ABSCISIC ACID INDUCED CHANGES IN SEED GERMINATION, SEEDLING GROWTH AND WATER RELATION BEHAVIOR OF WHEAT UNDER SALT STRESS CONDITION

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CERTIFICATE

This is to certify that the thesis entitled, "**ABSCISIC ACID INDUCED CHANGES IN SEED GERMINATION, SEEDLING GROWTH AND WATER RELATION BEHAVIOR OF WHEAT UNDER SALT STRESS CONDITION**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the result of a piece of bona fide research work carried out by **MOHAMMAD MAHAMUDUL HASAN** bearing Registration No. **11-04351** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Date:

Place: Dhaka, Bangladesh

Prof. Dr. Md. Abdullahil Baque

Research Supervisor

Dedicated To

My Beloved Parents

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ABSTRACT

Pre-sowing seed treated with Abscisic acid (ABA) assumed to be a potential priming agent to increase the germination, seedling growth and water relation behavior of grain under salt stress condition. With this view, a lab experiment was carried out to find out the effect of various ABA concentration on the germination, seedling growth and water relation behavior of wheat under salt stress condition at central laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from 21 September, 2016 to 19 November, 2016. This study was conducted with two different experiments. The experiment was laid out in a Completely Randomized Design (CRD) with five replications. In this experiment three wheat genotypes (ESWYT-5, ESWYT-6, and BARI Gom 28) were used as test crop; ABA and water were utilized as priming agent for hormonal and hydro priming and salt stress was induced by sodium chloride (NaCl) solution. Germination parameters of wheat like germination percentage, germination coefficient; growth parameters like shoot length, root length, fresh weight, vigour index, water relation parameters like water retention capacity, relative water content etc. were collected form this experiment. Data were analyzed by MSTAT-C software. The significance of difference among the treatment means was estimated by the Least Significant Difference (LSD) test at 1% level of probability. In the first experiment, the best treatment was carried out among different ABA concentrations on germination, seedling growth and water relation behavior of three wheat genotypes without any stress condition. It was found that ESWYT-5 (V_1) showed the highest germination rate (91.71%), shoot length (160.6 mm), root length (112.4 mm), shoot dry weight (54.58 mg), root dry weight (47.64 mg), relative water content (93.8%), water retention capacity (18.7) and vigour index (196.5) with 40 ppm ABA primed seeds for 9 hours. In the second experiment, seeds primed with 40 ppm ABA for 9 hours placed under salt stress condition and found that ESWYT-5 (V_1) showed the highest germination rate (93.2%), shoot length (160.6 mm), root length (110.0 mm), shoot dry weight (54.58 mg), root dry weight (47.64 mg), relative water content (90.39%), water retention capacity (12.6.) and vigour index (220.6) under control treatment. With other salt treatments all growth parameters of V_1 (ESWYT-5) reduced slowly but in other cultivars all parameters reduced drastically with increasing salt stress. From the result of the study, it was revealed that seeds primed with 40 ppm ABA for 9 hours showed the best result under salt stress condition.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

The human population is rapidly increasing and which needs a substantial increase in agricultural productivity worldwide. However, various biotic and abiotic stresses are major factors limiting crop productivity (Wani and Sah, 2014). To feed the world population, productivity must be increased by 70% for an additional 2.3 billion people by 2050 (Tilman *et al.*, 2011). The mechanisms underlying environmental stress response and tolerance in plants are different and more complex than animals (Qin *et al.*, 2011). Identifying the principles by which plants respond to various environmental stresses is one of the critical aspects for plant biotechnologists. Amongst various abiotic stresses, drought, salinity, and extreme temperatures are most widespread and significant (Wani *et al*., 2013). Soil salinity, one of the most severe abiotic stresses, limits the production of nearly over 6% of the world's land and 20% of irrigated land which represent about 15% of total cultivated areas and negatively affects crop production worldwide (Hasanuzzaman *et al*., 2012). Plants are frequently exposed to adverse environmental conditions, termed abiotic stresses such as salinity, drought, heat, cold, flooding, heavy metals, ozone, UV radiation, etc. therefore, they pose serious threats to the sustainability of crop yield (Bhatnagar-Mathur *et al*., 2008). Abiotic stresses remain the greatest constraint to crop production worldwide. It leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Wang *et al*., 2001).

The soil of 34 million hectares of irrigated land is salt-affected worldwide. Water logging and related salinity affect 60-80 million hectares (FAO, 2011). About 53% of the coastal areas have been seriously affected by salinity which is over 30% of the total cultivable lands of Bangladesh. Around 50% of cultivable lands will be lost by the middle of the 21st century (Wang *et al.*, 2003).

Seed germination and seedling growth are the two critical stages for the establishment of crops. Ascending salt concentrations not only prevent the seed germination, but also extend the germination time by delaying the start of germination (Thiam *et al.*, 2013). The effects of salinity at seedling stage of wheat range from reduction in germination percentage, fresh and dry weight of shoots and roots to the uptake of various nutrient ions. It is thought that the depressive effect of salinity on germination could be related

to a decline in endogenous levels of hormones (Afzal *et al*., 2006). In adverse condition especially salinity and drought, the water is limited and time bounding factor which is very much crucial for successful seed germination; more over successful crop establishment depends not only on the rapid and uniform germination of the seed, but also on the ability of the seed to germinate under low water availability (Fischer *et al.*, 1978). However, if the stress effect can be prevented at the germination stage, chances for attaining a good crop with economic yield production would be high (Ashraf and Rauf, 2001). It has been estimated that more than 50% of yield reduction is the direct result of abiotic stresses (Acquaah, 2007).

Especially, NaCl is one of the most abundant and powerful salt which causes nutrient deficiency and also create toxicity to the plant metabolism (Azevedo *et al*., 2005). The adverse effects of salinity have been attributed to an increase in sodium (Na^+) and chloride (Cl^-) ions and hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Both Na^+ and Cl^- produce many physiological disorders in plants (Mahajan and Tuteja, 2005). In addition to that, when the plants were exposed to the high salinity conditions, there having a capability to produce more Reactive Oxygen Species such as superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2) and hydroxyl radicals ($OH^{\bullet}$) (Implay, 2003). ROS formation leads to changes in intercellular redox homeostasis and it is now widely accepted that redox signals are key regulators of plant metabolism, morphology and development (Bowler and Fluhur, 2000; Foyer and Noctor, 2003). A plant's response to salt stress depends on the genotype, developmental stage, as well as the intensity and duration of the stress. The outcome of these effects may cause the disorganization of cellular membranes, inhibit photosynthesis, generate toxic metabolites and decline nutrient absorption, ultimately leading to plant death (Mahajan and Tuteja, 2005). In general, the response of a crop plant to salinity is reduced growth (Tavakkoli *et al*., 2011). Osmotic stress due to salinity leads to a slow growth rate and developmental characteristics such as vegetative development, net assimilation capacity, leaf expansion rate and leaf area index (Zheng *et al*., 2008; Hasanuzzaman *et al.*, 2009). A reduction in photosynthesis is also one of the most conspicuous effects of salinity stress (Leisner *et al*., 2010; Raziuddin *et al*., 2011).

Wheat (*Triticum* spp.) is a cereal grain originated from the Levant region of the Near East but now cultivated worldwide. It is grown in all types of soils and is classified as

a moderate to salt tolerant crop (Mass and Hoffman, 1977). It is estimated that approximately one-third of the world's people depend upon wheat for their nourishment. In 2015, world production of wheat was 734.1 million tons (FAO, 2016), making it the third most produced cereal after maize and rice. By considering annual production wheat is the third important cereal after maize and rice in Bangladesh (BBS, 2015). The total area under wheat crop has been estimated 429607 ha (1061602 acre), total production (1302998 Mt) and average yield (3, 1429 Mt/ha) (USDA, 2016). In Bangladesh, wheat provide 7% of the total output of food cereals. (BBS, 2015).

Seed priming is considered as an effective means to enhance stress tolerance capability of crop including drought. Seed priming is the induction of a particular physiological state in plants by the treatment of natural and synthetic compounds to the seeds before germination (Faijunnahar *et al*., 2017). Seed-priming technology has twofold benefits: enhanced, rapid and uniform emergence, with high vigor and better yields in vegetables and floriculture (Bruggink *et al*., 1999) and some field crops (Basra *et al*., 2005; Kaur *et al*., 2005) .The physiological state of plants in which plants are able to faster or better activate defense (responses or both is called the primed condition of the plant (Beckers and Conrath, 2007). It optimizes seed performance by rapid uniform germination, normal and vigorous seedlings growth (Basra *et al*., 2005; Cantliffe, 2003). Under stress condition primed seedling able to grow normally (Carbineau and Come, 2006; Ashraf and Foolad, 2005; Powell *et al*., 2000).

Priming allows some of the metabolic processes essential for germination to occur without germination take place (Faijunnahar *et al.,* 2017). Seeds are soaked in different solutions with high osmotic potential during priming. Thus the seeds were prevented from absorbing enough water for radical protrusion and retarding the seeds in the lag phase (Taylor *et al*., 1998). Seed priming has been commonly used to minimize the time between seed sowing and seedling emergence and to ensure synchronize emergence (Parera and Cantliffe, 1994). These effects of priming are collaborated with repairing and building up of nucleic acids, increased synthesis of proteins as well as the repairing of membranes (McDonald, 2000). Priming also increases the activities of anti-oxidative enzymes in treated seeds (Hsu *et al*., 2003; Wang *et al*., 2003).

Abscisic acid (ABA) use as hormonal priming agent. In response to environmental stresses, endogenous ABA levels increase rapidly, activating specific signaling pathways and modifying gene expression levels (Brien *et al.*, 2013). ABA also acts as an internal signal enabling plants to survive under adverse environmental conditions (Keskin *et al.*, 2010). High levels of ABA are important for the rapid osmotic adjustment in both individual cells and intact plants. ABA treatment is beneficial before exposing the plants or tissues to adverse environmental conditions and making plants more tolerant to future stress exposure. (Travaglia *et al.*, 2013**).** ABA application improved salt and osmotic stress (Nayyar and Walia, 2003). In *Phaseolus vulgaris* the addition of 1 μM ABA to the nutrient solution before the exposure to salt stress reduced the negative effect of NaCl (Khadri *et al.*, 2006). The chlorophyll and carotene contents increased in plants with exogenous ABA under salt stress respect to control (Travaglia *et al*., 2013**).** Carotenes are found accompanying chlorophylls, making up complex photosynthetic which acts as radiant energy capture and as protecting agents of the photosynthetic apparatus on possible injuries from visible light (Gross, 1991). ABA has been implicated to have a role in protecting cellular structures during dehydration (Frahm *et al.*, 2004). ABA treatment in plants grown under salinity kept low foliar temperature and enhanced stomatal conductance compared to control plants (Travaglia *et al*., 2013**)**.

Therefore, the present study was undertaken with the following objectives:

- To evaluate the effect of pre-sowing seed treatment with Abscisic acid on germination behavior of wheat in relation to salt tolerance.
- To optimize concentrations and priming time of Abscisic acid regarding improvement of rate and uniformity of seedling emergence and growth of wheat.
- To better understanding of the morpho-physiological responses during salt stress.

CHAPTER 2

REVIEW OF LITERATURE

Soil salinity, one of the most severe abiotic stresses, limits the production of nearly over 6% of the world's land and 20% of irrigated land which represent about 15% of total cultivated areas and negatively affects crop production worldwide. In Bangladesh wheat is the third important cereal crops, which is a great source of carbohydrate and protein. The whole Southern part of Bangladesh face the salinity problem, for this reason most of all cultivable lands keep fallow except rainy season. By seed priming with different chemicals salinity effect can be reduced which helps us to increase food production. Scientists conducted experiment for finding out the problem of salinity stress. The findings from this review will help to cultivate wheat under salt affected areas.

2.1 Effect of salinity

2.1.1 Effect of salinity on growth parameters

A pot experiment done by Kilic and Kahraman (2016) to observe the effects of salinity on Barley plant growth and development. Salt (NaCl) concentrations applied in the study were 0.0, 0.25, 0.275, and 0.30 M. The obtained results showed that in 0.30 M salt concentration germination index, vigor index, radicle length, coleoptile length and fresh weight of barley plants decreased 51%, 88%, 85%, 76% and 66%, respectively. They also showed that salt stress significantly affected photosynthetic apertures on both adaxial and abaxial surfaces of the leaves. Salt stress decreased stromata count by 45%, stromata widths by 30%, stromata length by 24%, and epidermis count by 16% on adaxial surface under 0.30 M salt stress compared to control. These results are in agreement with those of Ghoulam *et al.* (2001), who showed that salinity caused a marked reduction in growth parameters of shoots and roots of sugar beet plants.

Bakht *et al.* (2011) concluded that salinity levels and seed priming had a significant ($p < 0.5$) effect on plant height, shoot fresh weight, shoot dry weight and leaf area of maize. Increasing salinity levels had significantly ($p < 0.05$) reduced plant height, shoot fresh weight, and shoot dry weight. The experiment result showed that 75.76%

plant height, 65.89% shoot fresh weight and 75.92% shoot dry weight can reduced when seeds exposed to different salinity levels.

Ewase (2013) conduct a pot experiment to observe the effect of salinity stress on plants growth of coriander *(Coriandrum sativum* L.). He used four treatments of different concentrations of NaCl namely 0, 1000, 2000, 3000 and 4000 ppm. The obtained results showed that plant length, number of leaves, roots number and length were reduced by increasing the NaCl concentration and coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

Saberi *et al.* (2011) conducted an experiment with two forage sorghum varieties (Speed feed and KFS4) and grown under salinity levels of 0, 5, 10 and 15 dSm^{-1}. He reported that leaf area of plants were also reduced in response to salinity and decreasing soil water availability. While the suppressive effect was magnified under the combined effect of the two factors. Salinity and water stress significantly affected the total leaf area of ratoon crop. The maximum total leaf area was obtained in the control treatment but with increasing salinity and infrequent irrigation, this parameter was found to decrease. Maximum leaf area of 1167 mm^2 $plant^{-1}$ was attained in plants with normal irrigation, without water stress. Under effects of salinity 5, 10 and 15 dSm^{-1} the leaf area was reduced by 7%, 12% and 17%, respectively.

Nawaz *et al.* (2010) reported that under saline conditions 50 mM proline was more effective to reduce the effect of NaCl than 100 mM proline in Sorghum. Proline level of 50 mM showed 26.58% and 11.78% increased shoot length as compared to NaCl stresses plants. However, high concentration of proline was not so much effective as compared to low concentration.

Jafari *et al.* (2009) conducted a greenhouse experiment and observed the interactive effects of salinity, calcium and potassium on physio-morphological traits of sorghum *(Sorghum bicolor* L.). Treatments included 4 levels of NaCl (0, 80, 160, and 240 mM NaCl), 2 levels of $CaCl_2$ (0 and 20 mM), and 2 levels of KCl (0 and 20 mM). Result expressed that Salinity substantially reduced the plant growth as reflected by a decrease in the plant height, shoot and root weight.

Gorai *et al.* (2010) reported that, seed germination, seedling growth, flowering and fruiting were adversely affected by salinity, resulting in reduced yield and quality.

BINA (2008) reported that wheat varieties of high yielding and tolerant group recorded a higher number of effective tillers plant.

Liu *et al.* (2008) reported significant reduction in the dry biomass of halophyte *Suaeda salsa* when exposed to different concentration of NaCl under different water regimes.

Munns and Tester (2008) observed that osmotic effect, which develops due to increasing salt concentration in the root medium, was a primary contributor in growth reduction in the initial stages of plant growth. This stage can be characterized by reduction in generation of new leaves, leaf expansion, development of lateral buds leading to fewer branches or lateral shoots formation in plants.

