ENHANCEMENT OF SALT TOLERANCE CAPABILITY IN WHEAT THROUGH MAGIC GROWTH AND HYDROPRIMING

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CERTIFICATE

This is to certify that the thesis entitled **“ENHANCEMENT OF SALT TOLERANCE CAPABILITY IN WHEAT THROUGH MAGIC GROWTH AND HYDROPRIMING”** submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **NAZIR AHMED**, Registration No. **19-10190**under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

December, 2021
Dhaka, Bangladesh

(Prof. Dr. Md. Abdullahil Baque)
Supervisor

Dedicated to
My
Beloved Parents

ABBREVIATIONS AND ACRONYMS

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

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The Author

LIST OF CONTENTS

LIST OF CONTENTS (Cont’d)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ENHANCEMENT OF SALT TOLERANCE CAPABILITY IN WHEAT THROUGH MAGIC GROWTH AND HYDROPRIMING

ABSTRACT

The experiment was conducted under the laboratory conditions of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka from October 2020 to December 2020 to investigate the enhancement of salt tolerant capability in wheat through magic growth and hydropriming. In the 1st experiment seeds of wheat (BARI Gom30) were surface sterilized with 75% alcohol for 5 minutes. Wheat seeds were then pre-soaked in 0.5%, 1%, 1.5% and 2% magic growth solution and distilled water for 9 hours and untreated seeds were used as control treatment. Results showed that seed priming induces the germination percentage, growth parameters (shoot and root fresh weight, shoot and root length, shoot and root dry weight and vigour index) and water relation behaviours (relative water content, water retention capacity, water saturation deficit) of wheat. The highest germination percentage (81.94%), shoot and root length (193.00 mm and 192.25 mm, respectively), shoot and root fresh weight (121.20 and 120.45 mg, respectively), shoot and root dry weight (22.55 and 19.65 mg, respectively), vigour index (315.67), water retention capacity (11.38%), relative water content (92.06%) were obtained from seeds treated with 0.5% magic growth and then gradually decrease with increasing magic growth concentration. Highest water saturation deficit (16.25%) was obtained from 1.5%% magic growth and the lowest was obtained from seeds treated with 0.5% magic growth. In 2nd experiment primed (0.5% magic growth for 9 hours), hydro primed (distilled water for 9 hours) and non-primed seeds were placed under salinity stress condition induced by 0, 5, 10, 15 and 20 dSm^{-1} NaCl solution. Seeds treated with 0.5% magic growth showed better result regarding germination percentage, shoot and root length, shoot and root dry weight, relative water content, water retention capacity compared to hydro priming and control (non-primed) treatment and this value decreased with increasing concentrations of NaCl solution. Hydro priming also showed better result than non-primed seeds but not better than 0.5% magic growth priming solution. The result suggested that seeds primed with 0.5% magic growth for 9 hours considered as best priming concentration and next to hydropriming for salt tolerant capability in wheat.

CHAPTER I

INTRODUCTION

Wheat (*Triticumaestivum*) belongs to the Poaceae family, is one of the most important grain crops in Bangladesh. In Bangladesh, per annum demand for wheat is 7.70 m tons, but its production is only 1.15 m tons. The average production per hectare is only 3.38 tons (BBS, 2017).Wheat is a temperate cultivable cereal crop ranked second after rice mainly cultivated in the north and north-west region of Bangladesh. A huge amount of cultivable lands in the coastal belt remain fallow and the sole cropping pattern is fallow-Aman-fallow (Hasan *et al*., 2017). Inclusion of wheat in this traditional saline belt cropping pattern could be an effective means for optimizing land utilization to supplement the food production and nutritional deficit of the ever growing population of Bangladesh.

Soil salinity is one of the major limiting factors which directly affect plant physiology which causes severe reduction of crop production. World's 25% cultivable lands are salinity affected among 400 million ha of total land and the salt intrusion scenario is alarmingly increasing (Jisha *et al*., 2013).In Bangladesh the salinity affected area was 83.3 million ha in 1973, 102 million ha in 2000 and in 2009 it has reached up to 105.5 million ha and the area is being expanded with times being reported by Soil Resource and Development Institute (Farooq *et al*., 2006). Among abiotic stresses salinity is the most important stress, which adversely affects growth and yield characters of crop (Bakht*et al*., 2012). Soil salinity is one of dominant barriers which minimize the yield of crops (Yokoi *et al*., 2003). Salinity stress is very serious threat to agricultural productivity in arid and semi-arid area (Babu*et al*., 2012). Salinity in the arid and semi-arid region reduces the yield of major crops up to 50% (Dugasa*et al*., 2016). Salts increase soil osmotic potential (decrease water potential), causing water to move from areas of lower salt concentration (plant tissue) in the soil where salt concentration is higher (Horneck *et al*., 2007). Crop physiology is disturbed at cellular and plant level (Shahid*et al*., 2011) initially through osmotic effect, later on plant growth is suffered by toxic effect (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).

Salinity changes nutrient and water availability, lowers the quality of arable lands, and alters the structure of ecological communities. Salinity induced osmotic stress, the physiological equivalent of drought stress, typically reduces growth and photosynthesis in plants (Pasternak and Pietro, 1985; Datta *et al*., 2009). In saline soils, seeds with lower osmotic potential fail to absorb water; increase the accumulation of toxic ions (Na+ and Cl-) and finally there is a delay, decrease and disruption of seed germination (Ashraf and Foolad,2005). In general, growth reduction due to salinity is attributed to ion toxicity, nutrient imbalance and osmotic effect. Higher concentration of soluble salts in soil causes reduction in the germination percentage and delay in germination of seeds of many plant species (Greenway and Munns, 1980; Khan, 1992, Kumar *et al*., 2005). Seed embryo badly affected by higher salt concentration which result there is a delay and reduction of germination percentage of seed. Metabolism, physiological act and morphological feature of plant changed by soil salinity in and drastically reduce the growth and yield (Ashraf and Harris,2004). Percentage of germination, length of coleoptiles, length of root and seedling growth reduced by detrimental effect of salinity (Lallu and Dixit, 2005; Agnihotri*et al*.,2006). So an understanding of the physiological basis of seed germination under saline conditions is important since research is in progress to ameliorate the adverse effects of salinity on germination by employing certain chemical and biochemical agents.

Seed priming with salinity alleviating agents has positive effect on performance of plants in saline growth medium (Afzal *et al*., 2008). Seed priming is a technique in which seeds are exposed to low water potential, which reduce the hydration of seed. Halopriming 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). Seed priming induces the early emergence of seedlings through the regulation of metabolic processes in the early phases of germination under drought stress (Farooq *etal*., 2017). Seed priming can be performed through different methods such as hydro-priming (soaking in DW), osmo-priming (soaking in osmotic solutions such as PEG, potassium salts, e.g., KCl, K_2SO_4) and plant growth inducers (CCC, Ethephon, IAA) (Capron *et al*., 2000; Chiu *etal*., 2002). Seeds are soaked in low water potential solutions during priming and various inorganic salts, plant growth regulators and organic solutes are used as priming agents.Magic growth is a liquid fertilizer which may act as a growth promoter in agriculture. It can also be used a seed priming agent against salt stress. It is a unique enzyme based formulation on advanced herbal & biotechnological research. It can be applied at different stages to: 1) Increase yield, 2) Increase resistance to diseases, drought and salt stress, 3) Increase efficiency of nutrients uptake from the soil and their utilization and 4) Improve keeping quality of crops.

In Bangladesh, very few researches was conducted related to hydro priming and seed priming with magic growth andrelative information related to seed priming with osmotic priming agent inducing salinity tolerance in wheat or other crops. Therefore, the present research is undertaken with the following objectives:

1. To evaluate the effect of seed treatment with magic growth on germination behavior of wheat.
2. To evaluate the effect of magic growth on germination and vigor of wheat seed under salt stress.
3. To better understanding of the physiological mechanism involve during seed germination, seedling growth and water relation behavior under salt stress condition.

CHAPTER II

REVIEW OF LITERATURE

Salinity stress is a great problem in the coastal region of Bangladesh, where a vast area remains fallow for long time. Wheat is an important cereal crops in Bangladesh and it is a great source of carbohydrate and protein. The scientists of Bangladesh are conducting different experiments to adopt different crops in the saline area; wheat is one of them. Different treatments were applied before at different locations to overcome salt stress. Very limited research works have been conducted to adapt wheat in the saline area of Bangladesh. An attempt has been made to find out the performance of wheat at different levels of salinity. To facilitate the research works different literatures have been reviewed in this chapter under the following headings.

2.1 Salinity

Soil salinity emerging as a giant global issue adversely impacts agricultural productivity and sustainability. Salinity troubles appear under all climatic situations and can be considered as a result of both natural and human-induced actions. Generally speaking, saline soils appear in arid and semi-arid regions as rainfall here is not sufficient to fulfil the requirements of water in crops and mineral salts are leached out of the crop root-zone. The human-salinity connection is centuries long and records exist in history showing the failure of many civilizations due to increased salinity of agricultural fields, Mesopotamia (now Iraq) being the commonest known example.

2.2 Effects of salinity

Germination is vital process of plant life cycle. It is the determinant of the subsequent growth and yield indicatives of plants. For stressed environments, speedy germination and more stand establishment are the factors critical to crop production. Higher concentration of salts in seed planting area, fails the process of germination for maximum crops. The seeding depth of plants, lie within the top (10 cm) layer of soil and is the most saline zone (Esechie, 1995). Thus, seeds exhibit uneven germination and develop weaker seedlings. Salinity has shown negative effect on the germination and emergence of several crops such as wheat (*Triticumaestivum* L.) (Datta*et al*., 2009), barley (*Hordeumvulgare* L.) (Naseri*et al*., 2012), cabbage (*Brassica oleracea* L.) (Sarker*et al*., 2014), okra (*Abelmoschusesculentus* L.) (Dkhil*et al*., 2014), cowpea (*Vignaunguiculata* L. Walp.) (Thiam*et al*., 2013; El-Shaieny, 2015), celery (*Apiumgraveolens* L.) and radish (*Raphanussativus* var. radicula L.) (Sarker*et al*., 2014).

Literature says that wheat seeds tended to germinate with rate lower than normal and taken longer time when exposed to salt stresses of 125 mMNaCl (Afzal *et al*., 2008), 16 dSm^{-1} (Ghiyasi*et al*., 2008) and 12.5 dSm^{-1} (Akbarimoghaddam*et al*., 2011). The increased salinity levels increase the mean germination time but decrease the rate of germination. Decrease in germination percentage with rise of salinity levels (upto 200 mMNaCl) has been reported by Fuller *et al*., 2012. This fact is backed by the reason that increased concentrations of salt develop low osmotic potential in germination media which disturbs the imbibition process of seed, creating an enzymatic and hormonal imbalance in seed metabolome and finally deteriorating the food reserves of seed (Hasanuzzaman*et al*., 2013). Besides this, several plant and environment related factors also affect germination. These include age of seed, seed dormancy, seed coat hardness, seed polymorphism, seed vigour, moisture, temperature, gases, and light, etc. (Wahid *et al*., 2011).

El-Hendawy*et al*. (2011) proved that salinity did not affect final germination percentage, while seeds subjected to 80 and 160 mMNacl treatment. Salinity affected shoot growth more severely than root growth of seedlings. Height and dry weight of shoot of the genotypes ranked in the same order as their salt tolerance ranking in terms of grain yield, where as root dry weight did not. So, the measurement of shoot growth may be one of the effective criteria for screening wheat genotypes for salt tolerance at early growth stages.

Hameed *et al*. (2009) conducted an experiment with two wheat genotypes differing in salt tolerance and observed that the 3 days old wheat seedlings were subjected to 5, 10 and 15 dSm^{-1}NaCl salinity for 6 days, application of low salinity (5dSm^{-1}) growth was suppressed even in tolerant genotype. The cv. Lu-26, exhibited a better protection mechanism against salinity as indicated by lower salt induced proteolysis, higher biomass accumulation and protein contents than the relatively sensitive cv. Pak-81.

Datta*et al*. (2009) undertook an experiment with five varieties of wheat *viz*., HOW-234, HD-2689, Raj-4101, Raj-4123, and HD-2045 varying the salinity levels to (0, 25, 50, 75, 100, 125, 150mM NaCl). They observed that different level of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 125mM. Fresh weight and dry weight of root and shoot were reduced significantly with subsequent treatment. Maximum germination was found in variety HD2689 in all the tratments and maximum inhibition was found to be in case of HOW234 variety at 150mM salilnity level.

Rahman *et al*. (2008) conducted an experiment with four cultivars of wheat (*Triticumaestivum* L.) to NaCl salinity treatments measuring 0.00, -2.457, -4.914, and -14.742 bars at germination and early seeding growth stage. They observed that water uptake and germination decreased in all cultivars. Increased salt concentration also affected the early seedling growth. Among the cultivars under investigation Zarlasht cultivar appeared to be more sensitive at germination stage.

Tammam*et al*. (2008) conducted a pot experiment with salt tolerance wheat cv. Banysoif-1. Seedlings were irrigated by different saline waters (0, 60,120,180,240 and 320 mMNaCl). They observed that fresh and dry weight of roots was unchanged up to the level of 120 mMNaCl then a significant reduction obtained at 240 and 320 mMNaCl. In shoots and spikes, dry matters were either unchanged or even stimulated to increase toward 180 mMNaCl then a quick reduction was observed.

Rajpar and Sial (2002) conducted a pot experiment with eight varieties of wheat such as Khar-chia-65, Anmol, NIAB-20, PAI-81, TW161, Bakhtwar, KTDH-19 and SARC-l. They observed that under salinity condition up to EC 19 dSm^{-1}, plant height, shoot dry weight and root length were decreased.

Khan (2007) conducted an experiment and observed that maximum plant heights, shoot fresh and dry weight were high at control salinity level and at high salinity level ($10dSm^{-1}$) had a negative effect on these parameters. Yield and yield components of various genotypes were significantly reduced due to the exposure of plants to various salinity levels. Among genotypes, SR-40 and SR-23 performed better than the other genotypes under study when exposed to various salinity levels.

Islam and Salam (1996) conducted a pot experiment. The variety Pokkali, BINA 19, BINA 13 and IRATOM 24 were grown in nutrient solutions with different salinity levels (control, 0.9% NaCl). The biomass of BINA 19 was not affected with increased salinity. The biomass of Pokkali and IRATOM 24 decreased with increase in salinity.

Mohamad *et al*. (1995) conducted an experiment with five wheat lines (PK-15869, PK-15885, PL-16171, PK-16172 and PK-16187) under saline condition. These lines were tested for salt tolerance in the presence of specific ions (Na^+, Ca^{++}, Cl^-, SO_4^{--}). The seeds were germinated on agar medium containing varying salt concentrations (EC 0, 5, 10, 20, 25 and 30 dSm^{-1}). The genotypes PK-16171 showed the highest percentage germination, shoot length, plant fresh weight and dry matter yield under different salinity levels. Fresh and dry weights of plants were reduced in the presence of salinity in majority of the trails. Two genotypes, PK-15885 and PK-16171 showed salt tolerance.

2.3 Effect of seed priming against salt stress

Tolerance and susceptibility also cause variations in germination of different cultivars. The crop production under saline conditions is highly dependable on rapid and uniform seed germination and early seedling establishment. With the improved understanding of germination process, seed based methods are developed to alter this process which are applicable at agricultural level. These methods are known as 'seed enhancement techniques'. Commonest of all is the method called seed priming (Bewley*et al*., 1997; Paparella*et al*., 2015). Seed priming involves an initial exposure to an evoking factor which increases the plant tolerance to stress which it in future met with stress (Beckers and Conrath, 2007; Tanou*et al*., 2012).

Seed priming is of many types depending upon the priming material, which includes hydro-priming (continuous or successive addition of a definite amount of water to the seeds), osmo-conditioning or osmo-priming (exposing seeds to relatively low external water potential), halopriming (pre-sowing soaking of seeds in salt solution), hormonal priming (priming solutions containing the limited amount of growth regulators or hormones), nutripriming (seeds are soaked in solutions containing the plant growth-limiting nutrients instead of being soaked just in water), bio-priming (coating of seeds with biocontrol agents), redox priming (it represents the redox state of cell and regulates the key processes in growth and development as well as stress tolerance in response to any external stimuli; plants modify their redox state, and the degree change is dependent on the nature of the stimulus itself, the dose and the time to which the tissue is exposed as stated by Miller *et al*. (2009), solid matrix priming (mixing seeds with a solid or semisolid material and measured amount of water) (term was coined by Taylor *et* *al*., 1988), and pre-sowing soaking (soaking of seeds either in water or in any solution of low water potential before sowing) (Ashraf and Foolad, 2005).

Aymen*et al.* (2014) conducted an experiment to evaluate the effects of NaCl priming on growth traits and some biochemical attributes of safflower *(Carthamustinctorius* L. cv Safola) in salinity conditions. Seeds of safflower were primed with NaCl (5 g L^{-1}) for 12 h in 23°C. Primed (P) and non primed (NP) seeds were directly sown in the field. Experiments were conducted using various water concentrations induced by NaCl (0, 3, 6, 9 and 12 g L^{-1}) in salinity experiment. They found that growth (plant height, fresh and dry weight) and biochemical (chlorophyll, proline and proteins content) of plants derived from primed seeds were greater of about 15 to 30% than that of plants derived from non primed seeds.

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

Rastin*et al.* (2013) conducted an experiment to evaluate the effect of seed priming treatments on the seed quality of red bean. The first factor was primary seed priming, in which seeds were or were not treated with water, for 14 hours. The second factor was complementary seed priming which was conducted after drying the seeds treated in the first step and water, 100 ppm KCl, 0.5% $CaCl_2.2H_2O$, 50 ppm KH_2PO_4 and 20 ppm GA_3 were used to treat seeds for 14 hours. They found that primary seed priming had no significant effect on none of the measured traits but complementary seed priming significantly affected plant dry matter, grain yield, 100 grain weight and the number of pods. The highest plant dry matter (53.06 g) and the highest grain yield (5.98 t/ha) were achieved when seeds were first treated with water (as the primary seed priming) and after drying were treated with GA_3 (as the complementary seed priming).

