ROLE OF HALOPRIMING IN IMPROVING GROWTH AND YIELD OF SALT STRESS AFFECTED RICE

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CERTIFICATE

This is to certify that the thesis entitled **"ROLE OF HALOPRIMING IN IMPROVING GROWTH AND YIELD OF SALT STRESS AFFECTED RICE PLANT"** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **SHEIK MD. SHOWKAT AZIZ,** Registration No. **12-04844** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated: June, 2020.
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Dedicated to those who

“Working to feed the hungry planet”

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ABSTRACT

The experiment was conducted at the Research Field of the Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2018 to May, 2019 to investigate the role of halopriming (HP) in improving growth and yield of salt stress (S) affected rice (*Oryza sativa* L. cv. BRRI dhan67) plant. The experiment consists of nine treatments viz. T_1 =Control, T_2 = HP_1 (0.25 dSm^{-1}), T_3= HP_2 (0.5 dSm^{-1}), T_4 = S_1 (8 dSm^{-1}), T_5 = S_2 (12 dSm^{-1}), T_6 = S_1HP_1 (8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}),T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}) and T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}) based on a randomized complete block design (RCBD) with three replications. Data on different growth parameters, physiological parameters and yield contributing characters of rice plants were recorded. Salt stress drastically decreased plant height (cm), number of tillers plant^{-1} , leaf area, SPAD meter reading (chlorophyll measurement of leaf), days to flowering, number of effective tillers plant^{-1}, panicle length, number of fertile grains plant^{-1}, number of unfertile grains plant^{-1}, 1000 seed weight, total weight of grains, dry weight of stem, leaf, root leaf membrane stability index (LMSI), relative water content (RWC) and K contents in shoot and root whereas as increased Na in root and shoot. Between two salinity level (S_1, 8 dSm^{-1} and S_2, 12 dSm^{-1}), the damaging effect was higher in higher salinity level (S_2, 12 dSm^{-1}). On the other hand, the damaging effects of salt stress were improved by halopriming. The rice plants performed better in response to halopriming under salt stress condition. Between the different levels, halopriming with 0.50 dSm^{-1} NaCl (HP_2) showed the better results in terms of growth, physiology, yield attributes and yield.

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LIST OF ABBREVIATIONS

BRRI	Bangladesh Rice Research Institute
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate
ROS	Reactive oxygen species
SRDI	Soil Resource Development Institute
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
LAI	Leaf area index
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
^0C	Degree Celsius
mm	Millimeter
%	Percent
cv.	Cultivar
NPK	Nitrogen, Phosphorus and Potassium
CV%	Percentage of coefficient of variance
h	Hour
T	Ton
viz.	Videlicet (namely)
d	Days
HP	Halopriming
dSm^{-1}	Deci Siemens per meter
EC	Electrical conductivity

CHAPTER I
INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Poaceae and cultivated in warm climate, especially in East Asia. Rice is rich in carbohydrates and the protein content of rice is about 8.5 percent. The thiamin and riboflavin contents are 0.27 and 0.12 micrograms per gm of rice, respectively. It delivers the considerable amount of recommended zinc and niacin (Gopalan, 2007). 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).

Rice is the main staple food for more than half the world's population, in which Asia representing the largest producing and consuming region. In recent years, rice has also become an important staple all over Africa (FAOSTAT, 2013). Rice is a staple food for nearly half of the world's seven billion people. However, more than 90% of this rice is consumed in Asia, where it is a staple for a majority of the population, including the region's 560 million hungry people (IRRI, 2013). Rice is considered as a major food crop across major countries worldwide. It is the 2nd most vital crop in the world after wheat, covering almost 90% of area across Asia alone. As a food crop, it forms the staple food of more than three billion people accounting for about 50-80% of their daily calorie intake (Khush, 2005).

Constant change in climate challenges crop production through various abiotic stresses, which become major limitations to crop production due to the unpredictable and complex nature of the environment (Mittler and Blumwald, 2010). Plants are exposed to various adverse environmental conditions such as drought, salinity, extreme temperature, etc. and those abiotic stresses unfavorably disturb the plant growth and productivity which causes a variety of biochemical, physiological and metabolic changes in plants, eventually decreasing the yield (Xiong and Zhu 2002). Among them, salinity is one of the most overwhelming abiotic stresses because most of the crop plants are sensitive to salt stress (Hasanuzzaman *et al.*, 2013). About 20% of irrigated land has been affected by salinity (Pitman and Lauchli, 2002), salt stress will cause up to 50% loss of arable land in the middle of the 21st century (Mahajan and Tuteja, 2005). Salinity is usually used to define the presence of higher levels of different salts such as sodium chloride, magnesium and calcium sulphates and bicarbonates in soil and water (Hoang, 2014). The nature of damages due to salt stress is very complex because it causes both osmotic stress and ionic toxicity (Hasanuzzaman *et al.,* 2013). Plants exposed to higher levels of salinity which are affected by both hyperionic and hyperosmotic stress through amassing Na^+ and $Cl^–$ that causes membrane damage, nutrient imbalance, enzymatic inhibition, metabolic dysfunction, photosynthesis inhibition, and hinders other major physiological and biochemical processes that ultimately leads to growth inhibition or death of the plant (Mahajan and Tuteja, 2005; Ahmad and Sharma, 2008; Munns and Tester, 2008; Hasanuzzaman *et al*., 2012). Nowadays, salinity has been a potential threat affecting nearly 900 million ha of land which approximately accounts for 20% of the worldwide cultivated area and also half of the total irrigated land of the world (Munns, 2002 and FAO, 2007). Worldwide salt affected area accounts for about 1 billion ha of land (Fageria *et al*., 2012). Higher levels of salt in plant growth medium decline K^+ content and upsurge Na^+ uptake, like that, Na^+ causes K^+ efflux and triggers K leakage from plant cells. Higher levels of NaCl, Na dislocates Ca from membranes, that rises intracellular Na. As a result, under salinity conditions Na content surpasses K, resulting in a higher Na/K ratio as well as nutrient imbalance (Cramer *et al.,* 1985; Shabala *et al.,* 2006; Wu and Wang, 2012). Globally, soil salinity unfavorably distresses crop production, about 831 million hectares of lands are affected by salt stress (FAO, 2005). In Bangladesh, about 2.85 million ha of coastal soils occurring in the southern parts of the Ganges tidal floodplain (Brammer, 1978). According to Soil Resource Development Institute (SRDI, 2010) of Bangladesh, approximately 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.

Rice is considered as a salinity sensitive crop (Maas, 1986; Maas and Hoffman, 1977; Flowers and Yeo, 2004, Munns and Tester, 2008). Salinity persuaded stress inhibited seed germination constraints to attain unvarying seedling stand in rice (Almansouri *et al.,* 2001) and finally reduces economic yield and quality of produce (Ali *et al.,* 2004). The serious salinity level resulting in 50% yield loss which estimated to be around 6.9 $dSm^{−1}$ for rice (Van Genuchten and Gupta, 1993). Rice is sensitive particularly at young seedling stage, where varying degree of mortality occurs at 50 mM NaCl and about 50% of 14 days old seedlings may die in most salt sensitive varieties within ten days of salinity stress (Flowers and Yeo, 1981). Salt stress alone was found to cause reduction in germination percentage, shoot and root lengths, fresh weight and seedling vigor (Misra *et al.,* 1996; Promila and Kumar 2000; Misra and Dwivedi, 2004). Salt stressed plants mainly approve three mechanisms for salt tolerance such as (i) osmotic adjustment, (ii) salt inclusion/ exclusion and (iii) ion discrimination (Volkmar *et al.,* 1998). Additionally, salinity tolerance is mutable with growth stage, with seedling and 'panicle initiation to flowering' being the most sensitive periods (Moradi *et al.,* 2003). Overall, salt-stress affects the growth of rice plant at all stages of its life cycle, though reproductive stage is more sensitive than vegetative stage which has directly affected on grain yield (Afridi *et al.,* 1988). Plant height, total number of tillers, panicle length, grain weight per panicle, 1000-seed weight and quantity of grains declined progressively with increase in salinity levels (Abdullah *et al.,* 2001). Most of the rice plants are severely injured at an EC 8-10 dSm^{-1}. Due to salinity, yield loss was noted 30-50% and in Bangladesh, farmers usually or often grow local rice varieties due to unavailability of suitable salt tolerant high yielding varieties (Islam *et al.,* 2007). Better establishment of the crop is considered to be essential for the efficient use of resources like water and light. In the rainfed semi-arid tropics regions, the balance between water supply and demand is critical and more conservative population densities are often required. Good germination and emergence are the keys to controlling stand establishment. Vigorous early growth is also connected with better yields (Okonwo and Vanderlip, 1985; Austin, 1989; Carter *et al.,* 1992). Seeds spend a great deal of time just absorbing water from the soil when sowing, if this time is minimized by soaking seeds in water before sowing (seed priming), seed germination and seedling emergence is more rapid. Enhancement of salinity tolerance in crop species is one potential tactic in overcoming salinity problems in agriculture (Flowers, 2004; Yamaguchi and Blumwald, 2005).

Seed priming is a technique to reduce emergence time, accomplish uniform emergence time, better algometric (changes in growth of plant parts over time) attributes and deliver vital stand in many horticultural and field crops. Various prehydration or priming treatments have been employed to increase the speed and synchrony of seed germination (Bradford, 1986). Presowing seed priming helps to improve germination and stand establishment (Mehta *et al.*, 2014). Various priming techniques include osmopriming (soaking seeds in osmotic solutions such as polyethylene glycol), halopriming (soaking seeds in salt solutions) and hydropriming (soaking seeds in water). Osmopriming contributes to significant improvement in seed germination and seedling growth in different plant species (Pill, W. G. *et al.,*1991). Priming treatments improve seed germination comprise of hydropriming (Afzal *et al.,* 2008), osmopriming (Afzal *et al.,* 2006) and hormonal priming (Afzal *et al.,* 2007). Similar to other priming techniques, Seed priming with different salts (halopriming), especially NaCl, have shown to improve germination and growth of many crops under stressed conditions (Sivritepe and Sivritepe, 2007). However, the advantageous effect of priming has been related to various biochemical, cellular and molecular events including synthesis of DNA and proteins (Bray *et al.*, 1989).

In saline soil, dissolving NaCl in water to induce osmotic stress by limiting water availability to plants (Pagter M. *et al.* 2009). Higher concentration of Na^+ interrupts membrane integrity, internal solute balance and nutrient uptake, causing nutritional paucity symptoms (Ashraf *et al.,* 2018). It is demonstrated that maximum increase in germination and other seedling parameters was viewed in halopriming and in osmopriming and also improve the performance of crop by lessening the effect of salts under saline soil conditions (Mohammadi 2009). Various researches on priming has proved that crop seeds primed with water germinated early, root and shoot development started rapidly, grew more vigorously and seedling length was also significantly greater than nonprime seeds. Seeds primed with NaCl solution (1 mM) at different salinity levels 0, 3, 6 and 9 dSm^{-1} in relation to early growth stage resulted that seed priming with NaCl has been found to be better treatment as compared to nonprime seeds in case of hot pepper for improving the seedling vigor and stand establishment under salt stressed conditions (Khan *et al.,* 2009). Treatment of seeds also plays an important role in protecting the seeds and seedlings from seed borne diseases and insect pests distressing crop emergence and its growth (Nicholas and Steven, 2013). Seed priming of different crops lessens the adverse effects of salinity stress and increases crop yield (Ahmed *et al.* 1998; Hedegree and Varite, 2000; Harris *et al.,* 1999; Pill and Kilan, 2000). Seed priming with NaCl had lessened the negative effect of salt stress in all cultivars and primed plants showed better response to salinity compared to unprimed plants (Meriem *et al*., 2014).

Halopriming is a pre-sowing soaking of seeds in salt solutions (inorganic salts i.e $NaCl$, KNO_3, $CaCl_2$ and $CaSO_4$ etc.), which improves germination and seedling emergence uniformly under adverse environmental conditions. A number of studies resulted that a significant improvement in seed germination, seedling emergence and establishment and final crop yield in salt affected soil in response to halo-priming. Khan *et al.* (2009) have shown a result that the response of seeds primed with NaCl solution at different salinity levels 0, 3, 6 and 9 dSm^{-1} in relation to early growth stage and determined that seed priming with NaCl has found to be a better treatment as compared to nonprime seeds. Priming with NaCl and KCl was helpful in removing the deleterious effects of salts (Iqbal *et al.*, 2006). As the rice production of some regions of Bangladesh is often affected by salt stress and very little research works have been conducted on the effect of seed priming on salt affected rice plants. Therefore, the present study was carried out with the following objectives:

- To study the morphophysiology, yield contributing characters and yield of rice plant under salt stress.

- To observe the role of halopriming in alleviating salinity induced damages in rice plant.

CHAPTER II

REVIEW OF LITERATURE

Salt stress causes significant damages to the plants in terms of germination, growth, physiology. Salt stress also affects developmental processes of plants and decreases yield. This section reviews the effect of salt stress on plants in different perspectives. The role of halopriming in mitigating salt-induced damage has been also reviewed on the basis of available literature.

2.1 Effect of salt stress on plants

Salinity is a major factor for threatening crop productivity all over the world. Most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil. Day by day, considerable amount of land in the world is affected by salinity. Increasing salinity of agricultural land is expected to have destructive global effects, results show up to 50% loss of cultivable lands by the middle of the twenty- first century (Mahajan and Tuteja, 2005).

Mondal *et al.* (2001) stated that almost 30% of the crops land of Bangladesh is located on the southwest coastal region of the country which can continuously maintained crops productivity and GDP growth. But Karim *et al.* (1990). specified in the recent past, salinity diminished the contribution of crops to GDP. In total, 52.8% of the arable land in the coastal region of Bangladesh was affected by salinity in 1990. From the SRDI (2001). defined that the salt affected area has increased by 14600 ha per year.

FAO (2007). Stated that the changing degree of salinity of southwest coastal region of Bangladesh, crop production becomes very risky and crop yields, cropping intensity, production levels of crop and people ‘s quality of livelihood are much lower than that in the other parts of the country. Cropping intensity in saline area of Bangladesh is comparatively little, generally 170% ranging from 62% in Chittagong coastal region to 114% in Patuakhali coastal region.

Tavakkoli *et al.*, (2010). concluded that the negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the serious conditions for plant survival by seizing different plant mechanisms. Although both Na^+ and Cl^- are the major ions produce many physiological disorders in plant, Cl^- is the most hazardous.

Mahajan and Tuteja, (2005); Hasanuzzaman *et al*., (2012a). initiate that the salinity at higher levels causes both hyperionic and hyperosmotic stress and can lead to plant decease that may cause membrane damage, nutrient imbalance, different levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which eventually leading to plant death.

Khan and Weber (2008) observed that higher level of salt stress hinders the germination of seeds while lower level of salinity brings a state of dormancy. Hasanuzzaman *et al. (*2009) observed a significant reduction in germination rate of 4 rice cultivars when exposed to various concentration of salt (30-150 mM).

Nahar and Hasanuzzaman, (2009) resulted the sensitive cultivars were more prone to germination reduction under salt stress. Up to 55% germination percentage diminished when irrigated with 250 mM NaCl.

Khodarahmpour *et al.* (2012) noticed the drastic reduction in germination rate (32%), length of radicle (80%) and plumule (78%), seedling length (78%) and seed vigor (95%) when *Zea mays* seeds were exposed to 240 mM NaCl.

Peng *et al.* (2008) observed the negative effect of salinity on plant growth, development and yield. Salt stress has negative correlation with seed germination and vigor of wide variety of crops, salinity-induced ionic and osmotic stresses lessen rate of photosynthesis and consequently cause oxidative stress, which is also responsible for growth reduction the damages by higher salinity in plant started from germination and exist till demise of plant. The negative effects of salt stress finally reduced yield of most crops including rice, except some halophytes.