Memon *et al.* (2007) conducted a pot experiment on Sarokartuho variety of Sorghum *(Sorghum bicolor* L.) which was continuously irrigated with fresh (control) and marginally to slightly saline EC 2, 3, 4 and 5 (dSm^{-1}) waters. He reported that the increasing water salinity progressively decreased plant height and fodder yield (fresh and dry weight) per plant.

Mortazainezhad *et al.* (2006) had observed that tiller number decreased with increasing salinity levels imposed at all growth stages in rice. Soil salinity affects the growth of rice plant. But the degree of deleterious effect may vary on the growth stages of plant. During germination rice is tolerant, but it becomes very sensitive during the early seedling stage. Similar result was also reported by Rashid *et al*. (2006) in rice.

Sixto *et al.* (2005) stated that depending on increasing salinity levels, decrease in growth parameters (root, stem and shoot developments, fresh & dry stem and root weights; leaf area and number and yield) has been observed in plants.

Eisa (2012) conducted an experiment where *Chenopodium quinoa* plants were grown quick check system with 0, 100, 200, 300, 400, and 500 mM NaCl (equivalent to 0, 20, 40, 60, 80 and 100% seawater salinity). Result showed that higher salinity considerably reduced plant growth, with maximum reduction of 82% observed at 500 mM NaCl.

Akbarimoghaddam *et al.* (2011) conducted an experiment to evaluate salinity effects on seed germination and seedling growth of six bread wheat cultivars *(Triticum*

aestivum L). They reported that by increasing NaCl concentration, seed germination delayed and decreased. Increasing NaCl concentrations adversely affected shoot dry weight. Shoot dry weight fluctuated by varying NaCl concentration.

2.1.1 Effect of salinity on genotypes

A greenhouse growth experiment was done by Mahmoud (2014) with two wheat (*Tritium aestivum* L.) cultivars; Gemaiza 9 (G_9) and Sakha 93 (S_{93}) where G_9 is salt sensitive and S_{93} is salt tolerance cultivar. In this experiment soil used for wheat growth had electrical conductivity (ECe) of 7.37 dSm^{-1} which consequently had an influence on the seed germination, growth and tillering development. He showed that the level of soil salinity had reduced seed germination percentage to 80% of G_9 while did not affect S_{93}.

Bakht *et al*. (2011) reported maximum reduction of 60.61% in germination due to salinity exposure was noted in Sarhad yellow when compared with Azam (29.99%).

Rana (2007) carried out an experiment with 5 levels of salinity (0 dSm^{-1}, 3 dSm^{-1}, 6 dSm^{-1}, 9 dSm^{-1} and 12 dSm^{-1}) of three rice varieties viz., BRRl dhan-42, STM-1 and STM-2 and reported that plant height, number of tillers $hill^{-1}$, TDM $hill^{-1}$, leaf area $hill^{-1}$, root dry weight $hill^{-1}$ and yield contributing characters and yield decreased significantly with increase in salinity levels. Among the advanced rice lines BRRI dhan-42 showed more tolerance for all studied parameters compared to STM-1 and STM- 2.

A study was conducted by Madid *et al.* (2004) to determine the effects of salinity on seed germination and early vegetative growth of nine genotypes of barley (5 landraces & 4 breeding lines). The genotypes were evaluated by several criteria, at four salt concentrations (0 mM, 100 mM, 150 mM & 200 mM) and four seawater concentrations (0%, 20%, 30% and 40%). The results showed that the percentage of reduction for all variables increase with the increase in concentration of the salt. The most important percentages of reduction were recorded at the stage of germination by comparison to those obtained at the early growth stage. He also reported that there was no relation between the classifications of the various genotypes for the salinity tolerance at the stage of germination with the classification at the early growth stage.

Netondo *et al.* (2004) conducted an experiment to determine how salinity affects growth, water relations, and accumulation of cations of nutritional importance in various organs of grain sorghum. Two Kenyan sorghum varieties, Serena and Seredo, were grown in a greenhouse in quartz sand supplied with a complete nutrient solution to which 0 (control), 50 mM, 100 mM, 150 mM, 200 mM, and 250 mM NaCl was added. The 250 mM NaCl treatment significantly reduced the relative shoot growth rates, measured 25 days after the start of salt application, by 75% and 73%, respectively, for Serena and Seredo, and stem dry weight by 75% and 53% respectively.

2.1.2 Effect of salinity on physiological attributes of plant

Salinity reduces nutrient availability as well as transport to the growing regions of the plant, thereby affecting the quality of both vegetative and reproductive organs. For example, higher concentrations of Na^+ in soil decreased the Ca^{2+} activity in the external medium leads to limit its availability in *Celosia argentea* were reported by Carter *et al.* (2005).

Travagalia *et al.* (2013) conducted an experiment to find out the effect of salt stress on wheat varieties. In this experiment BI3000 wheat variety incubated with 65Mm sodium chloride solution for 48 h and germination percentage was 92%. They also reported that under salinity radical diameter of BI3000 variety decreased 23% due to plasmolysis of sub-epidermal parenchyma cells of the cortex.

Eisa (2012) conducted an experiment on *Chenopodium quinoa* plants with 0, 100, 200, 300, 400, and 500 mM NaCl (equivalent to 0, 20, 40, 60, 80 and 100% seawater salinity). The net photosynthesis rates were greatly decreased by high salinity, being 28% of initial control values at 500 mM NaCl. Salt- induced photosynthesis inhibition was accompanied with a decrease in transpiration rates but also with improved water use efficiency. Salt-induced growth reduction is presumably due to low photosynthetic supply as a consequence of impaired photosynthetic capacity.

Haghighiet (2012) carried out an experiment to evaluate the effectiveness of salinity on seed germination and growth characteristics of tomato. The experiment was performed with two levels of salinity (25 mM and 50 mM NaCl) and two

concentration of Si (1 mM and 2 mM) with 4 replications. The result showed that seed germination of *Lycopersicon esculentum* L. was significantly affected by salinity levels, Si and their interaction and germination characteristics of tomato decreased drastically by increasing NaCl concentrations.

Akbarimoghaddam *et al.* (2011) evaluated salinity effects on seed germination and seedling growth of six bread wheat cultivars *(Triticum aestivum* L). They reported that water uptake by seeds have a direct relationship with increases in NaCl levels.

Bavei (2011) studied the tolerance of sorghum varieties (Payam, Kimia, and Jambo) in terms of fresh weight, ion accumulations, proline content and peroxidase activity and concluded that after 15 and 30 days of treatment plant root and leaf tissues showed clear decline in K^+ and Ca^{2+} concentrations and increase in Na^+ and proline contents at each NaCl concentration in all varieties during the NaCl treatment.

Hamayun (2010) reported that the adverse effects of NaCl induced salt stress on growth attributes of soybean and the result showed that Chlorophyll content was significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

Patel *et al.* (2010) reported that in leaves of all the cultivars of cowpea salinity induced a significant increase in Na^+, Cl^- and proline concentrations, while reduced the accumulation of K^+ and Ca^{2+}.

Zuccarini (2008) studied the effect of Si on *Phaseolus vulgaris* L. under two level of salinity (30 and 60 mM). The results showed that salinity decreased stomatal conductance and net photosynthetic rate.

Memon *et al.* (2007) experimented on sarokartuho variety of sorghum with saline water and reported that saline water treated plants contained more Na^+, less K^+ and showed lower leaf K^+/Na^+ ratio.

Munns *et al.* (2006) suggested that Na+ exclusion in plants is attained by low up take of Na+ by the root cortex, controlled unloading of xylem by parenchyma in the stele. Initial step of transport of Na^+ from soil to plant shoot is entrance of Na^+ into root epidermis and cortex Na^+ influx.

Jamil *et al.* (2007) worked on radish and cabbage and revealed that salt stress can be reduced by accumulation of several nutrients specially N, Ca^{2+}, K^+ and similar

response also reported during conduct an experiment on canola by Ulfat *et al.* , (2007). Akram *et al.* (2007) also reported similar result on wheat and sunflower.

Parida and Das (2005) reported that salt-induced osmotic stress is the major reason of growth reduction at initial stage of salt stress, while at later stages accumulation of Na^+ occurs in the leaves and reduces plant growth. They observed salt stress affects some major processes such as root/shoot dry weight and Na^+/K^+ ratio in root and shoot.

2.1.3 Effect of salinity on yield and yield contributing parameters

Bakht *et al.* (2011) reported that salinity reduced grain yield of Azam by 231% when compared with control. The impact of salinity (8 dSm^{-1}) on grain yield was the highest in Sarhad yellow when compared with other cultivars and the plants did not reach reproductive stage when exposed to 8 dSm^{-1} and all the plants were completely barren.

Saberi *et al.* (2011) conducted an experiment and found that increased salinity significantly reduced forage dry yield from 44.09 gm $plant^{-1}$ in the control to 32.76 g $plant^{-1}$ at salinity with 15 dSm^{-1}. For every one unit increase in salinity, the forage yield decreased by 5.2 units and for every one unit increase in water stress (irrigation frequency), the forage yield decreased by 3.6 units.

Hamayun (2010) reported that the 1000 seed weight and yield of soybean significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

Prakash and Chen (2010) observed that all the physiological properties and yield were negatively affected by increasing salinity levels due to less water use and radiation interception. Compared to the low salinity level, medium and high salinity levels reduced the above-ground dry weight of the crop at harvest by 40 and 41% and grain yield by 41 and 48%, respectively.

Rafat and Rafiq (2009) reported that total chlorophyll content in tomato plant proportionally decreased with the increase in salinity levels up to 0.4% sea salt solution (EC 5.4 dSm^{-1}).

Karim (2007) reported that grain yield decreased with increased salinity levels. The yield was decreased due to production of decreased number of effective tillers $hill^{-1}$, decreased number of grains $panicle^{-1}$and 1000-seed weight. Similar result was also reported by many researchers (Hossain, 2006).

Hajer *et al.* (2006) and Cuartero and Munoz (1999) conducted two different experiment separately on tomato under saline condition and reported the effect of NaCl salinity stress on the growth of tomato plants was reflected in lower fresh and as well as dry weights.

Ali *et al.* (2005) conducted an experiment with three salinity levels (0, 6 and 9 dSm^{-1}) and observed that 1000-seed weight decreased with increased salinity level in sesame.

Thakral *et al.* (1996) studied six *B. carinatus* species under 0-125 meq L^{-1} chloride solution and observed that silique $plant^{-1}$, 1000-seed weight and seed yield decreased under salinity.

El-Hendawy *et al.* (2005) reported that tiller number of wheat was affected more by salinity than leaf number and leaf area at the vegetative stage. Salinity decreased dry weight per plant significantly at all growth stages. Spikelet number on the main stem decreased much more with salinity than spike length, grain number and 1000-grain weight at maturity. They also concluded that an increase in tiller number per plant and spikelet number per spike will improve the salt tolerance of wheat genotypes in breeding programs.

Uddin *et al.* (2005) conducted an experiment to study salt tolerance of *B. napus* and *B. campestris* varieties under saline conditions (1.2-11.5 dSm^{-1}) and observed that siliqua number and seeds $siliqua^{-1}$ decreased with increased salinity.

Gain *et al.* (2004) studied the effect of salinity (0 dSm^{-1}, 7.81 dSm^{-1}, 15.62 dSm^{-1}, 23.43 dSm^{-1} and 31.25 dSm^{-1}) on yield attributes and yield in rice and reported that number of spikelet $panicle^{-1}$, 1000-grain weight and dry mass decreased with increasing salinity levels but the decrement was less in salt tolerant varieties than salt susceptible varieties.

2.2 Effect of Priming

2.2.1 Effect of priming agents

The concentration of the priming agent (osmotic potential) is also a critical factor. Seed performance under drought or salt stress is also affected by the concentration of priming materials. Afzal *et al.* (2006) carried out an experiment to find out the influence of hormonal priming with abscisic acid (ABA), salicylic acid (SA), or ascorbic acid on wheat (*Triticum aestivum* cv. Auqab-2000). The results showed that seeds primed with 50 ppm ascorbic acid and 50 ppm SA not only improved final germination count but also reduced the germination time under saline conditions. Under saline conditions, maximum germination was obtained in seeds primed with 50 ppm ascorbic acid and salicylic acid, which was statically similar to priming with 10 or 30 ppm ABA, 200 ppm ascorbic acid and 100 ppm ascorbic acid. However, the lowest mean germination time (MGT) was achieved in seeds primed within 50 or 100 ppm ascorbic acid, 50 ppm salicylic acid and 30 ppm ABA followed by 10 ppm ABA treatment. Seedling raised from primed seeds with 50 ppm SA followed by 50 ppm ascorbic acid had significantly higher lengths and fresh and dry weight of shoot than other treated or non-primed seeds under non-saline and saline conditions. The results related to germination percentage can be related to earlier findings in which El-Tayeb (2005) found an improvement in seeds pretreated with SA solution than those of un-treated (controlled) seeds. These results are in consistent with those of Rajasekaran *et al.* (2002) and Shakirova *et al.* (2003), who showed a promotion in seed germination with SA application. Similarly, Al-Hakimi and Hamada (2001) reported that grain soaking in ascorbic acid exerted some favorable effects on growth and transpiration of wheat seedlings counteracting the inhibitory effects of salinity stress. In this experiment he also showed that Hormonal priming with 50 ppm SA induced maximum decrease in electrolyte leakage, while an increase in electrolyte leakage was observed by 10 ppm ABA and 100 ppm ascorbic acid. It is concluded that hormonal priming has reduced the severity of the effect of salinity but the amelioration was better due to 50 ppm SA and 50 ppm ascorbic acid treatments as these showed the best results on seedling growth, fresh and dry weights under non-saline and saline conditions.

Sakhabutdinova *et al.* (2003) investigated the effect of salicylic acid (SA) on plant resistance to environmental stress factors and result showed that treatment of wheat plants with 0.05 mM SA increased the level of cell division within the apical meristem of seedling roots which caused an increase in plant growth.

Kaya *et al.* (2010) showed that the highest 100 seed weight was obtained from chickpea when seeds were treated with 200 ppm GA3 treatments in both crop seasons. He also showed that 100 ppm GA3 and dH2O treatments gave the highest averages for the harvest index. Clua *et al.* (1997); Haque and Haque, (2002) also done similar experiments and showed that GA3 treatments applied (50 - 200 ppm) to either seeds or leaves increased total dry matter, leaf area index, relative growth rate and net assimilation rate. Deotale *et al.* (1998); Abd El-Fattah, (1997) and Kaur *et al.* (2000) also support this experiment findings and they reported that under stress condition seeds treated with GA3 treatment increased dry weight, number of seeds and yield. Seed yield increased with seed treatments in rice, corn and chickpea as reported by Harris *et al.* (1999) and Kaur *et al.* (2005). Nock *et al.* (1992) also concluded that plant growth regulators such as gibberellic acid delay leaf senescence and thus, increase plant weight and protein contents of plants.

Farooq *et al.* (2006) conducted an experiment top find out the effect of priming on field-sown rice seed and suggested that physiological changes produced by osmohardening enhanced the starch hydrolysis and made more sugars available for embryo growth which enhance germination.

Sun *et al.* (2010) conducted a field study to assess the effects of seed priming on germination and seedling growth under water stress in rice and reported that optimal priming concentrations of PEG were 20% for Gangyou 527 (*indica* hybrid rice) and 10%–15% for Nongken 57 (conventional *japonica* rice).

