INDUCTION OF DROUGHT TOLERANCE IN WHEAT THROUGH NUTRIENT AND HYDRO PRIMING

MST. SABRINA AKTAR

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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INDUCTION OF DROUGHT TOLERANCE IN WHEAT THROUGH NUTRIENT AND HYDRO PRIMING

BY

MST. SABRINA AKTAR

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Approved by:

……………………………………… …..……………………………………

Prof. Dr. Md. Abdullahil Baque
Supervisor

Prof. Dr. Parimal Kanti Biswas
Co-Supervisor

…………………………………………………..

Prof. Dr. Tuhin Suvra Roy
Chairman
Examination committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Ref:-.................................   Date:-…………………………

CERTIFICATE

*This is to certify that the thesis entitled, "**INDUCTION OF DROUGHT TOLERANCE IN WHEAT THROUGH NUTRIENT AND HYDRO PRIMING**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **MST. SABRINA AKTAR, Registration No.: 14-06244** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Place: Dhaka, Bangladesh

………………………………………

Prof Dr. Md. Abdullahil Baque

Department of Agronomy

Sher-e-Bangla Agricultural University

Supervisor

Dedicated

To My

Beloved Family

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ABSTRACT

The experiment was conducted under the laboratory condition of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka from August 2019 to July 2020 to investigate the effect of seed priming on germination behaviour, growth parameters and water relation behaviours of wheat (BARI Gom 30) under drought stress condition. In the 1st experiment seeds of wheat were surface sterilized with 75% alcohol for 5 minutes. Wheat seeds of BARI Gom 30 was pre-soaked in 0%, 1%, 2%, 3% and 4% KCI solution, distilled water for 9hrs and untreated seeds were used as control treatment. Results showed that seeds priming induces the germination percentage, growth parameters (seedling fresh weight, root length, shoot length, shoot dry weight, 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 (98%), root and shoot length (175.55mm and 162.34mm), plant fresh weight (276.40mg), root and shoot dry weight (17.81mg and 13.48), vigour index (331.57), water retention capacity (19.40%), relative water content (92.80%) were obtained from seeds treated with 2% KCI and then gradually decrease with increasing KCI concentration. Highest water saturation deficit (18.00%) was obtained from control seeds and lowest was obtained from seeds treated with 2% KCI. In 2nd experiment primed (2% KCI for 9hrs), hydro primed (distilled water for 9hrs) and non-primed seeds were treated under drought stress condition induced by 0%, 5%, 10%, 15% and 20% PEG solution. Seeds treated with 2% KCI showed better result compared to hydro priming and control (non-primed) seeds up to 10% PEG concentrations in all parameters and this value decreased with increasing concentrations of PEG solution. Hydro priming also showed better result than non-primed seeds in all parameters but not better than 2% KCI priming solution. So, seeds primed with 2% KCI and distilled water showed the better performance compared to non-primed seeds under drought stress condition. The result suggested that seeds primed with 2% KCI for 9 hrs considered as best priming concentration for inducing drought tolerance in wheat seeds in germination behaviour and all related growth parameters.

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LIST OF ACRONYMS

Acronym		Full meanings
AEZ	=	Agro-Ecological Zone
%	=	Percent
^{0}C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CV%	=	Percentage of coefficient of variance
Cm	=	Centimeter
CRD	=	Completely Randomized Design
et al.	=	And others
FAO	=	Food and Agriculture Organization
GI	=	Germination Index
GP	=	Germination percentage
Inter	=	International
LSD	=	Least Significant Difference
Mg	=	Milligram
Mm	=	Milimeter
Res.	=	Research
Sci.	=	Science
SAU	=	Sher-e-Bangla Agricultural University
Techno.	=	Technology
VI	=	Vigour Index

CHAPTER I

INTRODUCTION

Wheat (*Triticum spp*) is a most important cereal grain crop. People eat it mostly in the form of bread. It is a kind of grass plant whose fruits is a "head of wheat" with edible seeds. It was first originated in the Levant, a region of the Near East. Now it is cultivated worldwide. Wheat is one of the most important source of vegetable protein in human food. It contains higher protein content in major cereals such as maize or rice. In terms of total production, wheat is second as the primary human food crop and ahead of maize. Now, global wheat production is 770.4 tonnes, which is growing by 3.9% compared with the previous years (FAO, 2021). It is the major food of more than 36% of world people that contains about 55% of the carbohydrates and 20% of the food calories consumed as human diet (Lobell and Gourdji, 2012; Hasanuzzaman *et al*., 2017). Around the world, almost 30% area is roofed by wheat cultivation (Lobell and Gourdji, 2012).

The national wheat production during the year 2021 was 1130 metric tons which was 4.24% less than previous year (USDA, 2021). However, the wheat yield of Bangladesh is very little comparing the any other wheat producing countries in the world due to the growing wheat under rainfed condition (Bazzaz, 2013).For meeting the ongoing food crisis wheat production necessary to be increased in Bangladesh. The capability of increasing the cultivated land is limited in Bangladesh due to over population. So, the main path to meet the food demand is to increase the total production as yield per unit area.

Total world population by 2050 will be approximately 9-10 billion which will require more food production to feed this huge population (Waraich *et al*., 2011). Due to the effect of various abiotic and biotic stresses productivity of wheat is badly affected. Global climate changes due to unpredictable environmental conditions now become threat to the current and future agriculture and causes impact on global agriculture in terms of both biotic and abiotic stresses, which reduces plant growth and declined yield attributes (Hasanuzzaman *et al*., 2012b). There are various abiotic stresses, drought stress takes an important position due to its nature of demolition and losses to crop yields. For confronting this challenge, increase of yield potential is essential through increasing the yield potential by decreasing different kinds of biotic and abiotic stresses including drought (Tuteja *et al*., 2012). Plants are always experience various environmental disasters like drought, salinity, temperature extremes, toxic metals etc. more or less every year which give rise to 50% yield reduction annually.

