EFFECT OF DIFFERENT LEVELS OF SALINITY ON GROWTH AND YIELD OF RICE

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EFFECT OF DIFFERENT LEVELS OF SALINITY ON GROWTH AND YIELD OF RICE

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CERTIFICATE

This is to certify that the thesis entitled, **“Effect of different levels of salinity on growth and yield of rice”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **Master of Science in Soil Science,** embodies the result of a piece of *bona fide* research work carried out by **Md. Sabbir Ahmed,** Registration No.:**19-10057**, under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED TO MY BELOVED PARENTS

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Dhaka, Bangladesh
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ABSTRACT

A pot experiment was conducted at the net house of the Department of Soil Science at Sher-e-Bangla Agricultural University, Dhaka-1207. During boro rice growing season (December to April) of the year of 2019-2020 to know the effect of different levels of salinity on growth and yield of rice. The experiment was conducted using seven salinity levels with sodium viz. T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt. The experiment was carried out following Randomized Complete Block Design (RCBD) having one factor with three replications. The results on the effect of morphological characters indicated that plant height; number of tillers, leaf length, leaf breath, effective tiller, number of non-effective tiller, total dry matter weight, panicle length, thousand seed weight and grain yield were significantly influenced by salinity and sodium. All the measured morphological parameters were found highest in non-saline control treatment. But the parameters gradually declined in 2 and 12 dSm^{-1} salt treatment. However, sodium supplementation greatly mitigated the damaging effect of salt for the growth, development and yield of BRRI dhan47. But the mitigation effect was more prominent at low salinity stress (2 dSm^{-1}) compared to the higher stress (12 dSm^{-1}). Considering above facts, it can be concluded that the yield of BRRI dhan47 was gradually decreased by the increase of salinity levels and this reduction rate was decreased by exogenous supply of sodium. The best results were mostly found at T_1 treatment, which indicates that sodium has important roles in different physiological and metabolic processes of plants. When plants are subjected to salt stress then sodium played a crucial role to ameliorate stress condition.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
LAI	=	Leaf area index
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
RCBD	=	Randomized complete block design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
g	=	gram (s)
Kg	=	Kilogram
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Rice (Oryza sativa L.) is the staple food for more than half of the world's population. It is a cereal food crop of the grass family Gramineae, extensively cultivated in warm climates, especially in East Asia, producing seeds that are cooked and used as food. It is ranked second to wheat as the most extensively grown crop in the world, it is the most essential food crop and largest irrigated crop in the world (Roel et al., 1999). About 75% of the world's rice supply carries from 79 million hectare of irrigated land in Asia. Thereby, the present and future food security of Asia depends largely on the irrigated rice production system. About 90 percent of the population of Bangladesh is rice eaters. The Food Department of the Government of Bangladesh recommends 410gms of rice /day. Rice is rich in carbohydrates. The protein content is about 8.5 percent. The Thiamin and Riboflavin contents are 0.27 and 0.12 micrograms per gm of rice respectively. In Bangladesh total cultivable land is 90,98,460 hectare and near about 70 per cent of this land is under rice cultivation. In the year 2017-18, total production of rice was 3,62,793 metric tons (DAE, 2019).

About 2.8 million hectares of land in Bangladesh is within the grip of salinity which is equal to about one fifth of the total area. Out of the costal areas about 0.833 million hectares of the arable lands, which constitutes about 52.85% of the net cultivable area in 64 upazillas of 13 districts are affected by varying degrees of soil salinity.

Soil salinization adversely affects crop production worldwide and about 831 million hectares of lands are affected by salt stress (FAO 2005). The agricultural land is decreasing due to population pressure, adverse environmental condition, continuously increasing natural calamities, and global climate change (Hasanuzzaman *et al*., 2013).

In Bangladesh, there are approximately 2.85 million ha of coastal soils which occur in the southern parts of the Ganges tidal floodplain, in the young Meghna estuarine floodplain and in tidal areas of the Chittagong coastal plain and offshore islands (Brammer, 1978). About one million ha of land of these coastal and offshore areas are affected by varying degrees of salinity. These coastal saline soils are distributed unevenly in 64 thanas of 13 coastal districts covering 8 Agroecological zones (AEZ) of the country. The majority of the saline land (0.65 million ha) exists in the districts of Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola on the western coast and a smalle rportion (0.18 million ha) in the districts of Chittagong, Cox's Bazar, Noakhali, Lakshmipur, Feni and Chandpur. According to the report of Soil Resource Development Institute (SRDI, 2010) of Bangladesh, about 0.203 million ha of land is very slightly (2-4 dSm^{-1}), 0.492 million ha is slightly (4-8 dSm^{-1}), 0.461 million ha is moderately (8-12 dSm^{-1}) and 0.490 million ha is strongly (>12 dSm^{-1}) salt affected soils in southwestern part of the coastal area of Bangladesh. Large fluctuations in salinity levels over time are also observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November-December to March-April, until the onset of the monsoon rains.

Salinity in soil or water is one of the major stresses, can severely limit crop production (Shannon, 1998). The deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect, or (iv) a combination of these factors (Ashraf, 1994b; Marschner, 1995). All these cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels (Munns, 2002) and at molecular level (Mansour, 2000). It is often not possible to assess the relative contribution of these major constraints to growth inhibition at high substrate salinity, as many factors are involved. These include ion concentration, duration of exposure, plant species, cultivar, root stock (excluder and includer), and stage of plant development, plant organ and environmental conditions. So, to cope with the above constraints, salt stressed plants mainly adopt three mechanisms for salt tolerance such as (i) osmotic adjustment, (ii) salt inclusion/ exclusion and (iii) ion discrimination (Volkmar *et al*., 1998). Salt-induced osmotic stress, ion toxicity and nutrient deficiency primarily affectplant and causes growth reduction (Luo *et al*., 2005; Bhattacharjee, 2008). Salt stress decreases K^+ content and increase Na^+ uptake as Na^+ causes K^+ efflux and triggers K^+ leakage from plant cells. Na^+ displaces Ca^{2+} from membranes, which also increases intracellular Na^+ (Cramer *et al*., 1985; *Shabala* ***et al***., 2006; Wu and Wang, 2012). Generally, salinity affects the growth of rice plant at all stages of its life cycle. But reproductive stage is more sensitive than vegetative stage which has direct effect on grain yield (Afridi *et al*., 1988). Salt stress reduces the efficiency of water uptake by crop plants. Plant height, total number of tillers, panicle length, grain weight per panicle, 1000-seed weight and quantity of grains decreased progressively with increase in salinity levels (Abdullah *et al*., 2001). Rice is moderately susceptible to salinity, since most rice plants are severely injured at an EC 8-10 dSm-1. Yield loss due to salinity was recorded 30-50% and in Bangladesh farmers generally or often grow local rice varieties due to unavailability of suitable salt tolerant high yielding varieties (Islam *et al.,* 2007).

On the other hand, growth increases with increasing Na concentration in the medium until it reaches an optimal value in halophytes (Debez *et al*. 2006; Hussin *et al.* 2013). The same characteristics have been observed not only in halophytes but also in some glycophytes.

Sodium (Na^+) is a major plant micro-nutrient that plays important roles related to aid in metabolism and synthesis of chlorophyll. Na promotes growth cannot be explained by Na tolerance mechanisms. Few attempts have been made to clarify the mechanisms of growth promotion by Na. Na stimulates shoot succulence and cell expansion more significantly than K in Salicornia europaea L. (Lv *et al*. 2012b), and in Sesuvium portulacastrum L., Na maintains leaf succulence and promotes growth (Wang *et al.* 2012).

Response and adaptation of plant to salt stress involve alteration of cellular metabolism and invoking various defense mechanisms (Ghosh *et al*., 2011). Plants can survive under this stressful condition depending on their abilities to perceive the stimulus, generation and transmition of signals, and initiation of various physiological and biochemical changes (Tanou *et al*., 2009; El-Shabrawi *et al*., 2010). Under stress condition significant increase in reactive oxygen species (ROS), such as singlet oxygen ($1O_2$), superoxide (O_{2-}), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH).

Metabolic toxicity of Na is largely due to its ability to compete with K for binding site essential for cellular function (Bhandal and Malik 1988). At the early stages, a high concentration of solutes present in the soil brings about osmotic stress which reduces the capacity of root systems to absorb water and, meanwhile, accelerates the loss of water from the leaves. This is accompanied by ion-specific effects that cause the accumulation of toxic concentrations of Na^+ and Cl^- in the cells, which manifest in the form of chlorosis and necrosis of the leaves. The accumulation of internal solutes at low and moderate salt stress conditions may assist in overcoming osmotic stress in some plants [8]. A high salt concentration brings about similar deficiency symptoms as those caused by nutrient deficiency, because of the interference of ions in membrane functions, which affect the absorption of nutrients and the solute

At the same time, it also significantly reduced Na and Mg concentrations and consequently improved the K/Na, K/Mg and K/Ca ratios. Under saline conditions, the mineral nutrition of most plants can be expected to be detrimentally affected. The interactions between K and Na may be emphasized under such conditions and ultimately decrease plant growth (Noaman, 2004). In saline soils and other similar soils, the unfavorable conditions as well as inadequate and imbalance use of plant nutrients causes a considerable decline in paddy yield. Sodium is a micronutrient for plants that is required for physiological processes such as the maintenance of membrane potential and turgor, activation of enzymes, regulation of osmotic pressure, stomata movement and tropisms (Golldack, 2003). Nelson (1978) believed that Sodium has a positive role in plant growth under saline conditions, because this element plays an essential role in photosynthesis, osmoregulatory adaptations of plant to water stress. Adequate sodium supply is also desirable for the efficient use of Fe, while higher sodium application results in competition with Fe (Celik *et al*., 2010). Saqib *et al*. (2000) reported a significant reduction in all growth parameters considered and an increased concentration of Na and Cl, decreased K^+: Na^+ ratio.

