAPTER II
REVIEW OF LITERATURE

Comprehensive information is not yet available on the growth, yield and nutrient content in the plant like okra which is both affected by salt stress and salicylic acid (SA). In this chapter, attempts have been made to review some important findings pertinent to effect of salicylic acid (SA) under different level of salinity on the growth, yield and nutrient content in the okra plant.

2.1 Salinity and its effect on okra plant:

Arif *et al.*(2020)conducted a study following salinity is one of the major threats to sustainable agriculture that globally decreases plant production by impairing various physiological, biochemical, and molecular function. In particular, salinity hampers germination, growth, photosynthesis, transpiration, and stomatal conductance. Salinity decreases leaf water potential and turgor pressure and generates osmotic stress. Salinity enhances reactive oxygen species (ROS) content in the plant cell as a result of ion toxicity and disturbs ion homeostasis. Thus, it imbalances nutrient uptake, disintegrates membrane, and various ultra-structure. Consequently, salinity leads to osmotic and ionic stress.

Subudhi*et al.* (2020)initiated a research following salinity is a major environmental constraint that threatens world food security. It affects crop growth, development, and productivity due to reduced water uptake and increased concentration of salts. Soil salinization is increasing at an alarming rate with 1.5 million hectares of land becoming unsuitable for agriculture each year and 50% of the cultivable land is predicted to be unsuitable for farming by 2050. Salinity will continue to be a major constraint for crop production due to climate change and poor irrigation practices. Therefore, enhancing adaptation of major crop plants under saline condition and development of improved irrigation management practices are logical and pragmatic

approaches for increasing global food production.

Zhao*et al.* (2020) performed a study following mechanisms of plant responses and adaptation to soil.The method incorporated the low soil-water potential imposed by salinity causes a marked decline in stomatal conductance (G_s); the physiological rationale behind this reduction is the plant's attempt to minimize water loss under the conditions of reduced water availability ("physiological drought") imposed by salinity. This reduction in G_s comes, however, with a reduction in net CO_2 assimilation, and therefore a reduction in plant growth. Leaves can lose water even when stomata are fully closed. This process, which is termed residual transpiration, is controlled by several factors, one of which is stomatal density. Stomatal density is positively correlated with G_s and it was argued that a reduction in stomatal density may represent a fundamental mechanism.

Shah*et al.* (2020)carried out an analysis targeting salt stress coping mechanisms for stress tolerance in Brassica. Brassica genus comprises numerous cultivated brassica species with various economic importance. Salt stress is an overwhelming problem causing serious losses in Brassica species (e.g. B. napus, B. rapa, B. oleracea, B. juncea) growth and grain yield production by inducing ionic and ROS toxicity. Given that a significant variation exists in salt tolerance level in Brassica genus, Brassica species exhibited numerous salt tolerance mechanisms which were either overlooked or given less importance to improve and understand innate salt stress tolerance mechanism in Brassica species. In this review, they tried to highlight the importance and recent findings relating to some overlooked and potential mechanisms such as role of neurotransmitters, and role of cytosolic Ca^{2+} and ROS as signaling elements to enhance salt stress tolerance. Studies revealed that salt tolerant brassica species retained more K^+ in leaf mesophyll which confers overall salinity tolerance in salt tolerance brassica species. Neurotransmitter such as melatonin, dopamiane and eATP regulates K^+ and Ca^{2+} permeable ion channels and plays a very crucial role in ionic homeostasis under salinity stress in brassica. At the end, the numerous possible salt stress agronomic strategies were also discussed to mitigate the severity of the salt stress in Brassica species.

Sarker*et al.* (2020) carried outan investigation to elucidate growth, anatomical, physiological, and major ROS detoxification pathways involved in the tolerance of A.

tricolor under salinity stress. Both VA14 and VA3 varieties exhibited the reduction in relative water content (RWC), photosynthetic pigments, growth, increased electrolyte leakage (EL), and leaf anatomy adaptation under salinity stress, whereas VA14 was well adapted and performed better compared to VA3. Higher ROS accumulation was demonstrated in the sensitive variety (VA3) in comparison to the tolerant variety (VA14). Salinity stress changed the cellular antioxidant pool by increasing total carotenoids, ascorbate, proline, total polyphenol content (TPC), total flavonoid content (TFC), and total antioxidant capacity (TAC) in both varieties. Although a higher increment was demonstrated in the tolerant variety, the proline increment was much more pronounced in the sensitive variety. Non-enzymatic antioxidant, ascorbate, carotenoids, TPC, TFC, TAC, and antioxidant enzymes SOD and APX were noted to be a major H_2O_2 detoxifier in the tolerant A. tricolor variety, where there is a comparatively lower H_2O_2 load. It was complemented by GPOX and CAT activity at a comparatively higher H_2O_2 load (in the sensitive variety). SOD contributed to the dismutation of superoxide radical (SOR) both in the tolerant and sensitive varieties; however, it greatly contributed to the dismutation of SOR in the tolerant variety. The increase in SOD, ascorbate, and APX makes it predominantly evident that SOD and the AsA–GSH cycle had greatly contributed to quench reactive oxygen species (ROS) of the tolerant variety of A. tricolor.

Bhargava*et al.* (2020) investigated onAmaranthus spp. Which have been cultivated for centuries as a grain and foliage crop in many parts of the world due to the high nutritional value of its leaves and seeds as well as its resistance against both biotic and abiotic stresses like heat, drought, diseases, and pests. Many species of the genus have been reported to tolerate adverse environmental stresses which have been associated with their C_4 physiology, indeterminate flowering habit, long tap root system, extensive lateral root system, accumulation of compatible solutes, efficient water usage, and the expression of stress-related genes and transcription factors.

Zhan *et al.*(2019) evaluated a study to understand the effects of salt stress on the protein level of okra, a comparative proteomic analysis of okra seedlings grown in the presence of 0 or 300 $\mathrm{mmol\,L^{-1}}$ NaCl treatment was performed using an integrated approach of Tandem Mass Tag labeling and LC-MS/MS integrated approach. A total of 7179 proteins were identified in this study, for which quantitative information was available for 5774 proteins. In the NaCl/control comparison group, there were 317

differentially expressed proteins (DEPs), of which 165 proteins were upregulated and 152 proteins downregulated in the presence of NaCl. Based on the above data, we carried out a systematic bioinformatics analysis of proteins with information, including protein annotation, domain characteristics, functional classification, and pathway enrichment. Enriched gene ontology and Kyoto Encyclopedia of Genes and Genomes pathway analysis showed that the DEPs were most strongly associated with "response to stress" and "protein processing in endoplasmic reticulum".

Hamdy *et al.*(2019) was carried-out a greenhouse experiment to evaluate the effect of three rates of salinity as abiotic stress on okra plants (*Abelmoschus esculentus*) infected with the root-knot nematode *(Meloidogyne incognita)* as biotic stress. Plant lengths and weights were significantly ($p \leq 0.05$) reduced except root weight and there was a positive correlation between increasing the salinity concentration from 0.1 to 0.3% and increasing the rate of reduction in plant criteria. The number of J2 in soil, galls, and eggmasses were decreased linked to increased salinity rate as compared to nematode control treatment. However, peroxidase and catalase activities were significantly reduced linked to increasing the salinity concentration from 0.1 to 0.3%. There was no significant difference between total phenols at all treatments. Meanwhile, there was no significant improvement in N, P, and K contents whereas photosynthetic pigments (a, b) and carotene were significantly ($p \leq 0.05$) reduced by nematode infection and increasing the salinity rate from 0.1 to 0.3%.

Abdullah *et al.*(2019) conducted an experiment to investigate the effect of three factors, which included the response of two cultivars of Okra plant (Al-Knissry and Al-Batra) irrigated with water of different salinity levels (RO, 2,4,8 ds.m-1 NaCl), and external treatment with selenium (0,10, 20 mg L^{-1} Na_2SeO_4). it was conducted by spraying on the total vegetative at a rate of one spraying every three weeks for the period after two weeks of the germination to the age of two months (three sprayings during the cultivating season), and their interactions in the yield and the qualitative traits for the Okra plant. The results were analyzed using variance analysis and the averages were compared according to the least significant difference (L.S.D) at the probability level of 0.05. The most important results can be summarized as follows: The Irrigation with two saline concentrations (4, 8 ds.m-1 NaCl) led to reducing the number of pods per plant, the average weight of pod, plant yield, total production and the concentration of vitamin C in pod significantly, while the concentration of Total

Soluble Solids in the pods increased significantly with increasing the concentration of salinity in the irrigation water. Al-Knissry cultivar was significantly excelled on the Al-Batra cultivar in the number of pods per plant, the concentration of vitamin C and Total Soluble Solids in the pods. As for the average weight of pod and plant yield and total production, in which Al-Batra cultivar was significantly excelled on Al-Knissry cultivar. The interaction between the factors experiment had a significant effect on all studied traits. The plants spraying with selenium at a concentration of (20 $mgL^{-1}Na_2SeO_4$) led to a significant increase in the studied yield indicators and the concentration of vitamin C and Total Soluble Solids in the pods. The effect was increased by increasing the spraying concentration.

Islam *et al.*(2019) was conducted a study to confirm the effects of salinity stress on bioactive compounds and antioxidant activity of wheat microgreen extract. The microgreens were cultivated for 8 days in organic media with different concentrations of Na [0 (control), 12.5, 25, 50, and 100 mM from sodium chloride] which was contained in a growth chamber with controlled temperature (20/15 °C, day/night), light (14/10 h, light/dark; intensity 150 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with quantum dot light-emitting diodes), and humidity (60%). Treatment with increasing concentrations of Na resulted in an increase in the Na content of microgreens. Treatment with 12.5 mM of NaCl significantly maximized β-carotene (1.21 µg/mL), phenolic acid (41.70 µg/mL), flavonoid (165.47 µg/mL), and vitamin C (29.51 µg/mL) levels and the nitrite-scavenging activities (37.33%) in wheat microgreen extracts. In addition, the salt-stress caused due to treatment with 25 mM of NaCl resulted in the highest anthocyanin (51.43 µg/mL), 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (89.31%), and 2,2-diphenyl-1-picrylhydrazyl (63.28%) radical-scavenging activity. Therefore, attaining adequate levels of salt-stress may be useful for the industrial manufacturing of new products from wheat microgreen extract.

Nabi *et al.* (2019)undertook a research on nitric oxide which regulates plant responses to drought, salinity, and heavy metal stress se signaling molecules that initiate a cascade of stress-adaptation responses leading either to programmed cell death or plant acclimation. Nitric oxide (NO) is a small but important redox signaling molecule that in plants is involved in a diverse range of physiological processes including germination, development, flowering, senescence, and abiotic stress. Although the exact role of NO in plants remains unclear and is species dependent,

various studies have suggested a positive correlation between NO accumulations stress in plants. In this article, we review and discuss the biosynthesis of NO, sources and exogenous application of NO donors under drought, salt, and heavy metal stress. A review of publications indicated that, in general, application of exogenous NO alleviates the negative stress effects in plants and improves antioxidant activity in most plant species. In addition, S-nitrosylation and tyrosine nitration are two NO-mediated posttranslational modification. All these factors are important in protecting plants from diverse stresses and vary with the species.

Yu *et al.*(2019) studied to assess the response of plants to NaCl, the contribution of protein phosphorylation to the detoxification and tolerance of NaCl in okra (*Abelmoschus esculentus* L.) seedlings is unclear. The molecular bases of okra seedlings' responses to 300 mM NaCl stress are discussed in this study. Using a combination of affinity enrichment, tandem mass tag (TMT) labeling and high-performance liquid chromatography–tandem mass spectrometry analysis, a large-scale phosphoproteome analysis was performed in okra. A total of 4341 phosphorylation sites were identified on 2550 proteins, of which 3453 sites of 2268 proteins provided quantitative information. We found that 91 sites were upregulated and 307 sites were downregulated in the NaCl/control comparison group. Subsequently, we performed a systematic bioinformatics analysis including gene ontology annotation, domain annotation, subcellular localization, and Kyoto Encyclopedia of Genes and Genomes pathway annotation. The latter revealed that the differentially expressed proteins were most strongly associated with 'photosynthesis antenna proteins' and 'RNA degradation'. These differentially expressed proteins probably play important roles in salt stress responses in okra. The results should help to increase our understanding of the molecular mechanisms of plant post-translational modifications in response to salt stress.

Ayub *et al.*(2018) investigated to improve salt tolerance abilities in okra (*Abelmoschus esculentus* L.) by foliar application of potassium silicate and seed priming with GA_3. A pot experiment was conducted at Awan Nursery Farm, Haripur, to investigate whether seed priming with GA_3 and foliar application of potassium silicate could ameliorate the toxic effects of salinity on okra growth. Two okra

cultivars Sabz Pari and Mehak Pari were exposed to two levels of NaCl (control and 50mM) according to the saturation percentage of soil. Seeds of okra were primed with three levels of GA_3 (50mg/L, 75mg/L and 100mg/L) before sowing. After 18 days of germination okra plants were treated with three levels of potassium silicate (2mmol, 3mmol and 4mmol) exogenously as foliar spray to protect the plants against salt stress. Data for different growth parameters such as root length, shoot length, plant height, root and shoot fresh weight, root and shoot dry weight were collected. Okra cultivar Sabz Pari showed maximum resistance towards salinity as compared to Mehak Pari. Applications of GA_3 decreased the harmful effects of salinity and enhanced the overall growth of okra.

Elshaikh *et al*. (2018) hypothesized that biochar soil amendments could increase the okra salt threshold, alleviate salt stress and improve soil productivity. In this study, a pot experiment was conducted to investigate whether biochar could ameliorate the effects of salinity on okra plants. Three biochar amendment (BA) soil applications (0%, 5% and 10% by mass of soil) were considered for seven irrigation water salinity levels (0.75, 1.0, 2.0, 4.0, 5.0, 6.0 and 7.0 dS m^{-1}) in a randomized block design with three replications. The Maas and Hoffman salt tolerance model was used to evaluate the effects of BA on okra plant growth parameters (e.g. yield, biomass) and water use efficiency for each salinity treatment. The results showed that increasing the soil salinity levels caused significant decreases in plant yields and yield components. However, biochar application rates of 5% and 10% increased the okra threshold by 19.7% and 81.2%, respectively, compared to the control (0%). The 10% biochar application rate also resulted in the greatest okra plant growth and increased yield, indicating that the effects of salt stress were ameliorated; moreover, the soil bulk density was decreased, and the water content was increased. Hence, biochar soil amendments could be considered as an important agronomic practice that could potentially overcome the adverse effects of salt stress.

Esan *et al.* (2017) investigated the effects of phytohormones on seedling and fruit of okra. Okra seeds were germinated in polyethylene bags in a screen house under various salt conditions with or without application of compounds that can minimize the harmful effects of this environmental stress. The okra seeds (genotype LD 88)

were pre-soaked with salicylic acid (10^{-2}, 10^{-4},or 10^{-6} mM), indole acetic acid (0.4, 0.5, or 0.6 mM) or distilled water (control) for 12 h under natural environmental conditions, followed by 0, 50, 100 or 200 mM NaCl treatment. Results showed that activity levels of antioxidant enzymes significantly ($p < 0.05$) increased with increasing NaCl concentration. Increased in antioxidant activities were especially noticeable at high salinity levels (150 and 200 mM NaCl) the exception of catalase (CAT) and glutathione peroxidase (GPX) that showed low activities at high salinity level (200 mM) when compared to a control plant (0.0 mM NaCl). But CAT activity increased more in the presence of salicylic acid, and indole acetic acid at 10^{-6} mM and 0.4 mM respectively while GPX and superoxide peroxidase (SOD) activities were poorly expressed in the two treatments when compared to the control group. Increased in the 2,2-diphenyl-1-picryhydrazyl (DPPH) radical scavenging capacity in this study was as a result of increased in the activity of antioxidant enzymes in the plant, which mitigate the destructive effects of reactive oxygen species in the plant.

Hussain *et al.* (2017) performed the study to examine the effect of seed priming with AsA (50 and 100 mg L^{-1}), hydropriming and without priming (control) on physiochemical processes of okra cultivars (Subz-Pari and Arka Anamika) under Pb stress (0, 100 mg L^{-1}). Pb stress caused a considerable decline in plant growth and photosynthetic pigments. Contrarily, Pb stress exhibited rise in the contents of total amino acids, free proline, total soluble proteins and AsA. The POD, CAT, and SOD activities were recorded highest at 100 mg L^{-1} of Pb. Moreover, Pb stress markedly increased H_2O_2 and MDA levels that triggered oxidative stress. However, plants raised from seed primed with AsA and water exhibited better growth and had higher chlorophylls, free proline, total proteins, total amino acids, AsA and activities of enzymatic antioxidants. Priming with AsA (50 mg L^{-1}) induced better tolerance to Pb stress in okra plants. Plants of cv. Arka Anamika exhibited greater tolerance to Pb than that of cv. Subz-Pari as was evident from higher plant fresh and dry masses.

Esan*et al.* (2016) performedstudy on okra seeds of two genotypes (47-7 and LD 88) were presoaked with 10-2, 10-4, and 10-6 mM salicylic acid and control in distilled water, then the soil was treated with 0, 50, 100, 150 and 200 mM NaCl. The experiment was conducted to study the effect on osmoregulating solutes such as proline, salt stress protein (glycine betaine and proline betaine) and soluble sugars (glucose and fructose). Results showed that proline content increased with increased

in the concentrations of salinity. Also, treatment with salicylic acid (SA) improved salt stress proteins accumulation in both stressed genotypes. In contrast, decreased SA concentrations improved soluble sugar accumulation in the fruit of okra genotype 47-4. But in LD88, increased in the level of SA resulted to the increased soluble sugar accumulation in the leaf. Combined effect of SA and salinity caused a greater accumulation of protein and soluble sugar in leaf and fruit of both genotypes of stressed okra, but significant increased were seen only in the groups of LD88 treated with 10-4 mM SA at 50 mM NaCl in leaf and 10-2mM SA at 150 mM NaCl in fruit when compared with the control group. Salinity induced a marked decreased in reducing sugar accumulation of okra plant (LD88), especially at high salinity level (200 mM NaCl). Therefore, accumulations of compatible solutes such as salt stress proteins may provide plant a storage form of nitrogen that will be re-utilized later and may play a role in osmotic adjustment.