Munns (2002a, b). noticed, one of the earliest effects of salt stress on plant is the reduction of growth rate. The presence of salt in the soil reduces the water uptaking capacity of the plant and this rapidly causes reduction in the growth rate. This phase of the growth response is due to the osmotic effect of the soil solution containing salt and produces a package of effects similar to water stress.

Some crops are most sensitive under saline condition during vegetative and early reproductive stages, less sensitive during flowering and least sensitive during the seed filling stage. Dolatabadian *et al.* (2011) concluded that salinity stress significantly declined shoot and root weight, total biomass, plant height and leaf number but not affected leaf area while studying with *Glycine max*.

Parida *et al. (*2004) noticed that the photosynthesis rate was improved at low salinity while reduced at high salinity, whereas stomatal conductance remained unaffected at low salinity and diminished at high salinity.

Saha *et al.* (2010). resulted that a linear decrease in the levels of total Chl, Chl *a*, Chl *b* Car and xanthophylls as well as the intensity of Chl fluorescence in *Vigna radiata* under increasing concentrations of NaCl treatments. Hasanuzzaman *et al.* (2011) also observed that a higher chlorosis in wheat and rapeseed leaves when exposed to salt stress.

Romero-Aranda *et al.* (2006) found that increase of salinity in the root medium can lead to a decrease in leaf water potential and may affect many plant processes. Due to increase in solute concentration in the root zone, osmotic effects of salt on plants are the result of lowering of the soil water potential. At very low soil water potentials, plants capability to extract water from the soil and maintain turgor.

Ghoulam *et al.* (2002) showed that at low or moderate salt concentration (higher soil water potential), plants regulate osmotically (accumulate solutes) and maintain a potential gradient for the influx of water. Salt treatment caused a significant reduction in relative water content (RWC) in sugar beet varieties.

Steudle (2000) concluded that in transpiring plants, water is thought to come from the soil to the root xylem through apoplastic pathway due to the hydrostatic pressure gradient. This situation changes because of the restricted transpiration under salt stressed condition.

Many researchers indicated that salt stress significantly reduced the yield of crops, as Greenway and Munns (1980) reported that salt tolerant species such as sugar beet might have a reduction of only 20% in dry weight, a moderately tolerant species such as cotton might have a 60% reduction, and a sensitive species such as soybean might be deceased.

Murty and Murty (1982) investigated that the severe inhibitory effects of salts on fertility may be due to the differential competition in carbohydrate supply between vegetative growth and constrained supply of these to the developing panicles.

Hasanuzzaman *et al.,* (2009) resulted that, grain yield of rice varieties which is the definitive product of yield components greatly influenced by salinity levels. The loss of grain yield due to 150 mM salinity are 50%, 38%, 44% and 36% over control for the cultivars BR11, BRRI dhan41, BRRI dhan44 and BRRI dhan46, correspondingly.

Nahar and Hasanuzzaman, (2009). reported that different yield components of *V. radiata* were significantly affected by salinity stress. Numbers of pods per plant, seeds per pod and seed weight were negatively associated with salinity levels. The reproductive growth of *V. radiata* was also affected by salinity as the number of pods per plant considerably decreased with increasing salinity levels. An application of 250 mM NaCl reduced 77%, 73% and 66% yield in *V. radiata* cv. BARI mung-2, BARI mung-5 and BARI mung-6, respectively over control

2.2 Effect of salt stress on rice

Soil salinity is not a new problem for rice production. In the coastal area, rice has been growing in saline soils since long time. Excess salinity in soil is one of the major environmental factors that limit growth and yield of a wide variety of crops including rice. Rice is considered as salt-sensitive crop, and growth and yield of rice are greatly affected by salinity (Mishra *et al.,* 2013). Generally, rice can tolerate a small amount of salt water without compromising the growth and yield.

According to IRRI, soil salinity beyond EC ~4 dS m^{-1} is considered as moderate salinity for rice, while more than 8 dS m^{-1} is high. Excess salt caused both ionic toxicity and osmotic stress in rice plants. Under high salinity, rice plants show various morphological, physiological or biochemical alterations and symptoms and even may die when the salt stress becomes very high.

Moradi *et al.*, (2003) have shown that a very poor association exists between tolerances at seedling stage with that during reproduction, signifying that tolerance at these two stages is controlled by a different set of genes.

Munns (2002a) found that the reproductive stage is critical as it finally regulates the grain yield. Salinity lessens the growth of plant through osmotic effects, diminishes the capability of plants to take up water and this causes reduction in growth. There may be salt specific effects. If extreme amount of salt enters the plant, the concentration of salt will ultimately increase to a toxic level in older transpiring leaves causing premature senescence and reduces the photosynthetic leaf area of a plant to a level that cannot endure growth.

Alam *et al.* (2004) resulted that the possible reasons for decline in the shoot and root growth in salinized plants as reduction of photosynthesis, which in turn limits the supply of carbohydrates required for growth and reduction of turgor in expanding tissues resulting from lowered water potential in root growth medium.

Garciadebleas *et al.* (2003). demonstrated that plant roots experience the salt stress when Na^+ and Cl^- along with other cations are present in the soils in varying concentration (1 to 150 mM for glycophytes and more for halophytes). The toxic ions sneak into the plant along with the water stream which moves from soil to the vascular system of the root by different pathways like symplastic and apoplastic.

Haq *et al.* (2009) investigated seven rice cultivars at 100 mM of salt concentration and reported that with increase in salinity, a significant reduction was observed in shoot dry weight; shoot fresh weight and number of tillers plant^{-1} after 42 days of salt stress.

Hakim *et al.* (2010) resulted that salinity reduced the final germination percent and lead to reduction in shoot and root length and dry weight in all varieties. In addition, they noticed that magnitude of reduction increased with increasing salinity stress.

Alam *et al. (*2004) observed that growth reduction immediately after the application of 12.5 dS m^{-1} of EC in rice, but no significant variation was seen at lower levels (8.5 and 4.5 dS m^{-1}). They observed severe effects on leaf area, shoot and root fresh weight besides effect on all plant parts.

Haq *et al.* (2009) reported significant variation in leaf Na^+ under salt stress but not in control. The tolerant variety (CO-34) gathered lower Na^+ (14.9 mol m^{-3}) while susceptible variety (Monoberekan) accumulated 52.9 mol m^{-3} in the leaf sap. They further reported larger reduction in K^+ /Na^+ ratio under salt stress related to control. They exposed that the key feature of plant salt tolerance was the capability of plant cells to keep optimum K^+ /Na^+ ratio in the control.

Ali *et al. (*2004b) observed significant reduction of yield in many rice genotypes at a salinity level of 8.5 dS m^{-1} besides the reduction of many yield contributing parameters viz., chlorophyll content, productive tillers $plant^{-1}$, and panicle length and fertility percentage.

Uddin *et al.* (2007) resulted that salinity reduced the number of effective tillers $plant^{-1}$, number of grains $panicle^{-1}$, 100-grain weight and yield $plant^{-1}$ of rice.

Hasamuzzaman *et al.* (2009) reported that 1000-grain weight and grain yield diminished with increase in levels of salinity in rice.

Govindaraju and Balakrishnan (2002) concluded that plant height, number of productive tillers $hill^{-1}$, 1000-grain weight, grain yield, straw yield, chlorophyll content and photosynthetic ability of rice declined with increase of salinity.

Khatun *et al*. (1995) reported that salinity delayed flowering, reduced the productive tillers $plant^{-1}$, fertile florets $panicle^{-1}$, seed set (weight $grain^{-1}$), 1000-seed weight and overall grain yield.

2.3 Effect of halopriming on germination and seedling growth of rice

Halopriming is a technique for coping with salinity. Seed priming is a cost-effective technology that can increase early crop growth leading to earlier and more uniform stand with yield related to benefit in many field crops including oilseeds (Rehman *et al.,* 2011).

Jisha *et al*. (2014) conducted that seed priming progresses the seed performance and also helps the seedlings to improve the damaging effects of various stresses. Seed priming is also believed to bring about some biochemical changes in the metabolism within the seed, which ultimately favors germination and the further growth stages of the seedlings even under stressed conditions.

Balkan *et al.* (2015) conducted a research whose result exhibited that response of rice (O*ryza sativa* L. cv. Osmancık-97) to eight salinity (NaCl) levels (0, 2, 4, 8, 12, 16, 20 and 24 dS $m^{-1)}$ was studied at germination and early seedling stages, Germination was entirely detained at 20 and 24 dS m^{-1} salinity levels. While mean germination time increased with increasing salinity, water uptake, germination rate, coleoptile length and shoot length were significantly diminished. Root number, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight and shoot dry weight significantly increased up to 4 to 8 dS m^{-1}, and then these characters were significantly reduced by increasing salinity level. It was decided that rice cultivar viz. Osmancık-97 has tolerance up to a salinity level of 8 dS m^{-1} at the germination and early seedling stages.

Singh *et al* (2018) directed an experiment was laid out in randomized block design with three replication and two varieties Sambha Mahsuri and Sambha Mahsuri Sub1. Treatments contained of (T_1) Seed priming with GA_3 @ 25 ppm, (T_2) Seed priming with GA_3 @ 50 ppm, (T_3) Seed priming with JLE @ 2%, (T_4) Seed priming with KNO_3@ 0.5%, (T_5) Seed priming with KCl @ 0.2%, (T_6) Seed priming with NaCl @ 0. 5 %, (T_7) Seed priming with IAA @ 0.2 %, (T_8) Seed priming with $CaCl_2$ @ 0.1 %, (T_9) Control with distilled water and that results specified that all the priming treatments increased the germination percent, speed of germination, days to 50% flowering and days to physiological maturity. However, effect of GA_3 @ 50 ppm was found more noticeable on various parameters in both the variety but Sambha Mahsuri Sub1 exhibited more response of seed priming as compared to that of Sambha Mahsuri.

Taylor *et al.,* (1998) reported that seed priming technique progresses germination or seedling growth and rate or uniformity of the seedling establishment. Sivritepe *et al.,* (2003) exposed that seed priming with different salts, especially NaCl, have revealed to expand germination and growth of many crops under stressed conditions.

Jisha and Puthur (2014) was found to study the effect of hydropriming and halopriming in three rice varieties (Neeraja, Vaisakh, and Vytilla 6), with varied abiotic stress tolerance potential under NaCl and PEG stress. Normally, the application of both stresses, NaCl and PEG induced obstruction of growth and metabolism of the seedlings. However, seed priming treatments could diminish the extent of decrease in these biological attributes. Both hydro- and halopriming resulted in the enrichment of protein, carbohydrate, and photosynthetic pigment content, modulated antioxidant enzyme activities, reduced the lipid peroxidation of biomembranes, and improved the photochemistry and mitochondrial activities in rice seedlings subjected to NaCl and PEG stress as related to non-primed ones. According to the various morphological, physiological, and biochemical characteristics studied in the rice seedlings raised from primed and non-primed seeds, they confirmed that both hydropriming and halopriming had a positive influence on stimulating metabolism in rice seeds, which eventually resulted in better seedling vigor and tolerance under NaCl and PEG stress. Halopriming was found to be more effective than hydropriming in enhancing the seedling vigor, overall growth, and stress tolerance potential of rice varieties. Halopriming was found to be effective in delivery about a prominent increase in shoot length of seedlings particularly in the tolerant varieties subjected to the particular stressed conditions, for which the variety is known to be tolerant. Haloprimed Vytilla 6 showed the maximum increase in the shoot length of seedlings subjected to NaCl stress (109%) and haloprimed Vaisakh showed a prominent enhancement in the shoot length under PEG stress (74%) when compared to non-primed ones of respective varieties. seed priming significantly ameliorated the reduction in PS I and PS II activities under NaCl and PEG stress. However, halopriming brought about significant increase in PS I activity of the rice seedlings as compared to PS II activity and so the enhancement in PS I activity of haloprimed rice seedlings under conditions of NaCl and PEG stress could be explained as a means of meeting the demand for the additional requirement of ATP by the plants to counter the stress situation.

Varier *et al.,* (2010) conducted that priming progresses seed performance by activating the synthesis of many proteins and enzymes involved in cell metabolism such as carbohydrates (α and β amylases) and lipids mobilization (isocitrate lyase), which are implicated in the mobilization of storage reserves.

Hemalatha *et al.* (2017) observed that seed priming with SNP produced desirable results, both promoting the germination as well as increased the seedling growth and seedling vigor. The ill-effects of salinity stress could be alleviated to considerable extend by advocating seed priming with SNP under increased salinity conditions due to releasing of NO after the seed priming with SNP. The salt tolerant variety TNAU Rice TRY 3 performed better than other varieties under salt stress conditions. The seed priming treatment improved the germination performance of the salt sensitive variety ADT (R) 49 when compared with salt tolerant and moderately salt tolerant varieties due to priming treatments. Hence seed priming with SNP @ 80 µM could be recommended for mitigating the effect of salt stress in rice even under higher salt concentrations.

Barsa *et al*. (2005) reported that the primed seed usually display increased germination rate, greater germination uniformity and sometimes greater total germination percentage.

Harris *et al*. (1999) also reported that the direct effects of seed priming in all crops can lead to better stand establishment, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield.

According to Farooq *et al*. (2006a); Mathew and Mohanasarida (2005)., In rice, seed priming treatments reduced the time taken to initiate the germination process, improves the rate of germination and synchronization, furthermore, enhances the lengths of shoots and roots and thus increases the fresh and dry mass of the seedlings.

Chen *et al*. (2009); Mittova *et al.* (2004) reported that salt stress has negative effects on mitochondria causing lessened electron transport activities and increased lipid peroxidation due to the formation of reactive oxygen species, but Jisha and Puthur (2014) was found that the seedlings raised from hydroprimed as well as haloprimed seeds exhibited a lower reduction in the mitochondrial activity. However, Seed priming possibly improved the mitochondrial intactness by maintaining the membrane integrity and/or resulted in an increase in the distribution of mitochondria in unit area.

Jisha and Puthur (2014) also investigated that the increase of total protein content in the seedlings raised from primed (hydro- and haloprimed) seeds and that exposed to unstressed and stressed conditions (NaCl/PEG) indicate that seed priming resulted in the accumulation of certain additional proteins which might have a role in stress alleviation when the seedlings were exposed to NaCl/PEG stress.

Mondal (2011); Nawas *et al*. (2013) found that in rice, total soluble sugar content improved in the seedlings raised from primed seeds. Moreover, Jisha and Puthur (2014) shown that the significant enhancement in the carbohydrates in plants raised from primed seeds, on exposure to stress could be to counter the stress by increasing the osmoticum in the seedlings.

Subedi *et al.* (2015) conducted a laboratory experiment to study of the effect of different priming methods in rice that exposed to priming is helpful in reducing the risk of poor stand establishment under a wide range of environmental conditions. The experiment was done in completely randomized design and the treatments consisted; Control (No priming), Hydro priming (soaking of seeds in distilled water for 72 hrs), PEG6000 - 5% and 10%, $CaCl_2$ – 0.5% and 1%, KCl – 2% and 4%, KNO_3 – 1% and 2% and NaCl – 1.8% and 3.6% where seeds were soaked for 12 hours followed by 12 hours drying, Hydro priming and PEG6000 – 5% resulted better performances associated to other priming methods for different germination indices in the experiment. Therefore, it is advisable to practice hydro priming or priming with PEG6000 – 5% as a successful technique for increasing and hastening of seed germination and better crop stand. Hydro priming, KNO_3 - 2% and PEG – 5% presented significantly higher GERMINATION ENERGY(GE) than control and NaCl – 3.6%. Hydro priming, KNO_3, KCl, NaCl, PEG and $CaCl_2$) exhibited significantly higher germination index than control at both the levels. However, significantly reduction in germination index was observed with increase in level of NaCl and PEG. Hydro priming, KCl – 1%, KNO_3 - 2%, NaCl – 1.8%, PEG – 5% and $Cacl_2$ – 1% showed higher GERMINATION SPEED(GS) than control and NaCl – 3.6% where increase in salt concentration significantly reduced the GS. Hydro priming, KCl – 2%,KNO_3 - 2% and 4%, NaCl – 1.8%, $CaCl_2$ – 0.5% and PEG – 5% resulted higher radical length and plumule length than control. But increase in levels of NaCl and PEG significantly reduced the radical length and plumule length.