Baque *et al.* (2016) conducted an experiment and reported that plumule length, radical length and seedling length of wheat was affected by hydro priming and different PEG concentration. Plumule length, radical length and seedling length increases with increasing PEG concentration up to 10% then decreases gradually with increasing PEG concentration. The highest plumule length (83.20 mm), radical length (87.17 mm), seedling length (170.4 mm) of BARI Gom 28 was obtained from seeds pre-

treated with 10% PEG solution which is higher over control and osmoprimed seeds, respectively.

An experiment was conducted by Bakht *et al.* (2011) to study the effect of seed priming with 6 dSm^{-1} concentration of NaCl on growth and yield responses of two maize cultivars (Azam and Sarhad yellow) exposed to three levels of salinity (0 dSm^{-1}, 6 dSm^{-1}, 8 dSm^{-1}). Result of this experiment showed that priming of cv. Azam with $NaCl_2$ resulted in earlier emergence (2 days) and germination rate (31.92%), plant height (12%), shoot proline (950.33 µg g^{-1} fresh weight) and ABA levels (0.983 µg g^{-1} and 1.203 µg g^{-1} fresh weight) and yield (36% than the non-primed treatment).

Chauhan *et al.* (2009) reported that seeds treated with GA_3 showed significant difference with control indicated that the germination percentage decreases when the concentration increased, which shows that higher concentration inhibit germination and the longest radicle length was observed under 50 ppm GA_3 Concentration.

Jie *et al.* (2002) reported that osmopriming of the wild rye seeds with PEG 6000 resulted in higher Super Oxide Dismotase (SOD) and Peroxidase (POD) activity that ultimately resulted in higher germination rate.

Sun *et al.* (2010) also concluded that PEG priming with moderate concentration resulted in higher tolerance to drought stress than hydro-priming, while higher concentrations of PEG had negative effects on seed germination.

Afzal *et al.* (2007) studied the effect of halo priming with 10, 25 or 50 mM NaCl and $CaCl_2$ in wheat *(Triticum aestivum* cv. Auqab-2000) under saline conditions. The results showed that primed seeds with 25 and 50 mM of $CaCl_2$ significantly reduced the mean germination time and significantly increased the shoot length, and fresh and dry weight of seedlings more than all priming treatments. This improvement as affected by priming was also supported by the findings of Basra *et al.* (2005) and Iqbal and Ashraf (2005) with wheat.

Afzal *et al.* (2008) reported that the growth of wheat increased significantly by using 50 Mm $CaCl_2$ as seed priming treatment in saline medium.

2.2.2 Effect of priming duration

A lab investigation was carried out by Faijunnahar *et al.* (2017) to find out the suitable pre-sowing priming time on the germination, seedling growth and water relation behavior of four wheat genotypes viz., BARI Gom 28, ESWYT-5, ESWYT - 6 and ESWYT-7. The seeds of wheat genotypes were primed with 10% PEG solution for 3 h, 6 h, 9 h, 12 h and 15 h. The results of the experiment revealed that, among 4 wheat genotypes ESWYT-5 wheat genotype performed the best in most of the germination, seedling growth and water relation behaviors of wheat under all priming times followed by ESWYT-6 and BARI Gom 28 and ESWYT- 7 showed consistently poor performance. The germination, seedling growth and water relation behaviors' value of wheat genotypes increased with increasing priming time up to 9h and then gradually decreased. She also concluded that priming time might help to increased enzymatic activities of seed which trigger the vigorous plant growth and in consequence increased the shoot length of wheat; on the other hand over priming time might facilitate the ageing of seed which resulted loose the potentiality for better germination, growth and development of seedling. Similar findings were observed by Ajirloo *et el*., (2013); Dastanpoor *et al*. , (2013); Moradi *et al.* (2012); Sadeghi *et al*. , (2011), Yari *et al.* (2010) and Ahammad *et al.* (2014) who observed that the highest germination percentage in cv. Azar-2 was recorded when the seeds primed with 20% PEG solution for 12 h.

Munemasa *et al.* (2010) reported that, A 10 minute treatment with either ABA or methyl jasmonate (MeJA) resulted in a reduction of stomatal aperture in turgid and excised leaves of *Arabidopsis*.

Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 was recorded when the seed primed with 10% PEG solution for 12 hours.

Afzal *et al.* (2006) carried out an experiment to find out the influence of hormonal priming with abscisic acid (ABA), salicylic acid (SA), or ascorbic acid on wheat (*Triticum aestivum* cv. Auqab-2000) where seeds are presoaked for 12 hours. The results showed that seeds of all hormonal priming treatments decreased the electrolyte leakage of steep water as compared to that of non-primed seeds even after 12 h of soaking. McDonald (1980) also observed that an increase in electrolyte leakage by 10

ppm ABA at all soaking periods, which was probably due to the loss of ability to reorganize cellular membranes rapidly and completely.

Moradi Dezfuli *et al.* (2008) revealed that, hydro primed maize seeds for 36 h had the lowest values for mean germination time, followed by 24 h and 48 h seed treatments. He also concluded that lower priming duration (i.e., 12 and 24 h) enhanced germination under normal condition, while a higher priming duration (i.e., 36 h and 48 h) provided more protection when the seeds were exposed to drought stress. He also reported that the highest maize germination percentage was attained when seeds were primed for 36 hours.

Faijunnahar *et al.* (2017) studied that priming time had positive effect due to its role in impact the permeability of the membranes which ultimately leads to activation of enzymes involved in protein synthesis and carbohydrate metabolism. Preece and Read (1993) also had similar findings and revealed that, the maximum germination percentage of BARI Gom 27 was recorded when the seed primed with 10% PEG solution for 12 hours.

Hamidreza *et al.* (2013) studied the effects of osmo-hydropriming on seed germination and seedling growth of rye (*Secale montanum*) and concluded that, germination percentage of rye increased by increasing of hydro priming duration from 6 to 12 hours but it was decreased by increasing of hydro priming duration from 18 to 24 hours.

Yari *et al.* (2010) also reported that, priming time had significant effect on shoot length of sunflower and maximum shoot length was received when the seed was osmo-primed with PEG 10% for 24h. Lemrasky and Hosseini (2012) also revealed that, wheat seed priming with PEG 10% for 45 hours increased shoot length then the non-primed one.

A laboratory experiment was conducted by Baque *et al.* (2016) to find out the optimization of pre-sowing priming time on the germination behavior of BARI Gom 27. BARI Gom 27 was primed in 0 to 18 hours under 10% PEG solution and distilled water. The highest germination percentage (GP) (87.77%), vigor index (VI) (142.31) and germination index (GI) (41.23) were obtained from seeds pre-soaked in 12 hours with 10% PEG solution compared to hydro-priming (84.44%, 133.83 and 36.62 of GP,

VI and GI, respectively) and untreated control (57.77%, 84.85 and 29.75 of GP, VI and GI, respectively), and then decreased gradually with increasing priming time.

Afzal *et al.* (2004) found that priming treatments i.e.; osmopriming (jute mat) for 24 hours reduced the time to 50% emergence and mean emergence time.

Ghobadi *et al.* (2012) conducted an experiment to evaluate the effect of different seed priming techniques and early growth of wheat. The experiments were factorial arranged in a completely randomized design with four replications. The first factor was seed primed for 12, 18, 24 and 30hours, the second was four concentrations of gibberellic acid (50, 100, 150and 200 ppm), PEG-6000 (-0.3 MPa) and the third was two wheat cultivars. Seeds were primed for 12, 18, 24 and 30 hours at temperature 25°C in different solutions. Results showed that for hormonal priming, maximum shoot and root length, shoot and root dry weight and germination rate were observed at GA 50 ppm and 24 hours treatment in Cross-Alborz and Sardari cultivars. For osmmopriming maximum shoot and root length, shoot and root dry weight and germination rate were observed at 12 hours treatment.

Rashid *et al.* (2006) reported that hydropriming increased the germination rate, enhanced yields and provided good establishment of barley under saline and non-saline soils.

Golezani *et al.* (2008) claimed that hydro priming can enhance seedling emergence rate, emergence percentage and seedling establishment of lentil *(Lens culinaris* Medik.) as well as increase the length of roots.

Dezfuli *et al.* (2008) reported that hydro priming of two genotypes of maize (*Zea mays* L.) including B73 and MO17 by soaking in water for 12, 24, 36 or 48 hours improved seed germination and increased maximum length of the radicle.

Zheng *et al.* (2002) reported that numerous research efforts have concluded that treating crop seeds in water prior to sowing can enhance the resistance of crops to salinity

Ashraf and Rauf (2001) reported that soaking maize seed in water, the resistance of seeds to salinity has been improved and gave better germination percentage compared with the control.

Afzal *et al.* (2007) examined the effects of several priming treatments (hydro priming, matriconditioning, chilling, osmopriming and hardening) on wheat *(Triticum aestivum* L.). They found that the maximum emergence percentage (61%) was obtained from hydro primed seeds followed by 24 h chilling. Also the maximum shoot length (18 cm) and root length (28 cm) were recorded by hydro priming seeds followed by 24 hours of chilling.

2.2.3 Effect of Seed Priming

A lab experiment was conducted by Baque *et al.* (2016) to find out the effect of various Polyethylene Glycol (PEG) concentrations on the germination behavior of wheat. Wheat seeds of BARI Gom 27 and BARI Gom 28 were pre-soaked in 0, 5, 10, 15 and 20% PEG solution and untreated seeds were served as control. Results revealed that seed priming enhanced germination percentage (GP), vigor index (VI) and germination index (GI) of wheat seed. The highest GP (95.55%), VI (201.00) and GI (43.73) were obtained from seeds of BARI Gom 27 pre-treated with 10% PEG solution compared to BARI Gom 28 and then decreased gradually with increasing PEG concentration.

Kaya *et al.* (2010) conducted an experiment to investigate the effect of sowing times and different seed treatments (control, distilled water, 100, 200, 300 and 400 ppm Gibberellic acid) on 100 seed weight, harvest index, seed yield and protein content in 3 chickpea cultivars (Gokce, Akcin 91 and Ispanyol). Significant differences were detected for cultivars, sowing dates and seed treatments. The highest 100 seed weight, harvest index, seed yield and protein content were recorded as 32.7 - 44.2 g, 38.7 - 54.1%, 63.1 - 180.3 kg/da and 20.1 - 27.3%, respectively when seeds were treated with 100 ppm GA3.

Afzal *et al.* (2006) carried out an experiment to find out the influence of hormonal priming with abscisic acid (ABA), salicylic acid (SA), or ascorbic acid on wheat (*Triticum aestivum* cv. Auqab-2000). The results showed that Maximum shoot and root length was attained when seeds primed with 50 ppm salicylic acid , 30 ppm abscisic acid 50 ppm ascorbic acid, while 50 ppm ABA drastically effected under both normal and saline conditions. They also showed that maximum decrease in electrolyte

leakage was induced by 50 ppm salicylic acid after 24 h of soaking period. Working with wheat seeds, Roy and Srivastava (1999) also observed that germination percentage, root and shoot length, root-shoot ratio and amylase activity decreased with increasing salinity, while seeds treated with 50 ppm ascorbic acid, 100 ppm CaCl2, sodium benzoate and water decreased the negative effect of salinity. Singh and Ushu (2003) also found that SA application increased the dry mass of wheat seedlings under water stress. Khodary (2004) also reported that SA increases the fresh and dry weight of shoot and roots of stress maize plants.

Sarwar *et al.* (2006) reported that root length and biomass of roots and shoots of chickpea were better when seeds were treated with water and mannitol as priming agent and seedlings showed salt tolerance characteristics.

Nemhauser *et al.* (2006) conducted an experiment to find out the effects of plant hormones and reported that ABA transcriptionally regulates up to 10% of protein-encoding genes.

Nishiyama *et al.* (2011), studied gene expression, concluded that exogenous ABA treatment strongly down regulated iso-pentenyl-transferase (IPT), a key cytokinin biosynthetic pathway gene, but upregulated genes encoding cytokinin oxidases and dehydrogenases.

Rafiq *et al.* (2006) reported that priming with $CaCl_2$ significantly enhanced shoot and root length under both saline and non-saline conditions.

Dastanpoor *et al.* (2013) reported that, hydropriming was most efficacious in improving seed germination of *Salvia officinalis* L. that final germination percentage (FGP) was enhanced by 25.5% as compared to that of non-primed seeds.

Abnavi and Ghobadi (2012) observed that wheat seed priming with water for 12 h performed better than non-primed one. Similar findings also concluded by Lemrasky and Hosseini (2012) and Giri and Schillinger (2003).

Faijunnahar *et al.* (2017) reported that priming helps to increase enzymatic activities of seed which trigger the proliferous root growth and in consequence increased the root dry weight of wheat on the other hand, over priming facilitates the ageing of seed which resulted loose the potentiality for better germination, growth and development

of seedling. In her experiment result she found out that the highest root dry weight (0.043 mg) was found from wheat genotype ESWYT-5 with seed primed with 10% PEG solution for 9 h while the lowest root dry weight (0.005 mg) was found from wheat genotype ESWYT-7 with seed primed with 10% PEG solution for 3 h. Moghanibashi *et al.* (2012) also conducted an experiment to find out the effect of hydropriming on seed germination indices of sunflower (*Helianthus annuus* L.) under salt and drought conditions and reported that hydropriming for 24 hours enhanced root dry weight of sunflower as compared to non-primed one.

Huns and Sung (1997) reported that seed priming of sweet corn seeds resulted anti-oxidant increment as glutathione and ascorbate in seed. These enzymes make more germination speed via reduction of lipid per-oxidation activity.

Dastanpoor *et al.* (2013) reported that hydropriming (12 h at 30°Ñ) was most effective in improving seed germination of *Salvia officinalis* L. that final germination percentage (FGP) was increased by 25.5% as compared to that of non-primed seeds

An experiment conducted by Ghodrat and Rousta (2012) to study the effect of priming with Gibberellic acid (GA_3) on germination and growth of corn under saline conditions, an experiment was conducted as factorial with completely randomized design with three replications. The factors of the experiment are different levels of Gibberellic acid concentration (0, 1.5, 2.5 and 5 mgL^{-1}) and salinity (0, 5, 10, 12 and 15 dsm^{-1}). He also reported that in the level of 15 dsm^{-1} salinity germination rate (GR) and total water content (TWC) of seeds soaked with 1.5 mgL^{-1} GA_3 was increased compared to the control. Naeem and Muhammad, 2006 support the findings and reported that priming with higher concentration of GA_3 had good effect on germination and growth of cereal.

Hardegree and Van Vactor (2000) reported that osmotic priming of wheat seeds improved the germination rate.

Kim *et al.* (1993), Coale (1991) and Hays (1992) who indicated seed soaking in GA_3 solution increased the emergence rate in rice.

Jett *et al.* (1996) who reported that root growth rates of matric primed seeds were significantly higher than either osmotic or non-primed seedlings at most temperatures.

Afzal *et al.* (2002) reported that the electrical conductivity (EC) of leachate from non-primed and matriconditioned (press mud) seeds increased rapidly during the first 30 min of imbibition and maintained the increasing trend upto 12 h of imbibition. Hydroprimed and GA_3 soaked seed leachates showed the lowest EC during imbibition while the highest value of EC was observed in seeds treated with PEG after 24 h. Electrolyte leakage from hydroprimed, matriconditioned with compost and gunny bag and GA_3 soaked seeds was consistently less than non-primed and matriconditioned seeds with press mud during the imbibition.