Abdoli (2014) reported that germination and early growth under prevailing environmental conditions improves by seed priming technique. Their result showed that all the priming treatments significantly affect the fresh weight, shoot length, number of roots, root length, vigor index, time to start emergence, time to 50% emergence and energy of emergence of forage maize.

Menon *et al.* (2013) conducted an experiment on seed priming with boron to observe the efficacy of priming on germination and growth related attributes of the broccoli seedlings. Broccoli seeds (cultivar Marathon) were soaked in boric acid solution at 0.01, 0.05, 0.5 and 1% (w/v) for 18 hours. Seeds were also soaked in distilled water (hydropriming) and unprimed seeds were taken as control. The results showed that Germination percentage (GP), Mean germination time (MGT), Germination index (GI), Seedling vigor index (SVI), Chlorophyll content, Shoot and root related attributes were significantly influenced by primed seeds as compared to unprimed seeds. The highest germination index (6.289), seedling vigor index (1753.3), chlorophyll content (4.137 mg ml^{-1}) and less mean germination time (3.23 days), maximum length of shoot (5.97 cm), root (11.57 cm), weight of the shoot (15.35 g) and root (2.68 g) were observed from the treatment where seeds were primed with boron solution at the lowest concentration of 0.01%.

Shabbir*et al.* (2013) conducted a field experiment to investigate the effect of different seed priming agents on growth, yield and oil contents of fennel during winter 2010-11. Priming techniques used in the experiment were hydropriming with distilled water, osmopriming with $CaCl_2$ (2.2%), KCl (2.2%), moringa leaf extract (3.3%), salicylic acid (50ppm) and ascorbic acid (50ppm). Unprimed seeds were used as control treatment. They found that priming techniques significantly affected the parameters relating to seedling emergence. The $CaCl_2$ and KCl treatments showed exactly similar results for time taken to start seedling emergence (TTSE) as both took minimum TTSE (7 days). Mean emergence time and time taken to 50% seedling emergence were minimum in $CaCl_2$ (2.2%) treatment. Highest final emergence percentage and germination index were also recorded when seeds were primed with $CaCl_2$ (2.2%).

Short term seed priming with a low NaCl concentration also increases germination rate, field emergence and acquired stress tolerance (Nakaune*et al.,* 2012). Hydropriming and hydropriming along with proline can be used as a safe priming method for improving seed germination and growth of *Vignaradiata* seedlings at low temperature and also allowing fast repair of injuries caused by stress. More uniform germination and emergence were observed in primed seeds on canola *(Brassica compestris)* (Zheng *et al.,* 1994), wheat *(Triticumaestivum)* (Nayyar*et al.,* 1995). who described improved germination rate and percentage in seeds subjected to hydropriming and seed hardening for 24 h (Farooq *et al.,* 2006).

Osmotic seed priming of maize caryopses resulted in more homogenous and faster seed germination as compared to the control was reported by Fotia*et al.* (2008). Priming with KNO_3 can be used to increase watermelon germination and in tomato, seed priming with KNO_3 increased germination percentage, germination index, root length, shoot length and seedling fresh weight (Nawaz *et al*., 2011). It was reported that osmo and hydropriming of chickpea seeds with mannitol and water alleviated the adverse effects of water deficiency and salt stress on seedling growth. The treatment of seeds with water, 2 and 4% mannitol increased the length and biomass of roots and shoots of chickpea seedlings as compared to non-primed controls under salt stressed conditions (Kaur *etal.*, 2005).

Priming of seeds with water promoted seedling vigour, yield and crop establishment of chickpea, maize and rice in India (Harris *et.al.,*2004). It is well documented that salinity reduces the germination as well as seedling growth in crop plants and seed priming ameliorates salinity affects during early seedling growth (Ashraf and Harris, 2004).

Rouhi*et al.* (2011) also suggested that different priming techniques (hydro and osmo priming) had a varying effects on germination on each of the four grass species *(Bromusinermis, Festucaarundinacea, Agropyron e/ongatum* and *Festucaovina)* and the result showed that, for most evaluated germination parameters, osmopriming treatment (with PEG) was more useful technique to reduce abiotic stress than hydropriming treatment.

Although priming improves the rate and uniformity of seedling emergence and growth particularly under stress conditions, the effectiveness of different priming agents varies under different stresses and different crop species (Iqbal and Ashraf, 2005). Patade*et al.,* (2009) suggest that salt priming is an effective pre-germination practice for overcoming salinity and drought induced negative effects in sugar-cane. Farhoudi and Sharifzadeh (2006) while working with canola reported salt priming induced improvement in seed germination, seedling emergence and growth under saline conditions

Musa *et al.* (1999) reported that overnight priming of chickpea seeds gave better crop production in Bangladesh. Priming with H_2O_2 failed to improve emergence and seedling growth in rice cultivars which is inconsistent with Wahid *et al.* (2007) who reported improved salt tolerance in wheat by alleviation of salt stress and oxidative damage by H_2O_2 pre-treatment.

Harris *et al*. (2004) reported that higher plant dry weight and seed yield following seed priming. The increase in the dry matter and grain yield of chickpea was due to better emergence and better performance per plant. In basil *(Ocimumbasilicum* L.) under saline conditions, the seedling vigor, germination percentage and seedling dry weight was found to increase due to hydropriming (Farahani and Maroufi, 2011).

Sivritepe*et al.*(2003) evaluate the effect of salt priming on salt tolerance of melon seedling and reported that total emergence and dry weight were higher in melon seedlings derived from primed seeds and they emerged earlier than non-primed seeds. They also observed that total sugar and proline accumulation and prevented toxic and nutrient deficiency effects of salinity because less Na but more K and especially Ca was accumulated in melon seedlings.

Maiti*et al*. (2009) studied the effect of priming on seedling vigour and productivity of tomato, chilli, cucumber and cabbage during post-rainy seasons demonstrating that priming improved germination and seedling development and yield of these vegetable species. Seed priming significantly improved the germination rate and vigour of the mungbean seedlings (Umair*et al.,* 2010). It is also reported that seed priming improve the antioxidant enzymes activity which decrease the adverse effects of Reactive Oxygen Species (ROS) (Del Ryo *et al.,* 2002).

Afzal *et al.* (2005) also found that the priming-induced salt tolerance was associated with improved seedling vigor, metabolism of reserves as well as enhanced K^+ and Ca^{2+} and decreased Na^+ accumulation in wheat plants. Primed crops grew more vigorously, flowered earlier and yielded higher. This technique used for improvement of germination speed, germination vigour, seedling establishment and yield (Talebian*et al*., 2008).

It has been reported that primed seeds showed better germination pattern and higher vigour level than non- primed.It has been also reported invigorated seeds had higher vigour levels (Ruan*et al.*, 2002b), which resulted in earlier start of emergence as high vigour seed lots performed better than low vigour ones (Hampton and Tekrony, 1995).

Seed priming techniques such as hydropriming, hardening, osmo conditioning, osmo hardening and hormonal priming have been used to accelerate emergence of roots and shoots, more vigorous plants, and better drought tolerance in many field crops like wheat (Iqbal and Ashraf, 2005), chickpea Kaur *et al.,*(2002), sunflower (Kaya *et al.*, 2006) and cotton (Casenave and Toselli, 2007).

Fujikura *et al.* (1993) presented hydropriming as a simple and inexpensive method of seed priming and according to Abebe and Modi (2009), it is a very important seed treatment technique for rapid germination and uniform seedling establishment in various grain crops. Priming of seeds with water promoted seedling vigor, yield and crop establishment of chickpea, maize and rice in India.

Harris *et al.* (2004) also found that hydropriming enhanced seedling establishment and early vigour of upland rice, maize and chickpea, resulting in faster development, earlier flowering and maturity and higher yields.

Chiu *et al.* (2006) reported that KNO_3 effectively improved germination, seedling growth and seedling vigour index of the seeds of sunflower varieties

Under salinity stress, germination percentage and germination index decreased significantly, and also there is a decrease in chlorophyll a, chlorophyll b, and carotenoid content in maize. During germination, seed priming induces metabolic changes that help in better acclamation under salinity stress in maize (Sali*et al.*, 2015).

Anaya *et al*. (2015) studied the seed priming effect with salicylic acid on Viciafaba under different levels of salt stress and found that 0.25mM SA concentration significantly improved the germination percentage and speed.

Seed primed with CaCl2 followed by KCl induces salt tolerance in rice cultivar that is revealed by enhanced germination efficiency, seedling growth, and dry weight under saline medium (Afzal *et al*., 2012).

Jafar*et al*., (2012) tested the potential of seed priming techniques to improve the performance of wheat varieties (SARC-1 and MH-97) in saline conditions. Seeds were soaked in solutions of ascorbate (50 mg/l; ascorbate priming), salicylic acid (50 mg/l; salicylicate priming), kinetin (50 mg/l; kinetin priming) and $CaCl_2$ (50 mg/l; osmopriming), simple water (hydropriming) for 12 hrs; in addition, untreated seeds were also taken as control. Results showed that seed priming treatments substantially improved the stand establishment; osmopriming (with $CaCl_2$) was at the top.

High concentration of NaCl reduced the seed germination in wheat cultivars (Akbari *et al*., 2007). Seed treated with H_2O_2 showed improved salt tolerance in wheat cultivars (Wahid *et al*., 2007). Mustard seed primed with water, $CaCl_2$, and abscisic acid exhibited higher germination, and crop raised from primed seed contains high dry weight and chlorophyll content under common salt and PEG stress (Srivastava *et al*., 2010).

Iqbal and Ashraf (2005) examined the effect of pre-sowing chilling and hydropriming of seeds on performance of two wheat varieties and found that chilling was very effective in increasing germination rate and subsequent growth when compared with hydropriming and control under salt stress.

Hydropriming and KNO_3 treatment significantly improved germination and seedling growth under salinity and water deficit stress (Kaya *et al*., 2006).

Halopriming enhances the growth under salt and drought stress in sugarcane cultivars (Patade*et al*., 2009).

Yagmur and Kaydan (2008) studied the effects of seed priming treatments with 0.5% KH_2PO_4 and water on germination and seedling characters of hexaploid triticale in different osmotic potential of NaCl and PEG solutions. They concluded that priming treatments were effective in improving germination percentage and seedling growth and hydropriming was found very effective in improving germination and seedling growth in low stress. Water soaked seeds exhibited higher grain and straw yield than non-primed seed under salinesodic condition in barley (Rashid *et al*., 2006).

Among various environmental stresses, soil salinity has become a critical problem worldwide due to its dramatic effect on plant physiology and performance (Ahmad *et al*., 2012). These environmental stresses contribute significantly in reduction of crop yield below the maximum potential yield (Waraich*et al*., 2011; Abbas *et al*., 2013). Salinity delayed the germination events, resulting in reduced plant growth and final crop yield (Azzedine*et al*., 2011; Basiri*et al*., 2013). Shoot and root growth inhibition is a common response to salinity. The dry matter accumulation of root shoot system of wheat cultivar showed marked decreased as the salinity level was increased (Radi*et al*., 2013).

Patade*et al*. (2011) and Ansari and Sharif-Zadeh (2012) reported a significant reduction in the germination percentage; seed reserve utilization as well as growth of rye. Earlier, Rouhi*et al*. (2011) and Ansari and Sharif-Zadeh (2012) had shown relation to seed performance, germination percentage and seedling indices. Decline in seed reserve utilization, seedling growth and different indices of seeds under stress conditions were also reported for wheat (Soltani*et al*., 2006), and mountain rye (Ansariand Sharif-Zadeh(2012).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the enhancement of salt tolerance capability in wheat through magic growth and hydropriming. This chapter includes materials and methods regarding short description of the experimental site, temperature and humidity of the laboratory room, experimental materials, treatments and design, methods of the study, data calculation procedure and data analysis those were used in conducting the experiment that are presented under the following headings.

3.1 Experimental site and period

This study was implemented at the laboratory of the Department of Agronomy which is situated in the Central Laboratory, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, during the period from October 2021 to December 2021. During the experimentation, the temperature and relative humidity is presented in Appendix I. It was situated in 24.09°N latitude and 90.26°E longitudes.

3.2. Materials used for the experiment

In this experiment, seeds of the wheat variety BARI Gom 30 were collected from Bangladesh Agricultural Research Institute. The collected seeds were free from all types of visible defects, disease symptoms and pest infestations. This seeds were used as experimental material. Two priming chemicals Distilled water and magic growth were used during the study. In this experiment magic growth was used as a priming agent which helps to mitigate salinity stress. Different equipment such as growth chamber, electric balance, Petri dish, filter paper, micro pipette, electric balance, oven, paper bag, wash bottle, beaker, forceps etc. were used for this study.

3.2.1 Characteristics of BARI Gom 30

- It is a short duration crop
- Crop duration 102 to 108 days
- It is tolerant to leaf rust and leaf spot disease (blight)
- It is heat tolerant crop

3.2.2 Magic growth

Magic growth is a liquid fertilizer invented by Md. Arif Hossain Khan, Joint Director (Seed Marketing), Bangladesh Agricultural Development Corporation (BADC) which may act as a growth promoter in agriculture. It can also be used a seed priming agent against salt stress. It contains 10.51% total nitrogen, 5.58% phosphorus, 6.33% potassium, 0.10% Sulphur, 0.16%zinc, 0.04% copper, 0.006% iron, 0.006% manganese, 0.25% boron, 0.07% calcium and 0.007% magnesium, p^H=1.0.

3.3 Chemicals for seed priming

Magic growth and distilled water were used as priming agents. Magic growth was also used as mitigating agent against salinity stress.

3.4. Design and treatment of the experiment

Two different experiments were conducted in Completely Randomized Design (CRD) with three replications to achieve the desired objectives.

3.5 Experimental details

The experiment comprises of

1. In the first experiment, six levels of priming treatments including control *viz*. non-primed seeds, seeds primed with magic growth concentration at the rated of 0.5%, 1%, 1.5%, 2% and seeds primed with distilled water (hydro priming)

2. In the second experiment, three treatments (including control) *viz*. control, magic growth and hydro priming against five levels of salinity stress *viz*. 0 dSm^{-1} NaCl, 5 dSm^{-1} NaCl, 10 dSm^{-1} NaCl, 15 dSm^{-1} NaCl, and 20 dSm^{-1} NaCl.

3.6 Experiment-1: Study on the germination behavior of wheat at different concentrations of priming agents (magic growth and distilled water).

3.6.1 Weight of seeds

The 200 g seeds were weighed from the total seed from BARI Gom 30 variety to avoid the unnecessary loss of seeds. Remaining seeds were kept in refrigerator at airtight condition to protect from external damage.

3.6.2 Surface treatment

All seeds were surface sterilized with 75% alcohol for 5 minutes then sterilized seeds were rinsed 2 minutes with distilled water for 3 times to reduce the effect of alcohol from the seed surface. Then, seeds were dried in room temperature to remove excess moisture and retain the normal condition.

3.6.3 Treatments

The seeds of BARI Gam 30 were treated with six priming treatments including control as follows:

1. T_0 = Control (non-primed seeds)
2. T_1= Seeds primed with 0.5% magic growth concentration for 9 hours
3. T_2= Seeds primed with 1% magic growth concentration for 9 hours
4. T_3= Seeds primed with 1.5% magic growth concentrationfor 9 hours
5. T_4= Seeds primed with 2% magic growth concentrationfor 9 hours
6. T_5= Hydro priming (primed with distilled water)for 9 hours

Every priming media excluding control were prepared in distilled water and duration of soaking for hydro and nutrient priming were 9 hours (Kheya, 2018). After soaking seeds were primarily dried by kitchen tissue paper and then air dried, placed in Petridish. For each replication 30 seeds were placed in 12.5 cm Petridish on a layer of filter paper no. 102 moistened with 8 ml of distilled water.

3.6.4 Preparation of priming solutions

a) Magic growth preparations (0.5%, 1%, 1.5% and 2%)

The 0.5% magic growth solution was prepared by mixing 1.25 ml of magic growth at 250 mL distilled water. Similarly, 2.5 mL, 3.75 mL, 5 mL magic growth was mixed with 250 mL of distilled water to prepare 1%, 1.5% and 2% solution of magic growth, respectively.

b) Distilled water

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

3.6.5 Priming technique

Magic growth priming and hydro priming was done for BARI Gom 30 variety. Surface sterilized seeds were sub divided into three parts such as one for distilled water priming, another for magic growth priming and last one for control (non-primed). For magic growth priming seeds were divided into four parts and soaked in 0.5%, 1%, 1.5% and 2% magic growth separately and hydro priming seeds are soaked in distilled water for 9 hours. Different petridish with cover were used for avoiding evaporative loss. After 9 hours all the seeds were rinsed from water at same time. The primed seeds were rinsed with distilled water for 3 times carefully and then wiped out with tissue paper to remove excess water. After that all seeds are separately air dried for 72 hrs to back the normal condition.