Khan *et al*. (2009). observed the response of seeds primed with NaCl solution at different salinity levels 0, 3, 6 and 9 dSm^{-1} in relation to early growth stage and concluded that seed priming with NaCl has found to be better treatment as compared to nonprimed seeds.

Iqbal *et al.,* (2006) founded that Priming with NaCl and KCl was helpful in removing the harmful effects of salts.

Raun *et al.,* (2002) evaluated that priming the rice seed with KCl enhanced its germination index.

Afzal *et al.,* (2012) investigated the potential of seed priming for induction of salt tolerance in two fine aromatic rice cv. Shaheen Basmati (salt tolerant) and Basmati-2000 (salt sensitive) which were soaked in aerated solutions of $CaCl_2$ (Ψs=-1.25 MPa), KCl (Ψs=-1.25 MPa), and H_2O_2 (50 mM) each for 36 h. Primed seeds were exposed to 0, 40 and 80 mM NaCl in petri dishes and sand culture during germination and emergence respectively. Results showed that priming with $CaCl_2$ followed by KCl were more effective in inducing salt tolerance of both rice cultivars owing to enhanced germination capacity, speed of germination, seedling length and dry weight in saline medium. Salinity reduced total chlorophyll percentage (TCP) by two-fold in both cultivars but higher TCP was found at all salinity levels from $CaCl_2$ primed raised seedlings in salt tolerant cultivar. Salinity significantly reduced germination and early seedling growth of both rice cultivars while seed priming improved germination and related attributes i.e. final germination percentage (FGP), mean germination time (MGT) and time taken to 50% germination (T50) in comparison to non-primed control, halopriming with $CaCl_2$ following KCl improved final germination percentage and reduced germination time in both cultivars under salinity than untreated control. Maximum seedling emergence percentage was recorded in both cultivars by halopriming with KCl following $CaCl_2$ at high salinity level in salt tolerant cultivar compared with untreated control.

Farooq *et al.,* (2006b) observed that halopriming with $CaCl_2$ significantly improved emergence and seedling growth in Shaheen Basmati whereas as $CaCl_2$ and KCl verified better in case of Basmati-2000 which could be associated to dormancy breakdown of rice seeds due to improved seed K and Ca concentration and amylase activity. Finally, result showed that seed priming improved germination rates and uniformity of growth following reduced emergence time and increased yields are reported in many field crops including rice.

2.4 Effect of halopriming on yield of rice

Jisha and Puthur (2014) was found to the study of the effect of hydropriming and halopriming in three rice varieties (Neeraja, Vaisakh, and Vytilla 6), with varied abiotic stress tolerance potential under NaCl and PEG stress, resulted that halopriming led to a prominent increase in dry weight (up to 40%) under stressed (NaCl/PEG) conditions while in the unstressed conditions all varieties showed a lower percentage of increase in dry weight (up to 6%) of the seedlings. From the growth parameters studied in rice varieties, Vaisakh and Vytilla 6 showed a high percentage of increase in shoot length and fresh weight when the seeds were haloprimed.

A field experiment was conducted by Varanasi, Srivastava and Bose (2012) on seed priming of rice varieties with or without nitrate salts (Mg $(NO_3)_2$ and KNO_3, result showed that the beneficial effect of priming treatments which was clearly exhibited in plant height, leaf area and number of leaf and yield attribute characteristics i.e. fertile tillers, panicle and grain quality with nitrate treated varieties.

Afzal *et al.*, (2012) investigated the potential of seed priming for induction of salt tolerance in two fine aromatic rice cv. Shaheen Basmati (salt tolerant) and Basmati-2000 and found a result that root length; shoot length and seedling dry weight of both cultivars was also diminished with increasing salinity while halopriming with $CaCl_2$ following KCl enhanced root and shoot lengths and seedling dry weight than untreated control under saline conditions in both cultivars. Halopriming with $CaCl_2$ reduced root Na^+ uptake and leaf accumulation of salt tolerant cultivar than salt sensitive type with higher Na^+ values.

Farooq *et al.* (2006) reported that Seed priming improved germination and emergence, allometry, kernel yield, and its quality in rice seeds, whilst pre-germination displayed poor and erratic emergence of seedling followed by poor plant performance. Seed priming improved a-amylase activity, which increased the level of soluble sugars in the primed kernels.

Panga *et al.* (2019) conducted an experiment to the study of seed priming effect on Banyuasin and Ir 64 rice varieties growth at the seedling stage under salinity stress in the Laboratory of Plant Science, Faculty of Agriculture, Ehime University, Japan using an experiment with clustered randomized design pattern. There were eight packages of treatment, including $V_1H_0M_0$, $V_1H_0M_1$, $V_1H_1M_0$, $V_1H_1M_1$, $V_2H_0M_0$, $V_2H_0M_1$, $V_2H_1M_0$, and $V_2H_1M_1$ (V_1: IR 64 variety, V_2: Banyuasin variety, H_0: Seeds without priming, H_1: Seeds with priming, M_0: non-saline media. M_1: saline media of 1.2 m/s). The results showed that salinity suppressed seedling growth, but primed Banyuasin seeds presented the best results for the variables mean of plant height, root length, shoot biomass, root biomass, and plant biomass, (34.27 cm, 19.03 cm, 0.81 g, 0.18g, and 0.99 g) under salinity stress, and also showed that primed Banyuasin seeds growth under salinity stress can maintain the lowest Na^+ ions accumulation in the shoot. This data specified that seed priming improves plant ability to maintain lower Na^+ accumulation in a shoot, that is crucial to overcome salinity and to improve tolerance to salinity stress.

Kumar *et al.* (2018) studied the effect of seed priming on yield attributes and grain quality of rice under timely and Late Sown conditions, regarding grains panicle^{-1}, test weight, harvest index, panicle number hill$^{-1,}$ panicle length and amylose content of rice var. HUR 105 under timely and late sown conditions forecast that grain number panicle^{-1} was increased in primed sets over non primed sets under both studied conditions.

Binang *et al.,* (2012) also demonstrated that priming had a momentous effect on the number of tillers, number of fertile panicles, and consequently grain yield of new NERICA rice varieties.

Ali *et al.* (2013) reported that seed priming treatments reduced the mean emergence time and promoted germination, early canopy development, and tillering in comparison to the untreated control. The number of fertile tillers, plant height, 1000-grain weight, and grain and biological yield were also increased by different priming techniques.

According to Mamun *et al.* (2018), priming has beneficial effects which is improved the rate of germination at any particular temperature as well as primed seeds emerge from the soil faster and often more uniformly than non-primed seeds because of limited adverse environmental exposure. Priming accomplishes this important development by shortening the lag or metabolic phase in the germination process where the metabolic phase occurs just after seeds are fully imbibed and just prior to radical emergence. Since seeds have already gone through this phase during priming, germination times in the field can be reduced by approximately 50% upon subsequent rehydration. Nevertheless, priming has been commercially used to eliminate or greatly reduce the amount of seed-borne fungi and bacteria.

2.5 Effect of halopriming on germination and seedling growth of different crops

Sivritepe *et al.,* (2003); Ashraf and Foolad, (2005) found that seed germination and early seedling growth are the most sensitive stages which are stressed by salinity in most of the crops. Grassbaugh and Bennett, (1998) also found that salinity adversely affects seeds and seedlings and greatly contributes in estoblishment of poor stand and eventually poor production of vegetable crops.

Pill, (1995); Warren and Bennet, (1997); Powell *et al.,* (2000); Cantliffe,(2003) reported that seed priming improves seed performance by rapid and uniform germination, normal and vigorous seedlings, which resulted in faster and better germination and emergence in different crops.

Jisha and Puthur (2014) was investigated to study the effect of halopriming on NaCl and polyethylene glycol-6000 (PEG6000) induced stress tolerance potential of three *Vigna radiata* (L.) Wilczek varieties, with varied abiotic stress tolerance potential, resulted that the application of stresses (both NaCl and PEG) induced retardation of growth attributes (measured in terms of shoot length, fresh weight, dry weight) and decrease in physiological attributes like total chlorophyll content, metabolites, photosynthetic and mitochondrial activity of the seedlings, halopriming of the seeds could reduce the extent of decrease in these biological attributes, NaCl and PEG stress also caused increase in MDA content (a product of membrane lipid peroxidation). However, it could be concluded that halopriming improved the drought and salinity stress tolerance potential of all varieties.

Farhoudi R and Sharifzadeh F (2006) laid out an experiment that Seeds of canola (*Brassica napus*) cultivars "Hayola401" and "Zarfam" were primed with 14 dS m^{-1} NaCl solution for 24 hours at 20°C Comparing with non-primed seeds and found that total emergence and dry weight were higher in canola seedlings derived from primed seeds and they emerged earlier than non-primed seeds. NaCl priming enhanced proline accumulation and prohibited toxic and nutrient deficiency effects of salinity because less Na^+ but more K^+ and especially Ca^{2+} was accumulated in canola seedlings. NaCl salinity caused growth inhibition in canola seedlings due to an increase in MET and decreases in total emergence and dry weight.

Botia *et al*. (1998) and Pill *et al*. (1991) working with different plants such as melon and tomato and revealed these effects of salinity on canola cultivars. However, Farhoudi R and Sharifzadeh F (2006) reported that NaCl priming diminished inhibiting effect of salinity on seed germination and seedling growth in canola. NaCl priming had a positive effect on mean emergence time (MET) of seedlings of both cultivars. Seedlings from primed seeds emerged earlier than non-primed seeds under saline conditions. NaCl priming induced avoidance of canola seedlings from toxic and nutrient deficiency effects of salinity on growth because of less Na^+ but more K^+ and especially Ca^{2+} accumulation.

Although salt induced injuries can occur due to osmotic and oxidative effects and also toxic and nutrient deficiency effects of salinity, but Farhoudi R and Sharifzadeh F (2006) showed a result that NaCl treatments caused an increase in Na^+ concentration and a decrease in K^+ and Ca^{2+} concentrations of canola seedlings derived from non-primed seeds. Na^+: Ca^{2+} balances of seedlings derived from the primed seeds were significantly lower than non-primed seeds under salinity levels. These results showed that NaCl priming of canola seeds increased salt tolerance by promoting K^+ and Ca^{2+}accumulation, besides inducing osmoregulation by the accumulation of proline.
Biswas *et al.* (2018) laid out an experiment and develop cost-effective and farmer friendly halopriming technique to alleviate the adverse effects of salinity to some extent that occur during salt stress responses in *Cajanus cajan* L. var. *Rabi*. Seedlings raised from non-primed and haloprimed seeds, grown in hydroponic solution, were subjected to different concentrations of NaCl. The data were analyzed and indicated that the leaves responded most to NaCl induced stress than the stem and root with

production of beta-cyano-L-alanine and also increased level of different compatible solutes. O-Acetylsalicylic also found to increase in all the parts upon facing stress but, such up regulated metabolite production was down regulated in the leaves when the seeds were haloprimed before germination, although many of the metabolites, including beta-cyanoalanine, showed a trend of increase with increase in salt concentrations. Pre-germination of haloprimed seeds resulted in amelioration of NaCl induced stress, as the levels of stress induced metabolites were lowered. NaCl induced stress caused reduction in root and shoot lengths of 3 weeks old *C. cajan* seedlings. However, halopriming of seeds exhibited enhancement of root and shoot growth during acclimation process. Metabolites were identified from root, stem and leaf tissues of non-primed and haloprimed seedlings by GC-MS based metabolomics approach.

Kumari *et al.* (2017) conducted an experiment in order to regulate the suitable method of priming for maize seeds (var. SHIATS MS 3) with treatments of T_0-Unprimed (Control), T_1-Hydropriming with Distilled water, T_2-Hormonal priming with GA_3 100ppm, T_3-Hormonal priming with Salicylic Acid 100ppm, T_4-Hormonal priming with Ascorbic Acid 100ppm, T_5- Halo priming with KNO_3 1% and T_6-Halo priming with $CaCl_2$ hydration for 12 hours and find out that seed priming with Salicylic Acid and $CaCl_2$ were found to increase the seedling characters. Significantly higher germination per cent (98.00%) reported in treatment T_2 GA_3 100ppm followed by T_3 (96.25) primed with SA 100ppm and T_6 (95.00%) primed with $CaCl_2$ 1%. Minimum germination per cent recorded by T0 (91.00%) with unprimed control, highest germination index (34.80) was reported in the primed with T_2 Gibberellic Acid (GA_3) 100ppm followed by T_3 (32.81) primed with Salicylic Acid (SA) 100ppm and T_6 (32.50) primed with Calcium chloride ($CaCl_2$) 1%. Minimum germination index was recorded by T_0 (26.63) with unprimed control. Maximum seedling shoot length, highest seedling length, highest seedling fresh weight, highest seedling dry weight, highest seedling vigor was significantly improved compared with non-primed seeds.

According to Harris *et al*. (2007) seed priming is an effective technology to improve rapid and uniform emergence and to achieve high vigor, leading to better stand establishment and yield.

Halopriming is a pre-sowing soaking of seeds in salt solutions, which enhances germination and seedling emergence uniformly under adverse environmental conditions and normal condition. NaCl, KCl, KNO_3, and $CaCl_2$ is used. Bajehbaj A.F. (2010) evaluated the effects of NaCl priming with KNO_3 on the germination traits and seedling growth of four *Helianthus annuus* L. cultivars under salinity conditions and reported that germination percentage of primed seeds was greater than that of un-primed seeds.

Kadiri and Hussaini (1999) investigated an experiment to find out that sorghum seeds soaked in $CaCl_2$ or KNO_3 solution that increased the activity of total amylase and proteases in germinating seeds under salt stress.

Jyotsna and Srivastava (1998) reported that in pigeon pea seed treatment with $CaCl_2$ or KNO_3 generally showed enhancement in proteins, free amino acid and soluble sugars during germinating under salt stress.

Harris *et al.*, (2007) conducted an experiment and evaluated that seed priming led to better establishment and growth, earlier flowering, increased seed tolerance to adverse environment and higher yield in soybean.

Aymen and Hannachi (2012) conducted an experiment to evaluate the effect of NaCl seed priming techniques on germination and early growth of safflower (*Carthamus tinctorius* L.). Safflower seeds were primed with four concentrations of NaCl as priming media (5, 10, 15 and 20 g/l) for 12, 24 and 36 hours and resulted that different priming concentrations and duration have significant effect on total germination percentage, mean germination time, germination index and coefficient of velocity of safflower seeds. It was also stated that 12 hour priming duration had the most significant effect on studied traits as 5 g/l priming concentration treatment. They found that growth (plant height, fresh and dry weight) and biochemical (chlorophyll, proline and proteins content) of plants derived from primed seeds were greater of about 15 to 30% than that of plants derived from non-primed seeds. In general, primed seeds showed better performance than control in all studied parameters.

Elouaer and Hannachi (2012) investigated a germination experiment at Tunisia in which safflower seeds were primed with 5 g/l NaCl and KCl solutions for 12 and 24 hour respectively at 20Úc and reported that seed priming increased germination by 8.66% and 5.06% using NaCl and KCl solutions as compared to non-primed seeds. However, NaCl seed priming has the highest germination percentage (82.7%) followed closely by KCl seed priming (78.6%), control having the lowest total germination (73.6%) other parameters like germination index, coefficient of variation, shoot and root length was also recorded higher as compared to control. Finally, they reported that NaCl and KCl priming have improved germination parameters (germination percentage, mean germination time, germination index and coefficient of velocity) and growth parameters (radicle and seedling length, seedling fresh and dry weight and Vigor Index) of safflower under saline condition.