The indeterminacy of the global climate with precarious rainfall patterns is the major reasons of the rapid beginning of drought stress almost the world. Insufficient supply of water for longer periods, affects the yield and productivity causes bad impacts on phenology, growth, and reproduction. Cell division, elongation, and expansion were inhibited due to less water flow from the xylem to the others cells. Drought stress also reduces plant height, leaf area, stem extension, and root proliferation. Plants generally adapt to endure under drought stress through the induction of various morphological, physiological (osmotic adjustment and cell membrane stability), biochemical (proline, auxins, and ethylene), and molecular mechanisms as stress-responsive proteins (Basu *et al*., 2016). Due to the above-mentioned limitations of the available techniques, it has become necessary to figure out a substitute solution to avoid tolerance of plants against various stresses. The substitute solution would be more admissible if it is easy, cheap and can be accepted by the farmers very eagerly and it should be very feasible illuminating the tolerance.

Seed priming is deliberated as a promising technique to increase stress tolerance capability of crop plants including drought. Seed priming is the induction of certain physiological behavior in plants through treatment with natural and synthetic compounds to the seeds prior to germination. The physiological state in which plants are able to faster or better activate defense responses or both is called the primed state of the plant (Beckers and Conrath, 2007). Seed priming induces the early emergence of seedlings through the regulation of metabolic processes in the early phases of germination under drought stress (Farooq *et al*., 2017). It is an easy and cost-effective technique to get over unfavorable effects of abiotic stresses (Ibrahim *et al*., 2016; Wojtyla *et al*., 2016). Seed priming can promote the tolerance of plants against abiotic stresses through enhanced and advanced germination, improved mechanisms of protection against oxidative stress and reserved memory of previous stress (Chen and Arora, 2011). 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 *et al*., 2002; Harris *et al*., 1999 and Chivasa *et al*., 1998). 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. Seed priming with calcium salts has been more effective and economical in promoting stress tolerance in plants (Jaafer *et al*., 2012 and Tabassum *et al*., 2017) because calcium works as secondary messenger in signaling pathways (White and Broadley, 2009) and developed osmolytes accumulation and antioxidant activity under stressed conditions (Farooq *et al*., 2017).

Drought stress inhibited the growth and yield of crops, if the plants formerly exposed to one type of stress (stress priming/hardening) may develop tolerance to another kind of stress through promoted production of secondary metabolites (Tabassum *et al*., 2017; Farooq *et al*., 2017). Wheat seeds which are treated with DW for 12h increased nitrogen uptake for 11 kg/ha (Singh and Agarwal, 1977). Seed soaking in 2.5% KCl for 12 h before sowing increased wheat grain yield for 15% (Mishra and Dwivedi, 1980). Seed soaking with 0.5 to 1% solutions with KCl or K_2SO_4 significantly increased plant height, grain yield and its components in wheat genotypes (Paul and Choudhury, 1991).

Potassium is one of the major nutrient which is very essential for plant growth and development. Optimum soil concentrations of potassium varies from 0.04% to 3% (Sparks and Huang, 1985). Plants require potassium ions (K) for protein synthesis and for the opening and closing of stomata, which is regulated a proton pumps to pr0duce surrounding guard cells either turgid or flaccid. Potassium also maintains photosynthesis, protein synthesis, development of some phloem solute transport of photo assimilates into source organs and maintenance of cation and anion level in the cytoplasm and vacuole. The main role of potassium is to provide the appropriate iconic environment for metabolic process in the cytoplasm and as such functions as a regulator of various processes including growth regulation (Leigh and Wyn, 1984). Seed-priming technology has twofold benefits: enhanced, rapid and uniform emergence, with high vigor and better yields in vegetables and floriculture (Bruggink, 2004) and some field crops (Basra *et al*., 2005; Kaur *et al*., 2005). Under stress condition primed seedling able to grow normally (Ashraf and Foolad, 2005).

Seed priming are prevented seeds from absorbing enough water for radical protrusion and retarding the seeds in the lag phase (Taylor *et al*., 1998). Seed priming has been commonly used to minimize the time between seed sowing and seedling emergence and to ensure synchronize emergence (Parera and Cantliffe, 1994). The effect of priming are collaborated with repairing and building up of nucleic acids, increased synthesis of proteins as well as the repairing of membranes (McDonald, 2000).

Potassium chloride has been introduced as the osmoticum to enhance germination, emergence and growth of Poaceae plants (Mishra and Dwivedi, 1980). KCl a useful nutrient primer for safe seed germination in wheat crop under control conditions and inhibits the adverse and depressive effects of salinity and water stress on germination which are alleviated by various seed priming treatments (Solangi and Chachar, 2014). Different priming treatments of potassium chloride (KCl) increases seed germination, root length, shoot length, root growth rate, shoot growth rate, root fresh weight, shoot fresh weight, root dry weight, shoot dry weight, root moisture and shoot moisture respectively (Solangi and Chachar, 2014). Therefore, the salutary effects of priming may be more apparent under unfavorable rather than favorable conditions (Parera and Cantliffe, 1994). Primed seeds usually exhibit an increased germination rate, greater germination uniformity, and at times, greater total germination percentage (Basra *et al*., 2005). These attributes have practical agronomic implications, notably under adverse germination conditions (McDonald, 2000).

In Bangladesh very few number of people know about hydro priming and information related to seed priming with osmotic priming agent for inducing drought tolerance in wheat or other crops in Bangladesh is very rare. Therefore, the present research will be undertaken with the following objectives:

i) To evaluate the effect of pre-sowing seed treatment with various concentration of Potassium Chloride (KCl) on germination behavior, seedling growth and water relation of wheat in relation to drought stress

ii) To optimize the priming time on germination behavior, seedling growth and water relation behavior of wheat

iii) To better understanding of the physiological mechanism involve during seed germination, seedling growth and water relation behavior under drought stress condition.

CHAPTER II

REVIEW OF LITERATURE

Wheat is a most important cereal crop in Bangladesh but its production is greatly affected by drought stress. Pre-sowing treatment of seeds improve the germination behavior, seedling growth and under various stress conditions. Seed priming is the most important techniques to escape those adverse condition. Available literatures on priming of seeds on different legume and others corps are studied by different authors as followed:

2.1 Seed priming

Seed priming is a form of seed preparation in which seeds are pre-soaked before planting (Ahmad *et al.*, 2012). Chemo-priming with mannose, mannitol and H_2O_2 mitigate drought stress in wheat (Hameed *et al.*, 2014). Silicon as sodium silicate improves germination, growth, antioxidant enzymes activities and reduces lipid peroxidation during drought stress in wheat (Pei *et al.*, 2010). Activities of antioxidants (SOD, POD and CAT) stimulates after sodium silicate treatment in wheat under stress (Ali *et al.*, 2012). Halo priming with different concentrations of (1%, 2% and 3%) potassium chloride (KCl) increases seed germination and seedling growth of wheat (Solang and Chachar, 2014). Organic and inorganic pre-treatments can apply to cucumber (*Cucumis sativus* L.) seeds and increases seed germination (Isheri *et al.*, 2015).