3.6.6 Experimental set up

Initially, thirty seeds were selected randomly from each treatment and then place them in a 120 mm diameters petridishes and whatman no.1 papers were used as growth media. Whatman no.1 was kept saturated by spraying distilled water. All petridishes were placed at the laboratory room maintaining room temperature 25˚C under normal light which helps to faster germination of wheat seeds. This process was continued for 10 days. Emergence of 2 mm radicle indicates as germination occurred. Every 24 hours interval germination process was observed and germination progress was recorded as data for next work. Shorter, thicker and spiral formed hypocotyls and stunted primary rooted seedlings were considered as abnormal seedlings (ISTA, 2003). Abnormal, rotted, dead and seed attacked by fungus were taken off by using forceps very carefully at time of data recorded. At 10 day of germination five samplings from each treatment were selected randomly. Then root and shoot were separated and root and shoot weight and length of fresh plants were taken by using electric balance and data were recorded. Then root and shoot of each treatment were emerged in distilled water separately and cover all the petridishes by using a thick cloth to avoid sunlight which helps to reduce evaporative loss. After 24 hours, root and shoots were picked from water and wiped out by tissue paper. Then turgid weight of root and shoot from each treatment were taken separately and data recorded. Then root and shoot were packed in brown paper separately for oven dry. Then seedlings were dried in oven at 75^0C for 72 hours. After that oven dry weight root and shoot were taken carefully and data were recorded.

3.6.7 Achievement from the first experiment:

From the first experiment, 1.25 ml solution of magic growth gave the best result. So, 1.25 ml magic growth mixed with 250 ml of distilled water (0.5% magic growth) solution was used for the next experiment to evaluate best result under salt stress condition.

3.7 Experiment-2: Study on the germination behavior of primed seed under different salt stress condition

3.7.1 Weight of seeds

The 200 g seeds were weighed from the total seed from BARI Gom 30 variety to avoid the unnecessary loss of seeds. Remaining seeds were kept in refrigerator at airtight condition to protect from external damage.

3.7.2 Surface treatment

All seeds were surface sterilized with 75% alcohol for 5 minutes then sterilized seeds were rinsed 2 minutes with distilled water for 3 times to reduce the effect alcohol from the seed surface. Then, seeds were dried in room temperature to remove excess moisture and retain the normal condition.

3.7.3 Treatments

Three treatments were applied separately for BARI Gom 30 against 5 salinity stress including control which was as follows:

1. P_0 = Control (no seed priming)
2. P_1 = Magic growth (seeds primed with 0.5% magic growth concentration)
3. P_2 = Hydropriming (seeds primed with distilled water)

Here, 5 levels of salinity stress including control was (i) $S_0 = 0$ dSm^{-1}NaCl, (ii) $S_1 = 5$ dSm^{-1} NaCl, (iii) $S_2 = 10$ dSm^{-1} NaCl, (iv) $S_3 = 15$ dSm^{-1} NaCl and (v) $S_4 = 20$ dSm^{-1} NaCl

3.7.4 Priming solutions and time

The 0.5% of magic growth solution and distilled water used for BARI Gom 30 due to its best performance in the first experiment. Seeds were soaked in 0.5 magic growth solution and distilled water for 9 hours.

3.7.5 Preparation of priming solutions

a) Magic growth solutions (0.5%)

The 0.5% magic growth solution was prepared by dissolving 1.25 ml of magic growth at 250 ml distilled water by using a stirring machine.

b) Distilled water

Distilled water was collected from Agricultural Chemistry laboratory of Sher-e-Bangla Agricultural University.

3.7.6 Preparation of salinity stress solutions

Salt (NaCl) solutions (5%, 10%, 15% and 20%): 0.731 g of sodium chloride (NaCl) was dissolved in 250 ml of distilled water to prepare 5% solution of salt (NaCl). Similarly, 1.436 g, 2.18 g, 2.925 g sodium chloride (NaCl) was dissolved in 250 ml of distilled water to prepare 10%, 15% and 20% solution of NaCl, respectively.

3.7.7 Priming technique

Seeds of a sub-sample were soaked in distilled water for hydropriming and seeds of another sub-samples were pretreated with magic growth for osmo priming at a concentration of 1.25 ml for 9 hours, respectively. Priming was done in different petridishes covered with lids to prevent evaporation loss. All seeds were removed from the priming solution at the same time. The primed seeds were rinsed thoroughly with distilled water for three times and dried lightly using blotting paper and finally air dried near to original weight (Umair*et al.*, 2011) in room temperature for 24 hours back to the original moisture level.

3.7.8 Experimental set up

Initially, thirty seeds were selected randomly from each treatment and then place them in 120 mm diameters petridishes and whatman no.1 papers were used as growth media. Whatman no.1 was kept saturated by spraying NaClsolutions. Seeds were kept in different petridishes and all seeds were sprayed separately by (5 dSm^{-1}, 10 dSm^{-1}, 15 dSm^{-1} and 20 $^{-1}$) NaClseparately. Here, NaCl was used as salinity stress inducing agent. All petridishes were placed at the laboratory room maintaining room temperature 25^0C under normal light which helps to faster germination of wheat seeds. This process was continued for 10 days. Emergence of 2 mm radicle indicates as germination occurred. Every 24 hours interval germination process was observed and germination progress was recorded as data for next work. Shorter, thicker and spiral formed hypocotyls and stunted primary rooted seedlings were considered as abnormal seedlings (ISTA, 2003). Abnormal, rotted, dead and seed attacked by fungus were taken off by using forceps very carefully at time of data recorded. At 10 day of germination five saplings from each treatment were selected randomly. Then root and shoot were separated and root and shoot weight and length of fresh plant were taken by using electric balance and data recorded. Then root and shoot of each treatment were emerged in distilled water separately and cover all the petridish by using a thick cloth to avoid sunlight which helps to reduce evaporation loss. After 24 hours root and shoots were picked from water and wiped out by tissue paper. Then turgid weight of root and shoot from each treatment were taken separately and data recorded. Then root and shoot were packed in brown paper separately for oven dry. Then seedlings were dried in oven at 75^0C for 72 hours. After that oven dry weight of root and shoot were taken carefully and data were recorded.

3.8 Data collection

Data on seedling emergence for both the experiments were collected from 1 to 10 days after seed placement. Normal seedlings were counted and percent of seedling emergence was recorded upto 10 days after placing of seeds. Seedling mortality was also counted upto 10 days after seed placing. The seedlings were washed with tap water and excess water was removed with tissue paper.

The following data were collected:

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

3.9 Parameter measurement

The data referring to following characters were recorded from each Petridish. Data were collected on the following parameters-

3.9.1 Germination percentage

The number of sprouted and germinated seeds was counted daily commencing. Germination was recorded at 24 hours 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 using following formula:

Rate of germination (%) = (Total Number of normal seedlings/Total number of seed placed for germination) × 100 (Othman *et al*., 2006).

3.9.2 Shoot length (mm)

The shoot length of five seedlings from each petritdish was measured finally at 10 days after placement. Measurement was done using the unit millimeter (mm) by a meter scale.

3.9.3 Root length (mm)

The Root length of five seedlings from each petri dish was recorded finally at 10 days after placement. Measurement was done using a meter scale and unit was expressed in millimeter (mm).

3.9.4 Seedling length (mm)

Seedling length was measured in the 10th day using millimeter scale by summing shoot length and Root length.

3.9.5 Dry weight of shoot and root (g)

The dry weight of shoot and root of the five seedlings from each petridish was measured at finally at 10 days after placement. Dry weight was recorded by drying the sample in an oven at 70°C till attained a constant weight. Then the weight was converted to miligram (mg).

3.9.6 Relative water content (%)

Relative water content was measured using following formula:

Relative water content (RWC) (%) = {(Fresh weight-Dry weight)/ (Turgid weight-Dry weight) ×100 (Smart, 1974).

3.9.7 Water saturation deficit (%)

Water saturation deficit was recorded using following formula:

Water saturation deficit (WSD) (%) = 100- Relative water content (Sangakkara*et al.*, 1996).

3.9.8 Water retention capacity

Water retention capacity was measured using following formula: Water retention capacity (WRC) = Turgid weight/ Dry weight (Sangakkara*et al.*, 1996).

3.9.9 Vigor index

Vigor index was calculated using following formula:

Vigor index = (Total germination × seedling length in mm)/100 (Abdul-Baki and Anderson, 1970).

3.10 Statistical analysis

The data obtained for different parameters were statistically analyzed to observe the significant difference among the treatments. The mean value of all the parameters was calculated and analysis of variance was performed. The significance of difference among the treatments means was estimated by the least significant difference (LSD) test at 1% level of significance. A computer software MSTAT-C was used to carry out the statistical analysis. Drawings were made using Excel software.

CHAPTER IV

RESULTS AND DISCUSSION

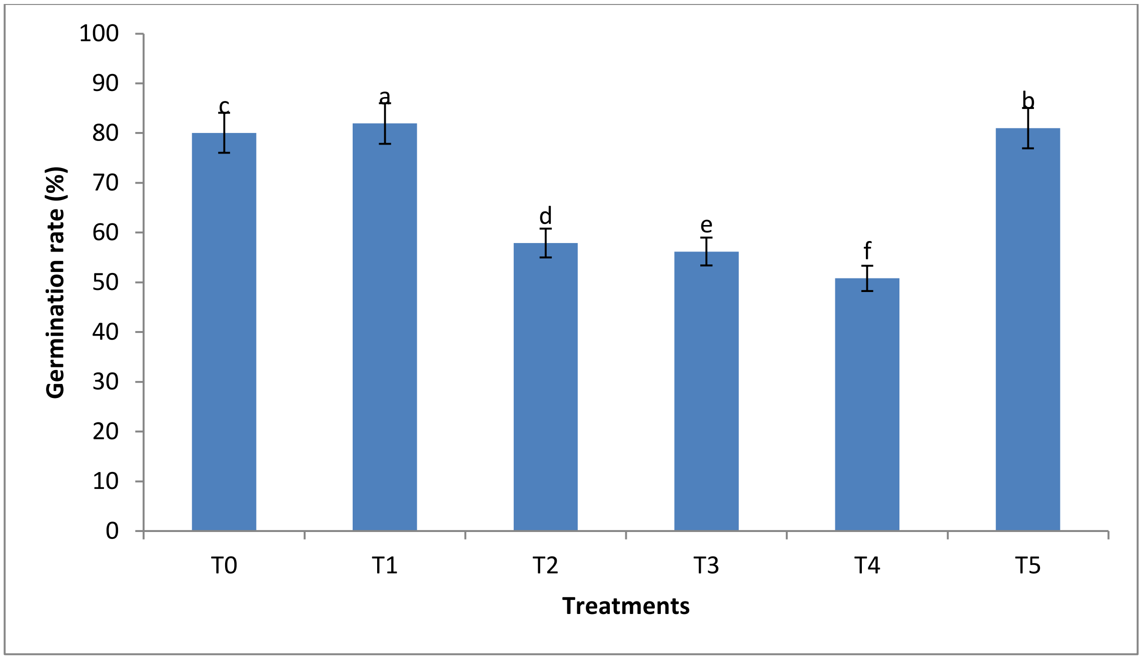
The experiment was conducted to study the ‘enhancement of salt tolerance capability in wheat through magic growth and hydropriming’. The result of the germination and growth parameters of wheat which influenced by different concentration of priming solutions (magic growth), hydropriming (distilled water) in salinity stress condition have been presented and discussed in this chapter. The result of the experiment have been summarized and presented by appropriate table and figures. The statistical analysis of variance in respect of all parameters have been shown in Appendix II to Appendix VI.

4.1 Experiment no: 1

Study on the germination behavior of wheat at different concentrations of priming agents (magic growth and distilled water).

4.1.1 Effect on total germination (%)

There was significant difference among different treatments of seed priming on germination percentage of wheat seeds (Figure 1). Germination percentage of variety BARI Gom 30 decreased with increasing priming concentrations with magic growth (Figure 1). Primed seeds T_1 showed the maximum germination percentage (81.94%) followed by the treatment T_5 (hydro priming; primed with distilled water) (81.02%). The lowest germination percentage (50.80%) was found from the treatment T_4 (seeds primed with 2% magic growth concentration). Similar result was also observed by Afzal *et al*. (2008) and Akbarimoghaddam*et al*. (2011) who reported higher germination rate with primed seeds compared to nonprime seeds of wheat.

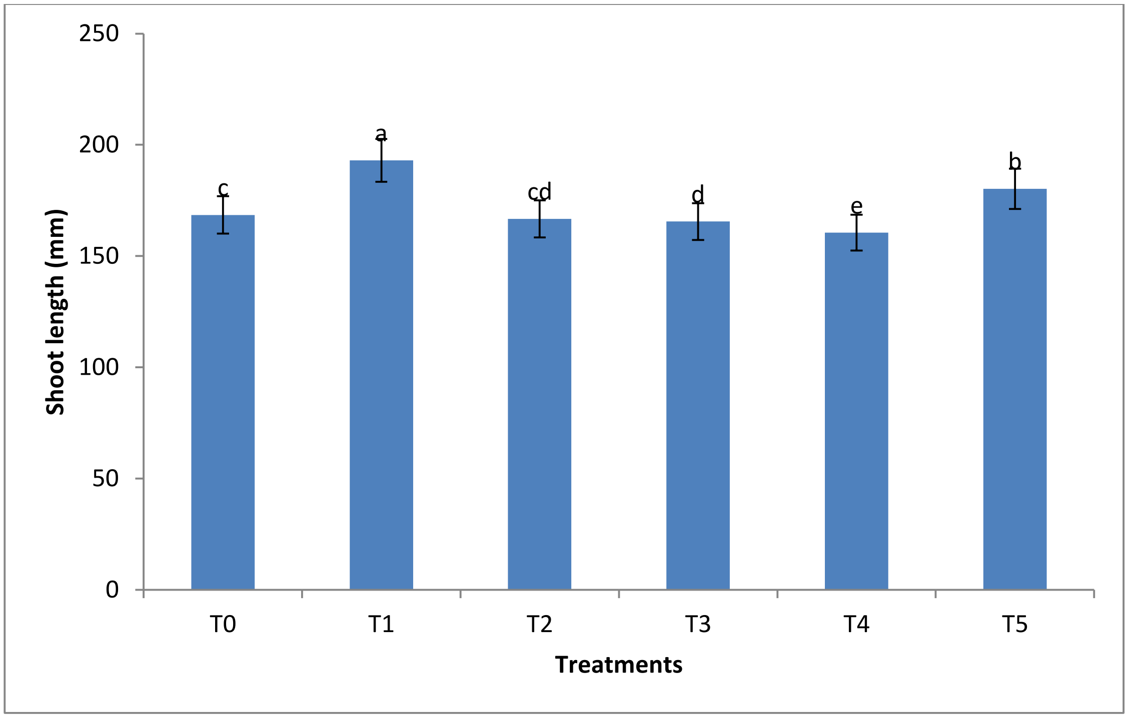


Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 1. Effect of different priming concentration on germination rate (%) of BARI Gom 30 ($LSD_{0.01}$ = 0.389).

4.1.3. Effect on shoot length

Shoot length (mm) of wheat affected significantly by different priming concentration of magic growth and hydropriming including control (Figure 2). Shoot length of variety BARI Gom 30 decreased with increasing priming concentration with magic growth. The treatment T_1 showed higher shoot length (193.00 mm) and gradually decreased shoot length was found due to increasing of magic growth concentration as seed priming agent (Figure 2). The lowest shoot length (160.50 mm) was found in the treatment T_4 (seeds primed with 2% magic growth concentration) compared to control treatment T_0 (non-primed seeds) (166.75 mm).

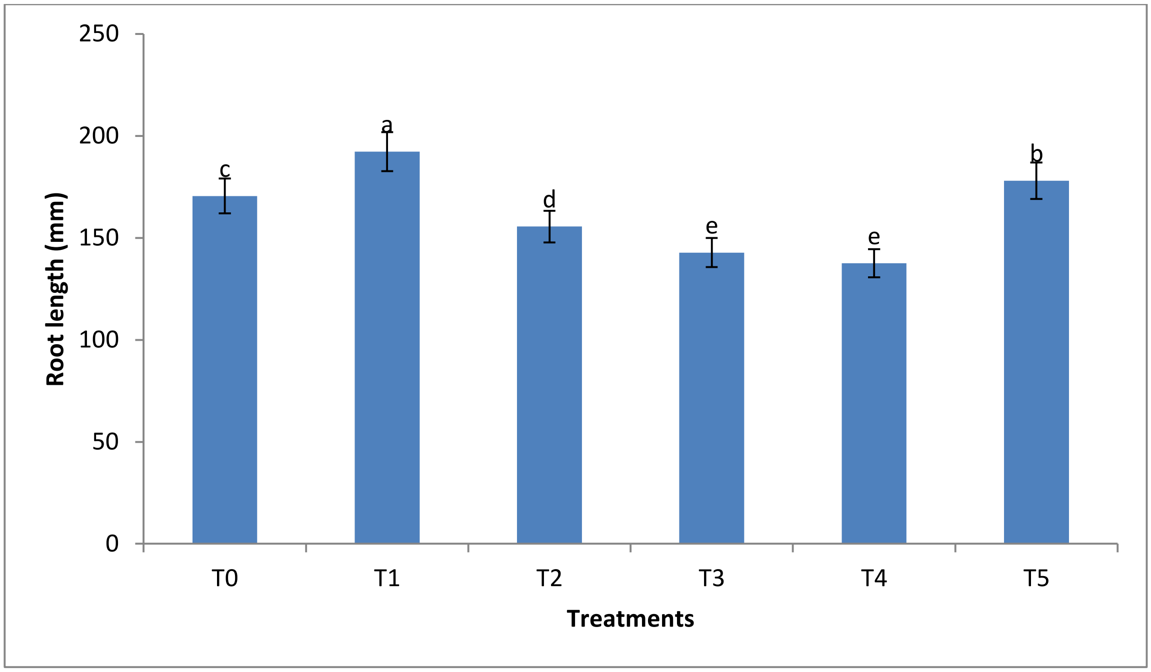


Here, T_0 = Control (non-primed seeds), T_1 = Seeds primed with 0.5% magic growth concentration, T_2 = Seeds primed with 1% magic growth concentration, T_3 = Seeds primed with 1.5% magic growth concentration, T_4 = Seeds primed with 2% magic growth concentration, T_5 = Hydro priming (primed with distilled water)

Figure 2. Effect of different priming concentrations on shoot length of BARI Gom 30 ($LSD_{0.01}$ = 2.299).