Mohamed and Ismail (2009) reported that ABA appears to mediate physiological processes in response to osmotic stress. Several studies have reported that the level of endogenous ABA increases in many plants including wheat (Mustafina *et al*., 1998), tomato (Makela *et a*l., 2003; Thompson *et al*. , 2004), and French bean and tobacco (Pospı´s´ilova´ *et al*., 2005) when subjected to osmotic stress. Furthermore, Jiang and Zhang (2002) working on maize leaves documented that, with an increase of the ABA content, the production of ROS and the activities of several antioxidant enzymes induced by drought stress.

Travagalia *et al.* (2013) reported that the chlorophyll and carotene contents increased in plants with exogenous ABA under salt stress respect to control.

Zareh *et al.* (2006) indicated that priming of wheat seed with GA_3 germination decreased but has a positive effect on shoot growth.

Ghana *et al.* (2003) reported that seed priming has limited practical worth for enhancing emergence and yield of winter wheat planted deep into summer fallow.

Ashraf & Foolad (2005) and Ashraf *et al*. (2008) reported that pre-treatment of seeds with different type of hormones and plant growth regulators is much effective in alleviating stress effects of salinity on the plants at different stages especially at early stage and it has been shown to improve crop germination as reported earlier under salt stress.

Afzal *et al.* (2004) also found that the osmopriming (jute mat) proved to be the best in reducing the time to 50% germination and mean germination time among all priming treatments.

Singh *et a1*. (1999) reported that osmotic priming of muskmelon with PEG result in higher amylase and dehydrogenises activity and germination rate in saline condition increased.

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 completely randomized design with three replications consisting of 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 12 hours or no seed priming). Results showed that seed priming and salinity had significantly ($p<0.05$) 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.

Aymen *et al.* (2014) conducted an experiment to evaluate the effects of NaCl priming on growth traits and some biochemical attributes of safflower *(Carthamus tinctorius* L. cv Safola) in salinity conditions. They concluded that growth (plant height, fresh and dry weight) and biochemical attributes (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.

Saleem *et al.* (2013) set an experiment to study the effect of seed soaking on seed germination and growth of bitter gourd cultivars. In this experiments, three cultivars of bitter gourd (Faisalabad Long, Jaunpuri and Palee) were soaked in water for various soaking durations (4, 8, 12 and 16 hours) along with control to determine the optimal soaking duration and find out the best growing cultivar. The highest germination percentage (85.18%), number of branches $plant^{-1}$ (8.64), fruits $plant^{-1}$ (20.70) were obtained when the bitter gourd seeds soaked for 12 hours. Earlier emergence (6.28) and earlier flowering (39.40) were recorded in plants where seeds soaked for 16 hours. Seed soaking in water for 12 hours has the potential to improve germination, seedling growth of bitter gourd cultivars.

Mehta *et al.* (2014) reported that pre-sowing seed priming helps to improve germination and stand establishment of bitter gourd.

Abdoli (2014) set an experiment to evaluate the effects of seed priming on certain important seedling characteristic and seed vigor of fennel *(Foeniculum vulgare L.).* Seeds were primed in water (H_2O), sodium chloride (NaCl, 100 mM) and polyethylene glycol 6000 (PEG-6000, water potential-1.6 MPa), in darkness for 18 hrs. Experiment result expressed that unsoaked seed (control) and hydro priming treatments had the lowest plumule, radicle and seedling length, seedling dry weight and seedling vigor index. PEG and NaCl in all of traits were better than the water priming treatments, respectively. PEG-6000 (1.6 MPa) is the best treatment for breaking of fennel seed dormancy.

Rastin *et al.* (2013) conducted an experiment to evaluate the effect of seed priming treatments on the seed quality of red bean. The experiment was conducted in split plot in the form of a randomized complete block design with three replications and two factors. They reported that the highest plant dry matter (53.06 g) and the highest grain yield (5.98 tha^{-1}) were achieved when seeds were first treated with water (as the primary seed priming) and after drying were treated with GA3 (as the complementary seed priming).

Meena *et al.* (2013) conducted an experiment to evaluate the influence of hydro priming on the water use efficiency and grain yield of wheat *(Triticum aestivum* L.) under water stress. The hydro primed and pre-germinated seeds established earlier than dry seeds leading to better crop establishment under optimum, sub optimum soil moisture as well as dry soil conditions leading to higher tillering and grain yield.

Ajirlo *et al.* (2013) reported that germination and early growth under prevailing environmental conditions improves by seed priming technique. Their result 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.

Aymen and Cherif (2013) reported that with increasing salinity, emergence traits (total emergence, mean emergence time), growth parameters (plant height, shoot fresh and dry weight) and mineral contents (K^+ and Ca^{2+}) decreased, but to a less degree in primed seeds. At different salinity levels, primed seeds possessed higher emergence and growth rate than control.

Dastanpoor *et al.* (2013) carried out an experiment to find out the influence of hydro priming treatments on seed parameters of *Salvia officinalis* L. (sage). Seeds of sage were treated by hydro priming at three temperatures 10, 20, 30°C for 0, 12, 24 and 48 hours. Hydro priming for 48 hours clearly improved the final germination percentage (FGP), mean germination time (MGT) and synchronized the germination of seeds at each three temperature.

Kisetu and Nagwale (2013) conducted a study to assess the effects of priming on okra *(Abelmoschus esculentus* L.) seeds var. clemson spineless in tap-water, di ammonium phosphate (DAP) and Minjingu (M) Mazao fertilizers at varying hours from non-primed (absolute control) to 48 h at an interval of 12 hours. The priming materials used contained 0.115 g L^{-1} DAP, 1 g L^{-1} M-Mazao, and 1 L tap-water. Seeds primed with DAP for 36 hours gave the highest number of pods, the highest yield (4.52 tha^{-1}) compared to the absolute control.

Ogbuehi *et al.* (2013) carried out a field experiment to assess the effect of hydro priming duration on performance of morphological indices of Bambara groundnut *(Vigna subterranean* (L.) Verdc) and result express that 24hours hydro priming duration found to improve the performance of growth indices measured whereas the 36 hours was the least effective.

Ali *et al.* (2013) reported that seed priming improves irrigation water use efficiency, yield, and yield components of late-sown wheat under limited water condition. Seed priming treatments reduced the mean emergence time and promoted germination, early canopy development, and tillering in comparison to the control. The number of fertile tillers, plant height, 1000-grain weight, and grain and biological yield were also increased by different priming techniques. On-farm priming and hydropriming for 12 hours gave higher grain and biological yields and higher harvest index than other priming treatments. Seed priming increased the irrigation water use efficiency (IWUE) of all irrigation regimes. Grain yields were linearly increased at 100% ETo while maximum IWUE was achieved at 80% ETo.

Amoghein *et al.* (2013) conducted an experiment on the effect of osmopriming and hydropriming on the different index of germination & early growth of wheat under salty stress. They reported that effect of seed soaking time (4 hours) only on hypocotyle length was significant.

Rizvi *et al.* (2001) studied that priming of *Hordeum vulgare* seeds with aqueous solutions (10^{-6} *M)* of gibberellic acid and / or kinetin for 6, 12 and 24 hours improved germination percentage. However, the best response was generated in the grains soaked in gibberellic acid for 12hours where germination increased by 156% over control.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted during the period from 21 September 2016 to 19 November 2016. The materials and methods those were used and methods followed for conducting the experiment have been presented under the following headings.

3.1 Experimental site

This study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. It was located in 24.09^0 N latitude and 90.26^0 E longitudes.

3.2 Duration of the study

The experiment was conducted during the period from 21 September 2017 to 19 November 2017.

3.3 Laboratory condition

The temperature and relative humidity of the laboratory room were recorded daily basis during the study period with a digital thermo hygrometer (TERMO, TFA, Germany). The average minimum and maximum temperature during the study period of the culture room was 25.2^0C to 34.4^0C, respectively and average minimum and maximum relative humidity was 56% and 84%, respectively.

3.4 Planting materials

Three wheat genotypes namely- BARI gom28, ESWYT-5, and ESWYT-6 were used for this experiment. Seeds were collected from Bangladesh Wheat and Maize Research Institute, Dinajpur and Bangladesh Agricultural Research Institute, Gazipur. The collected wheat genotypes were free from any visible defects, disease symptoms and insect infestations and transported to the laboratory of the Department of Agronomy, SAU, Dhaka with careful handling to avoid disease infestation and injury. Seedlings were raised in a separate petri dish for each genotype.

3.5 Experimental materials

Different equipment such as electric balance, petri dish, magnetic stirrer, beaker, filter paper, micro pipette, forcep, dry oven etc. were used for this study. Petri dish and filter paper were used for raising of seedlings where filter paper were cut according to the petri dish size and placed into the bottom of the dish. 30 sun dried seeds of each wheat genotypes were placed into the Petri dish.

3.6 Chemicals for seed priming

Different priming chemicals such as ABA (Abscisic Acid) and distilled water were utilized for hormonal primiming and hydro priming. NaCl salt utilized for salt stress induction.

3.7 Experimental design

The experiment was conducted in a completely randomized design (CRD) with five replications.

3.8 Experimental treatments

The experiment comprises of

i) Six levels of priming agent *viz*. water, 10 ppm, 20 ppm, 40 ppm, 60 ppm Abscisic acid solution and 0% (control)

ii) Five levels of salinity stress *viz*. Control (No salt), 5 dSm^{-1} NaCl, 10 dSm^{-1} NaCl, 15 dSm^{-1} NaCl, and 20 dSm^{-1} NaCl.

3.9 Steps of the experiment

This experiment was completed in two steps. The 1^{st} step was performed to find out the best ABA concentration with wheat genotypes and the 2^{nd} step was to find out the best result under salt stress condition.

3.9.1 First experiment: To find out the best ABA concentration with variety

Study on the effect of different concentrations of ABA on the germination and growth behavior of wheat.

3.9.1.1 Weight of seeds

250 g seeds were weighed from the total seed from each of three wheat genotypes.

3.9.1.2 Treatments

A. Three wheat genotypes: one wheat variety and two lines based on the findings of Hasan *et al.* (2016).
   i) V_1 = ESWYT-5
   ii) V_2 = ESWYT -6
   iii) V_3 = BARI gom-28

B. Seeds primed with distilled water and different levels of ABA Concentration
   i) P_1 = Seeds primed with distilled water
   ii) P_2 = Seeds primed with 10 ppm ABA solution
   iii) P_3 = Seeds primed with 20 ppm ABA solution
   iv) P_4 = Seeds primed with 40 ppm ABA solution
   v) P_5 = Seeds primed with 60 ppm ABA solution
   vi) P_6 = Seeds without priming (control)

3.9.1.3 Priming solutions

10 ppm, 20 PPM, 40 PPM, 60 ppm ABA solution and distilled water were used as priming solutions.

3.9.1.4 Preparation of priming solutions

a) ABA solutions (10 ppm, 20 PPM, 40 PPM and 60 ppm)

5 mg of ABA was dissolved in 500 ml of water to prepare 10 ppm solution of ABA Similarly, 10mg, 20mg, 30 mg ABA was dissolved in 500 ml of water to prepare 20ppm, 40ppm, and 60ppm solution of ABA, respectively.

b) Distilled water

Distilled water was collected from the laboratory of Sher-e-Bangla Agricultural University (SAU).

3.9.1.4 Priming technique

Two priming techniques viz., hormonal priming and hydropriming were applied on wheat genotypes. One of the sub-samples was considered as control (unprimed) and the other sub-samples were primed with priming chemicals. For hydropriming seeds of a sub-sample were soaked in distilled water and for hormonal priming seeds of another sub-sample were divided into another sub-samples and pre-treated with ABA a four levels of concentration of 10 ppm, 20 ppm, 40 ppm and 60 ppm for 9 hours (Faijunnahar *et al.* 2017). All seeds were removed from the priming solution at the same time. Then all seeds were surface sterilized with 2% Safex solution (Alcohol) for 5 minutes, then rinsed with sterilized water and air dried at room temperature. After that seeds were used for priming. After soaking seeds were air dried for 24 hours and placed in petri dish. For each replicate 30 seeds were placed in 12.5 cm petri dish on a layer of filter paper no. 102 moistened with 8 ml of distilled water (Faijunnahar *et al.* 2017).

Achievement from the first experiment:

From the first experiment, 40 ppm ABA treatment showed the best result. So, 40 ppm ABA solution was used for the next experiment as the best priming solution.

3.9.2 Second experiment: To find out the best result under salt stress condition

Germination and growth behavior of ABA primed wheat seed under salt (NaCl) stress condition.

3.9.2.1 Weight of seeds

250 g seeds were weighted from the total seed from each of three wheat genotypes.

3.9.2.2Treatments

A. Three wheat genotypes: one wheat variety and two lines based on the findings of Hasan *et al.* (2016).

i) V_1= ESWYT-5

ii) V_2= ESWYT-6

iii) V_3= BARI gom-28

B. Salt concentration: Five types of salt concentration were used as treatment

i) S_1 = Primed seeds placed without salt (control)

ii) S_2 = Primed seeds placed with 5 dSm^{-1} NaCl

iii) S_3 = Primed seeds placed with 10 dSm^{-1} NaCl

iv) S_4 = Primed seeds placed with 15 dSm^{-1} NaCl

v) S_5 = Primed seeds placed with 20 dSm^{-1} NaCl

3.9.2.3 Priming solutions and time

40 ppm ABA solution and 9 hours priming time (Faijunnahar *et.al*. 2017) were used to test salt stress.

3.9.2.4 Preparation of stress solutions

For preparing salt (NaCl) solutions (5 dSm^{-1} NaCl, 10 dSm^{-1} NaCl, 15 dSm^{-1} NaCl, and 20 dSm^{-1} NaCl), 1.462 g of sodium chloride (NaCl) was dissolved in 500 ml of water to prepare 5 dSm^{-1} solution of salt (NaCl). Similarly, 2.872 g, 4.36 g, 5.85 g sodium chloride (NaCl) was dissolved in 500 ml of water to prepare 10 dSm^{-1}, 15 dSm^{-1} and 20 dSm^{-1} solution of NaCl, respectively.

3.9.2.5 Priming technique

Seeds of a sub-sample were soaked in distilled water for hydropriming and seeds of another sub-samples were pretreated with ABA for osmopriming at a concentration of 40 ppm for 9 hours (Faijunnahar *et al*. 2017). All seeds were removed from the priming solution at the same time. Then all seeds were surface sterilized with 2% Safex solution (Alcohol) for 5 minutes, then rinsed with sterilized water and air dried at room temperature. After that seeds were used for priming. After soaking seeds were air dried for 24 hours and placed in petri dish. For each replicate 30 seeds were placed in 12.5 cm petri dish on a layer of filter paper no. 102 moistened with 8 ml of distilled water (Faijunnahar *et al*. 2017).

3.10 Data collection

Data on seedling emergence of all the wheat genotypes were collected from 1 to 10 days after sowing. Normal seedlings were counted and percent of seedling emergence was recorded up to 10 days after planting (DAP) of seeds. Seedling mortality was also counted up to 10 days after seed planting (DAP). The uprooted seedlings were washed with tap water and excess water was soaked with tissue paper. After 10 days of planting (DAP) data was collected from 5 randomly selected healthy seedlings.

The following data were taken:

1. Germination rate (%)
2. Shoot length (mm)
3. Root length (mm)
4. Fresh weight of whole plant
5. Shoot dry weight (mg)
6. Root dry weight (mg)
7. Relative water content (%)
8. Water saturation deficit
9. Water retention capacity
10. Vigor Index

3.11 Procedure of recording data

3.11.1 Germination percentage

The number of sprouted and germinated seeds was counted daily commencing. Germination was recorded at 24 hrs interval and continued up to 11th. More than 2 mm long plumule and radicle was considered as germinated seed.