Habib *et al.* (2016) characterized plant growth-promoting rhizobacteria (PGPR) containing 1-aminocyclopropane-1-carboxylate (ACC) deaminase and examined their effect on salinity stress tolerance in okra through the induction of ROS-scavenging enzyme activity. PGPR inoculated okra plants exhibited higher germination percentage, growth parameters, and chlorophyll content than control plants. Increased antioxidant enzyme activities (SOD, APX, and CAT) and upregulation of ROS pathway genes (CAT, APX, GR, and DHAR) were observed in PGPR inoculated okra plants under salinity. With some exceptions, inoculationwith *Enterobacter* sp. UPMR18 had a significant influence on all tested parameters under salt stress, as compared to other treatments. Thus, the ACC deaminase-containing PGPR isolate *Enterobacter* sp. UPMR18 could be an effective bioresource for enhancing salt tolerance and growth of okra plants under salinity stress.

Abbas *et al.* (2015) investigatedtwo okra [(*Abelmoschus esculentus* (L). Moench)] genotypes were used, i.e., salt-sensitive Okra-7080 and salt-tolerant OH-713. Seedlings were subjected to salt stress (EC 6 dS m^{-1}) and supplemented with optimized concentration of silicon (150 mg L^{-1}) to evaluate the changes in physio-biochemical and enzymatic characteristics of okra genotypes. Physiological attributes included measurement of gas exchange parameters (photosynthesis rate, stomatal

conductance, transpiration rate, number of stomata and stomatal size) and relative water contents; biochemical parameters included contents of various molecules (total chlorophyll, carotenoids, proline, glycine betaine, total free amino acids and total soluble sugars, total soluble protein, total phenolics and lipid peroxidation) and enzymatic activities (superoxide dismutase, peroxidase and catalase). The results demonstrated that silicon application under saline conditions resulted in significant differences in many traits and it was concluded that silicon was useful in alleviating salt-induced deleterious effects in okra at early growth stage. It was also suggested that enhanced salt tolerance in okra was highly linked with increased osmolyte accumulation and antioxidant activities, due to exogenously applied silicon.

Saeed *et al.,* (2014) carried out a study to determine the effect of organic mulch with or without gypsum amendment on relative water content (RWC) and electrolyte leakage (EL) in leaves of okra (lady finger) plant grown under saline water irrigation. The plants were grown in pots irrigated with S1 (ECiw = 2.0 dSm-1), S2 (ECiw = 4.2 dSm-1) and non-saline control (ECiw = 0.5 dSm-1). Increased EL was noted under salinity without mulch treatments, whereas, application of mulch reduce EL under all salinity treatments. Greater reduction was recorded under mulch amended with gypsum as compare to mulch alone. RWC in leaves of okra was proportionally decreased with increasing salinity. Organic mulch alone or amended with gypsum showed increased RWC under all salinities as compare to without mulch treatments. Results of the present study suggested that application of organic mulch to the soil surface can improves salinity tolerance up to certain extent and the mulch with gypsum up to greater extent by improving RWC and reducing EL in plant which are responsible for improvement of growth as well.

Raza *et al.* (2013) investigated role of seed priming in okra (Ablemoschus esculentus L.) in saline soil under field environment. A split plot design with two main factors including six priming treatments (control, hydropriming, ascorbic acid 50 mg L-1 ,100 mg L-1 and salicylic acid 50 mg L-1 , 75 mg L-1) and two stress levels (control and 125 mM NaCl) was implicated. Soil salinity hampered the growth of okra plants causing reduction in yield of un-primed plants. Maximum growth, pigments, and yield of okra was observed with priming concentration of ascorbic acid 100 mg L-1 under stress and non-stress conditions. However, lower concentration of SA priming (50 mg L-1) had more prominent effect on growth, chlorophyll contents as compared

to its higher dose (75 mg L-1). Seed soaking with ascorbic acid (100 mg L-1) and salicylic acid (75 mg L-1) enhanced antioxidative activities of CAT and POD in saline environment. Hydropriming was quite effective in improving growth, pigments and yield. Furthermore, optimization of time duration for water seed soaking can be done to draw out its role in modulating growth, physiological attributes and yield under normal and saline conditions.

Habib*et al.* (2012) experimented the effect of foliar-applied glycine betaine (50 mM GB) and glycine betaine containing sugarbeet extract (50 mM GB) on various physiological and biochemical attributes of okra plants under salt stress. The experiment comprised of two okra cultivars (Arka-anamika and Sabaz-pari), two salt levels (0 and 150 mM NaCl), and two GB sources (synthetic pure GB and sugarbeet extract) arranged in four replicates. Salt stress significantly suppressed the biomass production, yield, and different gas exchange attributes (*A*, *E*, C_i, and g_s). Glycine betaine and proline contents in leaves, and Na^+ and Cl^- contents in both leaves and roots increased, while K^+ and Ca^{2+} contents and K^+/Na^+ ratios decreased significantly. Foliar application of both pure GB and sugarbeet extract significantly reduced the adverse effects of salt stress on plant biomass production, plant yield, various gas exchange characteristics and leaf K^+, Ca^{2+}, Cl^- and Na^+ contents. However, GB and sugarbeet extract showed differential effects on *A*, g_s, *E*, C_i, C_i/Ca ratio, leaf K^+, Ca^{2+}, and Cl^- contents, and K^+/Na^+ ratio. Pure GB proved better than the sugarbeet extract in improving growth, while the reverse was true for plant yield under salt stress. However, with respect to different gas exchange attributes both GB and sugarbeet extract were found to be equally effective in reducing the adverse effects of salt stress on these photosynthetic attributes. Foliar-applied sugarbeet extract was found to be more effective as compared to pure GB in reducing the adverse effects of salt stress on K^+ and Ca^{2+} uptake and K^+/Na^+ ratio in shoot and root of both okra cultivars. Thus, sugarbeet extract could be used to induce salt tolerance in economically important crop plants.

Yang *et al.* (2011) studied that the control of Na+ accumulations and high K^+/Na^+ ratios may enhance salt tolerance and the K^+/Na^+ ratio has been used as a indicator by a number of authors to select salt tolerant in tomato crops. The result showed that a weak relationship between leaf Na^+ and photosynthetic pigments in tomato cultivars differing in salinity tolerance. They concluded that Chl *a* and*b* are not good indicators

for salt tolerance in tomato.

Marco *et al.* (2011) conducted a research on the effect of two sources of nitrogen on plant growth and fruit yield of chilli (Capsicum annuum L.) under increased salinity. An organic source extracted from grass clippings in rates of 120 and 200 kg N ha-1 , and another inorganic (ammonium nitrate) in rate of 7 120 kg ha-1 were combined with low, moderate and high (1.5, 4.5, and 6.5 dSm1) salinity levels. Research was conducted under controlled condition in greenhouse and arranged in a randomized complete block design with four replications. Finding of this research was that salinity treatments reduced dry matter production, leaf area, relative growth rate and net assimilation rate but increased leaf area ratio. Mean fresh fruit yields decreased for each N rate and source combinations as soil salinity increased.

Niu *et al*. (2010) studied on Salt tolerance of five cultivars of (Capsicum annuum L.). Three levels of salinity such as 0.82 dSm-1 (control, tap water), 2.5 dSm-1 , and 4.1 dSm-1 was made by adding NaCl, $MgSO_4$, and $CaCl_2$ to tap water at different amounts. It was concluded that The most salt tolerant cultivars had the lowest leaf Na+ accumulation, where the sensitive one had the highest Na+ in the leaves.

Humayun *et al.* (2010) conducted an experiment to evaluate the adverse effects of NaCl induced salt stress on growth attributes and endogenous levels of gibberellins (GA), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA) soybean cv. Hwangkeumkong by He reported that 70 mM and 140 mM concentrations of NaCl decreased 1000 seed weight and yield significantly.

Nawaz *et al.* (2010) conducted a research to study the salt tolerance induction in two cultivars of sorghum by exogenous application of different levels (0, 50 mM and 100 mM) of proline. Conclusion showed that germination percentage, growth and chlorophyll contents were adversely affected by Salt treatments (100 mM) in both the cultivars. Applications of proline alleviated the adverse effects of salt stress and to low concentration i.e. 50 mM was more effective than high concentration of proline (100 mM) in both cultivars.

Bybordi (2010) studied the salinity stress effects resulted from sodium chloride on germination and vegetative growth, elements concentration and proline accumulation in five canola cultivars. The outcomes of this research showed that different salinity

levels adversely effected germination percentage, germination speed, shoot and root length. In this pot experiment, salt stress showed adverse effect on plant height, leaf area, dry matter, elements concentration, proline accumulation and seed yield.

Gorai *et al.* (2010) and Jampeetong and Brix (2009) reported that, various plant growths and development processes viz. seed germination, seedling growth, flowering and fruiting are adversely affected under salt stressed condition salinity, ultimately reduced yield and quality.

Datta *et al.* (2009) evaluated the impact of salt stress under different salinity levels (0, 25, 50, 75, 100, 125, 150 mM NaCl) on five varieties of wheat. The experiment concluded that root and shoot length, fresh weight and dry weight of root and shoot were reduced significantly for Regarding biochemical analysis, the sugar, proline content increased with increasing salinity level where as protein content decreased in the physiologically active leaves of different treatments for all the varieties of wheat.

Magan *et al*. (2008) conducted a research to study the effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in 11 Mediterranean climatic conditions. Results stated that under salt stress huge reduction in flower number occurs.

Fanasca *et al.* (2007) studied the combined effects of electrical conductivity (an EC of 2.5 dS m–1 or 8 dS m–1 in the root zone) and fruit pruning (three or six fruit per truss) on tomato fruit quality were studied in a greenhouse experiment, taste related attributes [dry matter content (DM), total soluble solids content (SSC), titratable acidity (TA), glucose, fructose and citric acid content] and health promoting attributes (lycopene, βcarotene, vitamin C, and total anti-oxidant activity) of tomato fruits were determined. Though the quality of tomato fruits was improved by high EC. Results showed that EC and fruit pruning both had a strong effect on fruit size; however, EC had a much stronger impact on taste and health-related fruit quality attributes.

Qaryouti *et al.* (2007) had reported that the total yield of tomato (Lycopersicon esculentum M. cv. Durinta F1) is significantly reduced at salinity equal and above 5 dS m-1 , and a 7.2% yield reduction per unit increase in salinity.

Guiseppe (2006) reported that salinity improved fruit quality by increasing dry matter content and total soluble solid TSS content in plants.

Hajer *et al.* (2006) conducted experiment on tomato under saline condition and reported the effect of NaCl salinity stress on the growth of tomato plants was reflected in lower fresh and as well as dry weights.

Jamil *et al.* (2006) conducted a study to analyze the response of four vegetables species, treated with different concentrations of salt solution. Outcomes indicated that salinity caused significant reduction in germination percentage, germination rate, root and shoot lengths and fresh root and shoot weights.

Parida and Das (2005) carried out a study to understand salt tolerance and salinity effects on tomato plants. They found that plant growth hampers due to salt stress, which ultimately resulting a considerable decrease in fresh and dry weights of leaves, stems and roots of tomato. Increase in salinity levels also results in 12 significant reductions in shoot weight, plant height and root length. Salt stress leads to changes in growth, morphology and physiology of the root and that adversely affected water and ion uptake and the production of signals that sends information to shoot and ultimately the yield was reduced.

Sixto *et al.* (2005) observed that due to higher levels of salinity, vegetative growth parameters were reduced significantly in plants. Increase in salinity levels results in decreasing root, stem and shoot developments, fresh & dry stem and root weights, leaf area and number and ultimately the yield of plants.

Yosef (1982) states that salt depressed the PH of fruits from saline-treated plants. The fruit pH was, however, slightly decreased in accordance with the increase in total acidity.

2.2 Salicylic acid signaling in plant:

Janda*et al.* (2020) carried out a research on Salicylic acid (SA) which is ubiquitously distributed in the whole plant kingdom. The basal level of SA differs widely among species. It is generally present either in the free fraction or in the form of glycosylated, methylated, glucose-ester, or amino acid conjugates. In plants, SA can be synthesized via two distinct and compartmentalized enzymatic pathways, both requiring the primary metabolite chorismate. l-phenylalanine, derived from

chorismate, can be converted into SA via the precursors free benzoic acid, benzoyl glucose, or ortho-hydroxy-cinnamic acid, depending on the plant species. Chorismate can also be converted into SA via isochorismate in the chloroplast. Several physiological processes in which SA may play a role have been reported, including seed germination, growth regulation, flower induction, thermogenesis, and especially, the regulation of plant responses under biotic or abiotic stress conditions. SA may be involved in different signaling processes. For example, various hormones involved in plant defence mechanisms crosstalk with SA, and both negative and positive interactions have been reported. SA signaling also leads to the reprogramming of gene expression and protein synthesis. It may affect the antioxidative metabolism, and it modulates cellular redox homeostasis. However, in spite of the extensive work on SA-related processes, the exact mode of action is poorly understood.

Koo*et al.* (2020) developed a research programme and stated that since salicylic acid (SA) was discovered as an elicitor of tobacco plants inducing the resistance against Tobacco mosaic virus (TMV) in 1979, increasing reports suggest that SA indeed is a key plant hormone regulating plant immunity. In addition, recent studies indicate that SA can regulate many different responses, such as tolerance to abiotic stress, plant growth and development, and soil microbiome. In this review, they focused on the recent findings on SA's effects on resistance to biotic stresses in different plant-pathogen systems, tolerance to different abiotic stresses in different plants, plant growth and development, and soil micro-biome. This allows them to discuss about the safe and practical use of SA as a plant defense activator and growth regulator.

Ghafoor andMalik (2020) developed a research experiment. The research experiment was conducted in the greenhouse of the Institute of Molecular Biology and Biotechnology, The University of Lahore for determining the possible involvement of salicylic acid (SA) in seed priming and affects on the seedling growth and development under NaCl treatments in wheat variety ANAJ-2017, Shafaq-2006 and Galaxy-2013. The data was collected for various seedling traits and statistically analyzed, which revealed the significance of results for treatments, salt applications, genotypes and the interactions between salt treatments and genotypes. The lower coefficient of variation was recorded for all studied traits which revealed that there was consistency among the results for salicylic acid applications and salt or NaCl

treatments. It was concluded from our study that the application of salicylic acid (SA) under salt (NaCl) stress conditions helps wheat seedlings to withstand and compete with stressful conditions. The study revealed that the seed priming with salicylic acid helps to improve root length, shoot length, seedling moisture percentage and fresh seedling weights. The application of NaCl caused to increase the root length, number of roots and shoot length of wheat while salicylic acid (SA) was applied in foliar spray. The use of water priming shows medium effects for the seedling growth of wheat under salt stress environmental conditions. The wheat variety Galaxy-2013 has shown good performance for most of the studied traits of seedlings under salt stress conditions. It was suggested from the study that the variety Galaxy-2013 may be used under salt stress conditions or salt affected soils to improve grain yield of wheat.

Farhadi and Ghassemi-Golezani (2020) performed a pot experiment was to evaluate the response of Mentha pulegium to foliar spray of salicylic acid (SA) (0, 0.5, 1 and 1.5 mM) under different salinity levels (0, 25, 50 and 75 mM NaCl). The results revealed that accumulation of malondialdehyde, H_2O_2, proline, glycine betaine and total phenol as well as the activities of catalase, peroxidase, ascorbate peroxidase, superoxide dismutase and phenylalanine ammonia-lyase were increased with increasing salinity level. However, leaf water content and photosynthetic pigments were significantly decreased by salt stress. SA treatment had no significant effect on glycine betaine, total phenol content and phenylalanine ammonia-lyase activity in salt-stressed plants, while this treatment enhanced proline content via increasing pyrroline-5-carboxylate reductase activity and decreasing proline oxidase activity. Foliar spray of SA also stimulated the activities of catalase, ascorbate peroxidase and superoxide dismutase enzymes and thereby limited H_2O_2 accumulation and lipid peroxidation. Application of 1 and 1.5 mM SA considerably improved leaf water content and chlorophyll content of M. pulegium under different levels of salinity. These results suggest that exogenous application of 1 and 1.5 mM SA could mitigate salt toxicity and improve antioxidant capacity of M. pulegium under different levels of salinity.

Devarakonda*et al.* (2020) carried out the field cum laboratory study to find out the effect of plant elicitors on papaya (Carica papaya L.) cv. Red Lady, during November, 2015 to October, 2017 at Horticultural Research Station, Anantharajupeta, Kadapa district, Andhra Pradesh. The application of salicylic acid twice (at 45 and

120 DAT) @ 150 ppm (T9) recorded significantly highest plant height (257.58 cm) at 210 DAT, which was at a par with T8(S.A @ 100 ppm at 45 DAT and 120 DAT) (225.08 cm and 34.21 cm). T9 (SA @ 150 ppm at 45 and 120 DAT) recorded significantly highest fruit weight (1.06 kg), fruit length (18.33 cm), fruit girth (43.02 cm). The values for all these parameters were found to be at par with T8 and T7, whereas lowest values was recorded with T13 (control), i.e. fruit weight (0.84 kg), fruit length (16.20 cm), fruit girth (33.35 cm). Significantly highest number of fruits/plant (60.37) was observed in T8 which was found to be at par with T9 (59.29) and T7 (57.94). Weight of fruits/plant (kg), yield/plot (kg) and yield/hectare (tonnes) were highest in T9 (49.78 kg, 552.42 kg and 116.06 tonnes/ha) which was at par with T8 (47.17 kg, 546.59 kg and 114.83 tonnes/ha). The lowest values in this regard were recorded in control (T13) (25.20 kg, 370.57 kg and 77.85 tonnes/ha).

