PLANT BIOMETRY AND YIELD OF WHEAT UNDER SALT STRESS CONDITIONS AS INFLUENCED BY HALO-PRIMING

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CERTIFICATE

*This is to certify that thesis entitled, "**PLANT BIO-METRY AND YIELD OF WHEAT UNDER SALT STRESS CONDITIONS AS INFLUENCED BY HALO-PRIMING**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. FAJLA RABBI** , Registration no. **19-10185** 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 duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted on plastic pot in net house condition at Sher-e-Bangla Agricultural University during rabi season 2020-2021 (November 2020 to February 2021) to investigate the effect of halo priming on plant biometry and yield of wheat(BARI Gom 33) under salt stress conditions. The experiment comprised of two factors, factor A: Seed priming and factor B: different levels of salinity. Factor A consisted of 4 types of seed priming *viz;* i.No Priming (P_0), ii. Hydro Priming (P_1), iii. Priming with 5 mM NaCl (P_2) and iv. Priming with 5 mM Na-Acetate (P_3). Factor B consisted three levels of salinity*viz;* i.0 ds m^{-1}(S_0), ii. 4 ds m^{-1}(S_1), iii. 8 ds m^{-1} (S_2). This experiment was laid out in a randomized complete block design (RCBD) with five replications. Data were collected on different aspects of growth, yield attributes and yield of wheat. The results revealed that seed priming with 5 mM Na-acetate (P_3)exhibited its superiority compare with other priming treatmentsin terms of yield and yield attributes. Seed priming with Na-acetate showed the highest 1000-grain weight (47.06 g), seed yield (29.50 g pot^{-1}), straw yield (33.20 g pot^{-1}), biological yield (62.70 g pot^{-1}) and the harvest index (47.06 %) than other seed priming. Exposure of salinity showed significant differences on growth and yield of wheat. Exposure of 4 and 8 ds m^{-1} salinity decreased germination percentage (19 and 35%, respectively), effective tillers (8 and 67%, respectively), 1000-grain weight (14 and 45%, respectively), grain yield (17 and 67%, respectively), straw yield (10 and 63%, respectively), and biological yield (13 and 65%, respectively). Combination of seed priming and salinity also significantly influence growth and yield of wheat. Under 4 and 8 ds m^{-1} salinity, seed priming with 5 mM Na-acetate uplifted grain yield by 10 and 81%, respectively. Hydro-priming and seed priming with 5 mM NaCl also uplifted yield and yield attributes of wheat under all level of salinity. Hydro-priming and Halo-priming played positive role to upgrade germination percentage, growth and yield of wheat. However, among the seed priming treatments, seed priming with Na-acetate showed best results under salt stress conditions in terms of seed germination, growth and yield of wheat.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agric.
Agro-Ecological Zone	AEZ
And others	*et al.*
Applied	App.
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Centimeter	Cm
Cultivar	Cv.
Degree Celsius	°C
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
Gram	G
International	Intl.
Journal	J.
Kilogram	Kg
Least Significant Difference	LSD
Liter	L
Percentage	%
Science	Sci.
Serial	Sl.
Soil Resource Development Institute	SRDI
Technology	Technol.
Triple super phosphate	TSP

CHAPTER I

INTRODUCTION

Plants are frequently exposed to various environmental stresses that adversely affect their growth, development, and productivity (Khan *et al.,* 2015). Among them, soil salinity is a major environmental factor which limits the growth development and yield of plants (Hussain *et al.,* 2008). It is estimated that salinity affects approximately 20% of the irrigated land worldwide. It is also assumed that around 50% of the total cultivable land will be salt affected by the middle of the twenty-first century (Mahajan *et al.,* 2005). High soil salt concentrations reduce the capability of a plant to absorb water. Moreover, plants absorbed higher amount of Na^+ and Cl^- which adversely affect growth by ruining metabolic processes and reducing photosynthetic efficiency (Deinlein *et al.,* 2014). As a result, salinity caused osmotic stress, disturbed ion homeostasis, enhanced production of reactive oxygen species (ROS), thereby causing oxidation of membrane lipids, protein and nucleic acids (Gill and Tuteja, 2010). The potential antioxidant system in plants helps to counteract the adverse effects of ROS. The increased accumulation of osmoprotectants and compatible solutes are helpful to combating salt stress-impacts in plants (Khan *et al.,* 2012). Notably, these major mechanisms are integrated and triggered through the action of signaling molecules (Ahmad *et al.*, 2016).

Seed priming is one of the many ways for overcoming salinity-induced deleterious consequences. Prior exposure to a biotic or abiotic stress factor is used in the priming or hardening process to make a plant more resistant to future stress (Bradford, 1986). Seed priming is a physiological procedure used prior to seed germination that increases seed performance and allows for faster and more synchronized seed germination. Because primed seeds of plants have completed their chitting period (seed absorb maximum water and complete all processes before germination during priming) that boosts germination percentage and lowers time to emergence. Soaking the seed in the solution prevents enough water absorption for radical emergence and allows the seed to expand in the lag phase. Seed priming protects against disease by covering seeds with fungicides, bactericides, and nematicides. Seed priming is a technique for increasing seed germination and vitality (Nawaz *et al.,* 2013). Primed seeds have great potential to grow under stressful conditions. It has strong resistance against disease and insect attack (Ahmadvand *et al.*, 2012). Seed priming is a strategy for controlling seed hydration as well as metabolic activity within the seed, both of which are required for seed germination (Atalou, 2014). Seed priming is one of the most pragmatic and short-term approaches to combat the effects of environmental stresses on seedling emergence and stand establishment (Farooq *et al.,* 2010; Jafar *et al*., 2012). Abiotic factors are one of the major problem in crop production.

Halopriming is a pre-sowing soaking of seeds in salt solutions, which enhances germination and seedling emergence uniformly under adverse environmental conditions. Basra *et al.* (2005b) reported that salt tolerance in wheat can be increased by treating seeds with various salt solutions prior to sowing; moreover, Cayuela *et al.* (1996) showed that the higher salt tolerance of plants from primed seeds is the result of higher capacity for osmotic adjustment since plants from primed seeds have more Na^+ and Cl^- in roots and more sugars and organic acids in leaves than plants from non-primed seeds. Therefore, halopriming could be used as a suitable method to improve salt tolerance in crops.

Hydropriming elevated emergence and growth under salinity (Kaur *et al.*, 2002; Kaya *et al.*, 2006). Hydropriming is a starter procedure for germination without emergence of the radicle that involves soaking of seeds in water followed by drying (Ashraf and Rauf, 2001). Roy and Srivastava (2000), proposed that the negative effect of salinity on seed germination can be reduced by seed priming. Generally, seed germination and seedling emergence are enhanced by hydropriming. Hydropriming permits the seeds to rapidly attain good moisture with a persistent oxygen supply, thus resulting in increase of germination process/metabolites which associated with energy production. Generally, hydropriming has been established as profitable and is currently being explored. Hydropriming brings about certain physiological modifications in organic compounds, sugar content, and cumulated ions within the seed, root, and lastly in the leaves of plant leading to high germination rate and great resistance to unpleasant conditions (Alvarado *et al.,* 1987).

Seed priming with NaCl and Na-acetate can be considered as a simple method for improving stress tolerance of crop plants. Among the crop plants, Wheat ((*Triticum aestivum*) is the most important cereal belongs to the family Poaceae. It is also known as king of cereals. It ranks first in terms of global consumption and production of food (Costa *et al.,* 2013). In Bangladesh, it occupies around 0.44 million ha of land and makes up 6% of the total cereal production with an average yield of 3.08 t ha^{-1} (BBS, 2017). Considering the facts we discussed, the present study was conducted with the following objectives:

Objectives of the research:

i. To assess the effect of halo-priming on growth and yield of wheat,
ii. To determine the effect of salt stress on seed germination and seedling growth of wheat, and
iii. To find out the effect of halo-priming on wheat under salt stress conditions.

CHAPTER II

REVIEW OF LITERATURE

2.1 Wheat

Wheat (*Triticum aestivum* L.) belongs to the Poaceae family is one of the predominant cereal crops in the world. It is the main sources of carbohydrate and contains a considerable amount of protein, minerals and vitamins. It is the most important food grain and ranks first in terms of global consumption and production. It also known as king of cereals (Costa *et al.,* 2013). Around the World, production of wheat is stands at nearly 2744 million tone's (FAO, 2021). According to Lobell and Gourdji (2012), globally wheat contributes approximately 30% of total cereal production. In Bangladesh, wheat is the second important cereal crop next to rice grown mainly in rabi season under various agro-ecological circumstances (Al-Musa *et al.,* 2012). The area under wheat cultivation during 2018–2019 was about 3, 30,348 ha producing 10, 16,811 tons of wheat which is 1.66 % lower than that of previous year (2017–18) (BBS, 2020). However, the average yield of wheat in Bangladesh is 3.078 t ha^{-1} which is very low compared to the average yield of Ireland, Netherlands, Belgium and United Kingdom of Great Britain and Northern Ireland (9.38, 9.37, 9.33 and 8.93 t ha^{-1}, respectively) (FAO, 2019). The lower wheat yield in our country comparing to other wheat producing countries due to the fact of growing wheat under rain -fed condition (Bazzaz, 2013). As an important food crop, wheat is staple food for more than 36% of the world's population, and it provides 20% of the calories and 55% of the carbohydrates globally (Hasanuzzaman *et al.,* 2017; Chattha *et al.,* 2017a). Moreover, wheat is also an important source of micro and macronutrients which are necessary for human health (Hassan *et al.,* 2019; Hassan *et al.,* 2021 ; Muhsin *et al.,* 2021). The economic importance of wheat and its contribution to the diets of humans and livestock cannot be disputed. Wheat is unrivaled in its range of cultivation, from 67°N in Scandinavia and Russia to 45°S in Argentina, including elevated regions in the tropics and subtropics (Feldman, 1995).

2.3 Abiotic stress

Abiotic stress is defined as the negative impact of non-living factor on the living organism in a specific environment. Abiotic stresses reduce plant growth, yield, and the marketable produce quality, with annually considerable economic losses as a consequence. Abiotic stress is the combination of many stress such as, drought, flooding, salinity, toxic metal/metalloid stress, high temperature, low temperature, UV-radiation, pollutants such as heavy metals or pesticides. Abiotic stress increase reactive oxygen species (ROS) in the cellular levels of plants which resulted oxidative stress. Abiotic and oxidative stresses not only retard plant growth and diminish yield in cases of crop plants, but also severe stress can trigger programmed cell death (PCD) (Gadjev *et al.,* 2008; Gechev and Hille, 2005; Petrov *et al.*, 2015). Abiotic stress is one of the major threat on crop production worldwide and the reduction of yield by abiotic stress around 50 per cent (Rodríguez *et al*., 2005; Acquaah, 2007). Plants are induced to adverse environmental conditions day by day due to continuously changing climatic conditions. Abiotic stress adversely affects plant's morphological, physiological and biochemical activity, ultimately causes a reduction in productivity (Hasanuzzaman *et al.,* 2017; Vishwakarma *et al.,* 2017; Lohani *et al.,* 2020). To ensure global food security, improving plant stress tolerance is a prerequisite. For improving plant stress tolerance understanding the response of plants towards abiotic stress is a vital point (Hasanuzzaman *et al.,* 2017). Directly or indirectly, crop productivity is related to the economy, which means abiotic stresses are potential threats to the economy (Singh *et al.,* 2015).

2.4 Salt stress

Salinity is defined as the presence of excessive amounts of soluble salts that affect the normal functions of plant growth. It is measured in terms of electrical conductivity (ECe), with the exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) and pH of a saturated soil paste extract. Therefore, saline soils are those that have saturated soil paste extracts with an ECe of more than 4 dSm^{-1}, ESP less than 15 %, and pH below 8.5 (Abrol, 1986). Among abiotic stresses, salinity is one of the brutal stresses, which adversely affects growth and yield characters of crop (Bakht *et al.,* 2012). Globally, more than 20% of soils are salt-affected and the extent of these soils is continuously increasing owing to anthropogenic activities and climate change. It reduces the productivity of about 6% of the land area. About 20% of the irrigated land area and 17% of the total arable area are already salt-affected. The alarming issue is up to 50% of agricultural land loss may occur due to salinity by the next couple of decades (Munns *et al.,* 2008; Ding e*t al.,* 2021). In soil solution, sodium chloride (NaCl) and sodium sulfate (Na_2SO_4) are the most commonly found soluble salts. Moreover, calcium sulfate ($CaSO_4$), magnesium sulfate ($MgSO_4$), potassium nitrate (KNO_3), sodium bicarbonate ($NaHCO_3$), etc. are also found in the soil solution and most of these are partially soluble in the solution. An increase in salinity in most of the cases refers to mainly an increase in Na^+ and Cl^- ions. Both Na^+ and Cl^- ions produce toxic conditions for the plant, but between them, Cl^- is more dangerous (Hasanuzzaman *et al.,* 2013; Choudhury *et al.,* 2013).

2.5 Effect of salinity on crop

Salinity is one of the most destructive agents for the plants among various abiotic stressors. A surplus of salt in the soil, water, or plant is known as salinity. In the agricultural industry, salinity is often an underappreciated issue. Salinity is a serious threat to agricultural productivity in arid and semi-arid area (Babu *et al.,* 2012). The problem of salinity is caused by both natural and artificial activity, and it is getting worse with time. By 2050, it is anticipated that 50% of cultivable land will be affected by salinity (FAO, 2009). Many main field crops, such as wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.) , cotton (*Gossypium hirsutum*), and sugarcane (*Saccharum officinarum*), are sensitive to salinity. Plant performance and grain yield, on the other hand, may not suffer until a 'threshold' salinity level is achieved. The highest quantity of salt that a plant can withstand in its root zone without affecting growth is known as the salinity threshold. High salt in the rhizosphere impacts plant physiology, affecting germination rate, growth phases, and ultimately plant yield (Munns *et al.*, 2008).

Salts increase soil osmotic potential as a result crop physiology is disturbed at cellular and plant level initially (Shahid *et al.,* 2011), later on plant growth is suffered by toxic effct (Collado *et al.,* 2016). Poor emergence and reduced crop stand establishment are the main constraints in getting good yield, under high osmotic stress condition (Nawaz *et al.,* 2013). Wheat crop yield starts to decline at a salinity stress level of 6–8 dS m^{-1} (Royo and Abio, 2003). According to Food and Agriculture Organization (FAO, 2019), 397 million hectares under wheat cultivation are severely affected by salinity stress, which is imposing a serious threat to food security.

The productivity of wheat crops is negatively affected by salinity stress (Al-Ashkar *et al.,* 2019 ; Al-Ashkar *et al.,* 2020). Salinity stress causes ion toxicity and nutritional imbalance in plants, which disrupts the plant physiological processes, and consequently cause a serious reduction in final yield (Hajihashemi *et al.,* 2009; Huang *et al.,* 2010; Taha *et al.,* 2021). Initially, salinity stress causes a significant reduction in seed germination, and later it alters growth and reproductive behavior causing serious yield losses (Hussain *et al.,* 2021; Hafez *et al.,* 2015; Seleiman *et al.,* 2018). Moreover, salt stress disturbs the enzymatic activities, photosynthesis, membrane structure, hormonal balance, water, and nutrient uptake, and induces oxidative stress (Taha *et al.,* 2021; Ibrahimova *et al.,* 2021; Seleiman *et al.,* 2021a).

2.5.1 Effect of salinity on wheat (Triticum aestivum L.)

Wheat is consumed by over 36% of the world's population as a staple food, providing carbs (55%) and 20% of dietary calories (20%), as well as protein content (13%) that is higher than other cereal crops globally (Hasanuzzaman *et al.,* 2017). Salinity has a significant impact on wheat productivity. Salinity susceptibility in wheat begins at 6 dS m^{-1}. Water potential in soil decreases as salinity rises, and Na^+ concentration in plant tissues rises, putting the wheat plant under osmotic and ionic stress. Salinity stress has a passive effect on the wheat plant's agronomic, physiological, and chemical features. When the salinity level in the wheat plant exceeds the threshold level, the germination rate, net photosynthesis rate, transpiration rate, and yield decrease, and the Na^+ and Cl levels in the wheat plant rise, disrupting the plant's normal metabolism (Hasanuzzaman *et al.,* 2017).

Guo *et al.* (2015) discovered that wheat growth was reduced under salt stress compared to normal conditions. Zou *et al.* (2016) noticed a reduction in root and shoot lengths as well as their dry weight of wheat under salt stress condition. Asgari *et al.* (2012) looked into the loss in wheat growth parameters, which led to a decrease in wheat yield. Salt stress affects the quantity of spikelets, productive tillers, grain weight, and biomass production, among other yield parameters. Plant seedlings are extremely susceptible to stress, and salt stress can cause seedling death (Saddiq *et al.,* 2019). Wheat seedlings similarly slow down their growth when exposed to salinity stress for a few days (7–10 days) at a salt concentration of 100 mM NaCl. Similarly, with increased salinity stress, yield components such as number of spikes per plant, spike length, and number of spikelets per spike, above ground biomass, 1000-grain yield, harvest index, and grain yield per plant dropped (Asgari *et al.,* 2012). Wheat grain production decreases at a rate of 7.1 % with rising salinity per dS m^{-1} when the wheat plant crosses the salinity threshold (6 dS m^{-1}), and considerable yield decline occurs at 15 dS m^{-1} (Afzal *et al.*, 2013).

2.6 Seed Priming

Seed priming is a pre-sowing preparation that partially hydrates seeds while preventing them from emerging (Chen and Arora, 2011). Seed priming is a technique in which seeds are exposed to low water potential, which reduce the hydration of seed. Seed priming could play an important role in rapid germination and emergences, which is essential for successful crop establishment. Seed priming is a technique which controls the hydration level of seed and also controls the metabolic activity within the seed which is necessary for seed germination (Atalou, 2014). Better stand establishment and optimum plant populations are a major challenge for successful crop production (Chivasa *et al.,* 1998; Fanadzo *et al.,* 2010; Rehman *et al.,* 2011a). Seed priming is mainly used to increase germination and uniformity of different crops under non-supporting conditions. Mostly priming is used to get uniform and healthy crop stand and it increase the vigour of seed (Draganic and Lekic, 2012). During priming treatments seed absorbed the water which is sufficient for hydration and necessary for metabolic activities inside the seed. Primed seeds were complete their germination processes early as compared to non-primed seeds (Dezfuli *et al.*, 2008). Harris (1996), demonstrated that simply soaking seeds in plain water before sowing could increase the speed and homogeneity of germination and emergence, leading to better crop stands, and stimulated seedlings to grow much more vigorously. Seed priming protects the disease attack by apply the coating of fungicides, bactericides and nematicides. Seed priming is used to increase the germination percentage and seed vigor (Nawaz *et al.*, 2013). Seed priming that induces earlier emergence and uniform crop stands is usually associated with higher growth rates, dry matter, yield and quality under biotic and abiotic stresses. Seed priming increased yield by a similar percentage under stressed and non-stressed conditions (Xu and Qiu., 2007).