The present work has therefore, been designed and planned with the following objectives:

- To evaluate the effect of different levels of soil salinity on the growth yield of BRRI dhan47
- To find out the maximum level of soil salinity for maximum growth yield of BRRI dhan47

CHAPTER II

REVIEW OF LITERATURE

Saline soil contains sufficient water-soluble salts on the root zone to impair the growth of crop plants. Salt injury depends on species, variety, growth stage, environmental factors, and characteristics of the soil. Soil characteristics included salt source, nature and content of salts, distribution of salts (lateral, vertical, and seasonal), p^H, organic matter content, nutrient status, water regime, other soil-related toxicities and deficiencies. Hence, it is difficult to define saline soil precisely. The following section describes some of the findings observed and reported by other researchers.

2.1 Abiotic stress

Worldwide agriculture is facing a lot of challenges like producing 70% more food for an additional 9.7 billion people by 2050 while at the same time fighting with poverty and hunger, consuming scarce natural resources more efficiently and adapting to climate change (Wilmoth, 2015). Stress may be defined as an environmental adverse state that can be reduced the plant growth and potential yield of crops. It is usually divided into two groups viz. biotic and abiotic stress (Pandey *et al.,* 2017). These two stresses have occurred normally in nature. But abiotic stress causes more damages than biotic stress. (Pande and Arora, 2017). Surveys say that every year about 50% yield loss due to the abiotic stresses such as drought, salinity, high temperature, mineral deficiency and metals toxicity (Haggag *et al*., 2015). However, the productivity of crops is not increasing in parallel with the food demand. The lower productivity in most of the cases is attributed to various abiotic stresses. Lowering crop losses due to various environmental stressors is a major area of concern to cope with the increasing food requirements (Shanker and Venkateswarlu, 2011). Abiotic stresses regulate plant metabolism leading to harmful effects on growth, development and productivity. If the stress becomes very high and/or continues for an extended period it may lead to an intolerable metabolic load on cells, reducing growth, and in severe cases, result in plant death (Hasanuzzaman *et al*., 2012). Harmful chemical entities called reactive oxygen species (ROS), which include hydrogen peroxide (H_2O_2), superoxide radical (O^{2-}), hydroxyl radical (OH^-), etc. are produced in the plant due to abiotic stress (Choudhury *et al*., 2013).

Keunen *et al*. (2013) concluded that plants suffering from abiotic stress are commonly facing an enhanced accumulation of reactive oxygen species (ROS) with damaging as well as signaling effects at organellar and cellular levels. The outcome of an environmental challenge highly depends on the delicate balance between ROS production and scavenging by both metabolic and enzymatic antioxidants. To meet these challenges, genes, transcripts, proteins, and metabolites that control the architecture and/or stress resistance of crop plants in a wide range of environments will need to be identified, in order to facilitate the biotechnological improvement of crop productivity. However, dependent on duration and magnitude of stress plants, try to adjust the environmental stress through changes in morphological structure, physiological and biochemical activities. Adaptive responses of plants to abiotic stress include closure the stomata which limit the water loss and initiation of a series of physiological processes for maintaining the integrity of photosynthesis, CO_2 fixation apparatus and increase the antioxidant activities in plants (Pandey *et al*., 2017). All biochemical components are present in plants which required for stress tolerance, but the strength of these biochemical components shift species to species depend on the magnitude of stress. This difference of the plant's response to stress depends on the signaling insight, transduction and potentiality of defense machinery of plants which respond to these signals (Ben Rejeb *et al*.,2014; Scheres and Van der Putten, 2017). Traditional plant breeding approaches to improve abiotic stress tolerance of crops had limited success due to multigenic nature of stress tolerance.

2.2 Salt stress

Salt stress is considered as one of the most brutal abiotic stress that hamper the normal growth and development of plants (Ahmad *et al.* 2015; Ahanger and Agarwal 2017). Salinity/salt stress refers to the excess amount of salts in the plant, soil and/or water which significantly reduces vigor and yield of the crop. Common salts found in nature are- sodium chloride, sodium sulphate, magnesium sulphate, potassium sulphate etc. (Hasanuzzaman *et al*. 2013). A considerable amount of land around the world is affected by salinity which is increasing day by day. More than 45 million hectares (M ha) of irrigated land which account to 20% of total land have been damaged by salt worldwide and 1.5 M ha are taken out of production each year due to high salinity levels in the soil (Pitman and Läuchli 2002 ; Munns and Tester 2008) .

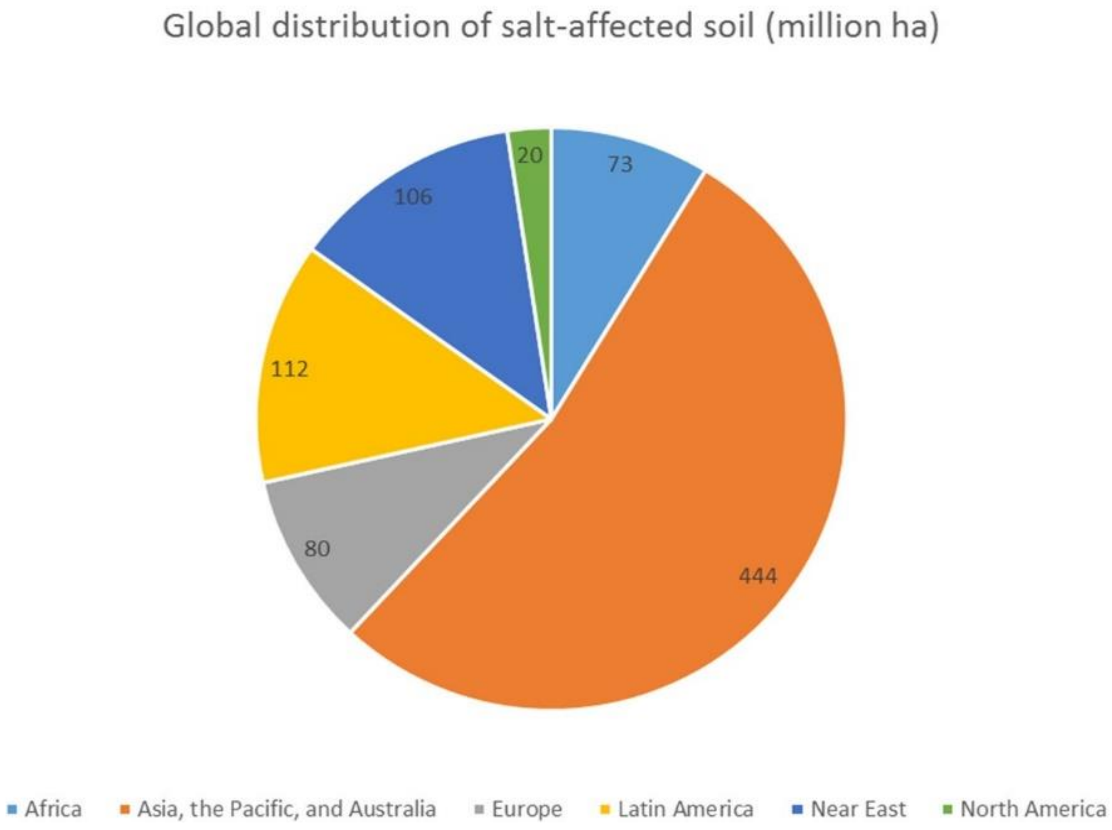

Figure 1: Global distribution of salt-affected soil (million ha) (Hoang et al. 2016)

In Bangladesh, around 20% of costal area covers approximately 30% of the net cultivable region (Shelley *et al*., 2016). As in monsoon season the coastal area flooded with saline water and contaminated groundwater which is low in concentration the problem is not severe, but in the dry season, salt concetntration increases because the contaminated groundwater comes out over the soil surface. For this reason land use varies with season to season; thus in winter season coastal area remains fallow. Whether, in wet-season, standing water decrease saline concentration in root zone which allows farmers to cultivate traditional rice varieties. The cropping intensity in saline area of Bangladesh is relatively low, mostly 170% ranging from 62% in Chittagong coastal region to 114% in Patuakhali coastal region (FAO, 2007).

Generally, two main stresses in plants viz. osmotic stress and ionic stress caused by salinity. Osmotic stress occurs when the salt concentration exceeds the tolerance level of plants around rhizosphere in soil, after that salt reaches in older leaves which increase the amount of Na^+ into plants and causes ionic stress, thus interruption the metabolic process and possess cell death (Munns and Tester, 2008; Hasanuzzaman *et al*., 2013a). Moreover, due to salinity many nutrients are unavailable for plant such as nitrogen (N), phosphorous (P), copper (Cu), zinc (Zn) and decrease potassium (K), calcium (Ca), magnesium (Mg) into plants causing significant yield loss (Nahar *et al*., 2016; Shelley *et al*., 2016).

Plants can be categorized into two groups on the basis of their salt tolerance and response to salt stress, such as (a) halophyte, (b) glycophte. Halophytes are those plants that can tolerate high concentration of salinity (400 mM); while glycophytes are tolerant to low concentration of salinity (Hoang *et al*., 2016). In nature, most of the crops are glycophytes and susceptible to salinity, except rye (*Secale cereale*) which is a salt- tolerant cereal crop which can withstand salt stressupto 11 dS m^{-1} electrical conductivity (USDA, 2016). However, rice is a moderate sensitive cereal crop to salinity having threshold electrical conductivity of 3 dS m^{-1} for most cultivated varieties (Mohanty, *et al*., 2013; Hoang *et al*., 2016, USDA, 2016), whereas, normally salinity is denoted in soil when electrical conductivity is above 4 dS m^{-1} (Rengasamy, 2006). For rice, even it was reported that rice yield reduce 10% and 50% at 3.5 dS m^{-1} and 7.2 dS m^{-1} of electrical conductivity respectively (Umali, 1993). Salinity stress tolerance among rice genotypes varies depending on different developmental stages. It has been reported that rice shows salt tolerant during germination, active tillering and toward maturity, but at the time of early vegetative stage and reproductive stage it shows susceptibility (Heenan *et al.*, 1988).