4.1.4 Effect on root length

Treatments of different priming concentrations including control showed significant variation on root length of wheat (Figure 3). Hydropriming also gave significant result. Root length of variety BARI Gom 30 increased with decreasing priming concentration of magic growth (Figure 3). Primed seeds T_1 showed maximum root length (192.25 mm) and it was lower with seed priming of magic growth concentration and gradually decreased with increasing of magic growth concentration and the lowest shoot length (142.75 mm) was found from the treatment T_4 (seeds primed with 2% magic growth concentration). The result obtained from the present study was similar with the findings of Menon *et* *al.*(2013) who recorded higher root length from primed seed whereas non-primed seeds showed least root length.

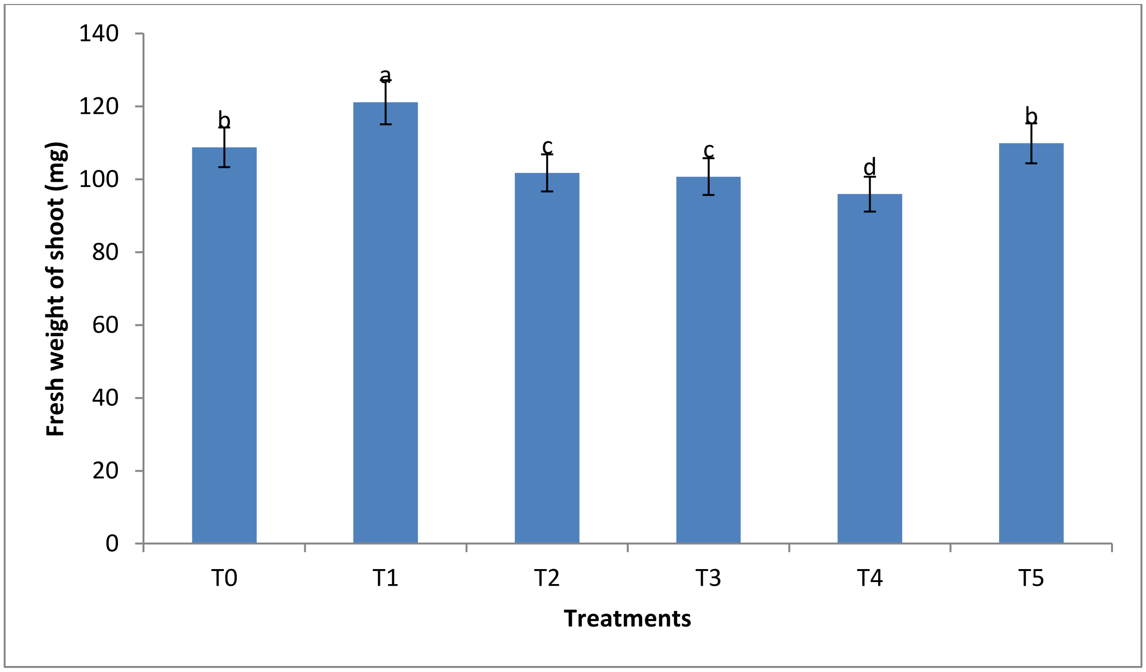


Here, T_0 = Control (non-primed seeds), T_1 = Seeds primed with 0.5% magic growth concentration, T_2 = Seeds primed with 1% magic growth concentration, T_3 = Seeds primed with 1.5% magic growth concentration, T_4 = Seeds primed with 2% magic growth concentration, T_5 = Hydro priming (primed with distilled water)

Figure 3. Effect of different priming concentrations on root length of BARI Gom 30 ($LSD_{0.01}$ = 5.399).

4.1.2. Effect on shoot fresh weight

Shoot fresh weight of wheat was influenced by different priming concentrations including control (Figure 4) and there were significant differences among the treatments of primed and non primed seeds (Figure 4). Treatment T_1 showed significantly highest shoot fresh weight (121.20 mg) which was followed by the treatment T_4 (seeds primed with 2% magic growth concentration). The treatment T_2(seeds primed with 1% magic growth concentration) and T_3(seeds primed with 1.5% magic growth concentration) showed non-significant difference between them whereas the control treatment T_4(primed seeds with 2% magic growth) showed the lowest shoot fresh weight of variety BARI Gom 30 (95.95 mg) and it was increased with seed priming treatments. Similar result was also observed by Khan (2007) and Mohammad *et al*. (1995).

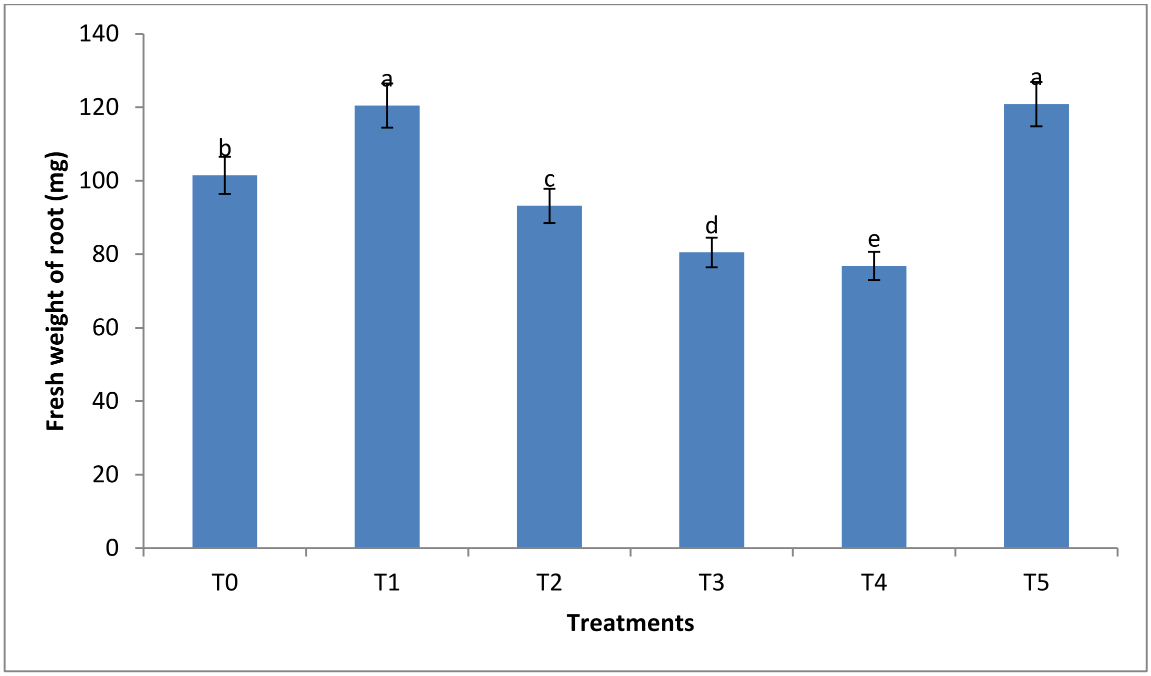


Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 4. Effect of different priming concentrations on shoot fresh weight of BARI Gom 30 ($LSD_{0.01}$ = 2.416).

4.1.2. Effect on root fresh weight

Root fresh weight of wheat was influenced significantly by different priming concentrations including control (Figure 5). Hydro priming treatment T_5 showed significantly highest root fresh weight (120.88 mg) which was significantly same to the treatment of T_2 (seeds primed with 1% magic growth concentration) whereas the treatment T_4 (seeds primed with 2% magic growth concentration) showed the lowest root fresh weight (76.85 mg) (Figure 5). Khan (2007) and Mohamad *et al*. (1995) also found similar result with the present study.

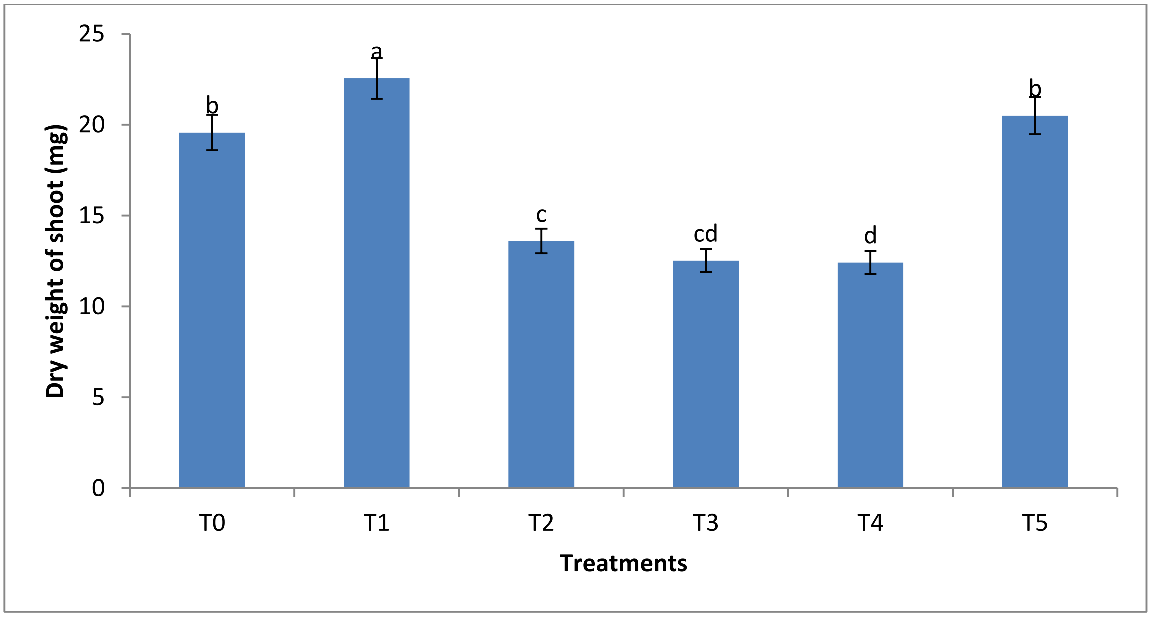


Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 5. Effect of different priming concentrations on root fresh weight of BARI Gom 30 ($LSD_{0.01}$ = 3.007).

4.1.5 Effect on shoot dry weight

Plant shoot dry weight of wheat was influenced significantly by different priming treatments including control (Figure 6). Results showed that the treatment T_1 (seeds primed with 0.5% magic growth concentration) gave the highest result on shoot dry weight (22.55 mg) which was significantly differed to other treatments which was followed by T_2 (seeds primed with 1% magic growth concentration) (Figure 6). Shoot dry weight was decreased with increasing of priming concentrations of magic growth. Treatment T_5 (hydro priming; primed with distilled water) also showed comparatively lower shoot dry weight. Treatment T_2 (seeds primed with 1% magic growth concentration) and control treatment T_0 (non-primed seeds) showed non-significant variation on shoot dry weight between them whereas T_4 (seeds primed with 2% magic growth concentration) treatment gave the lowest shoot dry weight (12.42 mg) which was significantly similar to T_3 (seeds primed with 1.5% magic growth concentration) treatment.

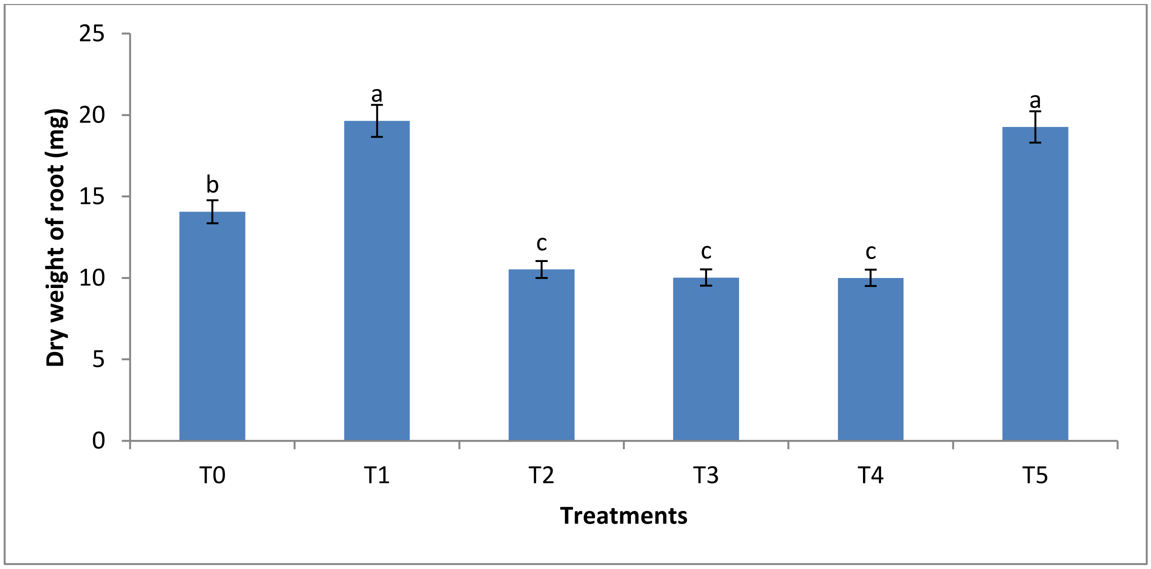


Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 6. Effect of different priming concentrations on shoot dry weight of BARI Gom 30 ($LSD_{0.01}$ = 1.105).

4.1.6 Effect on root dry weight

Different priming treatments including control had significant effect on root dry weight of wheat (Figure 7). The treatment T_1 (seeds primed with 0.5% magic growth concentration) showed the highest plant root dry weight (19.65 mg) which was significantly same to the treatment T_2 (seeds primed with 1% magic growth concentration). The lowest root dry weight (10.00 mg) was found in T_4 (seeds primed with 2% magic growth concentration) treatment which was statistically identical withT_3 (seeds primed with 1.5% magic growth concentration) and T_5 (hydro priming; primed with distilled water).



Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 7. Effect of different priming concentration on root dry weight of BARI Gom 30 ($LSD_{0.01}$ = 0.542).

4.1.8 Effect on relative water content (RWC)

Different priming treatments significantly influenced relative water content (RWC) of wheat and there was significant difference between control (non-primed) and primed seeds (Table 1). The treatment T_1 (seeds primed with 0.5% magic growth concentration) showed significantly highest RWC of wheat (92.06%) that was significantly different from other treatments followed by T_2 (seeds primed with 1% magic growth concentration) (Table 1). Control treatment T_0 (non-primed seeds) and T_2 (seeds primed with 1% magic growth concentration) showed non-significant difference between them on RWC. It was also observed that higher RWC was found with lower priming concentrations of magic growth. Relative water content (RWC) in case of hydro priming (T_5) was found 87.16%.

The lowest RWC (82.75%) was found in T_3 (seeds primed with 1.5% magic growth concentration) treatment which was statistically identical with T_5 (hydro priming; primed with distilled water).

Table 1: Effect of different priming concentrations on water relation behaviors of wheat seeds

Treatments	Water relation behavior		
	Relative water content (RWC) %	Water saturation deficit (WSD)%	Water retention capacity (WRC)
T_0	88.73 b	11.27 c	7.12 d
T_1	92.06 a	7.94 d	8.07 c
T_2	89.01 b	10.99 c	9.34 b
T_3	82.75 d	17.25 a	8.12 c
T_4	87.14 c	12.86 b	9.25 b
T_5	87.16 c	12.84 b	11.38 a
$LSD_{(0.01)}$	0.480	0.485	0.378
CV%	0.42	3.28	3.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

4.1.9 Effect on water saturation deficit (WSD)

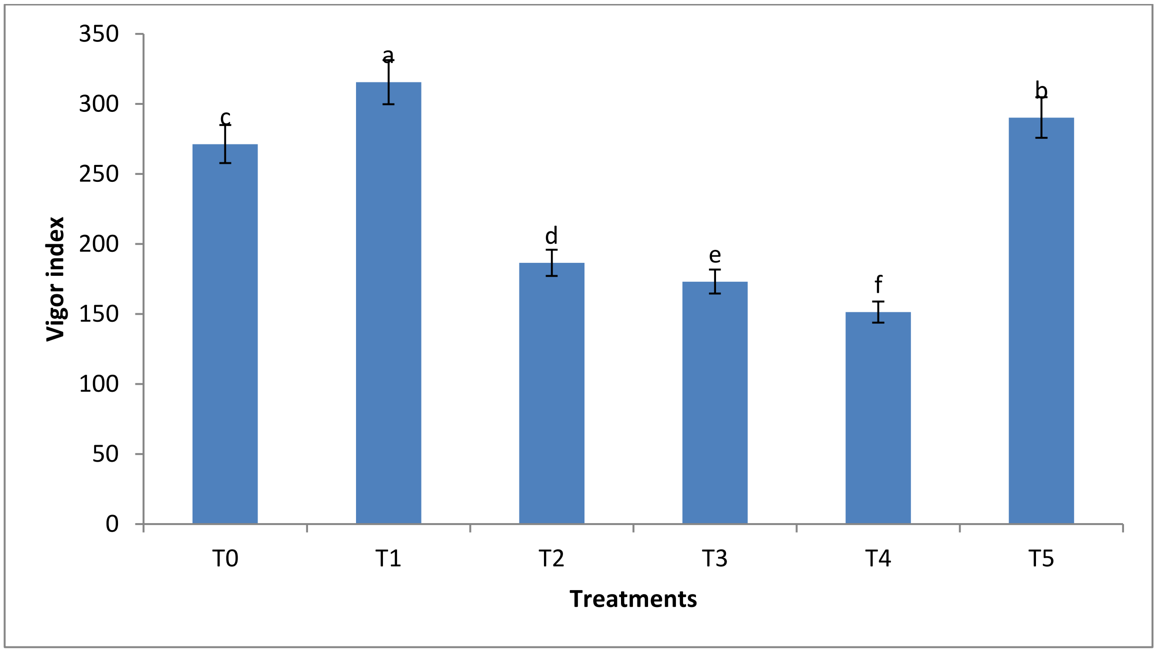
Water saturation deficit (WSD) of wheat was influenced significantly by different seed priming concentration of magic growth and hydropriming including control (Table 1). The highest WSD (17.25%) was found from the treatment T_3 (seeds primed with 1.5% magic growth concentration) which was followed by T_5 (hydro priming; primed with distilled water) and T_4 (seeds primed with 2% magic growth concentration). The lowest water saturation deficit (WSD) of wheat (7.94) was recorded from the priming treatment T_1 (seeds primed with 0.5% magic growth concentration). Water saturation deficit in case of hydro priming (T_5) was found 12.84% which had non-significant difference with T_4 (seeds primed with 2% magic growth concentration).