2.6.1 Hydro-Priming

In a range of crops, hydro-priming is an important strategy for improving seed germination, seed growth, and stand uniformity (Adebisi *et al.*, 2013). In an experiment to assess the effects of priming on okra seeds. Sikhondze and Ossom (2011), discovered that hydro-priming was helpful to seedling growth. In salt-affected soil, halo-priming has been shown to boost seed germination, seedling emergence, stand establishment, and final crop production in various experiments (Khan *et al.*, 2009). According to Kaur *et al.,* (2015), hydro-priming enhances a number of okra agronomic features, such as the number of days it takes to attain 50% flowering, seedling growth, fruit length and weight, total yield per plant, and so on. Bitter gourd seed germination, seedling growth, and yield are all improved by hydro-priming (Tania *et al.,* 2019). Wheat quality parameters increased when both hydro and halo priming were used (Singh *et al.*, 2017). The simplest form of seed priming is hydro-priming, which involves soaking seeds in pure water and re-drying them to their original moisture content before sowing. It is critical to dry the seeds after soaking them, as improperly dried seeds will cause more harm than good when stored (Thomas *et al.,* 2000). After soaking, the seeds were forced-dried to their original weight in the shade (Bennett and Waters, 1987). The advantage of hydro-priming is that it enhances physiological and biochemical events in seeds even when germination is halted due to low osmotic potential and insignificant matric potential of the absorbing media (Basra *et al.*, 2003). Furthermore, hydro-primed seed protoplasm is discovered to have a reduced viscosity, better permeability to water and nutrients, and the ability to hold water against dehydrating effects (Thomas *et al.,* 2000). In the case of hydro-priming, the major feature is an increase in seedling development connected with higher water intake by primed seeds (Yagmur and Kaydan, 2008). This method is low-cost and environmentally friendly because it does not need any additional chemical compounds as a priming agent. This is due to the fact that seeds have free access to water during hydro-priming, hence the rate of water uptake is solely determined by seed tissue affinity for water (Taylor *et al.,* 1998). Hydro-priming (Farooq *et al.,* 2009b), a simple hydration technique to a point of pre-germination metabolisms without actual germination, is one of the most pragmatic, simple, cost-effective, and short-term approaches to combating the effects of drought (Kaya *et al.*, 2006) and other abiotic stresses (Jafar *et al.*, 2012) on seedling emergence and crop establishment. Due to a reduction in the lag time of imbibitions that would otherwise take a long time (Brocklehurst and Dearman., 2008) and the build-up of germination boosting metabolites, hydro primed seeds usually have early, higher, and synchronized germination (Farooq *et al.,* 2006). Hydro-priming has been shown to improve seed germination and seedling growth in a variety of crop plants, including chickpea, maize, rice, mung bean, and capsicum, under both ideal and stress circumstances (Rehman *et al.,* 2014; Ghassemi *et al.,* 2010).

2.6.2 Halo-priming

Halo-priming is a method of pre-sowing seed soaking in salt solutions that improves germination and seedling emergence equally in both adverse and normal environmental conditions. The following salts are used: NaCl, KCl, $KN0_3$, and $CaCl_2$. The effects of NaCl priming with KNO_3 on the germination properties and seedling growth of four *Helianthus annuus* L. cultivars in salinity conditions were evaluated, and it was shown that primed seeds germination percentage was higher than un-primed seeds. (Bajehbaj, 2010). Halo-priming is one of those pre sowing seed treatment techniques which enhance germination and stand establishment. Seed priming is one of the simplest and low-cost strategies to induce salinity tolerance in crops (Afzal *et al.,* 2012). Halo-priming refers to soaking of seeds in solution of inorganic salts i.e., NaCl, KNO_3, $CaCl_2$ and $CaSO_4$ etc. Priming with NaCl and KCl was helpful in removing the deleterious effects of salts (Iqbal *et al.,* 2006). In sorghum seeds soaked in $CaCl_2$ or KNO_3 solution increased the activity of total amylase and proteases in germinating seeds under salt stress (Kadiri and Hussaini, 1999). Halo-priming causes seeds to have a physiological reaction that affects on plant stress memory, causing plants to respond swiftly and aggressively to abiotic stress (Jisha *et al.*, 2013). Plant stress memory is preserved after seed halo-priming and osmotic stress exposure (Qin *et al.,* 2017). As a result, mild pretreatment stress can increase tolerance to future shocks (Llorens *et al.*, 2020). As a result, seed halo-priming improves plant tolerance to harsh environmental circumstances while also increasing grain output (Patade *et al.*, 2009). Among organic acids, exogenous application of acetate improves drought stress tolerance in Arabidopsis, wheat, and maize by modulating JA signaling pathway and histone acetylation (Kim *et al.,* 2017). Both JA signaling and histone acetylation are also required for salt tolerance (Ismail *et al.,* 2012; Sako *et al.,* 2015).

2.7 Priming Induced Stress Tolerance

Seed priming has been shown to be a successful approach of instilling stress tolerance in plants. Seed priming is the process of inducing a specific physiological condition in plants by applying natural and synthetic substances to seeds prior to germination. The primed state of the plant refers to the physiological state in which plants are able to activate defense responses more quickly or more effectively, or both (Beckers and Conrath, 2007). Priming, particularly seed priming, has emerged as a promising method in modern stress (biotic and abiotic) management in recent years, as it protects plants from infections and abiotic stresses while having little impact on fitness (Van Hulten *et al.*, 2006). Seed priming is a potential approach for preventing and reducing the negative impacts of abiotic stressors on crops (Lal *et al.*, 2018). In terms of physiological status, young seedlings grown from primed seeds are developmentally advanced (Andreas *et al.*, 2016). When exposed to a stressful environment, seed priming encourages the production of dormant signaling molecules or transcription factors, which activate defense mechanisms (Bruce *et al.*, 2007). Under optimum and suboptimal conditions, such as rising temperatures, dryness, and salinity, seed priming improves crop development and production (Kaya *et al.*, 2006; Rehman *et al.*, 2012; Farooq *et al.*, 2013). Although priming at seed stage is the common practice and most reported, plants are also primed at seedling stage. For priming the seeds, seeds are partially hydrated until the germination process begins, but radical emergence does not occur (Bradford, 1986). Information on the application of priming in the field is limited (Capanoglu, 2010).

2.8 Sodium Chloride and Sodium Acetate-induced stress tolerance

High concentration of NaCl reduced the seed germination in wheat cultivars (Akbari *et al.*, 2007). Khan *et al.* (2009) observed that priming of seeds using NaCl improved seedling vigour and establishment under salt stress conditions. Seed priming improves seed performance by encouraging rapid, uniform, and vigorous germination which helps seedlings to grow in stressed conditions (Cantliffe , 2003; Ashraf and Foolad, 2005; Carbineau and Come, 2006). Similarly, Jafar *et al.* (2012) demonstrated that seed priming could be used successfully to assist the germination of wheat in the field.

Acetate, a low-cost chemical, was reported to enhance abiotic stress tolerance in plants by detoxifying ROS (Kim *et al.*, 2017; Utsumi *et al.*, 2019). Hossain *et al.* (2019) reported that Na-acetate enhance salt stress tolerance by improving antioxidant defense system and nutrient homeostasis. On the other hand, seed priming is one of the most pragmatic and short-term approaches to combat the effects of environmental stresses on seedling emergence and stand establishment (Jafar *et al.*, 2012).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description of the crop, experimental design, treatments, and cultural operations, collection of soil and plant samples and analytical methods followed in the experiment.

3.1 Experimental details

3.1.1 Study area

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the mitigation of salt stress in wheat by Halo-priming.

3.1.2 Experimental period

The experiment was conducted during the rabi season (from November to February) 2020-2021.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the Agronomy net house of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

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

3.2.3 Soil

The soil for filling the pot was collected from agronomic field belongs to the general soil type, shallow red brown terrace soils under tejgaon soil series. Soil pH ranges from

5.4–5.6 (Anon., 1989). The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in below table.

Table 1. The initial physical and chemical characteristics of soil used in this experiment

Physical characteristics	
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix- I.

3.3 Experimental material

3.3.1 Plant material

BARI Gom 33 was used as the plant material for conducting the experiment. The important characteristics of these varieties are mentioned below:

Released: 2017

Developed: Bangladesh Agriculture Research Institute (BARI).

Height: 100-105 cm

Specification: Blast-Resistant and Zinc (Zn) enriched (40-45 ppm)

P^H : 5.5-6

Seed: Creamy gray in color and medium in size

1000 Seed weight : 45-52g

Yield: 4.5-5.5 t ha^{-1}

3.3.2 Earthen pot

Earthen pots of having 12 inches diameter, 12 inches height with a hole at the centre of the bottom were used.

3.4 Experimental treatments

There were two factors in the experiment namely different salt stress as influenced by Halo-priming

Factor A: Priming level (4) *viz;*

1. P_0 = No Priming (C_0)
2. P_1= Hydro-priming
3. P_2= Priming with 5 mM NaCl
4. $P_{3=}$ Priming with 5 mM Sodium Acetate

Factor B: Salt level (3) : *viz;*

1. S_0 = 0 dS m^{-1}
2. S_1 = 4 dS m^{-1}
3. S_2 = 8 dS m^{-1}

3.5 Experimental design

The experiment was laid out in Randomized Completely Random Design (RCBD) with 2 factors. Total 60 pots were prepared for the experiment with 12 treatments having 5 replications.

3.6 Detail of experimental preparation

3.6.1 Seed collection

Seeds of BARI Gom-33 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.6.2 Soil preparation for pot

To prepare well pulverized and healthy soil for the experiment, soil was collected and then sun-dried and crushed. After that recommended basal dose of fertilizers were incorporated with the prepared soil. Each pot was filled up with around 12 kg well pulverized soil containing organic manures and fertilizers.

3.6.3 Fertilizer application

Fertilizer and manure dose for BARI Gom-33 as follows:

Fertilizers	Dose (kg ha^{-1})
Cowdung	5000
Urea	150-175
Triple superphosphate	135-150
Murate of potash	100-110
Gypsum	100-125

All fertilizers and manures were incorporated during final soil preparation.

3.7 Salinity treatment

The salinity treatments were applied before seed sowing. There were three salinity levels including control which was developed by adding respected amount of commercial NaCl salt to the pot as water dissolved solution. The level of salinity was measured by electrical conductivity (EC) meter by measuring EC of soil. The salinity levels were 0, 4 and 8 dS m^{-1} salinity. Around 8 and 16 g NaCl were added in each pot to develop 4 and 8 dS m^{-1} of EC.

3.8 Seed treatment

Wheat seed were treated as per treatments with distilled water, 5 mM NaCl and 5mM Na-acetate for 6 hours followed by washing several times with distilled water and dried for one hour in shed before sowing.

3.9 Seed sowing technique

Before seed sowing soil in the pot was irrigated with sufficient water to achieve the field capacity of soil for seed sowing. After that, fifty healthy seeds were sown at 5 cm depth in each pot on 30th November. All germinated seedling were kept for observation.

3.10 Intercultural operations

Weeding, mulching and irrigation

The pots were kept weed free by regular observation and hand weeding. Mulching and irrigation were done as per requirement.

3.11 General observations of the experimental pot

Regular observations were made to see the growth and visual difference of the crops. Incidence of Hairy caterpillar, ants were observed during vegetative growth stage and there were also some mites and nematodes were present in the experimental pot. But any bacterial and fungal disease was not observed. The flowering was mostly uniform.

3.12 Plant protection

Sumithion@57 EC was applied twice at 7 days interval (25 DAS and 33 DAS) to protect the plants from Hairy caterpillar. Furadan@5G was mixed with the soil to protect the plants from insects, mites and nematodes.

3.13 Harvesting

The wheat plants were uprooted carefully without disturbing the roots on March 27, 2020.

3.14 Collection of data

The yield and yield contributing parameters were measured at harvest. Growth, and physiological parameters were recorded during treatment. Data were collected on the following parameters:

Crop growth parameters:

i. Percentage of germination
ii. Vigor index
iii. Plant height
iv. Number of leaves plant^{-1}

Physiological parameters:

v. SPAD value of leaf
vi. Leaf relative water content (LRWC)

Yield and yield contributing parameters:

vii. spikelet length
viii. Spikelets plant^{-1}

ix. Grains spike^{-1}
x. Effective tiller pot^{-1}
xi. 1000-grain weight
xii. Grain yield
xiii. Straw yield
xiv. Biological yield
xv. Harvest index

3.15 Procedure of recording data

i. Percentage of germination

The number of germinated seeds was counted every day. Germination was recorded at 24 hrs interval and continued up to 10th days. More than 2 mm long plumule and radicle was considered as germinated seed.

The germination rate was calculated by using following formula of Othman *et al*. (2006).

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

ii. Vigor index

Vigor index was calculated by using following formula of (Abdul-Baki and Anderson, 1970).

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

iii. Plant height

The height of five selected plant was measured from the ground level to the tip of the plant at 30, 50 and 70 DAS. Mean plant height of wheat plant were calculated and expressed in cm.

iv. Number of leaves plant^{-1}

After the completion of the treatment duration, number of leaves plant^{-1} of five plants were counted and then averaged to determine the number of leaves plant^{-1}

v. SPAD value

After completion of the treatment duration, five leaves were randomly selected from each pot. The top, middle and bottom of each leaflet was measured with at LEAF (FT

Green LLC, USA) as at LEAF value. Then, the values were then averaged, total chlorophyll content was determined by the conversion of at LEAF value into SPAD units.

vi. Leaf relative water content (LRWC)

Three leaflets were randomly selected from each pot and cut with scissors. Leaf relative water content (RWC) was measured according to Barrs and Weatherley (1962). Leaf relative water content was measured at 45 DAT and 70 DAT. Leaf laminas were weighed (fresh weight, FW) and then immediately floated on distilled water in a petridish for 24 h in the dark. Turgid weights (TW) were obtained after drying excess surface water with paper towels. Dry weights (DW) were measured after drying at 80^0C for 48 h. Then calculation was done using the following formula:

$$\text{LRWC (\%)} = \frac{\text{FW- DW}}{\text{TW-DW}} \times 100$$

vii. Spikelet length

Spikelet length of five plants were counted and then averaged to determine the spikelet length of the pot and expressed in cm.

viii. Spikelets plant^{-1}

Number of spikelets plant^{-1} of five plants counted and then averaged to determine the spikelets^{-1} plant of the pot.

ix. Grains spike^{-1}

Number of grains spike^{-1} of five plants counted and then averaged to determine the grain spike^{-1} of the pot.

x. Effective tiller pot^{-1}

Number of effective tiller pot^{-1} was counted from the individual pot and then the average tiller number was calculated.

xi. 1000-grain weight

1000-grain were counted which were taken from the seed stock of each replication, then weighed it in an electrical balance and data were recorded in g.

xii. Grain yield

The mean seed weight was taken by threshing the plants of each sample and then weighed it in an electrical balance and data were recorded on dry weight basis and expressed in g.

xiii. **Straw yield**

The straw weights of wheat were calculated after threshing and separation of the seeds from the plant of sample and then weighed it in an electrical balance and data were recorded on dry weight basis and expressed in gram.

xiv. Biological yield pot^{-1}

The summation of grain yield and above ground straw yield was the biological yield that expressed in g.

Biological yield = (Grain yield + Stover yield).

xv. Harvest index

Harvest index was calculated on dry weight basis with the help of following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield = Grain yield + Stover yield

3.16 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

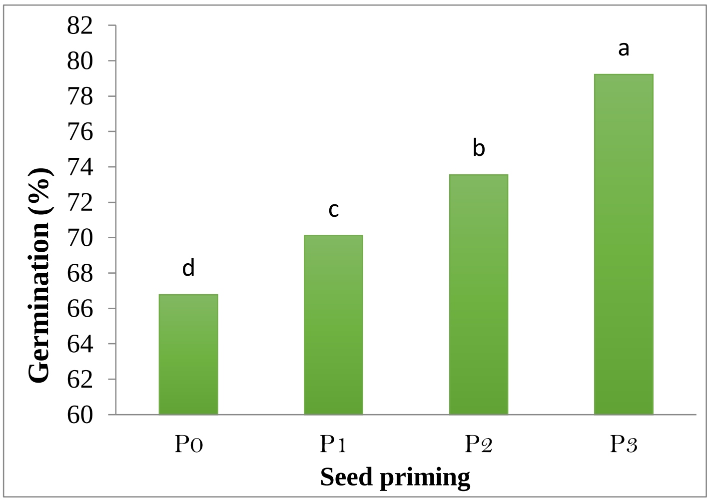
Results obtained from the study have been presented and discussed in this chapter with a view to amelioration of salt stress in wheat by different types of priming. The results of the germination and growth parameters of wheat as influenced by different concentrations of priming agent in salt stress condition have been presented and discussed in this chapter.

4.1 Effect of priming, salinity level and their interactions on growth attributes of wheat

4.1.1 Percentage of germination

4.1.1.1 Effect on priming

Halo-priming significantly influenced germination percentage of wheat (Figure 1). Results revealed that, the highest germination percentage (79%) was recorded from seeds pre-treated with 5mM Na-Acetate. The lowest germination percentage (67%) was found from control (No priming) treatment followed by priming with 5 mM NaCl (73.55%) and Hydro-priming (70.11%). Elkoca (2014) studied that, osmo-priming treatments increase germination percentage of pea. Anoshah and Hashemi (2020), reported that different types of seed priming have positive effects on germination, emergence, growth, yield as well as biochemical traits and quality of plants under saline and non-saline conditions.

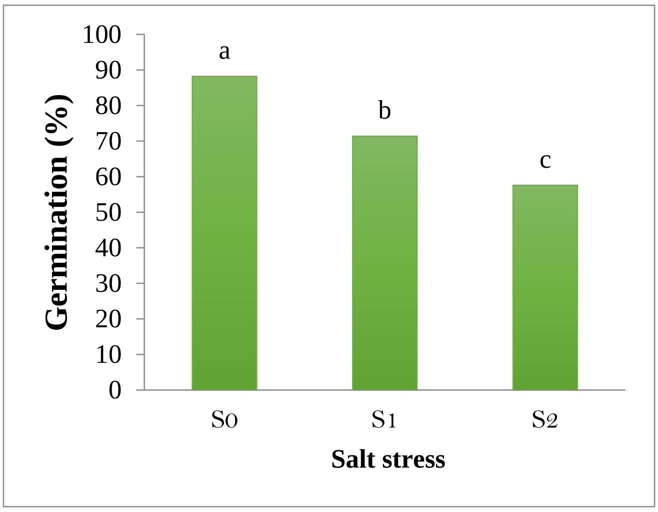


P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 1. Effect of different priming on germination percentages of wheat [$LSD_{(0.05)}$ = 1.23].

4.1.1.2 Effect on salinity

Exposure of salinity significantly influenced germination percentage of wheat (Figure 2). The percentage of germination decreased with increasing the salinity level. Exposure of 4 and 8 ds m^{-1} salinity decreased germination percentage by 19 and 34%, respectively, compared with control. Munns (2002), also examined that salinity affects seed germination process through osmotic stress, ion-specific effects and oxidative stress, shown by decreasing germination rate.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 2. Effect of different salinity level on germination percentages of wheat [$LSD_{(0.05)}$ = 1.06].

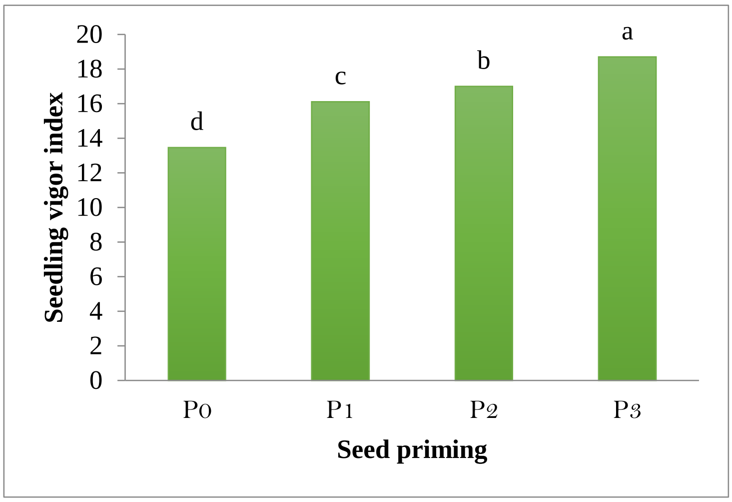
4.1.1.3 Combined effect of seed priming and salinity

The germination percentage of wheat significantly influenced by combined effect of seed priming and salinity (Table 1). Under 4 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased germination percentage of wheat by 6, 10 and 19%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased germination percentage of wheat by 7, 17 and 33%, respectively, compared with salt stress alone.