Soughir *et al*., (2012) evaluated a study to determinate the effect of NaCl seed priming on Fenugreek seed germination. Fenugreek seeds were primed with four concentrations of NaCl as priming media (0, 4, 6 and 8 g/l) for different durations. As a result, different priming concentration of NaCl and duration has significant effects on total germination percentage, mean germination tine, germination index and coefficient of velocity of fenugreek seeds and the best results was obtained with 4 g/l for 36 hours. The finding of this experiment showed that under undesirable conditions such as salinity stress, priming with NaCl can prepare a suitable metabolic reaction in seeds and can improved seed germination.

Sivritepe *et al*., (2002) laid out an experiment and studied the effect of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. They found that NaCl priming of melon seeds increased salt tolerance of seedling by promoting K and Ca accumulation, besides inducing osmo regulation by the accumulation of organic solutes.

Haroni *et al.*,(2015) studied the effect of seed halopriming with potassium nitrate on germination and emergence traits of *Cercis siliquastrum* L. seeds, conducted two experiment, one in the laboratory and the other in a greenhouse, evaluated with the treatments included non-priming and halopriming with potassium nitrate at one of four concentrations (0, 100, 250, 500 and 750 mM) for 48 h, for all treatments the seeds were boiled in water per 24 h. The results showed that seed halopriming with KNO_3 at the 750 mM concentration in the laboratory significantly increased several characteristics of germination. Emergence characteristics also were increased by pretreatment of seeds with potassium nitrate when planting in greenhouse. 100 mM treatment provided to show the highest emergence percentage (57%), speed of germination (1.54 seeds per day) emergence energy (44.8%) and lowest mean germination time (13.9 days). However, haloprimed achenes resulted in maximum final emergence and shoot length, root length, collar diameter, shoot dry weight, root dry weight, number of leaves, leaf area and seedling quality index treated with primed techniques were increased and compared with non-prime treatment. Cumulative seed germination of Judas tree showed that using the halopriming technique quickened the initiation of germination and reduced the overall germination period compared to non-haloprimed seed. Halopriming with KNO_3 salt solution can improve and invigorate the germination of Judas tree seed, thus increasing growth potential of seedlings and improving seedling competitiveness in a shorter time compared with non-haloprimed seed.

Cayuela *et al.* (1996) concluded that the higher salt tolerance of plants from primed (P) seeds seems to be the result of a higher capacity for osmotic adjustment since plants from P seeds have more Na^+ and Cl^- in roots and more sugars and organic acids in leaves than plants from non-primed (NP) seeds.

Kathiresan *et al.,* (1984) reported that maximum root and shoot growth; seedling height and field emergence in sunflower seeds in response to priming with $CaCl_2$.
Meriem *et al.* (2014) carried out an experiment to evaluate the interactive effect of salinity and seed priming on coriander. The experiment was carried out in four coriander genotypes (Tunisian cv, Algerian cv, Syrian cv and Egyptian cv) at two seed conditions (seed priming with 4 g L^{-1} NaCl for 12h or no seed priming). Results showed that seed priming and salinity had significantly ($p \leq 0.05$) affected all the parameters under study. Seed priming with NaCl had diminished the negative impact of salt stress in all cultivars and primed plants showed better response to salinity compared to unprimed plants.

Ajirlo *et al.* (2013) carried out an experiment to evaluate the effect of priming methods on emergence and seedling growth of maize (*Zea mays* L.) and reported that germination and early growth under prevailing environmental conditions improves by seed priming technique. They also showed that all the priming treatments significantly affect the fresh weight, shoot length, number of roots, root length, vigor index, time to start emergence, time to 50% emergence and energy of emergence of forage maize. The interactive effect of varieties and priming techniques were not significant for mean emergence time and coefficient of uniformity of emergence.

Chivasa *et al*. (2000) reported that priming sorghum seeds for 10 hours speeded up seedling emergence by 23 % and increased final emergence percent. Fourteen-day-old seedlings from primed seeds also had significantly more leaves and root axes and were taller and heavier than nonprimed seedlings.

Saeidi *et al.* (2008) conducted an experiment and find out that priming of mustard with different solutions increased the mean stem and root dry weight or mean germination rate at suitable priming times can cause better and faster seedling establishment in the early season and thus can improve the plant tolerance against unfavorable environmental conditions.

Parera and Cantliffe, (1994) concluded that during osmotic priming (halopriming), ions in a potassium nitrate and sodium chloride solution accumulate within the seeds, increasing water absorption by reducing water potential.

Yousaf *et al.* (2011) laid out in an experiment of effects of seed priming with 30 mM NaCl on various growth and biochemical characters of 6 wheat varieties (Tatara-96, Ghaznavi-98, Fakhri Sarhad, Bakhtawar-92, Pirsabaq-2004 and Auqab- 2000) under 4 salinity levels (0, 40, 80 and 120 mM) and observed the effects of varieties and salinity were significant ($P \leq 0.05$) and of seed priming was non-significant ($P > 0.05$) on plant height (cm), root length (cm) and shoot chlorophyll contents.

Tzortzakis (2009) observed with his experiment that halopriming (KNO_3) or growth regulators (gibberellic acid; GA_3) enhanced the rate of germination of endive and chicory and reduced the mean germination time needed. 30 min pre-sowing treatment with $NaHClO_3$, methyl jasmonate and dictamus essential oil decreased seed germination as well as seed radicle length in vitro. 6 benzyl aminopurine (BAP) or $NaHClO_3$ treatment reduced plant growth. He suggested that KNO_3 and secondly GA_3 treatments may improve rapid and uniform seedling emergence and plant development in nurseries and/or in greenhouses, which is easily applicable by nursery workers with economic profits.

Farahbakhsha *et al.* (2009) was investigated to the effects of seed priming on agronomic traits in maize using NaCl solutions containing different salt concentrations. Salinity treatments were 0, 4, 8 and 12 $dS.m^{-1}$ and salt solutions for priming were 0.0, 0.5 and 1.0 molar NaCl. Observed seed characteristics like shoot dry weight, stem length, number of leaves, leaf area, chlorophyll and ion leakage were measured. Results showed that the effects of salinity and seed priming on shoot dry weight, stem length, number of leaves, leaf area, chlorophyll and ion leakage were significant at the probability level of 1% ($P< 0.01$). The increase in salinity up to 12 dSm^{-1} negatively influenced all traits except ion leakage and the amounts of reduction for the mentioned traits were 75.67, 52.25, 25, 69.97 and 21.17%, respectively, as compared with the control. In the case of ion leakage, the difference was 3.03 times less than that of control. Seed priming compensated the negative effects of salinity on plant traits and all the traits positively responded to the treatment of seed priming.

Amjad *et al.* (2007) laid out an experiment to evaluate the influence of seed priming using different priming agents (distilled water, NaCl, salicylic acid, acetyl salicylic acid, ascorbic acid, PEG-8000 and KNO_3) on seed vigor of hot pepper cv. And found that all priming treatments significantly enhanced seed performance over the control. KNO_3 primed seeds excelled over all other treatments; declined time taken to 50% germination, increased root and shoot length, seedling fresh weight and vigor over all other priming agents. Seeds were primed in water (hydropriming) and NaCl (1% solution) (halopriming) and sown in pots at different salinity levels [1.17 (control), 3, 5 and 7 $dS\ m^{-1}$], along with unprimed seeds. Emergence rate (ER), final emergence percentage (FEP), reduction percentage of emergence (RPE), shoots length, number of secondary roots, seedling fresh weight and vigour were significantly improved by both priming treatments over the control; halopriming was more effective than hydropriming. Number of secondary roots was maximum in haloprimed and unprimed seeds.

Mohan Kumar and Manonmani (2011) conducted that haloprimed in sunflower seeds with 2% KNO_3 maintain the storage potential by recording maximum germination and field emergence after six month of storage than unprimed seed.

Hoseini *et al.* (2013) observed the effect of priming on laboratory experiments and field studies and found that the influence of various treatments on germination percentage and rate were significant. They observed the length of plumule and radicle in magnetic field in comparison with others were the highest. Some treated seeds were stored and reduction of germination percentage were also observed. Considering physiological characters, the most Leaf Area Index and Leaf Area Ratio were seen in magnetic field treatment. The effects of priming on plant height, biomass dry weight and essential oil were significant. Different durations of magnetic field had the most positive effect on essential oil.

Abbasdokht *et al.* (2013) examined the effect of priming and salinity on physiological and chemical characteristics of wheat (*Triticum aestivum* L.). Results showed that primed plants significantly reduced its gas exchanges by accelerating senescence under a series of salt stress, which became more serious along with the increasing of salt concentrations, especially at 21 d after anthesis. They observed that dry matter accumulation of primed plants was always higher than the non-primed plants under each level of salt stress. Primed plants provided higher potassium selectivity against sodium than non-primed plants. Salt stresses caused significant declines in growth period of wheat by accelerating leaf senescence at reproductive stage. Primed plants of wheat successfully preserved normal growth by maintaining *P*n, K^+/Na^+, leaf area duration (LAD) and dry matter accumulation (DMA), while non-primed plants decreased considerably in those parameters.
Afzal I *et al.,* (2008) conducted to investigate whether salt tolerance may be induced in Seeds of two wheat cultivars (Inqlab-91and SARC-1) at germination stage by halopriming with different inorganic salts ($CaCl_2$, NaCl and $CaSO_4$). Seed were primed in 50 mmol solutions of $CaCl_2$, NaCl or $CaSO_4$ for 12 h separately and germinated under non-saline and saline (125 mmol NaCl) conditions. Results showed

that priming with $CaSO_4$ enhanced germination, maximum root length and fresh and dry weights followed by $CaCl_2$. Na^+ was highest in seedlings raised from seeds primed with NaCl whereas the concentration of K^+ was highest in the seedlings primed with $CaSO_4$.Maximum total sugars and reducing sugars were observed when seeds were treated with $CaCl_2$ followed by $CaSO_4$. In conclusion that different salts used for priming in wheat seeds improved the salt stress tolerance; however, $CaSO_4$ and $CaCl_2$ proved to be the most effective priming agents in inducing salt tolerance in both wheat cultivars whereas NaCl was a less effective priming agent.

Ahmad *et al.* (2017) was conducted to investigate the effects of seed priming (halopriming with 25 mM, 50 mM and 100 mM of calcium chloride ($CaCl_2$), potassium nitrate (KNO_3), potassium chloride (KCl) and Hydropriming) on germination and seedling vigor of *Gerbera jamesonii* and *Zinnia elegans*. Seeds of *Gerbera jamesonii* and *Zinnia elegans* were primed in salt solutions and distilled water for 24 h and 12 h, respectively, and germinated at 25 ± 1 °C with 40-60% R.H. in 16/8 hours day/night conditions. Results showed that pre-sowing seed treatment particularly halopriming with $CaCl_2$ was the most effective for invigoration of gerbera and zinnia seeds. For *Gerbera jamesonii*, 25 mM $CaCl_2$ and for *Zinnia elegans*, 50 mM $CaCl_2$ proved best priming treatments followed by 100 mM KCl and 50 to 100 mM KNO_3 for both tested species. This was interpreted by reduced time to 50% germination (1.2 d for gerbera and 2.4 d for zinnia), higher final germination %age (11% for gerbera and 7% for zinnia), seedling vigor (83% for gerbera and 46% for zinnia), and fresh weight (0.95 g for gerbera and 2.29 g for zinnia) and dry weight (0.3 g for gerbera and 0.5 g for zinnia) of the seedlings. These halopriming treatments (25 to 50 mM $CaCl_2$ or 50 to 100 mM KCl and KNO_3) can be commercially used by the growers for early, uniform and healthy nursery stand of the tested species, which can ensure uniform maturity and flower harvesting of ornamentals.

Ahmed *et al.* (2017) was conducted on seed priming of solanaceous vegetables to explore effects of seed priming on seed germination and vigor of the seedlings was done at the Postgraduate laboratory and another part of seedling growth at the Orchard, Department of Horticulture, Sindh Agriculture University, Tandojam. The seeds were halo primed with NaCl solution (w/v) by maintaining EC at 1, 2, 3 and 4 dS m^{-1} for 18 hours and hydroprimed with distilled water and also unprimed seeds were taken as control treatment. The experiment was laid out in Completely Randomized Design (CRD) with three replications. The data was recorded on seed germination (%), mean germination time (days), germination index (GI), seedling vigor index (SVI), shoot length (mm), root length (mm), fresh weight of shoot, fresh weight of root and electrolyte leakage of leaf (%). The finding revealed that all the observed parameters in the present study were significantly ($P<0.05$) affected by seed priming treatments and solanaceous vegetables. The results showed that most of the germination and growth-related attributes of the seedlings were observed decreased with increasing levels of NaCl. The best mean results for germination (96.66%), seedling vigor index (1190.9), shoot length (122.48 mm), root length (32.77 mm), fresh weight of shoot (1.99 g) and fresh weight of root (0.60 g) were observed from the treatment where seeds were primed in NaCl solution by maintaining EC of 1 dS m^{-1}. However, minimum mean germination time (4.44 days) and leakage of the electrolytes was observed from hydro and unprimed seeds, respectively. The interactive effect of seed priming and solanaceous vegetables was also observed highly significant. On the basis of interaction, tomato and chillies produced statistically similar results for germination percentage (100; 100%), germination index (7.73; 8.13) seedling vigor index(1264; 1302), shoot length (126.10; 129.87 mm), root length (34; 33.66 mm), and fresh weight of shoot (2.80; 2.38 g) in response to the treatment where seeds were primed in NaCl solution had EC level of 1 dS m^{-1}. Regarding comparison of the solanaceous vegetables, tomato exhibited the best mean results for most of the parameters included germination percentage (65.56), seedling vigor index (663.02), shoot length (93.61 mm), fresh weight of shoot (1.75 g) and fresh weight of root (0.46 g). The lowest leakage of the electrolytes (10.50%) and minmum mean days to germination (6.22 days) were recorded in Chillies. However, fresh weight of root had statistically no differences among solanceous vegetables.

Muhammad *et al.* (2015) studied the effect of halopriming on the induction of NaCl salt tolerance in different wheat genotypes and conducted to assess the induction of salt tolerance in seven wheat genotypes (Bakhtawar-92, Bhakar-2002, Fakhar-e-Sarhad, Khyber-87, Nasir-2000, Pirsabak-2005, and Uqab-2000) at germination and seedling stage through halo-priming with NaCl separately. Halo-primed seeds of each wheat genotype were subjected to 0.02 (control), 2, 4, 6 and 8 dS/m NaCl salinity under laboratory conditions. All the seedling growth characters (germination, plumule growth, fresh and dry weight of seedling and moisture contents) exhibited significant differences among wheat genotypes as well as under the applied salt concentration except for radicle growth which varied non-significantly under salt stress. Interaction between various wheat genotypes and salt concentration was also significant for all the seedling growth characters, while it was non-significant for germination percentage age. Finally, concluded that NaCl proved to be effective priming agents in inducing salt tolerance in the tested wheat genotypes.