4.1.10 Effect on water retention capacity (WRC)

Different priming treatments of magic growth and hydropriming including control had significant variation on water retention capacity (WRC) of wheat (Table 1). The hydropriming treatment (T_5) showed the highest WRC (11.38%) that was significantly different from other treatments followed by T_2 (seeds primed with 1% magic growth concentration) and T_4 (seeds primed with 2% magic growth concentration). The lowest WRC (8.07%) was found in T_1 (seeds primed with 0.5% magic growth concentration) treatment.

4.1.7 Effect on vigor index (VI)

Priming with various concentrations of magic growth and hydropriming including control showed significant influence on vigor index of wheat seed (Figure 8).



Here, T_0= Control (non-primed seeds), T_1= Seeds primed with 0.5% magic growth concentration, T_2= Seeds primed with 1% magic growth concentration, T_3= Seeds primed with 1.5% magic growth concentration, T_4= Seeds primed with 2% magic growth concentration, T_5= Hydro priming (primed with distilled water)

Figure 8. Effect on different priming concentrations on vigor index of BARI Gom 30 ($LSD_{0.01}$ = 3.488).

Treatment T_1(primed with 0.5% magic growth) showed the highest vigor index which was significantly higher than other treatments which was followed by the treatment T_5(seeds primed with distilled water) (Figure 8). Plant vigor index of variety BARI Gom 30 decreased with increasing priming concentrations of magic growth and the lowest vigor index (81.08) was observed from the treatment T_4 (seeds primed with 2% magic growth concentration). Menon *et al.* (2013), Afzal *et al.* (2005) and Harris *et al*. (2004) found similar result with the present study and reported higher vigor index from primed seeds compared to non-primed seeds.

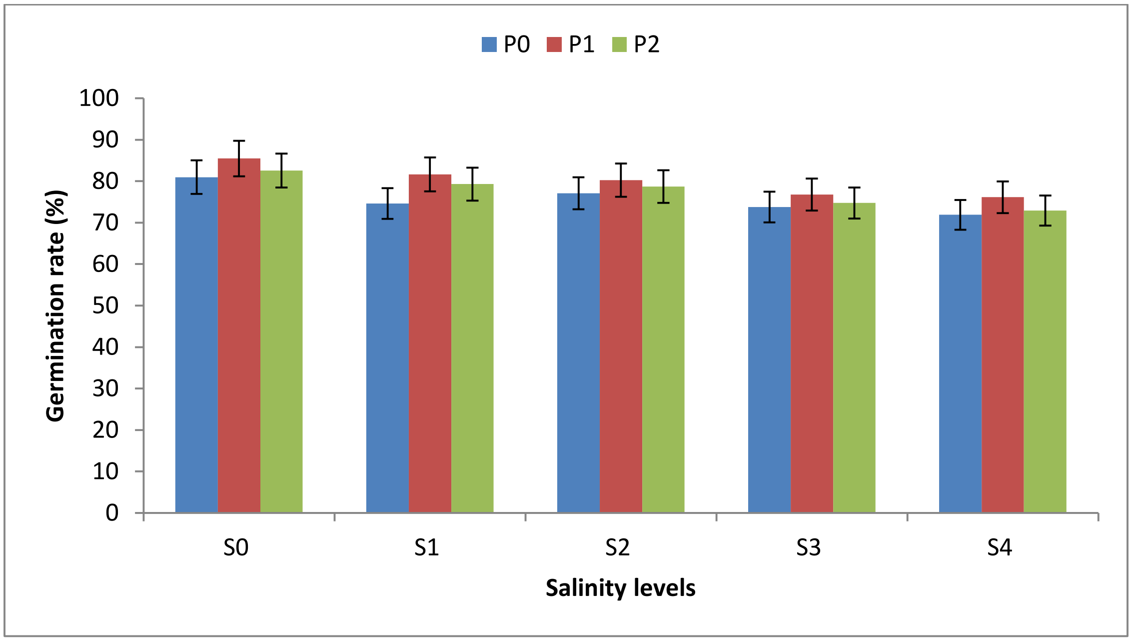
4.2 Experiment 2

Study on the germination behavior of primed seed under different salt stress condition

Experiment-2 was conducted under laboratory condition. Seeds of BARI Gom 30 were primed with 0.5% magic growth solution and hydropriming for 9 hours. Dry seed used as control (no priming) and was exposed to 0, 5, 10, 15 and 20% NaCl induced salt stress conditions in petridishes. The results have been presented separately in Figures 21 to 30 and Appendices VII to XVII under the following headings:

4.2.1 Effect on germination percentage (%)

Different salt stress levels showed significant difference in germination percentage influenced by different seed priming treatments (Figure 9). Results showed that the germination from primed and non-primed seeds decreased gradually with increasing rate of salinity stress level. But germination percentage of 0.5% magic growth priming and hydro priming was higher compared with control seeds (without priming) at different salt stress condition. It was observed that the treatment P_1 (seeds primed with 0.5% magic growth concentration) gave the promising result on seed germination at all salt concentration and germination rate was highest in no salinity level (85.48%). But under salinity stress, the maximum germination rate was found in primed seeds placed with 5 dSm^{-1}NaCl and thereafter gradually decreased germination rate was observed with the increasing salinity levels. It was also recorded that the highest germination rate (85.48%) was observed from P_1 (seeds primed with 0.5% magic growth concentration) treatment under primed seeds placed without salt and this treatment also showed highest results at 5, 10, 15 and 20 dSm^{-1} NaCl salinity stress (81.64, 80.28, 76.76 and 76.13%, respectively) followed by P_2 (hydropriming; seeds primed with distilled water) whereas control treatment P_0 (no seed priming) showed lowest germination percentage at all salinity levels (80.95, 74.60, 77.06, 73.77 and 71.90% at 0, 5, 10, 15 and 20 dSm^{-1} NaCl level, respectively).



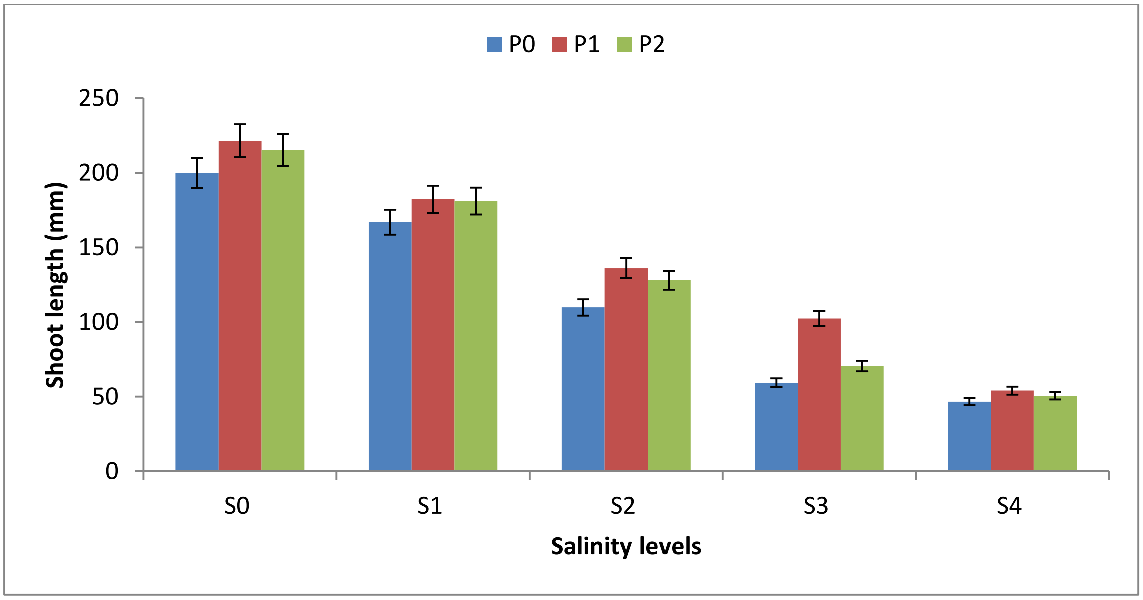
P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 9. Effect of different levels of salinity stress on germination (%) of BARI Gom 30 ($LSD_{0.01}$ = 1.972, 2.723, 1.935, 2.288 and 2.048 at at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

It was also observed that at S_2 (10 dSm^{-1}NaCl) and S_3 (15 dSm^{-1}NaCl) salinity levels, P_1 and P_2 showed significantly similar result on germination percentage between each other. Similar result was also found by Ghiyasi*et al*. (2008) and El-Hendawy*et al*. (2011); they reported decreased germination rate with increased salinity levels.

4.2.3 Effect on shoot length

Different priming treatments of seed including control (no seed priming) significantly influenced shoot length at different salinity levels (Figure 10). Results showed that shoot length of primed seeds was higher than and non-primed seeds at different salinity stress. Again, it was also observed that shoot length was higher in lower salinity level compared to higher salinity stress and the maximum shoot length was in no salinity stress (Figure 10). Shoot length of P_1 (magic growth; seeds primed with 0.5% magic growth concentration) priming and hydro priming was higher compared with control seeds (without priming).



P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

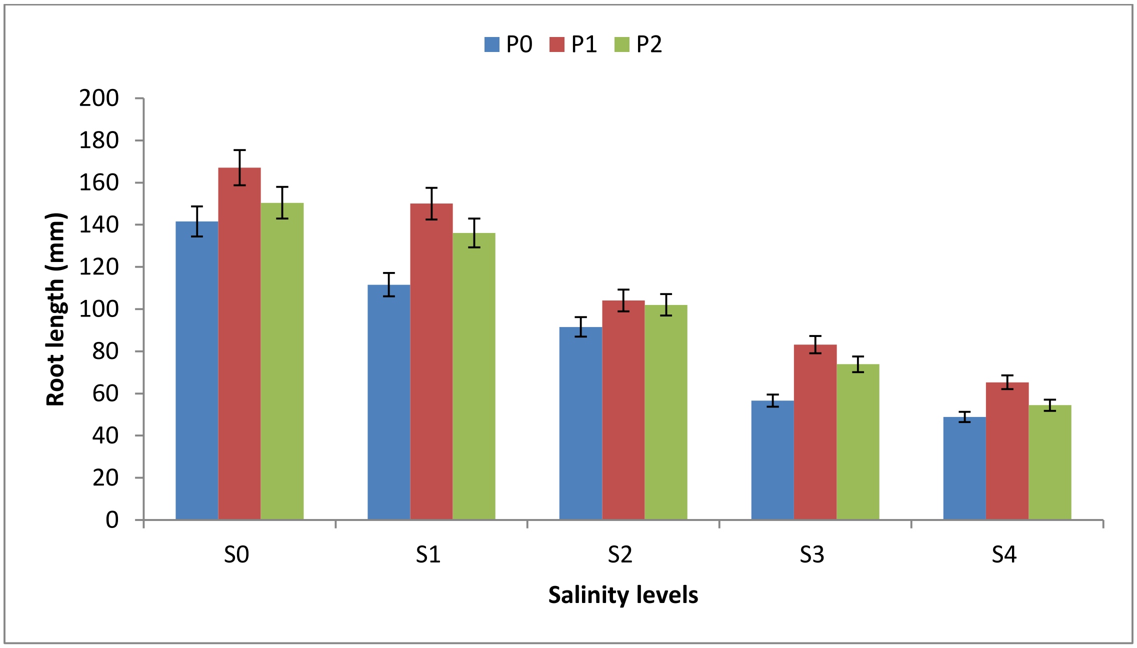
Figure 10. Effect of different levels of salinity stress on shoot length of BARI Gom 30 ($LSD_{0.01}$ = 2.508, 2.248, 2.381, 1.094 and 2.043 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

At no salinity level S_0 (0 dSm^{-1}NaCl), P_1 (magic growth; seeds primed with 0.5% magic growth concentration) gave highest shoot length (221.40 mm) followed by P_2 (hydropriming; seeds primed with distilled water) (215.20 mm) whereas control treatment P_0 (no seed priming) gave lowest shoot length (199.80 mm). At 5, 10, 15 and 20 dSm^{-1}NaCl salinity level, the highest shoot length (182.30, 136.10, 102.30 and 54.04 mm, respectively) was also achieved from the treatment P_1 (magic growth; seeds primed with 0.5% magic growth concentration) which was followed by P_2 (hydropriming; seeds primed with distilled water) whereas the lowest shoot length (167.00, 109.80, 59.35 and 46.60 mm, respectively) was recorded from control treatment P_0 (no seed priming) (Figure 10). At S_1 (5 dSm^{-1}NaCl) salinity level, treatment P_1 and P_2 showed non-significant variation between them on shoot length. Radi*et al*. (2013) observed growth inhibition of shoot growth with higher salinity level whereas primed seeds showed higher shoot growth compared to control at salinity stress which supported the present findings.

4.2.4 Effect on root length

Significant variation of root length was found in case of magic growth priming and hydro priming regarding salinity stress (Figure 11). With increasing rate of salinity stress, root length of primed and non-primed seeds decreased gradually. But root length of 0.5% magic growth priming (P_1) and hydro priming (P_2) was higher compared with control seeds (no seed priming; P_0). The 0.5% magic growth (P_1) priming seed had maximum root length (167.00 mm) followed by hydro priming (150.40 mm) and the minimum root length (141.60 mm) from control seed found in no salinity level S_0 (0 dSm^{-1}NaCl). In S_1 (5 dSm^{-1}NaCl) salinity level, root length was maximum (150.00 mm) with P_1 (seeds primed with 0.5% magic growth concentration) treatment followed by P_2 (hydropriming; seeds primed with distilled water) treatment whereas control treatment P_0 (no seed priming) showed minimum root length (111.60 mm). Again, gradually decreased root length was observed in S_2 (10 dSm^{-1}NaCl), S_3 (15 dSm^{-1}NaCl) and S_4 (20dSm^{-}

^{1}NaCl) salinity level compared to S_1 (5 dSm^{-1}NaCl) salinity level and each salinity level P_1 (seeds primed with 0.5% magic growth concentration) treatment gave maximum root length followed by P_2 (hydropriming; seeds primed with distilled water) whereas control treatment P_0 (no seed priming) showed minimum root length. At 10, 15 and 20 dSm^{-1}NaCl salinity stress, the maximum root length (104.10, 83.14 and 65.30 mm, respectively) was recorded from P_1 (seeds primed with 0.5% magic growth concentration) whereas the minimum root length (91.56, 56.60 and 48.85 mm, respectively) was found from control treatment P_0 (no seed priming). Similar result was also observed by Radi*et al*. (2013) and Nawaz *et al*. (2011); they reported higher root growth at salinity stress compared to control treatment.

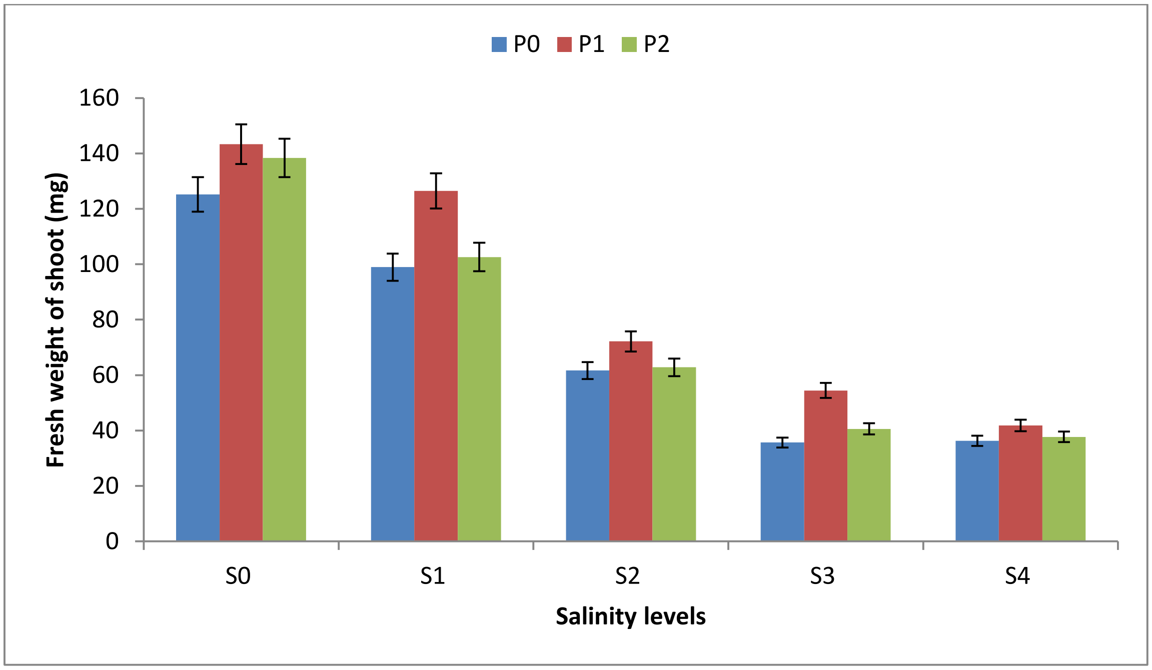


P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 11. Effect of different levels of salinity stress on root length of BARI Gom 30 as influenced by seed priming treatments ($LSD_{0.01}$ = 2.868, 1.662, 1.949, 1.736 and 2.062 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

4.2.2 Effect on fresh weight of shoot

Different salinity stress levels showed significant difference in shoot fresh weight (Figure 12). Results showed that shoot fresh weight from primed and non-primed seeds decreased gradually with increasing rate of salinity level. Again, among different priming treatments of seeds against salinity stress, seeds primed with 0.5% magic growth concentration (P_1) and seeds primed with distilled water; hydropriming (P_2) was higher compared with control treatment P_0 (no seed priming).