4.1.2 Seedling vigor index

4.1.2.1 Effect of Priming

Significant influence was found on seedling vigour index due to different seed priming treatments (Figure 3). The highest seedling vigour index (18.70) was recorded for seed priming with 5 mM Na-Acetate, where the lowest vigor index (14.11) was recorded from no priming.

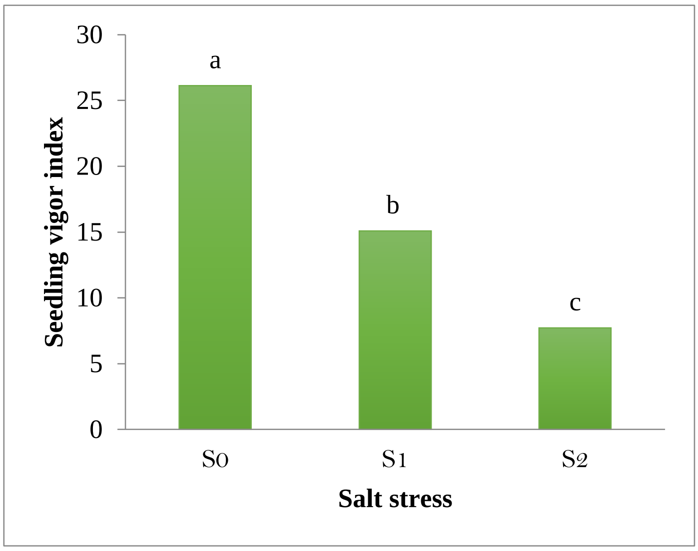


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 3. Effect of different priming on seedling vigor index of wheat [$LSD_{(0.05)}$ = 0.40].

4.1.2.2 Effect of saltinity

The significant variation was observed on seedling vigor for exposure of different levels of salinity (Figure 4). Results revealed that seedling vigor decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased germination percentage by 42 and 70%, respectively, compared with control.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 4. Effect of different salinity level on seedling vigor index of wheat [$LSD_{(0.05)}$ = 0.30].

4.1.2.3 Combined effect of seed priming and salinity

The seedling vigor of wheat was significantly influenced by combined effect of seed priming and salinity (Table 2). Under 4 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased seedling vigor index of wheat by 16, 16 and 31%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increase seedling vigor index percentage of wheat by 40, 58 and 96%, respectively, compared with salt stress alone.

Table 2. Combined effect of salt stress and different priming on germination and seedling vigor index of wheat

Treatment combinations	Germination (%)	Seedling vigor index
P_0S_0	84.33 d	22.20 d
P_1S_0	87.00 c	25.80 c
P_2S_0	89.33 b	27.60 b
P_3S_0	92.33 a	28.90 a
P_0S_1	65.66 h	13.00 g
P_1S_1	69.33 g	15.20 f
P_2S_1	72.33 f	15.20 f
P_3S_1	78.33 e	17.00 e
P_0S_2	50.33 k	5.20 k
P_1S_2	54.00 j	7.33 j
P_2S_2	59.00 i	8.20 i
P_3S_2	67.00 h	10.20 h
$LSD_{(0.05)}$	2.13	0.68
CV (%)	2.32	3.37

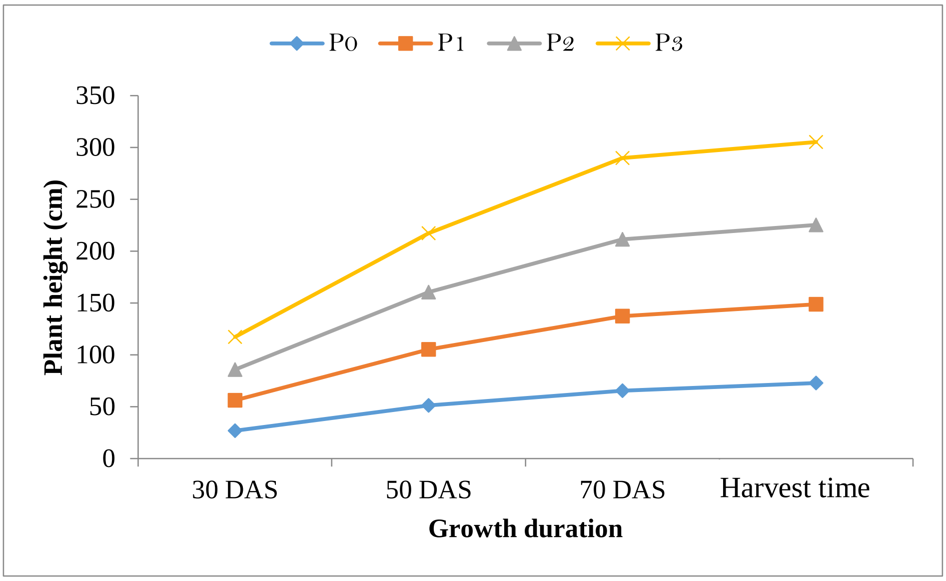
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}.

4.1.2 Plant height

4.1.3.1 Effect of different priming

Plant height of wheat was significantly influenced by seed priming throughout entire growth period (Figure 5). Experimental result revealed that the tallest plant at 30, 50, 70 DAS and at harvest (31.41, 56.87, 78.32 and 80.84 cm, respectively) were recorded when seed primed with 5 mM Na-acetate compared to control treatment. Whereas the shortest plant at 30, 50, 70 DAS and at harvest, (26.78, 51.18, 65.52 and 76.99 cm, respectively) were recorded in control treatment. The variation of plant height was due to the various effect of different seed priming that increased plant growth considerably by growth promoting substances which stimulates growth. It has also been reported that seed priming improves emergence, stand establishment, tillering, and straw yields increase in plant height, number of leaves and leaf area as compared to non-treated control (Farooq *et al.*, 2008).

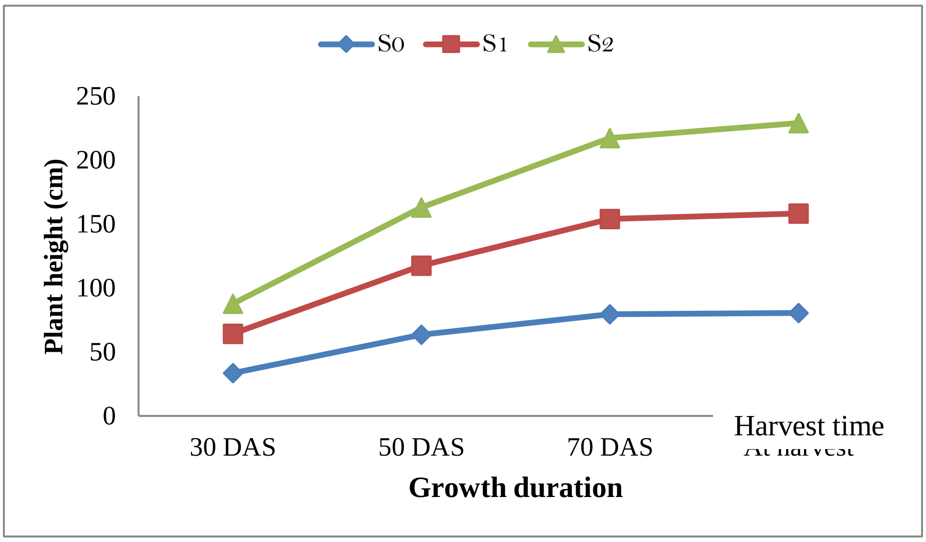


P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 5. Effect of different priming on plant height of Wheat [$LSD_{(0.05)}$ = 0.78, 1.35, 1.96 and 1.16 at 30, 50, 70 DAS and at harvest, respectively].

4.1.3.2 Effect of salinity

Plant height is an important morphological character that acts as a potential indicator of plant growth. Plant height was recorded at 30, 50, 70 DAS and at harvest. Different levels of salinity significantly influence plant height of wheat throughout the growth period (Figure 6). From the present experiment it is found that, the highest plant height at 30, 50, 70 DAS and at harvest (33.62, 63.43, 79.47 and 80.96 cm, respectively) were recorded in S_0 (Control) treatment. The plant height decreased with increasing the salinity level and lowest plant height at 30, 50, 70 DAS and at harvest (23.66, 45.34, 63.31 and 75.82 cm, respectively) were recorded in S_2 (8 dS m^{-1} pot^{-1}) treatment which was lower compared to control treatment. Gradual decrease in plant height might be due to the nutrient unavailability caused by increased salinity or the inhibition of cell division or cell enlargement. The result obtained from the present study was similar with the findings of (El-Eswai *et al.*, 2018) and they reported that salinity adversely affects plant growth.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 6. Effect of different salinity level on plant height of Wheat [$LSD_{(0.05)}$ = 0.68, 1.71, 1.70 and 1.00 at 30, 50, 70 DAS and at harvest, respectively] .

4.1.3.3 Combined effect of salt stress and priming

Combined effect of salt stress and seed priming had significant influenced on plant height of wheat at different days after sowing (Table 3). Under 4 dS m^{-1} salinity, priming with 5 mM Na-acetate upgraded plant height of wheat 6%, at harvest compared with salt stress alone. hydropriming and and priming with 5 mM NaCl had no impact on plant height at harvest. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate showed statistically similar results on plant height.

Table 3. Combined effect of salt stress and different priming on plant height of wheat

Treatment combinations	Plant height (cm)			
	30 DAS	50 DAS	70 DAS	At harvest
P_0S_0	32.55 b	60.58 c	70.01 d	79.15 cd
P_1S_0	32.99 b	61.45 c	80.36 b	79.99 bc
P_2S_0	33.37 b	64.14 b	81.52 b	80.58 bc
P_3S_0	35.56 a	67.50 a	85.99 a	84.12 a
P_0S_1	30.26 c	52.86 d	68.29 de	77.06 ef
P_1S_1	30.78 c	54.45 d	73.64 c	77.76 de
P_2S_1	30.57 c	54.45 d	76.09 c	79.17 cd
P_3S_1	30.84 c	55.01 d	80.34 b	81.84 b
P_0S_2	17.52 f	40.09 f	58.26 f	74.75 g
P_1S_2	24.49 e	46.36 e	61.37 f	75.17 fg
P_2S_2	24.78 e	46.81 e	64.97 e	76.79 ef
P_3S_2	27.84 d	48.10 e	68.62 d	76.55 e-g
$LSD_{(0.05)}$	1.35	2.35	3.40	2.02
CV (%)	3.63	3.40	3.69	2.01

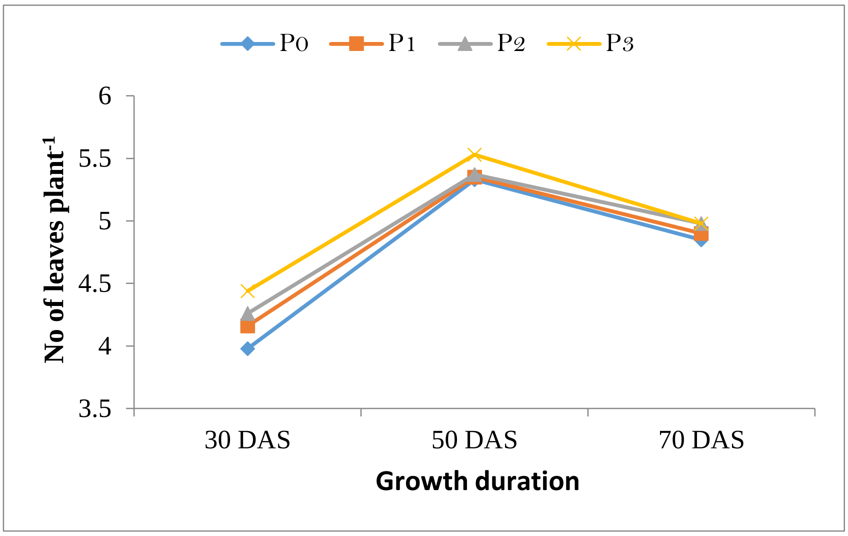
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

4.1.4. Number of leaves plant^{-1}

4.1.4.1 Effect of priming

Priming of seed significantly influenced number of leaves plant^{-1} of wheat at 50 DAS (Figure 8). Experimental result revealed that the highest number of leaves plant^{-1} of wheat (5.53) was recorded in P_3 (5 mM Na-acetate) treatment which was higher over control and others treatment. Whereas the lowest number of leaves plant^{-1} of wheat (3.98) at 30 DAS was recorded in control treatment (P_0). Primed-induced available nutrients might be play role in enhancing the number of leaves and leaf area and improved growth of wheat. Pirasteh-Anosheh *et al.*, (2014) reported that cycocel priming reduced adverse effects of the stress on seedling emergence and vegetative growth and improved the level of leaf free proline and chlorophyll content index in wheat, barley, maize, sunflower, safflower, and rapeseed.



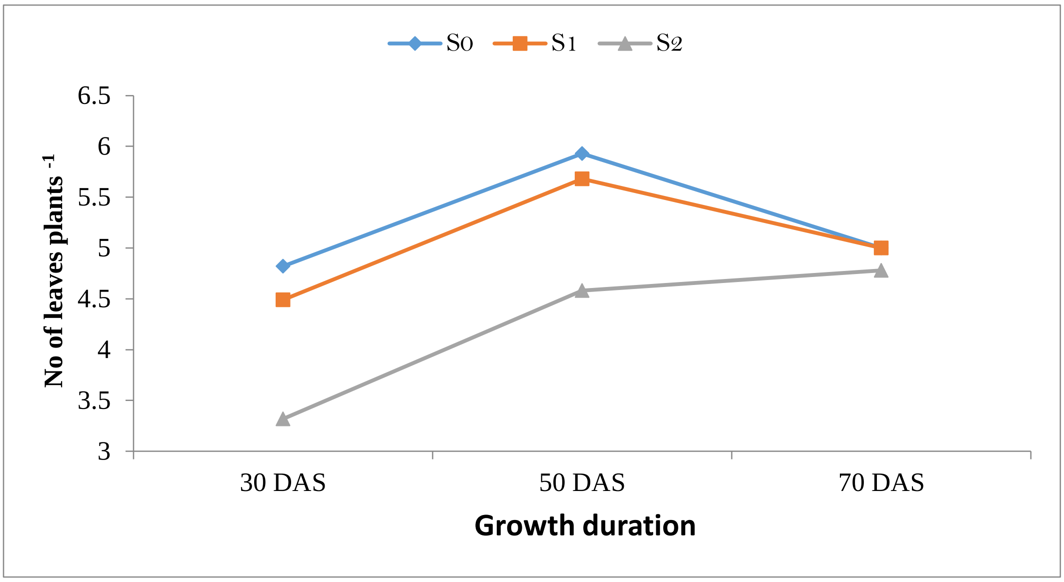
P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate.

Figure 7. Effect of different priming on number of leaves plant^{-1} of wheat [$LSD_{(0.05)}$ = 0.02, 0.05 and 0.04 at 30, 50 and 70 DAS, respectively] .

4.1.4.2 Effect of salinity

A leaf is the principal lateral appendage of the vascular plant stem, usually borne above ground and specialized for photosynthesis Tozer *et al*., (2015). In this experiment number of leaves plant^{-1} of wheat was varied with different salinity conditions at 30

DAS (Figure 7). Experimental result showed that the highest number of leaves plant^{-1} of wheat (5.93) at 50 DAS was recorded in S_0 (Control) treatment. With the increasing salinity levels the number of leaves plant^{-1} of wheat drastically reduced. So the minimum number of leaves plant^{-1} of wheat (3.32) at 30 DAS was recorded in S_2 (8 dS m^{-1}pot^{-1}) treatment which was lower comparable to control treatment. Extreme salt stress causes chlorosis, necrosis and premature senescence of adult leaves and thus limits the photosynthetic area of salt-affected plants. Hamayun *et al.*, (2017) reported that shoot length, leaf number, leaf area and transpiration rate decreased under 70 and 140 mM NaCl-induced salt stress, compared to control.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 8. Effect of different salinity level on number of leaves plant^{-1} of wheat [LSD$_{(0.05)}$ = 0.05, 0.04 and 0.03 at 30, 50 and 70 DAS, respectively].

4.3.4.3 Combined effect of salt stress and priming on leaves number plant^{-1}

Combination of salt stress and seed priming significantly affected number of leaves per plant of wheat at different days after sowing (Table 4). Under 4 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate produced similar number of leaves per plant compared to salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate enhanced the leaves number plant^{-1} of wheat by 3, 8 and 8%, respectively, at 70 DAS compared with salt stress alone.

Table 4. Combined effect of salt stress and priming on no. of leaves plant^{-1} of wheat

Treatment combinations	No. of leaves plant^{-1}		
	30 DAS	50 DAS	70 DAS
P_0S_0	4.80 a	5.92 a	5.00 a
P_1S_0	4.80 a	5.92 a	5.00 a
P_2S_0	4.84 a	5.96 a	5.00 a
P_3S_0	4.84 a	5.92 a	5.00 a
P_0S_1	4.48 bc	5.68 b	5.00 a
P_1S_1	4.48 bc	5.68 b	5.00 a
P_2S_1	4.44 c	5.68 b	5.00 a
P_3S_1	4.56 b	5.68 b	5.00 a
P_0S_2	2.65 g	4.40 d	4.56 c
P_1S_2	3.20 f	4.44 d	4.70 b
P_2S_2	3.49 e	4.48 d	4.93 a
P_3S_2	3.92 d	4.99 c	4.93 a
$LSD_{(0.05)}$	0.10	0.10	0.08
CV (%)	1.93	1.51	1.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

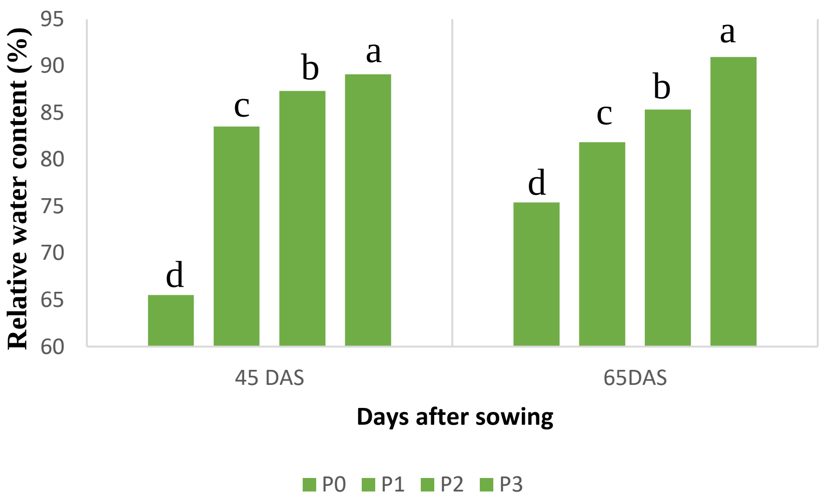
P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

4.2 Physiological parameters

4.2.1 Leaf relative water content (LRWC)

4.2.1.1 Effect of priming

Priming of seed with different priming agents influenced leaf relative water content of wheat at 45 and 65 DAS (Figure 9). The present study revealed that the highest leaf relative water content at 45 and 65 DAS (89.09 and 90.94 %, respectively) were recorded in P_3 (5 mM Na-acetate) treatment which was 36 and 21% higher comparable to control treatment. The present study was similar with the findings of Naghashzadeh (2014), who reported that relative water content and cell membrane stability in inoculated plant were higher than non-inoculated plant.