Parmoon *et al*. (2013) reported that priming allowed to begin the biochemical processes and metabolism of sugars which acted as a hydrolysis inhibitors during the first and the second stages of germination prior to the emergence of the radical. It is reported that seed priming alleviates physiological and pathological stresses and causes utilization, activation and enhancement of various cellular defense responses and resistance (Conrath *et al*., 2002). Hydro and osmo priming improved the germination parameter of Tall Wheatgrass (*Agropyron elongatum*) under stimulated drought stress by PEG (Rouhi *et al*., 2015). Farhana *et al*. (2014) conducted that seeds primed with (KCl and KOH) caused significant development in seedling fresh and dry biomass during extreme salinity level in *Pisum sativum* seeds.

Munns and Tester, (2008) and Taiz and Zeiger, (2006) observed that Poly ethylene glycol (PEG) is most commonly used to induce the osmotic stress in plants and also increases the growth of leaves, stems, leaf area, number of tillers, development of new leaves, lateral buds, branches and root growth. Arruje *et al*. (2013) conducted that seed priming with sodium silicate (SS) enhances seed germination and seedling growth under water-deficit stress induced by polyethylene glycol (PEG). The objective of this study was to evaluate the effects of priming with sodium silicate on improvement of germination percentage and seedling growth of wheat under simulated drought stress. Result indicated that seed priming with different concentrations of sodium silicate and hydro priming increases final germination percentage and improves seedling growth comparing with non-primed seeds under drought stress condition.

Ajirloo *et al*. (2013) reported that seeds primed for 20, 40 and 60 hours in seven priming media (PEG 5%, PEG 10%, KNO_3 1%, KNO_3 2%, KCl 2%, KCl 4% and distilled water as control). Best result given seed primed by KNO_3 2% which showed maximum seed germination percentage. The highest seedling length and radical length were observed by seeds treated with KCl 2% for 60 h and KCl 4% respectively. Germination percentage also increased when the seed soaked KNO_3 2% compared with PEG, KCl and water. This priming technique improved some parameters such as seedlings length, radicle length, stem dry weight and rate of germination.

2.2 Effect on germination parameters

2.2.1 Total Germination (%)

Seed priming is a pre-sowing seed treatments in water or other osmotic solution which permits seed to imbibe water and helps seed germination but prevents radical protrusion through seed coat. The most popular and functional priming treatments are hydro priming and halo priming. Seed priming is a simple, low cost and effective process and also a controlled hydration process followed by re-drying and very effective to reduces salinity effects in many crops (Wahid *et al*., 2007; Afzal *et al*., 2011). Seed priming improved the germination percentage and seedling growth by reducing emergence time and increased yields in field crops including rice (Farooq *et al*., 2006b; Afzal *et al*., 2006; Afzal *et al*., 2011). Sun *et al*. (2010) reported that PEG priming with moderate concentration showed higher tolerance to drought stress than hydro-priming, though higher concentrations of PEG had negative effects on seed germination. Baque *et al*. (2016) concluded that seed priming with Polyethylene Glycol (PEG) helps to increase germination behavior on wheat seed.

Seed priming induces crop growth and higher yields in a range of crops. Harris *et al*. (2007a) reported that seed priming helps to better establishment and growth, earlier flowering, increase seed tolerance to adverse environment and greater yield in maize. Seed priming has a beneficial effect in many field crops such as wheat, sweet corn, mungbean, barley, lentil, cucumber etc. (Sadeghian and Yavari, 2004). Roy and Srivastava (1999) concluded that soaking wheat kernels in water enhanced their germination rate under saline conditions. Seed priming increased on field emergence its rate and early seedling growth of maize crop and improved the field stand and plant growth at vegetative and maturity of maize (Nagar *et al*., 1998). Afzal *et al*. (2006) reported that wheat cultivar treated with different priming agents i.e. Abscisic acid (ABA), Salicylic acid (SA) and ascorbic acid and were sown under normal and saline condition (15 dSm^{-1}), and under saline conditions these treatment reduced the time for 50% germination, increased final germination count, and significantly increased the fresh and dry weight but ascorbic acid did not gives such result.

Salehzade *et al*. (2009) conducted a study to enhance germination and seedling growth of wheat seeds using osmo-priming treatments where seeds were osmo-primed with PEG-8000 solution for 12 hours. By doing these treatments the seedling stand establishment parameters improved. Mishra and Dwibedi (1980) found that before sowing seed soaking in 2.5% KCl for 12 hours increased 15% wheat yield compare to normal seed.

Hypocotyls growth rate of soybean crop is directly associated with the amount of GA_3 which enhanced plant height, improved and faster plant emergence with GA_3, KH_2PO_4 and KCl primed seed plots (Bensen et al,. 1990). Park *et al*. (1997) reported that osmo-priming of rice seed with KCl improved its germination index. Seed priming with KCl is related to the osmotic advantage and K^+ helps to improve cell water saturation, act as co-factor in activities of numerous enzymes (Taiz and Zeiger, 2002). Ahmadvand *et al*. (2012) reported that KNO_3 treating seed caused a significant enhance germination and emergence percentage, radical and plumule length, seedling dry weight, plant height, plant leaf area and plant dry weight of soybean. Seed priming helps to increase leaf area per plant and leaf area of non-primed seeds was decreased by 78%.