P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

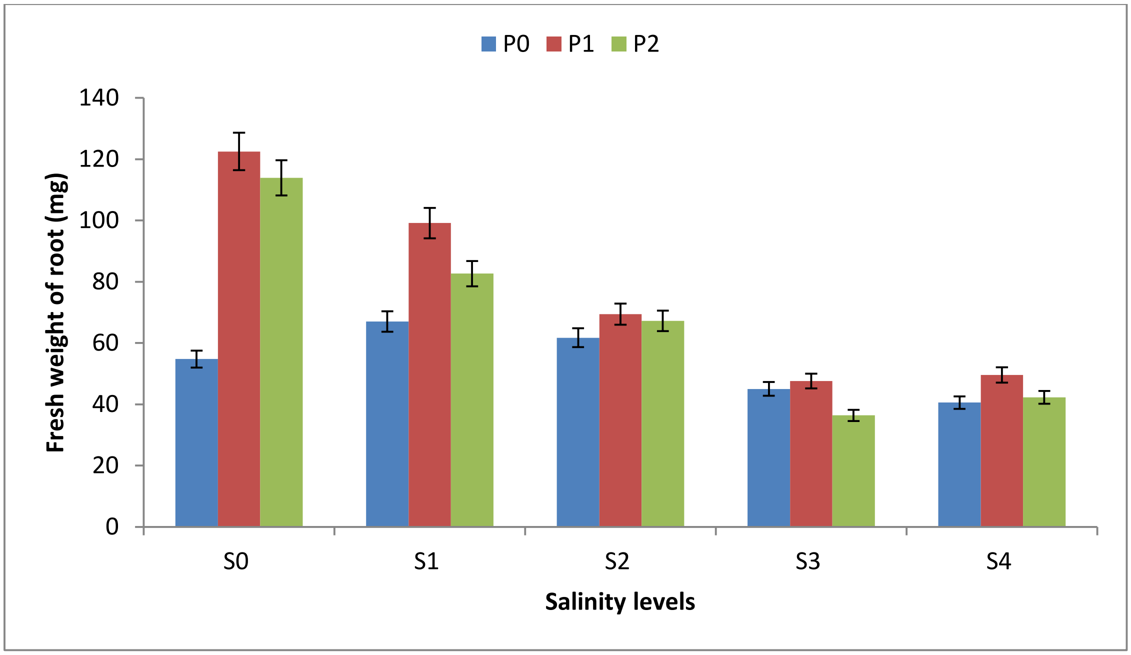
Figure 12. Effect of different levels of salinity stress on shoot fresh weight of BARI Gom 30 influenced by seed priming treatments ($LSD_{0.01}$ = 1.778, 1.885, 1.25, 1.133 and 1.646 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

At no salinity level (S_0), the maximum fresh weight of shoot (143.30 mm) was observed in P_1 (seeds primed with 0.5% magic growth concentration) treatment followed by P_2 (hydropriming; seeds primed with distilled water) (138.40 mm) whereas control treatment P_0 (no seed priming) had minimum fresh weight of shoot (125.20 mm). Again, at 5, 10, 15 and 20 dSm^{-1}NaCl salinity levels, treatment P_1 (magic growth; seeds primed with 0.5% magic growth concentration) also showed the maximum fresh weight of shoot (126.50, 72.15, 54.47 and 41.87 mm, respectively) followed by P_2 (hydropriming; seeds primed with distilled water) at all salinity levels whereas control treatment P_0 (no seed priming) showed least shoot fresh weight (98.94, 61.65, 35.67 and 36.28 mm, respectively). Similar findings was also recorded from the findings of El-Hendawy*et al*. (2011) who reported higher salt tolerance from primed seed and recorded higher fresh shoot weight compared to non-primed seeds.

4.2.2 Effect on fresh weight of root

Fresh weight of root at different salinity levels including control varied significantly due to different seed priming treatments (Figure 13). Results showed that root fresh weight from primed and non-primed seeds decreased gradually with increasing rate of salinity. Again, among different priming treatments of seeds against salinity stress, P_1 (seeds primed with 0.5% magic growth concentration) and P_2 (hydropriming; seeds primed with distilled water) treatments gave higher fresh weight of root compared to control treatment P_0 (no seed priming). It was observed that at no salinity level (S_0), the maximum fresh weight of root (122.50 mm) was observed in P_1 (seeds primed with 0.5% magic growth concentration) treatment followed by P_2 (hydropriming; seeds primed with distilled water) (113.90 mm) whereas control treatment P_0 (no seed priming) gave minimum fresh weight of root (54.76 mm). But at different salinity levels (5, 10, 15 and 20 dSm^{-1}NaCl), treatment P_1 (magic growth; seeds primed with 0.5% magic growth concentration) also showed the maximum fresh weight of root (99.13, 69.39, 47.58 and 49.59 mm, respectively) followed by P_2 (hydropriming; seeds primed with distilled water) at all salinity levels whereas control treatment P_0 (no seed priming) showed least root fresh weight (67.02, 61.71, 45.01 and 40.55 mm, respectively).

The present findings was similar with the findings of El-Hendawy*et al*. (2011) who observed higher salt tolerance and found higher root weight from primed seed compared to non-primed seeds against different salinity levels.

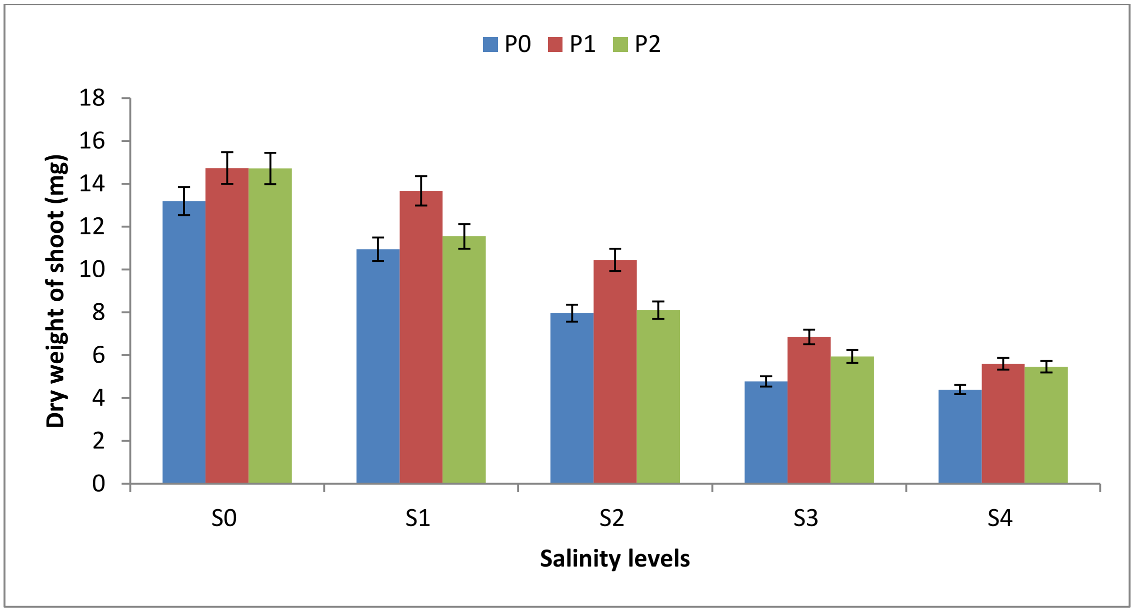


P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 13. Effect of different levels of salinity stress on root fresh weight of BARI Gom 30 influenced by seed priming treatments ($LSD_{0.01}$ = 2.071, 2.318, 1.312, 2.066 and 0.867 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

4.2.5 Effect on shoot dry weight

Different priming treatments including control had significant variation on shoot dry weight of wheat at different salinity stress (Figure 14). Shoot dry weight from primed and non-primed seeds decreased gradually with increasing rate of salinity level. Again, seeds primed with 0.5% magic growth concentration and hydropriming showed higher shoot dry weight compared to control treatment (no seed priming). Results revealed that at 0, 5, 10, 15 and 20 dSm^{-1}NaCl salinity levels, the maximum shoot dry weight (14.73, 13.67, 10.44, 6.85 and 5.60 mg, respectively) was found from the treatment P_1 (seeds primed with 0.5% magic growth concentration) followed by P_2 (hydropriming; seeds primed with distilled water) whereas control treatment P_0 (no seed priming) had minimum shoot dry weight (13.19, 10.94, 7.96, 4.77 and 4.39 mg, respectively) at all salinity levels. Datta*et al*. (2009) and Tammam*et al*. (2008) reported that salinity stress hampared to accumulate dry matter which resulted lower dry content of shoot and root but primed seeds showed higher dry matter production compared to non-primed seeds.



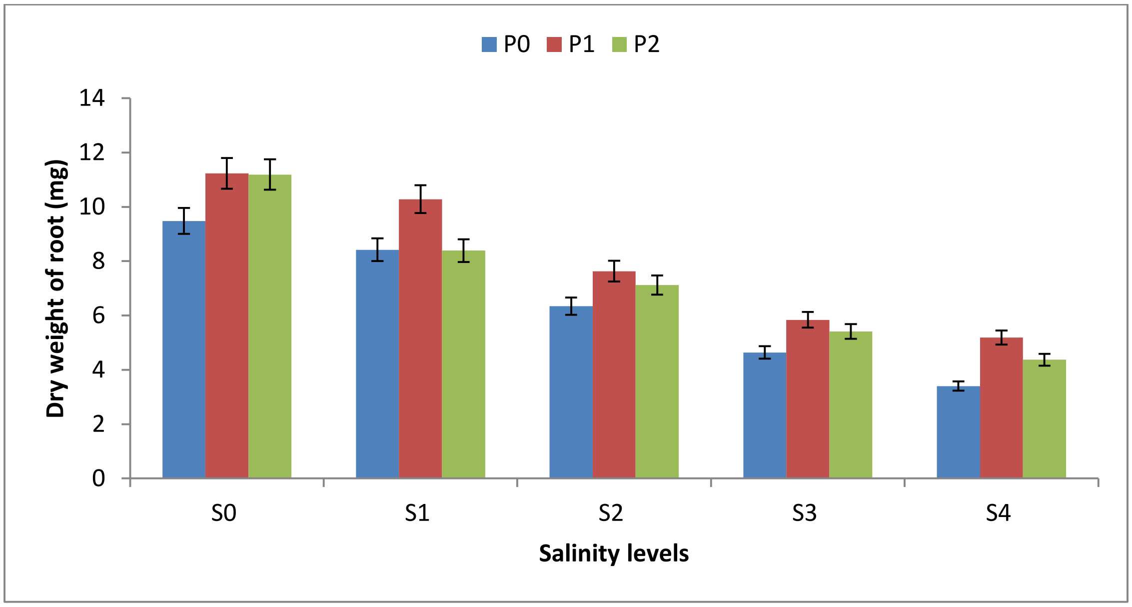
P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 14. Effect of different levels of salinity stress on shoot dry weight of BARI Gom 30 ($LSD_{0.01}$ = 0.748, 1.265, 0.499, 0.336 and 0.345 at 0, 5, 10, 15 and 20 dSm^{-1}NaCl salinity levels).

4.2.6 Effect on root dry weight

Different salinity stress levels showed significant difference on root dry weight as influenced by seed priming treatments (Figure 15). Results indicated that root dry weight from primed and non-primed seeds decreased gradually with increasing rate of salinity stress level. But root dry weight of 0.5% magic growth priming (P_1)

and hydropriming (P_2) was higher compared with control seeds (no seed priming). The 0.5% magic growth priming seed had maximum root dry weight (11.23 mg) followed by hydropriming (11.19 mg) compared to control seed which had minimum root dry weight (9.48 mg) found from no salinity (S_0) level.



P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 15. Effect of different levels of salinity stress on root dry weight of BARI Gom 30 influenced by seed priming treatments ($LSD_{0.01}$ = 0.939, 1.004, 0.654, 0.756 and 0.524 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

In S_1 (5 dSm^{-1}NaCl) salinity stress level, root dry weight from P_1 (seeds primed with 0.5% magic growth concentration) (10.28 mg) was highest followed by P_2 (hydropriming; seeds primed with distilled water) (8.39 mg) whereas control seed had minimum root dry weight (8.42 mg). Similarly, at 10, 15 and 20 dSm^{-1} salinity levels, the maximum root dry weight (7.63, 5.84 and 5.19 mm, respectively) was recorded from P_1 (seeds primed with 0.5% magic growth concentration) treatment whereas the minimum root dry weight (6.34, 4.64 and 3.40 mg, respectively) was found from control treatment P_0 (no seed priming).

4.2.7 Effect on relative water content (RWC)

Relative water content (RWC) at no salinity level had no significant variation among the priming treatments but at different salinity levels, different seed priming treatments including control showed significant variation (Table 2). With increasing rate of salinity stress level, relative water content of primed and non-primed seeds decreased gradually. But relative water content of 0.5% magic growth priming (P_1) and hydropriming (P_2) was higher compared with control seeds (P_0). The P_1 (0.5% magic growth priming seed) treatment had maximum relative water content (93.75%) followed by P_2 (hydropriming) (93.32%) compared to control treatment (P_0) which had minimum relative water content (93.19%) found from no salinity (S_0) level. In S_1 (5 dSm^{-1}NaCl) salinity stress level, relative water content from P_1 (seeds primed with 0.5% magic growth concentration) (92.33%) was highest which had non-significant difference with P_2 (hydropriming; seeds primed with distilled water) (92.05%) whereas control treatment (P_0) had minimum relative water content (84.21%). Similarly, at 10, 15 and 20 dSm^{-1} salinity levels, the maximum relative water content (87.11, 85.17 and 81.39%, respectively) was recorded from P_1 (seeds primed with 0.5% magic growth concentration) treatment whereas the minimum relative water content (78.81, 74.92 and 64.22%, respectively) was found from control treatment P_0 (no seed priming).

Table 2. Effect of different levels of salt stress on relative water content (RWC) of wheat seeds

Treatments	Relative water content at different salt level %				
	S_0	S_1	S_2	S_3	S_4
P_0	93.19	84.21 b	78.81 c	74.92 c	64.22 c
P_1	93.75	92.33 a	87.11 a	85.17 a	81.39 a
P_2	93.32	92.05 a	83.44 b	78.87 b	75.10 b
$LSD_{(0.01)}$	NS	0.822	0.929	0.507	0.882
CV%	0.38	0.63	0.77	0.53	0.18

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

4.2.8 Water saturation deficit (WSD)

Among different priming treatments, different salinity stress levels showed significant difference on water saturation deficit (WSD) but at no salinity level non-significant variation was found (Table 3). Results showed that water saturation deficit (WSD) from primed and non-primed seeds increased gradually with increasing rate of salinity levels. Water saturation deficit (WSD) of control treatment (P_0) was higher compared to 0.5% magic growth priming (P_1) and hydropriming (P_2).

Table 3. Effect of different levels of salt stress on water saturation deficit (WSD) of wheat

Treatments	Water saturation deficit at different salt level %				
	S_0	S_1	S_2	S_3	S_4
P_0	6.81	15.79 a	21.19 a	25.08 a	35.78 a
P_1	6.25	7.67 c	12.89 c	14.83 c	15.61 c
P_2	6.68	7.95 b	16.56 b	21.13 b	24.90 b
$LSD_{(0.01)}$	NS	0.402	0.479	0.607	0.428
CV%	2.70	2.71	1.94	2.04	1.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)

S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

The control treatment P_0 (no seed priming) treatment had maximum water saturation deficit (6.81%) followed by P_2 (hydropriming) (6.68%) compared to P_1 (seeds primed with 0.5% magic growth concentration) treatment which had minimum water saturation deficit (6.25%) found from no salinity (S_0) level. In S_1 (5 dSm^{-1}NaCl) salinity stress level, water saturation deficit from control treatment P_0 (no seed priming) (15.79%) was highest followed by P_2 (hydropriming; seeds primed with distilled water) (7.95%) whereas P_1 (seeds primed with 0.5% magic growth concentration) treatment had minimum water saturation deficit (7.67%). Similarly, at 10, 15 and 20 dSm^{-1} salinity levels, the maximum water saturation deficit (21.19, 25.08 and 35.78%, respectively) was recorded from control treatment P_0 (no seed priming) whereas the minimum water saturation deficit (12.89, 14.83 and 15.61%, respectively) was found from P_1 (seeds primed with 0.5% magic growth concentration) treatment.