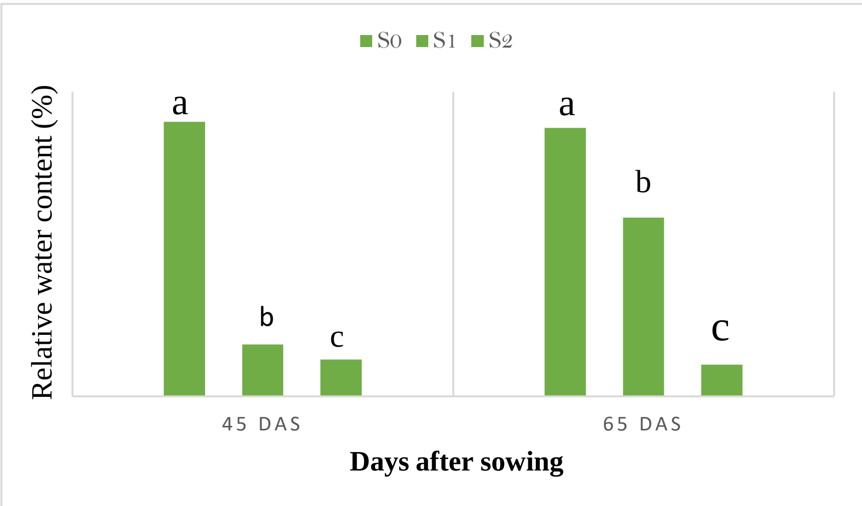


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 9. Effect of different priming on relative water content of wheat [$LSD_{(0.05)}$ = 0.78 and 1.16 at 45 and 65 DAS, respectively] .

4.2.1.2 **Effect of salinity**

Relative water content is described as the amount of water in a leaf at the time of sampling relative to the maximal water a leaf can hold. It is an important parameter in water relation studies, e.g. it allows the calculation of the osmotic potential at full turgor (Tanentzap *et al.*, 2015). In this experiment, exposure of salt significantly influenced leaf relative water content of wheat at 45 and 65 DAS (Figure 10). The highest leaf relative water content (89.42 and 89.09 %) at 45 and 65 DAS were recorded in control (S_0) treatment which was gradually decreasing with increasing salt concentration. The lowest leaf relative water content at 45 and 65 DAS (76.94 and 76.66 %) were recorded in S_2 (8 dS $m^{-1)}$ treatment. Romero-Aranda *et al.*, (2006) reported that increase of salt in the root medium can lead to a decrease in leaf water potential and, hence, may affect many plant processes. Osmotic effects of salt on plants are the result of lowering of the soil water potential due to increase in solute concentration in the root zone. At very low soil water potentials, this condition interferes with plants ability to extract water from the soil and maintain turgor. However, at low or moderate salt concentration (higher soil water potential), plants adjust osmotically (accumulate solutes) and maintain a potential gradient for the influx of water. Ghoulam *et al.*, (2002) and Katerji *et al.*, (1997) also reported that a decrease in RWC indicates a loss of turgor that results in limited water availability for cell extension processes.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 10. Effect of different salinity level on number of leaves plant^{-1} of wheat [$LSD_{(0.05)}$ = 0.67 and 1.00 at 45 and 65 DAS, respectively] .

4.2.1.3 **Combined effect of salt stress and priming**

Interaction effect of salt stress and seed priming have significant effect on relative water content of wheat at different days after sowing (Table 5). Under 4 dS m^{-1} salinity, Hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased relative water content of wheat by 47, 56 and 57%, respectively, at 45 DAS, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM

NaCl and 5 mM Na-acetate increased relative water content percentage of wheat by 48, 57 and 60%, respectively, at harvest compared with salt stress alone.

Table 5. **Combined effect of salt stress and priming on relative water content of wheat**

Treatment combinations	Relative water content (%)	
	45 DAS	65 DAS
P_0S_0	86.41 de	87.29 c-e
P_1S_0	88.49 c	87.10 de
P_2S_0	90.15 b	89.21 bc
P_3S_0	92.64 a	92.78 a
P_0S_1	55.56 g	78.33 gh
P_1S_1	81.58 f	81.72 f
P_2S_1	86.41 de	86.54 e
P_3S_1	87.38 cd	90.97 ab
P_0S_2	54.55 g	60.61 i
P_1S_2	80.52 f	76.67 h
P_2S_2	85.42 e	80.26 fg
P_3S_2	87.27 cd	89.08 b-d
$LSD_{(0.05)}$	1.34	2.01
CV (%)	1.31	1.89

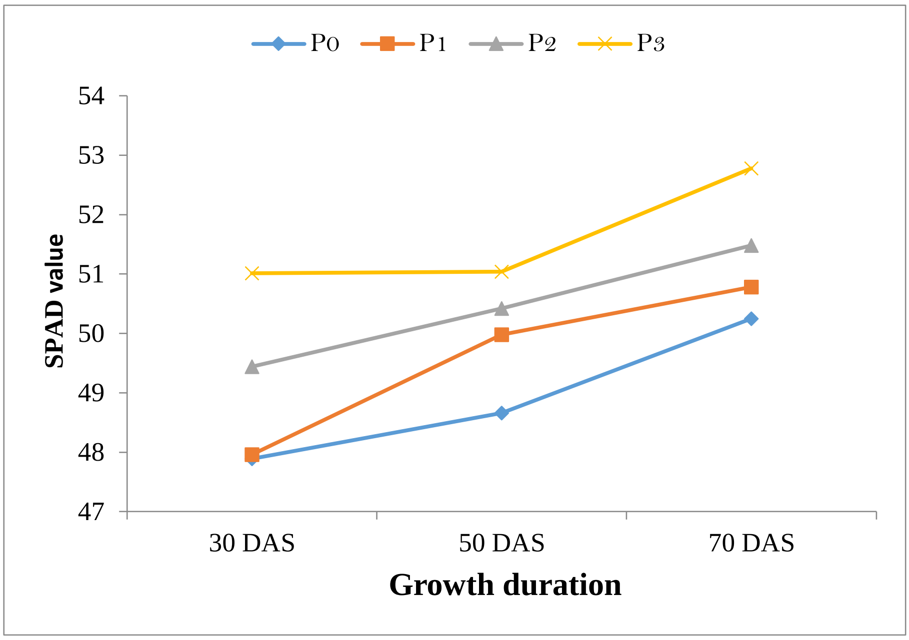
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1} .

4.2.2 SPAD value

4.2.2.1 Effect of Primining

SPAD value determine leaf chlorophyll concentrations. Chlorophyll is the natural compound present in green plants that gives them their color. It helps plants to absorb energy from the sun as they undergo the process of photosynthesis (Croft *et al.*, 2017). The SPAD value of wheat varied for application of different priming agent at 30, 50 and 70 DAS (Figure 11). Our results revealed that the highest SPAD value of wheat at 30 , 50 and 70 DAS (51.01, 51.04 and 52.78, respectively) were recorded in P_3 treatment and the lowest SPAD value at 30 and 45 DAS (47.89, 48.66 and 50.25, respectively) were recorded in P_0 treatment. The result obtained from the present study was similar with the findings of Jamal *et al.*, (2011) who investigated the impact of priming on growth and chemical properties of green leaf of chlorophyll b had been significantly increased by seed priming.

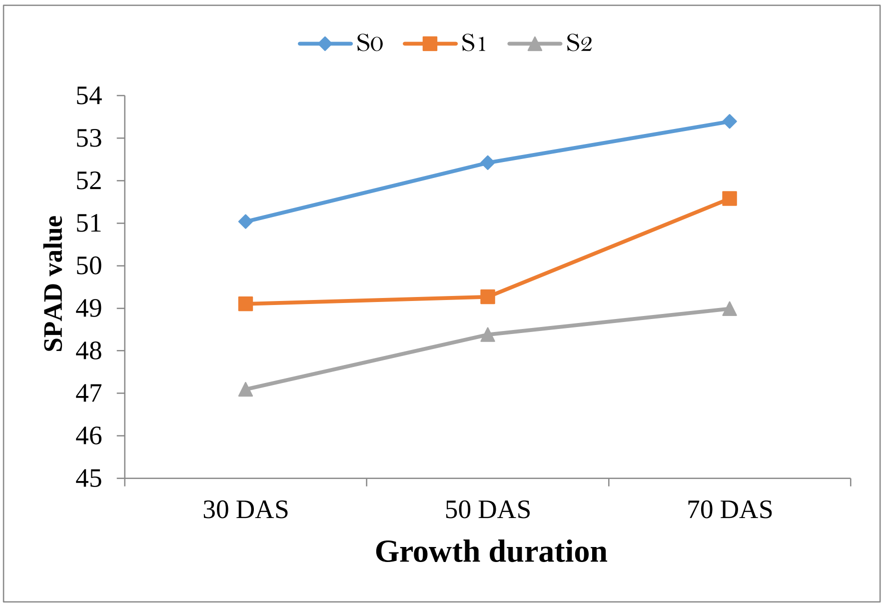


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 11. Effect of different priming on SPAD value of wheat [$LSD_{(0.05)}$ = 0.60, 0.51 and 0.76 at 30, 50 and 70 DAS, respectively] .

4.2.2.2 Effect of salt stress

In this experiment, different salt stress condition significantly effects SPAD value of wheat at 30, 50 and 70 DAS (Figure 12). The highest SPAD value of wheat at 30 ,50 and 70 DAS (51.04, 52.42 and 53.39, respectively) were recorded in control (S_0) treatment and the lowest SPAD value at 30, 50 and 70 DAS (47.09, 48.38 and 48.99) were recorded in S_2 treatment. SPAD value decreased with increasing salinity level. Ashraf and Harris (2013), also found similar result which supported the present finding and reported that photosynthetic pigments, chl a and chl b, are greatly affected by different abiotic stresses including salinity. Accumulation of toxic Na^+ reduces the precursor of chl biosynthesis (such as glutamate and 5-aminolevullinic acid) and thus interrupts chl biosynthesis under saline condition.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 12. Effect of different salinity level on SPAD value of wheat [$LSD_{(0.05)}$ = 0.52, 0.44 and 0.66 at 30, 50 and 70 DAS, respectively] .

4.2.2.3 Combined effect of salt stress and priming

Interaction of salt and priming significantly influence SPAD value of wheat at 30 , 50 and 70 DAS (Table 6). The highest SPAD value of wheat at 30, 50 and 70 DAS (52.62, 55.15 and 56.16, respectively) were recorded in P_3S_0 treatment and the lowest chlorophyll content at 30, 50 and 70 DAS (44.88, 49.35 and 48.37, respectively) were recorded in P_0S_2 treatment.

Table 6. Combined effect of salt stress and Priming on SPAD value of Wheat

Treatment combinations	SPAD value		
	30 DAS	50 DAS	70 DAS
P_0S_0	50.58 b	49.17 ef	52.12 bc
P_1S_0	50.37 bc	52.20 c	52.60 b
P_2S_0	50.59 b	53.16 b	52.69 b
P_3S_0	52.62 a	55.15 a	56.16 a
P_0S_1	48.22 e	47.45 h	50.27 de
P_1S_1	48.23 e	50.25 d	51.04 cd
P_2S_1	48.89 de	49.61 de	52.47 b
P_3S_1	51.07 b	49.78 de	52.55 b
P_0S_2	44.88 f	49.35 ef	48.37 f
P_1S_2	45.27 f	47.48 h	48.69 f
P_2S_2	48.85 de	48.49 fg	49.27 ef
P_3S_2	49.34 cd	48.21 gh	49.63 ef
$LSD_{(0.05)}$	1.04	0.90	1.32
CV (%)	1.68	1.41	2.02

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

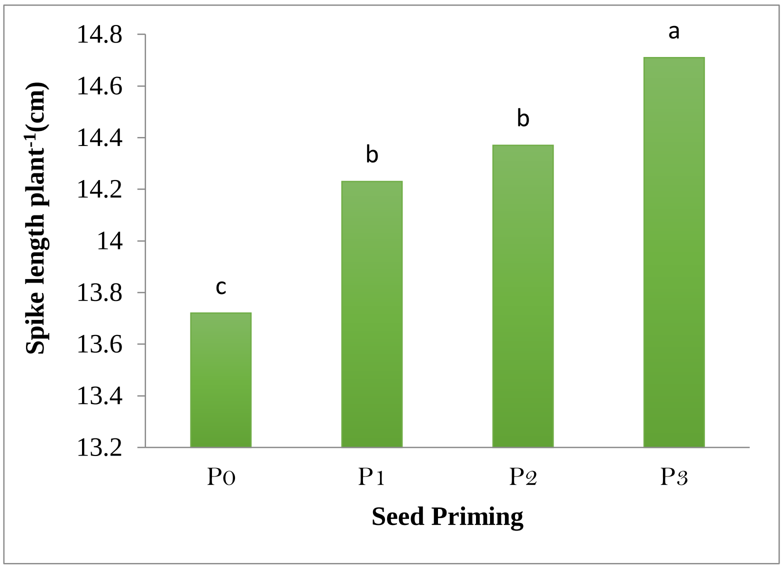
P_0 = No priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}.

4.3 Yield and yield contributing parameters

4.3.1 Spike length

4.3.1.1 Effect of priming

Significant influence was found spike length due to different seed priming treatments (Figure 13). The highest spike length (14.71) was recorded from the treatment seed priming with 5 mM Na-acetate. Where the lowest spike length (13.72) was from control.

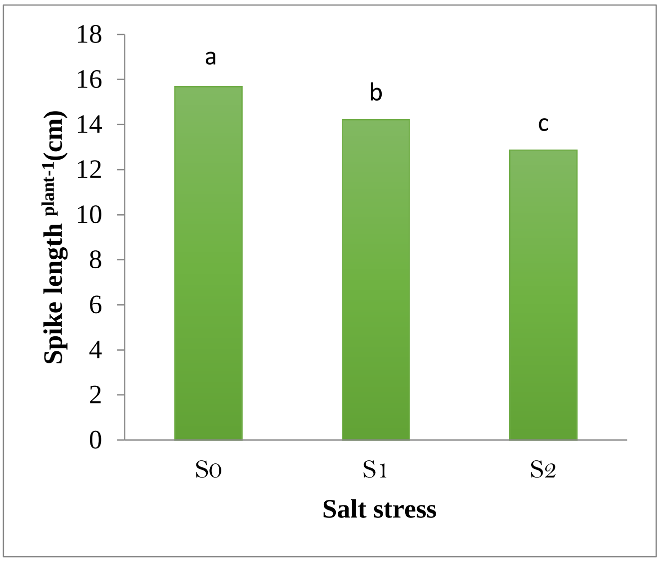


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 13. Effect of different priming on spike length of wheat [$LSD_{(0.05)}$ = 0.22].

4.3.1.2 Effect of salinity

The significant variation was observed on spike length for exposure of different levels of salinity (Figure 14). Results revealed that spike length decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased spike length by 9 and 18% respectively, compared with control. Earlier, a decrease due to salinity in spike length, spike bearing tillers and seed yield per spike has also reported (Maas and Grieve, 1990).



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 14. Effect of different salinity level on Spike length of wheat [$LSD_{(0.05)}$ = 0.22].

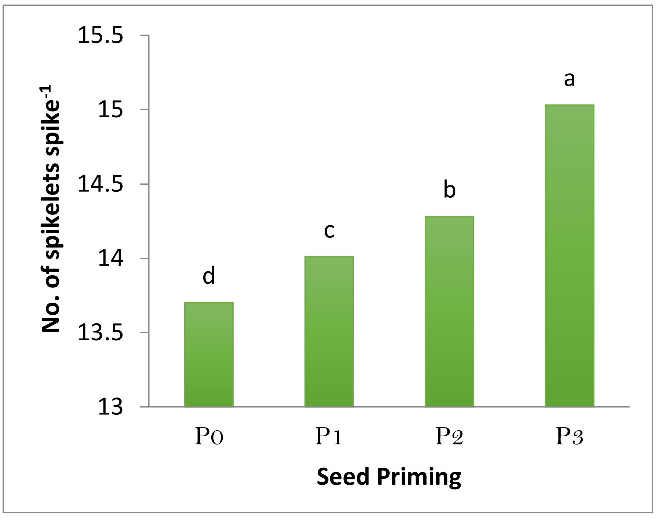
4.3.1.3 Combined effect of salt stress and priming

The spike length of wheat was significantly influenced by interaction effect of seed priming and salinity (Table 7). Under 4 dS m–1 salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased spike length of wheat by 4, 4 and 7%, respectively, compared with salt stress alone. On the other hand, under 8 dS m–1 salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increase spike length of wheat by 8, 14 and 10%, respectively, compared with salt stress alone.

4.3.2 Spikelets spike^{-1}

4.3.2.1 Effect of priming

Number of spikelets spike^{-1}was varied for different seed priming treatments (Figure 15). The highest number of spikelets spike^{-1} (15.03) was recorded for seed priming with 5 mM Na-Acetate. Where the lowest spikelets spike^{-1} (13.7) was for no priming.

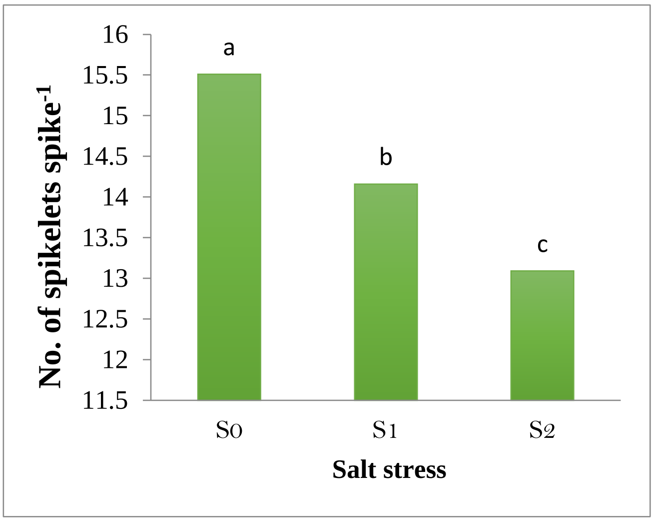


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 15. Effect of different priming on spikelets spike^{-1} of Wheat [$LSD_{(0.05)}$ = 0.21].

4.3.2.1 Effect of salt stress

The significant variation was observed on spike length for exposure of different levels of salinity (Figure 16). Results revealed that the number of spikelets plant^{-1} decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased spike length by 9 and 16% respectively, compared with control. The findings indicate that salinity has an adverse impact on wheat production and resulted in decreased spike length, number of spikelets spike^{-1}, number of kernels spike^{-1}, kernel weight spike^{-1}, 1000-kernel weight, and yield similar result was also supported by Maas and Grattan (1999).



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 16. Effect of different salinity level on spikelets spike^{-1} of wheat [$LSD_{(0.05)}$ = 0.18].