The germination rate was calculated using following formula:

Rate of germination (%) = $\frac{Total\ Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ placed\ for\ germination} \times 100$

3.11.2 Shoot length

The shoot length of five seedlings from each petri dish was measured finally at 11 DAS. Measurement was done using the unit millimeter (mm) by a meter scale.

3.11.3 Root length

The root length of five seedlings from each petri dish was recorded finally at 11 DAS. Measurement was done using a meter scale and unit was expressed in millimeter (mm).

3.11.4 Dry weight of shoot and root

The dry weight of shoot and root of the five seedlings from each petridish was measured finally at 11 DAS. Dry weight was recorded by drying the sample in an oven at 70°C till attained a constant then dry weight of shoot and root were recorded using electric balance.

3.11.5 Relative water content (%)

Relative water content was measured using following formula

Relative water content (RWC) (%) = $\frac{Fresh\ weight - Dry\ weight}{Turgid\ weight - Dry\ weight} \times 100$

3.11.6 Water saturation deficit

Water saturation deficit was recorded using following formula; (Baque *et al*., 2002)

Water saturation deficit (WSD) = 100- Relative water content

3.11.7 Water retention capacity

Water retention capacity was measured following formula (Baque *et al*., 2002):

Water retention capacity (WRC) $= \frac{Turgid\ weight}{Dry\ weight}$

3.11.8 Vigour index

Vigour index was calculated using following formula (Abdul-Baki and Anderson, 1970):

Vigour index $= \frac{Total\ germination \times Seedling\ length\ (mm)}{100}$

3.11.9 Germination co-efficient

Germination coefficient (GC) was calculated using the following formula (Copeland, 1976):

$$\text{Germination coefficient (\%)} = \frac{A_1 + A_2 + \ldots.. + Ax}{A_1T_1 + A_2T_2 + \ldots.. + AxTx} \times 100$$

Where,

A= Number of seeds germinated

T= Time corresponding to A

x= Number of days to final count

3.12 Statistical Analysis

The collected data were analyzed statistically following CRD design by MSTAT-C software package program and the treatments were compared by Least Significance Differences (LSD) test at 1% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate Abscisic acid (ABA) induced changes in seed germination and seedling growth of wheat *(Triticum aestivum* L.*)* under salt stress condition. The results of the germination and growth parameters of wheat genotypes as influenced by different concentrations of priming agent (ABA) and priming time in salt stress condition have been presented and discussed in this chapter.

4.1 First experiment: To find out the best ABA concentration with varieties

Results obtained from the present study regarding the effects of different concentrations of ABA the germination rate of wheat varieties have been presented, discussed and compared in this chapter.

4.1.1 Rate of germination (%)

Non-significant variation was observed in case of germination rate among the genotypes where seeds of different genotypes were without priming solution (P_6) (Table 4.1.1 and Appendix II). But significant variation was found in terms of germination rate due to varietal performance and seed priming with water and with different concentration of ABA (Table 4.1.1 and Appendix II). Results indicated that the genotype, V_1 (ESWYT-5) showed the highest germination rate at all seed priming concentration followed by V_2 (ESWYT-6) whereas genotype V_3 (BARI gom-28) showed the lowest germination rate at all priming treatments. Among all the test sample, the highest germination rate (91.71%) was found from V_1 (ESWYT-5) which was primed with P_4 (seeds primed with 40 ppm ABA for 9 hours), was statistically identical with V_2 (ESWYT-6) at P_4 (seeds primed with 40 ppm solution for 12 hours) treatment (86.73%) but V_1 and V_2 showed significant difference with V_3 (BARI gom-28). V_3 showed 81.4% germination rate with P_4 (seeds priming with 40 ppm ABA solution for 9 hours). The lowest germination rate (70.2%) was observed from V_3 (BARI gom 28) with P_6 (seeds without priming) treatment followed by P_5 (seeds primed with 60 ppm ABA solution for 9 hours) and P_1 (seeds primed with water for 9 hours) treatment with the same variety. These findings are consistent of the results of Afzal *et al.* (2016). He concluded that influence of hormonal priming with 10 to 30

ppm abscisic acid (ABA) on wheat (*Triticum aestivum* cv. Auqab-2000) showed maximum germination rate. Ajirlo *et al.* (2013) reported that germination improves by seed priming technique. Ali *et al.* (2013) reported that seed priming treatments reduced the mean emergence time and promoted germination. Moradi Dezfuli *et al.* (2008) revealed that, hydro primed maize seeds for 36 hours had the lowest values for mean germination time.

Table 4.1.1 Effect of different concentrations of ABA on germination rate of primed and non-primed (control) seeds

Genotypes	Rate of germination (%) at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	80.4 a	82 a	87.13 a	91.71 a	82.4 a	73.6 a
V_2	78.92 a	80.4 a	82.4 b	86.73 a	78.92 a	71.4 a
V_3	73.6 b	74.8 b	78.6 c	81.4 b	73.6 b	70.2 a
$LSD_{(0.01)}$	4.624	4.372	4.959	5.314	4.658	4.081
CV%	4.32	4.01	4.35	4.45	4.32	4.13

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water,
P_2 = Seeds primed (socked) with 10ppm ABA solution,
P_3 = Seeds primed (socked) with 20ppm ABA solution,
P_4 = Seeds primed (socked) with 40ppm ABA solution,
P_5 = Seeds primed (socked) with 60ppm ABA solution,
P_6 = Seeds without priming (control)

4.1.2 Shoot length (mm)

Significant variation was observed on shoot length among the test genotypes priming with control, water and different concentration (20 ppm & 60 ppm) of ABA (Table 4.1.2 and Appendix III). When wheat genotypes seed treated with P_4 (seeds primed with 40 ppm ABA solution for 9 hours) treatment result showed that among V_1 (ESWYT-5) & V_2 (ESWYT-6); V_2 (ESWYT-6) & V_3 (BARI gom 28) shoot length was statistically identical but statistical significant among V_1 (ESWYT-5) & V_3 (BARI gom 28). Also it was found that the genotype, V_1 (ESWYT-5) showed the highest shoot length in all priming treatments whereas genotype V_2 (ESWYT-6) showed moderate shoot length and V_3 (BARI gom 28) showed the lowest shoot length in all priming treatments. It was also observed that the maximum shoot length (160.6 mm) was recorded for genotype, V_1 (ESWYT-5) in P_4 (seeds primed with 40 ppm ABA solution for 9 hours) treatment followed by V_2 (ESWYT-6) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment (152.3 mm). The lowest shoot length (79 mm) was observed from V_3 (BARI gom 28) with P_6 (seeds without priming; control) treatment followed by P_6 (seeds without priming; control) treatment on V_2 (ESWYT-6) genotype (90.04 mm). Primed seeds can changes enzyme concentration and formation which reduces lag time between imbibition and radicle emergence (Bradford *et al*., 1990). Earlier and faster synthesis of DNA, RNA and proteins are also observed which enhanced growth (Bray *et al*., 1989). Gray and Steckel (1983) also concluded that priming increased embryo length, which resulted in early initiation of germination and higher shoot length. Primed seed showed increase shoot length of seedlings that is supported by the findings of Basra *et al*., (2005) and Iqbal & Ashraf, (2007) in wheat. Rafiq *et al.* (2006) reported that priming with $CaCl_2$ significantly enhanced shoot length under both saline and non-saline conditions. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 was recorded when the seed primed with 10% PEG solution for 12 hours.

Table 4.1.2 Effect of different concentrations of ABA on shoot length (mm) of primed and non-primed (control) seeds

Genotypes	Shoot length (mm) at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	127.4 a	130 a	147.1 a	160.6 a	142.7 a	110.6 a
V_2	120.4 b	124.2 ab	130.2 b	152.3 ab	130.1 b	90.04 b
V_3	110.6 c	117.8 b	120.4 c	146.1 b	117.6 c	79 c
$LSD_{(0.01)}$	6.419	7.251	7.211	8.262	7.642	5.098
CV%	3.9	4.24	3.95	4.09	4.26	3.97

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water,
P_2 = Seeds primed (socked) with 10ppm ABA solution,
P_3 = Seeds primed (socked) with 20ppm ABA solution,
P_4 = Seeds primed (socked) with 40ppm ABA solution,
P_5 = Seeds primed (socked) with 60ppm ABA solution,
P_6 = Seeds without priming (control)

4.1.3 Root length (mm)

Significant variation was observed on root length among the test genotypes priming with water and different concentration of ABA (Table 4.1.3 and Appendix IV). It was found that the genotype, V_1 (ESWYT-5) showed the highest root length in all seed priming treatment where genotype V_3 (BARI gom 28) showed the lowest root length. It was also observed that the maximum root length (112.4 mm) was recorded for V_1 (ESWYT-5) in P_4 (seeds primed with 40 ppm ABA solution for 9 hours) treatment. The lowest root length (50.96 mm) was observed from V_3 (BARI gom 28) with P_6 (seeds without priming; control) treatment followed by P_6 (seeds without priming; control) treatment with V_2 (ESWYT-6) genotype (58 mm). The root length of seedlings obtained from primed seeds was increased significantly compared to unprimed seeds. This improvement as affected by priming is supported by the findings of Basra *et al*. (2005) and Iqbal and Ashraf (2007) with wheat. Rafiq *et al.* (2006) reported that priming with $CaCl_2$ significantly enhanced root length under both saline and non-saline conditions. Afzal *et al.* (2008) reported that the growth of wheat increased significantly by using 50 mM $CaCl_2$ as seed priming treatment in saline

medium. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 was recorded when the seed primed with 10% PEG solution for 12 hours.

Table 4.1.3 Effect of different concentrations of ABA on root length (mm) of primed and non-primed (control) seeds

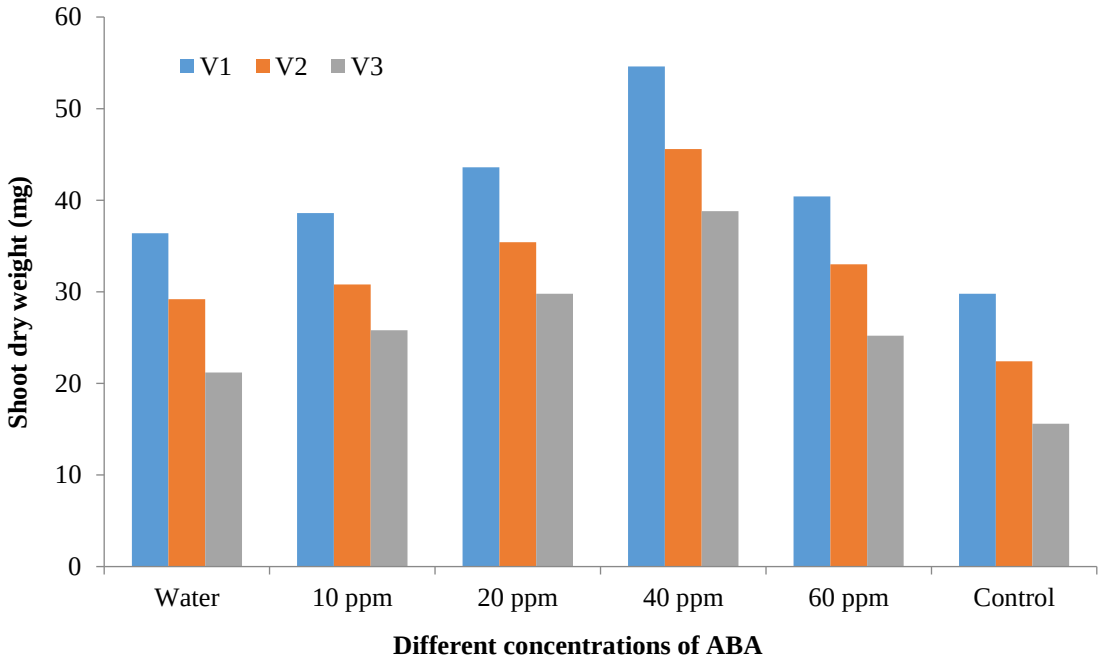
Genotypes	Root length (mm) at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	78.84 a	86.36 a	95.88 a	112.4 a	103.2 a	69.68 a
V_2	68.92 b	72.64 b	85.52 b	104.6 b	89.4 b	58 b
V_3	59.6 c	67.12 c	78.28 c	92.36 c	78.28 c	50.96 c
$LSD_{(0.01)}$	4.021	4.544	4.23	6.594	5.172	3.349
CV%	4.22	4.38	3.55	4.64	4.16	4.08

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water,
P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution,
P_6 = Seeds without priming (control)

4.1.4 Shoot dry weight (mg)

Statistical significant variation was found as effect of different concentrations of priming solution with different wheat genotypes on shoot dry weight of primed (ABA and water) and non-primed (control) seeds (Figure 1 and Appendix V). Dry weight of shoot increase with all treatments for all the genotypes of wheat compared to control (P_6). Results showed that the highest shoot dry weight (54.58 mg) was recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment. The lowest shoot dry weight (15.74 mg) was observed from V_3 (BARI gom-28) with P_6 (seeds without priming; control) treatment. Results also showed that shoot dry weight of all wheat genotypes increased with ABA treatment and highest showed dry weight obtained from 40 ppm ABA treatment. More than 40 ppm ABA treatment showed lower result than 40 ppm ABA treatment but higher than control in all wheat

genotypes. These results are in agreement with those of Pill and Necker (2001) who reported that primed compared to non-primed plants resulted in greater seedling dry weights. Basra *et al*. (2005) and Iqbal and Ashraf (2007) also observed primed seeds gave increased shoot dry weight significantly compared to unprimed seeds in wheat. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 was recorded when the seed primed with 10% PEG solution for 12 hours.

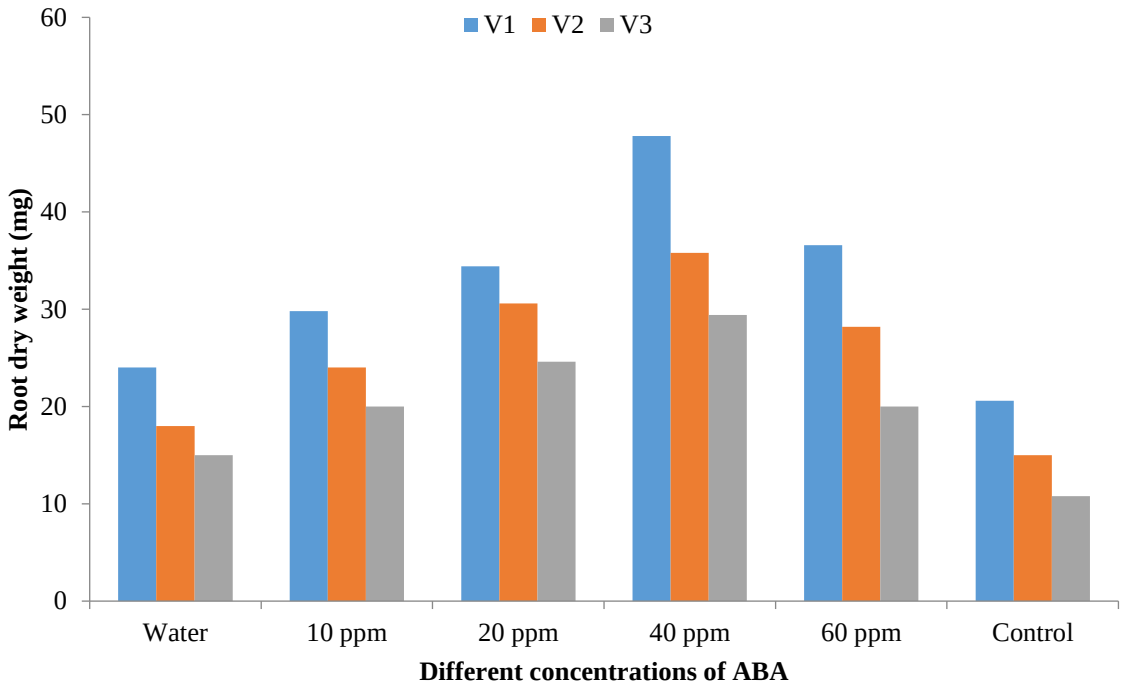


V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

Figure 1. Effect of different concentrations of ABA on shoot dry weight of primed and non-primed (control) seeds

4.1.5 Root dry weight (mg)

Statistically significant variation was found in case of root dry weight of different genotypes of wheat due to priming with water, all ABA treatment and control (Figure 2 and Appendix VI). Results revealed that the highest root dry weight (47.64 mg) was recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment followed by P_5 (Seeds primed with 60 ppm ABA solution for 9 hours). The lowest root dry weight (10.78 mg) was observed from V_3 (BARI gom-28) with P_6 (seeds without priming; control) treatment. The root dry weight of seedlings obtained from primed seeds was increased significantly compared to unprimed seeds and this improvement as affected by priming is supported by the findings of Basra *et al*. (2005) and Iqbal and Ashraf (2007) with wheat.