Table 4. Effect of different levels of salt stress on water retention capacity (WRC) of wheat

Treatments	Water retention capacity at different salt level				
	S_0	S_1	S_2	S_3	S_4
P_0	8.48 b	7.89 c	7.30 c	6.27 c	6.24 c
P_1	11.10 a	10.48 a	10.09 a	9.51 a	9.56 a
P_2	8.59 b	8.65 b	8.63 b	8.40 b	7.36 b
$LSD_{(0.01)}$	0.306	0.375	0.413	0.394	0.160
CV%	2.22	2.86	3.02	2.79	1.07

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability

P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

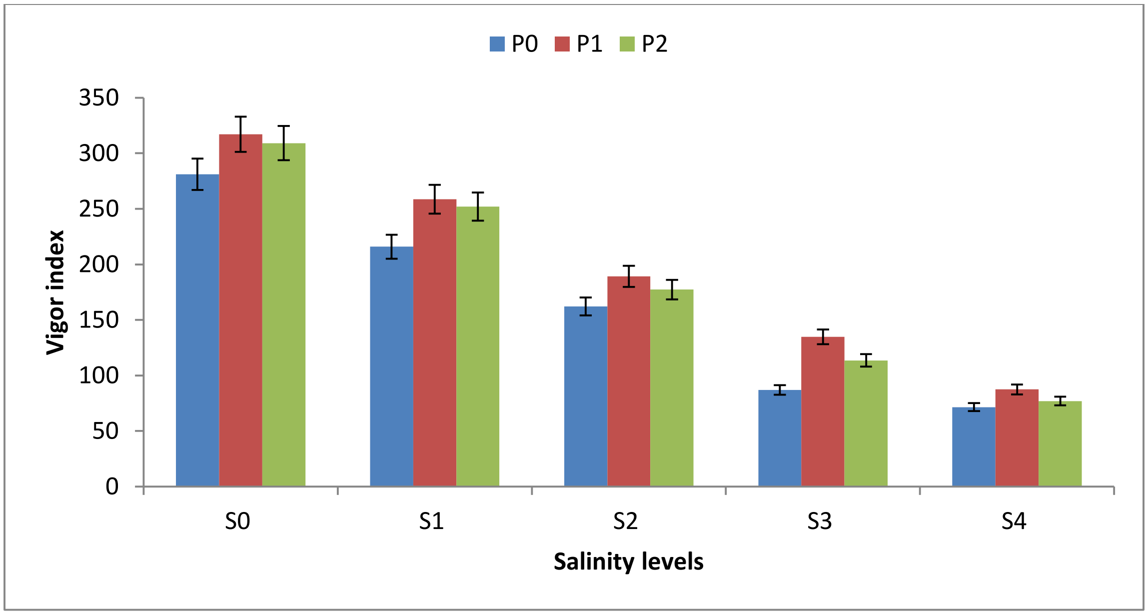
4.2.9 Water retention capacity (WRC)

Different salinity stress levels showed significant difference on water retention capacity (WRC) as influenced by seed priming treatments (Table 4). Results indicated that water retention capacity from primed and non-primed seeds decreased gradually with increasing rate of salinity stress level. Water retention capacity (WRC) of 0.5% magic growth priming (P_1) and hydropriming (P_2) was higher compared with control seeds (no seed priming). The 0.5% magic growth priming seed (P_1) had maximum water retention capacity (11.10%) followed by hydropriming (8.59%) compared to control seed which had minimum water retention capacity (8.48%) found from no salinity (S_0) level. In S_1 (5 dSm^{-1}NaCl) salinity stress level, water retention capacity (WRC) from P_1 (seeds primed with 0.5% magic growth concentration) (10.48%) was highest followed by P_2 (hydropriming; seeds primed with distilled water) (8.65%) whereas control treatment (P_0) had minimum water retention capacity (7.89%). Similarly, at 10, 15 and 20 dSm^{-1} salinity levels, the maximum water retention capacity (10.09, 9.51

and 9.56%, respectively) was recorded from P_1 (seeds primed with 0.5% magic growth concentration) treatment whereas the minimum water retention capacity (7.30, 6.27 and 6.24%, respectively) was found from control treatment P_0 (no seed priming).

4.2.10 Vigor index (VI)

Vigor index at different salinity levels had significant variation among the priming treatments (Figure 16). With increasing rate of salinity stress level, vigor index of primed and non-primed seeds decreased gradually. But vigor index of 0.5% magic growth priming (P_1) and hydropriming (P_2) treatments was higher compared with control treatment (P_0). The P_1 (0.5% magic growth priming seed) treatment had maximum vigour index (317.00) followed by P_2 (hydropriming) (309.20) compared to control treatment (P_0) which had minimum vigor index (281.10) found from no salinity (S_0) level.



P_0 = Control (no seed priming), P_1 = Magic growth (seeds primed with 0.5% magic growth concentration), P_2 = Hydropriming (seeds primed with distilled water)
S_0 = 0 dSm^{-1}NaCl, S_1 = 5 dSm^{-1}NaCl, S_2 =10 dSm^{-1}NaCl, S_3 =15 dSm^{-1}NaCl, S_4 =20 dSm^{-1}NaCl

Figure 16. Effect of different levels of salinity stress on vigor index of BARI Gom 30 as influenced by seed priming treatments ($LSD_{0.01}$ = 1.407, 0.587, 0.257, 0.336 and 0.512 at 0, 5, 10, 15 and 20 dSm^{-1} salinity levels, respectively).

In S_1 (5 dSm^{-1}NaCl) salinity stress level, vigor index from P_1 (seeds primed with 0.5% magic growth concentration) (258.70) was highest followed by P_2 (hydropriming; seeds primed with distilled water) (252.10) whereas control treatment (P_0) had minimum vigor index (216.00). Similarly, at 10, 15 and 20 dSm^{-1} salinity levels, the maximum vigor index (189.20, 134.80 and 87.42, respectively) was recorded from P_1 (seeds primed with 0.5% magic growth concentration) treatment whereas the minimum vigor index (162.20, 86.88 and 71.47, respectively) was found from control treatment P_0 (no seed priming). Abdoli (2014) and Menon *et al.* (2013) reported similar result with the present findings and recorded higher vigor index from primed seed against salinity stress whereas non-primed seeds showed lower vigor index.

CHAPTER V

SUMMARY AND CONCLUSION

The whole experiment was conducted at the central laboratory of the department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka from October 2020 to December 2020 to study the enhancement of salt tolerance capability in wheat through magic growth and hydropriming. The research studies were conducted with two different experiments laid out in Completely Randomized Design (CRD) with five replications.

In the 1st experiment wheat seeds of BARI Gam 30 was pre-soaked in 0.5%, 1%, 1.5%, 2% magic growth respectively for 9 hours and untreated seeds were used as control treatment. Hydropriming seeds also done by pre-soaking seeds in distilled water. Results showed that all the characteristics related to germination percentage, growth parameters (fresh weight of shoot and root, shoot length, root length, shoot dry weight, root weight, vigor index) and water relation behaviors (relative water content, water retention capacity and water saturation deficit) were significantly influenced by different concentrations of magic growth followed by hydro priming. All the parameters were given best result in 0.5% magic growth compared with other treatments. Hydro priming seeds has given better result than control but not more than 0.5% magic growth priming seeds. Growth, germination and water relation behaviors of all parameters were increases up to 0.5% magic growth priming and decreased gradually with increasing magic growth concentrations.

In the 2nd experiment, primed seeds (0.5% magic growth priming and hydro priming for 9 hours) and non-primed seeds were germinated under salinity stress condition (NaCl) to calculate the germination behavior. 0.5% magic growth priming, hydro priming and control (non-primed) seeds were germinated under 0%, 5%, 10%, 15% and 20% dSm^{-1}NaClsolution induced salinity stress condition.

Results showed that under salinity stress condition osmo/nutrient priming given better result than hydro primed seeds in case of all germination, growth and water relations parameters (germination percentage, shoot length, root length, shoot and root dry weight, shoot and root fresh weight, relative water content, water retention capacity and vigor index). Under control condition means without stress or 0% stress condition all the characters germination percentage, shoot and root fresh weight, shoot length, root length, shoot and root dry weight, relative water content, water retention capacity, vigor index and water saturation deficit showed best results. Seed priming with 0.5% magic growth solution with 9 hours priming for BARI Gam 30 expressed better results over non-primed and hydro primed seeds at salinity stress condition. Results revealed that germination behavior and seedling growth of non- primed and hydro primed seeds decreased drastically as salinity stress increased but nutrient primed seeds with 0.5% magic growth showed considerable tolerance capability up to stress level then significantly decreased with increasing salinity stress.

CONCLUSION

In this study nutrient priming in wheat variety showed better response. Germination, growth and water relation behaviors of BARI Gam 30 gave the best result when treated with 0.5% magic growth solution compared to hydro primed and non-primed seeds and decreased gradually with increasing concentrations of magic growth. So, priming wheat seeds with 0.5% magic growth for 9 hours is considered as best priming concentration and priming time to induce salinity tolerance capability of wheat for increasing germination behavior, seedling growth and water relations behavior under a certain level of salinity stress condition.

RECOMMENDATION

In this study seeds treated with 0.5% magic growth for 9 hours gave the best result compared to hydro primed and non-primed seeds. Nutrient primed seeds enhance germination, growth and water relations behaviors of wheat variety. Under salinity stress conditions, it is recommended that seeds should be treated with 0.5% magic growth for 9 hours. It is suggested that further study should be carried out with different priming agents in different concentrations and different time duration in field or different location will be give better result. Under the present study, seeds primed with higher concentration of magic growth showed lower performance on germination, growth and water relations behaviors of wheat variety. So, further study can be conducted with lower concentration of magic growth than 0.5% such as 0.1, 0.2, 0.3 and 0.4% to get better performance.

REFERENCES

Abbas, G., Saqib, M., Rafique, Q., Ur-Rahman, M.A., Akhtar, J., Ul-Haq, M.A. and Nasim M. (2013). Effect of salinity on grain yield and grain quality of wheat (*Triticumaestivum* L.). *Pak. J. Agril. Sci*. **50**: 185-189

Abdoli, M. (2014). Effect of seed priming on seed dormancy, vigor and seedling characteristics of fennel *(Foeniculumvulgare*L.*)Acta Adv. Agril. Sci.* **2**(8)*:*18-24.

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

Abebe, A.T.andModi, A.T. (2009). Hydropriming in dry bean *(Phaseolus vulgaris L.).Res. J. SeedSci*.**2**:23-31.

Afzal, I., Basra, S.M.A., Ahmad, N. and Farooq, M. (2005). Optimization of hormonal priming techniques for alleviation of salinity stress in wheat *(Triticumaestivum*L.*).Caderno de PesquisaSeriBiol*.**17**:95-109.

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

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

Agnihotri, R.K., Palni, L.M.S. and Pandey, D.K. (2006). Screening of land races of rice under cultivation in Kumaun Himalayan for salinity stress during germination and early seedling growth. *Indian J. Pl. Physiol*. **11**(30): 262-272.

Ahmad, K., Saqib, M., Akhtar, J. and Ahmad, R. (2012). Evaluation and characterization of genetic variation in maize (Zea mays L.) for salinity tolerance. *Pak. J. Agri. Sci*. **49**(4): 521-526.

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

Akbarimoghaddam, H., Galavi, M., Ghanbari, A. and Panjehkeh, N. (2011). Salinity effects on germination and seedling growth of bread wheat cultivars. *Trakia J. Sci*. **9**(1): 43-50.

Anaya, F., Fghire, R., Wahbi., S. and Loutfi, K. (2015). Influence of salicylic acid on seed germination of Viciafaba L. under salt stress. *J. Saudi Soc.Agril. Sci*.**17**(1): 1-8.

Ansari, O. and Sharif-Zadeh, F. (2012). Osmo and hydro priming improvement germination characteristics and enzyme activity of mountain rye (Secalemontanum) seeds under drought stress. *J. Stress Physiol. Biochem*. **8**(4):253-261.

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.

Ashraf, M. and Harris, P. J. C. (2004). Potential biochemical indicators of salinity tolerance in plants. *Pl. Sci*. **166**: 3-16.

Aymen, E. M., Meriem, B. F., Kaouther, Z., Cheri, H.(2014). Influence of NaCl Seed Priming on Growth and Some Biochemical Attributes of Safflower Grown under Saline Conditions. *Res. Crop Ecophysiol.* **9**(1): 13-20.

Azzedine, F., Gherroucha, H. and Baka, M. (2011). Improvement of salt tolerance in durum wheat by ascorbic acid application. *J. Stress Physiol. Biochem*. **7**: 27-37.

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. Pl. Sci*. **22**(1): 159-164.

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.

Basiri, H.K., Sepheri, A. and Sadeghi, M. (2013). Effect of salinity stress on the germination of safflower seeds (*Carthamustinctorius* L. cv. Poymar). *Tech. J. Eng. App. Sci*. **3**(11): 934-937.

BBS. (2017). Bangladesh Bureau of Statistics, Statistical Year Book of Bangladesh, Statistics Division.

Beckers, G.J.M. and Conrath, U. (2007). Priming for stress resistance: from the lab to the field. *Curr.Opin. Pl. Biol*. **10**: 1–7.

Bewley, J.D. (1997). Seed germination and dormancy. *The Plant Cell*. **9**(7): 1055-1066.

Capron, I., Corbineua, F., Dacher, F., Job, C., Come, D. and Job, D. (2000). Sugar beet seed priming: Effects of priming conditions on germination, solubilization of 11globulin andaccumulation of LEA proteins. *Seed Sci. Res*. **10**: 243-254.

Casenave, E.C.andToselli, M.E. (2007). Hydro priming as a pre-treatment for cotton germination under thermal and water stress conditions. *Seed Sci. Technol*. **35**: 88-98.

Chiu, K.Y., Chen, C.L. and Sung, J.M. (2002). Effect of priming temperature on storability of primed sh-2 sweet corn seed. *Crop Sci*. **42**: 1996-2003.

Chiu, K.Y., Chuangm S.J. and Sung, J.M. (2006). Both anti-oxidation and lipid-carbohydrate conversion enhancements are involved in priming- improved emergence of *Echinacea purpurea* seeds that differ in size. *Sci.Hort.* **108**:220-226.

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

Datta, J. K., Nag, S., Banerjee, A. and Mondal, N. K. (2009). Impact of salt stress on five varieties of wheat (*Triticumaestivum* L.) cultivars under laboratory

Del Ryo, L.A., Corpas, F.J., Sandalio, L.M., Palma, J.M., Gomez,M. and Barroso, J.B. (2002). Reactive oxygen species, antioxidant systems and nitricoxide in peroxisomes. *J.Exp. Bot.***372**: 1255-1272.

Dkhil, B.B., Issa, A. and Denden, M. (2014). Germination and seedling emergence of primed okra (*Abelmoschusesculentus* L.) seeds under salt stress and low temperature. American. *J. Pl. Physiol*. **9**: 38–45.

Dugasa, T., Bebie, B.,Tomer,R.P.S. and Barnabas,J. (2016). Effect of seed priming on salt tolerance of bread wheat (*Triticumaestivum* L.) varieties Tesfayedugasa. *J. Agric. Sci*. **6**(3): 139-153.

El-Hendawy, S.E., Hu-Yuncai, andSchmidhalter, U. (2011). Assessing the suitability of various Physiological traits to screen wheat. *Intl. Integ. Pl. Biol*. **49**(9): 1352-1360.

El-Shaieny, A.A.H. (2015). Seed germination percentage and early seedling establishment of five cowpea[*Vignaunguiculata* L. (Walp)] genotypes under salt stress. *European J. Expt. Biol*. **5**: 22–32.

Esechie, H.A. (1995). Partioning of chloride ion in the germinating seed of two forage legumes under varied salinity and temperature regimes. *Communic. Soil Sci. Pl. Anal*. **26**: 3357–3370.

Farahani, H.A. and Maroufi, K. (2011).Effect of hydropriming on seedling vigour in basil *(OcimumbasilicumL.)* under salinity conditions.*Adv.Environ. Biol.***5**:828-833.

Farhoudi, R. and Sharifzadeh, F. (2006).The effects of NaCl priming on salt tolerance in canola *(Brassica napus*L.) seedlings grown under saline conditions.*Indian. J. Crop Sci.***1**(1-2): 7478.

Farooq, M., Basra, S.M.A. and Wahid, A. (2006b). Priming of field- sown rice seed enhances germination, seedling establishment, algometry and yield. *Pl. Growth Regul*.**49**:285-294.

Farooq, S., Hussain, M., Jabran, K., Hassan, W., Rizwan, M. S. and Yasir, T. A. (2017). Osmopriming with $CaCl_2$ improves wheat (*Triticumaestivum* L.) production under water-limited environments. *Environ. Sci. Pollute. Res.***24**(15): 13638-13649.

Fotia, R., Aburenia, K., Tigerea, A., Gotosab, J. andGerec, J. (2008). The efficacy of different seed priming osmotica on the establishment of maize (Zea*mays* L.) caryopses.*J.Arid Environ.***72**: 1127-1130.

Fujikura, Y., Kraak, H.L., Basra, A.S.andKarssen, C.M. (1993). Hydropriming, a simple and in expensive priming method.*SeedSci.Technol*.**21**:639-642.

Fuller, M.P., Hamza, J.H., Rihan, H.Z. and Al-Issawi, M. (2012). Germination of primed seed under NaCl stress in wheat. International Scholarly Research Notices: Botany. Article ID 167804. doi:10.5402/2012/167804

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

Greenway, H. and Munns,R. (1980). Mechanism of salt tolerance in non-halophtes. Annuals Review of *Pl. Physiol*.**31**: 149–190.

Hameed, A., Naseer, S., Iqbal, T., Syed, H, And Haq, M.A. (2009). Effects of NaCl salinity on seedling growth, Senescence, catalase and protease activities in Two wheat genotypes differing in salt tolerance. *Pak. J. Bot.* **40**(3): 1043-1051.

Hampton, J.G. and Tekrony, D.M. (1995). Handbook of ISTA vigour test methods. 3rdEdn., Zurich: ISTA. 10. Jeng TL, Sung JM. 1994. Hydration effect on lipid peroxidation and peroxide-scavenging enzyme activity of artificially aged peanut seeds. *Seed Sci. Technol.***22**: 531-539.