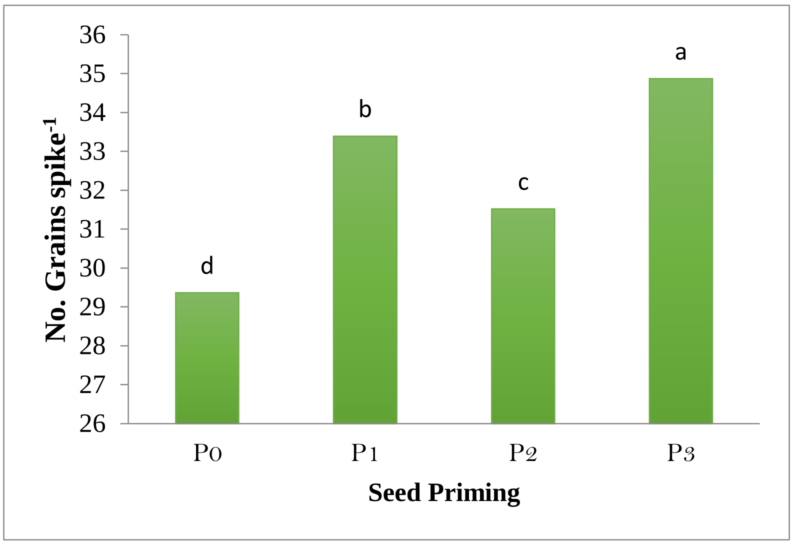
4.3.2.3 **Combined effect of salt stress and priming**

The spikelets plant^{-1} of wheat was significantly influenced by combined effect of seed priming and salinity (Table 7). Under 4 dS m^{-1} salinity, seed priming with 5 mM Na-acetate showed highest number of spikelets plant^{-1} which is 11% higher compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased the number of spikelets plant^{-1} of wheat by 10, 9 and 13%, respectively, compared with salt stress alone.

4.3.3 **Grains spike^{-1}**

4.3.3.1 **Effect of Priming**

Significant influence was found on number of grains spike^{-1} length due to different seed priming treatments (Figure 17). The highest grains spike^{-1} (34. 87) was recorded from P_3 treatment (seed priming with 5 mM Na-Acetate). Where the lowest grains spike^{-1} (29.36) was recorded from no priming.

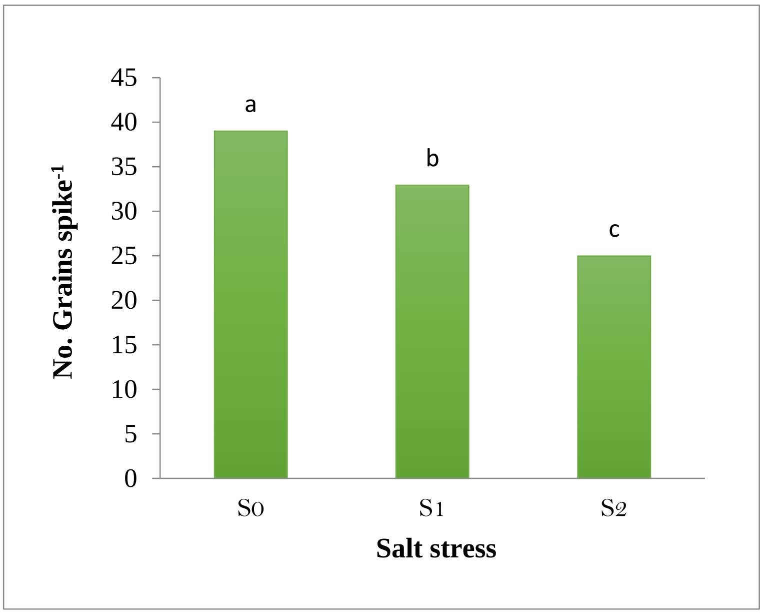


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 17. Effect of different priming on grains spike^{-1} of wheat [LSD$_{(0.05)}$ = 0.92].

4.3.3.2 Effect of salinity

The significant variation was observed on spike length for exposure of different levels of salinity (Figure 18). Results revealed that the number of grains spike^{-1} decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased the number of grains spike^{-1} by 16 and 36% respectively, compared with control. Similarly, Maas and Grieve (1990) showed that NaCl stressed during apex vegetative stage, had a shorter spikelet development stage, which resulted in fewer spikelets spike^{-1}, thus reducing the number of grains spike^{-1}of wheat.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 18. Effect of different salinity level on grains spike^{-1} of Wheat) [LSD$_{(0.05)}$ = 0.80].

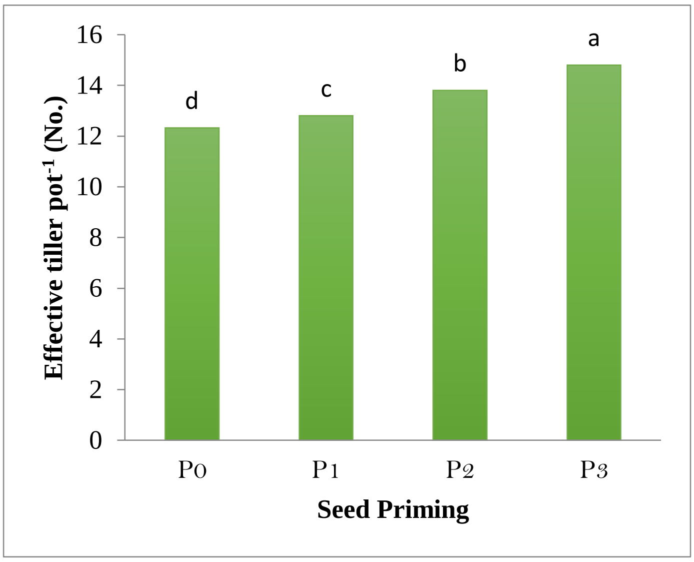
4.3.3.3 **Combined effect of salt stress and priming on**

Interaction effect of different seed priming and different concentration of salinity level showed significant influence on number of grains spike^{-1} of wheat (Table 7). Under 4 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased grains spike^{-1} of wheat by 27, 7 and 22%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased grains spike^{-1} of wheat by 6, 13 and 22%, respectively, compared with salt stress alone.

4.3.4 Effective tillers pot^{-1}

4.3.4.1 Effect of priming

Effective tillers pot^{-1} of wheat showed significant variation due to the effect of different seed priming (Figure 19). The highest number of effective tiller pot^{-1} (14.80) was recorded from 5 mM Na-acetate treatment (P_3) while lowest number of Effective tiller pot^{-1} (12.32) was obtained from the control treatment P_0. Kaur *et al.*, (2005); Farooq *et al.*, (2006b, 2006c, 2008, 2019b), mentioned similar kindS of findings in his study. Seed priming substantially increased the number of tillers, a result of the more vigorous seedlings earlier in the growth phase. Seed-priming treatments increase cell division of primordia, leading to a greater number of tillers harvested in wider rows (Farooq *et al.*, 2006a).



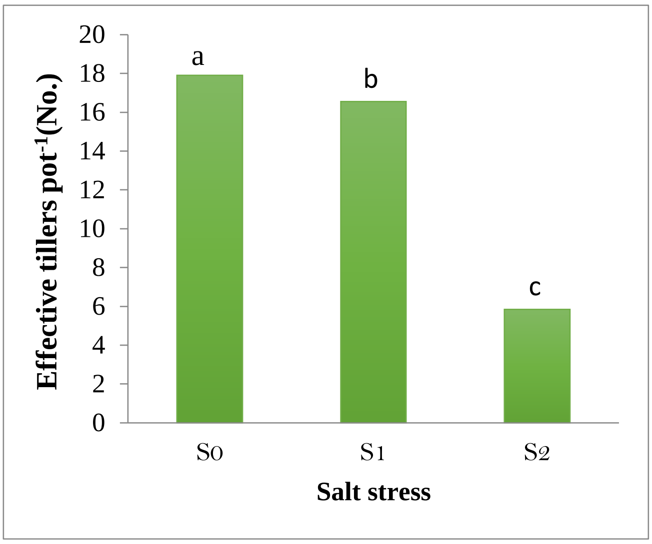
P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 19. Effect of different Priming on Effective tiller pot^{-1} of wheat [$LSD_{(0.05)}$ = 0.41] .

4.3.4.2 Effect of salt stress

The significant variation was observed on effective tillers for exposure of different levels of salinity (Figure 20). Results revealed that the number of effective tiller pot^{-1} decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased effective tiller pot^{-1} by 8 and 67% respectively, compared with control.

Mohamed *et al.*, (2010) reported that salinity decreases most yield contributing parameters of wheat i.e. number of tillers and weight of grains.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 20. Effect of different salinity level on effective tillers pot^{-1} of wheat [$LSD_{(0.05)}$ = 0.35].

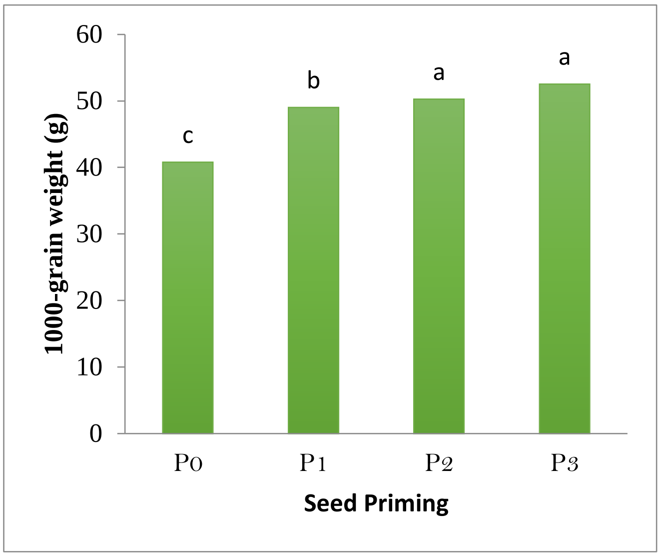
4.3.4.3 Combined effect of salt stress and priming

Interaction effect of different seed priming and different salinity levels showed significant influence on number of effective tiller pot^{-1} of wheat (Table 7). Under 4 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased effective tiller pot^{-1} of wheat by 8 , 9 and 13 %, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased effective tiller pot^{-1} of wheat by 5, 26 and 60%, respectively, compared with salt stress alone.

4.3.5 1000-grain weight

4.3.5.1 Effect of different priming

Different types of seed priming significantly influenced 1000-grain weight of wheat at harvest (Figure 21). Experimental result revealed that the highest 1000-grain weight of wheat (38.22 g) was recorded in P_3 (5 mM Na-acetate) treatment the lowest 1000-grain weight of wheat (34.13 g) was recorded in P_0 treatment.

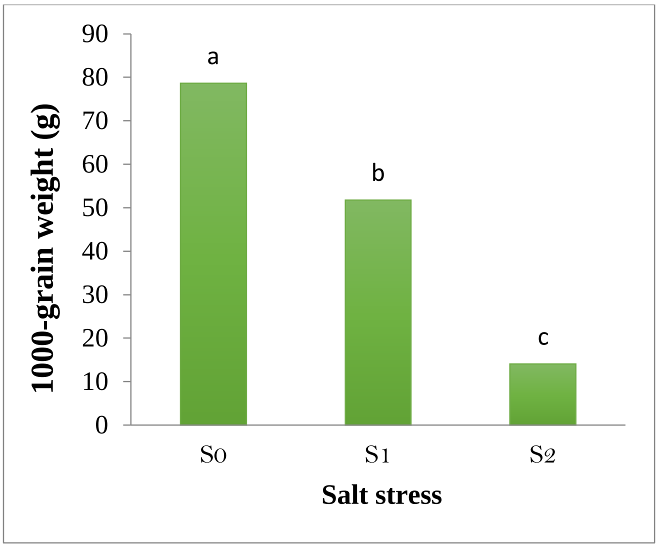


P_0 = No Priming, P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 21. Effect of different priming on 1000-grain weight of wheat [$LSD_{(0.05)}$ = 0.91].

4.3.5.2 Effect of salt stress

The significant variation was observed on 1000-grain weight for exposure of different levels of salinity (Figure 20). Results revealed that 1000-grain weight decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased 1000-grain weight by 14 and 45% respectively, compared with control. The variation of 1000-grain weight among different treatment due to reason that salt availability in soil can disturb normal functioning of plant metabolism, consequently leading to stunted growth and low crop productivity. Akram *et al.*, (2002) and Kamkar *et al.*, (2004) showed that salinity reduces yield primarily by a sever reduction in 1000 grain weight of wheat.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 22. Effect of different salinity level on 1000-grain weight of wheat [$LSD_{(0.05)}$ = 0.79].

4.3.5.3 Combined effect of salt stress and priming

Interaction effect of different types of seed priming and different concentration of salinity level showed significant influence on 1000-grain weight of wheat (Table 7). Under 4 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased 1000-grain weight of wheat by 4, 7 and 9%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased 1000-grain weight of wheat by 9, 19 and 21%, respectively, compared with salt stress alone.

Table 7. Combined effect of different levels of priming and salt stress on yield and harvest index

Treatment combinations	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Effective tillers pot^{-1} (no.)	1000-grain weight (g)
P_0S_0	15.25 b	15.22 b	36.60 cd	16.80 cd	42.76 c
P_1S_0	15.26 b	14.71 c	39.57 b	16.80 cd	45.05 b
P_2S_0	16.10 a	16.00 a	38.05 bc	18.60 b	46.56 ab
P_3S_0	16.12 a	16.12 a	41.72 a	19.40 a	47.06 a
P_0S_1	13.98 d	13.76 d	28.88 f	15.40 e	37.23 f
P_1S_1	14.48 c	13.96 d	36.56 cd	16.60 d	38.57 ef
P_2S_1	13.49 e	13.64 de	30.92 e	16.80 cd	39.70 de
P_3S_1	14.93 b	15.28 b	35.20 d	17.40 c	40.56 d
P_0S_2	11.93 g	12.12 g	22.60 h	4.75 h	22.40 i
P_1S_2	12.94 f	13.36 ef	24.04 gh	5.00 h	24.38 h
P_2S_2	13.52 e	13.20 f	25.60 g	6.00 g	26.56 g
P_3S_2	13.09 f	13.68 de	27.68 f	7.60 f	27.04 g
$LSD_{(0.05)}$	0.38	0.37	1.60	0.70	1.59
CV (%)	2.13	2.07	3.89	4.10	3.42

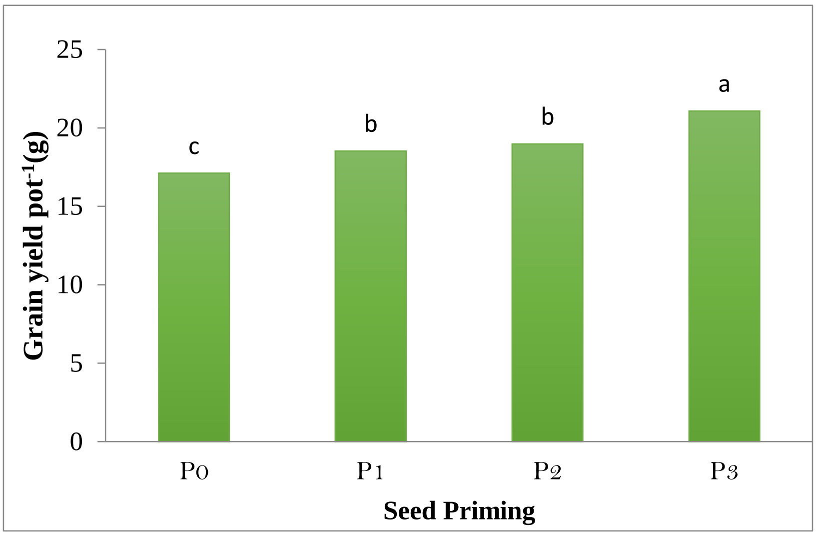
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

4.3.6 Grain yield

4.3.6.1Effect of different priming

Different types of seed priming significantly influenced grain yield of wheat (Figure 23). The highest grain yield (21.09 g pot^{-1}) was recorded from P_3 treatment (5 mM Na-acetate) while the lowest grain yield (17.12 g pot^{-1}) was obtained from control or no priming (P_0). The result of this study was supported by some previous researchers found significant effect of seed priming on seed yield at barely, bean and wheat (Rashide *et al.*, 2006; Kant *et al.*, 2006; Harries *et al.*, 2001).

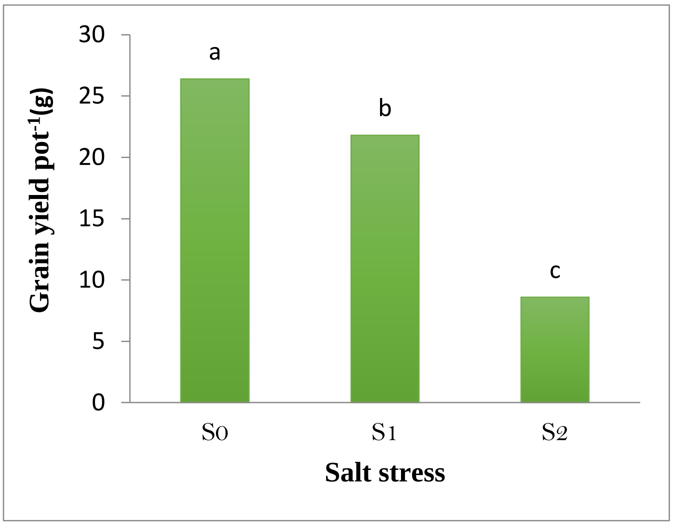


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 23. Effect of different priming on grain yield of wheat [$LSD_{(0.05)}$ = 0.60].

4.3.6.2 **Effect of salt stress**

The significant variation was observed on grain yield for exposure of different levels of salinity (Figure 24). Results revealed that the grain yield decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased grain yield by 17 and 67% respectively, compared with control. Akram *et al.*, (2002) and Kamkar *et al.*, (2004) showed that salinity reduces yield primarily by a sever reduction the grain yield of wheat.



$S_0 = 0$ dS m^{-1}, $S_1 = 4$ dS m^{-1} and $S_2 = 8$ dS m^{-1}

Figure 24. Effect of different salinity level on Grain yield of wheat [$LSD_{(0.05)}$ = 0.52].

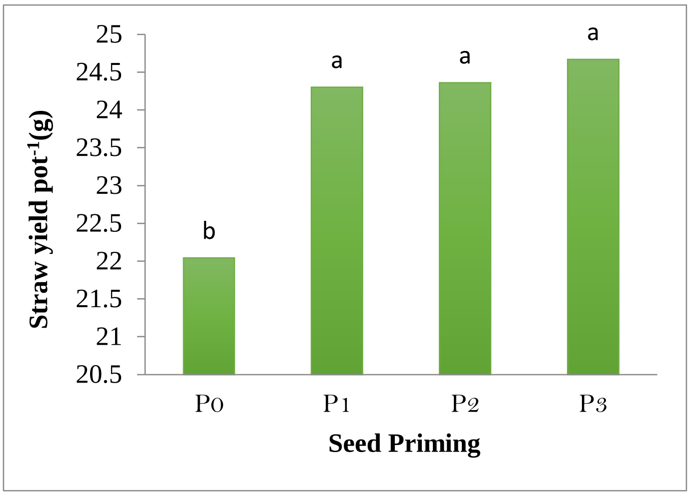
4.3.6.3 Combined effect of salt stress and priming

Interaction effect of different types of seed priming and different concentration of salinity level showed significant influence on grain yield of wheat (Table 8). Under 4 dS m^{-1} salinity, priming with 5 mM Na-acetate increased grain yield of wheat by 11%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased grain yield of wheat by 51, 48 and 81%, respectively, compared with salt stress alone.

4.3.7 Straw yield

4.3.7.1 Effect of different priming

Different type of seed priming treatments significantly influenced on Straw yield (g pot^{-1}) of wheat (Figure 25). The maximum straw yield (24.67 g pot^{-1}) was recorded from the treatment P_3 (5 mM Na-acetate) while the minimum straw yield (22.04 g pot^{-1}) was obtained from the treatment P_0 (control). Jafar *et al.*, (2012) and Rehman *et al.*, (2011) concluded that primed seeds usually have earlier and uniform emergence, and that the increase of the straw and kernel yields.