According to Basra *et al*. (2003) and Salinas (1996) germination percent, seedling emergence and seedling establishment improved by using seed priming techniques. In fact priming enhances a range of biochemical changes in the seed which increases the germination process i.e., breaking of dormancy, hydrolysis or metabolism of inhibitors, imbibition and enzymes activation (Ajouri *et al*., 2004). Arrjue *et al*., (2013) set an experiment on seed germination and seedling growth of wheat seed primed under water deficit conditions. They found that the germination percentage (GP) (normal seedling percentage (NSP), germination index and seedling length were more in osmo-priming conditions than non-primed seeds. They also found that seed priming treatments not only improved the seed germination but also enhanced the wheat seedling growth under water-deficit stress induced by PEG. Beneficial effects on seed germination and seedling vigor indicated an improvement in water deficit stress tolerance of treated seeds.

Tabassum *et al*. (2017) reported that number of grains per spike (14%), 100-grain weight (32%) and grain yield (21%) were improved by osmo priming the seed from terminal drought stressed source. More number of productive tillers (21%) and harvest index (10%) was observed by osmo priming the seed from well watered crop, as compared to non-primed control. Yari *et al*. (2010) conducted an experiment to measure the effect of different seed priming techniques on germination and early growth of two wheat cultivars. Seeds were primed for 12, 24 and 36 hours at different temperature where four priming media (PEG 20%, KCl 2%, KH_2PO_4 0.5 and KH_2PO_4 1%). They found that KH_2PO_4 and KCl given good result to enhance germination, emergence, growth and grain yield of wheat.

An experiment was conducted by Vazirimehr *et al*. (2014) and they found that potassium nitrate solution in five seed priming levels (0, 0.5%, 1%, 1.5%, and 2 %) on corn showed very good result. They conclude that 1% potassium nitrate given significant results as compared to other levels. Highest germination percentage (92.6 %), biological yield (33.2%), harvest index (10.4%) and tassel weight (4.3%) of corn became possible due to osmo-priming with 1 % potassium nitrate. Which accelerated germination, shorten seed emergence time and prevention of biotic and abiotic factors also improves dry matter partitioning to grain and increased harvest index and seed yield.

Faijunnahar *et al*. (2017) conducted an experiment reported that 10% PEG is sufficient to improve the germination, seedling growth and water relation behavior of wheat genotypes. Eivazi (2012) concluded that wheat seeds which were primed with 2.5% KCl for 16 h enhanced drought tolerance in plants besides increasing the grain yield.

2.2.2 Mean germination time (days)

Mean germination time (MGT) is a measure of the rate and time-spread of germination. MGT used to compare specific pairs or groups of means and to evaluate seed vigor. Speed of germination helps to accelerated germination of primed seeds might be due to increased rate of cell division (Bose and Mishra, 1992). Priming treatment shorten the planting time and seed emergence and to protect seeds from biotic and abiotic stress during critical phase of seedling establishment. Basra *et al*. (2005) reported that priming helped to reduce mean germination time over the non-primed seed. MGT depends on imbibition duration and internal metabolic activities after imbibition.

Arif *et al*., (2008) conducted an experiment in Peshawar, Pakistan and they reported that priming improved the seed establishment in soybean which might be due to the completion of pre germination metabolic activities earlier and makes the seed ready for radical protrusion. Grain yield decreased with extending seed priming duration. Seed priming duration of 6 hours showed faster and better emergence and higher grain yield of soybean as compared to 12 and 18 hours. Priming decreased the optimum temperature and ceiling temperature for germination and also helped in advancing the germination time and did not decrease the final percentage emergence (Finch-Savage *et al*., 2004).

Hydro priming treatments influences seed parameters of *Salvia officinalis* L. (sage) was found by Dastanpoor *et al*. (2013). Seeds of sage were treated by hydro priming at three temperatures 10, 20, 30°C for 0, 12, 24 and 48 hrs. Result indicated that Hydro priming improved the final germination percentage (FGP), mean germination time (MGT) and synchronized the germination of seeds at each three temperature. It was observed that all the treatments enhanced germination except hydro primed seeds for 48h at temperature 30°C. Hydro priming with 12 h at 30°C was most effective in enhancing seed germination that FGP was increased by 25.5% as compared to that of non-primed seeds.

Harris *et al*. (1999) reported that early emergence and maturity in seed priming treatment could be due to advancement in metabolic state. Seed priming improves plant stand and provide benefits in term of maturity was concluded by Musa *et al*. (1999). Seed priming increased earlier emergence of seedlings by 1-3 days and also increased plant stand and initial growth vigour. Priming of seeds increased 47% grain yield advantage and showing positive effects of priming. Seed priming treatment influenced the MGT compared with control seeds at all of the germination temperatures Yucel, (2012). In generally, seeds primed for 24hrs reduced hours required reaching 50% germination compared with the seeds primed for 12hrs. Kumar *et al*. (2002) conducted an experiment and reported that priming of finger millet seeds for 8hrs in water resulted in an increased mean plant height by 9 cm, reduced mean time to 50 per cent flowering and maturity by about 6 days and finally increased grain yield. Narayanareddy and Biradarpatil (2012) conducted experiment to study the influence of seed priming on sunflower. The seeds treated with polyethylene glycol (PEG) with $CaCl_2$ and water hydrations treatments recorded significantly higher germination (71.30%), speed of germination (31.56), root length (12.12 cm), shoot length (12.24 cm), seedling dry weight (165.85 mg), seedling vigour index (1738) and lower electrical conductivity (0.470 dS/m).

Janmohammadi *et al*. (2008) described hydro priming as a suitable, cheap and easy seed invigoration treatment for inbreed lines of maize, when germination is affected by salinity and drought stress. Hydro priming showed result in the earlier germination of desert cacti (Dubrovsky 1996), *Allium porrum* (Ashraf and Bray 1993), pyrethrum (*Tanacetum cinerariifolium*) (Li *et al*., 2011), and coriander (Rithichai et *al*., 2009). Moradi Dezfuli *et al*., (2008) revealed hydro primed seeds for 36 h had lowest values (T50 and MGT).

Ghassemi-Golezani *et al*. (2008) conducted an experiment about seed germination properties of lentil under osmo- and hydro-priming techniques. They observed that seed priming enhanced germination and field performance of lentil compared with non-primed seed but the effect of different priming was also significant. Hydro-priming showed higher seedling emergence in the field, compared to control and seed priming with PEG. Seedling emergence rate was increased by priming seed with water. So, Hydro-priming is a simple and effective method for improving seed germination and seedling emergence of lentil in the field.