V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

Figure 2. Effect of different concentrations of ABA on root dry weight of primed and non-primed (control) seeds

4.1.6 Relative water content (%)

Relative water content of different genotypes of wheat showed statistically significant variation due to different concentrations of ABA solutions and water priming except 60 ppm ABA (Table 4.1.4 and Appendix VII). Among the different genotypes, V_1 (ESWYT-5) showed the highest relative water content (%) at all priming treatments where V_3 (BARI gom-28) showed the lowest relative water content (%) with all priming treatments. Results revealed that the highest relative water content (93.8%) was recorded in V_1 (ESWYT-5) with P_4 (Seeds primed with 40ppm ABA solution for 9 hours) treatment where the lowest relative water content (44.68%) was observed from V_3 (BARI gom-28) with P_6 (seeds without priming) treatment. Ghodrat and Rousta (2012) reported that in the level of 15 dsm^{-1} salinity germination rate (GR) and total water content (TWC) of seeds soaked with 1.5 mgL^{-1} GA3 was increased compared to the control. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 were recorded when the seed primed with 10% PEG solution for 12 hours.

Table 4.1.4 Effect of different concentrations of ABA on relative water content of primed and non-primed (control) seeds

Genotypes	Relative water content (%) at different priming solution					
	Water (P_1)	**10 ppm ABA (P_2)**	**20 ppm ABA (P_3)**	**40 ppm ABA (P_4)**	**60 ppm ABA (P_5)**	**Control (P_6)**
V_1	67.26 a	79.77 a	84.12 a	93.8 a	83.15 a	60.26 a
V_2	57.44 b	64.2 b	73.44 b	86.94 b	79.77 a	50.86 b
V_3	50.01 c	57.43 c	66.26 c	75.17 c	66.2 b	44.68 c
$LSD_{(0.01)}$	3.794	3.368	3.728	5.266	4.334	2.924
CV%	4.73	3.64	3.63	4.48	4.12	4.09

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60ppm ABA solution, P_6 = Seeds without priming (control)

4.1.7 Water saturation deficit

Different genotypes of wheat showed variation on water saturation deficit due to different concentrations of ABA solutions, water priming and control (Table 4.1.5 and Appendix VIII). Among the different genotypes, V_1 (ESWYT-5) confirmed the lowest water saturation deficit at all priming treatments where V_3 (BARI gom-28) showed the highest water saturation deficit with all priming treatments. Results revealed that the lowest water saturation deficit (6.2%) was recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment where the highest water saturation deficit (55.32%) was observed from V_3 (BARI gom-28) with P_6 (Control) treatment. Ali *et al.* (2013) reported that seed priming improves irrigation water use efficiency resulted lower water saturation deficit. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 were recorded when the seed primed with 10% PEG solution for 12 hours.

Table 4.1.5 Effect of different concentrations of ABA on water saturation deficit of primed and non-primed (control) seeds

Genotypes	Water saturation deficit (%) at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	32.74 c	20.23 c	15.88 c	6.2 c	16.85 c	39.74 c
V_2	42.56 b	35.8 b	26.56 b	13.06 b	20.23 b	49.14 b
V_3	49.99 a	42.57 a	33.74 a	24.83 a	33.78 a	55.32 a
$LSD_{(0.01)}$	2.458	1.889	2.289	0.793	1.183	2.646
CV%	4.27	4.17	6.54	3.91	3.63	3.99

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

4.1.8 Water retention capacity

Water retention capacity of different genotypes of wheat was influenced by different priming treatment of ABA and water priming (Table 4.1.6 and Appendix IX. Among the different genotypes, V_1 (ESWYT-5) showed the highest performance on water retention capacity with all priming treatments where V_2 (ESWYT-6) showed moderate performance and V_3 (BARI gom-28) showed the lowest performance on water retention capacity with all priming treatments. Results revealed that the highest water retention capacity (18.7) was recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment where the lowest water retention capacity (7.764) was observed from V_3 (BARI gom-28) with P_6 (seeds without primed) treatment. Among V_2 and V_3 no statistical difference of water retention capacity with P_4, P_5 and P_6 treatments. Ali *et al.* (2013) reported that seed priming improves irrigation water use efficiency which helps to increase higher water retention capacity. Ogbuehi *et al.* (2013) concluded that 24 hours hydro priming improves the performance of groundnut growth indices.

Table 4.1.6 Effect of different concentrations of ABA on water retention capacity of primed and non-primed (control) seeds

Genotypes	Water retention capacity at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	10.26 a	11.86 a	12.33 a	18.7 a	14.09 a	9.218 a
V_2	9.442 b	10.64 b	11.71 a	16.2 b	12.33 b	8.274 b
V_3	8.064 c	9.906 c	10.66 b	15.61 b	11.86 b	7.764 b
$LSD_{(0.01)}$	0.489	0.556	0.620	1.069	0.758	0.539
CV%	3.84	3.73	3.89	4.61	4.31	4.64

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

4.1.9 Vigour index

Significant influence was found in terms of vigour index of different wheat genotypes due to different priming solution (10 pm & 60 ppm) of ABA and water priming (Table 4.1.7 and Appendix X). Among the different genotypes, V_1 (ESWYT-5) showed the best performance on vigour index with all priming treatments where V_3 (BARI gom-28) showed the lowest performance on vigour index with all priming treatments. Results revealed that the highest vigour index (196.5) was recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment where the lowest water vigour index (68.65) was observed from V_3 (BARI gom-28) with P_6 (Control) treatment. Vigor index of V_1 (ESWYT-5) and V_2 (ESWYT-6) with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment was statistically identical but both are statistically significant V_3 (BARI gom-28) when treated with P_4 (seeds primed with 40ppm ABA solution for 9 hours) treatment. Similar findings were also found by several authors. Ogbuehi *et al.* (2013) concluded that 24 hours hydro priming improves the performance of groundnut growth indices. Nahar *et al.* (2016) reported that the maximum germination, seedling growth and water relation behavior of BARI Gom 27 were recorded when the seed primed with 10% PEG solution for 12 hours.

Table 4.1.7 Effect of different concentrations of ABA on vigour index of primed and non-primed (control) seeds

Genotypes	Vigor index at different priming solution					
	Water (P_1)	10 ppm ABA (P_2)	20 ppm ABA (P_3)	40 ppm ABA (P_4)	60 ppm ABA (P_5)	Control (P_6)
V_1	114.7 a	127.8 a	152.7 a	196.5 a	164.1 a	112 a
V_2	106.9 b	120.8 b	132.7 b	192.4 a	156.1 b	82.26 b
V_3	73.46 c	108.4 c	125.3 b	179.9 b	147.2 c	68.65 c
$LSD_{(0.01)}$	6.575	6.576	7.843	10.51	7.682	4.931
CV%	4.58	4.01	4.16	4.03	3.58	4.08

V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28

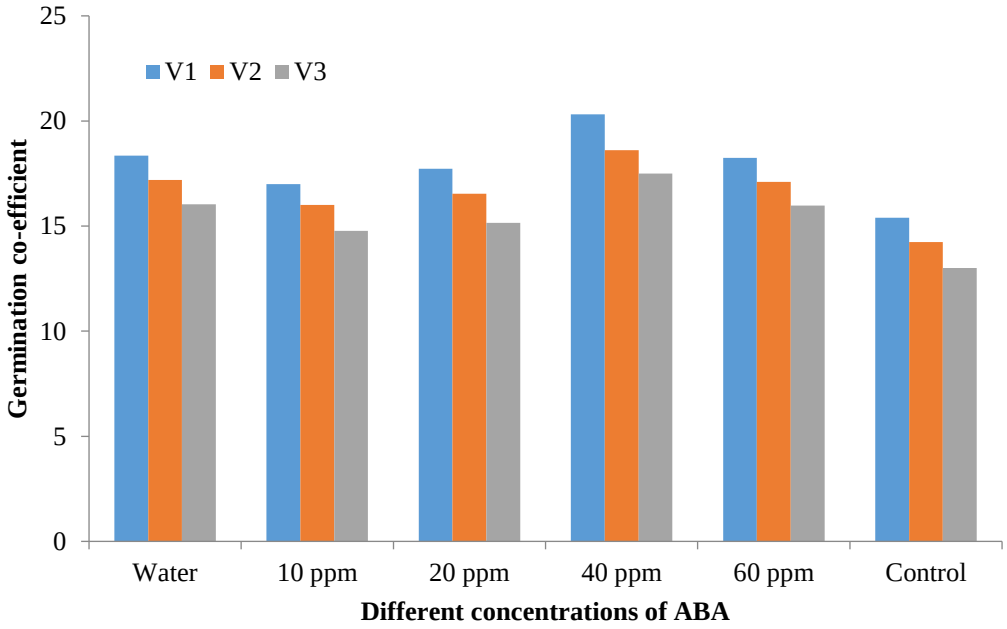
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution, P_3 = Seeds primed (socked) with 20 ppm ABA solution,

P_4 = Seeds primed (socked) with 40 ppm ABA solution,

P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

4.1.10 Germination Co-efficient

Statistically significant difference was found in case of germination co-efficient of different wheat genotypes due to priming with water, all concentrations of ABA and control (Figure 3 and Appendix XII). Priming with 40 ppm ABA (P_4) solution for 9 hours all test genotypes showed the highest result compared to other treatments. Result showed that the highest germination co-efficient (20.31) recorded in V_1 (ESWYT-5) with P_4 (seeds primed with 40 ppm ABA solution for 9 hours) treatment followed by P_5 (seeds primed with 60 ppm ABA solution for 9 hours) treatment. The lowest germination co-efficient (13.00) was observed in V_3 (BARI gom 28) with P_6 treatment. So the result concluded that priming can increase germination co-efficient. Similarly, Harris *et al.* (2007) reported that seed priming led to better establishment and growth, earlier flowering, increased seed tolerance to adverse environment and higher yield in soybean which support the results claimed by Golezani *et al.*, (2008) for lentil.



V_1 = ESWYT-5, V_2 = ESWYT-6, V_3 = BARI gom-28
P_1 = Seeds primed (socked) with distilled water, P_2 = Seeds primed (socked) with 10 ppm ABA solution,
P_3 = Seeds primed (socked) with 20 ppm ABA solution,
P_4 = Seeds primed (socked) with 40 ppm ABA solution,
P_5 = Seeds primed (socked) with 60 ppm ABA solution, P_6 = Seeds without priming (control)

Figure 3. Effect of different concentrations of ABA on germination co-efficient of primed and non-primed (control) seeds

4.2 Second experiment: To find out the best result under salt stress condition

This experiment was conducted under laboratory condition. Three wheat genotypes were primed in 40 ppm ABA solution for 9 hours. Wheat seed was exposed to 0 (water), 5, 10, 15 and 20 dSm^{-1} NaCl induced salt stress conditions in petri dishes. The results are presented separately under the following headings:

4.2.1 Rate of germination (%)

Different salinity levels revealed significant variation in respect of germination rate (Table. 4.2.1 and Appendix XII). Result showed that the germination rate of primed seeds decreased significantly with increasing salinity level. It was found that the variety, V_1 (ESWYT 5) gave the promising result on seed germination at all salt concentration and germination rate was the highest in no salinity level (S_1 treatment). But under salinity level the highest germination rate was found in primed seeds placed with S_2 treatment (5 dsm^{-1} NaCl) and thereafter germination rate gradually decreased with increased salinity levels. It was observed that the highest germination rate (93.2 %) was in V_1 (ESWYT-5) under primed seeds placed in water (S_1 treatment) and after that the second highest germination rate (92.6%) was in V_1 (ESWYT-5) with primed seeds placed with S_2 treatment (5 dSm^{-1} NaCl) where the lowest germination rate (69.8%) was obtained from V_3 (BARI Gom-28) with Primed seeds placed with 20 dSm^{-1} NaCl (S_5 treatment). Edalat-Pisheh *et al*. (2010) declared that total germination percentage in wheat seeds decreased when salinity of both primed and unprimed (control group) treatments increased. Kilic and Kahraman (2016) reported that 0.30 M salt concentration decreased germination index, vigor index, radicle length, coleoptile length and fresh weight of barley plants 51%, 88%, 85%, 76% and 66%, respectively.

Table 4.2.1 Effect of different salinity levels on germination rate of ABA primed wheat genotypes

Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	93.2 a	92.6 a	91.8 a	89.6 a	87.2 a
V_2	86.73 b	84.8 b	82 b	79.92 b	75.6 b
V_3	81.4 c	78.92 c	75.2 c	72.2 c	69.8 c
$LSD_{(0.01)}$	5.088	4.534	4.736	4.37	4.462
CV%	4.24	3.85	4.14	3.94	4.18

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control), S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl, S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.2 Shoot length (mm)

Shoot length of different wheat genotypes was significantly influenced by different salinity levels (Table 4.2.2 and Appendix XIII). Results revealed that the highest shoot length (160.6 mm) was observed from V_1 (ESWYT-5) in S_1 (primed seeds placed without salt, control) treatment followed by V_2 (ESWYT -6) in S_1 (primed seeds placed without salt, control) treatment. The lowest shoot length (73.8 mm) was observed from V_3 (BARI gom 28) in S_5 treatment (primed seeds placed with 20 dSm^{-1} NaCl solution). Salinity has both osmotic and specific ionic effects on seedlings growth (Dioniso-Sese and Tobita, 2000). Bakht et al. (2011) showed that 75.76% plant height, 65.89% shoot fresh weight and 75.92% shoot dry weight can reduced when seeds exposed to different salinity levels. Significant improvement in root and shoot length may be attributed to earlier germination induced by primed over non-primed seeds (Farooq *et al*., 2005), which resulted in vigorous seedlings with more root and shoot length than the seedlings from non-primed seeds.