Morteza *et al.* (2014) studied the comparative effects of hydropriming and halopriming on germination performance of *Secale montanum* Guss. under salinity stress. For the Halopriming treatments, concentrations of 0, 125, 250 and 500 mM of sodium chloride were prepared with four levels of salinity stress. The results of this study indicated that Halopriming had a negative effect on the germination and growth of *S. montanum*. The disadvantage may be due to the varied plant species, imbibing time and seed moisture. On the other hand, these effects are probably due to an excessive increase and accumulation of Na^+ and Cl^- ions to the seed tissue. From the present study, it can be concluded that seeds of *S. montanum* are sensitive to priming technique and priming of this species needs to use the other priming methods.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research Field of the Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December, 2018 to May, 2019. This chapter consists of materials used and methods followed during the experimental period. It contains a short description of materials used, treatments, location of the experimental site, characteristic of soil, climate and weather, experimental design, fertilizer application, transplanting of the seedlings, application of plant growth enhancer, intercultural operations, harvesting, data collection and statistical analysis were described in this chapter.

3.1 Description of the experimental site

3.1.1 Experimental sites

The experiment was conducted at the Research Field of the Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from December, 2018 to May, 2019. Location of the site is 90°33' E longitude and 23°77' N latitude with an elevation of 8 meter from sea level (UNDP - FAO, 1988) in Agro-Ecological Zones of Madhupur Tract (AEZ No. 28) (Appendix I).

3.1.2 Soil

The soil of the trial area was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 6.7 and had organic carbon 0.45%. The details were presented in Appendix II.

3.1.3 Climatic conditions

The geographical location of the experimental site was under the subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March) which is suitable for boro rice cultivation in Bangladesh. Details of the monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Station, Bangladesh Meteorological Department, and presented during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar,Dhaka (Appendix III).

3.2 Experimental treatments

3.2.1 Plant materials

Rice (*Oryza sativa* L. cv. BRRI dhan67) was used as the test crop in this experiment. This variety was released in 2014 by Bangladesh Rice Research Institute (BRRI), Gazipur. It can tolerate salinity 12-14 dSm^{-1} (up to 3 weeks) during seedling stage and 8 dSm^{-1} during reproductive stage.

3.2.2 Experimental design and lay out

The pots experiment was laid out in a Randomized Complete Block Design (RCBD) having one factor with three replications. The treatments of the experiment were assigned at random into 27 pots of size with 30cm × 20cm. In each of 3 replications following the experimental design.

3.2.3 Treatments

The present experiment was included different level of halopriming (HP) and salinity. The treatment was as follows:

1. T_1 = Control
2. T_2 = HP_1(0.25 dSm^{-1} salt)
3. T_3= HP_2(0.5 dSm^{-1} salt)
4. T_4 = S_1 (8 dSm^{-1} salt)
5. T_5 = S_2 (12 dSm^{-1} salt)
6. T_6 = S_1HP_1(8 dSm^{-1} salt + 0.25 dSm^{-1} salt)
7. T_7 = S_1HP_2 (8 dSm^{-1} salt + 0.5 dSm^{-1} salt)
8. T_8 = S_2HP_1 (12 dSm^{-1} salt + 0.25 dSm^{-1} salt)
9. T_9 = S_2HP_2(12 dSm^{-1} salt + 0.5 dSm^{-1} salt)

3.2.4 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 loamy texture belonging to the AEZ 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.

3.2.5 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.

3.2.6 Halopriming technique

To determine the effective NaCl concentration, which could bring about halo priming effect, the uniform sized sterilized seeds of BRRI dhan67 (10g) were soaked in various concentrations of NaCl (0.25 dSm^{-1} and 0.50 dSm^{-1}) for 12 h in a screw cap bottle. The soaked seeds were further placed on a piece of clean filter paper, allowing dehydration under shade at 25°C till the seeds retrieved the original moisture level as that of pre-priming stage. Seed weights were tested repeatedly at fixed intervals to ensure the seeds have attained the original dry weight. The untreated seeds were used as the control. After ~24 h dehydration, the seeds were germinated in light transparent plastic bottles (19×11 cm) containing absorbent cotton soaked with distilled water. The growth and biochemical attributes of seedlings germinated from primed seeds were recorded on 4 d after germination.

3.2.7 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1m wide adding nutrients as per the requirements of soil. The sterilized non primed seed were soaked with water for 24 hours, washed thoroughly in clean water, and incubated for sprouting and after 5 days the germinated seeds were sown in the wet seed bed. The sprouted priming seeds also sown in wet seed bed after 4 days. Seeds were sown on 27 November, 2018 in order to have seedlings of 30 days.

3.2.8 Preparation of pots and application of salinity stress:

The size of the pot was 30 × 20cm. The soil was collected from 0-15cm depth. The collected soil was well pulverized and dried in the sun and required amount of decomposed cowdung was mixed with the soil. Each pot was filled up with 12 kg soil. A basal dose of triple super phosphate (TSP), muriate of potash (MP) and gypsum were used as the source of phosphorus, potassium and sulphur applied at the rate of 180kg ha^{-1}, 100kg ha^{-1} and 20kg ha^{-1}, respectively (1ha = 3×106 kg fresh soil) at the time of final pot preparation. Urea @ 150 kg ha^{-1} was applied as 3 equal splits One-third of urea and the whole amount of other fertilizers were incorporated with soil at final pot preparation before sowing. Rest of the nitrogen were applied in two equal splits one at 30 days after transplanting (DAT) and second at 45 days after transplanting (DAT). Thereafter, the pots containing soil were moistened with water.

3.2.9 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted in the morning without causing much mechanical injury to the roots.

3.2.10 Transplanting of seedlings on pots and application of salinity stress:

Thirty day's old seedlings were transplanted in the experimental plot on the 18th December, 2018. Healthy seedlings were uprooted carefully from the seed bed and two seedlings 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 everyday with an EC meter and necessary adjustments were made by adding water.

3.3 Intercultural operation

After transplanting of the seedlings, different intercultural operations were carried out for better growth and development of the plant.

3.3.1 Weeding

Sometimes there were some small aquatic weeds observed in pots that were removed by hand pulling.

3.3.2 Irrigation and drainage

During cultivation from December 2018 to April 2019, irrigated saline water was done one day interval each pot without the pots containing of control (C) and only

Haloprimed (HP_1 and HP_2) seedling for creating salinity stress. About 3-4 cm depth of water was maintained in the pot until the crop attained maturity.

3.3.3 Plant protection measures

Before heading green leafhopper infestations were observed in the crop and they were successfully controlled by applying Durshban of two times on 55 DAT and 62 DAT at 20ml/10L of water. Rice stem borer also attacked and it was controlled by the application of Furadan 5G at 2.5 g/pot. From heading onwards, the pots were netted to protect the rice grain from the attack of birds.

3.3.4 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each pot. Maturity of crop was determined when 80-90% of the grains become golden yellow in color. Ten pre-selected hills per pot from which different data were collected and areas from middle portion of each pot was separately harvested and bundled, properly tagged and then brought to the threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Then the plant samples were carried out to the laboratory. Plant height, leaf area index, total tillers and length of panicle were counted. Fresh weight of grain and straw were recorded pot wise. Finally, the weight was adjusted to a moisture content of 14%. Then the plant parts such as root, leaf, stem, and panicles (after panicle initiation) were dried by an electric oven at 65°C for 72 hours. The straw was sun dried and the yields of grain and straw pot^{-1} were recorded and converted to t ha^{-1}

3.4 Collection of data

Data on the following parameters were recorded during the course of the experiment.

1. Plant height(cm)
2. Number of tillers $hill^{-1}$
3. Total leaf Area (Length x Breadth of leaf) (cm^2)
4. SPAD meter reading (Chlorophyll measurement of leaf)
5. Days of Flowering
6. Number of effective tillers $hill^{-1}$
7. Number of non-effective tillers $hill^{-1}$
8. Panicle length (cm)

9. Number of fertile grains hill^{-1}
10. Number of unfertile grains hill^{-1}
11. 1000 seed weight
12. Total grains weight plot^{-1} or ha^{-1}
13. Dry Weight of –
    a. Stem
    b. Leaf
    c. Root
14. Relative water content (RWC)
15. Leaf membrane stability index (LMSI)
16. Na content
17. K content

3.5 Procedure of sampling for growth parameters

3.5.1 Plant height:

Plant height was measured from the ground level to the tip of the longest leaf/flag leaf by taking the average value of ten random samples, but before heading it was measured from base to tallest leaf tip

3.5.2 Number of tillers hill^{-1}

Total tiller number was counted after that the total number of tillers hill^{-1} was collected at 45,60,75,90 DAT and at harvest.

3.6 Procedure of sampling phenological parameters

3.6.1 SPAD meter reading (Chlorophyll measurement of leaf)

SPAD meter reading was collected by SPAD meter at 60 and 100 DAT which indicates greenness present in a leaf. Three leaves were randomly selected from each pot. The selective chl were measured by SPAD meter from the base, middle and tip of each leaves were measured with SPAD meter as at leaf value, then it was averaged and total chlorophyll content was measured.

3.6.2 Relative water content (RWC)

Three leaves were randomly selected from each pot and cut with scissors. Relative water content (RWC) was measured according to Barrs and Weatherley (1962). Leaf laminas were weighed (fresh weight, FW) and then immediately floated on distilled water in a petridis for 4 h in the dark. Turgid weights (TW) were obtained after drying excess surface water with paper towels. Dry weights (DW) were measured after drying at 80∘C for 48 h. Then calculation was done using the following formula:

$$RWC (\%) = [(FW - DW)/ (TW - DW)] \times 100.$$

3.6.3 leaf membrane stability index (LMSI):

Membrane stability index was estimated 100-mg leaf material by using two sets of test tubes containing 10 ml of double distilled water (Sairam 1994). One set was heated at 40 °C for 30 min in a water bath, and the electrical conductivity of the solution was recorded using conductivity meter (C_1). Second set was boiled at 100 °C on a boiling water bath for 10 min, and its conductivity (C_2) was measured as above. Membrane stability index (MSI) was calculated as:

$$MSI (\%) = (1-C1/C2) \times 100$$

3.6.4 Na and K contents in shoot and root

Root and shoot samples were oven-dried at 80˚C for 48 h. Dried samples were crushed and subjected to acid digestion in HNO_3:$HClO_4$ (5:1 v/v) mixture at 80˚C. The Na and K contents were measured by means of flame atomic absorption spectrophotometer (Nahar *et al.* 2016).

3.7 Procedure of sampling yield contributing parameter

3.7.1 Total leaf Area (Length x Breadth of leaf) cm^2

Length and breadth of the leaf of each sample plant was 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. Then total leaf area measured by multiplying length and breadth.

Leaf area = Length x Width

3.7.2 Days of Flowering

Flowering stage was executed by manually by daily field inspection.

3.7.3 Number of effective tillers

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

3.7.4 Number of non-effective tillers

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

3.7.5 Panicle length

Panicle length was measured from the basal node of the rachis to the apex of each panicle. Average panicle length (cm) was calculated by taking the lengths of all the panicles hill^{-1}.

3.7.6 Number of fertile grains hill^{-1}:

Total number of fertile grains panicle^{-1} of each plant were counted manually and averages and data were recorded from each pot.

3.7.7 Number of unfertile grains hill^{-1}:

Total number of unfertile grains panicle^{-1} of each plant were counted manually and averages and data were recorded from each pot.

3.7.8 1000-seeds weight:

1000-seed were counted, which were taken from the seed sample of each pot separately and then weighed in an electrical balance and data were recorded.

3.7.9 Weight of grain hillt^{-1}:

The grains from each plant were weighed by using an electrical balance with sun dried and oven dried.

3.7.10 Total dry matter:

The total dry matter was recorded by drying the plants at 70 ± 2°C for 72 hours and calculated from summation of leaves, stem, roots weight as observed in an electronic balance.

3.8 Statistical analysis:

Data were analyzed following Analysis of Variance (ANOVA) technique and mean differences were adjusted by the multiple comparison test (Gomez and Gomez, 1984) using the statistical computer based programme MSTAT-C v.2.1. (Russel, 1994) Means were compared by using Lsd test.

CHAPTER IV
RESULT AND DISCUSSION

The result obtained from the present study has been presented, discussed and compared in this chapter with different tables and figures. The results have been presented, discussed and also possible interpretations are given under the following headings.

4.1 Plant Height

The plant height of BRRI dhan67 decreased with the increasing level of salinity. The plant height was influenced significantly due to the response of varied priming levels at different days after transplanting (DAT) (Table 1). AT 45, 60, 75, 90 DAT and harvest, the tallest plant height (51.67, 66.10, 83.47, 110.50 and 118.81, respectively) was observed from T_1 treatment which was statistically similar (47.83, 59.60, 75.20, 104.23 and 111.03, respectively) to T_3 treatment and T_2 treatment respectively. On the other hand, the shortest plant height (28.67, 39.23, 56.20, 75.37 and 82.89, respectively) was noticed from T_5 treatment which was statistically similar (31.37, 41.50, 61.50, 79.67 and 86.66, respectively) to T_4 treatment and followed by T_6, $T_{7,}$ $T_{8,}$ and T_9 treatment.

Khan *et al.* (1997) exhibit a pot experiment and reported that plant height was seriously decreased by salinity. Hasanuzzaman *et al.* (2009) also observed that plant height is negatively influenced by the increase of salinity levels in the rice varieties. From this experiment, it was reported that salinity level greatly reduced the plant height at the desirable extend, salinity stress might inhibit cell division or cell enlargement so that plant height was reduced, but when the seed was treated with prime (halopriming) which may recover the damaging effect of the plant. Among the different treatments, 0.5 dSm^{-1} NaCl of halopriming showed the best performance under salt stress. Halopriming increased plant height, where this growth component of rice was adversely affected by increasing salinity. These results are in agreement with that of Panga *et al.* (2019) who conducted an experiment to reported that seed priming enhances plant height under salinity.

Table 1. Effect of halopriming on plant height at different days after transplanting.

Treatment	Plant Height (cm)				
	45 DAT	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
T_1	51.67 a	66.10 a	83.47 a	110.50 a	118.81 a
T_2	42.63 cd	55.23 c	72.33 b	100.13 c	111.50 ab
T_3	47.83 b	59.60 b	75.20 b	104.23 b	111.03 b
T_4	31.37 gh	41.50 f	61.50 c	79.67 g	86.66 ef
T_5	28.67 h	39.23 f	56.20 c	75.37 h	82.89 f
T_6	39.13 de	52.13 cd	69.27 b	92.17 e	96.83 cd
T_7	43.03 c	61.13 b	75.07 b	96.57 d	102.92 c
T_8	34.37 fg	46.83 e	69.10 b	83.70 f	89.42 ef
T_9	36.60 ef	50.40 d	69.53 b	89.93 e	92.08 de
$LSD_{(0.05)}$	**3.66**	**3.33**	**6.17**	**3.50**	**7.38**
CV (%)	**5.35**	**3.67**	**5.08**	**2.19**	**4.30**

In a column, having similar letter do not differ significantly as per Lsd.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.2 Number of tillers hill^{-1}

As the salinity level increased, the number of tiller plant^{-1} of BRRI dhan67 decreased at different days after transplanting (DAT). The tiller number plant^{-1} of BRRI dhan67 differed significantly due to responses on different priming levels (Table 2) at different days after transplanting (DAT). At 45 DAT, 60 DAT, 90 DAT and harvest, the maximum number of tillers plant^{-1} (7.00, 14.00, 21.33, 29.67 and 22.40, respectively) were recorded in T_1 treatment which was statistically similar (6.00, 12.33, 19.33, 26.00 and 19.64, respectively) to T_2 treatment and followed by T_3, T_6 and T_7 treatment while the lowest tiller number plant^{-1} (2.00, 5.67, 8.67,11.00 and 9.99, respectively) was observed from T_5 treatment which was statistically similar (2.00, 8.00, 10.67, 14.33 and 12.31, respectively) to T_4 and followed by T_8 and T_9 treatment.