2.3 Effect of salt stress on plant

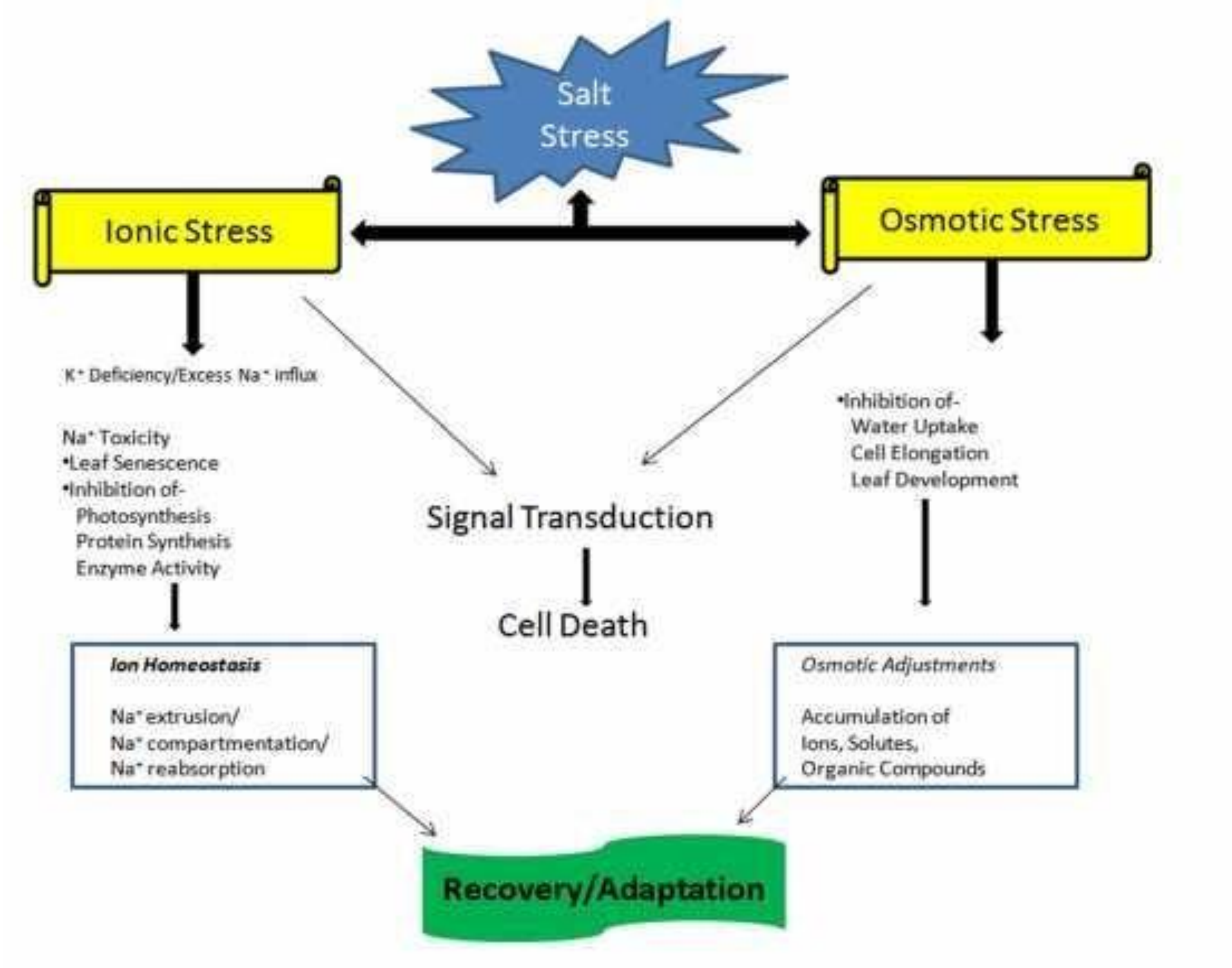

Figure 2: Possible responses of plants under salt stress

2.4.1 Effect of salt on plant water relations

Relative water content (RWC), leaf water potential, stomatal movements, transpiration rate, leaf and canopy temperature are the main characteristics of plant which effect on water relations. Effects of salt on plants water relations have been described in many previous studies. Mainly two components are involved in plant water relations namely water potential and hydraulic conductivity (Negrão *et al*., 2017). Salinity increases osmotic effect on plants due to the reduction of soil water potential surrounding the root zone, which interrupt the ability of water uptake from soil to maintain turgor pressure (Sabir *et al*., 2009). Moreover, under low and moderate salinity stress plants can maintain a potential gradient to uptake water through accumulation of osmolyte solutes. With increased evidence many researchers found that water potential and osmotic potential became more negative with increased salinity, whether, turgor pressure increased (Gulzar *et al*., 2003). In wheat (Triticum aestivum L.) plant, Nishida *et al*. (2009) pointed out that under high salinity concentration leaf water potential and transpiration rate of tomato plant was decreased. Similarly, several authors reported leaf water potential was decreased with the increased of salinity concentration in rice (Siddiqui *et al*., 2014); maize (Prasad *et al*., 2016). Ueda *et al.* (2013) were carried out an experiment with two rice cultivars namely CFX 18 (salt-tolerant) and Juma67 (salt-sensitive). They reported that leaf area, root-shoot fresh and dry weight, leaf water content and leaf water potential significantly decreased in Juma67 than CFX 18 with increased salinity, therefore, CFX 18 considered more salt tolerant. According to Ueda *et al*. (2013) it can be suggested that under higher salinity concentration plants sequester more NaCl in leaf tissue than normally occurs, thus, lower osmotic potentials and reduction in the root hydraulic conductance decreases water flow rate from root to shoot, causing water stress in the leaf tissue

2.4.2 Effect of salt on plant nutrient availability

Salt stress limits the nutrients uptake in plant. It also increases the Na^+ and Cl^- ions in plants; therefore, the concentrations of sodium (Na^+), calcium (Ca^{2+}) and nitrate (NO^{3-}) are decreased in plants (Tavakkoli *et al*., 2011). Both Na+ and Cl^- ions inhibit the growth of plants through reduced absorption of other ions and nutrients which are required for plants growth (Ahmed *et al*., 2015). It has also been reported that due to the accumulation of Na+ and Cl- in plant tissue potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and manganese (Mn^{2+}) reduced, whereas chloride (Cl-) ions limits the absorption of nitrate (NO3-), phosphate (PO_4^{3-}) and sulfate (SO_4^{2-}) ions (Termaat and Munns, 1986), which limited the growth of plants. Moreover, Na^+ and Cl^- ions due to salinity stress disturb the specific transport system of these ions into plants (Maathuis, 2006). On the other hand, in a greenhouse experiment Tunçtürk *et al.* (2011) investigated the effect of salinity on micronutrients of twelve canola (Brassica napus L.) cultivars and they observed due to 150 Mm NaCl stress iron (Fe), manganese (Mn) and copper (Cu) increased all the parts of plants except some of canola cultivars, whereas zinc (Zn) content in leaves of canola was not significantly affected. Ahmed *et al*. (2013b) reported that accumulation of calcium (Ca), manganese (Mn) and iron (Fe) was increased in wild barley (XZ5) than cultivated barley (CM72) under combined stress of drought and salinity. In contrast, Chakraborty *et al.* (2015) found that under salinity stress (6.76 dS m^{-1}) the accumulation of nitrogen (N), manganese (Mn), iron (Fe) and zinc (Zn) was decreased significantly in susceptible cultivar than tolerant cultivars of Brassica spp.

2.4.3 Effect of salt on photosynthetic pigments

Chlorophyll is a major chloroplast component of photosynthesis; therefore, chlorophyll contents have a correlation with photosynthetic rate. Salt stress decreases the chlorophyll contents through accumulation of Na^+ into older leaves. Due to the toxicity of Na^+ into the older leaves start to develop chlorosis and senescence (Yang *et al*., 2011). In some earlier studies on different plant species showed that salinity stress decreased the chlorophyll contents such as wheat (Triticum aestivum L.) (Perveen *et al*., 2010); corn (Zea mays L.) (Molazem *et al*., 2010); (Akram and Ashraf, 2011). Ghosh *et al*. (2015) carried out an experiment with mungbean (Vigna radiate L.) crop to investigate effect of salinity stress on plants and they observed that chlorophyll contents of mungbean (Vigna radiata L.) leaves decreased with the increased of salinity. Furthermore, the toxicity of Na^+ into oldest leaves impair the biosynthesis of chlorophyll contents or increase the degradation of photosynthetic pigments. Bhusan *et al.* (2016) observed in an experiment that under salinity stress chlorophyll b and total chlorophyll contents of rice cultivars decreased but chlorophyll a was increased significantly. Moreover, experiment on sunflower *(Heliantus annus L.)* (Akram and Ashraf, 2011) under salinity stress have showed that the important precursors of chlorophyll viz. glutamate and 5-aminolaevulinic acid (ALA) decreased during stress, which denoted that salinity stress affects more significantly on chlorophyll biosynthesis than breakdown. Although, it has been reported that reduction of chlorophyll contents under salinity stress depend on plant species because of chlorophyll contents increase in salt-tolerant cultivars, decrease in salt-sensitive cultivars (Khan *et al*., 2009). For this it has been suggested that increase of chlorophyll contents in salt-tolerant plants are a physiological indicator of salinity stress tolerance in wheat *(Triticum aestivum L)* (Raza *et al*., 2006); alfalfa (Medicago sativa) (Monirifari and Barghi, 2009); rice *(Oryza sativa L.)* (Chunthaburee *et al*., 2016).