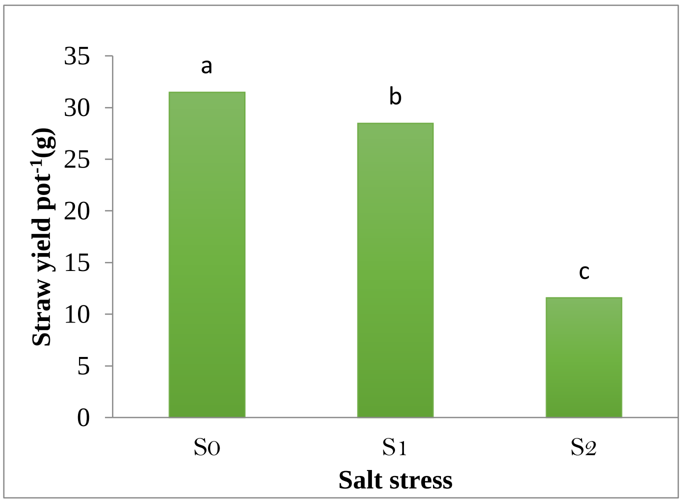


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 25. Effect of different priming on straw yield of wheat [$LSD_{(0.05)}$ = 0.19] .

4.3.7.2 Effect of salt stress

Application of different level of salt significantly affect straw yield (g pot^{-1}) of wheat (Figure 26). Results revealed that straw yield decreased with the increment of salinity levels. Exposure of 4 and 8 dS m–1 salinity decreased straw yield by 10 and 63% respectively, compared with control. Akram *et al.*, (2002) and Kamkar *et al.*, (2004) showed that salinity reduces yield primarily by a sever reduction the grain yield of wheat. Earlier, a decrease due to salinity in straw yield and 100 grain weight (Maas and Poss, 1989; Maas and Grieve, 1990; Saqib and Qureshi, 1998) has also been reported.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 26. Effect of different salinity level on straw yield of wheat [$LSD_{(0.05)}$ = 0.34].

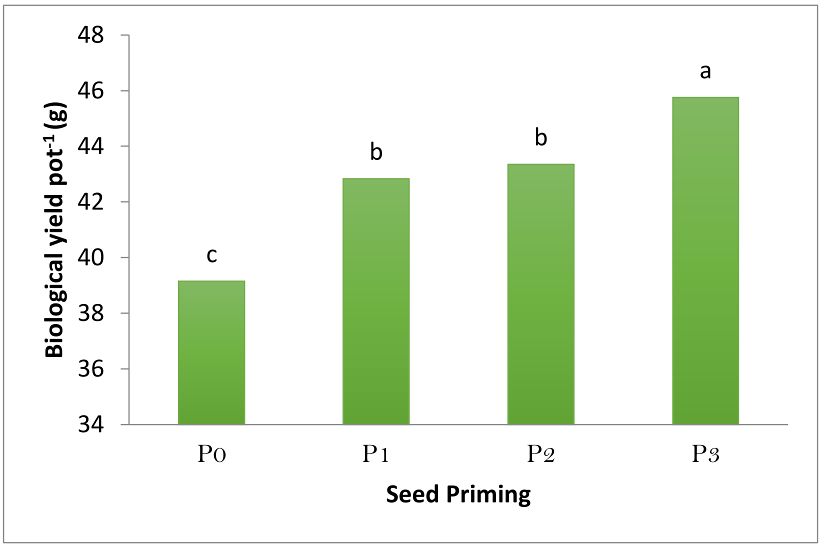
4.3.7.3 Combined effect of salt stress and priming

Interaction effect of different doses of priming and different concentration of salinity level showed significant influence on straw yield of wheat (Table 8). Under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased straw yield of wheat by 46, 33 and 50%, respectively, compared with salt stress alone.

4.3.8 Biological yield pot^{-1}

4.3.8.1 Effect of priming

Different types of priming application had significant influence on biological yield of wheat (Figure 27). The highest biological yield (45.76 g pot^{-1}) was recorded from the treatment P_3 (5 mM Na-acetate) while the lowest biological yield (39.15 g pot^{-1}) was obtained from the treatment P_0. Harris *et al.*, (2001) and Zheng *et al.*, (2002), supported the findings of this study.

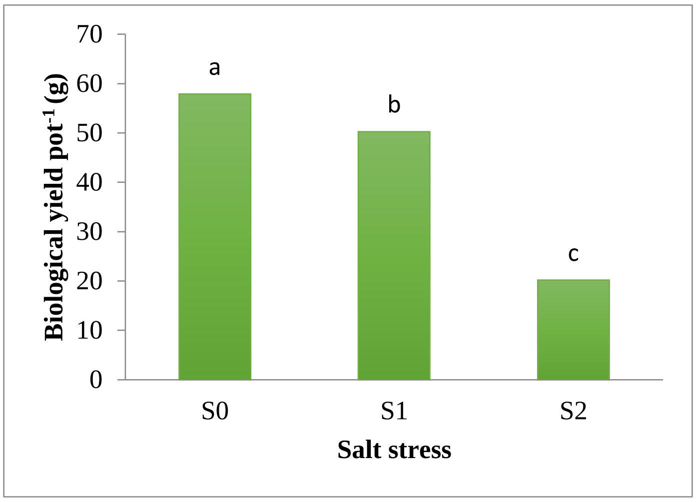


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 27. Effect of different priming on biological yield pot-1 of wheat [$LSD_{(0.05)}$ = 0.72].

4.3.8.2 Effect of salt stress

The significant variation was observed on biological yield of wheat for exposure of different levels of salinity (Figure 28). Results revealed that biological yield decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased biological yield by 13 and 65% respectively, compared with control. Singh and Singh (2000), supported the findings of this study.



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 28. Effect of different salinity level on biological yield pot-1 of wheat [$LSD_{(0.05)}$ = 0.63].

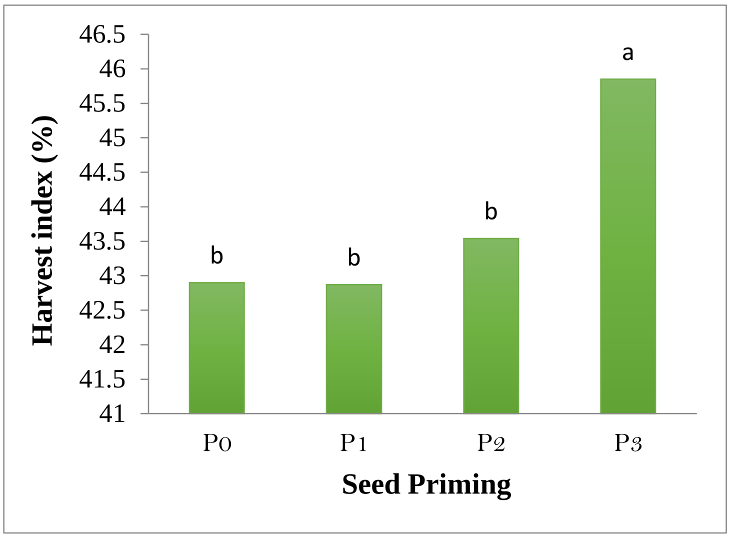
4.3.8.3 Combined effect of salt stress and priming

Interaction effect of different types of seed priming and different concentration of salinity level showed significant influence on grain yield of wheat (Table 8). Under 4 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate showed biological yield similar with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased grain yield of wheat by 48, 38 and 62%, respectively, compared with salt stress alone.

4.3.9 Harvest index

4.3.9.1 Effect of different priming

Different types of seed priming application significantly influenced harvest index of wheat (Figure 29). Experimental result showed that the maximum harvest index (42.90 %) was recorded in P_3 (5 mM Na-acetate) treatment which was higher over others treatment. Whereas the minimum harvest index (42.90 %) was recorded in P_0 treatment. Tilahun *et al.*, (2013) observed that the highest harvest index was obtained by treating the seed with different agent.

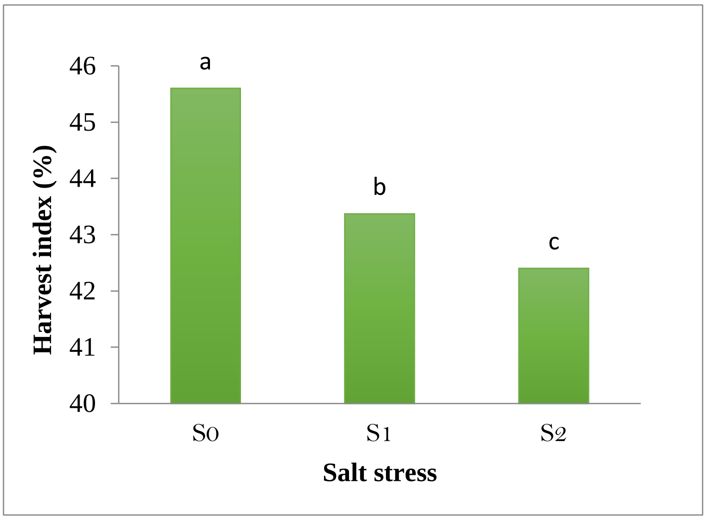


P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate

Figure 29. Effect of different priming on harvest index of wheat [$LSD_{(0.05)}$ = 0.70].

4.3.9.2 Effect of salt stress

Application of different level of salinity significantly affected harvest index of wheat (Figure 30). Results revealed that harvest index decreased with the increment of salinity levels. Exposure of 4 and 8 dS m^{-1} salinity decreased harvest index by 5 and 7% respectively, compared with control. Singh and Singh (2000), supported the findings of this study. The differences of harvest index at different salt level due to reason that increasing the level of salt decreased yield contributing characters of plant which ultimately impact on harvest index (Ashraf and Foolad, 2007).



S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}

Figure 30. Effect of different salinity level on harvest index of wheat [$LSD_{(0.05)}$ = 0.70].

4.3.9.3 Combined effect of salt stress and priming on

Interaction effect of different types of seed priming and different concentration of salinity level showed significant influence on grain yield of wheat (Table 8). Under 4 dS m^{-1} salinity, hydro-priming, priming with 5 mM NaCl and 5 mM Na-acetate increased grain yield of wheat by 5, 6 and 10%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, hydropriming, priming with 5 mM NaCl and 5 mM Na-acetate increased grain yield of wheat by 2, 5 and 11%, respectively, compared with salt stress alone.

Table 8. Combined effect of different levels of priming and salt stress on yield and harvesting index

Treatment combinations	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Biological yield (g pot^{-1})	Harvest index (%)
P_0S_0	24.60 c	27.60 e	52.20 d	47.00 a
P_1S_0	25.10 c	32.00 b	57.10 c	43.98 b-d
P_2S_0	26.40 b	33.10 a	59.50 b	44.37 bc
P_3S_0	29.50 a	33.20 a	62.70 a	47.06 a
P_0S_1	20.80 f	29.76 c	50.56 e	41.14 f
P_1S_1	21.50 ef	28.10 de	49.60 e	43.34 cd
P_2S_1	21.90 e	28.30 d	50.20 e	43.63 cd
P_3S_1	23.00 d	27.70 de	50.70 e	45.37 b
P_0S_2	5.95 i	8.75 h	14.70 i	40.55 f
P_1S_2	9.00 h	12.80 f	21.80 g	41.28 ef
P_2S_2	8.67 h	11.67 g	20.34 h	42.63 de
P_3S_2	10.78 g	13.10 f	23.88 f	45.14 b
$LSD_{(0.05)}$	1.05	0.67	1.25	1.39
CV (%)	4.96	2.23	2.31	2.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

P_0 = No Priming , P_1= Hydro-priming, P_2= Priming with 5 mM NaCl, P_3= Priming with 5 mM Na-acetate , S_0 = 0 dS m^{-1}, S_1 = 4 dS m^{-1} and S_2 = 8 dS m^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted on plastic pot in net house condition at Sher-e-Bangla Agricultural University during rabi season 2020-2021 to investigate the effect of halo priming on plant biometry and yield of wheat variety under salt stress conditions. The results revealed that seed priming and different levels of salinity and their interaction significantly influenced growth, yield and yield contributing parameters. The results revealed that seed priming with 5 mM Na-acetate exhibited its superiority compare with that of other priming treatments such as control, hydro-priming and seed priming with 5 mM NaCl. The highest grain yield pot^{-1} (21.09 g), biological yield (45.76 g) and harvest index (45.09) recorded for seed priming with 5 mM Na-acetate. Significant differences observed on growth, yield and yield contributing parameters of wheat. Exposure of 4 and 8 dS m^{-1} of salinity decreased germination percentage (19 and 34%, respectively), effective tillers per pot (8 and 67%, respectively), 1000-grain weight (20 and 71%, respectively), grain yield (17 and 67 %, respectively), straw yield (10 and 63%, respectively) and biological yield (13 and 65%, respectively) compared with control. The growth and yield reduction of wheat increased with the increment of salinity level. Combination of seed priming and salt stress significantly influenced germination, growth and yield of wheat. Under 4 dS m^{-1} salinity, seed priming with 5 mM Na-acetate increased germination percentage, effective tillers pot^{-1}, 1000-grain weight, grain yield pot^{-1} of wheat by 19, 13, 9 and 11%, respectively, compared with salt stress alone. On the other hand, under 8 dS m^{-1} salinity, seed priming with 5 mM Na-acetate increased germination percentage, effective tillers pot^{-1}, 1000-grain weight, grain yield pot^{-1} by 33, 60, 21 and 81% respectively, compared with salt stress. Hydro-priming and seed priming with 5 mM NaCl also showed positive response on seed germination, growth and yield of wheat under saline and non-saline conditions. However, seed treatment with 5 mM Na-acetate showed the best result in improving germination percentage, seedling vigor, growth and yield of wheat under saline and non-saline condition.

Recommendation

Considering the results of the present experiment, further studies in the following areas are suggested:

- Different priming agent may be used with different concentration of salt for getting wider range of growth promoter recommendation for combating salinity problem.

- Studies of similar nature could be carried out in different agro-ecological zones (AEZ) of Bangladesh which is mostly saline affected for the evaluation of zonal adaptability.

REFERENCES

Abdul-Baki, A.A. and Anderson J.D. (1970).Viability and leaching of sugars from germinating barley. *Crop Sci.* **10**: 31-34.

Abrol, I.P. (1986). Salt-affected soils: an overview. In: Chopra V. L. and Paroda S. L. (Eds) Approches for incorporating drought and salinity resistance in crop plants. Oxford and IBH Publishing Company, New Delhi, India: 1–23

Acquaah, G. (2007). Principles of plant genetics and breeding. Blackwell, Oxford. p. 385.

Adebisi, M.A., Kehinde T.O., Abdul-Rafiu M.A., Esuruoso O.A., Oni, O.D and Ativie, O. (2013). Seed physiological quality of three Capsicum species as affected by seed density and hydropriming treatment durations. *J. Agron.* **12**: 38–45.

Afzal, I., Basra, S.M.A., Hameed, A. and Farooq, M. (2006). Physiological enhancements for alleviation of salt stress in wheat. *Pakistan J. Bot.* **38**: 1649–1659.

Afzal, I., Butt, A., Rehman, H., Basra, S.M.A. and Afzal, A. (2012). Alleviation of salt stress in fie aromatic rice by seed priming. *Aust. J. Crop Sci*. **6**: 1401-1407.

Afzal, I., Rauf, S., Basra, S.M.A. and Murtaza, G. (2008). Improves vigor, metabolism of reserves and ionic contents in wheat seedlings under salt stress. *Plant Soil Environ.* **54**: 382-388.

Afzal, I., Basra, S.M.A., Cheema, M.A., Farooq, M., Jafar, M.Z. and Shahid, M. (2013). Seed priming: A shotgun approach for alleviation of salt stress in wheat. *Int. J. Agric. Biol.* **15**:1199-1203.

Ahmad, S., Anwar M. and Uliah, H. (1998). Wheat seed pre-soaking for improved germination. *J. Agron. Crop Sci.* **181**: 125-127.

Ahmad, P., Abdel Latef, A.A., Hashem, A., Abd_Allah, E.F., Gucel, S. and Tran, L.S.P. (2016). Nitric oxide mitigates salt stress by regulating levels of osmolytes and antioxidant enzymes in chickpea. *Front. Plant Sci***.** **7**: 347.

Ahmadvand, G., Soleymani, F., Saadatian, B. and Pouya, M. (2012). Effects of seed priming on seed germination and seedling emergence of cotton under salinity stress. *World Appl. Sci. J.* **20**: 1453-1458.

Akbari, G., Sanavy S.A. and Yousefzadeh, S. (2007). Effect of auxin and salt stress (NaCl) on seed germination of wheat cultivars (*Triticum aestivum* L.). *Pakistan. J. Biol. Sci.* **10**:2557–2561

Akram, M., Hussain, M., Akhtar, S. and Rasul, E. (2002). Impact of NaCl salinity on yield components of some wheat accessions/varieties. *Int. J. Agric. Biol.* **1**: 156–8.

Al-Ashkar, I., Alderfasi, A., El-Hendawy, S., Al-Suhaibani, N. and El-Kafafi, S. (2019). Detecting salt tolerance in doubled haploid wheat lines. *Agrono*. **9**:211.

Al-Ashkar, I., Alderfasi, A., Romdhane, W., Seleiman, M.F. and El-Said, R.A. (2020). Morphological and genetic diversity within salt tolerance detection in eighteen wheat genotypes. *Plants.* **9**: 287.

Al-Musa, M.A.A., Ullah, M.A., Moniruzzaman, M., Islam, M.S. and Mukherjee, A. (2012). Effect of BARI wheat varieties on seed germination, growth and yield under Patuakhali district. *J. Environ. Sci. Nat. Res.* **5**(2): 209–212.

Alvarado, A.D., Bradford, K.J. and Hewitt, J.D. (1987). Osmotic priming of tomato seed: effect on germination, field emergence, seedling growth and fruit yield. *J. Am. Soc. Hort. Sci.* **112**:427–432

Amirjani, M.R. (2010). Effect of NaCl on some physiological parameters of rice. *European J. Biol. Sci.* **3**(1):6-16.

Amooaghaie, R. and Tabatabaie, F. (2017). Osmopriming-induced salt tolerance during seed germination of alfalfa most likely mediates through H_2O_2 signaling and upregulation of heme oxygenase. *Protoplasma*. **3**:1791-1803.

Andreas, S., Ali, S., Tester, M. and Fotopoulos, V. (2016). Chemical priming of plants against multiple abiotic stresses: mission possible? *Trends Plant Sci.* **4**: 329–340.

Anonymous. (1989). Annual Weather Report, meteorological Station, Dhaka, Bangladesh.

Anonymous. (1988 a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (1988 b). Land resources appraisal of Bangladesh for agricultural development. Report No.2. Agro-ecological regions of Bangladesh, UNDP and FAO. pp. 472–496.

Anonymous. (2004). Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

Anosheh, H.P. and Hashemi, S.E. (2020). Priming a promising practical approach to improve seed germination and plant growth in saline conditions. *Asian J. Agric. Food Sci*. **8**: 2321-1571.

Asgari, H.R., Cornelis, W. and Damme, P.V. (2012). Salt stress effect on wheat (*Triticum aestivum* L.) growth and leaf ion concentrations. *Int. J. Plant Prod.* **6**:195-208.

Ashkan, A., Jalal, M. (2013). Effects of salinity stress on seed germination and seedling vigor indices of two halophytic plant species (*Agropyron elongatum* and *A. pectiniforme*). *Int. J. Agric. Crop Sci.* **5**(22): 2669- 2676.

Ashraf, M. and Foolad, M. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environ. Exp. Bot.* **59**(2): 206-216.