Hoque*et al.* (2020) performed a study that salicylic acid (SA) is a phenolic compound involved in the regulation of plant growth, development and defense responses. SA is a critical signaling molecule that is known to participate in the responses of plants to salinity stress, through extensive signaling crosstalk with other hormones that results in physiological and biochemical responses in plants and changes in gene expression. SA is an important regulator of Na^+ exclusion and sequestration, through the modulation of sodium and potassium transporters, and is associated with the control of photosynthesis and nutrient metabolism, proline and glycinebetaine synthesis, reactive oxygen species metabolism, and plant–water relations, in plants under salt stress. Furthermore, applying SA has been shown to improve plant tolerance to salinity by regulating multiple stress-responsive pathways and processes. Recent studies with transgenic and mutant plants have shown the diverse roles SA in plant stress biology. This chapter summarizes the current knowledge of the roles of SA in salinity tolerance, the responses of plants to salt, and the potential mechanisms underlying SA-mediated salinity tolerance in plants.

Esan *et al.* (2020) carried out an alternative strategy that exogenous application of plant growth regulators. The study was carried out to study the effect of seed pretreatment with salicylic acid on some growth parameters, volatile compounds and antioxidant activity of salt-stressed two genotypes of okra plant. The results of this study showed that the salicylic acid is a valuable biological plant growth regulator that could enhance salt tolerance in okra plant under 50, 100, 150, and 200 mM NaCl

levels resulting in an increase in plant growth and antioxidant enzymes activities, when compared with the NaCl-treated control groups. Therefore, salicylic acid is a promising tool to improve plant growth and quality under harsh environmental conditions.

Nawaz *et al.*(2020) carried out a field experiment to assess the different genotypes of A. esculentus during growing season (July–August) against B. tabaci. Plant genotype resistance and vigor were also evaluated in this study. Meanwhile, morphological parameters were also recorded as well as whitefly-infested and healthy leaves were collected for biochemical analysis. The obtained results revealed that the Okra varieties A. esculentus OK-1304 and Pen Beauty were less infested (mean populations 4.10, 4.97 adults/leaf, respectively) while OK-1307 was highly susceptible to B. tabaci (10.22 adults/leaf). Meanwhile, comparative analysis revealed that B. tabaci population was negatively correlated to relative humidity and positively correlated with low and high temperature. The low concentrations (0.5%) of salicylic acid and citric acid effectively reduced the infestation to 4.63 adults/leaf and 4.87 adult/leaf, respectively, as compared to control (10.17 adult/leaf). The biochemical analysis represented that the catalase concentration decreased in infested leaves and the concentrations of peroxidase, phenolics and superoxide dismutase that act as resistant compound against insect feeding increased.

Alam *et al.* (2020) carried out a study to assess the response of salicylic acid and irrigation intervals on growth and yield of Okra variety TS-NARGIS using RCB Design with split plot arrangement having two factors i.e. irrigation intervals (5, 10 and 15 days) and Salicylic acid (0, 80, 160 and 240mgl-l), replicated three times. Data regarding morphological traits (plant height, stem diameter, number of leaves per plant) and yield related traits (Number of pods per plant, single pod weight, average pod length, and total yield per hectare) were recorded. Results showed that the reduction of irrigation interval from 15 to 5 days statistically improved maximum plant height, number of leaves, stem diameter, while minimum days to flowering, minimum days to first picking and maximum single pod weight, pod length, no of pods plant-1 and high yield were recorded at 10 days irrigation interval. Application of salicylic acid at 240mgl-1 had minimum days to flowering, days to picking and maximum single pod weight, average pod length, plant height, no of leaves plant-1, number of pods plant-1, stem diameter and yield.

Jaafar *et al.* (2020) was carried out an experiment in a private field in the Najaf Governorate, Kufa District for the 2019 growing season to study the response of two okra Abelmoschus esculentus (L.) Moench cultivars, Hussainawiya the local and Clemson from Turkeya newly adopted cultivar, to foliar spray with amino acids (AA) at 0, 2 or 4 ml $L^{-1}$and to evaluate the effect of AA on plant vegetative growth and yield. The plants were sprayed twice during the growing season, at 45 and 60 days post planting. The experiment was developed as a split-plot with three replicates based on Randomized Complete Blocks Design (R.C.B.D.). Okra cultivars were placed in the main-plots and the AA concentrations were in the sub-plots. Plant growth parameters and yield characters including plant height, stem diameter, number of leaf.plant-1, leaf content of total chlorophyll, number of pod per plant, pod weight and total yield were compared among treatments and cultivars according to the least significant difference (L.S.D.) at $P \leq 0.05$.Results showed that the local cultivar Hussainawiya in general was better than cultivar Clemson in all the evaluated growth and yield parameters. Although the local cultivar resulted in higher values of growth and yield parameters, Clemson Turkey was more affected by AA treatment concentration than local Hussainawia. All the studied parameters of Clemson okra, except stem diameter and total chlorophyll, had much higher percent increase due to AA than Hussainawia. AA at 2 and 4 ml L^{-1} increased yield over the untreated control plants of both cultivars by 10.79% and 26.56% for the local Hussainawia and 27.2% and 46.6% for the Turkish

Wangkheirakpam *et al.*(2020) investigate the effect of Salicylic Acid (SA) and Boron (B) application on growth and yield of Rapeseed (Brassica campestris) var. M-27 under no-tilled and rainfed condition was conducted Agricultural Research Farm, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur District, Manipur, India during the year 2018-2019. The experiment was conducted in Factorial Randomized Block Design with 4 replications. The results of the experiment revealed that foliar application of boron (0.25 %) twice at 30 days after sowing (DAS) and at flowering coupled with foliar spray of SA (200 ppm) at 25, 50 and 75 DAS gave the highest growth and yield of rapeseed.

Osama*et al.* (2019) evaluate the impact of drought stress and foliar spraying of

salicylic acid (SA) on the secondary metabolites particularly the γ-pyrones and total polyphenolic content in the different organs of Ammi visnaga L. plant. The following were measured: different growth parameters, γ-pyrones, total polyphenolic content (TPC) and the antioxidant activity of the methanolic extracts. From the results obtained, it was clear that drought stress had a negative impact on growth of the plant and on the yield of the fruits, whereas it caused an increase in the percentage of the two major γ-pyrones: khellin and visnagin in most organs. The adverse effects of drought stress on growth parameters was found to be partially alleviated by the salicylic acid foliar spray. On the other hand, combination of SA foliar spray and normal irrigation gave the highest percentage of khellin ($1.544 \pm 0.002\%$) and visnagin ($0.902 \pm 0.002\%$), as well as an increase in the yield of fruits per plant. In contrast, drought alone and in combination with SA significantly ($p < 0.001$) increased the polyphenolic content and the radical scavenging activity. The highest polyphenolic content was recorded in the water stressed aerial parts sprayed with 2 mM SA, where it reached 78.28 ± 0.14 mg/gm dry weight calculated as gallic acid equivalent (GAE). Antioxidant activity, using DPPH assay, was measured for the different plant organs under different treatments where a reduction from 12.967 ± 0.983 to 2.803 ± 0.262 µg/ml in the IC_{50} was noted in the drought stressed aerial parts sprayed with 2 mM SA vs the normally irrigated plant. UPLC/MS analysis was used to demonstrate the effect of SA foliar application on the γ-pyrones and total polyphenolic content in Ammi visnaga L. fruits.

Rostami and Rostami (2019) aimed to investigate the effect of salicylic acid (a phenolic phytohormone) and mycorrhizal fungi on the growth and phytoremediation ability of tall fescue in the soil contaminated by fluoranthene. The initial concentrations of fluoranthene in this study were 100, 200, and 300 $mg\,kg^{-1}$. The experimental treatments were included: T0 uncultivated soil; T1 cultivated soil with tall fescue; T2 cultivated soil with tall fescue + salicylic acid application; T3 cultivated soil with tall fescue + application of mycorrhizal fungi; T4 cultivated soil with tall fescue + salicylic acid and mycorrhizal fungi application; and P planting tall fescue in uncontaminated soil. The removal of fluoranthene was measured after 90 days. Furthermore, at the end of the experiment, the amount of shoot and root biomass, soil bacteria, and dehydrogenase activity were measured the concentration of fluoranthene had a negative effect on the shoot and root biomass in different

treatments. Salicylic acid and mycorrhizal fungi significantly increased the shoot and root biomass and also the number of soil bacteria, dehydrogenase activity, and fluoranthene removal in T2, T3, and T4 treatments compared to T1. At the highest concentration of fluoranthene, as a result of simultaneous application of salicylic acid and mycorrhizal fungi (T4), the fluoranthene removal increased by 63, 21, 13, and 16% in comparison with T0, T1, T2, and T3, respectively. Based on the results, salicylic acid and mycorrhizal fungi, either alone or in combination, have a significant effect on the improvement of phytoremediation potential in tall fescue.

Poór *et al.*(2019) conducted a study and stated that salicylic acid (SA) is a key component of plant defense, which exerts a concentration-dependent effect on photosynthesis under multi-faceted influence of light. Photosynthetic activities and chloroplast morphology were studied in tomato plants after treatment with a sublethal, 0.1 mM, and a cell death-inducing, 1 mM concentrations of SA under normal photoperiod during light phase and after a prolonged dark phase. SA (1 mM) decreased the maximal (Fv/Fm) and effective quantum yields of PSII [Y(II)] and PSI [Y(I)] under both environmental conditions, however, the photoprotective processes were not significantly different between light and dark samples. Decrease in grana height, thylakoid dilation and deformation of lumen were also observed in the light. In contrast to illuminated samples, 0.1 mM SA decreased Y(II) and Y(I) after dark incubation, but nonphotochemical energy dissipation and cyclic electron flow increased, suggesting that the photoprotective mechanisms could be activated in plants exposed to prolonged darkness.

Li*et al.* (2019) reported on heavy metal toxicity, which is one of the main factors that limit crop growth and yield in the world. Salicylic acid (SA) is thought to be a plant hormone that plays an important role in plant growth, development, and resistance to abiotic stresses. To uncover the toxic alleviation effects of SA on potato plants to cadmium (Cd) stress, the morphological, physiological, and biochemical indexes including antioxidant defense system were assayed in potato plants under 200 μM Cd stress in 1/2 Hoagland solution with foliar application of 600 μM SA concentration (10 ml/plant). Interestingly, exogenous SA treatment mitigated Cd toxicity by increasing the relative water content (RWC), chlorophyll, proline, and endogenous SA contents along with decline in malondialdehyde (MDA), hydrogen peroxide (H_2O_2), and superoxide anion radicals (O_2^-). Correspondingly, our study also

proved that SA may stimulate the antioxidant enzymatic mechanism pathway including superoxide dismutase (SOD, EC 1.15.1.1), catalase (CAT, EC 1.11.1.6), ascorbate peroxidase (APX, EC 1.11.1.11), and glutathione reductase (GR, EC 1.6.4.2) in potato plants subjected to Cd stress. Moreover, the expression level of selected genes relate to SA and reactive oxygen species (ROS) metabolism (StSABP2, StSOD and StAPX) were enhanced in SA-treated potato plants under Cd stress, indicating that SA treatment regulated the expression of these genes, which in turn enhanced potato tolerance to Cd stress. Taken together, our results indicated that exogenous SA can play a positive regulatory role in alleviating Cd toxicity in potato plants.

Sha *et al.* (2019) analyzed the short term and long-term effect of SA on the dry matter (DM) and nitrogen (N) accumulation, partitioning, and translocation in two contrasting rice genotypes (salt-tolerant LD5, salt-susceptible MDJ30) under salt stress. Forty two-day-old rice plants were exposed to salinity stress (0, 4.6 dS m-1) for two weeks and then the salt group was sprayed with 60 ml SA (0, 0.5 mmol L-1) per pot for two days. The short-term and long-term effects of SA were analyzed by sampling at 6 and 12 days after the SA treatment, and at heading and maturity stage, respectively. The results showed that salt stress significantly reduced the DM and N accumulation of each above-ground organ, changed allocation pattern and reduced their translocation to panicles. Genotypes showed differences in DM and N distribution and translocation under salt stress. Compared with MDJ30, LD5 accumulated more DM under salt stress, had a higher proportion of stem-sheath DM and maintained the DM translocation to panicle. The response of N accumulation to salt stress in LD5 was higher than that in MDJ30 at tillering stage but was less than that at heading and maturity stage, reflecting that salt tolerant variety gradually adapted to the restriction of N acquisition due to salinization. Exogenous SA promoted the accumulation of DM and N in stem + sheath at short-term and in above-ground organs of rice under salt stress at long-term. SA increased the partitioning ratio of DM and N in panicles of MDJ30 under salt stress but decreased that in LD5. This was mainly due to the fact that SA increased the translocation of assimilates from vegetative organs to panicles of MDJ30, but decreased that of LD5 as its short-term promotion effect resulted in an excessive accumulation in stem + sheath. These results suggested that SA promoted assimilates accumulation in the above-ground

organs of rice under salt stress, changed the distribution pattern of nutrients, and its effect on the translocation of assimilates was related to the salt tolerance of genotypes.

Eman *et al.* (2018) carried out an investigation on Gladiolus grandifloras. The aim of this work was to study the effect of different levels of methyl jasmonate at rates of (zero, 50, 75 and 100 ppm) and salicylic acid at rates of (zero, 50, 100 and 150 ppm) on the vegetative growth, flowering and Corm Production of Gladiolus grandifloras, L. From the obtained results it was concluded that treating Gladiolus plants with combination of salicylic acid at 150ppm and methyl jasmonate at 75 ppm improve the vegetative growth, flowering characteristics, Corm Production and the contents of total chlorophyll in the leaves of Gladiolus plants.

D. Jini, B. Joseph (2017) investigated on how application of salicylic acid (SA) improved the growth and yield under salt stress conditions and its physiological mechanisms for salt tolerance. Germination and growth rates decreased by the salt stress were significantly increased by the SA application (SA + NaCl). The treatment of SA to the high and low saline soils enhanced the growth, yield and nutrient values of rice. It was revealed that the increased accumulation of Na+ and Cl^- ions by the salt stress were reduced by SA application.

Mohsen Kazemi (2014) conducted a study, which was aimed to understand the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits by The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, also reduced blossom end rot incident. While, MJ (1 mM) application significantly decreased vegetative growth and increased reproductive growth. The combination of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content as well as improved the yield and fruit quality of tomato.

Babar *et al.* (2014) carried out an experiment to alleviate the salinity-induced harmful effect on biomass production and physiochemical attributes of fenugreek by foliar application of salicylic acid. They experimented on Two varieties named Deli Kabul

and Kasuri, which were grown in two different growth medium; one media were treated with (100 mM NaCl) and another one remain untreated i.e. 0 mM NaCl. They found that shoot fresh weight and net CO2 assimilation rate were higher in Deli Kabul and both remained lower in Kasuri and Foliar application of SA mitigated growth biomass reduction in both plants. Similarly, CO2 assimilation rate, transpiration rate, stomatal conductance reduced due to salinity and Exogenous application of salicylic acid helped to mitigate this reduction in gas exchange attributes of the plants.

Laila Khandaker *et al.* (2011) conducted a study at Gifu University, Japan, by to determine the effect of foliar salicylic acid (SA) applications on growth, yield and bioactive compounds of red amaranth grown under greenhouse conditions. 3 different concentrations (10-3 , 10-4 and 10-5 M) of SA was applied at three times at 7-day intervals one week after sowing. plant height, stem length, number and size of leaves, root length, fresh and dry matter weight; along with bioactive compounds like beta-cyanins, chlorophyll, total polyphenol and antioxidant activity were also determined from the leaves of treated and control plants were recorded from plants on 28 days after sowing. Foliar SA applications of several doses enhanced the plant growth, yield and leaf's bioactive compounds compared to the control. The highest yield, antioxidant activity, amount of beta-cyanins, chlorophyll and total polyphenol was observed in 10-5 M SA treatment in red amaranth.

Humayun (2010) investigated the adverse effects of NaCl induced salt stress on growth attributes and endogenous levels of gibberellins (GA), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA) of soybean cv. Hwangkeumkong. Plant length, biomass, chlorophyll content, number of pods, 100 seed weight and yield was significantly decreased when exposed to 70 mM and 140 mM concentrations of NaCl. The endogenous GA and free SA content decreased under salt stress, whereas while endogenous ABA and JA contents were increased significantly. They observed that growth and yield components of soybean was affected by salt stress significantly.

Sibgha and Ashraf (2008) experimented to study the adverse effects of salt stress on sunflower plants and its amelioration by foliar application of exogenous SA. Two lines of sunflower (Hisun-33 and SF-187) were grown under normal or saline (120 mM NaCl) conditions. Different levels of salicylic acid (0, 100, 200, 300 mg L-1)

were applied as a foliar spray. Result showed that both the cultivars were equally responsive to the stress and growth of the both lines was reduced significantly. But application of 200 mg L-1 of SA caused an increase 16 in biomass and photosynthetic rate of both cultivars under control and saline conditions, particularly in line SF187.

Mohsina *et al.* (2008) experimented to study the effect of salicylic acid seed priming on growth and some biochemical attributes in wheat (Triticum aestivum L.) under saline conditions. Wheat seeds of cv. Inqlab and S-24 were soaked in water and 100 mg /L salicylic acid solution for 24 hours, and then sown in sand which was exposed to 0, 50 or 100 mM NaCl. Result indicated that all growth parameters i.e. shoot and root length, shoot and root dry weights were decreased significantly with the increase of salinity. Whereas this adverse effect of salinity on growth parameters were alleviated througth salicylic acid treatment. Salinity decreased the chlorophyll a and b content and chlorophyll a/b ratio in both the lines, which could be a useful marker for selection of salt tolerant wheat.

Kaydan *et al.* (2007) showed that seed soaking pre-treatment using salicylic acid, positively affected the osmotic potential, shoot and root dry mass, K+/Na+ ratio and photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) concentration in wheat tissues, under both salt and non-salt treatments.

El-Tayeb (2005) studied the interactive effect of salinity and salicylic acid on barley. The result indicated that foliar application of 1.0 mM SA increased RWC, fresh and dry weights, water content, soluble protein, total free amino acids, proline content, photosynthetic pigments, and phosphorus and peroxidase activity of barley seedlings under varying salt treatments.

Tari *et al.* (2002) reported that tomato plants tolerated 100 mM NaCl at low levels of SA concentration (10-7 to 10-4 M range) by a substantial increase in photosynthetic rate, transpiration rate and stomatal conductance. Coronado et al. (1998) investigated and find out a significant increase in biomass of shoots and roots of soybean were observed due to application of SA.