2.4.4 Effect of salt on photosynthesis

Many studies have been reported on the reduction of photosynthetic activity under salt stress in a number of plant species (Stepien and Johnson, 2009; Pérez-López *et al.,* 2012). Photosynthesis activity impaired in salt stress due to the lower stomatal conductance, hampered in CO2 fixation process, photochemical capacity inhibited (Ahmed *et al.,* 2015). In a previous study Muranaka *et al*. (2002) observed that under 100 mM salt stress the photosynthesis rate was decreased in two wheats *(Triticum aestivum L)* at two stages. At first photosynthesis was decreased slowly without any visible changes in photochemical and after that in second stage photosynthesis was reduced together with impaired the energy generation efficiency of photo-system two (PSII). However, excessive accumulation of Na^+ under salinity stress in plants affects the electron transport system which reduced photosynthesis activity. Zeid (2009) reported that in maize (Zea mays L.) crop salinity stress reduced the photosynthesis activity through impaired the hill reaction. Moreover, at the time of reproductive stage salinity stress reduced the stomatal conductance, net CO_2 assimilations of wheat genotypes leaves (Perveen *et al*., 2010). Furthermore, reduction of photosynthesis in plants due to the salinity stress is related to reduce production of ATP through impair the electron transport system (Curtiss *et al*., 2011). Ionic toxicities of Na^+ and Cl^- reduced the growth and photosynthesis of plants through impaired the photosynthetic apparatus reported by Tavakkoli *et al.* (2011). With increased evidence it was reported that photosynthesis activity of plant species reduced under salinity stress such as tomato *(Solanum lycopersicum)* (Sholi, 2012);

mustard *(Brassica juncea L.)* (Wani *et al*., 2013); cotton *(Gossypium hirsutum L.)* (Zhang *et al.,* 2014). Wang *et al*. (2017) observed in their experiment that specific ionic toxicity of Na^+ and Cl_- decreased the photosynthetic rate, CO_2 concentration and also impaired the electron transport system in rice (Oryza sativa L.) crop leaves.

2.4.5 Effect of salt on plant yield

Salt stress affects on plant growth at different stages of life cycle. The adverse effect of salinity on rice crop at different stage was observed by Zeng *et al*. (2001) and they were exposed the rice crop to salinity at the time of seeding, first leaf, third leaf, panicle initiation (PI) and booting stages respectively. They point out that salinity stress before PI reduced shoot dry weight and grain yield. Yield of plants are closely associated with grain number and weakly associated with grain size; therefore, Harris *et al.* (2010) carried out a greenhouse experiment with barley (*Hordeum vulgare L.*) and wheat *(Triticum aestivum L.)* to observe the effect of salinity on growth and yield. They observed at high salinity stress grain number reduced at 31%, 22% in barley and wheat crop respectively and also grain size reduced in both crops. Moreover, salinity stress at flowering stage also detrimental as like drought stress. In tomato *(Solanum lycopersicum L.)* plant, salinity reduced the yield due to the tomato plants were subjected to salinity at flowering and fruiting stages (Zhang *et al*., 2017). Plants yield also correlated with spikelet fertility and grain filling. For this, Ahmed *et al.* (2013) observed in a greenhouse experiment on barley *(Hordeum vulgare L.)* cultivars that under single or combined stress of drought and salinity during anthesis period reduced spike length and grain filling per spike in CM72 and XZ16 at 22.6%, 27.7% and 36.8%, 19.9% respectively.

2.5 Effect of salt stress on rice plants

Higher level of salinity stress decreased the biomass remarkably in plants. According to Ishak *et al.* (2015) high concentration of salinity (300 mM NaCl) reduced the shoot dry weight of wild-type Nippobare upto 57.14%.

In a greenhouse experiment Hussain *et al*. (2016) used eleven diverse rice genotypes to investigate the effect of salinity stress. For this they exposed the rice plant under 200 mM (NaCl) concentration salinity stress at reproductive stage and observed that the reduction of plant height is higher in BRRI dhan56 (7.67%), followed by BRRI dhan40 (7.18%), BRRI dhan41 (6.52%), BRRI dhan53 (5.55%), IR29 (5.06%), Nona Bokra (4.17%), FL-

478 (3.99%) and Binadhan-8 (1.50%) with little reduction in Binadhan-7 (0.91%), whereas Binadhan-10 was not affected.

Mostofa *et al*. (2015) conducted an experiment with rice crop (BR11) at different concentration of salinity (150 mM and 250 mM). They exposed fourteen-day-old rice seedlings in salinity stress and observed relative water content (RWC) decreased at 15- 25% and total chlorophyll content decreased at 17-38%.

Ebrahimi *et al.* (2012) carried out pot experiment in 2011 in Rice Research Institute of Iran to examine the effects of potassium application methods on rice *(Oryza sativa L.)* under different soil salinity levels. Four methods of sodium application: N0: spraying with distilled water every 10 days interval (control); Na1: the use of 65mg $NaKg^{-1}$ soil; Na_2: spraying 5% NaCl solution in every 10 days interval; NO: the use of 65mg Na Kg^{-1} soil plus spraying with 5% NaCl solution every 10 days interval and four levels of irrigation water salinity (tap water and salinities 2, 4 and 6 dSm^{-1}) were investigated in complete randomized block design with three replications. Results showed that soil salinity affected growth and yield components in most of the cases. Sodium application alleviated the stress condition and significantly improved dry matter yield and yield components in rice. Grain, straw, total biological yield, harvest index, 100 grains weight, root dry weight and total tillers significantly decreased with increasing salinity. The interaction between salinity levels and methods of sodium application was significant only for root dry weight. Based on the results use of 65 mg Na Kg^{-1} soil plus spraying with 5% NaCl solution every 10 days interval was most effective in increasing the above features.

Kandil *et al*. (2010) conducted three field experiments at El-Sirw Agricultural Research Station, Damietta during 1999, 2000 and 2001 under saline soil. The field experiments were laid out in split-split plot design with four replications. The main plots were devoted to four irrigation treatments i.e., continuous flooding (I1), water withholding for 12 days at 15 days after transplanting (DAT) (I2), at 25 DAT (I3) and at 35 DAT (I4). The sub plots were allocated to the three rice cultivars viz. Sakha 101, Sakha 102 and Giza 178. Three K rates 0, 48 and 46 kg K_2O ha^{-1} was randomized in the sub-sub-plots. The growth characteristic like leaf area index (LAI), dry matter productions (DM) g/m2, chlorophyll content, heading date were studied along with the chemical traits i. e Na and K contents of shoot as well as Na/K ratio. It was observed that water stress at any growth stage significantly decreased LAI, DM and chlorophyll content and delayed the heading date. Similarly, water stress increased Na and K contents (%) in shoots while it had no effect on Na/K ratio. Varietal differences were found significant in all studied characters. Giza 178 had the superiority in this concern as compared to other varieties while Sakha 102 was found inferior in all parameters under these conditions. Na rates significantly increased LAI, DM, chlorophyll content and Na% up to 48 kg K_2O ha^{-1} while lessen Na% and Na/K ratio and hastened the heading date. The interaction between irrigation treatments and varieties affected LAI, DM, chlorophyll content and heading date while the interactive effects of irrigation and K^+ rates had significant effect on LAI, while cultivars and K^+ rates significantly affected DM and chlorophyll content.

Ashraf *et al*. (2010) conducted a hydroponics experiment to evaluate the role of sodium (Na) and silicon (Si) in mitigating the deleterious effects of NaCl on rice cultivars differing in salt tolerance. Two salt-sensitive (CPF 243 and SPF 213) and two salt-tolerant (HSF 240 and CP 77-400) rice cultivars were grown for six weeks in ½ strength Johnson's nutrient solution. The nutrient solution was salinized by two NaCl levels (0 and 100 mmol L^{-1} NaCl) and supplied with two levels of Na (0 and 3 mmol L^{-1}) and Si (0 and 2 mmol L^{-1}). Applied NaCl enhanced Na^+ concentration in plant tissues and significantly ($P \leq 0.05$) reduced shoot and root dry matter in four rice cultivars. However, the magnitude of reduction was much greater in salt-sensitive cultivars than salt-tolerant cultivars. The salt interfered with the absorption of Na^+ and Ca^{2+} and significantly ($P \leq 0.05$) decreased their uptake in rice cultivars. Addition of K and Si either alone or in combination significantly ($P \leq 0.05$) inhibited the uptake and transport of Na^+ from roots to shoots and improved dry matter yields under NaCl conditions. Potassium uptake, K^+/Na^+ ratios, Ca^{2+} and Si uptake were also significantly ($P \leq 0.05$) increased by the addition of Na and/or Si to the root medium. In this study, K and Si-enhanced salt tolerance in rice cultivars was ascribed to decreased Na^+ concentration and increased Na^+ with a resultant improvement in K^+/Na^+ ratio, which is a good indicator to assess plant tolerance to salt stress. Zayed *et al*. (2007) conducted two field experiments at the experimental farm of El Sirw Agriculture Research Dammiatta prefecture, Egypt during 2005 and 2006 seasons.