The effect of NaCl seed priming techniques on germination and early growth of safflower (*Carthamus tinctorius* L.) was studied by Aymen and Hannachi (2012). Safflower seeds were primed with four concentrations of NaCl as priming media (5, 10, 15 and 20 g/l) for different durations (12, 24 and 36 hours). Results showed that different priming concentrations and durations have cabalistic effect on total germination percentage, mean germination time, germination index and coefficient of velocity of safflower seed. The experiment that 12 hour priming duration had the most significant effect on studied traits as 5 g/l priming concentration treatment. In general, primed seeds showed better performance, prepare a metabolic reaction in seeds and increases seed germination.

An experiment was conducted by Vazirimehret *et al*. (2014) at Iran with potassium nitrate solution in five concentrations (0, 0.5%, 1%, 1.5%, and 2 %) on corn. They concluded that 1% potassium nitrate showed best results as compared to rest of the levels. Highest germination percentage (92.6 %), biological yield (33.2%), harvest index (10.4%) and tassel weight (4.3%) was observed in osmo-priming with 1% potassium nitrate. It accelerated germination, shorten the time from seed emergence and helped to prevention of biotic and abiotic factors also improves dry matter partitioning to grain and increased harvest index and seed yield. Various literatures suggested that seed priming with nitrate salts could manipulate the yield determining parameters successfully in many diverse environment and various crops (Bose and Mishra, 2001; Bose and Pandey, 2003; Sharma and Bose, 2006; Bose *et al*., 2007 and Sharma *et al*., 2009).

Park *et al*. (1997) reported that the primed seeds of soybean resulted in good germination and stand establishment in the field trials. Tavili *et al*. (2011) reported that speed of germination of Bromus increased with seed priming treatments rather than that of control. Elkoca *et al*. (2007) also determined that hydro priming treatment in chickpea enhanced faster and more synchronous germination compared with the unprimed seeds. Fotia *et al*. (2008) reported that osmotic seed priming of maize caryopses resulted in more homogenous and faster seed germination as compared to the control.

2.2.3 Seed germination index

Germination Index (GI) is an estimate of the time (in days) it takes a certain germination percentage to occur and subsequent germination/emergence counts are treated similarly and the summation of the values is called (GI). Assefa *et al*. (2010) reported that seed priming with GA_3 enhance emergence and germination rate of soybean.

Soughir *et al*. (2012) conducted a study in order to develop an optimum protocol for fenugreek and determinate the effect of NaCl seed priming on seed germination. Fenugreek seeds were primed with four concentrations of NaCl as priming media (0, 4, 6 and 8 g/l) for 12, 24, and 36 hours. Results indicated that different priming concentration of NaCl and duration has significant effects on total germination percentage, mean germination time, germination index and coefficient of velocity of fenugreek seeds. It was also observed that 4 g/l for 36 hour showed better performance. The result of this experiment showed that under undesirable conditions such as salinity stress, priming with NaCl can prepare a suitable metabolic reaction in seeds and can improved seed germination.

Abro *et al*. (2009) reported that sodium silicate application resulted in higher germination percentage and germination index of wheat seedlings and ultimately leads to improved yield. Misra and Dwivedi (1980) reported positive effect of seed priming with potassium and distilled water on growth, dry matter accumulation, grain and straw yield in 12 wheat varieties under rain-fed conditions. In trials with 12 wheat varieties grown under rain-fed conditions, soaking seeds in 2.5% KCl sol. at 300 cm3/500 g seed increased dry matter accumulation and grain and straw yields by 15%. Soaking seeds in distilled water was less effective than soaking in KCl solution.

Moradi *et al*. (2012) carried out an experiment and reported that seed priming increased germination percentage, seed germination index, seedling length, root-shoot ratio and decreased mean germination time. The usefulness of these treatments varied depending on the level of the stress (zero or -8 bar), and the priming condition including temperature, different duration, type and osmotic potential of solution. The lower priming duration (i.e., 12 and 24 h) improved germination under normal condition. Otherwise higher priming duration (i.e., 36 and 48 h) provided more protection when the seeds were exposed to drought stress. In this study, priming with urea had better results than other treatments and seed priming with fertilizers might serve as an appropriate treatment for advancing germination under optimum and drought stress conditions.

Seed priming enhanced speed of germination, better crop stand and increased yields in different situations for a lot of crops (Rashid et al., 2006). Seed priming hasten germination index and helps to buildup germination metabolites or osmotic regulations during priming (Arif, 2005).

2.2.4 Coefficient of velocity

The coefficient of velocity of germination gives means indication of the rapidity of germination. Its value increases with increasing the number of germinated seeds and the time required for germination decreases (Jones and Sanders, 1987).

2.2.5 Energy of emergence (%)

Seed priming helps to enhance rapid and uniform emergence and also help to achieve high vigour, which leading to better stand establishment and yield. Hu *et al*. (2005) conducted an experiment. In this priming experiment a priming method called sand priming was practiced where sand was used as a priming solid matrix. Seeds were mixed with sands that contained 3.8% (v/w) water and sealed in plastic box after that they were primed at 18°C for 72 h. The results showed that the energy of germination, germination percentage, germination index and vigor index were improved in four varieties. Otherwise, seedling height, root length, number of root and root dry weight were significantly higher compare to the non-primed controls. Field experiments showed that the seed establishment and yield in sand primed seeds were significantly increased by 19.8% ~ 22.9% and by 9.8% ~ 31.2%, respectively as compared to soaked seeds without priming. Therefore these findings suggest that sand priming method may useful way to improve seedling establishment in direct-sown rice and possible to be used in the field crop production.

Khalil *et al*. (2010) reported that Seed priming enhances speed and uniformity of germination and induces several biochemical changes in the seed that are required to start the germination process such as breaking of dormancy, hydrolysis or mobilization of inhibitors, imbibition and enzyme activation. Seed priming induces many of the metabolic processes involved in the early phases of germination, and primed seeds seedlings emerge faster, grow more vigorously, and perform better in adverse conditions (Cramer, 2002). Germination are trigged by priming and persist following the re-desiccation of the seeds (Asgedom & Becker, 2001). Priming method resulted in more germination speed mainly in drought stress, saline stress and low temperatures in sorghum, sunflower and melon (Sivritepe *et al*., 2003; Kaya *et al*., 2006; Foti *et al*., 2002).