Eris (1983) experimented on pepper seedlings and found out that stomatal conductance or resistance was increased and transpiration rate was reduced in due to foliar application of SA.

CHAPTER III

MATERIALS AND METHODS

A pot experiment on okra genotypes (BARI Dherosh-2) was carried out to determine the growth rate of okra under different level of salinity as well as to assess the effect of salicylic acid (SA) on growth, yield and nutrient content of okra genotypes. In this chapter the description of different materials used and the methodology followed during the experimental period are narrated below:

3.1 Experimental site

The research was conducted at the Net House of Agro-Environmental Chemistry Laboratory of Department of Agricultural Chemistry, SAU during the summer season (Mid March- Mid July). The experimental field is located at 24°9´ N latitude and 90°26' E longitudes at a height of 8.4 m above the mean sea level.

3.2 Characteristics of soil that used in pot

The soil was collected from 0-15 cm depth from Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka. The soil was clay loam in texture having pH 5.6 and electrical conductivity (EC) 2.0 dS m^{-1}. The initial soil (0-15 cm depth) test revealed that the soil contained 0.03% total N, 0.45% organic matter, 20 µg g^{-1} available P, 45 µg g^{-1} available S and 0.01 meq 100 g^{-1} exchangeable K(Source: SRDI).

3.3 Climatic condition of the experimental site

The area had sub-tropical climate. It was characterized by high temperature (280°-320°C) accompanied by moderately high rainfall during Kharif (April-September) season and low temperature (15°-20°C) in the Rabi (October-March) season. The weather data of experimental site was collected during the period of experiment from the Bangladesh Meteorological Department (Climate Division), Agargoan, Dhaka.

3.4 Experimental material

Okra (BARI dherosh-2)were used as the test crop. The seeds of the tested varieties were collected from Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.5 Preparation of soil and filling of pots

A total of 27 plastic pots were prepared with 8 kg air dried soil. The size of the pot was 30 cm top diameter with a height of 25 cm. Thus the surface area of an individual pot was 706.5 sq cm. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with well rotten cow dung and fertilizers before filling the pots. The soil was treated with insecticides (Cinocarb 3G @ 4kg/ha) at the time of final pot preparation to protects young plants from the attack of soil inhibiting insects such as cutworms, ants and mole cricket. The pots were placed in the net house.

3.6 Determination of initial salinity of soil

Three random samples of growth medium each with 50g were taken, sun dried. Pulverized and sieved with a fine sieve. Twenty ml distilled water was added to 10 g of this sieved media and was stirred for 30 minutes at 250 rpm. In following day, it was stirred again and intense of salinity was measured by electrical conductivity meter.

3.7 Experimental treatments and design

The experiment was set up in single factor completely randomized design (CRD) with three replications. Thus 27 experimental pots were placed in ambient air at the Net house of Agro-Environmental Chemistry Laboratory of Department of Agricultural Chemistry, SAU.

3.8 Treatments

The experiment consisted of two factors:

1) Factor A: Salinity level (3 levels of salt concentration)
    i. $S_0 = 0$ dSm^{-1}
    ii. $S_6 = 6$ dSm^{-1}
    iii. $S_{12} = 12$ dSm^{-1}

2) Factor B: Mitigation level (3 levels Salicylic Acid concentration)
    i. $SA_0 = 0$ (Control)

ii. $SA_{0.75}$ = 0.75 mM of Salicylic Acid

iii. $SA_{1.5}$ = 1.5 mM of Salicylic Acid

There were total 9 (3×3) Treatment Combinations, such as:

S_0SA_0, $S_0SA_{0.75}$, $S_0SA_{1.5}$, S_6SA_0, $S_6SA_{0.75}$, $S_6SA_{1.5}$, $S_{12}SA_0$, $S_{12}SA_{0.75}$ and $S_{12}SA_{1.5}$

3.9 Application of Fertilizer in the pot

The required amount of fertilizers; 258, 178, 154, 108, 8, 12 kg ha^{-1} urea, TSP and MoP, gypsum, zinc hepta-hydrate and boric acid respectively with cowdung @ 8 t ha^{-1} was estimated for pot preparation. Therefore, the total 27 pot require 27.86 g of urea, 19.17 g of TSP, 16.63 g of MoP, 11.66 g of zypsum, 1 g of zinc hepta-hydrate, 1.3 g of boric acid and 548.64 g of cowdung.

One third of urea and entire amount of cowdung, TSP, MoP, gypsum, zinc hepta-hydrate and boric acid were mixed with the soil in each pot before sowing. Rest of the urea was applied as side dressing.

3.10 Imposition of salinity treatments

Salinity was imposed as per treatments. The developed irrigation water salinity and pot soil were measured by using an electrical conductivity meter HACH SensION EC5 (Direct Salinity Meter) which was expressed in mS/cm.

3.11 Raising the seedling

Okra seedlings were raised in several polybags at the farm of Sher-e-Bangla Agricultural University, Dhaka. The size of each polybag was 2m × 1m. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. Weeding and removing of stubbles were done when necessary and 5 kg well rotten cowdung was applied during soil preparation in polybags. The seeds were sown in the polybag at 15 March, 2019 to get 15 days old seedlings. Germination occurs within 4 days after seeds sowing. After sowing, seeds were covered with light soil to a depth of about 0.6 cm. Sevin was applied as precautionary measure against ants and worm around the seedbed. Seedlings emergence was visible within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were provided when necessary and required and no chemical fertilizer was used in this seedbed.

3.12 Uprooting and transplanting the seedlings

Healthy and uniform 15 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 30 April 2019, each pot containing only one seedling. The seedlings were irrigated before uprooting from the polybags, which helps to minimize damage to roots by ensuring maximum retention of roots. The seedlings were also irrigated after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from scorching sunlight.

3.13 Application of the treatments

Okra plants were treated with 0, 6 and 126 dSm^{-1}salinity levels which were maintained by adding 0, 1.92 and 3.84 g of sodium chloride (NaCl) respectively per pot containing 8 kg of soil. These total amounts of salts were applied through irrigation water in three splits; 3 dSm^{-1} and 6 dSm^{-1} during pot preparation, 6 dSm^{-1} and 9 dSm^{-1} at 25 DAT and 12 dSm^{-1} at 35days after transplanting. As a salt stress mitigation agent, salicylic acid was used as 0, 0.75and 1.5 mM of s concentration which were maintained by adding 0, 414 and 828 mg of salicylic acid (SA) respectively by dissolving in irrigation water as foliar application at 28 and 38 DAT. The salicylic acid (SA) was applied by foliar spraying which was two times in a day at the morning and at the afternoon.

3.14 Intercultural operations

Proper intercultural operations were done for better growth and development plants in pots. Weeding and mulching were accomplished as and when necessary to keep the crop free from weeds, better soil aeration and to break the soil crust.

3.14.1 Staking

When the plants were well established, staking was given to each plant by bamboo sticks. This is done to give support to keep the plant erect to protect from damage caused by storm and strong wind. The plants were tied by plastic ropes to the stems with bamboo slices which are hung above them.

3.14.2 Irrigation

Light watering was provided with water cane immediately after transplanting the seedlings and this technique of irrigation was used as every day at early morning and sometimes also in evening throughout the growing period. But the frequency of irrigation became less in harvesting stage. Irrigation in those days when treatment was applied was done at evening as salt was applied with irrigation water. The amount of

irrigation water was limited up to that quantity 24 which does not leached out through the bottom. As such the salinity status was maintained in the desired level.

3.14.3 Weeding

Weeding was done whenever it was necessary, mostly in vegetative stage.

3.14.4 Earthing-up

Earthing-up was done at 20 and 40 days after transplanting by taking the soil from the boundary side of pots by hand at the basement of plant.

3.14.5 Plant protection measures

Bavistin @ 2 g/litre of water applied at the early vegetative stage as precautionary measure against disease attack of okra during foggy weather. Ripcord 50 EC @ 2 ml/litre was also applied @ 2 gm per L of water against yellow vein mosaic virus (YVMV)of okra. Carbicron 100 EC@ 1 ml/litre of water was sprayed against attack from shoot and fruit borer of okra plant. Melathion @ 2 ml/litre of water was sprayed against attack from aphid and leaf hopper.

3.15 Harvesting of fruits

Fruits were harvested at alternate days during early ripe stage. Harvesting was started from 25 April 2019 and was continued up to 1st week of May 2019. The young fruits was harvested in the morning as delay in harvesting may make the fruits fibrous and they lose their tenderness and taste.

3.16 Parameter studied

Experimental data were recorded from 30 days after transplanting and continued until harvest. The following data were recorded during the experimental period.

- **Morphological characters**
  1. Plant height (cm) at 30 and at harvest
  2. Number of branches plant^{-1} at 30 DAT and at harvest
  3. Number of leaves per plant at 30 DAT and at harvest
  4. Length of leaves plant^{-1} at 30 DAT and at harvest

- **Physiological and yield contributing characters**
  1. No. of flower per plant
  2. No. of fruits per plant
  3. Individual fruit weight
  4. Fruit yield per plant

5. Fresh weight of plant
6. Dry weight of plant

- **Chemical analysis**

1. Determination of N,P,K in fruits
2. Determination of N,P,K in shoot
3. Determination of N,P,K in root

3.17 Preparation of sample for P and K determination

The samples were dried in an oven at 70°C to obtain constant weight. Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed properly and stored in plastic vials. Exactly 1g oven-dried samples of okra plants (BARI Dherosh-2) were measured with the help of electrical balance. Then 1g dried samples were taken in conical flask. About 20 mL of di-acid mixture (nitric acid : perchloric acid = 2:1) was taken in a conical flask and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 100°C. The temperature was increased to 365°C gradually to prevent frothing (50°C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool at the room temperature. About 40 ml of distilled water was carefully added to the conical flask and the contents filtered through Whatman No. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with distilled water. The samples were then stored at room temperature with clearly marked containers.

After digestion, approximately 100 mL of each digest samples was stored in a clearly marked plastic bottle for determination of the P and K. Content of P was determined by Spectrophotometer and content of K was determined by Flame Photometer. After that, the percent of P and K values were also calculated from the concentration of P and K in the plant tissues.

3.18 Determination of nitrogen

The Macro Kjeldahl method used to determine the total Nitrogen in straw of plant samples. There were three steps in this method. These are as follows:-

A. Digestion: It is the first step of this method. Organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators in this step (Catalyst Mixture) at a temperature of 360°C-440°C.

$$N + H_2SO_4 = (NH_4)_2SO_4$$

B. Distillation: The solution was made alkaline from the distillation of ammonia in this step. The distilled ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH = Na_2SO_4 + NH_3 + H_2O$$

$$2NH_3 + H_3BO_3 = (NH_4)_3BO_3$$

C. Titration: To determine the amount of NH_3, ammonium borate was titrated with standard sulfuric acid solution.

$$(NH_4)_3BO_3 + H_2SO_4 = (NH_4)_2SO_4 + H_3BO_3$$

Reagents: 4% Boric Acid solution, Mixed indicator (Bromocresol green and Methyl red),40% Sodium Hydroxide solution, Standard sulphuric Acid solution 0.05 N and 0.05 N Na_2CO_3 solution.

Procedure: About 0.5 g of oven dried sample was weighed with the help of electrical balance and then taken into a 250 mL kjeldahl flask. Then 5g catalysts mixer (K_2SO_4:$CuSO_4.5H_2O$: Se=100:1:1) was added in to flask. After that about 25mL concentrated H_2SO_4 was also added o the flask. The flask was heated until the solution become clear and then allowed to cool at room temperature and then about 120 mL of distilled water was added and 5-6 glass bead into the flask. After digestion, 40% NaOH 125mL was added to the conical flask and attached quickly to the distillation set. Then the flask was heated continuously. In the meantime, 25mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in a 500mL receiver conical flask. After distillation, about 150ml distillate was collected into receiver

conical flask. The distillate was then titrated with standard H_2SO_4 taken from a burette until the green color completely turns to pink color at the end point. The same procedure was followed for a blank sample. The result was calculated using the following formula-

$$\%N = (T-B) \times N \times 1.4/S$$

Where, T= Titration value for sample (mL), B= Titration value for blank (mL), N= Normality of H_2SO_4 (N), S= Weight of the sample (g), 1.4= Conversion factor.

3.19 Determination of phosphorus

The amount of Phosphorus (P) was estimated from the plant extract by ascorbic acid blue color method with the help of a Spectrophotometer at 660 *n*m.

Reagents required

A. Mixed reagent: 12.0 g ammonium molybdate $(NH_4)_6Mo_7O_{24}.4H_2O$ was dissolved

   in 250 mL distilled water. About 0.2908 g antimony potassium tartarate $K_2Sb_2(C_4H_2O_6)_2.3H_2O$ was dissolved in 1000 mL H_2SO_4. Two solutions were mixed together and volume was made up to 2000 mL with distilled water and stored in a pyrex bottle in a dark cool secure place.

B. Color developing reagent: 0.53 g ascorbic acid was added to 100 mL of the mixed reagent.

C. Standard Phosphorus solution (100 ppm): 0.439 g potassium dihydrogen phosphate (KH_2PO_4) was weighed into a 1L volumetric flask. About 500 mL distilled water was added and shaked the contents until the salt dissolved. Then the volume was made up to 1L with distilled water.

Procedure

A. Color development: About 20 mL of the extract was pipetted out in a 100 mL volumetric flask. About 20 mL color developing reagent was added slowly and carefully to prevent the loss of sample because of excessive foaming. After the evolution of CO_2 had ceased, the flask was shaked gently to mix the contents. The volume was made up to the mark with distilled water.

B. Preparation of working standard P solution: About 20 mL of the standard P solutions (100 ppm) was pipetted to a 1L volumetric flask and volume was made up to the mark by distilled water. This solution contained 2 ppm P. About 0, 5, 10, 15, 20 and 25 mL aliquot were pipetted out from 2 ppm solution in 100 mL volumetric flask respectively. About 20 mL color developing reagent was added to each flask, mixed and volume was made with distilled water. These solutions gave 0, 0.1, 0.2, 0.3, 0.4 and 0.5 ppm of P solution respectively. The solution was allowed to stand for 15 minutes and then color intensity (% absorbance) was measured at 660 nm. A standard curve was prepared from the spectrophotometer reading and concentrations of plant samples were calculated from the curve.

3.20Determination of potassium

The amount of Potassium (K) in the plant extract was determined with the help of a Flame photometer.

Preparation of primary potassium standard solution (1000 ppm): 1.918 g potassium chloride was taken in a 1L volumetric flask. About 200-300 mL distilled water was added and the flask was shaked properly until a clear solution was obtained. The volume was made up to the mark with distilled water. Thus, 1000 ppm K solution was prepared

Preparation of secondary potassium solution (100 ppm and 10 ppm): About 10 mL of the1000 ppm K solution was taken in a 100 mL volumetric flask. The volume was made up to mark with distilled water and shaked properly. In this way, 100 ppm K solution was prepared. From 100 ppm solution, 10 mL was taken in a 100 mL volumetric flask. The volume was made up to the mark with distilled water and shaked properly. Thus, 10 ppm solution was obtained.

Preparation of potassium standard series solution: A series of standard solution containing 1, 2, 3, 4, 5 ppm and 6 ppm respectively were prepared by pipetting 10, 20, 30, 40, 50 and 60 mL of 10 ppm K solution in six different 100 mL volumetric flask

respectively. The volume was made up to the mark by distilled water and shaked properly. Then, the reading (% emission) were taken from flame emission spectrophotometer and a standard curve was prepared from the reading taken. Plant samples were taken in volumetric flask and volume was made up to the mark by distilled water. Then the samples reading were taken and concentrations were calculated from the standard curve.

3.21 Statistical analysis

The data obtained for different characters were statistically analyzed by using "Statistics 10" software to find out the significance of the difference for effects of salicylic acid on growth, yield and nutrient of okra (BARI Dherosh-2) under different level of salinity. The mean differences among the treatments were adjusted by Welch's Test for Mean Differences and LSD (Least Significant Difference) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

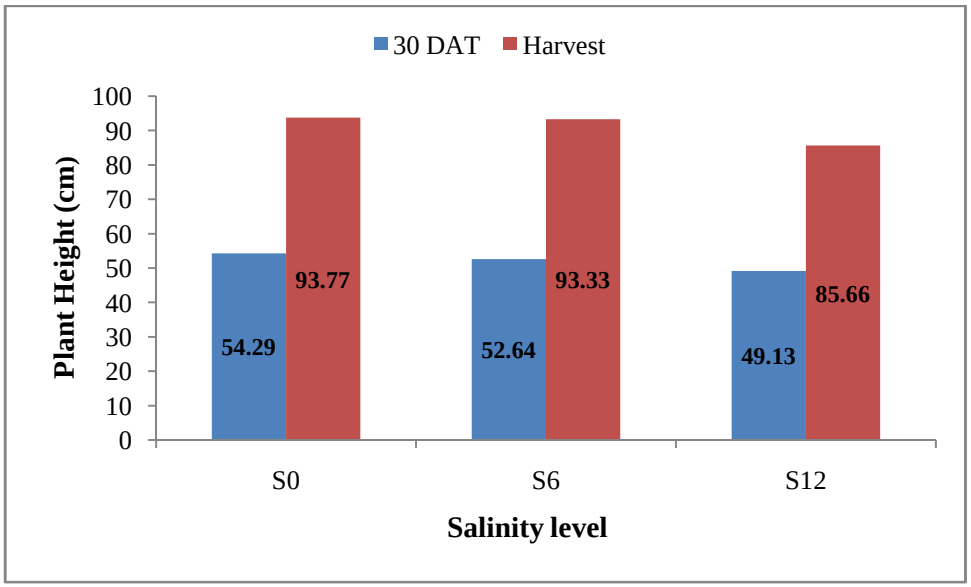
The experiment was conducted to investigate the growth and yield of okra plant (BARI Dherosh-2) in response to application of sodium chloride (NaCl)) and salicylic acid (SA). Data on different parameters were analyzed statistically and the results have been presented through Figures and Tables. The results of the present study have been presented and discussed in this chapter under the following headings.