The study aimed toinvestigate the effect of various potassium rates; Zero, 24, 48 and 72 Kg K_2O ha^{-1}, on growth, sodium, potassium leaf content and their ratio at heading, grain yield and yield components of three hybrids: SK2034H, SK2046H, SK2058H and three varieties; Giza 177, Giza 178 and Sakha 104. The economic values were also estimated. The experimental soil was clayey with salinity levels of 8.5 and 8.7 dSm-1 in the first and second seasons, respectively. The experiments were performed in a split plot design with four replications. The main plots were devoted to the tested rice varieties, while potassium rates were distributed in the sub plots. The studied varieties varied significantly in their growth parameters, Na^+ and K^+ leaf content at heading as well as ratio, yield components and their economic values. SK2034H surpassed the rest varieties without any significant differences with SK2046H. SK2058H didn't show advantage over Giza 178 or Sakha 104. Giza 177 was the worst under such conditions. Increasing potassium rate significantly improved all studied traits leading to high grain yield. Furthermore, potassium succeeded to reduce Na^+, lower Na^+ /K^+ ratio and raised K^+ resulted in considerable salinity withstanding. The hybrids of SK2034H and SK2046H as well as the salt sensitive rice variety Giza 177 were the most responsive cultivars to potassium fertilizer up to 72 kg K_2O ha^{-1}. Consequently, the economic estimates SK2034H had the higher net return and the high potassium level of 72 kg K_2O ha^{-1} gave the highest values of economic parameters under the tested saline soil conditions. Mehdi *et al*. (2007) conducted a field experiment to evaluate the response of rice crop to potassium fertilization in saline-sodic soil during 2005. Soil samples were collected before transplanting of rice crop and analyzed for physical and chemical properties of the soil. In this experiment five rates of K_2O (0, 25, 50, 75 and 100 kg ha^{-1}) were applied in the presence of basal doses of N and P_2O_5 i.e., 110 and 90 kg ha^{-1}, respectively. Whole of P, K and ½ of N were applied at the time of rice transplanting. Twelve and half kg ha^{-1} $ZnSO_4$ was also applied 15 days after rice transplanting. The remaining half of N was applied 30 days after rice transplanting. The system of layout was Randomized Complete Block Design with four replications. The net plot size was 6x4 m. Fertilizer sources of NPK were urea, TSP and SOP, respectively. Rice salt tolerant line PB-95 was used as test crops. The data of growth parameters and yield was recorded and samples of paddy and straw were collected treatment-wise and analyzed for N, P and K contents. Soil samples after harvesting the crop were also collected, processed and analyzed for the changes in the extractable soil K. The results showed that increasing rates of potassium fertilizer increased the number of tillers m-2, plant height (cm), 1000-paddy weight and paddy as well as straw yield significantly. Maximum paddy (3.24 t ha^{-1}) and straw (3.92 t ha^{-1}) yields were obtained in T5 (100 kg Na_2O ha^{-1}) which was at par with T4 (75 kg Na_2O ha^{-1}). With increasing rates of sodium fertilizer, concentration of sodium in paddy and straw increased significantly. After harvesting the crop, the extractable potassium contents of soil increased from that of the original soil. It was concluded from the results that there was an increase of 30.65% in paddy over control by applying potassium (100 kg Na_2O ha^{-1}) in saline-sodic soil. Cha-um *et al*. (2005) conducted an investigation with an objective to evaluate the effective salt-tolerance defense mechanisms in aromatic rice varieties. Pathumthani 1 (PT1), Jasmine (KDML105), and Homjan (HJ) aromatic ricevarieties were chosen as plant materials. Rice seedlings photoautotrophically grown in-vitro were treated with 0, 85, 171, 256, 342, and 427 mM NaCl in the media. Data, including sodium ion (Na^+) and potassium ion (K^+) accumulation, osmolarity, chlorophyll pigment concentration, and the fresh and dry weights of seedlings were collected after salt-treatment for 5 days. Na^+ in salt-stressed seedlings gradually accumulated, while K^+ decreased, especially in the 342-427 mM NaCl salt treatments. The Na^+ accumulation in both salt-stressed root and leaf tissues was positively related to osmolarity, leading to chlorophyll degradation. In case of the different rice varieties, the results showed that the HJ variety was identified as being salt-tolerant, maintaining root and shoot osmolarities as well as pigment stabilization when exposed to salt stress or Na+ enriched cells. On the other hand, PT1 and KDML105 varieties were classified as salt-sensitive, determined by chlorophyll degradation using Hierarchical cluster analysis. In conclusion, the HJ-salt tolerant variety should be further utilized as a parental line or genetic resource in breeding programs because of the osmoregulation defensive response to salt-stress.

Zafar *et al*. (2004) investigated the response of rice cultivars Basmati-370 (salt-sensitive) and IR6 (salt-tolerant) to 2 salinity levels (4.0 (control) and 10 dSm-1) in a pot experiment in a wire-house. They took four harvests at an interval of 10 days each after imposition of salinity treatment, growth and chemical analyses of plant samples were carried out. Plant biomass showed an inverse relationship with increasing salinity levels. A general trend of decrease in dry weight of plant with salinity was noted in both cultivars. The mean values for dry weight were higher in Basmati-370 in the control condition. Analysis of variance showed a significant increase in Na^+ and Cl^- uptake with increasing salinity. Varietal means were highly significant and the maximum increase in Na^+ uptake (18.69%) was recorded in Basmati-370. Harvest means showed that Na^+ uptake increased with the passage of time. However, at maturity there was a decline in Na^+ content in both cultivars. Cl^- increased with increasing salinity levels. Cultivar x treatment interaction revealed an increase in Na^+ and Cl^- uptake over the control in both cultivars. However, it was less in IR6. The cultivars differed significantly for K^+, $Ca^{2+,}$ P and N uptake. K^+ and Ca^{2+} uptake increased with the passage of time. Basmati-370 and IR6 showed 45.20 and 15.55% decrease in Ca^{2+} over the control. P and N uptake increased with increasing salinity levels. An increase of 23.21% P uptake was recorded in Basmati-370 compared to IR-6. However, IR-6 accumulated higher (22.16%) N compared to Basmati-370 under the control and saline conditions.

Wu and Wang (2012) conducted to investigate the effects of Ca^{2+} on cation accumulation and K^+/Na^+ selectivity, in this study, two-week-old rice (*Oryza sativa* L.) plants were exposed to 25 or 125 mmol/L NaCl with or without 10 mmol/L $CaCl_2$. At low salinity (25 mmol/L NaCl), Ca^{2+} significantly decreased Na^+ accumulation in roots, increased K^+ accumulation in shoots, and maintained higher K^+/Na^+ ratios in both roots and shoots of rice plants. At high salinity (125 mmol/L NaCl), however, Ca^{2+} did not have any effects on Na^+, K^+ accumulation and K^+/Na^+ ratios in plants. Further analysis showed that, at low salinity, the addition of Ca^{2+}significantly enhanced the selective absorption and transport capacity for K^+ over Na^+ in rice. Although Na^+ efflux and Na^+ influx were remarkably reduced by Ca^{2+} under both low and high salt stresses, their ratio was lowered only under low salt stress. In summary, these results suggest that Ca^{2+} could regulate K^+/Na^+ homeostasis in rice at low salinity by enhancing the selectivity for K^+ over Na^+, reducing the Na^+ influx and efflux, and lowering the futile cycling of Na^+.

Regulation of ion transport is one of the important factors responsible for salt tolerance in plants. Membrane proteins play a significant role in selective distribution of ions within the plant or cell (Ashraf and Harris, 2004). According to Du-Pont (1992) the membrane proteins involved in cation selectivity and redistribution of Na^+ and $K^{+.}$ These proteins are: (a) primary H^{+-}ATPases which generate the H^+

electrochemical gradient that drives ion transport, (b) Na^+/H^+ antiports in the plasma membrane for pumping excess Na+ out of the cell, (c) Na^+/H^+ antiports in the tonoplast for extruding Na^+ into the vacuole and (d) cation channels with high selectivity for K^+ over Na^+. It is well established that Na+ moves passively through ageneral cation channel from the saline growth medium into the cytoplasm of plant cells (Marschner, 1995; Jacoby, 1999; Mansour *et al*., 2003) and the active transport of Na^+ through Na^+/H^+ antiports in plant cells is also evident (Shi *et al.,* 2003). Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). Energy-dependent transport of Na^+ and Cl^- into the apoplast and vacuole can occur along with the H^+ electrochemical potential gradients generated across the plasma membrane and tonoplast (Hasegawa *et al*., 2000). The tonoplast H^+ pumps (H^+-ATPase and H^+-pyrophosphatase) also play a significant role in the transport of H+ into the vacuole and generation of proton (H^+) which operates the Na^+/H^+ antiporters (Mansour *et al*., 2003; Blumwald, 2000).

Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al*. (1997) conducted a pot experiment with three rice cultivars and reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by Saleque *et al.* (2005). During vegetative period, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent (Alam *et al.,* 2001). The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and high plant yield (Baloch *et al*., 2003).

Baba and Fujiyama (2003) investigated short-term (72 h) responses of the water and nutritional status to Na-salinization in rice (Oryza sativa L. cv. Koshihikari) andtomato (Lycopersicon esculentum Mill cv. Saturn) using pot experiments. The short-term effect of supplemental Na and Cl to the nutrient solution on the water status absorption and transportation of ions in the plants was also investigated. In both species, Na salinity resulted in the deterioration of the water status of tops and in nutritional imbalance. However, in rice, it was possible to prevent the deterioration of the nutrient status by enhancing the transport of cations, especially Na, while tomato could maintain an adequate water status by inhibiting the water loss associated with transpiration. On the other hand, the water status in rice and the nutritional status in tomato markedly deteriorated by high Na level in the solution. Supplemental Na and Cl could not ameliorate the water status in both species, and even worsened the status in rice. In rice, a close relationship was observed between the osmotic potential (OP) of the solution, water uptake and water content. The water status of rice, therefore, seemed to depend on OP of the solution. Supplemental K and Ca, on the other hand, were effective in the amelioration of the nutritional status. In tomato, supplemental Ca could improve the nutritional balance by suppressing the transport of Na and enhancing that of the other cations in avoidable deterioration of the water status. Thus, the differences in the responses of the water and nutritional status of rice and tomato to high Na salinization and to supplemental K and Ca were evident in a short-term study and supported a similar tendency observed in a long-term study.

Fageria (2003) evaluated the dry matter production and the concentration of nutrients in rice *(Oryza sativa L.)* cultivars from soil adjusted to different levels of salinity under a greenhouse condition. Soil salinity levels were produced by applying 0.34 mol L^{-1} solution of NaCl which resulted in the following levels, control (0.29), 5, 10 and 15dSm^{-1} conductivity of saturation extract. The effect of salinity on dry matter production varied from cultivar to cultivar. The concentrations of P and K in the top of rice cultivars decreased with increasing soil salinity but the concentrations of Na, Zn, Cu and Mn increased. Significant varietal differences were found in relation to salinity tolerance.