Harris, D., Joshi, A., Khan, P.A., Gothkar, P.andSodhi, P.S. (2004). On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. *Exp. Agric.***35**: 15-29.

Hasan, M. M., Baque, M. A., Habib, M. A., Yeasmin, M. and Hakim, M. A. (2017). Screening of Salt Tolerance Capability of Wheat Genotypes under Salt Stress Condition. *Universal J. Agric.Res*. **5**(4): 235-249.

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

Horneck, D.A., Ellsworth, J.W.,Hopkins, B.G.,Sullivan, D.M. and Stevens,R.G. (2007). Managing salt affected soil for crop production. A Pacific Northwest extension publication oregon State University, University of Idaho, Washington State University. PNW 601-E.

Iqbal, M. and Ashraf, M. (2005). Pre-sowing seed treatment with Cytokinin and its effect on growth, photosynthetic rate, ionic levels and yield of two wheat cultivars differing in salt tolerance. *J. Integ. Pl. Biol*., **47**: 1315-1325.

Iqbal, M. and Ashraf, M. (2005). Changes in growth, photosynthetic capacity and ionic relations in spring wheat (Triticumaestivum L.) due to pre-sowing seed treatment with polyamines. *Pl. Growth Regul*. **46**(1): 19–30.

Islam, M.R. and Salam, M.A. (1996). Growth and yield performance of some selected rice lines under different salinity regimes. *Bangladesh J. Training Dev*. **9**(2): 53-56.

ISTA. (2003). International Seed Testing Association, ISTA Handbook on Seedling Evaluation, 3rd.

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**(1): 38–45.

Jisha, K.C., Vijayakumari, K. and Puthur. J.T. (2013). Seed priming for abiotic stress tolerance: an overview. *Acta. Physiol. Pl.*.**35**(5): 1381-1396.

Kaur, S. (2002).Effect of osmo and hydro priming of chickpea seeds on the performance of the crop in the field.*Int. Chickpea Pigeon pea Newsl.***9**: 15-17.

Kaur, S., Gupta, A.K. and Kaur, N. (2005). Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *J. Agron. and Crop Sci.***191**: 81-87.

Kheya, M.D., Okc, G. andAtak, Y.C. (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., Maguire, J.D.,Abawi,G.S. and Illas,S. (1992). Matriconditioning of vegetable seed to improve stand establishment in early field planting. *J. American Soc. Hort.Sci*. **117**: 41–47.

Khan, M.J. (2007). Physiological and biochemical mechanisms of salinity tolerance in different wheat genotypes. PhD thesis Department of Agricultural Chemistry/NWFP Agriculture University Pshawar. p. 114.

Kheya, (2018). Induction of drought tolerance capability of soybean through polyethylene glycol and hydro priming. M.S. thesis, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Kumar, A., Bandhu, P. and Das, A. (2005). Salt tolerance and salinity effects on plants: a review. *Ecotoxicol. Environ. Saf*. **60**: 324-349.

Lallu, R. and Dixit, R.K. (2005). Salt tolerance of Mustard genotype at seedling stage. *Indian J. Pl. Physiol*. **14**(2): 33-35.

Maiti, R.K., Arnab Gupta, Umasahankar, P., Raj Kumar, D. andVidyasagar, P., (2009). Effect of priming on seedling vigour and growth and productivity of few vegetable species: Tomato, Chilli, Cucumber and Cabbage. *Intl. J.Agril.Environ.Biotechnol***.**2(4): 368-374.

Menon, N.U.N., Gandhi, M.B., Pahoja, V.M. and Sharif, N. (2013).Response of seed priming with Boron on germination and seedling sprouts of Broccoli. *Intl. J. Agric. Sci. Res.***2**(2):1-16.

Miller, G., Suzuki, N., Ciftci-Yilmaz, S. and Mittler, R. (2009). Reactive oxygen species homeostasis and signaling during drought and salinity stresses. *Plant Cell Environ*.**33**: 453–467.

Mohmand, A. S., Riai, S. and Niazi, B. (1995). Performance of some wheat germplasm under the ion effect wider saline conditions. *Sarhad J. Agril*. **11**(3): 341-348.

Mussa, A., Johanse,C., Kumar,J., and Harris,D.(1999).Response of chickpea to seed priming in the High Barind Tract of Bangladesh. *Intl.Chickpea Pigeonpea Newsletter*.**6**:20-22.

Nakaune, M., Hanada,A., Yin,Y.G., Matsukura,C.and Yamaguchi,S. (2012). Molecular and physiological dissection of enhanced seed germination using short-term low-concentration salt seed priming in tomato.*Pl.Physiol. Biotechnol*.**52**:28-37.

Naseri, R., Emami, T., Mirzaei, A. and Soleymanifard, A. (2012). Effect of salinity (sodium chloride) on germination and seedling growth of barley (*Hordeumvulgare* L.) cultivars. *Intl.J. Agric. Crop Sci*. **4**(13): 911-917.

Nawaz, A., Amjad, M., Pervez, M.A.andAfzal, I. (2011).Effect of halopriming on germination and seedling vigor of tomato.*African J. Agric.Res*.**6**:3551-3559

Nawaz, J., M. Hussain, A. Jabbar, G.M. Nadeem, Sajid,M.,Subtain,M.U. and Shabbir,I.(2013). Seed priming a technique. *Intl. J. Agric. Crop Sci*. **6**(6-20): 1373-1381.

Nayyar, H., Walia,D.P. and Kaishta,B.L.(1995). Performance of bread wheat *(Triticumaestivum* L.) seeds primed with growth regulators and inorganic salts. *Intl. J. Agric. Sci*.**65**:112-116.

Othman, Y., Al-Karaki, G., Al-Tawaha, A.R., and Al-Horani, A. (2006). Variation in germination and ion uptake in barley genotypes under salinity conditions. *World J. Agril. Sci*. **2**(1): 11-15.

Paparella, S., Araújo, S.S., Rossi, G., Wijayasinghe, M., Carbonera, D. and Balestrazzi, A. (2015). Seed priming: state of the art and new perspectives. *Plant Cell Reports*. **34**: 1281–1293.

Pasternak, D. and Pietro,S. (1985). Biosalinity in action: Bioproduction with saline water. *Plant and Soil*. **89**: 1-413.

Patade, V.Y., Maya, K. and Zakwan, A. (2011). Seed priming mediated germination improvement and tolerance to subsequent exposure to cold and salt stress in capsicum. *Res. J. Seed Sci*. **4**(3): 125-136.

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

Radi, A.A., Farghaly, F.A. and Hamada, A.M. (2013). Physiological and biochemical responses of salt-tolerant and salt-sensitive wheat and bean cultivars to salinity. *J. Biol. Earth Sci*. **3**(1): B72-B88.

Rahman, M., Soomro, U. A., Haq, M. Z. and Gul, S. (2007). Effects of NaCl salinity on wheat (*Triticumaestivum* L.) cultivars. *World J. Agril. Sci*. **4**(3): 398-403.

Rahman, M., Soomro, U. A.,Haq, M. Z. and Gul, S. (2008). Effects of NaCI Salinity on Wheat (Triticumaestivum L.) Cultivars. *W.J. Agril. Sci*. **4**(3): 398-403.

Rajpar, I. and Sial, N.B. (2002). Effect of salinity and sodicity with and without soil conditioner (polyerylamide) on the seedling emergencies and growth of different wheat varieties. *Pakistan J. Appl. Sci*. **2** (6): 631-636.

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.

Rastin, S., Hamid Madani, H. and Shoaei, S. (2013). Effect of seed priming on red bean *(Phaseoluscalcaratus)* growth and yield. *Ann. Biol. Res*. **4**(2):292-296.

Rouhi, H.R., Aboutalebian, M.A. and Sharif-Zadeh, F. (2011). Effects of hydro and osmopriming on drought stress tolerance during germination in four

Sali, A., Rusinovci, I., Fetahu, S., Gashi, B., Simeonovska, E. and Rozman, L. (2015). The effect of salt stress on the germination of maize (*Zea mays* L.) seeds and photosynthetic pigments. *ActaAgriculturaeSlovenica*. **105**: 85–94.

Sangakkara, U. R., Hartwig, U. A. and Nosberger, J. (1996). Responses of root branching and shoot water potentials of french bean (*Phaseolus vulgaris* L.) of soil moisture and fertilizer potassium. *J. Agron. Crop Sci*. **177**: 165-173.

Sarker, A., Hossain, M.D.I. and Kashem, A.M.D. (2014). Salinity (NaCl) tolerance of four vegetable crops during germination and early seedling growth. *Intl.J. Lat. Res.Sci. Technol*. **3**: 91–95.

Shabbir,I., Shakir,M., Ayub,M., Tahir,M., Asif, Tanveer, A., Muhammad Shahbaz, M. and Hussain, M.(2013). Effect Of Seed Priming Agents On Growth, Yield And Oil Contents Of Fennel *(FoeniculumVulgareMill.). Adv. Agri. Biol.***1**(3): 58-62.

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

Sivritepe, N., Sivritepe, H.O. and Eris, A.(2003).The effects of NaCl priming on salt tolerance in melon seedlingsgrown under saline *conditions. Scientia Hort.***97**(3-4): 229-237.

Smart, R. E. (1974). Rapid estimates of relative water content. *Pl. Physiol*. **53**: 258- 260.

Soltani, A., Gholipoor, M. and Zeinali, E. (2006). Seed reserve utilization and seedling growth of wheat as affected by drought and salinity. E*nv. Exp. Bot.* **55**: 195-200.

Srivastava, A.K., Lokhande, V.H., Patade, V.Y., Suprasanna, P., Sjahril, R. and D‘Souza S.F. (2010). Comparative evaluation of hydro-, chemo-, and hormonal priming methods for imparting salt and PEG stress tolerance in Indian mustard (*Brassica juncea* L.). *ActaPhysiologiaePlantarum*. **32**: 1135-1144.

Talebian, M.A., Sharifzadeh, F., Jahansouz, M.R., Ahmadi, A.andNaghavi, M.R. (2008). Evaluation the effect of seed priming on germination, seedling stand and grain yield of wheat cultivars (*Triticumaestivum* L.) in three different regions in Iran. *Ir. J. CropSci*. **39**(1): 145-154.

Tammam, A.A.,Abou, M.F.,Alhamd and Hemeda, M.M. (2008). Study of salt tolerance in wheat (*Triticumaestium* L.) cultivar Banysoif-1. *Agric. J. Crop Sci*. **1**(3): 115-125.

Tanou, G., Fotopoulos, V. and Molassiotis, A. (2012). Priming against environmental challenges and proteomics in plants: update and agricultural perspectives. *Frontiers Pl.Sci*.**3**: 216.

Taylor, A.G., Allen, P.S., Bonnett, M.A., Bradford, K.J., Burris, J.S. and Misra, M.K. (1998). Seed enhancements. *Seed Sci. Res*. **8**(2): 245–256.

Thiam, M., Champion, A., Diouf, D. and MameOureye, S.Y. (2013). NaCl effects on in vitro germination and growth of some Senegalese cowpea (*Vignaunguiculata* (L.) Walp.) Cultivars. ISRN Biotechnology. Article ID 382417. http://dx.doi.org/10.5402/2013/382417

Umair, A., Bashir,K.and Hussain,S.(2010). Evaluation of different seed priming techniques in mungbean*(Vignaradiata).S. Environ.***29**: 181-186.

Wahid, A., Farooq, M., Basra, S.M.A., Rasul, E. and Siddique, K.H.M. (2011). Germination of seeds and propagules under salt stress. In: Pessarakli M (ed) Handbook of Plant and Crop Stress, 3rdedn. Boca Raton: CRC Press; pp. 321–337.

Wahid, A., Perveen, M., Gelani, S.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. Pl. Physiol.***164**:283-294.

Waraich, E.A., Ahmad, R., Saifullah, Ashraf, M.Y. and Ehsanullah (2011). Role of mineral nutrition in alleviation of drought stress in plants. *Aust. J. Crop Sci*. **5**: 764-77.

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.

Yokoi, S.,Bressan,R.A. and Hasegawa,P.M..(2003). Salt stress tolerance of plants. *JIRCAS* Working Report. 25-3.

Zheng, G.H., Wilen, R.W., Slinkard, A. E. and Gusta, L.V. (1994). Enhancement of canola seed germination and seedling emergence at low temperature by priming.*Crop Sci.***34**: 1589-1593.

APPENDICES

Appendix I. Monthly records of air temperature, relative humidity and rainfall during the period from October 2021 to December 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	October	30.42	16.24	23.33	68.48	52.60
2020	November	28.60	8.52	18.56	56.75	14.40
2020	December	25.50	6.70	16.10	54.80	0.0

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

Appendix II: Effect of different priming concentrations on germination behavior of wheat

Sources of variation	Degrees of freedom	Mean square of germination rate
Factor A	5	1046.85*
Error	20	0.09

* = Significant at 5% level

Appendix III: Effect of different priming concentrations on different growth characters of wheat

Sources of variation	Degrees of freedom	Mean square of growth characters			
		Shoot length (mm)	Root length (mm)	Fresh weight of shoot (mg)	Fresh weight of root (mg)
Factor A	5	722.333*	2253.00*	399.318**	1812.16*
Error	20	3.104	17.10	3.427	5.31

* = Significant at 5% level ** = Significant at 1% level

Appendix IV: Effect of different priming concentrations on dry matter content of shoot and root of wheat

Sources of variation	Degrees of freedom	Mean square of dry matter content	
		Dry weight of shoot (mg)	Dry weight of root (mg)
Factor A	5	102.098**	103.600**
Error	20	0.716	0.173

** = Significant at 1% level

Appendix V: Effect of different priming concentrations on water relation behaviors of wheat

Sources of variation	Degrees of freedom	Mean square of water relation behavior		
		Relative water content (RWC)	Water saturation deficit (WSD)	Water retention capacity (WRC)
Factor A	5	46.7900*	47.1471*	10.9229**
Error	20	0.1352	0.1380	0.0840

* = Significant at 5% level ** = Significant at 1% level

Appendix VI: Effect of different priming concentrations on germination behavior of wheat

Sources of variation	Degrees of freedom	Mean square of vigor index
Factor A	5	2312.364*
Error	20	24.73

* = Significant at 5% level

Appendix VII. Effect of different levels of salt stress on germination rate (GR) of wheat

Sources of variation	Degrees of freedom	Mean square of germination rate at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	26.366*	64.266*	12.978**	11.597**	24.332*
Error	8	1.828	3.487	1.760	2.462	1.972

* = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Effect of different levels of salt stress on shoot (SL) length of wheat

Sources of variation	Degrees of freedom	Mean square of shoot length (mm) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	621.246*	362.381*	905.705*	2482.867*	69.273**
Error	8	2.956	2.376	2.665	0.563	1.963

* = Significant at 5% level ** = Significant at 1% level

Appendix IX. Effect of different levels of salt stress on root length (RL) of wheat

Sources of variation	Degrees of freedom	Mean square of root length (mm) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	833.511*	1895.618*	226.427**	906.733*	349.997*
Error	8	3.866	1.299	1.786	1.417	1.999

* = Significant at 5% level ** = Significant at 1% level

Appendix X. Effect of different levels of salt stress on fresh weight of shoot (FWS) of wheat

Sources of variation	Degrees of freedom	Mean square of fresh weight of shoot (mg) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	438.09*	1123.33*	165.88*	474.87*	42.088**
Error	8	1.487	1.670	0.735	0.603	1.273

* = Significant at 5% level ** = Significant at 1% level

Appendix XI. Effect of different levels of salt stress on fresh weight of root (FWR) of wheat

Sources of variation	Degrees of freedom	Mean square of fresh weight of root (mg) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	6795.70*	1288.812*	78.189**	171.481*	115.256*
Error	8	2.017	2.525	0.809	2.007	0.353

* = Significant at 5% level ** = Significant at 1% level

Appendix XII. Effect of different levels of salt stress on dry weight of shoot (DWS) of wheat

Sources of variation	Degrees of freedom	Mean square of dry weight of shoot (mg) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	3.897**	10.275*	9.687*	5.436*	2.212**
Error	8	0.263	0.752	0.117	0.053	0.056

* = Significant at 5% level ** = Significant at 1% level

Appendix XIII. Effect of different levels of salt stress on dry weight of root (DWR) of wheat

Sources of variation	Degrees of freedom	Mean square of dry weight of root (mg) at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	4.990*	5.867*	2.118**	1.859**	10.274*
Error	8	0.415	0.474	0.201	0.269	0.129

* = Significant at 5% level ** = Significant at 1% level

Appendix XIV. Effect of different levels of salt stress on relative water content (RWC) of wheat

Sources of variation	Degrees of freedom	Mean square of relative water content at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	0.431^{NS}	106.36**	86.334**	585.457*	133.795*
Error	8	0.326	0.318	0.406	0.366	0.121

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XV. Effect of different levels of salt stress on water saturation deficit (WSD) of wheat

Sources of variation	Degrees of freedom	Mean square of water saturation deficit at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	0.319^{NS}	96.331**	103.215**	579.234*	144.555*
Error	8	0.332	0.076	0.108	0.086	0.173

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XVI. Effect of different levels of salt stress on water retention capacity (WRC) of wheat

Sources of variation	Degrees of freedom	Mean square of water retention capacity at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	10.981*	8.844*	4.330**	2.303**	17.754*
Error	8	0.044	0.066	0.080	0.073	0.012

* = Significant at 5% level ** = Significant at 1% level

Appendix XVII. Effect of different levels of salt stress on vigor index (VI) of wheat

Sources of variation	Degrees of freedom	Mean square of vigor index at different salt level				
		S_0	S_1	S_2	S_3	S_4
Factor A	2	1781.56*	2642.088*	914.429*	2887.206*	328.01**
Error	8	0.931	0.162	0.031	0.053	0.123

* = Significant at 5% level ** = Significant at 1% level