4.1 Growth parameters

4.1.1 Plant height

Effect of salinity

Naturally plant height increased with the increasing age. But due to salinity plant height of okra (BARI Dherosh-2) was reduced significantly with the increase of salinity (Figure 1).



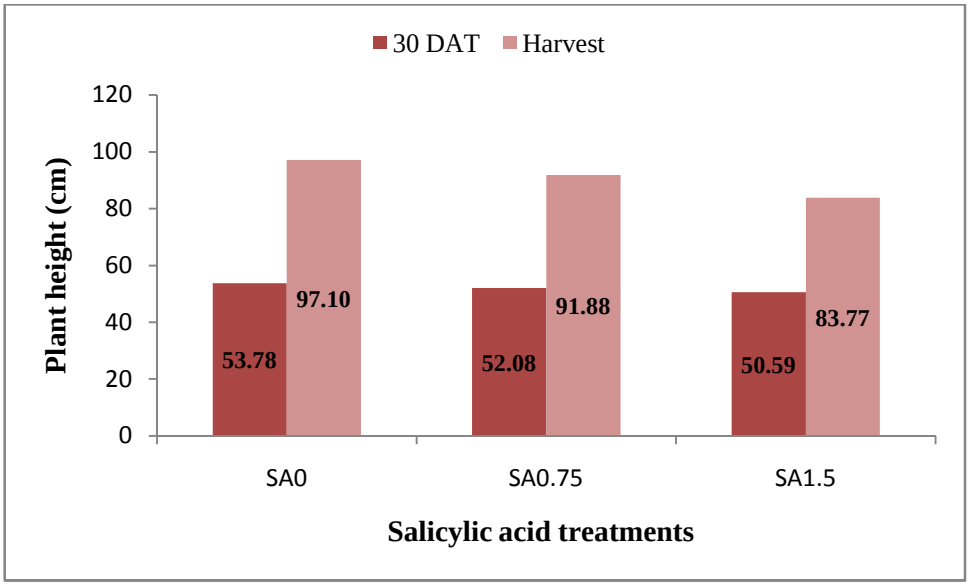
S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 1. Effect of different levels of salinity on plant height (cm) of okra (BARI Dherosh-2) at 30 DAT and at harvest

The result revealed that at 30 DAT and at harvest S_0 produced 54.29 cm and 93.77 cm tall plant respectively, which was reduced by S_6 (52.64 cm and 93.33 cm) at 30 DAT and at harvest respectively. With the increasing level of salinity the shortest plant was produced by S_{12} (49.17 cm and 85.66 cm) at 30 DAT and at harvest respectively. Shalaby et.,al (2015) have reported the same i.e morphological traits like plant height reduced due to increasing salinity.

Effect of salicylic acid (SA)

In this experiment SA have significant effect on plant height, so with increasing of SA, plant height decreased gradually (Figure 2).The result revealed that at control treatment (SA_0) the tallest plant was 53.78 cm and 97.10 cm at 30 DAT and at harvest respectively. At $SA_{0.75}$ plant height further decreased by 52.08 cm and 91.88 cm at 30 DAT and at harvest respectively.



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 2. Effect of salicylic acid (SA) on plant height (cm) of okra (BARI Dherosh-2) at 30 DATand at harvest

With the increasing level of SA treatment the shortest plant was produced at$SA_{1.5}$(50.59 cm and 83.77 cm) at 30 DAT and at harvest respectively. Shahba et al.,(2010) have reported the same i.e morphological traits like plant height may reduce due to increasing salicylic acid concentration.

Effect of different levels of salinity and salicylic acid (SA)

Statistically significant variation was recorded for the effect of salicylic acid on plant height of okra (BARI Dherosh-2) under different levels of salinity at harvest (Table 1). At 30 DAT, plant height was reduced due to the effect of salinity and salicylic acid. Shalaby et.,al (2015)

Table 1: Effect of different levels of salinity and salicylic acid (SA) on plant height (cm) of okra (BARI Dherosh-2) at 30 DAT and at harvest.

Treatments		Plant height (cm)	
		30 DAT	Harvest
S_0	SA_0	57.43 a	102.33 a
	$SA_{0.75}$	53.83 ab	93.00 abc
	$SA_{1.5}$	46.33 c	86.00 bc
S_6	SA_0	52.53 abc	99.33 ab
	$SA_{0.75}$	53.10 ab	94.66 ab
	$SA_{1.5}$	53.83 ab	86.00 bc
S_{12}	SA_0	51.40 abc	89.66 abc
	$SA_{0.75}$	49.33 bc	88.00 bc
	$SA_{1.5}$	46.33 c	79.33 c

$LSD_{0.05}$	0.46	0.55
Significant level	*	*

* - Significant at 5% level
SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid
S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl
In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

Data shows that the tallest plant 102.33 cm was produced by control treatment S_0SA_0at harvest due to lower concentration of NaCl. With the increasing level of salinity plant height gradually decreased. However, the effect of salicylic acid (SA) to mitigate saline stress was not significantly observed at 6 and 12 dSm^{-1} of NaCl. Moreover, it showed that SA decreased plant height. These results are in agreement with Tantawy et al.,(2009) and Ayub et al.,(2018).

4.1.2 Number of branches $plant^{-1}$

Effect of salinity

Effect of different levels of salinity on number of branches $plant^{-1}$ of okra (BARI Dherosh-2) was observed statistically insignificant (Appendix II).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on number of branches $plant^{-1}$ of okra (BARI Dherosh-2) was observed statistically insignificant ((Appendix II).

Effect of different levels of salinity and salicylic acid (SA)

Effect of different levels of salinity and salicylic acid (SA) showed significant variation on number of branches $plant^{-1}$branches of okra plant (BARI Dherosh-2) at harvest(Table 2). Results indicated that the highest number of branches $plant^{-1}$ (2.00) was recorded in control treatment S_0 (no salinity) with 1.5 mM of SA concentration which was statistically similar with $S_6SA_{1.5}$ and $S_6SA_{0.75}$. The lowest number of branches $plant^{-1}$ (1.33) was obtained with $S_{12}SA_0$(12 dSm^{-1}NaCl) and S_6SA_0 (6 dSm^{-1} NaCl) treatment; followed by treatment $S_0SA_{o.75}$.

Table 2: Effect of different level of salinity and salicylic acid (SA) on number of branches of okra plant (BARI Dherosh-2) at harvest

Treatments		Number of branches per plant
		Harvest
S_0	SA_0	1.66 ab
	$SA_{0.75}$	1.69 ab
	$SA_{1.5}$	2.00 ab
S_6	SA_0	1.333 b
	$SA_{0.75}$	2.00 ab

	$SA_{1.5}$	2.00 ab
	SA_0	1.33 ab
	$SA_{0.75}$	1.66 ab
S_{12}	$SA_{1.5}$	1.33 b
$LSD_{0.05}$		0.60
Significant level		*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid
S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl
In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

Meanwhile, at ($S_6SA_{1.5}$) treatment number of branches $plant^{-1}$ (2.0000) obtained which is statistically significant due to application of salicylic acid (SA) Almost similar result was obtained by (Kaouther, *et al.,* 2012, Hajer *et al.* (2006).

4.1.3 Number of leaves $plant^{-1}$

Effect of salinity

Effect of different levels of salinity on number of leaves $plant^{-1}$ of okra (BARI Dherosh-2) was observed statistically insignificant(Appendix III).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on number of leaves $plant^{-1}$ of okra (BARI Dherosh-2) was observed statistically insignificant (Appendix III).

Effect of different levels of salinity and salicylic acid (SA)

Effect of different levels of salinity and salicylic acid (SA) on number of leaves per plant showed significant harvest but remained non-significant at 30 DAT (Table3).The total number of leaves per okra plant (BARI Dherosh-2) was recorded highest (11.66) from S_0 $SA_{1.5}$ treatment as 0 dSm^{-1} NaCl and 1.5mM salicylic acid at harvest. On the contrary, the lowest value was observed from S_{12} (7.33) due to high concentration of NaCl. However, effect of salicylic acid (SA) was also observed at $S_6SA_{0.75}$ treatment with 6dSm^{-1} NaCl and 0.75mM salicylic acid concentration where number of leaves per plant increased (10.33) comparatively to other treatment. Similar result was found from Jogendra et al., (2011), Ahmet et al., (2009) and Sixto et al. (2005).

Table 3: Effect of different level of salinity and salicylic acid (SA) on number of leaves of okra plant (BARI Dherosh-2) at 30 DAT and at harvest.

Treatments		Number of leaves	
		30 DAT	Harvest
S_0	SA_0	7.66	9.33 ab
	$SA_{0.75}$	8.66	9.66 ab
	$SA_{1.5}$	8.00	11.66 a
S_6	SA_0	9.33	8.33 b
	$SA_{0.75}$	10.00	10.33 ab
	$SA_{1.5}$	8.33	9.00 ab
S_{12}	SA_0	9.66	7.33 b
	$SA_{0.75}$	9.00	9.33 ab
	$SA_{1.5}$	8.33	9.33 ab
$LSD_{0.05}$		0.72	0.80
Significant level		NS	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

4.1.4 Length of leaves plant^{-1}

Effect of salinity

Effect of different levels of salinity on length of leaves plant^{-1} of okra (BARI Dherosh-2) was observed statistically insignificant both at 30 DAT and at harvest ((Appendix IV).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on length of leaves plant^{-1} of okra (BARI Dherosh-2) was observed statistically insignificant both at 30 DAT and at harvest (Appendix IV).

Effect of different levels of salinity and salicylic acid (SA)

Effect of different levels of salinity and salicylic acid (SA) showed statistically insignificant on length of leaves per plant of okra both at 30 DAT and at harvest (Appendix IV).

4.2. Yield contributing parameters and yield

4.2.1 Number of flowers plant^{-1}

Effect of salinity

Effect of different levels of salinity on number of flowers plant^{-1} of okra (BARI Dherosh-2) was observed statistically insignificant at 30 DAT (Appendix V).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on number of flowers plant^{-1} of okra (BARI Dherosh-2) was observed statistically insignificant at 30 DAT (Appendix V).

Effect of different levels of salinity and salicylic acid (SA)

Number of flowers per plant^{-1}of okra (BARI Dherosh-2 varied significantly for different levels of salinity and salicylic acid at 30 DAT (Table 4). Total number of flowers per plant of okra was recorded highest (3.33) from control treatment S_0 and$SA_{0.75}$(0.75) mM concentration of salicylic acid at 30 DAT. On the contrary, the lowest value was observed from S_{12} (1.3333) treatment due to higher concentration of NaCl. Data shows that, number of flowers decreased gradually with the increasing level of salinity; similar results were found from Magan et al., (2008).

4.2.2 Number of fruits plant^{-1}

Effect of salinity

Effect of different levels of salinity on number of fruits plant^{-1} of okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VI).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on number of fruits plant^{-1}of okra (BARI Dherosh-2) was observed statistically insignificant at harvest(Appendix VI).

Effect of different levels of salinity and salicylic acid (SA)

Total number of fruits per okra plant varied significantly for different levels of salinity and salicylic acid (Table4). Data shows that, number of fruits per okra plant was recorded highest

Table 4: Effect of different level of salinity and salicylic acid (SA) on number of flowers at 30 DAT and number of fruits, individual fruit weight (g) and fruit yield (g) at harvest.

Treatments		Number of flowers	Number of fruits (pods)	Single fruit weight (g)	Total weight of fruits (g)
		30 DAT	Harvest	Harvest	Harvest
S_0	SA_0	3.00 a	10.33 ab	16.86 ab	174.29 d

	$SA_{0.75}$	3.33 a	12.33 ab	16.00 ab	197.33 c
	$SA_{1.5}$	2.66 ab	13.66 a	16.76 ab	229.15 a
S_6	SA_0	2.66 ab	10.00ab	16.37 ab	163.77 d
	$SA_{0.75}$	2.33 ab	11.00 ab	19.26 a	211.94 b
	$SA_{1.5}$	2.33 ab	14.00 a	16.50 ab	231.00 a
S_{12}	SA_0	2.66 ab	8.33 b	12.80 b	106.66 e
	$SA_{0.75}$	2.66 ab	11.66 ab	16.26 ab	189.79 c
	$SA_{1.5}$	1.33 b	8.333 b	16.76 ab	191.27 c
$LSD_{0.05}$		1.47	4.35	6.15	13.74
Significant level		*	*	*	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

(14.00) from $S_6SA_{1.5}$ treatment. In control treatments it was observed that with 0.75 and 1.5 mM concentration of salicylic acid application number of fruits per okra plant was slightly increased. But 6 $dSm^{-1}$of NaCl accelerate number of fruits per plant of okra with 1.5 mM concentration of salicylic acid (Alireza Pazoki 2015). On the contrary, the lowest value was observed from S_{12} (8.3333) treatment with high concentration of NaCl; similar results were found from Jamal et al., (2014), Sixto et al., (2005).

4.2.3 Single fruit weight (g)

Effect of salinity

Effect of different levels of salinity on single fruit weight (g) of okra (BARI Dherosh-2) was also observed statistically insignificant at harvest (Appendix VI).

Effect of salicylic acid (SA)

Effect of salicylic acid (SA) on number of fruits $plant^{-1}$ of okra (BARI Dherosh-2) was also observed statistically insignificant at harvest (Appendix VI).

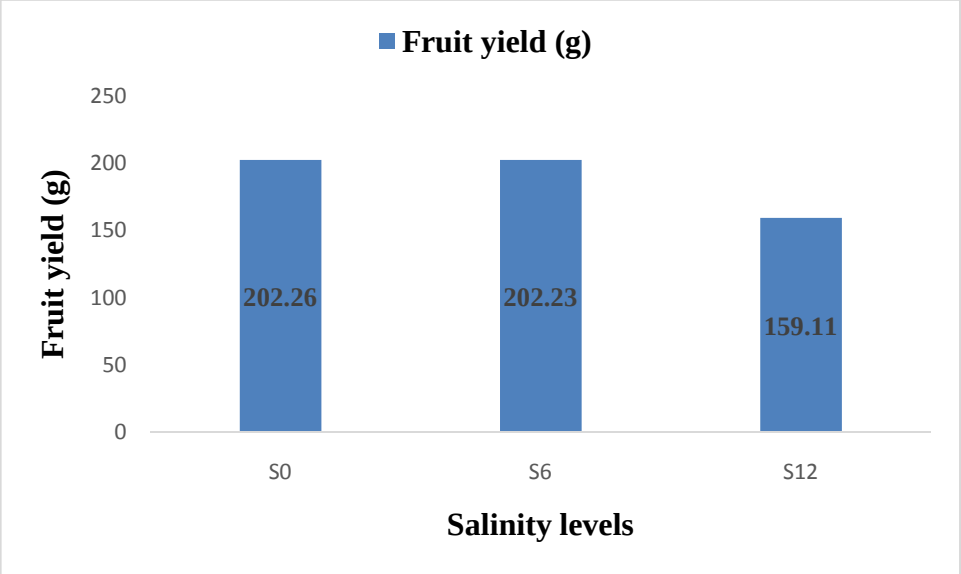
Effect of different levels of salinity and salicylic acid (SA)

Different salinity levels showed significant influence on single fruit weight of okra (Table 4). The highest single fruit weight (19.26 g) was recorded in S_6 treatment with 0.75 mM concentration of salicylic acid which was significantly different from other salinity levels. Treatment S_{12} (12 dSm^{-1} NaCl) also showed comparatively higher

result (16.76g) with 1.5 mM concentration of salicylic acid which was significantly different from control treatment S_0 (no salinity). The lowest single fruit weight (12.800 g) was obtained with S_{12} treatment (12 dSm^{-1}NaCl) with no salicylic acid. Similarly Humayun (2010) states that SA enhances growth and yield related characters.

4.2.4 Fruit yield plant^{-1} (g)

Effect of salinity



S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

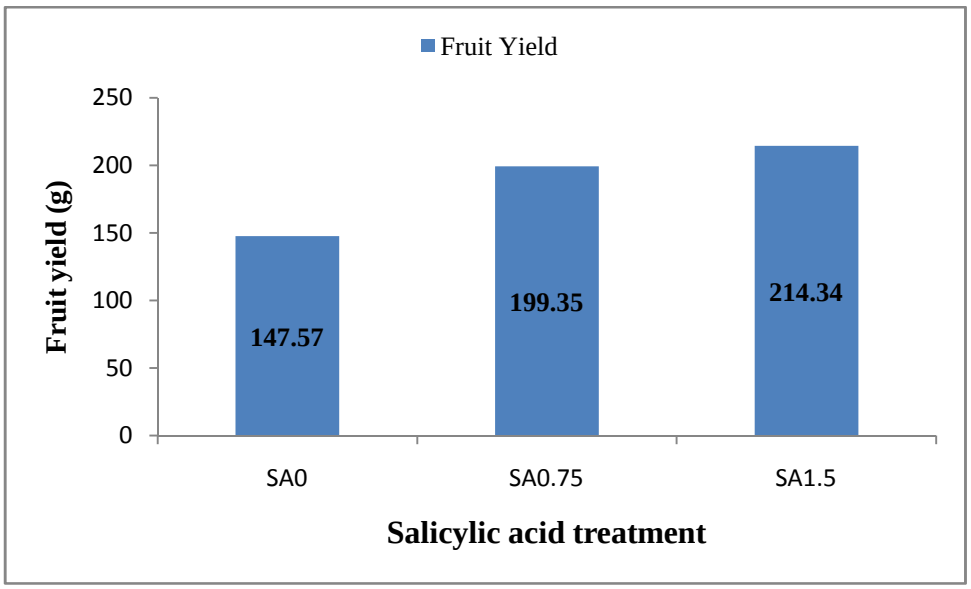
Figure 3. Effect of different levels of salinity on fruit yield of okra (BARI Dherosh-2) at harvest

Although fruit yield per plant is a genetically characters but the management practices also influences the yield per plant. (Biswas et al.,2015). Figure 3 shows that due to salinity fruit yield of okra (BARI Dherosh-2) was reduced significantly with the increase of salinity. At control treatment (S_0)the yield was observed 202.23 g which was significantly reduced by 159.11 g at S_{12} treatment with increasing level of

salinity. But interestingly, at 6 dSm^{-1} salinity fruit yield was not affected; because in many cases it was found that, low level salinity work as stimulator; (Shalaby et al.,2015).The yield is significantly reduced due to salinity, reported by Humayun et al.,(2010) and Siddiky et al. (2012).