Ashraf, M. and Rauf, H. (2001) Inducing salt tolerance in maize (*Zea mays* L.) through seed priming with chloride salts: growth and ion transport at early growth stages. *Acta. Physiol. Plant*. **23**:407–414

Atalou, F.R. (2014). Vishkaei. Hormonal Seed priming with GA and Kinetin Influences seed and oil yields in two Sesame cultivars. *Int. J. Fund. Appli. Life Sci*. **4**: 266-270.

Auge, R.M., Moore, J. L., Stutz, J.C., Sylvia, D.M., AlAgely, A.K. and Saxton, A.M. (2003). Relating foliar dehydration tolerance of mycorrhizal Phaseolus vulgaris to soil and root colonization by hyphae. *J. Pl. Physiol.* **160**: 1147-1156.

Babu, M.A., Singh, D. and Gothandam, K.M. (2012). The effect of salinity on growth, hormones and mineral elements in leaf and fruit of tomato cultivar PKM. *J. Anim. Plant Sci.* **22**(1): 159-164.

Bajehbaj, A.F. (2010). The effects of NaCl priming on salt tolerance in sunflower germination and seedling grown under salinity conditions. *African J. Biotech*. **12**: 1764-1770.

Bakht, J., Khan, M.J. Shafi, M., Khan, M.A. and Sharif, M. (2012). Effect of salinity and ABA application on proline production and yield in wheat genotypes. *Pak. J. Bot.* **44**(3): 873-878.

Bakht, J., Shafi, M., Jamal, Y. and Sher, H. (2011). Response of maize (*Zea mays* L.) to seed priming with NaCl and salinity stress. *Spanish J. Agric. Res.* **9**: 252–261.

Barrs, H.D. and Weatherley, P. E. (1962). A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian. J. Biol. Sci.* **15**(3): 413-428.

Basra S.M.A., Afzal I., Rashid, R.A. and Hameed A. (2005b): Inducing salt tolerance in wheat by seed vigor enhancement techniques. *Int. J. Biol. Biotechnol.* **2**: 173–179.

Basra, S.M.A., Pannu, I.A. and Afzal, I. (2003) Evaluation of seedling vigor of hydro and matriprimed wheat (*Triticum aestivum* L.) seeds. *Int. J. Agric. Biol.* **5**: 121–123.

Bazzaz, M. (2013). Growth, production physiology and yield in wheat under variable water regimes. Ph.D. thesis, Dept. Agron., Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur

BBS (Bangladesh Bureau of Statistics). (2020). Estimates of Wheat, 2018–19. pp. 79–80.

BBS (Bangladesh Bureau of Statistics). (2016). Year Book of Agricultural Statistics of Bangladesh, Bangladesh Bureau of Statistics, Planning Division, Ministry of

Planning, Government of People's Republic of Bangladesh. Dhaka. Published in January, 2018.

BBS (2019). Estimates of Wheat, 2017-18 [WWW Document]. Agric. Wing, Bangladesh Bur. Stat. Gov. Bangladesh.

Beckers, G.J.M. and Conrath, U. (2007). Priming for stress resistance: from the lab to the field. *Curr. Opin. Plat. Biol.* **10**: 425–431.

Bennett, M.A. and Waters, L. (1987). Seed hydration treatments for improved sweet maize germination and stand establishment. *J. Am. Soc. Hort. Sci.* **112**: 45–49.

Bradford, K.J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. *Hort. Sci*. **21**: 1105–1112.

Brocklehurst, P.A. and Dearman, J. (2008). Interaction between seed priming treatments and nine seed lots of carrot, celery and onion II. Seedling emergence and plant growth, *Ann. Appl. Biol.* **102**: 583–593.

Bruce, T.J.A., Matthes, M.C., Napie, J.A. and Pickett, J.A. (2007). Stressful memories of plants: evidence and possible mechanisms. *Plant Sci.* **173**: 603–608.

Cantliffe, D.J. (2003). Seed enhancements. *Acta Hort.* **607**: 53–62.

Capanoglu, E. (2010). The potential of priming in food production. *Trends Food Sci. Technol.* **21**: 399–407.

Carbineau, F. and Come, D. (2006). Priming: a technique for improving seed quality, *Seed Testing Int.* no. 132.

Cayuela, E., Perez-Alfocea, F., Caro, M. and Bolarin, M.C. (1996): Priming of seeds with NaCl induces physiological changes in tomato plants grown under salt stress. *Physiol. Plant.* **96**: 231–236.

Chattha, M.U., Hassan, M.U., Khan, I., Chattha, M.B. and Mahmood, A. (2017). Biofortification of wheat cultivars to combat zinc deficiency. *Frontiers Plant Sci.* **8:** 281

Chen, K. and Arora, R. (2011). Dynamics of the antioxidant system during seed osmo-priming, post-priming germination, and seedling establishment in spinach *(Spinacia oleracea*). *Plant Sci*. **180**: 212-220.

Chivasa, W., Harris, D., Chiduza, C., Nyamudeza, P. and Mashingaidze, A.B. (1998). Agronomic practices, major crops and farmers' perceptions of the importance of good stand establishment in Musikavanhu Communal Area, Zimbabwe. *J. Appl. Sci. Southern Africa*. **4**: 9–25.

Choudhury, S., Panda, P., Sahoo, L. and Panda, S.K. (2013). Reactive oxygen species signaling in plants under abiotic stress. *Plant Signal. Behav*. **8**(4): 23681.

Coasta, R., Pinheiro, N., Ameida ,A. S., Gomes C., Coutinho, J., Coco, J., Costa, A. and Nacas, B. (2013). Effect of sowing date and seeding ratio on bread wheat yield and test weight under Mediterranean conditions. *Emirates J. Food Agric*. **25**: 951-961.

Collado, M.B., Aulicino, M.B., Arturi, M.J. and Molina, M.D.C. (2016). Selection of maize genotypes with tolerance to osmotic stress associated with salinity. *Agric. Sci*. **7**: 82-92.

Deinlein, U., Stephan, A.B., Horie, T., Luo, W., Xu, G. and Schroeder, J.I. (2014). Plant salt-tolerance mechanisms. *Trends plant Sci.* **19**(6): 371–9.

Dezfuli, P. M., Sharif-Zadeh, F. and Janmohammadi, M. (2008). Influence of priming techniques on seed germination behavior of maize inbred lines (*Zea mays* L.). *ARPN J. Agric. Biol. Sci.* **3**: 22-25.

Ding, Z., Kheir, A.S., Ali, O.A., Hafez, E. and Elshamey, E.A. (2021). A vermicompost and deep tillage system to improve saline-sodic soil quality and wheat productivity. *J. Environ. Mng.* **277**: 111–388.

Draganic, I. and Lekic, S. (2012). Seed priming with antioxidants improves sunflower seed germination and seedling growth under unfavorable germination conditions. *Turkish J. Agric. Forestry.* **36**: 421-428.

Edris, K. M., Islam, A. M. T., Chowdhury, M. S. and Haque, A. K. M. M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, BAU and Govt. Peoples Republic of Bangladesh. p. 118.

Elcoka, E. (2014). Osmo- and hydro-priming enhance germination rate and reduce thermal time requirement of pea (*Pisum sativum* L. cv. Winner) seeds. *Academic J. Agric*. **3**(1): 1-12.

El-Esawi, M. A., Alaraidh, I.A., Alsahli, A. A., Alamri, S. A., Ali, H. M. and Alayafi, A. A. (2018). *Bacillus firmus* (SW5) augments salt tolerance in soybean (*Glycine max* L.) by modulating root system architecture, antioxidant defense systems and stress-responsive genes expression. *Pl. Physiol. Biochem*. **132**: 375-384.

Fanadzo, M., Chiduza, C., Mnkeni, P.N., Van der Stoep, I. and Stevens, J. (2010). Crop production management practices as a cause for low water productivity at Zanyokwe Irrigation Scheme. *Water SA* **36**: 27–36.

FAO. (2009) Food and agriculture: High Level Expert Forum- How to Feed the World in 2050. Rome, Italy: Economic and Social Development, Food and Agriculture Organization of the United Nations.

FAO. (2017). Food and Agriculture: driving action across the 2030 agenda for sustainable development. FAO, Rome.

FAO. (2019). Food and Agriculture: Statistical Year Book. MO. UN, Rome, Italy.

FAO. (2021). Food and Agriculture: driving action across the 2030 agenda for sustainable development. FAO, Rome.

Farooq, M., Irfan, M., Aziz, T., Ahmad, I. and Cheema, S.A. (2013). Seed priming with ascorbic acid improves drought resistance of wheat. *J. Agron. Crop Sci.* **199**: 12–22.

Farooq, M., Basra S.M.A., Khalid, M., Tabassum R., & Mehmood T. (2006). Nutrient homeostasis, metabolism of reserves and seedling vigor as affected by seed priming in coarse rice. *Canadian J. Bot*. **84**: 1196–1202.

Farooq, M., Basra, S.M.A., Hafeez-u-Rehman and Saleem, B.A. (2008). Seed priming enhances the performance of late sown wheat (*Triticum aestivum* L.) by improving chilling tolerance. *J. Agron. Crop Sci.* **194**(1): 55-60.

Feldman, M. (1995). Wheats. Evolution of crop plants. Longman Scientifi and Technical, Harlow, UK. Pp. 185–192.

Fuller, M.P., Hamza, J.H., Rihan, H.Z. and AlIssawi, M. (2012). Germination of primed seed under NaCl stress in wheat. *ISRN Bot.* **5**: 167801.

Gadjev, I., Stone, J.M., Gechev, T.S. (2008). Programmed cell death in plants: new insights into redox regulation and the role of hydrogen peroxide. *Int. Rev. Cell Mol. Biol.* **270**: 87 –144.

Gechev, T.S., Hille, J. (2005). Hydrogen peroxide as a signal controlling plant programmed cell death. *J. Cell Biol*. **168**: 17 –20.

Ghassemi, F., Jakeman, A.J. and Nix, H.A. (1995). Salinisation of Land and Water Resources: Human Causes, Extent, Management and Case Studies. Sydney, Australia, and CAB International, Wallingford, UK: UNSW Press.

Ghassemi, G.K., Jabbarpour, S., Zehtab, S. and Mohammadi, A. (2010). Response of winter rapeseed (Brassica napus L.) cultivars to salt priming of seeds. *African J. Biotech*. **5**: 1089-1094.

Ghiyasi, M., Seyahjani, A.A., Tajbakhsh, M., Amirnia, R., Salehzadeh, H. (2008). Effect of osmopriming with polyethylene glycol (8000) on germination and seedling growth of wheat (*Triticum aestivum* L.) seeds under salt stress. *Res. J. Biol. Sci.* **3**: 1249 -1251.

Ghoulam, C., Foursy, A. and Fares, K. (2002). Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environ. Exp. Bot*. **47**(1): 39-50.

Gill, S.S. and Tuteja, N. (2010). Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant Physiol. Biochem*. **48**: 909–930.

Gomez, M.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. pp. 97-215.

Guo, Q., Wang, Y., Zhang, H., Qu, G., Wang, T., Sun, Q. and Liang, D. (2017). Alleviation of adverse effects of drought stress on wheat seed germination using and drought stress tolerance induced in maize (*Zea mays* L.) by three plant atmospheric dielectric barrier discharge plasma treatment. *Sci. Rep.* **7**: 16680.

Hafez, E. M., Abou El Hassan, W. H., Gaafar, I.A. and Seleiman, M. F. (2015). Effect of gypsum application and irrigation intervals on clay saline-sodic soil characterization, rice water use efficiency, growth, and yield. *J. Agric. Sci.* **7**: 208–219.

Hajihashemi, S., Kiarostami, K., Enteshari, S., Saboora, A. (2009). Effect of paclobutrazol on wheat salt tolerance at pollination stage. *Russian J. Plant Physiol*. **56**: 251–257.

Hamayun, M., Hussain, A., Khan, S. A., Kim, H.Y., Khan, A. L., Waqas, M., Irshad, M., Iqbal, A., Rehman, G., Jan, S. and Lee, I.J. (2017). Gibberellins producing endophytic fungus Porostereum spadiceum AGH786 rescues growth of salt affected soybean. *Front. Microbiol.* **8**: 686.

Harris, D. (1996). The effects of manure, genotype, seed priming, depth and date of sowing on the emergence and early growth of sorghum bicolor (L.) Moench in semi-arid Botswana. *Soil Tillage Res.* **40**: 73-88.

Harris, D., Raghuwanshi, B.S., Gangwar, J.S., Singh, S.C., Joshi, K.D., Rashid, A. and Hollington P.A. (2001). Participatory evaluation by farmers of on-farm seed priming in wheat in India, Nepal and Pakistan. *Expt. Agric.* **37**: 403-415.

Hasanuzzaman, M., Nahar, K., Rahman, A., Anee, T.I. and Alam, M.U. (2017). Approaches to enhance salt stress tolerance in wheat. UK: IntechOpen Limited 5 Princes Gate Court London. . pp. 151–187.

Hasanuzzaman, M., Nahar, K. and Fujita, M. (2013). Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. In: Ecophysiology and Responses of Plants under Salt Stress. P. Ahmed, M. M. Azooz, M. N. V. Prasad, (eds.). Springer, New York. pp. 25-87.

Hasanuzzaman, M., Nahar, K., Rahman, A., Mahmud, J.A., Hossain, S., Alam, K. and Fujita, M. (2017). Actions of biological trace elements in plant abiotic stress tolerance. In: Essential Plant Nutrients. Springer, Cham. pp. 213-274.

Hassan, M.U., Aamer, M., Nawaz, M., Rehman, A. and Aslam, T. (2021). Agronomic Bio-fortification of wheat to combat zinc deficiency in developing countries. *Pakistan J. Agric. Res.* **34**: 66–78.

Hassan, M.U., Chattha, M.U., Ullah, A., Khan, I. and Qadeer, A. (2019). Agronomic bio fortification to improve productivity and grain Zn concentration of bread wheat. *Int. J. Agric. Biol.* **21**: 615–620.

Hossain, M.S. (2019). Present scenario of global salt affected soils, its management and importance of salinity research. *Int. Res. J. Biol. Sci*. **1**: 3.

Huang, Y., Bie, Z., He, S., Hua, B. and Zhen, A. (2010). Improving cucumber tolerance to major nutrients induced salinity by grafting onto cucurbita ficifolia. *Environ. Expt. Bot.* **69**: 32–38.

Hussain, S., Bai, Z., Huang, J., Cao, X., Zhu, L., Zhu, C., (2019). 1-Methylcyclopropene modulates physiological, biochemical, and antioxidant responses of Rice to different salt stress levels. Frontiers in Plant Science, **10**:124.

Hussain, S., Hussain, S., Ali, B., Ren, X. and Chen, X. (2021). Recent progress in understanding salinity tolerance in plants: Story of Na+/K+ balance and beyond. *Plant Physiol. Biochem.* **160**: 250–256.

Hussain, T.M., Hazara, M., Sultan, Z., Saleh, B.K. and Gopal, G.R. (2008). Recent advances in salt stress biology a review. *Biotechnol. Mol. Biolo. Rev.* **3**(1): 8–13.

Ibrahimova, U., Zivcak, M., Gasparovic, K., Rastogi, A., Allakhverdiev, S. I. (2021). Electron and proton transport in wheat exposed to salt stress: Is the increase of the thylakoid membrane proton conductivity responsible for decreasing the photosynthetic activity in sensitive genotypes? *Photosynthesis Res.* **1**: 11-17.

Islam, M.T., Croll, D., Gladieux, P., Soanes, D.M., Persoons, A., Bhattacharjee, P., Hossain, M.S., Gupta, D.R., Rahman, M.M., Mahboob, M.G., Cook, N., Salam, M.U., Surovy, M.Z., Sancho, V.B., Maciel, J.L.N., NhaniJúnior, A., Castroagudín, V.L., Reges, J.T. de A., Ceresini, P.C., Ravel, S., Kellner, R., Fournier, E., Tharreau, D., Lebrun, M.-H., McDonald, B.A., Stitt, T., Swan, D., Talbot, N.J., Saunders, D.G.O., Win, J., Kamoun, S., (2016). Emergence of wheat blast in Bangladesh was caused by a South American lineage of Magnaporthe oryzae. *BMC Biol*. **14**: 84.

Ismail, A., Riemann, M. and Nick, P. (2012). The jasmonate pathway mediates salt tolerance in grapevines. *J. Exp. Bot.* **63**(5): 2127–2139.

Jafar, M.Z., Farooq, M., Cheema, M. A., Afzal, I., Basra, S.M.A., Wahid, M.A., Aziz,T. and Shahid, M. (2012). Improving the performance of wheat by seed priming under saline conditions. *J. Agron. Crop Sci.* **198**: 38–45.

Jamal, Y., Shafi, M. and Bakht, J. (2011). Effect of seed priming on growth and biochemical traits of wheat under saline conditions. *African J. Biotechnol*. **10**(75): 17127-17133.

Jamal, Y., Shafi, M., Bakht, J. and Arif, M. (2011). Seed priming improves salinity tolerance of wheat varieties. *Pakistan J. Bot.* **43**: 2683-2686

Jisha, K., Vijayakumari, K. and Puthur, J.T. (2013). Seed priming for abiotic stress tolerance: An overview. *Acta Physiol. Plant.* **35**: 1381–1396.

Kadiri, M. and Hussaini, M. A. (1999). Effect of hardening pre-treatment on vegetative growth, enzyme activities and yield of *Pennisetum americanum* and *Sorghum bicolor*. L. *Global J. Pure Appl. Sci*. **5**: 179-183.

Kamkar, B., Kafi, M. and Mahallati, A. N. (2004). Determination of the most sensitive development period of wheat (*Triticum aestivum*) to salt stress to optimize saline water utilization. 4th International Crop Science Congress, Iran.

Kant, S., Pahuja, S.S. and Pannu, R. K. (2006). Effect of seed priming on growth and phenology of wheat under latesown conditions. *Trop. Sci*. **44**: 9-150.

Katerji, N., van Hoorn, J. W., Hamdy, A., Mastrorilli, M. and Moukarzel, E. (1997). Osmotic adjustment of sugar beets in response to soil salinity and its influence on stomatal conductance, growth and yield. *Agric. Water Mng*. **34**(1): 57-69.

Kaur, S., Gupta, A.K. and Kaur, N. (2002) Effect of osmo- and hydropriming of chickpea seeds on seedling growth and carbohydrate metabolism under water deficit stress. *Plant Growth Regul.* **37**(1): 17–22

Kaur, H., Chawla, N. & Pathak, M. (2015). Effect of different seed priming treatments and priming duration on biochemical parameters and agronomic characters of okra (*Abelmoschus esculentus* L.). *Int. J. Plant Physiol. Biochem.* **7**(1): 1–11.

Kaya, M. D., Okçu, G., Atak, M., ÇIkIlI, Y. and KolsarIcI, O. (2006). Seed treatments to
overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). *European J. Agron.* **24**: 291–295.

Khan, A.A. (1993). Preplant physiological seed conditioning. *Hort. Rev.* **13**: 131-181.

Khan, H.A., Ayub, C.M., Pervez, M.A., Bilal, R.M., Shahid, M.A. and Ziaf, K. (2009). Effect of seed priming with NaCl on salinity tolerance of hot pepper (*Capsicum annuum* L.) at seedling stage, *Soil Environ.* **28**(1): 81–87,

Khan, A.L., Hamayun, M., Kang, S.M., Kim, Y.H., Jung, H.Y., Lee, J.H. and Lee, I.J. (2012). Endophytic fungal association via gibberellins and indole acetic acid can improve plant growth under abiotic stress: an example of Paecilomyces formosus LHL10.BMC Microbiol.**12**: 3.

Khan, M.I.R., Fatma, M., Per, T.S.,Anjum, N.A., Khan, N.A., (2015). Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. *Front. Plant Sci*. **6**: 462.