Table 4.2.2 Effect of different salinity levels on shoot length of ABA primed wheat genotypes

Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	160.6 a	159.0 a	154.7 a	152.2 a	140.0 a
V_2	140.9 b	132.6 b	122.6 b	105.3 b	89.6 b
V_3	138.4 b	126.8 b	110.9 c	97.0 c	73.8 c
$LSD_{(0.01)}$	7.41	6.96	6.97	6.42	5.41
CV%	3.67	3.62	3.91	3.94	3.88

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control), S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl, S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.3 Root length (mm)

Root length of different wheat genotypes was significantly influenced by different salinity levels (Table 4.2.3 and Appendix XIV). Results revealed that the highest root length (110.0 mm) was observed in V_1 (ESWYT -6) in S_1 (primed seeds placed without salt, control) treatment followed by V_2 (ESWYT -5) in S_1 (primed seeds placed without salt, control) treatment. The lowest root length (52.1 mm) was observed in V_3 (BARI gom-28) in S_5 (20 dSm^{-1} NaCl solution) treatment. Significant improvement in root and shoot length may be attributed to earlier germination induced by primed over non-primed seeds (Farooq *et al*., 2006), which resulted in vigorous seedlings with more root and shoot length than the seedlings from non-primed seeds. Similarly, Bakht et al. (2011) showed that 75.76% plant height, 65.89% shoot fresh weight and 75.92% shoot dry weight can reduced when seeds exposed to different salinity levels.

Table 4.2.3 Effect of different salinity levels on root length of ABA primed wheat genotypes

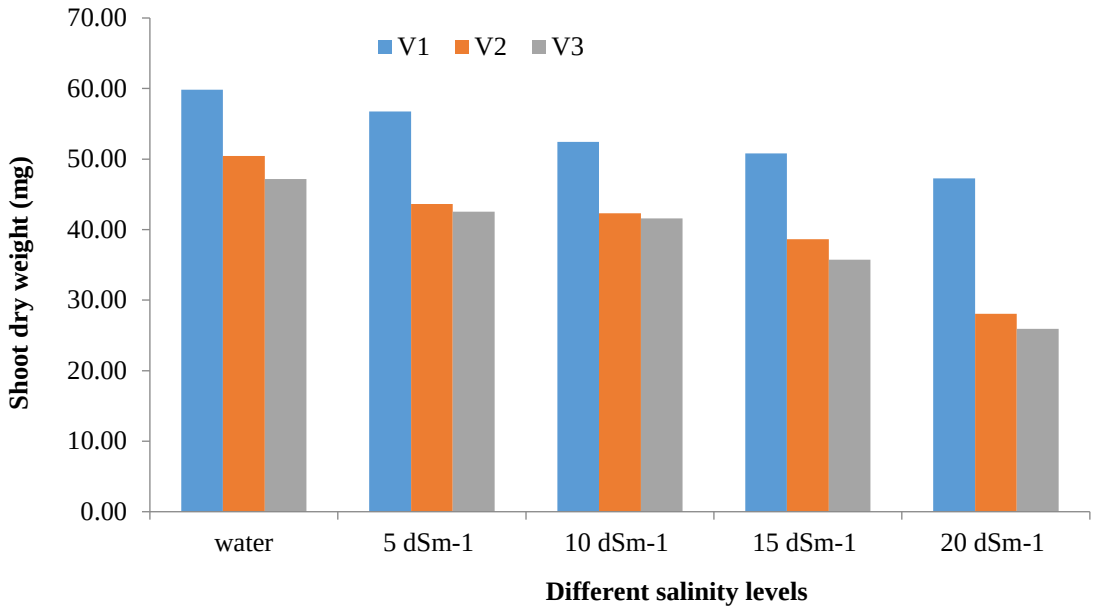
Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	110.0 a	105.4 a	101.8 a	96.4 a	85.0 a
V_2	101.8 b	91.6 b	85.8 b	79.5 b	71.7 b
V_3	96.4 c	75.7 c	69.0 c	60.2 c	52.1 c
$LSD_{(0.01)}$	5.1	4.5	5.1	4.9	4.6
CV%	3.6	3.6	4.3	4.5	4.8

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control), S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl, S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.4 Shoot dry weight (mg)

Significant variation was found for shoot dry weight of different wheat genotypes affected by different salinity levels (Figure 4 and Appendix XV). The results showed that that the highest shoot dry weight (59.84 mg) was observed in V_1 (ESWYT-5) with S_1 treatment (primed seeds placed without salt) where the lowest shoot dry weight (25.92 mg) was observed in V_3 (BARI gom 28) with S_5 (20 dSm^{-1} salt solution) treatment. Bakht et al. (2011) showed that 75.76% plant height, 65.89% shoot fresh weight and 75.92% shoot dry weight can reduced when seeds exposed to different salinity levels. Gorai *et al.* (2010) reported that, seed germination, seedling growth, flowering and fruiting are adversely affected by salinity, resulting in reduced yield and quality.



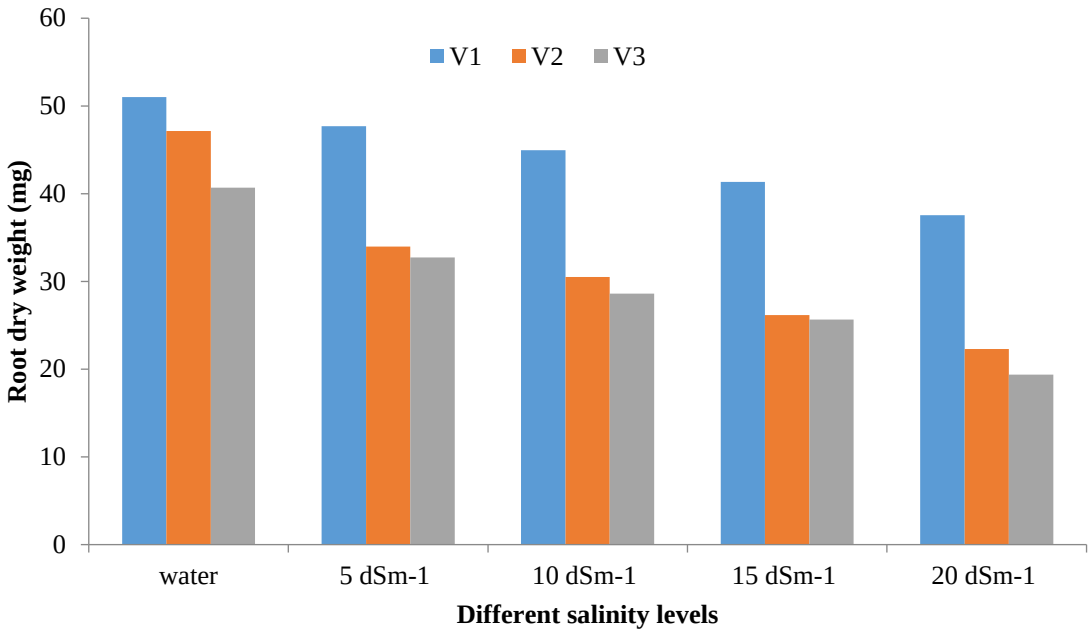
V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

Figure 4. Effect of different salinity levels on shoot dry weight (mg) ABA primed wheat genotypes

4.2.5 Root dry weight (mg)

Significant variation was found for root dry weight of different wheat genotypes affected by different salinity levels (Figure 5 and Appendix XVI). The results showed that that the highest root dry weight (51.0 mg) was observed in V_1 (ESWYT-5) with S_1 (primed seeds placed without salt; control) treatment where the lowest root dry weight (19.38 mg) was found in V_3 (BARI gom-28) with S_5 (primed seeds placed with 20 dSm^{-1} NaCl) treatment. Liu *et al.* (2008) reported significant reduction in the dry biomass of halophyte *Suaeda salsa* when exposed to different concentration of NaCl under different water regimes. Similarly, Sixto *et al.* (2005) stated that depending on increasing salinity levels, decrease in growth parameters (root, stem and shoot developments, fresh & dry stem and root weights; leaf area and number and yield) has been observed in plants.



V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

Figure 5. Effect of different salinity levels on root dry weight (mg) of ABA primed wheat genotypes

4.2.6 Relative water content (%)

Relative water content of different wheat genotypes was significantly influenced by different salinity levels (Table 4.2.4 and Appendix XVII). Results indicated that the highest relative water content (90.39%) was observed in V_1 (ESWYT-5) with S_1 (primed seeds placed with water) treatment followed by V_1 (ESWYT-5) with S_2 (primed seeds placed with 5 dSm^{-1} NaCl) treatment. The lowest relative water content (63.23%) was observed in V_3 (BARI gom 28) with S_5 (primed seeds placed with 520 dSm^{-1} NaCl) treatment. Saberi *et al.* (2011) conducted an experiment with two forage sorghum varieties (Speed feed and KFS4) and grown under salinity levels of 0, 5, 10 and 15 dSm^{-1}. They reported that leaf area of plants were also reduced in response to salinity and decreasing soil water availability.

Table 4.2.4 Effect of different salinity levels on relative water content of ABA primed wheat genotypes

Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	90.39 a	89.39 a	89.03 a	87.37 a	87.3 a
V_2	87.3 ab	86.96 ab	84.81 ab	82.03 b	78.54 b
V_3	85.78 b	82.54 b	80.69 b	76.96 c	63.23 c
$LSD_{(0.01)}$	4.276	4.983	6.041	4.783	4.481
CV	3.53	4.19	5.17	4.23	4.25

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.7 Water saturation deficit

Significant influence was found in terms of water saturation deficit of different wheat genotypes affected by different salinity levels (Table 4.2.5 and Appendix XVIII). Results indicated that the highest water saturation deficit (36.77) was observed in V_3 (BARI gom-28) with S_5 (primed seeds placed with 20 dSm^{-1} NaCl) treatment where the lowest water saturation deficit (9.608) was observed in V_1 (ESWYT-5) with S_1 (primed seeds placed with water) treatment followed by V_1 (ESWYT-5) with S_2 (primed seeds placed with 5 dSm^{-1} NaCl) treatment. Akbarimoghaddam *et al.* (2011) evaluated salinity effects on seed germination and seedling growth of six bread wheat cultivars *(Triticum aestivum* L). They reported that water uptake by seeds have a direct relationship with increases in NaCl levels.

Table 4.2.5 Effect of different salinity levels on water saturation deficit of ABA primed wheat genotypes

Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	9.608 c	10.61 c	10.97 c	12.63 c	12.7 c
V_2	12.7 b	13.04 b	14.99 b	17.97 b	21.46 b
V_3	14.21 a	17.46 a	19.31 a	23.04 a	36.77 a
$LSD_{(0.01)}$	0.6239	0.7305	0.6821	0.9754	1.137
CV%	3.72	3.87	3.28	3.96	3.49

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.8 Water retention capacity

Significant influence was found for water retention capacity of different wheat genotypes affected by different salinity levels (Table 4.2.6 and Appendix XIX). Results indicated that the highest water retention capacity (12.6) was observed in V_1 (ESWYT-5) with S_1 (primed seeds placed with water) treatment where the lowest water retention capacity (3.104) was observed in V_3 (BARI gom-28) with S_5 (primed seeds placed with 20 dSm^{-1} NaCl) treatment. Akbarimoghaddam *et al.* (2011) evaluated salinity effects on seed germination and seedling growth of six bread wheat cultivars *(Triticum aestivum* L). They reported that water uptake by seeds have a direct relationship with increases in NaCl levels. Hamayun (2010) reported that, the 1000 seed weight and yield of soybean significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

Table 4.2.6 Effect of different salinity levels on water retention capacity of ABA primed wheat genotypes

Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	12.6 a	11.6 a	10.56 a	9.386 a	8.306 a
V_2	10.32 b	9.028 b	7.629 b	6.36 b	5.006 b
V_3	10.27 b	8.736 b	7.071 c	5.226 c	3.104 c
$LSD_{(0.01)}$	0.6522	0.4833	0.4018	0.3849	0.3672
CV%	4.27	3.58	3.46	4.00	4.88

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.9 Vigour index

Significant influence was found for vigour index of different wheat genotypes affected by different salinity levels (Table 4.2.7 and Appendix XX). Results indicated that the highest vigour index (220.6) was observed from V_1 (ESWYT-5) with S_1 (primed seeds placed with water) treatment where the lowest vigour index (8.876) was observed from V_3 (BARI gom-28) with S_5 (primed seeds placed with 20 dSm^{-1} NaCl) treatment. Ruan *et al*. (2002b) also found similar results who observed that primed rice seeds showed higher vigour index than non-primed ones. Hamayun (2010) reported that, the 1000 seed weight and yield of soybean significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

Table 4.2.7 Effect of different salinity levels on vigour index of ABA primed wheat genotypes

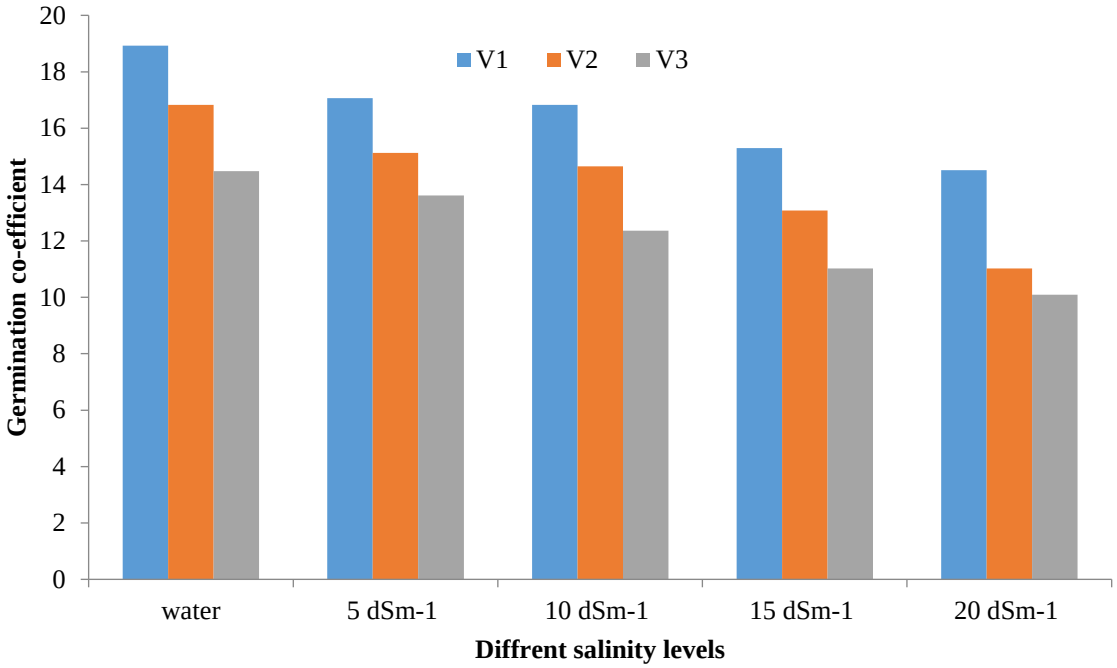
Genotypes	Different salt concentrations				
	0 (S_1)	**5 dSm^{-1} (S_2)**	**10 dSm^{-1} (S_3)**	**15 dSm^{-1} (S_4)**	**20 dSm^{-1} (S_5)**
V_1	220.6 a	206.9 a	200.5 a	196.9 a	191 a
V_2	195.7 b	187.1 b	177.9 b	169.1 b	155.3 b
V_3	185.3 b	174.9 c	162.1 c	152.7 c	132.5 c
$LSD_{(0.01)}$	11.93	9.181	10.08	9.609	8.876
CV%	4.32	3.51	4.06	4.03	4.04

V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control), S_2= Primed seeds placed with 5 dSm^{-1} NaCl, S_3= Primed seeds placed with 10 dSm^{-1} NaCl, S_4 =Primed seeds placed with 15 dSm^{-1}NaCl, S_5= Primed seeds placed with 20 dSm^{-1} NaCl

4.2.9 Germination co-efficient

Statistically significant difference was found in case of germination co-efficient of different wheat genotypes affected by different salinity levels (Figure 6 and Appendix XXI). Result showed that the highest germination co-efficient (18.92) recorded in V_1 (ESWYT-5) with S_1 (primed seeds placed with water) treatment followed by S_2 (primed seeds placed with 5 dSm^{-1} NaCl) treatment. The lowest germination co-efficient (10.09) was observed in V_3 (BARI gom 28) with S_5 (primed seeds placed with 20 dSm^{-1} NaCl) treatment. Similarly, Harris *et al.* (2007) reported that seed priming led to better establishment and growth, earlier flowering, increased seed tolerance to adverse environment and higher yield in soybean which support the results claimed by Golezani *et al.*, (2008) for lentil.