Seed priming techniques such as hydro priming, hardening, osmo priming, osmo hardening, hormonal priming and hydro priming used to enhance germination and more vigorous plants and better drought tolerance in many field crop like wheat (Baque *et al*., 2016), chickpea (Kaur *et al*., 2002), sunflower (Kaya *et al*., 2006), cotton (Casenave and Toselli, 2007) triticale (Yagmur and Kaydan, 2008).

Shete *et al*. (2018) reported an experiment entitled "Effect of seed priming on yield of soybean [Glycine max (L.) Merrill.]", different priming treatments are given before one day of sowing with seven treatments and three replication such as hydro priming, osmo priming, halo priming and control. The experimental design was randomized block design with three replications and seven treatments such as T_1- Hydro priming for 30 minutes, T_2-Hydro priming for 1 hour, T_3-0.5% KNO_3 (Osmo priming for 30 min), T_4- 1% KNO_3 (Osmo priming for 1 hour), T_5- 0.1% NaCl (Halo priming for 30 min), T_6 -0.2% NaCl (Halo priming for 1 hour), T_7-Control. Results indicated relatively higher mean performance of hydro priming for one hour in yield and yield and contributing trades such as days to field emergence, number of pods per plant, seed yield per plant, seed yield per ha, test weight and harvest index.

Baque *et al*. (2016) were conducted a lab experiment to find out the effect of different levels of drought stress on germination behavior of BARI Gam 27. Non primed and primed seeds (osmo primed and hydro primed) were germinated under 0, 5, 10, 15 and 20% PEG solution induced drought stress conditions. Results showed that wheat seeds primed with 10% PEG and distilled water enhanced germination behavior and seedling growth over non-primed seeds. The drought tolerance capability of non -primed and hydro primed seeds decreased drastically as drought stress increased, but osmo primed seeds showed considerable tolerance capability up to stress level induced by 10% PEG then significantly decreased with increasing drought stress. Seeds pre-soaked with 10% PEG and distilled water showed better performance in terms of germination behavior and seedling growth compared to untreated control under drought stress.

Dey *et al*. (2013) set an experiment at the Seed Laboratory of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from January to April 2012 to study the effect of hydro priming on field establishment of seedlings obtained from primed seeds of Boro rice cv. For this experiment BRRI dhan29 seeds were soaked in water for 0, 24, 30, 36, 42, 48, 54 and 60 hours. They examined that priming treatments had significant effect on germination and other growth parameters of rice seedlings. The highest germination, vigor index, population m^2, length of shoot and root and their weights were found at 15 and 30 DAS. The lowest mean germination time was observed from hydro priming of seeds with 30 hours soaking. On the contrary, no priming treatment showed the lowest germination, vigor index, population m^2, and the highest mean germination time.

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

Yuanyuan *et al*. (2010) conducted an experiment for disclosing the effects of seed priming with water and polyethylene glycol (PEG) on physiological characteristics in rice (*Oryza sativa* L.), the seeds of 4 rice cultivars were treated with H_2O and different concentrations of PEG before germination. Primed or non-primed (control) seeds were then germinated under drought stress conditions simulated with PEG in a serious of concentrations. Compared to hydro-priming, priming with PEG in a proper concentration had a better effect on seed germination and seedling growth under drought stress, and the optimal priming concentrations of PEG were 20% for Gangyou 527 (*indica* hybrid rice) and 10%– 15% for Nongken 57 (conventional japonica rice). Even higher concentrations of PEG had negative effects on seed germination. Moderate priming intensity improved metabolism of rice seed, germination indices, seedling quality, and drought tolerance of seedlings under drought stress for all cultivars. However, such effects had limited capability, and severe drought stress inhibited germination and caused damages of rice seedlings.

Rice cultivars had significant impact on priming effect, and *indica* rice showed better performance than japonica rice.

2.3 Effect on growth parameters

2.3.1 Shoot length (mm)

Hydro priming improves shoot length of Nerica and also helps to increase seedling growth of it (Mamun *et al*., 2018). Seed priming increased germination percentage, germination speed, seedling length, root-shoot ratio and decreased mean germination time reported by Moradi *et al*. (2012). Results showed that seed priming with fertilizers might serve as an appropriate treatment for advancing germination under optimum and drought stress condition.

Akbari *et al*. (2007) observed an experiment and reported that auxin treatments increased the hypocotyl length, seedling fresh and dry weight and hypocotyl dry weight in wheat seed. In case of wheat seed hydro priming has resulted in 3 to 4-fold increases in root and shoot length in comparison with seedlings obtained from non-primed seeds in drought condition (Kaur *et al*., 2002). Kumar *et al*. (2017) conducted an experimented on chickpea and reported that higher shoot length has recorded in case of osmo-primed seeds than that of non-primed seeds. Among different osmo-priming treatments 20% PEG showed the highest shoot length followed by 4% mannitol and control showed the lowest shoot length.

A field experiment was conducted by Gupta and Singh (2012) to find out the effects of seed priming on chickpea. The treatments consisted of seed priming (seed soaking in water for 8hrs). The results showed that the growth parameters of chickpea were significantly affected by seed priming. Soaking 14 chickpea seeds in water for about 8hrs significantly influenced plant height and nodule dry weight in comparison to non-primed seeds.

Singh *et al*. (2017) conducted and experimented and reported that hydro priming and osmo-priming treatments on shoot length provide significant variation. They showed that 20% Polyethylene glycol (PEG) for 24hrs (13.14cm) gives better effect on rest of the treatments except at 100 ml distilled water for 12hrs (12.11 cm) and 20% Polyethylene glycol (PEG) for 12hrs (12.77 cm) on pea (*Pisum sativum*).

Zamirifar and Bakhtiari (2014) observed an experiment and investigate that effects of seed priming, germination percentage and rate, radical and hypocotyl length and dry weight, root and shoot length, root and shoot and leaves dry weight, leaf number and leaf area per plant. Results showed that *Nigella sativa* germination was sensitive to drought and higher drought intensity resulted in lower germination percentage and rate. Other seedling traits injured by drought too. Seed priming diminished negative effects of drought and higher germination percentage and rate observed in primed seeds. Drought resulted in lower green area in each plant by reducing leaf number and leaf area, thus photosynthesis decreased. Total dry matter aggregation decreased due to low photosynthesis capacity in each plant.