Effect of salicylic acid (SA)

Fruits yield (g) per okra plant (BARI Dherosh-2) varied significantly for salicylic acid treatment (Figure 4). Data shows that, fruit yield of okra increased with the increasing concentration of salicylic acid. In SA_0 treatment the yield was recorded 147.57 g, which was



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 4. Effect of salicylic acid (SA) on fruit yield of okra (BARI Dherosh-2)at harvest

significantly increased by 199.35 g and 214.34 g at $SA_{0.75}$ and $SA_{1.5}$ mM concentration of salicylic acid respectively; Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in okra fruit yield.

Effect of different levels of salinity and salicylic acid (SA)

Fruit yield of okra plant varied significantly for different levels of salinity (Table 4). Data shows that, total fruit weight per okra plant was recorded highest 231.00 g at S_6 treatment with 1.5 mM concentration of salicylic acid which was significantly different from other salinity levels. On the contrary, the lowest value was observed

from S_{12} (106.66 g). similar results was found from Humayun (2010) and Siddiky et al. (2012).

Salicylic acid as mitigation agent had significant effect on fruit yield per okra plant. Data shows that fruit yield gradually increase with increasing concentration of SA. But 6 dSm^{-1} of NaCl accelerate number fruit yield per plant of okra with 1.5 mM concentration of salicylic acid (Alireza Pazoki 2015). Whereas the lowest value observed from $S_{12}SA_0$ (106.66 g) treatment with no salicylic acid concentration, which is similliar toeman et al., (2018) and increased with the application of SA@ 0.75 and 1.5 mM.

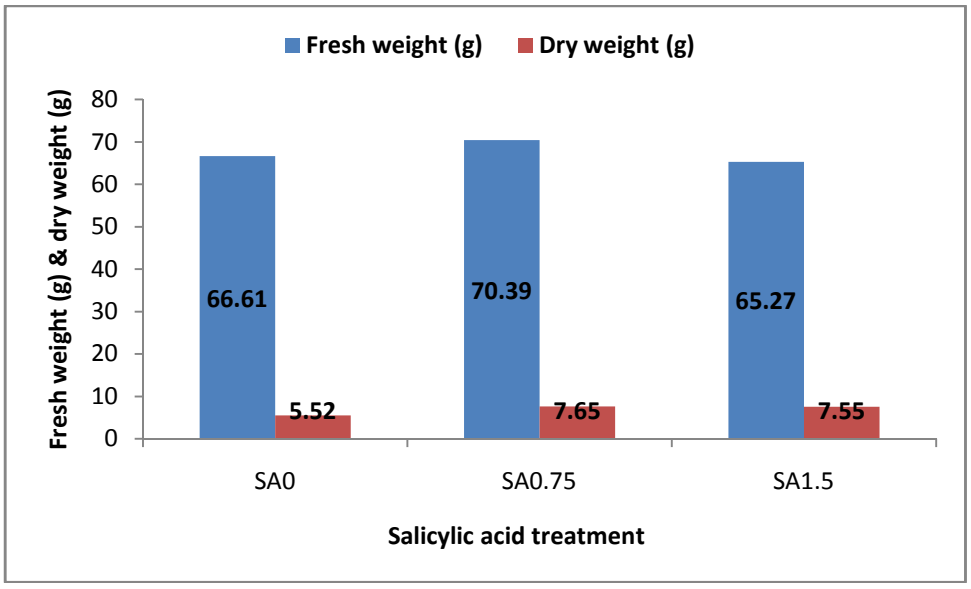
4.2.5Fresh (shoot) weight (g) and dry weight (g)

Effect of salinity

Effect of salinity on fresh weight (g) and dry weight (g) of okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VII).

Effect of salicylic acid (SA)

Salicylic acid has a significant effect on fresh weight (g) and dry weight (g) of okra (BARI Dherosh-2) (Figure 5). Data shows that, both the fresh weight and dry weight of plant was low at control treatment S_0A_0. Meanwhile, both the fresh weight and dry weight of plant increased significantly at $SA_{0.75}$treatmentby 70.39 g and 7.65 g respectively with increasing of salicylic acid concentration. Reduction in plant biomass yield by NaCl stress was also observed by Ahmad et al., (2015). Supplementation of SA enhanced the fresh and dry weight in the present study and the results confirm with the results of Iqbal et al., (2006)



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 5. Effect of salicylic acid (SA) on fresh weight (g) and dry weight (g) of okra (BARI Dherosh-2)

Effect of different levels of salinity and salicylic acid (SA)

Different salinity levels showed significant influence on fresh weight (g) of okra plant at harvest (Table 5). The highest fresh weight (95.333 g) of shoot was recorded in treatment S_0 (0 dSm^{-1}NaCl) with 1.5 mM of salicylic acid at harvest. The lowest fresh weight of shoot (52.500 g) was obtained with S_6 (6 dSm^{-1} NaCl) treatment with 1.5 mM salicylic acid. Similar result was found from Esan et al., (2020).

Different salinity levels showed significant influence on dry weight (g) of okra plant at harvest (Table 6). The highest dry weight (10.167 g) of shoot was recorded in treatment S_6 (6 dSm^{-1} NaCl) with highest doses of salicylic acid (1.5 mM) at harvest. The lowest dry weight of shoot (5.0000 g) was obtained with S_{12} (12 dSm^{-1} NaCl) treatment with no salicylic acid concntration. Similar result was found from Esan et al., (2020).

Table 5: Effect of different level of salinity and salicylic acid (SA) on fresh (shoot) weight and dry weight of okra plant (BARI Dherosh-2) at harvest.

Treatments		Fresh weight of plant (shoot) (g)	Dry weight of plant (g)
		Harvest	Harvest
S_0	SA_0	65.000 ab	6.1667 b
	$SA_{0.75}$	95.333 a	10.167 a
	$SA_{1.5}$	90.167 ab	8.8333 ab
S_6	SA_0	70.500 abc	5.5000 b
	$SA_{0.75}$	52.700 bc	6.7667 ab
	$SA_{1.5}$	52.500 bc	6.5000 ab
S_{12}	SA_0	64.333 abc	5.0000 b
	$SA_{0.75}$	63.000 abc	6.0333 b
	$SA_{1.5}$	53.167 bc	7.3333 ab
$LSD_{0.05}$		38.600	3.9615
Significant level		*	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

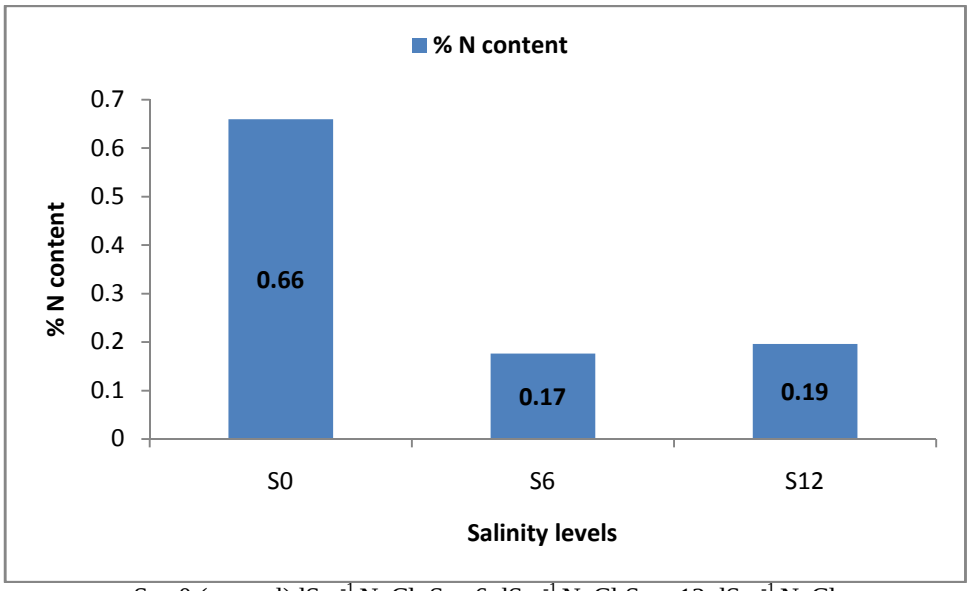
4.3 Chemical composition

4.3.1N, P, K content in fruits of okra plant (BARI Dherosh-2)

Nitrogen (N) content in fruits

Effect of salinity

Effect of different levels of salinity on %N content in fruits okra (BARI Dherosh-2) was observed significant (Figure 6). Data shows that % N content increases at high salinity at S_{12} (0.19 %) which was comparatively low in S_6 (0.17 %)treatment. The salinity stress interferes with nitrogen consumption and absorption. The salt stress condition could have effect on different stages of nitrogen metabolism, such as absorption, ionic reduction and protein synthesis (Meloni et al., 2004).The increasing of amino acid in the plant tissue under stress is related to protein fraction (Hussein et al., 2007).



S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 6. Effect of different levels of salinity on % N content in fruits of okra (BARI Dherosh-2)

Effect of salicylic acid

Effect of salicylic acid (SA) on %N content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VIII).

Effect of different levels of salinity and salicylic acid (SA)

Nitrogen (N) content in fruits of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 6).There are many reports about increasing of protein level in salinity stress. The soluble protein and free amino acid in barley organs (root and bud) increased with NaCl increasing. The study of maize plant and also all amino acids increased with salicylic acid (El Tayeb 2005). Data shows that at control ttreatment (S_0) %N content increase in fruit in $SA_{0.75}$ and$SA_{1.5}$ treatment with increasing SA concentratin. At S_6 treatment it was observed that nitrogen content gradually decreases but in S_{12} treatment %N content in fruit of okra further increased with 1.5 mM of SA. The highest %N content (0.86%) was observed in fruit from the treatment ($S_0SA_{1.5)}$with 0 salinity and 1.5 mM of salicylic acid (SA). The lowest amount of %N (0.84%) was found in fruits for the treatment (S_{12} $SA_{0)}$ with 12 dSm^{-1}NaCl and no salicylic acid doses. which is similiar to Solangi et al., (2015).

Table 6: Effect of different levels of salinity and salicylic acid (SA) on N, P, K content in fruits of okra plant (BARI Dherosh-2).

Treatments		Nutrient content in Fruits		
		N (%)	P (%)	K (%)
S_0	SA_0	0.30 c	0.90 a	3.20 a
	$SA_{0.75}$	0.84 a	0.60 ab	2.50 b
	$SA_{1.5}$	0.86 a	0.70 ab	2.80 ab
S_6	SA_0	0.30 c	0.50 b	2.40 b
	$SA_{0.75}$	0.12 d	0.40 ab	2.70 ab
	$SA_{1.5}$	0.11 d	0.60 ab	2.90 ab
S_{12}	SA_0	0.70 d	0.60 ab	2.50 b
	$SA_{0.75}$	0.84 d	0.70 ab	2.80 ab
	$SA_{1.5}$	0.43 b	0.60 ab	2.70 ab
$LSD_{0.05}$		.2219	0.3616	0.5425
Significant level		*	*	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

Phosphorus (P) content in fruits

Effect of salinity

Effect of different levels of salinity on % P content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VIII).

Effect of salicylic acid

Effect of salicylic acid (SA) on % P content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VIII).

Effect of different levels of salinity and salicylic acid (SA)

Phosphorus (P) content in fruits of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 6). The highest P content (0.90%) was observed in fruit from the control treatment S_0SA_0. Data shows that phosphorus content was decreased gradually with increasing level of salinity. At $S_6SA_{0.75}$ treatment% P content in fruit of okra decreased by 0.40% which was recorded as the lowest value. But % P content further started to increase with increasing SA concentration at $S_{12}SA_{0.75}$ treatment(0.70%), which is statistically similar with $S_0SA_{1.5}$; which is similiar to Solangi et al., (2015).

Potassium (K) content in fruits

Effect of salinity

Effect of different levels of salinity on % K content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VIII).

Effect of salicylic acid

Effect of salicylic acid (SA) on % K content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix VIII).

Effect of different levels of salinity and salicylic acid (SA)

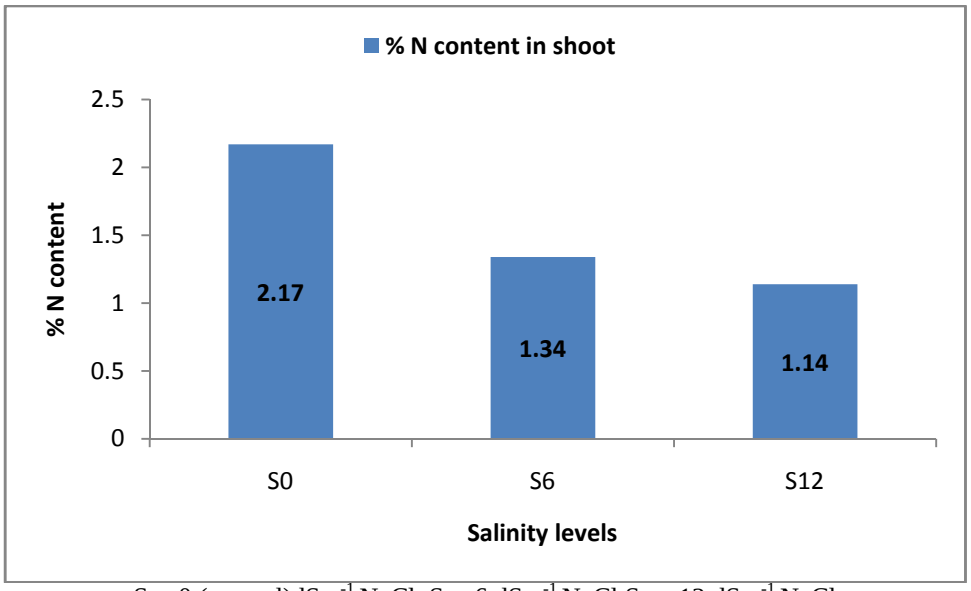
Potassium (K) content in fruits of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 6). The highest K content (3.20%) was observed in fruit from control treatment ($S_0SA_{0)}$.Data shows that potassium content was decreased gradually with increasing level of salinity. At $S_6SA_{0.}$treatment% K content in fruit of okra decreased by 2.40% which was recorded as the lowest value. But % P content further started to increase with increasing SA concentration at $S_6SA_{0.75}$(2.70%),$S_6SA_{1.5}$ treatment (2.90%) and $S_{12}SA_{1.5}$ (2.80%); which is similiar to Solangi et al., (2015).

4.3.2 N, P, K content in shoot of okra plant (BARI Dherosh-2)

Nitrogen (N) content in shoot

Effect of salinity

Effect of different levels of salinity on %N content in shoot okra (BARI Dherosh-2) was observed significant (Figure 7). Data shows that at control treatment nitrogen content in shoot of okra was2.17%. Nitrogen content decreases at increasing level of salinity at S_6 (1.34%) which was comparatively low in S_{12}treatment (1.5%). The salinity stress interferes with nitrogen consumption and absorption. The salt stress condition could have effect on different stages of nitrogen metabolism, such as absorption, ionic reduction and protein synthesis (Meloni et al., 2004).The increasing of amino acid in the plant tissue under stress is related to protein fraction (Hussein et al., 2007).

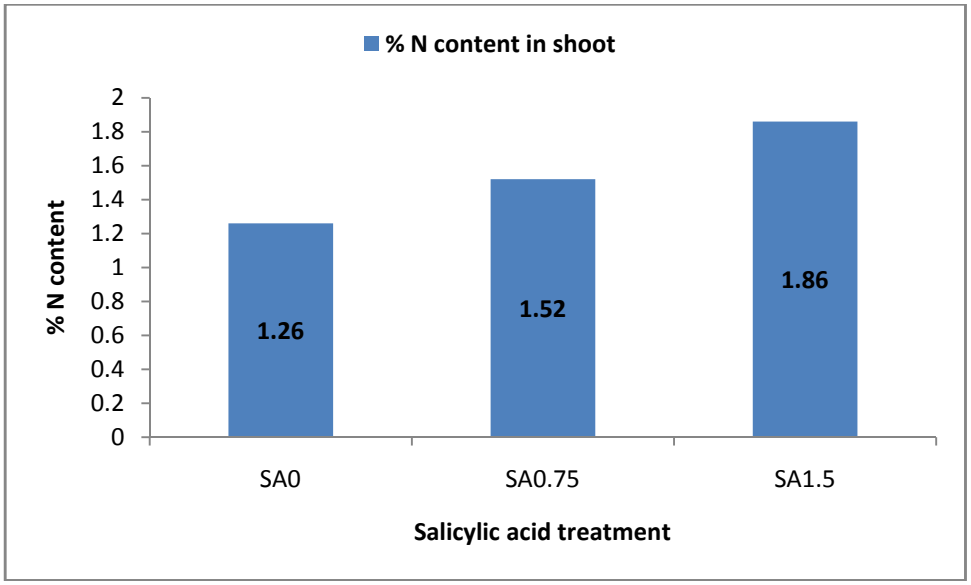


S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 7. Effect of different levels of salinity on % N content inshoot of okra (BARI Dherosh-2)

Effect of salicylic acid

Effect of different SA on %N content in shoot of okra (BARI Dherosh-2) was observed significant (Figure 8). Data shows that % N content increased with high SA concentration at $SA_{0.75}$ treatment by 1.52% and at $SA_{1.5}$ treatment by 1.86% with high concentration of SA compared to control treatment SA_0 (1.26%). The leaf protein level decreased by salt stress but salicylic acid could increase it. The cause of protein reduction at salinity condition is the prevention of nitrate reductase activity (Undovenko, 1971).



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 8. Effect of salicylic acid on % N content in shoot of okra (BARI Dherosh-2)

Effect of different levels of salinity and salicylic acid (SA)

Nitrogen (N) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 7). There are many reports about increasing of protein level in salinity stress. The study of maize plant and also all amino acids increased with salicylic acid (El Tayeb 2005). Data shows that at control treatment (S_0) %N content decrease in shoot in $SA_{0.75}$ and$SA_{1.5}$ treatment with increasing SA concentration. At S_6 treatment it was observed that nitrogen content gradually decreases but in S_{12} treatment % N content in shoot of okra further increased with 0.75 and 1.5 mM of SA. The highest N content was observed in shoot from the control treatment $S_0SA_{1.5}$(2.52%).The lowest amount of %N (0.84%) was found in fruits for the treatment (S_{12} $SA_{0)}$ with 12 dSm^{-1}NaCl and no salicylic acid doses; which is similiar to Solangi et al., (2015).