Choi *et al.* (2003) noticed that the tiller number of rice decreased by 0.5% saline water in the soil with a low salinity level. Zeng *et al.* (2001) also reported that the reduction in tiller number plant^{-1} was significant only when plants were salinized for 20 days duration before panicle initiation (PI) of rice. Grattan *et al.* (2002) noticed that the 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}). From the above experiment, it was reported that the tiller number plant^{-1} was badly affected at higher salinity levels, but when the seed was treated with prime (halopriming) which may recover the damaging effect salt injury of the plant. Among the different treatments, 0.5 dSm^{-1} NaCl of halopriming showed the best performance. Halopriming increased tillers number hill^{-1} where rice was adversely affected by higher salinity levels.

Table 2. Effect of halopriming on tillers number plant^{-1} at different days after transplanting.

Treatment	**Tillers Number Plant^{-1}**				
	45DAT	**60DAT**	**75DAT**	**90DAT**	**At harvest**
T_1	5.00 cd	10.67 c	17.00 c	23.33 bc	16.78 c
T_2	6.00 b	12.33 b	19.33 b	26.00 ab	19.64 b
T_3	7.00 a	14.00 a	21.33 a	29.67 a	22.40 a
T_4	2.00f	8.00 e	10.67 f	14.33 ef	12.31 ef
T_5	2.00 f	5.67 f	8.67 g	11.00 f	9.99 f
T_6	4.67 d	9.67 d	16.00 c	20.67 bcd	16.83 c
T_7	5.67 bc	11.67 b	18.67 b	23.33 bc	19.33 b
T_8	3.33 e	8.33 e	12.67 e	17.00 de	13.50 de
T_9	3.67 e	10.33 cd	14.33 d	18.67 cde	15.33 cd
$LSD_{(0.05)}$	**0.75**	**0.88**	**1.39**	**5.56**	**2.42**
CV (%)	**9.97**	**5.05**	**5.23**	**15.71**	**8.61**

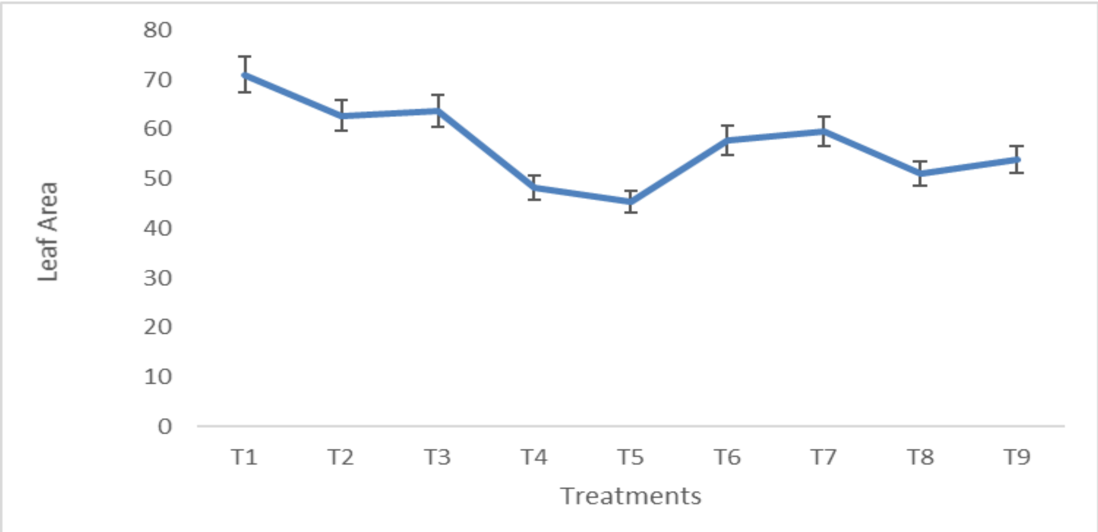
In a column, having similar letter do not differ significantly as per Lsd.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.3 Leaf Area (cm^2/leaf)

The leaf area (cm^2/leaf) was influenced significantly due to the response of varied priming levels (Figure 1). Leaf area decreased with an increasing concentration of salinity. The largest leaf area plant^{-1} (70.99 cm^2) was recorded from T_1 treatment while the smallest leaf area plant^{-1} (45.33 cm^2) was observed from T_5 treatment which was statistically identical (48.30 cm^2) to T_4. Other treatments also gave a satisfactory result which indicates mitigation of the salt stress by application of different halopriming treatments.

Hernandez *et al.* (2003) resulted that salt stress inhibited the cell division and cell expansion, consequently leaf expansion and as a result leaf area is reduced. However, halopriming mitigated the salinity stress by increasing the cell division and cell expansion resulting in broader leaf area of rice plant.



T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

Figure 1. Effect of halopriming on leaf area (cm^2) of rice.

4.4 Leaf, Root, Shoot and Total Dry Weight plant^{-1} (g)

The dry mass production and distribution were differed remarkedly by the effect of different treatments (Table 3). The highest leaves dry weight (15.967 g) was observed from T_1 treatment which was statistically similar (14.203 g) to T_2 treatment and followed by T_3 and T_7 treatment. On the other hand, the lowest leaves dry weight (6.517 g) was noticed from T_5 treatment which was statistically similar (6.857 g) to T_4 treatment and followed by T_6, $T_{8,}$ and T_9 treatment. The maximum stem dry weight (14.450 g) was observed from T_1 treatment which was statistically similar to T_2 treatment and followed by T_3 and T_7 treatment while the minimum stem dry weight (6.467 g) was noticed from T_5 treatment which was statistically similar (7.713 g) to T_4 treatment and followed by T_6, $T_{8,}$ and T_9 treatment. The uppermost root dry weight (5.7767 g) was observed from T_1 treatment which was statistically similar to T_2 treatment and followed by T_3 and T_7 treatment while the lowermost root dry weight (2.8833 g) was noticed from T_5 treatment which was statistically similar (3.4533 g) to T_4 treatment and followed by T_6, $T_{8,}$ and T_9 treatment. The greatest total dry weight (18.023 g) was observed from T_1 treatment which was statistically similar (31.707 g) to T_2 treatment and followed by T_3 and T_7 treatment while the lowest total dry weight (15.867 g) was noticed from T_5 treatment which was statistically similar (18.023 g) to T_4 treatment and followed by T_6, $T_{8,}$ and T_9 treatment.

Kumar and Khare (2016) concluded that salt stress (100 mM NaCl ≈10 dS m^{-1}) reduced the root length, root dry weight, shoot length and shoot dry weight both insensitive and in tolerant cultivar where growth reduction is higher in sensitive cultivar compared with tolerant. Ologundudu *et al.* (2014) reported that root and shoot length, root and shoot dry weight, and total dry matter production decreased with increasing the level of salinity. According to Farooq *et al*. (2006a); Mathew and Mohanasarida (2005) in rice plant, seed priming treatments reduced the time taken to initiate the germination process, improves the rate of germination and synchronization, moreover enhances the lengths of shoots and roots and thus increases the fresh and dry mass of the seedlings.

Table 3. Effect of halopriming on the leaf dry weight plant^{-1}, root dry weight plant^{-1}, shoots dry weight plant^{-1}and total dry weight plant^{-1} of rice.

Treatment	Leaf Dry Weight (g)	Stem Dry Weight (g)	Root Dry Weight (g)	Total Dry Weight (g)
T_1	15.967 a	14.450 a	5.7767 a	36.193 a
T_2	13.077 bc	11.550 bc	4.4233 bc	29.050 b
T_3	14.203 ab	12.717 ab	4.7867 ab	31.707 b
T_4	6.857 f	7.713 ef	3.4533 cd	18.023 ef
T_5	6.517 f	6.467 f	2.8833 d	15.867 f
T_6	9.777 de	9.873 cde	3.8233 bcd	23.473 cd
T_7	11.303 cd	10.733 bcd	3.9767 bc	26.013 c
T_8	7.297 f	7.930 ef	3.5467 cd	18.773 ef
T_9	8.343 ef	8.957 de	3.6633 cd	20.963 de
$LSD_{(0.05)}$	**2.02**	**2.32**	**1.0**	**2.95**
CV (%)	**11.24**	**13.36**	**14.32**	**6.96**

In a column, having similar letter do not differ significantly as per LSD.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.5 SPAD value

The chlorophyll content (SPAD reading) in leaves was decreased with increasing salinity levels (Table 4). Analysis of variance indicated that the effect of treatments on rice the chlorophyll content (SPAD reading) varied significantly. At 90 DAT, the highest chlorophyll contents (49.67) was reported from T_1 treatment which was statistically similar (44.27, 47.27, 46.43 and 44.20) to T_3, T_2, T_7 and T_9 treatment, while the lowest chlorophyll contents (38.80) was observed from T_5 treatment which was statistically identified (41.23) to T_4 treatment and followed by T_6 and T_8 treatment. At 60 DAT, the highest chlorophyll contents (45.07 SPAD units) was reported from T_1 treatment which was statistically similar (41.77 SPAD units) to T_2 and followed by T_3, T_7 and T_9 treatment while the lowest chlorophyll contents (33.23) observed from T_5 treatment which was statistically identical (34.73 SPAD units) to T_4 and followed by T_5, T_6 and T_8 treatment.

Hasanuzzaman M. *et al.* (2013) subjected to that rate of photosynthesis declines due to osmotic stress that results in stomatal closure and by the higher accumulation of Na^+ and $Cl^−$ that can damage the thylakoid membrane in the chloroplast. Photosynthetic pigments, chl a and chl b, are greatly affected by salt stresses. Ashraf and Harris (2013) resulted that accumulation of toxic Na^+ reduces the content of precursor of chl biosynthesis (such as glutamate and 5-aminolevulinic acid) and thus interrupts chlorophyll biosynthesis under saline condition. Salinity may cause the disorganization of cellular membranes, inhibits photosynthesis, generate toxic metabolites and decline nutrient absorption, ultimately leading to plant death. Halopriming may reduce this damaging injury of the plant where 0.5 dSm^{-1} NaCl of halopriming showed the best performance among the different treatments.

Table 4. Effect of halopriming on SPAD VALUE (%) at different days after transplanting

Treatment	SPAD VALUE (%)	
	60 DAT	90 DAT
T_1	45.07 a	49.67 a
T_2	40.77 bc	44.27 bcd
T_3	41.77 ab	47.27 ab
T_4	34.73 de	41.23 de
T_5	33.23 e	38.80 e
T_6	37.07 cde	42.97 cd
T_7	40.37 bc	46.43 abc
T_8	36.73 cde	43.10 cd
T_9	38.27 bcd	44.20 bcd
$LSD_{(0.05)}$	**4.09**	**3.68**
CV (%)	**6.11**	**4.81**

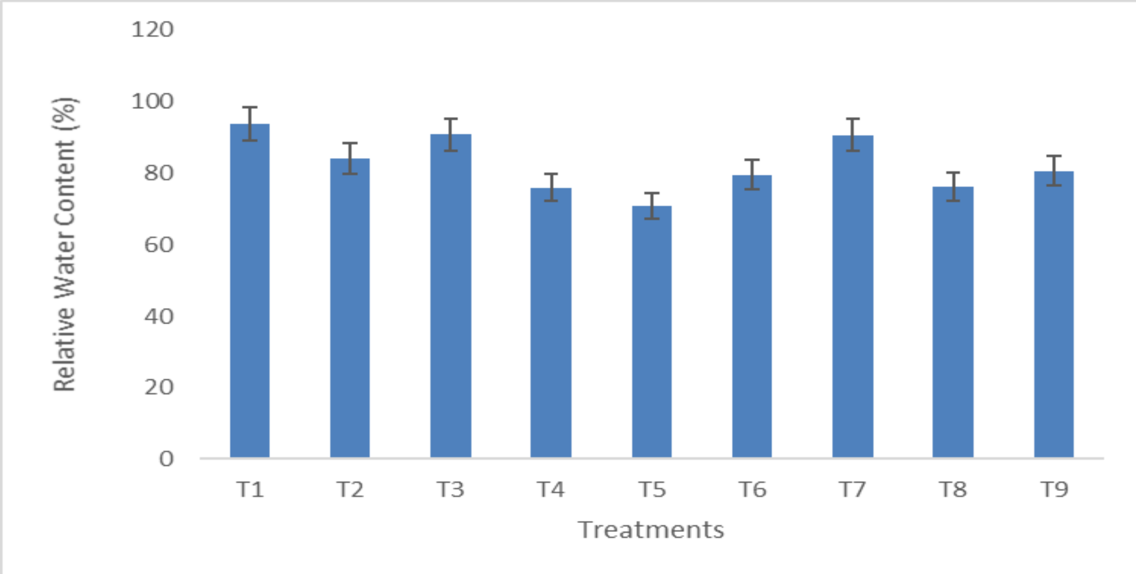
In a column, having similar letter do not differ significantly as per LSD.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.6 Relative water content (RWC)

The analysis of different salinity levels on rice leaf showed that, relative water content (RWC) of rice decreased considerably by an increase the level of salinity (Figure 2). The topmost relative water content (93.90) was recorded from T_1 treatment which was significantly similar (90.78 and 90.67) to T_2 and T_7 treatment while the lowest relative water content (70.88) was observed from T_5 treatment which was significantly similar to T_4, T_6 and T_9 treatment.

Steudle (2000) found that in transpiring plants water is thought to come from the soil to the root xylem through the apoplastic pathway due to the hydrostatic pressure gradient. Due to salt-stressed conditions, this situation changes because of the restricted transpiration. More water follows a cell-to-cell path, flowing across membranes of living cells under these situations (Vysotskaya *et al*. 2004). However, from the above results, it can be concluded that halopriming has an important role in mitigating salt stress and 0.5 dS m^{-1} NaCl of halopriming resulted in the best performance.



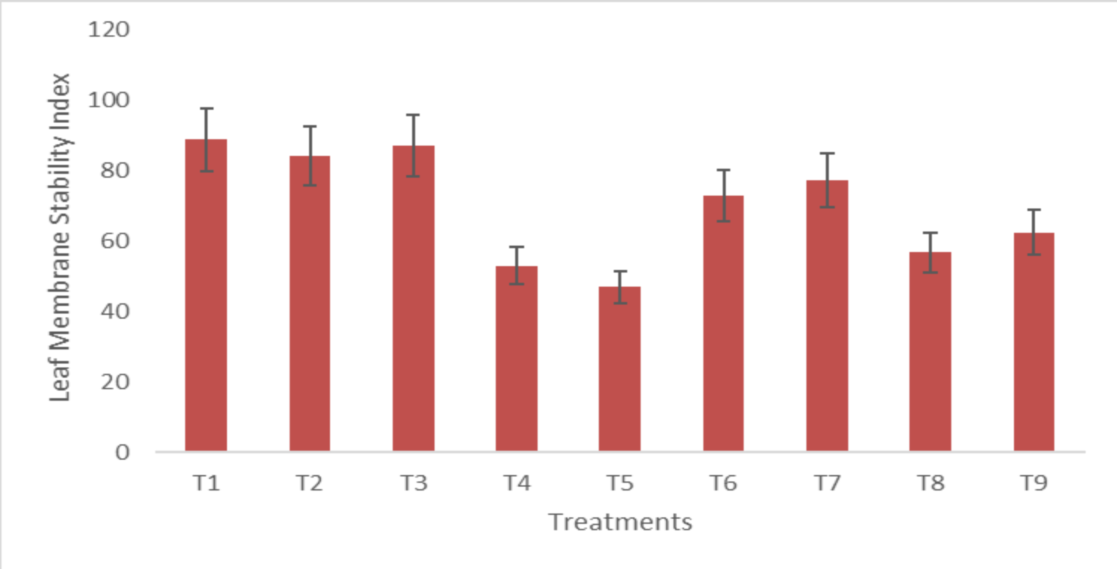
T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

Figure 2. Effect of halopriming on the relative water content (RWC) of rice.