Many scientists have suggested that selection is more convenient and practicable if the plant species possesses distinctive indicators of salt tolerance at the whole plant, tissue or cellular level (Ashraf, 2002; Epstein and Rains, 1987; Jacoby, 1999; Munns, 2002). Physiological criteria are able to supply more objective information than agronomic parameters or visual assessment while screening for component traits of complex characters (Yeo, 1994). There are no well-defined plant indicators for salinity tolerance that could practically be used by plant breeders for improvement of salinity tolerance in a number of important agricultural crops. This is partly due to the fact that the mechanism of salt tolerance is so complex that variation occurs not only among the species but, in many cases, also among cultivars within a single species (Ashraf, 1994a; 2002). During the course of plant growth, the form and functions of various organs undergo significant change and the ability of the plant to react to salinity stress depend on those genes that are expressed at the stage of development during which the stress is imposed (Epstein and Rains, 1987). The mechanism of salinity tolerance becomes even more complicated when the response of a plant also varies with the concentration of saline medium and the environmental conditions in which the plant is grown. Considerable improvements in salinity tolerance have been made in crop species in recent times through conventional selection and breeding techniques (Shannon, 1998; Ashraf, 1994a; 2002). Most of the selection procedures have been based on differences in agronomic characters, which represent the combined genetic and environmental effects on plant growth and include the integration of the physiological mechanisms conferring salinity tolerance. Typical agronomic selection parameters for salinity tolerance are yield, biomass, plant survivalism, plant height, leaf area, leaf injury, relative growth rate and relative growth reduction.

Din *et al*. (2001) used artificially salinized soils to see the effect of foliar and soil application of K on rice. Results indicated that the number of tillers plant-1, paddy and straw yield and grains to straw ratio significantly decreased with the increase in salinity. All K application methods increased the above parameters significantly at all salinity levels over distilled water spray. Increasing levels of salinity decreased K concentration in shoots and straw, which was increased significantly by foliar and soil application. Both methods of K application remained at par with each other. Sodium concentration increased the with increase in salinity in both shoots and straw and decreased by foliar and soil application of Na. Foliar application of Na proved better than soil application in this respect. The K/Na ratio decreased significantly by the increase of salinity, while this ratio increased significantly by the foliar and soil application of Na.

Alamel al. (2001) stated that the critical EC level of salinity for seedling growth was about 5 dSm^{-1}. They observed that dry matter, seedling height, root length and emergence of new roots of rice decreased significantly at an electrical conductivity value of 5-6 dSm^{-1} and during the early seedling stage, higher salinity caused rolling and withering of leaves, browning of leaf tips and ultimately death of seedlings. They speculated that both osmotic imbalance and Cl^- was responsible for suppressing the growth. These authors showed that the shoot growth was more suppressed than that of root and salt injury was more severe at high temperature (35°C) and low humidity

(64%) due to increased transpiration and uptake of water and salt by rice plants. At the reproductive stage, salinity depressed grain yield much more than that at the vegetative growth stage. These authors found that at critical salinity levels straw yield was normal but produced little or no grain. The decrease in grain yield was found proportional to the salt concentration and the duration of the saline treatment. When the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains hence caused an increase in the number of sterile florets. The greatest injurious effect was on the panicle. Salinity severely reduced the panicle length, number of primary branches per panicle, number of spikelet per panicle, seed setting percentage, panicle weight and reduced the grain yield. The weight of 1000-grain was also reduced. Salt injury resulted in the production of small grains in grain length, width and thickness. Most rice cultivars were severely injured in submerged soil cultures at EC of 8-10 dSm-1 at 25^{o} C; sensitive ones were hurt even at 2 dSm^{-1}. At comparable EC's injury was less in sea water than in solutions of common salt, in neutral and alkaline soils than in acid soils, at 20oC than at 35oC and in 2-week-old seedling than in 1-week old seedlings. Since rice plant is susceptible to salinity at transplanting and gains tolerance with age, they advised that aged seedlings (6 weeks old) be planted in saline fields.

Abdullah *et al*. (2001) performed an experiment on the effect of salinity stress (50 mM) on floral characteristics, yield components, biochemical and physiological attributes of the sensitive rice variety IR-28. The results showed significant decrease in panicle weight, panicle length, primary branches per panicle, filled and unfilled grain, total grains and grain weight per panicle, 1000-grain weight and total grain weight per hill. They further observed significant reduction in both chlorophyll a and chlorophyll b content in different parts of the rice leaves at saline condition. In another experiment, Abdullah *et al.* (2002) studied the effect of salinity on photosynthate translocation in panicle branches and developing spikelets, carbohydrate content of different vegetative parts and suggested that reduction in grain number and grain weight in salinized panicles were not merely due to reduction in pollen viability and higher accumulation of Na^+ and less K^+ in different floral parts but also due to higher accumulation of photosynthates (sugar) in primary and secondary panicle branches, panicle main stalk and panicle stem coupled with reduced activity of starch synthetase in developing grains.

Several salt-induced proteins have been identified in plant species and have been classified into two distinct groups such as (i) salt stress proteins, which accumulate only due to salt stress and (ii) stress associated proteins, which also accumulate in response to heat, cold, drought, water-logging and high and low mineral nutrients (Pareek *et al*., 1997; Ali *et al*., 1999; Mansour, 2000). Proteins that accumulate in plants grown under saline conditions may provide a storage form of nitrogen that is neutralized when stress is over and may play a role in osmotic adjustment (Singh *et al*., 1987). A higher content of soluble proteins has been observed in salt tolerant than in salt sensitive cultivars of barley, sunflower (Ashraf and Tufail, 1995) and rice (Lutts *et al.,* 1996; Pareek *et al.,* 1997). Pareek *et al.* (1997) also suggested that stress proteins could be used as important molecular markers for improvement of salt tolerance using genetic engineering techniques.

Amino acids have been reported to have accumulated in higher plants under salinity stress (Ashraf, 1994b; Mansour, 2000). The important amino acids are alanine, arginine, glycine, serine, leucine and valine, together with the amino acid - proline and the non-protein amino acids- citrulline and ornithine (Mansour, 2000). Lutts *et al.* (1996) found that proline did not take part in osmotic adjustment in salt stressed rice and its accumulation seemed to be a symptom of injury rather than an indicator of salt tolerance. On the contrary, Garcia *et al*. (1997) reported that exogenously applied proline exacerbated the deleterious effects of salt on rice. The salt tolerant rice cultivars Nona Bokra and IR 4630 accumulated less proline in their leaves than the salt sensitive Kong Pao and IR 31785 (Lutts *et al.,*1996). These contrasting reports on the role of proline in salt tolerance and its use as selection criterion for salt tolerance in rice has been questioned.

Franco *et al*. (1999) studied the effect of supplemental $CaCl_2$ on growth and osmoregulation in NaCl stressed cowpea seedlings. They found that salinity inhibited the length of root and shoot of cowpea but the inhibitory effect could be ameliorated by the addition of Ca^{2+}. The concentration of organic osmoregulators (proline, soluble carbohydrates, soluble amino-nitrogen, and soluble proteins) increased in root tips of seedlings grown in salt-stressed condition with supplemental Ca. They indicated that

Ca^{2+} could have a protective effect in root tips, which is of fundamental importance for the maintenance of root elongation in NaCl stressed cowpea seedlings. Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentration of either inorganic ions or low molecular weight organic solutes. Although both of these play a crucial role in higher plants grown under saline conditions, their relative contribution varies among species, among cultivars and even between different compartments within the same plant (Ashraf, 1994a).

Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al.* (1997) conducting a pot experiment with three rice 2005cultivars reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by Saleque *et al*. (2005). During vegetative period, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent (Alam *et al*., 2001). The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and high plant yield (Baloch *et al*., 2003).

Salinity affected rice during pollination, decreased seed setting and grain yield (Maloo, 1993). Finck (1977) suggested that deficiency of Na and Ca elements might play a significant role in plant growth depression in many saline soils. Girdhar (1988) observed that salinity delayed germination, but did not affect the final germination up to the EC of 8 dSm^{-1} by evaluating the performance of rice under saline water irrigation. In normal conditions, the Na^+ concentration in the cytoplasm of plant cells was low in comparison to the K^+ content, frequently 10^{-2} versus 10^{-1} and even in conditions of toxicity, most of the cellular Na^+ content was confined into the vacuole (Apse et al., 1999).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experiment period, site description, climate condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operation, data collection and statistical analysis.

3.1 Experimental location

To study the morpho-physiological and yield responses of rice, this experiment was conducted at the experimental shed of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka during the period from Dccember-2019 to April-2020.

3.2 Soil condition

The soil of experimental area situated at the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgaon soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.5 - 6.5. The physical and chemical characteristics of the soil have been presented in Appendix III.

3.3 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September).

3.4 Selection of cultivars

BRRI dhan47 is a salt tolerant variety, which was used as the test crop in this experiment. This variety was released in 2007 by Bangladesh Rice Research Institute (BRRI), Gazipur. It can tolerate salinity 12-14 dSm^{-1} (up to 3 weeks) during seedling stage and 6 dSm^{-1} during reproductive stage. Grain is medium fine. Its plant height is 105 cm and yield are 5-6 t ha^{-1}. Life cycle of this variety ranges from 150 to 155 days.

3.5 Experimental design

The experiment was set up using Randomized Complete Block Design (RCBD) having single factor with three replications. The treatment combination of the experiment was assigned at random into 21 pots of each at 3 replications.