2.3.2 Root length (mm)

Seed priming help to early and rapid emergence, stand establishment, higher water use efficiency, deeper roots, increasing in root growth, uniformity in emergence, germination in wide range of temperature, break of seed dormancy (Farhoudi and Sharifzadeh, 2006).

Eivazi, (2012) conducted an experiment for evaluating the effects of seed priming on wheat cultivars. Arrangement of treatments were Zarrin, Shariar, Sardary and Azar cultivars as A factor, and priming treatments including distilled water (DW), osmotic solutions (10% PEG, 2.5% KCl, 4% MN, 10% Urea, 5% NaCl W/V) and plant growth inducers (20 ppm IAA, 1000 ppm CCC) with non-primed seed as a control established B factor. During the second year of field experiment two separate treatments were done under drought stress and well watered conditions. Drought stress was withheld by irrigation at booting stage of plants. Maximum amount of absorbed water was determined in cultivar Shariar, 15.5 g DW. Seed weight of all cultivars increased the most when primed with CCC and IAA. Irrespective of the cultivar seedlings related traits revealed that treatment with CCC increased plumule and radical dry weights (11.5 and 8.0 mg) and their lengths (17.2 and 17.8 cm). In opposite, urea pretreatment had negative effects on seedlings growth. All priming treatments increased grain yield and its components, chlorophyll content and nitrogen absorbed under field and green house conditions in four cultivars in comparison to control. Plants arising from seeds primed with potassium chloride under drought stress had the lowest percentage of variation for traits such as relative water content (-9.3%), total dry matter (-10.7%) and grain yield (-4.0%) in comparison with well watered plants. Potassium chloride improved drought tolerance at all wheat cultivars. There were significant correlations between grain yield at primed with KCl and following wheat traits: number of spikes per square meter (0.91**), number of grains per spike (0.92**) and total dry matter (0.79*). Therefore, it seems that these traits could be used as indirect criteria for selection of high grain yield for primed seed.

Riedell *et al*. (1985) and Maske *et al*. (1997) observed an experiment and reported that GA3 treated soybean seeds recorded better field performance and its stimulation effect in enzymes formation which are important in the early phase of germination which helps for a fast radical protrusion in many field crops.

Higher concentrations of PEG 6000 decreased germination percentage and rate, while shoot and root lengths and shoot fresh and dry weights decreased beyond 60g/L and increased up to 120g/L PEG but further increase in stress negatively influenced cultivars tolerance was founded by (Ashagre *et al*., 2014).

2.3.3 Shoot dry weight (mg) and root dry weight (mg)

Seed priming gives higher plant dry weight and seed yield (Harris *et al*., 2004). The increase in the dry weight and grain yield of mungbean was due to better emergence and better performance per plant (Parera and Cantliffe, 1994). Kumar *et al*. (2017) experimented on chickpea and found that in case of seedling dry weight it was higher (1.02 mg to 1.59mg) in PEG 20% seeds followed by mannitol 4% when compared with control. Laghari *et al*. (2016) found that, shoot and root dry weight (mg) has affected by temperature regimes, hydro-priming periods showed highly significant where as their interaction was significant for shoot dry weight. The maximum mean shoots dry weight mg (54.74) was recorded at hydro-priming period 4 hours whereas the lower shoot dry weight mg (38.56) found at no priming or check. The maximum mean root dry weight mg (7.898) was observed at hydro-priming period 4 hours whereas the lower root dry weight mg (5.496) found at no priming or check.

Hamayun *et al*. (2010) investigated the adverse effects of drought stress on growth, yield and endogenous phytohormones of soybean. Polyethylene glycol (PEG) solutions of elevated strength (8% & 16%) were used for drought stress induction. Drought stress period span for two weeks each at pre and post flowering growth stage. They reported that growth and yield attributes of soybean was adversely affected by PEG induced drought stress. Soybean plants were found to be more susceptible to an early drought stress as compared to drought stress at a later growth stage. The level of endogenous growth hormones was also affected by drought stress, as the contents of plant growth promoting hormone (gibberellin) declined, while those of JA and ABA increased under drought stress. It shows that JA and ABA are concerned with plant stress and reaffirms their role in plant resistance to abiotic stress. SA is related to systemic acquired resistance (SAR) of plant and an increase in the quantity of endogenous SA shows that soybean become more susceptible to injuries and pathogens under drought stress.

Miraj *et al*. (2013) set a field experiment to assess the effect of different phosphorus priming sources on seedling growth and yield of maize. Phosphorus concentration (1% P), using potassium di-hydrogen phosphate (KH_2PO_4), single super phosphate (SSP) and di-ammonium phosphate (DAP) along with amended solutions of SSP (20 g l-1 KOH, 15 g l-1 NaOH and 12.5 g l-1 Na_2CO_3) were included in the experiment. Water primed and non-primed seeds were also used as controls. Seeds were primed for 16 h and were then air-dried for 30 minutes. The nutrient uptake of seedling was increased four times due to 1 % P solution priming with KH_2PO_4. Yield of maize was also increased in response to P priming showing significant results in cobs yield, grain and straw yields. Phosphorus content of grain was also enhanced as compared to control. Priming maize with SSP + 20 g 1-1 KOH showed almost the same effect as that of KH_2PO_4.

Abbasdokht *et al*. (2013) studied the effect of priming and salinity on physiological and chemical characteristics of wheat (*Triticum aestivum* L.). They showed that primed plants significantly reduced its gas exchanges by accelerating senescence under a series of salt stress, which became more serious along with the 12 increasing of salt concentrations, especially at 21 d after anthesis. Under each level of salt stress, dry matter accumulation of primed plants was always higher than the non-primed plants. Primed plants had higher potassium selectivity against sodium than non-primed plants. Salt stresses caused significant declines in growth period of wheat by accelerating leaf senescence at reproductive stage. Primed plants of wheat successfully preserved normal growth by maintaining Pn, K^+/Na^+, leaf area duration (LAD) and dry matter accumulation (DMA), while non-primed plants decreased considerably in those parameters.