Table 7: Effect of different level of salinity and salicylic acid (SA) on N, P, K content in shoot of okra plant (BARI Dherosh-2).

Treatments	Nutrient content in Shoot		
	N (%)	P (%)	K (%)

S_0	SA_0	1.84 bc	0.90 a	1.63 a
	$SA_{0.75}$	2.17 ab	0.50 b	1.46 a
	$SA_{1.5}$	2.52 a	0.30 bc	0.90 ab
S_6	SA_0	1.12 ef	0.20 c	0.46 b
	$SA_{0.75}$	1.22 cd	0.20 c	0.90 ab
	$SA_{1.5}$	1.68 cd	0.30 c	0.43 b
S_{12}	SA_0	0.84 f	0.20 bc	0.53 b
	$SA_{0.75}$	1.19 ef	0.40 bc	0.26 b
	$SA_{1.5}$	1.40 de	0.50 b	0.50 b
$LSD_{0.05}$		0.3983	0.2620	0.7927
Significant level		*	*	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

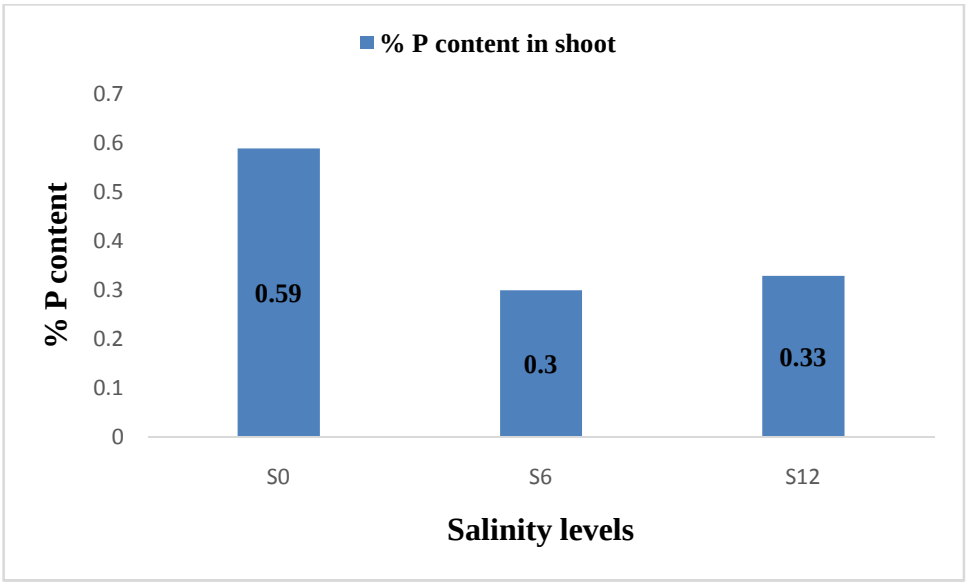
Phosphorus (P) content in shoot

Effect of salinity

Phosphorus (P) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of salinity (Figure 8). Data shows that, % P content in shoot was observed 0.59% at control treatment S_0. It was decreased by 0.3% at S_6 treatment and finally increased by 0.33% at S_{12} treatment with high salinity; which is similiar to Solangi et al., (2015).

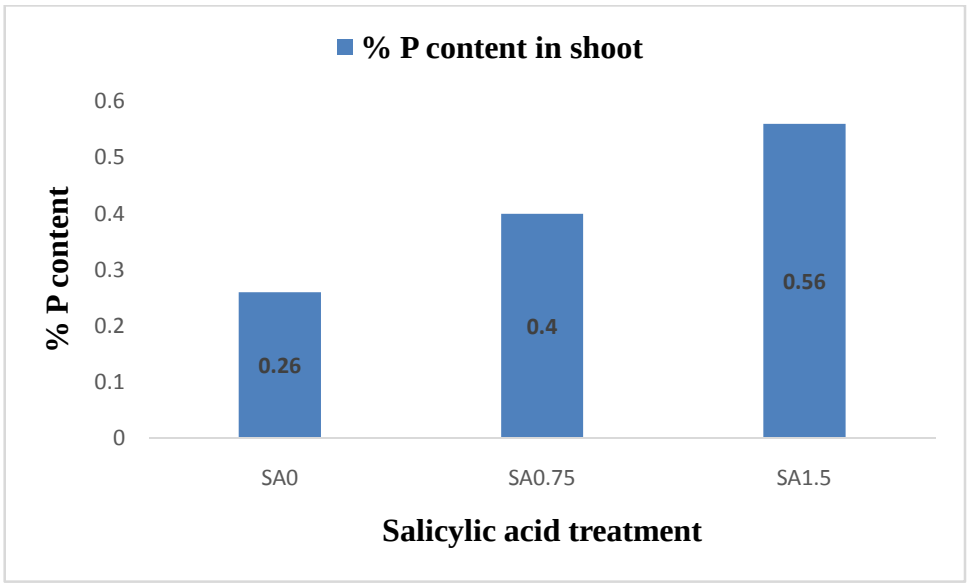
Effect of salicylic acid

Phosphorus (P) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to salicylic acid treatment (Figure 9). Data shows that, % P content in shoot was observed 0.26%% at control treatment S_0. It was increased by 0.40% at S_6 treatment and finally increased 0.56% at S_{12} treatment with high concentration of salicylic acid; which is similiar to Solangi et al., (2015)



S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 9. Effect of different levels of salinity on % P content in shoot of okra (BARI Dherosh-2)



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 10. Effect of salicylic acid on % P content inshoot of okra (BARI Dherosh-2)

Effect of different levels of salinity and salicylic acid (SA)

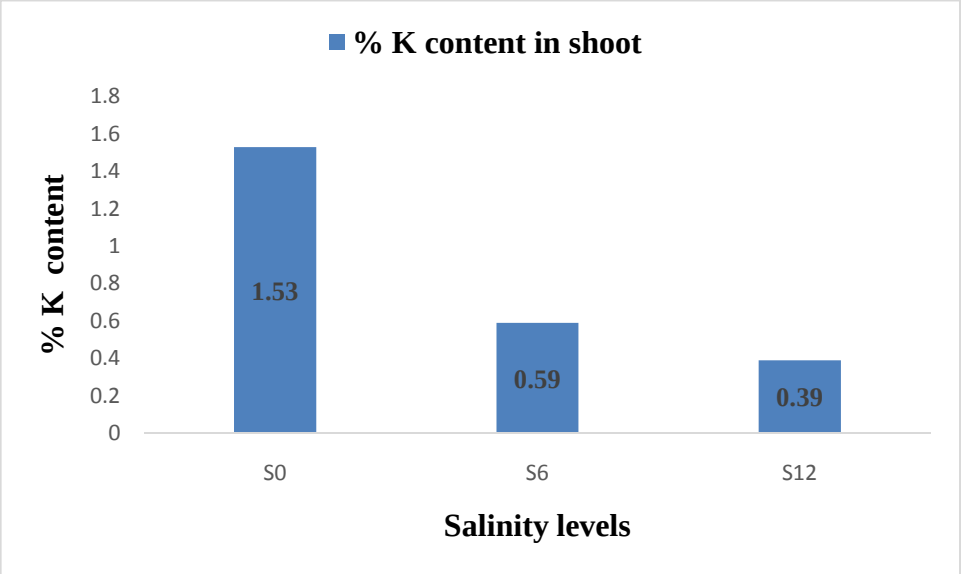
Phosphorus (P) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses

(Table 7). The highest P content (0.90%) was observed in shoot from the control treatment S_0SA_0. Data shows that phosphorus content was decreased gradually with increasing level of salinity. At $S_{12}SA_0$ treatment% P content in shoot of okra decreased by 0.20% which was recorded as the lowest value; followed by S_6SA_0 and $S_6SA_{0.75}$ treatment recorded as same value. But % P content further started to increase with increasing SA concentration at $S_{12}SA_{0.75}$ treatment (0.40%)and $S_{12}SA_{1.5}$(0.50%); which is similiar to Solangi et al., (2015).

Potassium (K) content in shoot

Effect of salinity

Potassium (K) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of salinity (Figure 10). Data shows that, % K content in shoot was observed 1.53% at control treatment S_0. It was decreased by 0.59% at S_6 treatment and 0.39% at S_{12} treatment with high salinity; which is similiar to Solangi et al., (2015).

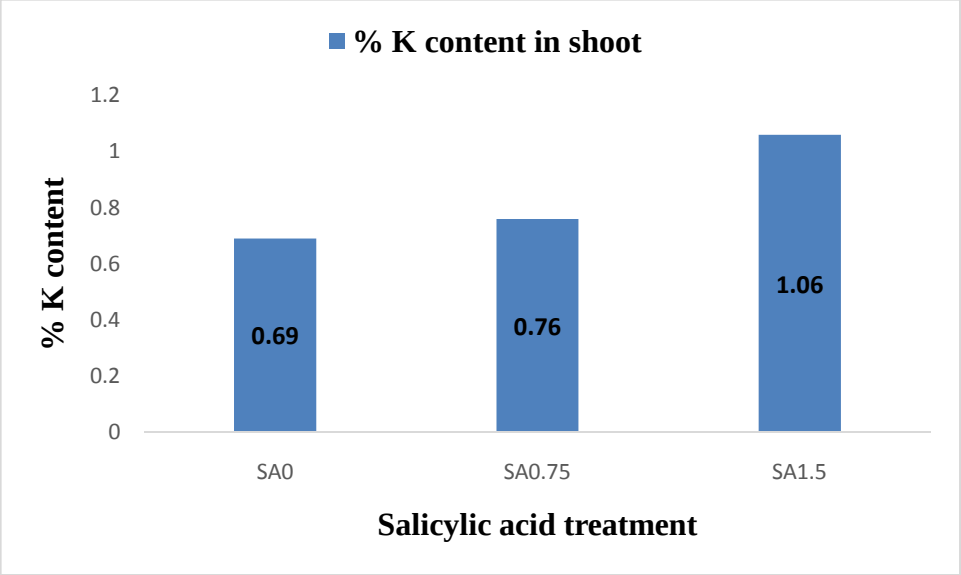


S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 11. Effect of different levels of salinity on % K content in shoot of okra (BARI Dherosh-2)

Effect of salicylic acid

Potassium (K) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to salicylic acid treatment (Figure 9). Data shows that, % P content in shoot was observed 0.69% at control treatment S_0. It was increased by 0.76% at S_6 treatment and finally increased 1.06% at S_{12} treatment with high concentration of salicylic acid; which is similiar to Solangi et al., (2015)



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 12. Effect of salicylic acid on % K content in shoot of okra (BARI Dherosh-2)

Effect of different levels of salinity and salicylic acid (SA)

Potassium (K) content in shoot of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 7). The highest K content (1.63 %) was observed in shoot from the control treatment S_0SA_0. Data shows that phosphorus content was decreased gradually with increasing level of salinity. At $S_{12}SA_{0.75}$ treatment% K content in shoot of okra decreased by 0.26% which was recorded as the lowest value. But % K content increase with increasing SA concentration at $S_{12}SA_{1.5}$treatment (0.50%); which is similiar to Solangi et al., (2015).

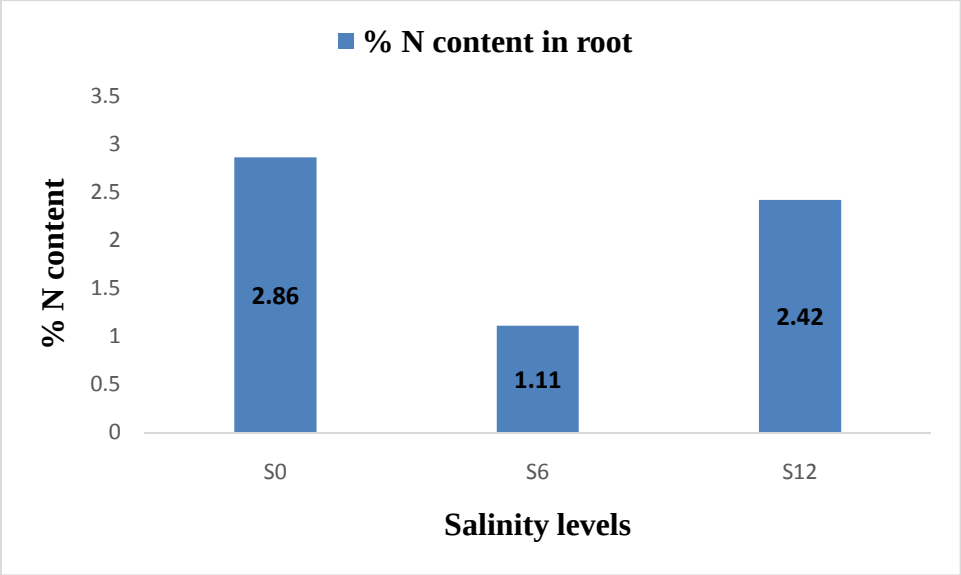
4.3.3 N, P, K content in root of okra plant (BARI Dherosh-2)

Nitrogen (N) content in root

Effect of salinity

Effect of different levels of salinity on %N content in shoot okra (BARI Dherosh-2) was observed significant (Figure 12). Data shows that at control treatment nitrogen content in root of okra was 2.86%.Nitrogen content increases at high salinity at S_{12} (2.42%) which was comparatively low in S_6(1.1%)treatment. The salinity stress interferes with nitrogen consumption and absorption. The salt stress condition could have effect on different stages of nitrogen metabolism, such as absorption, ionic

reduction and protein synthesis (Meloni et al., 2004).The increasing of amino acid in the plant tissue under stress is related to protein fraction (Hussein et al., 2007).



S_0= 0 (control)dSm^{-1} NaCl, S_6= 6 dSm^{-1} NaCl,S_{12}= 12 dSm^{-1} NaCl

Figure 13. Effect of different levels of salinity on % N content in root of okra (BARI Dherosh-2)Effect of salicylic acid

Effect of salicylic acid (SA) on % N content in roots okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix IV).

Effect of different levels of salinity and salicylic acid (SA)

Nitrogen (N) content in fruits of okra plant (BARI Dherosh-2) showed statistically significant difference due to different levels of salinity and salicylic acid (SA) doses (Table 8).There are many reports about increasing of N level in salinity stress. The soluble protein and free amino acid in barley organs (root and bud) increased with NaCl increasing. The study of maize plant and also all amino acids increased with salicylic acid (El Tayeb 2005). Data shows that at control ttreatment (S_0) %N content increase in fruit in $SA_{0.75}$ and$SA_{1.5}$ treatment with increasing SA concentratin. At S_6 treatment it was observed that nitrogen content gradually decreases but in S_{12} treatment %N content in fruit of okra further increased with 0.75 mM of SA. The highest %N content (4.48%) was observed in fruit from the treatment (S_0 $SA_{0.75)}$with 0 salinity and 0.75 mM of salicylic acid (SA). The lowest amount of %N (0.91%) was found in root for the treatment ($S_6SA_{0)}$ with 6 dSm^{-1}NaCl and no salicylic acid doses. which is similiar to Solangi et al., (2015).

Table 8: Effect of different level of salinity and salicylic acid (SA) doses on N, P, K content in root of okra plant (BARI Dherosh-2).

Treatments		Nutrient content in Shoot		
		N (%)	P (%)	K (%)
S_0	SA_0	1.60cdef	0.90 a	1.00 a
	$SA_{0.75}$	4.48 a	0.60 bc	0.30 ab
	$SA_{1.5}$	2.50 bc	0.60 bc	0.40 b
S_6	SA_0	.91 f	0.30 d	0.30 b
	$SA_{0.75}$	1.05 ef	0.80 ab	1.00 a
	$SA_{1.5}$	1.40 def	0.40 cd	0.40 b
S_{12}	SA_0	2.03 bcde	0.30 d	0.40 b
	$SA_{0.75}$	2.87 b	0.50 cd	0.30 b
	$SA_{1.5}$	2.38 bcd	0.30 d	0.60 ab
$LSD_{0.05}$		0.9962	0.2916	0.4645
Significant level		*	*	*

* - Significant at 5% level

SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid
S_0 = 0 dSm^{-1} NaCl, S_6 = 6 dSm^{-1} NaCl, S_{12} = 12 dSm^{-1} NaCl
In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

Phosphorus (P) content in root

Effect of salinity

Effect of different levels of salinity on % P content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix IV).

Effect of salicylic acid

Effect of salicylic acid (SA) on % P content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix IV)

Effect of different levels of salinity and salicylic acid (SA)

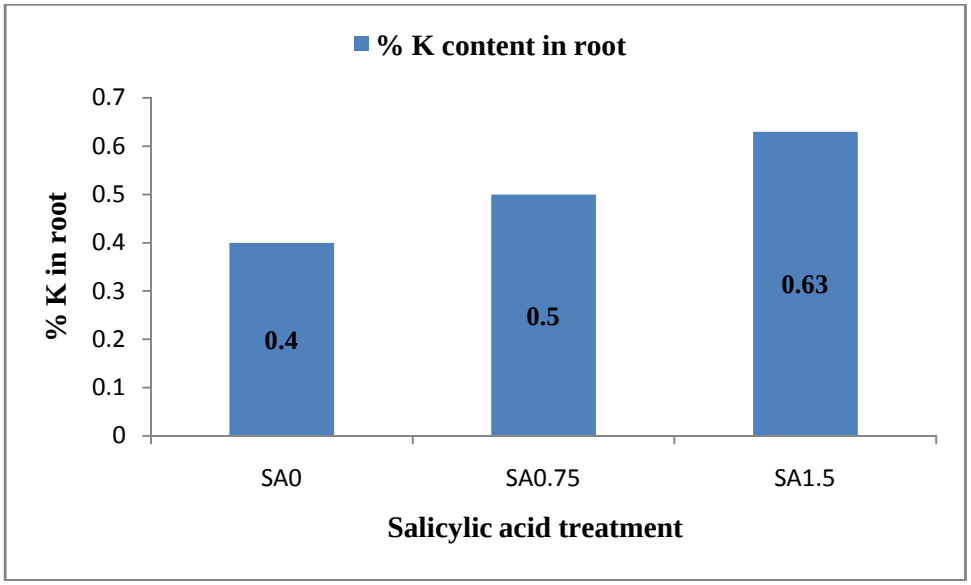
Phosphorus (P) content in root of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of salinity and salicylic acid (SA) doses (Table 8). The highest P content (0.90%) was observed in root from the control treatment S_0SA_0. Data shows thatphosphorus content was decreased gradually with increasing level of salinity. At $S_{12}SA_0$ treatment% P content in root of okra decreased by 0.30% which was recorded as the lowest value; followed by S_6SA_0 and $S_{12}SA_0$treatment recorded as same value. But % P content further started to increase with increasing SA concentration at $S_6SA_{0.75}$ and $S_{12}SA_{0.75}$ treatment by 0.80% and 0.50% respectively; which is similiar to Solangi et al., (2015).