3.6 Treatments

The experiment consisted of one factor salinity level and sodium concentration

1. T_0 = Control
2. T_1 = 2 dSm^{-1} NaCl Salt
3. T_2 = 4 dSm^{-1} NaCl Salt
4. T_3 = 6 dSm^{-1} NaCl Salt
5. T_4 = 8 dSm^{-1} NaCl Salt
6. T_5 = 10 dSm^{-1} NaCl Salt
7. T_6 = 12 dSm^{-1} NaCl Salt

3.7 Collection and preparation of soil

The soil of the experiment was collected from Sher-e-Bangla Agricultural University (SAU) farm. The soil was non-calcareous Red Brown Terrace soil with silty loam texture belonging to the AEZ-28 Madhupur Tract. The collected soil was pulverized and inert materials, visible insect pest and plant propagules were removed. The soil was dried in the sun, crushed carefully and thoroughly mixed.

3.8 Sterilization of seed

Prior to germination, seeds were surface sterilized with 1% sodium hypochlorite solution. The glass vials containing distilled water for seed rinsing was sterilized for 20 minutes.

3.9 Sowing of seeds in seed bed

The sterilized seed were soaked with water for 24 hours, washed thoroughly in clean water, and incubated for sprouting, which were sown in the wet seed bed. Required amount of fertilizers were applied one day before sowing seeds in the seed bed.

3.10 Raising of seedlings

The seedlings were grown in pots and the soil was used as growth medium. Chemical fertilizers namely Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Ammonium Sulphate and Zinc Sulphate were used for N, P K, S and Zn at the rate of 140, 120, 100, 12 and 2 kgha^{-1} respectively before final preparation of the seed bed. The fertilizers were applied one day before sowing seeds.

3.11 Seedling transplant in the pots and application of salinity stress

The chemical fertilizers i.e., Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Ammonium Sulphate and Zinc Sulphate were applied as N, P K, S and Zn at the rate of 2.34gm N, 0.3gm P, 1.6gm K, 0.2gm S and 32mg Zn in every pot respectively. Sodium Sulphate used as per requirement. The whole amount of TSP, Gypsum and 1/3rd of urea were applied before the final preparation of the pots. After the pots containing soil with moistened water. Five weeks old seedlings of BRRI dhan47 were transplanted in the respective pots. There were two hills in each pot. Two weeks after transplanting, the salt solutions were applied in each pot according to the treatments. To avoid osmotic shock, salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. The electrical conductivity (EC) of each pot was measured every day with a EC meter and necessary adjustments were made by adding water. The remaining 2/3rd urea were top dressed at two equal divisions after 25 and 50 days of transplanting.

3.12 Collection of data

3.12.1 Plant height

The plant height (cm) was measured from the surface level of the growth media to the tip of the longest panicle at harvesting by taking the average value of ten random samples, but before heading it was measured from base to tallest leaf tip.

3.12.2 Total tiller hill^{-1}

Total tiller number hill^{-1} has counted at maximum tillering stages. At the final harvest, the data on yield components like number of effective tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1} and grain yield hill^{-1} were recorded.

3.12.3 Length and breath of leaf

Length and breadth of the leaf of each sample plant has recorded and sum total of them were divided by the total number of leaves of the sample plant. Leaf breadth was measured at the middle (widest part of the leaf) of each leaf.

3.12.4 Number of effective tillers

Effective tiller number hill^{-1} has counted at harvesting. There were two hills in each pot. The effective tiller number hill^{-1} was counted from the pot.

3.12.5 Number of non-effective tillers

Number of sterile tillers has also counted by subtracting the number of effective tillers from the total tiller number hill^{-1}.

3.12.6 Total dry matter

The total dry matter was recorded by drying the plants at 80 ± 2^{o}C for 48 hours and calculated from summation of leaves, stem, roots and panicle weight as observed in an electronic balance.

3.12.7 Panicle length

Average panicle length (cm) was calculated by taking the lengths of all the panicles hill^{-1}.

3.12.8 Grain yield per hill

The grain yield of each hill has measured for those hills which had effective tiller and then data were recorded.

3.12.9 Statistical analysis

The collected data were analyzed statistically following CRD design by MSTAT-C computer package programme developed by Russel (1986). The treatment means were compared by Duncan's Multiple Range Test (DMRT) and regression analysis were performed as and where necessary.

CHAPTER IV

RESULTS AND DISCUSSION

Result obtained from the present study have been presented and discussed in this chapter. The data have been presented in different tables and figures. The results have been presented and discussed, and possible interpretations are given under the following headings.

4.1 Plant height

The height of the plant was significantly influenced by salinity and sodium at 30, 60, 90 DAT (Days After Transplanting) and harvesting (Table 1). At 30 DAT, the highest plant height (80.07 cm) was observed at control (T_1) treatment and the lowest plant height (53.68 cm) was observed at T_0 (2 dSm^{-1} salt) treatment. The tallest plant height (106.4 cm) was obtained at control (T_1) treatment which was followed by T_5, T_3, and T_6 while the shortest plant height (63.37 cm) was obtained by T_0 (2 dSm^{-1} salt) treatment at 60 DAT. At 90 DAT, the tallest plant height (128.0 cm) was obtained by at control (T_1) treatment which was followed by T_2, and by T_4 while the shortest plant height (82.11 cm) was obtained by at T_0 (2 dSm^{-1} salt) treatment. At harvest, the tallest plant height (126.6 cm) was obtained at control (T_1) treatment which was followed by T_3, T_2, and by T_6 while the shortest plant height (82.00 cm) was obtained by T_0 (2 dSm^{-1} salt) treatment. Choi *et al*. (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al*. (1997) conducting a pot experiment with three rice cultivars reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by Saleque *et al*. (2005).

4.2 Number of total tillers hill^{-1}

Total number of tiller hill^{-1} was statistically influenced by different salinity level with sodium at 30, 60, 90 DAT (Days After Transplanting) and harvesting. The maximum number of tiller hill^{-1} (12.00) was produced from control treatment (T_1) and the minimum number of tiller hill^{-1} (6.33) was produced form T_0 treatments at 30 DAT. At 60 DAT, the maximum number of tiller hill^{-1} (17.33) was produced from treatment (T_1), which was followed by T_3 (16.00) and the minimum number of tiller hill^{-1} (10.33) was produced form T_0 treatments. At 90 DAT, the maximum number of tiller hill^{-1} (17.00) was produced from control treatment (T_1), which was followed by T_3

(15.67) and T_2 and the minimum number of tiller hill^{-1} (9.33) was produced form T_0 treatments. Zeng and Shannon (2000) stated that tiller number hill^{-1} and spikelet number per panicle contributed the most variation in grain yield hill^{-1} under salinity. Choi *et al*. (2003) observed that tiller number of rice decreased in 0.5% saline water in the soil with low salinity level. Zeng *et al*. (2001) observed that reduction in tiller number per plant was significant only when plants were salinized for 20 days duration before panicle initiation (PI) of rice. The tiller number decreased significantly at 15.62 dSm^{-1} salinity level in BR11 rice (Gain *et al.*, 2004). Grattan *et al*. (2002) reported that salinity threshold for rice yield was at the EC of 3.0 dSm^{-1} and tiller densities reduced by 40% as compared to control (0.4 dSm^{-1}).

4.3 Leaf length

Length of leaf showed statistically significant differences due to the different levels of salinity with sodium. The longest leaf (43.11 cm) was found at control (T_1) treatment, which was followed by T_2, T_5, T_3, T_6 and T_1 and the lowest leaf length (37.94 cm) was recorded at T_0 treatment (Table 2).

4.4 Leaf breath

Breath of leaf showed statistically significant differences due to the different levels of salinity with sodium. The maximum leaf breath (1.62 cm) was obtained at treatment (T_1), which was followed by T_2, T_5 and T_3 and the minimum leaf breath (1.22 cm) was recorded at T_0 treatment, which was followed by T_1 and T_6 (Table 2).

4.5 Total dry mater plant^{-1}

Salinity with sodium had a significant influence on the total dry mater plant^{-1}. The highest total dry mater plant^{-1} (23.99 g) was recorded in T_1 (control), which was followed by T_3, T_2, T_6, T_5 and T_1. The lowest total dry mater per plant (11.56g) was recorded in T_0 (Table 2).

Table 1. Interaction Effect of Different Salt Concentrations and Sodium Levels on The Plant Height of Rice at Different Days After Transplanting

Treatment combinations	Plant height (cm) at different days after transplanting							
	30 DAT		60 DAT		90 DAT		At harvest	
T_0	53.68	d	63.37	d	82.11	c	82.00	c
T_1	80.07	a	106.4	a	128.0	a	126.6	a
T_2	77.31	ab	103.5	a	125.0	a	122.9	ab
T_3	72.10	b	101.2	a	121.1	d	118.6	ab
T_4	65.94	c	90.14	b	107.9	b	105.8	b
T_5	62.37	cd	76.78	cd	100.3	bc	100.1	bc
T_6	58.69	cd	81.76	c	99.02	c	99.55	bc
LSD $_{(0.05)}$	**4.40**		**7.12**		**17.82**		**7.43**	
Significance level	*		*		*		*	
CV (%)	**6.88**		**5.59**		**2.62**		**6.84**	

T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt

*-Significant at 5% level, NS-Non-Significant

At 30 DAT the lowest plant height is 53.68 cm obtained by (T_0), which was statistically similar with T_0, T_1, T_2, T_3, T_4, T_5 and T_6 treatment respectively. At 60 DAT, the highest plant height obtained by T_1 (106.4 cm) which was statistically similar with T_0, T_1, T_2, T_3, T_4, T_5 and T_6 treatment respectively. In 90 DAT the highest plant height obtained by T_1 (128.0 cm) which was statistically with T_0, T_1, T_2, T_3, T_4, T_5 and T_6 treatment. At harvest the highest plant height 126.6 cm (T_1), it was statistically similar with T_0, T_1, T_2, T_3, T_4, T_5 and T_6 treatment respectively. At 60 DAT the lowest plant height obtained by T_0 (63.37 cm) statistically similar with T_0, T_1, T_2, T_3, T_4, T_5 and T_6 treatment respectively). Results are in agreement with that of Rahman *et al*. (2016a)