V_1= ESWYT-5, V_2= ESWYT -6, V_3= BARI gom-28

S_1= Primed seeds placed without salt (control),
S_2= Primed seeds placed with 5 dSm^{-1} NaCl,
S_3= Primed seeds placed with 10 dSm^{-1} NaCl,
S_4 =Primed seeds placed with 15 dSm^{-1}NaCl,
S_5= Primed seeds placed with 20 dSm^{-1} NaCl

Figure 6. Effect of different salinity levels on germination co-efficient of ABA primed wheat genotypes

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from 21 September 2016 to 19 November 2016 to study the abscisic acid (ABA) induce changes in seed germination behavior and seedling growth of wheat (*Triticum aestivum*. L) under salt stress condition. A set of experiment was conducted in two different experiments. The experiment was laid out in a Completely Randomized Design (CRD) with five replications.

Three wheat genotypes namely- ESWYT-6, ESWYT-5 and BARI gom-28 were used as test crop. Different priming chemicals such as ABA, salt (NaCl) and distilled water were utilized for osmo and hydro priming.

Priming was done in room temperature and all the primed seeds were removed from the priming solution at the same time. Thirty seeds from each of the treatments were selected randomly and placed in 90 mm diameter petri dishes on whatman No.1filter paper and filter paper was moistened with 8 ml of distilled water.

Germination was measured to have occurred when radicles were 2 mm long. Germination progress was examined and data were collected at every 24 h intervals and continued up to 10 days. The abnormal or dead seedlings were excluded during counting. The data on germination parameters of wheat like germination percentage and growth parameters like root length, shoot length, dry weight and vigour index. Data were analyzed using a computer software MSTAT-C program. The significance of difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 1% level of probability.

5.1 First experiment

The first experiment was conducted to find out the effect of different concentration of ABA on germination and growth behavior of three wheat genotypes (ESWYT-5, ESWYT-6 and BARI gom-28) without any stress condition. Four levels of ABA such as 10 ppm, 20 ppm, 40 ppm and 60 ppm were used for hormonal priming and distilled water used as hydropriming agent for 9 hours, respectively. The priming treatments were P_1 = seeds primed with distilled water, P_2 = seeds primed with 10ppm ABA solution, P_3 = seeds primed with 20 ppm ABA solution, P_4 = seeds primed with 40ppm ABA solution, P_5 = seeds primed with 60 ppm ABA solution and P_6 = seeds without priming (control).

Among the genotypes, V_1 (ESWYT-5) gave the best results on studied parameters. Results revealed that the variety V_1 (ESWYT-5) showed the highest germination rate (91.71%) with P_4 (seeds primed with 40 ppm ABA for 9 hours) treatment. Again, V_1 (ESWYT-5) also showed the highest shoot length (160.6 mm), root length (112.4 mm), shoot dry weight (54.6 mg), root dry weight (47.8 mg), relative water content (93.8 %), water retention capacity (18.7) and vigour index (196.5) with P_4 (seeds primed with 40 ppm ABA solution for 9 hours) treatment.

5.2 Second experiment

In the second experiment germination and growth behavior of primed seeds of wheat genotypes (ESWYT-5, ESWYT-6 and BARI gom-28) under salt stress condition was evaluated. ABA solution 40ppm were used as priming solutions and 9 hours as priming time and salt stress levels 5 dSm^{-1}, 10 dSm^{-1}, 15 dSm^{-1} and 20 dSm^{-1} were used in this experiment. The treatments *viz*. S_1 = primed seeds placed without salt (control), S_2 = primed seeds placed with 5 dSm^{-1} NaCl, S_3 = primed seeds placed with 10 dSm^{-1} NaCl, S_4 = primed seeds placed with 15 dSm^{-1} NaCl and S_5 = primed seeds placed with 20 dSm^{-1} NaCl were used.

Results revealed that genotype V_1 (ESWYT-5) with S_1 (Primed seeds placed without salt; control) treatment gave the highest germination rate (93.81%), shoot length (160.6 mm), root length (110.00 mm) and vigour index (233.5), shoot dry weight

(59.84 mg), root dry weight (51.0 mg), relative water content (90.39%) and water retention capacity (12.6) and also showed the lowest water saturation deficit (9.61).

From the results of the study, it may be concluded that the performance of ABA treated wheat cv. ESWYT-5 was better in respect of germination and growth parameters. Priming with 40ppm ABA concentration and 9 hours priming time increased the germination and growth behavior of wheat seeds. Reduction in germination parameters and seedling growth was more profound in control seeds than primed seeds under salt stress condition. Thus, the priming may be an effective method to meet the demands of farmers during the installation of the culture in the field and especially in conditions of salt stress. For this reason, further studies are needed to assess the efficacy of seed priming during the later stages of the culture.

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APPENDICES

Appendix I. Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period of November 2016

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2016	September	32.5	28.6	30.0	69.5	90.0	263.2
2016	October	29.5	18.6	24.0	69.5	50.0	233.2
2016	November	26.4	15.6	21.0	68.6	00	230.4

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212.Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212.

Appendix II. Effect of different concentrations of ABA on germination rate of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of germination rate at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	14.90^{NS}	63.96**	71.47**	91.36**	133.02**	98.22**
Error	12	4.46	5.73	5.12	6.59	7.56	5.81

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix III. Effect of different concentrations of ABA on shoot length of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of shoot length at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	1285.96**	357.84**	186.16**	911.62**	265.41**	788.77**
Error	12	6.96	11.04	14.08	13.93	18.29	15.64

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix IV. Effect of different concentrations of ABA root length of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of root length at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	447.0**	462.9**	490.7**	391.3**	512.4**	776.7**
Error	12	3.004	4.33	5.53	4.79	11.65	7.17

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix V. Effect of different concentrations of ABA on shoot dry weight of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of shoot dry weight at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	251.48**	277.1**	211.2**	242.8**	333.0**	284.3**
Error	12	0.348119	0.78	0.96	1.17	1.56	1.25

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix VI. Effect of different concentrations of ABA on root dry weight of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of root dry weight at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	119.93**	108.05**	126.07**	121.72**	415.43**	349.47**
Error	12	0.24	0.32	0.56	0.91	1.15	0.76

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix VII. Effect of different concentrations of ABA on relative water content of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of relative water content at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	307.76**	374.33**	656.56**	403.77**	443.72**	402.46**
Error	12	2.29	3.86	3.039	3.72	7.43	5.03

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix VIII. Effect of different concentrations of ABA on water saturation deficit of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of water saturation deficit at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	307.8**	374.3**	656.56**	403.8**	443.7**	401.4**
Error	12	1.88	1.62	0.96	1.40	0.17	0.38

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix IX. Effect of different concentrations of ABA on water retention capacity of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of water retention capacity at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	2.72**	6.14**	4.85**	3.57*	13.46*	6.95*
Error	12	0.078	0.064	0.083	0.10	0.31	0.15

**Significant at 1% level of significance
**Significant at 5% level of significance
^{NS} = Non-significant

Appendix X. Effect of different concentrations of ABA on vigour index of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of vigour index at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	2458.76**	2398.84**	480.17**	1006.42*	372.56**	357.62**
Error	12	6.51	11.58	11.58	16.477	29.59	15.81

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XI. Effect of different concentrations of ABA on germination co-efficient of primed and non-primed (control) seeds

Source of variation	Degrees of freedom	Mean square of germination co-efficient at different priming solution					
		Control	Water	10ppm	20ppm	40ppm	60ppm
Treatment	2	0.34**	2.37**	0.37**	0.64**	8.49**	3.48**
Error	12	0.24	0.194	0.19	0.26	0.21	0.28

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XII. Effect of different salinity levels on germination rate of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of germination rate on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	174.59**	235.40**	348.20**	380.04**	392.62**
Error	12	6.93	5.51	6.01	5.12	5.33

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XIII. Effect of different salinity levels on shoot length of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of shoot length on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	737.35*	1467.60*	2577.20**	4424.10**	5982.34**
Error	12	14.70	12.98	12.99	11.044	7.84

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XIV. Effect of different salinity levels on root length of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of root length on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	234.28**	1107.35**	1348.38**	1636.75**	1366.47**
Error	12	7.08	5.48	6.93	6.32	5.77

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XV. Effect of different salinity levels on shoot dry weight of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of shoot dry weight on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	216.258**	311.541**	183.001**	318.925**	690.513**
Error	12	2.56	2.22	1.715	1.73	1.23

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XVI. Effect of different salinity levels on root dry weight of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of root dry weight on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	135.386**	343.693**	398.241**	398.202**	477.001**
Error	12	1.94	1.36	0.97	0.81	0.84

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XVII. Effect of different salinity levels on relative water content of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of relative water content on different salinity level				
		Water	50 ppm	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}
Treatment	2	27.59**	60.20**	86.91**	135.49**	742.15**
Error	12	4.89	6.65	9.78	6.13	5.38

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XVIII. Effect of different salinity levels on water saturation deficit of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of water saturation deficit on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	27.56**	60.20**	86.92**	135.46**	742.20**
Error	12	0.10	0.14	0.13	0.26	0.35

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XIX. Effect of different salinity levels on water retention capacity of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of water retention capacity on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	8.85**	12.41**	17.57**	23.12**	34.64**
Error	12	0.11	0.063	0.043	0.040	0.036

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XX. Effect of different salinity levels on vigour index of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of vigour index on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	1646.72**	1308.49**	1861.88**	2501.05**	4340.23**
Error	12	38.124	22.58	27.22	24.73	21.10

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

Appendix XXI. Effect of different salinity levels on germination co-efficient of ABA primed wheat seeds

Source of variation	Degrees of freedom	Mean square of germination co-efficient on different salinity level				
		Water	5 dSm^{-1}	10 dSm^{-1}	15 dSm^{-1}	20 dSm^{-1}
Treatment	2	0.27**	0.08**	0.11**	0.13**	0.26**
Error	12	0.29	0.22	0.21	0.22	0.21

**Significant at 1% level of significance

**Significant at 5% level of significance

^{NS} = Non-significant

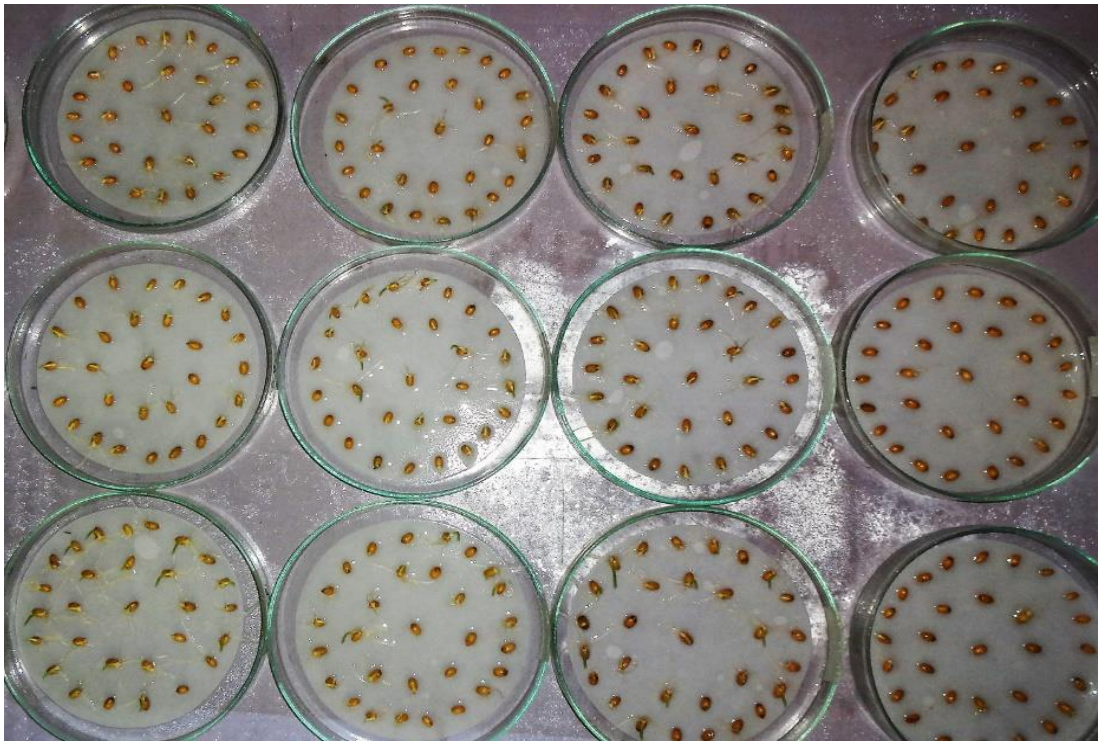

Plate 1: Placement of different wheat genotypes seeds for germination

Plate 2: Experiment set up in the laboratory rack

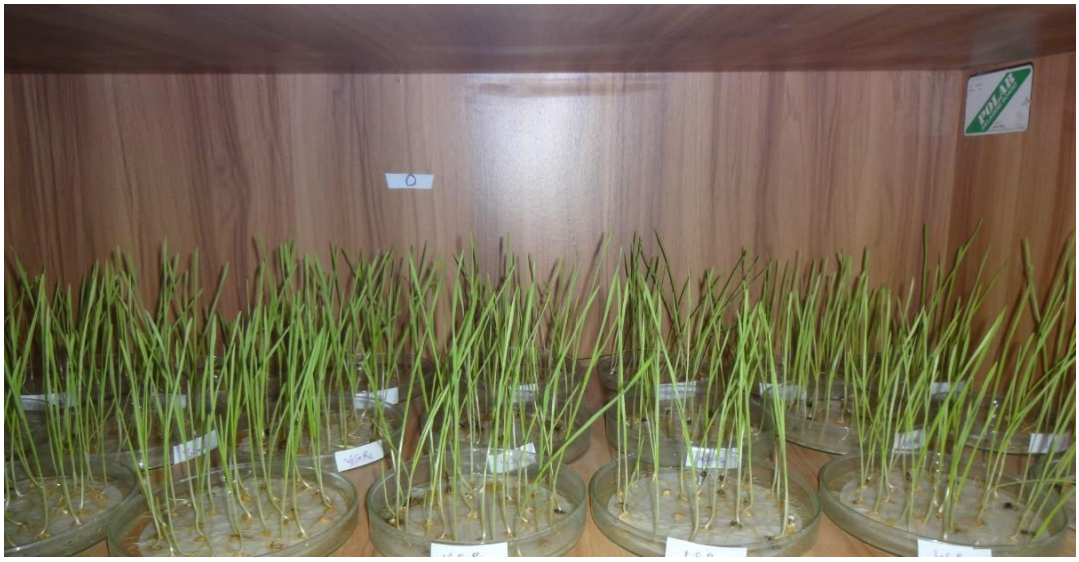

Plate 3: Different wheat genotypes seedling after 10 days of placement in petri dishes

Plate 4: Randomly selected seedlings for data collection purpose