Kim, J.M., Matsui, A., Tanoi, K., Kobayashi, N.I., Matsuda, F. and Bashir, K. (2017). Acetate-mediated novel survival strategy against drought in plants. *Nat. Plants*. **3**: 17-97.

Lal, S.K., Kumar, S., Sheri, V., Mehta, S., Varakumar, P., Ram, B., Borphukan, B., James, D., Fartyal, D. and Reddy, M.K. (2018). Advances in seed priming. In 'Seed Priming: An Emerging Technology to Impart Abiotic Stress Tolerance in Crop Plants'. (Eds A Rakshit, HB Singh) pp. 41–50.

Llorens, E., González-Hernández, A.I., Scalschi, L., Fernández-Crespo, E., Camañes, G., Vicedo, B. and García-Agustín, P. (2020). Priming mediated stress and cross-stress tolerance in plants: Concepts and opportunities. In Priming-Mediated Stress and Cross-Stress Tolerance in Crop Plants; Elsevier: Amsterdam, The Netherlands, pp. 1–20.

Lobell, D.B. and Gourdji, S.M. (2012). The influence of climate change on global crop productivity. *Plant Physiol.* **160**(4): 1686–1697.

Lohani, N., Jain, D., Singh, M.B. and Bhalla, P.L. (2020). Engineering multiple abiotic stress tolerance in canola, Brassica napus. *Front. Plant Sci.* **11**: 3.

Ashraf, M. and Foolad, M.R. (2005). Pre-sowing seed treatment-A shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Adv. Agron.* **88**: 223–271.

Maas, E.V. and Grieve, C.M. (1990). Spike and leaf development in salt-stressed wheat. *Crop Science.* **30**: 1309–1313.

Maas, E. V. and Poss, J. A. (1989). Salt sensitivity of wheat at various growth stages. *Irrigation Sci.* **10**: 29–40.

Maas, E.V. and Grattan, S. (1999). Crop yields as affected by salinity. *Agron. J.* **38**: 55–110.

Mahajan, S. and Tuteja, N. (2005). Cold, salinity and drought stresses: an overview. *Archives Biochem. Biophy*. **444**(2): 139–58.

Meena, R.P., Sharma, R.K., Sendhil, R., Tripathi, S.C. and Chander, S. (2018). Quantifying water productivity using seed priming and micro irrigation in wheat (*Triticum aestivum*). *Wheat Barley Res*. **10**(1): 20–24.

Mohmed, M.F., Thalooth, A.T. and Khalifa, R.K.M. (2010). Effect of Foliar Spraying With Uniconazole and Micro Nutrients on Yield and Nutrients Uptake of Wheat Plants Grown under Saline Condition. *J. Am. Sci.* **6**(8): 398-404.

Muhsin, M., Nawaz, M., Khan, I., Chattha, M. B. and Khan, S. (2021). Efficacy of seed size to improve field performance of wheat under late sowing conditions. *Pakistan J. Agric. Res*. **34**: 247–254.

Munns, R. and Termaat, A. (1986). Whole-plant responses to salinity. *Func. Plant Biol.* **13**(1): 143-160.

Munns, R. and Tester, M. (2008). Mechanism of salinity tolerance. Ann. Rev. Plant Biol. **59**: 651–681.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant Cell Environ*. **25**: 239-250.

Naghashzadeh, M. (2014). Response of relative water content and cell membrane stability to mycorrhizal biofertilizer in maize. *Electronic J. Biol.* **10**(3): 68-72.

Nawaz, J., Hussain, M., Jabbar, A., Nadeem, G. A., Sajid, M., Subtain, M. U., and Shabbir, I. (2013). Seed Priming a technique. *Int. J. Agric. Crop Sci.* **6**: 1373.

Patade, V.Y.. Bhargava, S. and Suprasanna, P. (2009). Halopriming imparts tolerance to salt and PEG induced drought stress in sugarcane. *Agric. Ecosyst. Environ.* **134**: 24–28.

Petrov, V., Hille, J., Mueller-Roeber, B. and Gechev, T.S. (2015). ROS-mediated abiotic stressinduced programmed cell death in plants. *Front. Plant Sci.* **6:** 69.

Pirasteh-Anosheh, H., Emam, Y. and Ashraf, M. (2014). Impact of cycocel on seed germination and growth in some commercial crops under osmotic stress conditions. *Arch. Agron. Soil Sci.* **60**(9): 1277–1289.

Qin, F., Xu, H.I. and Ci, D. (2017). Drought stimulation by hypocotyl exposure altered physiological responses to subsequent drought stress in peanut seedlings. *Acta Physiol. Plant.* **39**: 1–15.

Rashid, A., Hollington, P. A., Harris, D. and Khan, P. (2006). On-farm seed priming for barley on normal, saline and saline-sodic soils in North West Frontier Province, Pakistan. *European J. Agron*. **24**: 276-281.

Rehman, A., Farooq, M., Cheema., Z.A. and Wahid, A. (2012). Seed priming with boron improves growth and yield of fine grain aromatic rice. *Plant Growth Regu*. **68**: 189–201.

Rehman, H.U., Nawaz, M.Q., Maqsood, S., Ahmad, Basra., Irfan, Afzal., Azra, Yasmeen and Hassan, F.U. (2014). Seed priming influence on early crop growth, phonological development and yield performance of linseed (*Linum usitatissimum* L.). *J. Int. Agric.* **13**: 990-96.

Rehman, H., Basra, S.M.A., Farooq, M., Ahmed, N. and Afzal, I. (2011). Seed priming with $CaCl_2$ improves the stand establishment, yield and some quality attributes in direct seeded rice (*Oryza sativa*). *Int. J. Agric. Biol. Engi.* **13**: 786–790.

Rodríguez, M. Canales, E. and Borrás-Hidalgo, O. (2005). Molecular aspects of abiotic stress in plants. *Biotechnol*. **22**: 1–10.

Roy, N. K. and Srivastava, A.K. (2000) Adverse effect of salt stress conditions on chlorophyll content in wheat (*Triticum aestivum* L.) leaves and its amelioration through pre-soaking treatments. *Indian J. Agric. Sci.* **70**: 777–778

Royo, A. and Abió, D. (2003). Salt tolerance in durum wheat cultivars. *Spanish J. Agric. Res*. **1**: 27–35.

Sako, K., Kim, J.M., Matsui, A., Nakamura, K., Tanaka, M., Kobayashi, M. and Yoshida, M. (2015). Ky-2, a histone deacetylase inhibitor, enhances high-salinity stress tolerance in Arabidopsis thaliana. *Plant Cell Physiol*. **57:** 776–783.

Saqib, M. and Qureshi, R. H. (1998). Combined effect of salinity and hypoxia on growth, ionic comoposition and yield of wheat line 234-1. *Pakistan J. Biol. Sci*. **1**: 167–169.

Sarlach, R. S., Sharma, A. and Bains, N. S. (2013). Effect on seed germination, yield parameers and grain yield. *Society Sci. Dev. Agric. Tech.* **8**(1): 109-112.

Seleiman, M.F., Almutairi, K.F., Alotaibi, M., Shami, A. and Alhammad, B.A. (2021). Nano-fertilization as an emerging fertilization technique: Why can modern agriculture benefit from its use? *Plants.* **10**: 2.

Seleiman, M. F., Kheir, A. M. (2018). Saline soil properties, quality and productivity of wheat grown with bagasse ash and thiourea in different climatic zones. Chemosphere, **193**: 538–546.

Shabala, S. (2013). Learning from halophytes: physiological basis and strategies to improve abiotic stress tolerance in crops. *Ann. Bot.* **112**: 1209-1221.

Shahid, M.A., Pervez, M.A., Balal, R.M., Ahmad, R., Ayyub, C.M., Abbas T. and Akhtar, N. (2011). Salt stress effcts on some morphological and physiological characteristics of okra (*Abelmoschus esculentus* L.). *Soil Environ.* **30**(1): 66-73.

Sharma, P.K. and Gupta, J.P. (1994). Effect of phosphorous on the yield of wheat at different growth stages. *J. Ind. Soc. Soil Sci.* **42**: 77-80.

Sikhondze, D.K. and Ossom, E.M. (2011). Impact of priming okra (*Abelmoschus esculentus* L.) seeds on seedling performance in Swaziland. *Adv. in Environ. Biol*.**5**: 1221–1228.

Singh, B.A., Gangwar, C.S., Singh, P. and Maurya, C.L. (2017). Effect of seed priming on quality parameters of wheat (Triticum aestivum L.) seeds harvested under irrigated & rainfed conditions. *J. Pharma. Phytochem.* **6**(4): 1646–1650.

Singh, K., Pandey, S.N. and Mishra, A. (2015). Preference of heavy metals accumulation, tolerance limit and biochemical responses of *Eichhornia crassipes* (Mart.) exposed to industrial waste water. *Int. J. Curr. Res*. **7**: 11818–11822.

Singh, S.(2015). Assessment of multiple tolerance indices for salinity stress in bread wheat (*Triticum aestivum* L.). *J. Agric. Sci.* **7**(3): 49-57.

Singh, S. and Singh, M. (2000). Genotypic basis of response to salinity stress in some crosses of spring wheat *Triticum aestivum* L. *Euphytica*. **115**: 209-214.

Taha, R.S., Seleiman, M.F., Alhammad, B.A., Alkahtani, J. and Alwahibi, M.S. (2021). Activated yeast extract enhances growth, anatomical structure, and productivity of Lupinus termis L. plants under actual salinity conditions. *Agron.* **11**: 74.

Taha, R.S., Seleiman, M.F., Shami, A., Alhammad, B.A. and Mahdi, A.H.A. (2021). Integrated application of selenium and silicon enhances growth and anatomical structure, antioxidant defense system and yield of wheat grown in salt-stressed soil. *Plants.* **10**: 1040.

Tanentzap, F., Stempel, A. and Ryser, P. (2015). Reliability of leaf relative water content (RWC) measurements after storage: Consequences for in situ measurements. *Bot*. pp. 93.

Tania, S.S., Hossain, M.M. and Hossain, M.A. (2019). Effects of hydropriming on seed germination, seedling growth and yield of bitter gourd. *J. Bangladesh Agric. Univ*. **17**(3): 281–287.

Taylor, A.G., Allen, P.S., Bennett, M.A., Bradford, J.K., Burris, J.S. and Mishra, M.K. (1998). Seed enhancements. *Seed Sci. Res.* **8**: 245-256.

Thomas, U.C., Varughese, K., Thomas, A. and Sadanandan, S. (2000). Seed priming—for increased vigour, viability and productivity of upland rice. *Leisa India*. **4**: 14.

Tilahun,T.F., Nigussie, D.R., Bayu, W. and Gebeyehu, S. (2013). Effect of hydro-priming and pre-germinating rice seed on the yield and terminal moisture stress mitigation of rain-fed lowland rice. *Agric. Forestry Fish*. **2**(2): 89-97.

Van Hulten, M., Pelser, M., van Loon, L.C., Pieterse, C.M.J. and Ton, J. (2006). Costs and benefits of priming for defense in Arabidopsis. *Proc. Natl. Acad. Sci.* USA, **103**: 5602–5607.

Vishwakarma, K., Upadhyay, N., Kumar, N., Yadav, G., Singh, J., Mishra, R.K. and Sharma, S. (2017). Abscisic acid signaling and abiotic stress tolerance in plants: A review on current knowledge and future prospects. *Front. Plant Sci.* **8**: 161.

Wahid, A., Perveen, M., Gelani, S., Shahzad, M.A. and Basra, S.M.A. (2007). Pretreatment of seed with H2O2 improves salt tolerance of wheat seedlings by alleviation of oxidative damage and expression of stress proteins. *J. Plant Physiol.* **164**: 283–294.

Xu, K. and Qiu, B.S. (2007). Responses of superhigh-yield hybrid rice Liangyoupeijiu to enhancement of ultraviolet-B radiation. *Plant Sci*. **172**: 139–149.

Yagmur, M. and Kaydan, D. (2008). Alleviation of osmotic strength of water and salt in germination and seedling growth of triticale with seed priming treatments. *African. J. Biotechnol*. **7**: 2156–2162.

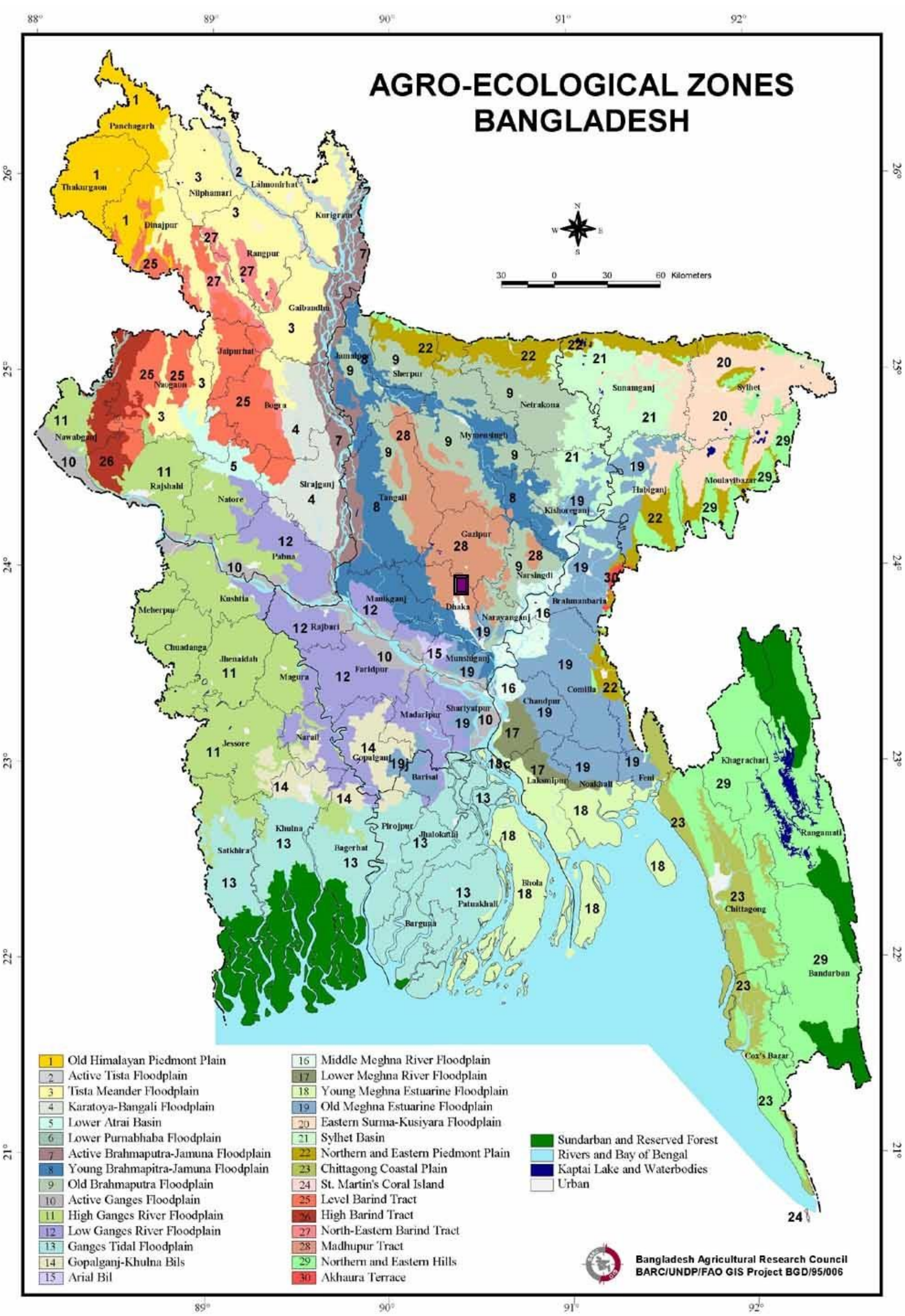
Younesi, O. and Moradi, A. (2014). Effect of priming of seeds of Medicago sativa 'bami' with gibberellic acid on germination, seedlings growth and antioxidant enzymes activity under salinity stress. *J. Hort. Res*. **22**: 167–174.

Zheng, H.C., Jin, H.U., Zhi, Z., Ruan, S.l. and Song, W.J. (2002). Effect of seed priming with mixed- salt solution on germination and physiological characteristics of seedling in rice (*Oryza sativa* L.) under stress conditions. J. *Zhejiang Univ. Agric. Life Sci*. **28**: 175-178.

Zou, P.; Li, K., Liu, S., Xing, R., Qin, Y., Yu, H., Zhou, M. and Li, P. (2016). Effect of chitooligosaccharides with different degrees of acetylation on wheat seedlings under salt stress. Carbohyd. Polym. **126**: 62-69.

APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

Appendix II. Analysis of variance of the data of germination and vigor index of wheat seed

Source of Variation	**DF**	Mean square of	
		Germination	Vigor index
Replication	4	1.54	0.67
priming	3	423.73*	71.56*
salt	2	4716.76*	1713.72*
priming*salt	6	18.97*	2.81*
Error	44	2.81	0.30
Total	59		

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix III. Analysis of variance of the data of plant height wheat at different DAS

Source of Variation	**DF**	Mean square of plant height			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	4	2.042	7.04	3.50	13.500
priming	3	54.612*	85.49*	429.59*	42.930*
salt	2	522.012*	1634.21*	1374.91*	134.521*
priming*salt	6	24.935*	15.64*	12.81*	4.182*
Error	44	1.133	3.41	7.14	2.500
Total	59				

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data of number of leaves plant^{-1}, leaf relative water content of wheat at different DAS

Source of Variation	DF	Mean square of		
		Number of leaves	Leaf relative water content	
		30 DAS	30 DAS	45 DAS
Replication	4	0.0084	7.042	2.04
priming	3	0.5601*	634.780*	1757.47*
salt	2	12.5152*	789.070*	976.99*
priming*salt	6	0.4377*	130.461*	278.24*
Error	44	0.0066	2.496	1.13
Total	59			

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of SPAD value of wheat at different DAS

Source of Variation	DF	Mean square of SPAD		
		30 DAS	50 DAS	70 DAS
Replication	4	1.0417	1.0417	2.1667
priming	3	32.6345*	15.3725*	17.9456*
salt	2	78.2208*	90.0009*	97.9305*
priming*salt	6	4.6596*	13.1902*	3.6130*
Error	44	0.6780	0.4962	1.0758
Total	59			

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of number of spike length, spikelets plant^{-1}, grains spike^{-1}, effective tiller pot^{-1}and 1000-grain weight

Source of Variation	**DF**	Mean square of				
		Spike length (cm)	**Spikelets plant^{-1} (no.)**	**Grains spike^{-1} (no.)**	**Effective tiller pot^{-1}**	**1000-grain weight (g)**
Replication	4	0.2017	0.0443	2.667	0.667	3.38
priming	3	2.5519*	4.8207*	85.109*	18.251*	50.25*
salt	2	39.5726*	29.4755*	986.190*	873.614*	2148.54*
priming*salt	6	1.4331*	1.2855*	13.590*	1.114*	0.82*
Error	44	0.0926	0.0870	1.576	0.303	1.56
Total	59					

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of grain yield, straw yield, biological yield and harvest index of wheat

Source of Variation	**DF**	Mean square of			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	4	1.04	0.2017	3.10	1.3649
priming	3	40.65*	2.5519*	111.78*	29.8527*
salt	2	1707.47*	39.5726*	7946.44*	53.9354*
priming*salt	6	3.86*	1.4331*	32.29*	9.6305*
Error	44	0.68	0.0926	0.98	1.2043
Total	59				

Ns: Non significant

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

PLATES

Plate 1. Picture showing wheat seedling germination at different level of priming

Plate 2. Picture showing seedling germination at different level of salinity on wheat plant