4.7 Leaf Membrane Stability Index (LMSI)

A highly significant variation in the leaf membrane stability index (LMSI) of rice plant was observed due to the different level of treatments (Figure 3). The analysis of different salinity levels on LMSI showed that increase in salinity concentration caused a significant reduction of LMSI. The maximal LMSI (88.83) was observed from T_1 treatment which was significantly similar to T_3 treatment and followed by T_2, T_6 and T_7 treatment while the minimal LMSI (46.933) was observed from T_5 treatment which was significantly similar to T_4, T_8 and T_9 treatment.

Tufail *et al.* (2018) suggested that the membrane stability index of leaf decreased under increasing salinity level. Ali *et al*. (2004) noticed that salinity (8.5 dS m^{-1}) lowering the grain yield of rice by reducing photosynthesis, leaf area index and productive tiller. Halopriming has played an important role in mitigating salt stress by improving the leaf membrane stability index of rice plants where 0.5 dSm^{-1} NaCl of halopriming showed the best result.



T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

Figure 3. Effect of halopriming on the leaf membrane stability index (LMSI) of the rice plant.

4.8 Panicle length (cm)

Length of panicle showed statistically significant variations due to different levels of treatments (Table 5). The largest panicle length (26.37 cm) was noticed from T_1 treatment which was statistically identical (24.29, 23.53, 23.53 and 23.06) to T_7, T_2, T_6 and T_3 treatment. On the other hand the smallest panicle length (20.49 cm) was noticed from T_5 treatment which was statistically identical (22.33, 21.99 and 21.31) to T_9, T_8 and T_4 treatment.

According to Khatun *et al.* (1995) and Alam *et al.* (2001), salinity severely reduced the panicle length, seed setting percentage and panicle weight. Aref (2013) reported that rice plant to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with the other two stages. Similar to panicle bearing tillering in halopriming treatment under salinity condition, panicle length also increased by mitigating salt stress on rice plants where 0.5 dS m^{-1} NaCl of halopriming showed the best performance.

Table 5. Effect of halopriming on the Length of Panicle of rice.

Treatment	Length of Panicle
T_1	23.06 bcd
T_2	23.53 bc
T_3	26.37 a
T_4	21.31 de
T_5	20.49 e
T_6	23.53 bc
T_7	24.29 b
T_8	21.99 cde
T_9	22.33 bcde
$LSD_{(0.05)}$	**2.0**
CV (%)	**5.04**

In a column, having similar letter do not differ significantly as per LSD.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.9 Na content in Shoot

The analysis of different salinity levels on rice shoot showed that, Na content of rice shoot increased considerably by an increase the level of salinity (Table 6). The greatest Na content (512.15 µmol g^{-1} DW) was observed from T_5 treatment which was significantly similar to T_4 (449.95 µmol g^{-1} DW) treatment and followed by T_6, T_7, T_8 and T_9 treatment while the smallest Na content (33.42 µmol g^{-1} DW) was observed from T_1 treatment which was significantly similar to T_2 and T_3 treatment.

Higher concentration of Na^+ and Cl^- and excessive salt in soil or nutrient solution under salinity condition can causes a decrease in nutrient uptake by plant such as N and K in rice (Abdelgadir *et al.*, 2005). Also ionic imbalance is an effect of salt stress, which occurs in the cells due to excessive Na^+ and Cl^- and reduces the absorption of mineral nutrients such as K^+, Ca^{2+} and Mn^{2+} (Haseagawa *et al.*, 2000; Sudhir; Murthy, 2004). But halopriming may reduce this damaging injury of the plant where 0.5 dSm^{-1} NaCl of halopriming showed the best performance among the different treatments.

4.10 Na content in Root

The analysis of different salinity levels on rice shoot showed that, Na content of rice root increased considerably by an increase the level of salinity (Table 6). The maximal Na content (402.30 µmol g^{-1} DW) was observed from T_5 treatment which was significantly similar to T_4 (321.67 µmol g^{-1} DW) treatment and followed by T_6, T_7, T_8 and T_9 treatment while the minimal Na content (23.08 µmol g^{-1} DW) was observed from T_1 treatment which was significantly similar to T_2 and T_3 treatment.

Na+ is the principal cause of ion specific damage. Carden *et al.* (2003) reported that the cytosolic Na^+/K^+ ratio rather than the absolute Na+ concentration, may be life-threatening for NaCl tolerance. Increasing NaCl can causes NaCl toxicity in plant. Garciadebleas *et al.* (2003). demonstrated that the salt stress when Na^+ and Cl^- along with other cations are present in the soils in varying concentration (1 to 150 mM for glycophytes and more for halophytes) from plant root experiment. The toxic ions sneak into the plant along with the water stream which moves from soil to the vascular system of the root by different pathways like symplastic and apoplastic. Halopriming has played an important role in mitigating salt stress by improving the Na content in roots where 0.5 dS m^{-1} NaCl of halopriming showed the best result.

4.11 K Content in shoot

The K content in shoot was decreased with increasing salinity levels. The analysis of different salinity levels on rice shoot showed that, K content of rice shoot decreased considerably by an increase the salinity (Table 6). The highest K content (398.62 µmol g^{-1} DW) was showed from T_1 treatment which was significantly similar to T_2 (393.04 µmol g^{-1} DW) treatment and followed by T_3, T_6, T_7 and T_9 treatment while the lowest K content (138.71 µmol g^{-1} DW) was observed from T_5 treatment which was significantly similar to T_4 and T_8 treatment.

Salt stress increases Na^+ in plant which inhabit K uptake, as a result amount of K content reduced and show K deficiency (Nahar k. *et al.* 2016). Halopriming improved K content in shoot and reduced K deficiency.

4.12 K content in Root

The K content in root was decreased with increasing salinity levels. The analysis of different salinity levels on rice root showed that, K content of rice root decreased considerably by an increase the salinity (Table 6). The highest K content (385.19 µmol g^{-1} DW) was showed from T_3 treatment which was significantly similar to T_2 (379.71 µmol g^{-1} DW) treatment and followed by $T_{1,}$ $T_{6,}$ T_7 and T_9 treatment while the lowest K content (111.68 µmol g^{-1} DW) was observed from T_5 treatment which was significantly similar to T_4 and T_8 treatment.

Root cap cells may function in Na^+ exclusion under salinity stress. In rice roots, the Casparian band also functions as a barrier to water and ion movement through the apoplast (Morita et al., 1996; Ranathunge et al., 2005; Watanabe et al., 2006).which inhabit K ion influx in root zone. As a result K deficiency occurred in plant. Our research showed that halopriming improved K content in root zone.

Table 6. Effect of halopriming on the Na and K content on the shoot and root of rice.

Treatment	Na Content of Shoot (μmol g^{-1} DW)	Na Content of Root (μmol g^{-1} DW)	K Content of Shoot (μmol g^{-1} DW)	K Content of Root (μmol g^{-1} DW)
T_1	37.42 f	27.08 g	398.62 a	385.19 a
T_2	33.65 f	23.00 g	377.63 b	370.22 b
T_3	35.49 f	25.52 g	393.04 ab	379.71 ab
T_4	449.95 b	321.67 b	211.71 d	201.01 f
T_5	512.15 a	402.30 a	138.71 e	111.68 g
T_6	314.14 d	179.78 e	305.15 c	285.69 d
T_7	207.57 e	135.87 f	379.52 b	300.86 c
T_8	407.26 c	243.52 c	212.34 d	207.19 f
T_9	306.34 d	220.33 d	301.76 c	260.61 e
LSD(0.05)	**16.502**	**7.5871**	**18.489**	**12.534**
CV (%)	**2.22**	**1.49**	**2.11**	**1.55**

In a column, having similar letter do not differ significantly as per LSD.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.13 Days to flowering (DAT- Days after transplanting)

It was observed that, as the salinity level increased, the number of days to flowering increased significantly (Table 7). The maximum number of days required for flowering (70.33 DAT) was recorded from T_5 treatment which was statistically similar (68.33, 66.33, 65.67 and 64.67 DAT) to T_4, T_9, T_8 and T_6 treatment, while the minimum number of days required for flowering (60.67 DAT) was found from T_1 which was statistically similar (62.33, 62.67 and 63.33 DAT) to T_2, T_3 and T_7 treatment, respectively.

Rao *et al.* (2008) found that flowering is delayed with the increase of salinity and it reduces grain quality and quantity ultimately. Salinity stress reduced the plant growth and delayed to reach the maturity level and ultimately lately flowering from normal conditions. However, halopriming reduced the stress condition and accelerate the plant growth and reduced the days for flowering.

Table 7 Effect of halopriming on the days to flowering of rice.

Treatment	**Days to Flowering**
T_1	60.67 e
T_2	62.67 de
T_3	62.33 e
T_4	68.33 ab
T_5	70.33 a
T_6	64.67 cd
T_7	63.33 cde
T_8	65.67 bcd
T_9	66.33 bc
$LSD_{(0.05)}$	**3.41**
CV (%)	**3.04**

In a column, having similar letter do not differ significantly as per Lsd.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2 (12 dSm^{-1} + 0.5 dSm^{-1}).

4.14 Number of effective tillers hill^{-1}

The number of effective tillers plant^{-1} of rice was significantly influenced by different halopriming levels (Table 8). The maximum number of effective tillers hill^{1} (19.72) was recorded from T_1 treatment which was significantly similar (16.53, 15.33, 14.21 and 12.87) to T_2,T_3,T_7, and T_6, respectively and the minimum number of effective tillers plant^{-1} (8.00) was recorded from T_5 traetment which was significantly similar (9.61, 10.70, and 11.47) to T_4,T_8, and T_9, respectively.

Khatun *et al.* (1995) concluded that salinity delayed flowering, reduced the number of productive tillers and number of fertile florets panicle^{-1}. A similar result also found from Zeng *et al.* (2002) where he observed that seed yield, seed weight, panicle^{-1}, spikelet number panicle^{-1} and tiller number plant^{-1} were reduced with increasing salinity from salt tolerance indexes. The results also reported that the percentage of effective tiller plant^{-1} was badly affected at higher salinity levels but halopriming mitigate to some extent by increasing effective tiller hill^{-1}.

4.15 No of non-effective tillers hill^{-1}

It was observed that as the salinity level increased, the number of non-effective tillers plant^{-1} increased significantly (Table 8). The effect of different halopriming influenced drastically the number of non-effective tillers hill^{-1}. The highest number of non-effective tillers plant^{-1} (3.55) was recorded from T_5 treatment which was significantly similar (2.94, 2.61 and 2.33) to T_4, T_8 and T_9 treatment, respectively while the lowest number of non-effective tillers plant^{-1} (0.61) was found from T_1 treatment which was significantly similar (1.05, 1.50,1.94 and 1.99) to T_3, T_1, T_7 and T_6, respectively.

According to Alam *et al.* (2001) at the reproductive stage of rice, salinity depressed grain yield much more than that at the vegetative growth stage and at critical salinity levels it might give a normal straw yield of rice but produced little or no grain. Salinity also affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains and hence caused an increase in the number of sterile florets when the plants were continuously exposed to saline media. Halopriming enhanced panicle growth by minimizing the toxicity effect of salinity and reduce non-effective tillers plant^{-1}.

Table 8. Effect of halopriming on the effective tillers plant^{-1}, non-effective tillers plant^{-1} of rice.

Treatment	Effective Tillers Plant^{-1} (No.)	Non-effective Tillers Plant^{-1} (No.)
T_1	19.72 a	0.61 h
T_2	15.33 bc	1.50 f
T_3	16.53 b	1.05 g
T_4	9.61 g	2.94 b
T_5	8.00 h	3.55 a
T_6	12.87 de	1.99 de
T_7	14.21 cd	1.94 e
T_8	10.70 fg	2.61 bc
T_9	11.47 ef	2.33 cd

LSD$_{(0.05)}$	1.5	0.37
CV (%)	6.61	10.25

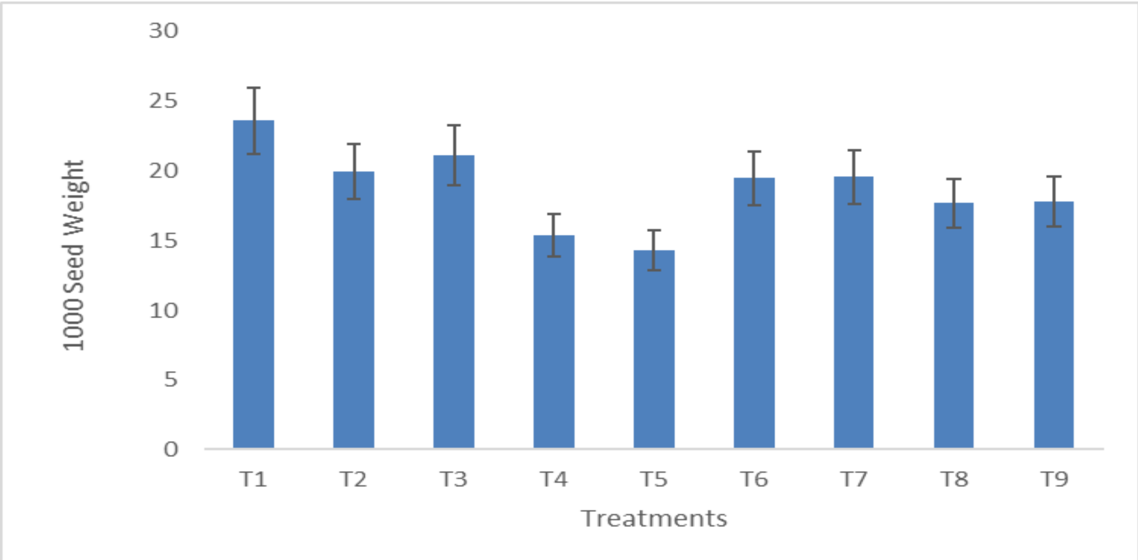
In a column, having similar letter do not differ significantly as per LSD.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

4.16 1000- grain weight (g)

The 1000 grain weight influenced significantly by applying different treatments (Figure 4). The highest amount of 1000- grain weight (g) (23.61) was recorded from T_3 treatment which was significantly similar (21.12 g) to T_2 treatment, while the lowest amount of 1000-grain weight (g) (14.30) was observed from T_5 treatment which was significantly similar (15.37 g) to T_4 treatment.

Hasanuzzaman *et al.* (2009)) concluded that the number of 1000-grain weight and yield plant^{-1} of rice was reduced with increasing salinity levels. Ali *et al.* (2013) reported that seed priming treatments reduced the mean emergence time and promoted germination, early canopy development, and tillering in comparison to the untreated control. The number of fertile tillers, plant height, 1000-grain weight, and grain and biological yield was increased by different priming techniques. However, from the above results it might be concluded that halopriming has an important role in mitigating salt stress as a result of increasing 1000- grain weight.



T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1}).

Figure 4. Effect of halopriming on the 1000- grain weight of rice

4.17 Number of filled grains panicle^{-1}

The number of filled grain panicle^{-1} influenced remarkedly by different salinity levels (Table 9). The highest number of filled grain panicle^{-1} (162.67) was recorded from T_1 treatment which was significantly similar (148.63) to T_2 treatment and followed by T_3 (129.78), T_6 (108.75) T_9 (105.21) treatments while the lowest number of filled grain panicle^{-1} was found from T_5 (69.58) treatment which was significantly similar to T_4 (85.30) and T_8 (93.95) treatment.

Along with the vegetative stages, salt stress affects the reproductive stage of rice that reduces yield, yield contributing parameters and grain quality. Hasanuzzaman *et al.* (2009) were found that the filled grain and grain weight also significantly decrease with the increasing salinity level. Kumar and Khare (2016) exhibit that tolerant and sensitive cultivar to 100 mM NaCl (≈10 dS m^{-1}) and noted that salinity reduced the number of grains panicle^{-1}, filled grain percentage, 1000-grain weight and grain yield both insensitive and intolerant cultivar where yield reduction was higher in the sensitive cultivar. They also noticed that the grain quality of rice deteriorated by salinity through the reduction of protein and starch content of grain. This study suggested that halopriming improves the number of filled grain panicle^{-1} in rice plants which was strongly related to the yield.