Table 2. Effect of Salinity with Sodium on Leaf length, Leaf breath and Total Dry Mater Weight on Rice

Treatment combinations	Leaf length (cm)		Leaf breath (cm)		Total dry mater weight (g)	
T_0	33.36	d	1.13	d	10.11	de
T_1	43.11	a	1.62	a	23.99	a
T_2	42.29	a	1.36	b	17.15	b
T_3	41.64	b	1.34	b	16.79	b
T_4	41.41	b	1.29	c	14.44	c
T_5	39.29	c	1.28	c	14.32	c
T_6	37.94	cd	1.22	cd	11.56	d
LSD $_{(0.05)}$	**1.625**		**0.082**		**2.313**	
CV (%)	**11.82**		**8.59**		**3.41**	

T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

4.6 Number of effective tillers hill^{-1}

The number of effective tillers hill^{-1} of rice was significantly influenced by different levels of salinity with sodium (Table 3). The highest number of effective tillers hill^{-1} (15.00) was recorded at T_1 treatment and the lowest (5.90) was found at T_0 treatment. Bohra and Doerffling (1993) observed that plant height, number of tillers and shoot dry weight reduced under salinity stress in both salt tolerant and salt sensitive rice cultivars. They observed that salinity stress wasted more energy in salt sensitive rice cultivars than that of salt tolerant ones. Khatun *et al*. (1995) found that salinity delayed flowering, reduced the number of productive tillers, the number of fertile florets panicle^{-1}. Salt tolerance indexes in terms of seed yield, seed weight panicle^{-1}, spikelet number panicle^{-1} and tiller number plant^{-1} were reduced with increasing salinity (Zeng *et al.,* 2002). Our results also indicate that the percent effective tiller hill^{-1} was badly affected at higher salinity levels. However, Sodium supplementation has mitigated to some extent by increasing effective tiller hill^{-1}.

4.7 Number of non-effective tillers hill^{-1}

The mean effect of different salinity levels with sodium influenced the number of non-effective tillers hill^{-1} (Table 3). The highest number of non-effective tillers hill^{-1} (2.33) was observed in T_4 treatment and it was least in control treatment (0.67) Sodium supplementation enhanced panicle growth through minimizing toxicity effect of salinity. Alam *et al.,* (2001) stated that the salinity at reproductive stage of rice depressed grain yield much more than that at the vegetative growth stage and at critical salinity levels it might give normal straw yield of rice but produced little or no grain. They also observed that when the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains and hence caused an increase in number of sterile florets. The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles plant^{-1} (Baloch *et al.,* 2003).

Table 3. Effect of Salinity with Sodium on Number of Effective Tiller and Non-Effective Tiller Per Hill on Rice

Treatment combinations	Number of effective tiller per hill		Number of non-effective tiller per hill	
T_0	5.90	ef	0.67	c
T_1	15.00	a	1.33	b
T_2	13.67	ab	1.33	b
T_3	12.50	ab	1.33	b
T_4	10.33	c	2.33	a
T_5	8.00	d	0.67	c
T_6	6.33	e	0.67	c
LSD $_{(0.05)}$	**1.52**		**0.28**	
CV (%)	**2.83**		**1.98**	

T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

4.8 Length of the panicle

Length of panicle showed statistically significant differences due to different levels of salinity with sodium (Table 4). The longest panicle (25 cm) was found at T_1 treatment and the lowest panicle length (18.33 cm) was recorded at T_6 treatment. Khatun *et al.* (1995) and Alam *et al.* (2001) reported that salinity severely reduced the panicle length, seed setting percentage and panicle weight. Similar to panicle bearing tillering in sodium supplemented salinity treatment, panicle length also recovered by Na supplementation. But the effect was more prominent in higher salinity level (160 dSm^{-1} salt) (Table 44)

4.9 Grain yield pot^{-1}

A highly significant variation in grain yield hill^{-1} of rice cultivars (BRRI dhan47) was observed due to different salinity levels with sodium (Table 4). The highest grain yield (216.83g) was recorded at T_1 treatment, which was followed by T_2 and T_3 and it was lowest (112.01g pot^{-1}) at T_6 treatment. In comparison to control (without salt), the reduction of grain yield was highest in T_4 (8 dSm^{-1} salt) treatment (47.28%) followed by T_1 (2 dSm-1 salt) treatment (39.45%). But in both of the salt treatment, Sodium supplementation greatly mitigated. The damaging effect of salinity thereby reducing grain yield reduction. However, the mitigation effect was more in less salinity stress (2 dSm^{-1} salt). Grain yield is the function of number of panicles hill^{-1}, number of filled grain panicle^{-1} and 1000-grain weight. All the yield contributing characters contributed for the yield reduction hill^{-1} under saline conditions; contribution of the seriously affected number of unfilled grains panicle^{-1} was the highest (Grattan *et al.,* 2002). Baloch *et al.* (2003) observed that the mutant variety of rice “Shua-92” maintained its superiority over other varieties in various characteristics such as plant height, higher number of fertile panicles plant^{-1}, more fertile grains panicle^{-1}, heavy grain size and high plant yield at 7.11- 8.0 dSm^{-1} salinity.

4.10 Number of primary branch panicle^{-1}

The number of primary branch panicle^{-1} was significantly influenced by different salinity levels with sodium (Table 4). The highest number of primary branch per panicle (10.78) was recorded at T_1 treatment and the lowest (9.22) was found at T_6 treatment. Primary branches panicle^{-1} was greatly affected in high salinity stress.

However, the mitigation effect of sodium was found better for low salinity level (10 dSm^{-1}).

4.11 Thousand seed weight

A highly significant variation in thousand seed weight of rice cultivars was observed due to different salinity levels with sodium (Table 3). The highest thousand grain weight (21.75g hill-1) was recorded at T_1 treatment and it was lowest (16.99 g hill-1) at T_6 treatment. Similar affect was observed for thousand grain weight ie. More reduction of 1000- grain weight was observed for higher salinity level but mitigation of reduction in 1000-grain weight was least in 10 dSm^{-1} salinity. Grain yield is the function of number of panicles $hill^{-1}$, number of filled grain $panicle^{-1}$ and 1000-grain weight. All the yield contributing characters contributed for the yield reduction $hill^{-1}$ under saline conditions; contribution of the number of unfilled grains $panicle^{-1}$ was the highest (Grattan *et al.*, 2002). Baloch *et al*. (2003) observed that the mutant variety of rice "Shua-92" maintained its superiority to other varieties in various characteristics such as plant height, higher number of fertile panicles $plant^{-1}$, more fertile grains $panicle^{-1}$, heavy grain size and high plant yield at 7.11- 8.0 dSm^{-1} level of salinity.

Table 4. Effect of Salinity with Sodium on Yield and Yield Contributing Character of Rice

Treatment combinations	Length of panicle (cm)		Primary branch per panicle		Thousand seed weight (g)		Yield (g/pot)		Yield (ton ha^{-1})	
T_0	16.35	d	8.21	d	15.38	de	112.01	e	4.36	e
T_1	25.00	a	10.78	a	21.75	a	216.83	a	7.91	a
T_2	21.67	b	9.81	b	19.11	b	189.86	b	6.92	b
T_3	20.67	bc	9.56	bc	17.79	c	173.54	bc	6.33	c
T_4	19.33	bc	9.34	bc	16.36	d	167.02	c	6.09	c
T_5	18.00	c	9.33	c	15.03	e	158.69	cd	5.79	cd
T_6	17.33	cd	9.22	c	16.99	cd	139.87	d	5.10	d
LSD $_{(0.05)}$	**1.44**		**0.43**		**1.12**		**17.48**		**0.60**	
CV (%)	**6.67**		**12.35**		**7.45**		**4.90**		**5.22**	

T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at the net house of the Department of Soil Science at Sher-e-Bangla Agricultural University, Dhaka-1207. During boro rice growing season (December to April) of the year of 2019-2020 to know the effect of different levels of salinity on growth and yield of rice. The experiment was conducted using seven salinity levels with sodium viz. T_0 = Control, T_I = 2 dSm^{-1} NaCl Salt, T_2 = 4 dSm^{-1} NaCl Salt, T_3 = 6 dSm^{-1} NaCl Salt, T_4 = 8 dSm^{-1} NaCl Salt, T_5 = 10 dSm^{-1} NaCl Salt, T_6 = 12 dSm^{-1} NaCl Salt. The experiment was carried out following Randomized Complete Block Design (RCBD) having one factor with three replications.

The results on the effect of morphological characters indicated that plant height; number of tillers, leaf length, leaf breath, effective tiller, number of non-effective tiller, panicle length, thousand seed weight and grain yield were significantly influenced by salinity and sodium. All the measured morphological parameters were found highest in non-saline control treatment. But the parameters gradually declined in 2 and 12 dSm^{-1} salt treatment. However, sodium supplementation greatly mitigated the damaging effect of salt for the growth, development and yield of BRRI dhan47. But the mitigation effect was more prominent at low salinity stress (2 dSm^{-1}) compared to the higher stress (12 dSm^{-1}).

Considering above facts, it can be concluded that the yield of BRRI dhan47 was gradually decreased by the increase of salinity levels and this reduction rate was decreased by exogenous supply of sodium. The best results were mostly found at T_1 treatment, which indicates that sodium has important roles in different physiological and metabolic processes of plants. When plants are subjected to salt stress then sodium played a crucial role to ameliorate stress condition.

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APPENDICES

The experimental site under study

Appendix I. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace.
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

Appendix II. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	22
% Silt (0.02-0.002 mm)	57
% Clay (<0.002 mm)	21
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic Matter (%)	1.09
Total N (%)	0.3
Available K (ppm)	15.63
Available P (ppm)	10
Available S (ppm)	2.1

(SAU Farm, Dhaka)