Potassium (K) content in root

Effect of salinity

Effect of different levels of salinity on % K content in fruits okra (BARI Dherosh-2) was observed statistically insignificant at harvest (Appendix IV).

Effect of salicylic acid



SA_0 = 0 (Control), $SA_{0.75}$ = 0.75 mM of salicylic acid, $SA_{1.5}$ = 1.5 mM of salicylic acid

Figure 14. Effect of salicylic acid on % K content in root of okra (BARI Dherosh-2)

Effect of different levels of salinity and salicylic acid (SA)

Potassium (K) content in root of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of salinity and salicylic acid (SA) doses (Table 7). The highest K content (1.00 %) was observed in root from the control treatment S_0SA_0. Data shows that K content was decreased gradually with increasing level of salinity. At S_6SA_0 treatment% K content in root of okra decreased by 0.30% which was recorded as the lowest value. But % K content increase with increasing SA concentration at $S_{12}SA_{1.5}$ treatment (0.60%); which is similiar to Solangi et al., (2015).

CHAPTER V

SUMMARY AND CONCLUSION

Saline effect on plant height was recorded at 30 DAT and at harvest. The result revealed that at 30 DAT and at harvest S_0 produced 54.29 cm and 93.77 cm tall plant

respectively, which was reduced by S_6 (52.64 cm and 93.33 cm) at 30 DAT and at harvest respectively. Shortest plant was produced by S_{12} (49.17 cm and 85.66 cm) at 30 DAT and at harvest respectively. In this experiment SA have significant effect on plant height, so with SA increasing, plant height decreased gradually (Figure 2).The result revealed that at control treatment (SA_0) the tallest plant was 53.78 cm and 97.10 cm at 30 DAT and at harvest respectively. At $SA_{0.75}$plant height further decreased by 52.08 cm and 91.88 cm at 30 DAT and at harvest respectively.

In case of effect of different doses of SA under different levels of salinity show that, the tallest plant 102.33 cm was produced by control treatment S_0 SA_0 at harvest due to lower concentration of NaCl. The effect of SA to mitigate saline stress was not significantly observed till 6 dSm^{-1} of NaCl. But at $S_{12}SA_{0.75}$ treatment plant height significantly increases by 88.00 cm at higher concentration (12 dSm^{-1})of NaCl due to application of 0.75 mM of SA. Effect of different levels of salinity on number of branches $plant^{-1}$ of okra (BARI Dherosh-2) was observed statistically insignificant and effect of different levels of salinity on number of branches $plant^{-1}$ of okra (BARI Dherosh-2) was also observed statistically insignificant. Meanwhile, effect of different levels of salinity and SA showed significant variation on number of branches $plant^{-1}$branches of okra plant (BARI Dherosh-2) at harvest. The maximum number of branches $plant^{-}$(2.00) was recorded in control treatment S_0 (no salinity) with 1.5 mM of SA concentration. The lowest number of branches $plant^{-1}$ (1.33) was obtained with S_{12} (12 dSm^{-1} NaCl) treatment. The total number of leaves per okra plant (BARI Dherosh-2) was recorded highest (11.66) from S_0 $SA_{1.5}$ as 0 dSm^{-1} NaCl and 0.75 mM SA at harvest. On the contrary, the lowest value was observed from S_{12} (7.33) due to high concentration of NaCl. Effect of different levels of salinity and SA showed statistically insignificant on length of leaves per plant of okra both at 30 DAT and at harvest.

Total number of flowers per plant of okra was recorded highest (3.33) from control treatment S_0 and $SA_{0.75}$ (0.75) mM concentration of SA at 30 DAT. On the contrary, the lowest value was observed from S_{12} (1.33) treatment. Number of fruits per okra plant was recorded highest (14.00) from S_6 treatment. On the contrary, the lowest value was observed from S_{12} (8.33) treatment. Number of fruits per okra plant was recorded highest (19.26) from S_6 treatment with higher doses of SA (1.5 mM). The highest single fruit weight (19.26g) was recorded in S_6 treatment with (1.5 mM)

concentration of SA which was significantly different from other salinity levels. Treatment S_{12} (12 dSm^{-1} NaCl) also showed comparatively higher result (16.76g) with (1.5 mM) concentration of SA but significantly different from control treatment S_0 .The lowest single fruit weight (12.80g) was obtained with S_{12} treatment (12 dSm^{-1}NaCl) with no SA. Fruit yield per okra plant was recorded highest (231.00) S_6 treatment with (0.75 mM) concentration of SA which was significantly different from other salinity levels. On the contrary, the lowest value was observed from S_{12} (106.66 g). SA as mitigation agent had significant effect on total fruit weight per okra plant. Highest result was recorded from $S_{12}SA_{1.5}$ (191.27 g) with (1.5 mM) concentration of SA which was significantly different from other SA doses. Whereas the lowest value was observed from $S_{12}SA_0$ (106.66 g) treatment with no SA concentration. The highest fresh weight (95.33 g) of shoot was recorded in treatment S_{12} (12 dSm^{-1} NaCl) with highest doses of SA (1.5 mM) at harvest. The lowest fresh weight of shoot (52.50 g) was obtained with S_6 (6 dSm^{-1} NaCl) treatment with 1.5 mM SA.

In case of effect of different doses of SA under different levels of salinity on N, P, K content in fruits of okra plant (BARI Dherosh-2) show that, the highest N content (0.86%) was in fruit from the treatment (S_0 $SA_{1.5)}$with 0 salinity and 1.5 mM of SA. The lowest amount of N (0.8400%) was found in fruits for the treatment (S_{12} $SA_{0)}$ with 12 dSm^{-1} NaCl and no SA doses. Phosphorus (P) content in fruits was observed highest (0.90%) was in fruit from the control treatment (S_0 $SA_{0)}$. The lowest amount of P (0.40%) was found in fruits for the treatment (S_0 $SA_{0.75)}$ with no NaCl and 0.75 mM of SA concentration. The highest K content (3.20%) was observed in fruit from control treatment (S_0 $SA_{0)}$. The lowest amount of P (2.40%) was found in fruits for the treatment (S_{12} $SA_{0.75)}$ with no salinity and 0.75 SA doses.

N, P, K content in shoot of okra plant (BARI Dherosh-2) was recorded. Highest N content (6.30%) was observed in shoot from the treatment ($S_0SA_{0.75)}$ with 0 salinity and 0.75 mM of SA. The lowest amount of N (0.8400%) was found in fruits for the treatment (S_6 $SA_{1.5)}$ with 6 dSm^{-1} NaCl and 1.5 mM of SA doses. The highest P content (0.90%) was observed in shoot from the treatment (S_0SA_0)with 0 salinity and 0.75 mM of SA. The lowest amount of P (0.20%) was found in fruits for the treatment (S_6 $SA_{0.75)}$ with 12 dSm^{-1} NaCl and 1.5 mM salicylic acid doses. The

highest K content (3.20%) was observed in shoot from control treatment ($S_0SA_{0)}$.The lowest amount of K (2.90%) was found in shoot for the treatment (S_6SA_0).

N, P, K content in root of okra plant (BARI Dherosh-2) was recorded. The highest N content (4.48%) was observed in root from the control treatment control treatment $S_0SA_{0.75}$. The lowest amount of (0.90%) was found in root for the treatment (S_6 SA_0). The highest P content (0.91%) was observed in root from the treatment ($S_0SA_{0)}$ with 0 salinity and 0 mM of SA. The lowest amount of P (0.30%) was found in root for the treatment (S_{12} $SA_{0)}$ with 12 dSm^{-1} NaCl and 0 mM SA doses. Potassium (K) content in shoots of okra plant (BARI Dherosh-2) showed statistically significant difference due to different level of NaCl and salicylic acid (SA) doses (Table 8). The highest K content (1.00%) was observed in root from the control treatment ($S_0SA_{0)}$. The lowest amount of K (0.30%) was found in root from the treatment (S_6SA_0)with 6 dSm^{-1} NaCl and 0.75 mM of SA concentration.

From the above discussion, it can be concluded that:

i. Salinity more than 6 dSm^{-1} had adverse effect on the growth and yield of okra (BARI Dherosh-2)
ii. Salicylic acid at 0.75 and 1.5 mM concentration significantly mitigate the salinity stress.
iii. In fruit and shoot, N, P, K content was reduced due to salinity stress but in root N content increase at 12 dSm^{-1}.

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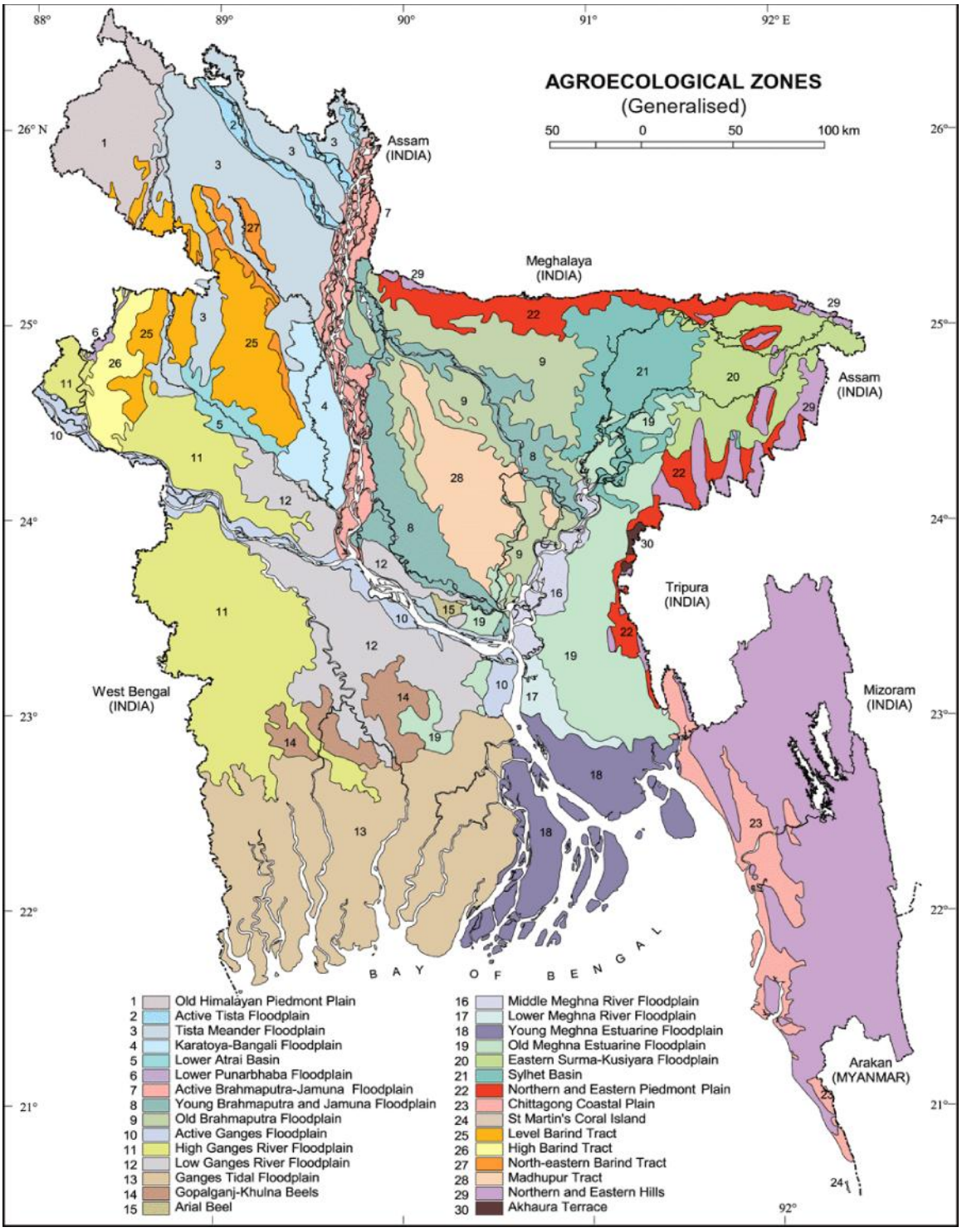
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Effect of salinity and salicylic acid on number of branches plant^{-1}

Treatment	Saline effect
	Number of branches plant^{-1}
S_0	1.66
S_6	1.99
S_{12}	1.55
$LSD_{0.05}$	1.23
Significant level	NS

Treatment	Salicylic acid effect
	Number of branches plant^{-1}
SA_0	1.55
$SA_{0.75}$	1.66
$SA_{1.5}$	1.99
$LSD_{0.05}$	1.17
Significant level	NS

Appendix III. Effect of salinity and salicylic acid on number of leaves plant^{-1}

Treatment	Saline effect	
	30 DAT	60 DAT
S_0	8.10	9.22
S_6	9.22	9.77
S_{12}	8.99	8.00
$LSD_{0.05}$	1.70	2.26
Significant level	NS	NS

Treatment	Salicylic acid effect	
	30 DAT	60 DAT
SA_0	8.88	8.32
$SA_{0.75}$	9.21	9.99
$SA_{1.5}$	8.22	9.77
$LSD_{0.05}$	1.92	2.11
Significant level	NS	NS

Appendix IV. Effect of salinity and salicylic acid on length of leaves plant^{-1}

Treatment	Saline effect	
	30 DAT	60 DAT
S_0	3.21	13.79
S_6	2.99	14.75

S_{12}	2.88	3.72
$LSD_{0.05}$	1.25	1.59
Significant level	NS	NS

Treatment	Salicylic acid effect	
	30 DAT	60 DAT
SA_0	2.99	15.20
$SA_{0.75}$	3.10	14.23
$SA_{1.5}$	2.88	12.86
$LSD_{0.05}$	0.91	2.97
Significant level	NS	NS

Treatments		Length of leaves per plant (cm)	
	SA_0	30 DAT	Harvest
S_0	$SA_{0.75}$	3.00	13.73
	$SA_{1.5}$	3.33	15.23
	SA_0	3.33	12.43
S_6	$SA_{0.75}$	3.33	16.23
	$SA_{1.5}$	3.00	14.63
	SA_0	2.66	13.50
	$SA_{0.75}$	2.66	15.66
S_{12}	$SA_{1.5}$	3.33	12.83
$LSD_{0.05}$		1.32	4.19
Significant level		NS	NS

Appendix V. Effect of salinity and salicylic acid on number of flowers plant^{-1}

Treatment	Saline effect
	Number of flowers plant^{-1}
S_0	3.00 a
S_6	2.44 a
S_{12}	2.10 a
$LSD_{0.05}$	1.20
Significant level	NS

Treatment	Salicylic acid effect
	Number of flowers plant^{-1}
SA_0	1.01 a
$SA_{0.75}$	2.77 a

$SA_{1.5}$	2.10 a
$LSD_{0.05}$	1.01
Significant level	NS

Appendix VI. Effect of salinity and salicylic acid on number of fruits plant^{-1} and single fruit weight (g) plant^{-1}

Treatment	Saline effect	
	Number of fruits plant^{-1}	Single fruit weight (g)
S_0	11.21 a	15.68 a
S_6	12.22 a	17.550 a
S_{12}	11.22 a	15.16 a
$LSD_{0.05}$	3.31	4.17
Significant level	NS	NS

Treatment	Salicylic acid effect	
	Number of fruits plant^{-1}	Single fruit weight (g)
SA_0	11.99	16.64
$SA_{0.75}$	10.99	16.02
$SA_{1.5}$	11.66	16.00
$LSD_{0.05}$	2.58	3.61
Significant level	NS	NS

Appendix VII. Effect of salinity on fresh (shoot) weight (g) and dry weight (g)

Treatment	Saline effect	
	Fresh weight (g)	Dry weight (g)
S_0	61.10	7.04
S_6	57.62	6.25
S_{12}	74.22	7.16
$LSD_{0.05}$	17.02	2.21
Significant level	NS	NS

Appendix VIII. Effect of salinity and salicylic acid on N, P, K content in fruit

Treatment	Saline effect	
	%P	%K
S_0	0.66	2.81
S_6	0.56	2.76
S_{12}	0.63	2.53
$LSD_{0.05}$	0.26	0.37
Significant level	NS	NS

Treatment	Salicylic acid effect		
	%N	%P	%K

SA_0	3.76 a	0.696 a	2.86 a
$SA_{0.75}$	3.29 a	0.53 a	2.53 a
$SA_{1.5}$	4.70 a	0.63 a	2.73 a
$LSD_{0.05}$	2.98	0.23	0.36
Significant level	NS	NS	NS

Appendix IX. Effect of salinity and salicylic acid on N, P, K content in root

Treatment	Saline effect	
	%P	%K
S_0	0.49	0.63
S_6	0.53	0.56
S_{12}	0.53	0.33
$LSD_{0.05}$	0.21	0.35
Significant level	NS	NS

Treatment	Salicylic acid effect	
	%N	%P
SA_0	1.8367	0.5000
$SA_{0.75}$	2.4700	0.6300
$SA_{1.5}$	2.0900	0.4000
$LSD_{0.05}$	0.7871	0.2678
Significant level	NS	NS