4.18 Number of unfilled grains panicle^{-1}

The level of salinity increased, the number of unfilled grain panicle^{-1} increased significantly (Table 9). The highest number of unfilled grain panicle^{-1} was recorded from T_5 (29.08) treatment which was significantly similar (23.83 and 20.00) to T_4 t and T_8 treatment while the lowest number of unfilled grain panicle^{-1} was found from T_1 (5.75) treatment which was significantly similar (8.67) to T_2 and followed by $T_{1,}$ $T_{7,}$ T_6 T_9treatments.

Hasanuzzaman *et al.* (2009) found that the number of unfilled grain significantly increased with the increasing salinity level. However, halopriming mitigate the salinity levels by decreasing the number of unfilled grain panicle^{-1} in rice plants.

4.19 Grain Yield Plant^{-1}

The grain yield of rice plant differed considerably by applying the different levels of treatments (Table 9). The highest number of grain yield plant^{-1} was recorded from T_1 (27.33 g) treatment which was significantly similar to T_2 (25.18 g) treatment and followed by T_3 (23.87 g), T_7 (23.17 g) and T_6 (21.47 g) treatment while the lowest number of grain yield plant^{-1} (g) was found from T_5 (16.03) treatment which was significantly similar to T_4 (18.13 g) treatment and followed by T_9 (20.53 g) and T_8 (19.97 g) treatment.

Yield and grain quality of rice are greatly influenced by salinity level where salinity hampers growth, photosynthesis and net assimilation rate. Zheng and Shannon (2000) subjected that salinity decreased grain yield by decreasing tiller number, pollen viability, fertility percentage and 1000-grain weight where the level of yield reduction increased with increasing the level of salinity. Hasanuzzaman *et al.* (2009) was found that the filled grain and grain weight also significantly decrease with the increased salinity level. On the other hand, Ali *et al.* (2013) reported that the number of fertile tillers, plant height, 1000-grain weight and grain and biological yield were increased by different priming techniques. From this experiment, it was observed that halopriming increased the tolerance capacity of the plant by reducing the saline stress effect.

Table 9. Effect of halopriming on the number of filled grain panicle^{-1}, unfilled grain panicle^{-1} and grain yield plant^{-1} (g) of rice.

Treatment	Filled Grain Panicle^{-1} (No.)	Unfilled Grain Panicle^{-1} (No.)	Grain Yield Plant^{-1} (g)
T_1	162.67 a	5.75 h	27.33 a
T_2	129.78 c	8.67 g	23.87 bc
T_3	148.63 b	10.67 fg	25.18 b
T_4	85.30 f	23.83 b	18.13 f
T_5	69.58 g	29.08 a	16.03 g
T_6	108.75 d	15.00 de	21.47 de
T_7	125.42 c	13.00 ef	23.17 cd
T_8	93.95 ef	20.00 c	19.97 ef
T_9	105.21 de	16.42 d	20.53 e
$LSD_{(0.05)}$	**12.71**	**2.46**	**1.94**
CV (%)	**6.42**	**8.97**	**5.14**

In a column, having similar letter do not differ significantly as per Lsd.

T_1= Control , T_2= HP_1(0.25 dSm^{-1}), T_3= HP_2(0.5 dSm^{-1}), T_4= S_1 (8 dSm^{-1}), T_5= S_2 (12 dSm^{-1}), T_6 = S_1HP_1(8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}), T_9 = S_2HP_2(12 dSm^{-1} + 0.5 dSm^{-1})

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted in the net house of the Department of Agricultural Botany and in the Laboratory of Agricultural Botany of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period of December-May, 2018-2019 to find out the role of halopriming in improving growth and yield of salt stress affected rice plant. *Oryza sativa* cv. BRRI dhan67 was used as a test crop. The experiment consists of nine treatments viz. T_1 =Control,T_2 = HP_1 (0.25 dSm^{-1}), T_3= HP_2 (0.5 dSm^{-1}), T_4 = S_1 (8 dSm^{-1}), T_5 = S_2 (12 dSm^{-1}), T_6 = S_1HP_1 (8 dSm^{-1} + 0.25 dSm^{-1}), T_7 = S_1HP_2 (8 dSm^{-1} + 0.5 dSm^{-1}), T_8 = S_2HP_1 (12 dSm^{-1} + 0.25 dSm^{-1}) and T_9 = S_2HP_2 (12 dSm^{-1} + 0.5 dSm^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data on different growth parameters, physiological parameters and yield contributing characters of rice plants were recorded. The collected data were statistically analyzed for the evaluation of the treatment effect. The observation was made on plant height (cm), number of tillers $plant^{-1}$, leaf area, SPAD meter reading (Chlorophyll measurement of leaf), days of flowering, number of effective tillers, number of non-effective tillers, panicle length, number of fertile grains $plant^{-1}$, number of unfertile grains $plant^{-1}$, 1000 seed weight, total weight of grains, dry weight of stem, leaf, root and relative water content (RWC), Na and K content of root and shoot.

In this experiment, saline water was applied throughout the life cycle of the rice plant to keep the soil in the saline condition. Plant in non-saline control treatment showed the maximum height more or less over the growth period whereas the lowest height was recorded from 12 dS m^{-1} treated plants. AT 45, 60, 75, 90 DAT and harvest, the tallest plant height (51.67, 66.10, 83.47, 110.50 and 118.81, respectively) was observed from T_1 treatment. On the other hand, the shortest plant height (28.67, 39.23, 56.20, 75.37 and 82.89 respectively) was noticed from T_5 treatment At 45 DAT, 60 DAT, 90 DAT and harvest, the highest number of tillers $plant^{-1}$ (7.00, 14.00, 21.33, 29.67 and 22.40, respectively) was recorded from T_1 treatment while the lowest tiller number $plant^{-1}$ (2.00, 5.67, 8.67, 11.00 and 9.99 respectively) was observed from T_5 treatment. At 60 DAT, the highest chlorophyll contents (49.67) was reported from

T_1 treatment while the lowest chlorophyll contents (38.80 SPAD units) was observed from T_5 treatment At 100 DAT, the highest chlorophyll contents (45.07) reported from T_3 treatment while the lowest chlorophyll contents (33.23) observed from T_5 treatment. The tallest panicle (26.37 cm) was noticed from T_1 treatment On the other hand, the shortest panicle (20.49 cm) was noticed from T_5 treatment. The largest leaf area plant^{-1} (70.99 cm^2) was recorded from T_1 treatment while the smallest leaf area plant^{-1} (45.33 cm^2) was observed from T_5 treatment. The highest number of days required for flowering (70.33 DAT) was recorded from T_5 treatment while the lowest number of days required for flowering (60.67 DAT) was found from T_1 treatment. The maximum number of effective tillers plant^{-1} (19.72) was recorded from T_1 treatment and the minimum number of effective tillers plant^{-1} (8.00) was recorded in T_5 treatment. The highest number of non-effective tillers plant^{-1} (3.55) was recorded from T_5 treatment while the lowest number of non-effective tillers plant^{-1} (0.61) was found from T_1 treatment. The highest number of filled grain panicle^{-1} (162.67) was recorded from T_1 treatment while the lowest number of filled grain panicle^{-1} was found from T_5 (69.58) treatment. The highest number of unfilled grain panicle^{-1} was recorded from T_5 (29.08) treatment while the lowest number of unfilled grain panicle^{-1} was found from T_1 (5.75) treatment. The highest number of grain yield plant^{-1} was recorded in T_1 (27.33 g) treatment while the lowest number of grain yield plant^{-1} (g) was found from T_5 (16.03) treatment. The topmost amount of 1000- grain weight (23.61 g) was recorded from T_1 treatment while the bottommost amount of 1000-grain weight (14.30 g) was observed from T_5 treatment. The highest relative water content (93.90) was recorded from T_1 treatment while the lowest relative water content (70.88) was observed from T_5 treatment. The largest leaf membrane stability index (88.833) was observed from T_1 treatment while the smallest leaf membrane stability index (46.933) was observed from T_5 treatment. The highest leaves dry weight (15.967 g) was observed from T_1 treatment. On the other hand, the lowest leaves dry weight (6.517 g) was noticed from T_5 treatment. The highest stem dry weight (14.450 g) was observed from T_1 treatment while the lowest stem dry weight (6.467 g) was noticed from T_5 treatment. The highest root dry weight (5.7767 g) was observed from T_1 treatment while the lowest root dry weight (2.8833 g) was noticed from T_5 treatment. The maximum total dry weight (18.023 g) was observed from T_1 treatment while the minimum total dry weight (15.867 g) was noticed from T_5 treatment. The greatest Na content (512.15 µmol g^{-1} DW) was observed from T_5 treatment while the smallest Na content (33.42 µmol g^{-1} DW) was observed from T_1 treatment. The maximal Na content (402.30 µmol g^{-1} DW) was observed from T_5 treatment while the minimal Na content (23.08 µmol g^{-1} DW) was observed from T_1 treatment. The highest K content (398.62 µmol g^{-1} DW) was showed from T_1 treatment while the lowest K content (138.71) was observed from T_5 treatment. The highest K content (385.19 µmol g^{-1} DW) was showed from T_1 treatment while the lowest K content (111.68 µmol g^{-1} DW) was observed from T_5 treatment.

Conclusions

The results from the experiments indicated that the salt stress adversely affected growth, development and physiology of rice plants; the yield of rice was gradually decreased by the increase of salinity levels but this adverse effect could be alleviated by applying halo priming. Halopriming greatly mitigated the damaging effect of salt for the growth, physiology, development and yield of rice plants. Among the different halopriming levels, 0.50 dSm^{-1} NaCl halo priming in salt stress condition showed the best results in terms of growth, physiology and yield parameters.

Recommendations

However, further study may be needed regarding the effect of salinity on growth and yield of BRRI dhan67 in different halo priming of Bangladesh to recommend a package of technology for use at farmers' level.

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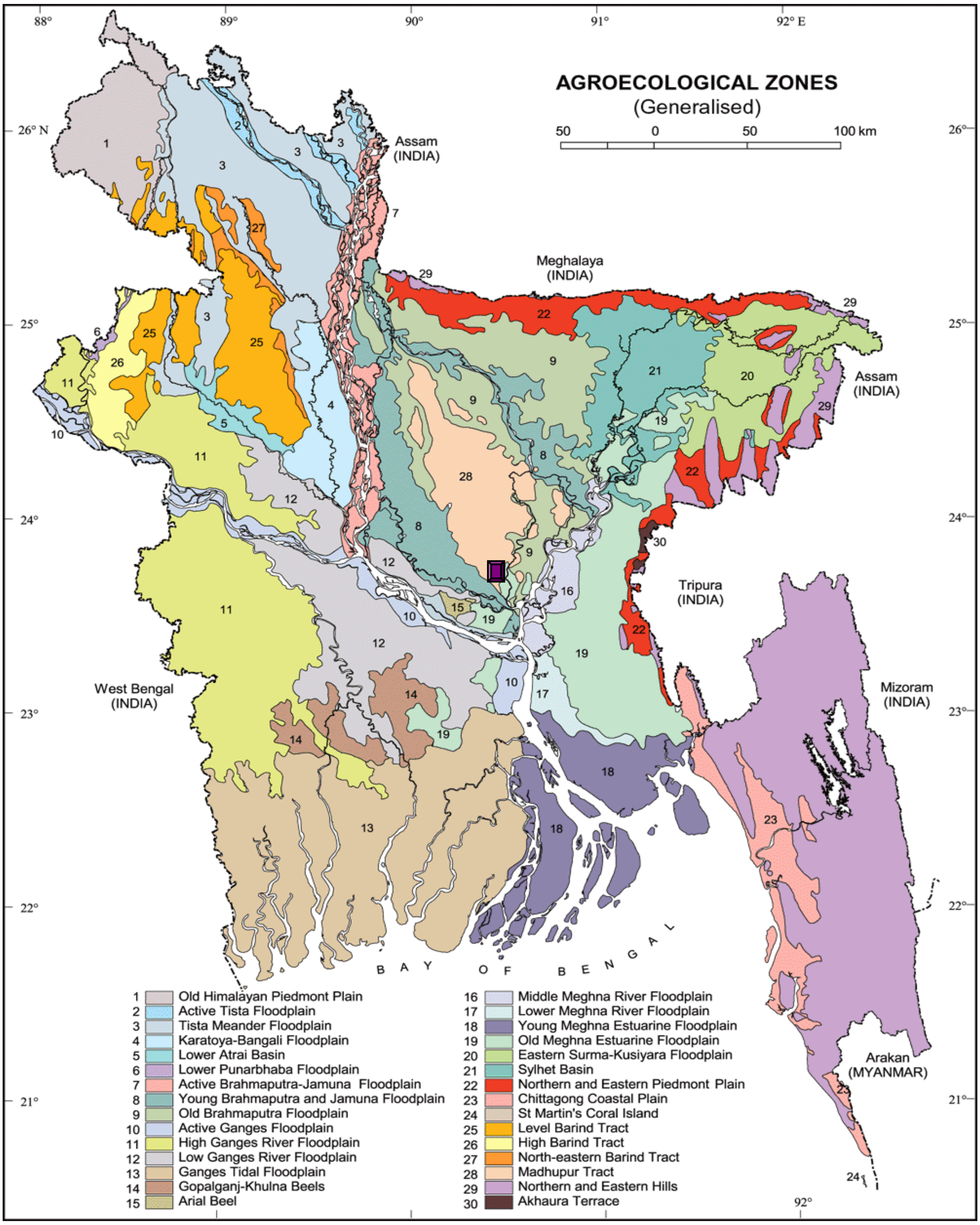
APPENDIXES

Appendix I: Map showing the experimental sites under study



The experimental site under study

Appendix II: Characteristics of soil of experimental as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Field laboratory, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix III. Maximum and minimum monthly temperature (^{o}C), relative humidity and rainfall during November, 2018 to April, 2019 at the farm of SAU

Name of the Months	Average air temperature (^{O}C)		Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November, 2018	31	18	63	1.9
December, 2018	28	16	61	3.5
January. 2019	27	13	57	12.3
February, 2019	34	15	57	8.1
March, 2019	34	16	57	73.4
April, 2019	35	20	66	178.5

(Weather station, Sher-e-Bangla Agricultural University, Dhaka-1207)

PLATES

A B

C

Plate 1 (A, B & C): Pot preparation, Germinated halopriming seed & Seed sowing in nursery seedbed

A

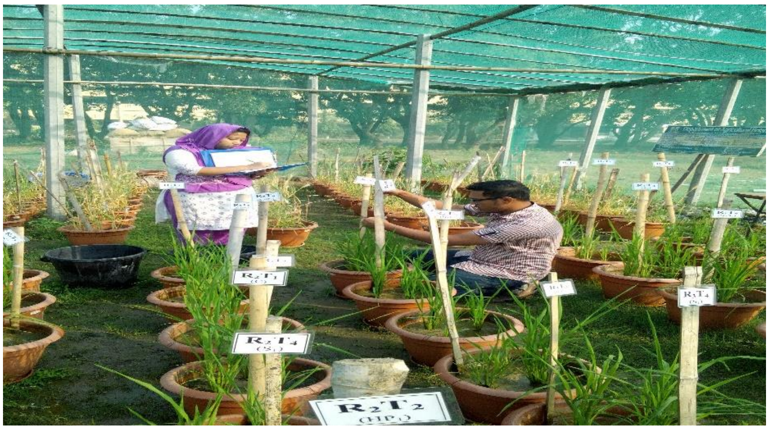
B

C

Plate 2 (A, B and C): Measurement of fertilizer and Transplanting seedling from seedbed to pot

A

B



C

Plate 3 (A, B and C): Oven dry, Lab test and measurement