Amoghein *et al*. (2013) conducted an experiment on the effect of osmo priming and hydro priming on the different index of germination & early growth of wheat under salty stress. They reported that the simple effect of priming for all the characteristics under study, except of shoot dry weight and simple effect of salinity for all the characteristics under study in the experiment at 1% level was significantly simple effect of seed soaking time (4 hours) only on hypocotyle length was significantly. Interaction of salinity on seed priming for root dry weight, longest root on the 5% level showed a statistical significant difference. Also shoot dry weight had a positive and significant correlation with the first and second leaf length, root number and root longest at the %1 level.

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

Khalil *et al*. (2010) observed that phenology and dry matter are important traits being affected by seed priming and soil phosphorus (P_2O_5) application. Priming enhanced days to emergence, anthesis and increased dry matter (DM) production compared with non-primed (control). Seed primed with 0.3% P_2O_5 solution took less time to anthesis (110 days). DM yield increased with each increment of priming and maximum DM yield (6051 kg ha^{-1}) was obtained from seeds primed in 0.2% P_2O_5 solution. Water primed seed took less time to emergence (16 days). Soil P_2O_5 application enhanced days to heading, anthesis, maturity and increased DM yield, while days to emergence, spike m^{-2} and spike length were not affected. Earlier heading, anthesis, maturity and highest DM yield was recorded at 75 kg P_2O_5 ha^{-1}.

Hu *et al*. (2005) conducted an experiment where a priming method called sand priming was developed using sand as a priming solid matrix. Seeds were mixed with sands that contained 3.8% (v/w) water and sealed in plastic box and then were primed at 18°C for 72 h. The results showed that the energy of germination, germination percentage, germination index and vigor index were improved in four varieties. Meanwhile, seedling height, root length, number of root and root dry weight were significantly higher than the non-primed controls. Field experiments showed that the seed establishment and yield in sand primed seeds were significantly increased by 19.8% ~ 22.9% and by 9.8% ~ 31.2%, respectively as compared to soaked seeds without priming. It is indicated that sand priming method may help to improve 18 seedling establishment in direct-sown rice and possible to be used in the field crop production.

Singh *et al*. (2016) cited on different hydro priming and osmo-priming treatments on dry weight. Polyethylene glycol (PEG) @ 20% for 24hrs (0.54) shows significant effect on Untreated (0.40), Mannitol @ 3% for 12hr (0.44), Mannitol @ 3% for 24hrs (0.43), Glycerol @ 5% for 12hrs (0.46) and Glycerol @ 5% for 24hrs (0.48) on dry weight parameters.

Gholami *et al*. (2009) conducted an experiment and found that increase of the synthesis of the hormone gibberellin, which Trigg the activity of α-amylase and other germination specific enzymes like protease and nuclease involved in hydrolysis and assimilation of the starch enhance dry weight of the shoot and dry weight.

2.3.4 Vigor Index (VI)

Eisvand *et al*. (2010) experimented that the effects of hormonal priming on physiological quality and antioxidant enzymes of aged seeds of tall wheatgrass were evaluated under control and drought (-0.5MPa) conditions. Rate of germination, vigour index and growth of root, shoot and seedling were declined by stress conditions. According to the results, hormonal priming improved physiological quality of deteriorated seeds of tall wheatgrass under drought and control conditions. Germination percentage and rate of germination of primed seeds were higher than non-primed seeds under drought condition. 50ppm of auxin increased germination of naturally aged seeds by 18% under drought condition. Likewise, cytokinin treatment resulted in the highest vigour index. Auxin decreased root length and increased number of seminal roots. For other hormones, seed priming by 100ppm of gibberellin, 50ppm of cytokinin, and 50ppm of abscisic acid (ABA) improved seed performance under control and drought conditions.

Sadeghi *et al*. (2011) performed an experiment to evaluate the effect of seed osmo priming by using PEG6000 priming media on germination behavior and seed vigor of soybean (cultivar 033). Seeds were primed with six levels of poly ethylene glycol (PEG 6000) as priming media (distilled water as control, -0.4, -0.8, -1.2, -1.6 and-2 MPa) for 6, 12, 24 and 48 hours at 25°C. Experimental units were arranged factorial in a completely randomized design with three replications. Dry soybean seeds considered as a control treatment (non-primed). Results of variance analysis made clear that different osmotic potential and priming duration had significant effect on germination percentage, mean germination time, germination index, and the time to get 50% germination, seed vigor and electrical conductivity of seeds. Also -1.2 MPa osmotic potential increased germination percentages, germination index and seed vigor meanwhile decreased mean germination time, the time to get 50% germination and electrical conductivity of seeds. Also it was observed that 12 h priming duration had most effect on studied traits as-1.2 MPa osmotic potential treatment. Generally primed seeds showed better condition than control treatment in aspect of studied criteria.

Amjad *et al*. (2007) set an experiment to evaluate the influence of seed priming using different priming agents (distilled water, NaCl, salicylic acid, acetyl salicylic acid, ascorbic acid, PEG-8000 and KNO_3) on seed vigour of hot pepper cv. They found that all priming treatments significantly improved seed performance over the control. KNO_3 primed seeds excelled over all other treatments; decreased time taken to 50% germination, increased root and shoot length, seedling fresh weight and vigour over all other priming agents. Seeds were primed in water (hydro priming) and NaCl (1% solution) (halo priming) and sown in pots at different salinity levels [1.17 (control), 3, 5 and 7 dS m^{-1}], along with unprimed seeds. Emergence rate (ER), final emergence percentage (FEP), reduction percentage of emergence (RPE), shoots length, number of secondary roots, seedling fresh weight and vigour were significantly improved by both priming treatments over the control; halo priming was more effective than hydro priming. Number of secondary roots was maximum in halo primed and unprimed seeds. Post-harvest seed enhancement treatments improve germination and seedling vigour (Taylor, 1998). 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 (Maiti *et al*., 2009).

Umair *et al*. (2010) also reported that seed priming significantly improved the germination rate and vigour of the mungbean seedlings. 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*. (2011) observed that the priming-induced salt tolerance was associated with improved seedling vigour, metabolism of reserves as well as enhanced K^+ and Ca^{2+} and decreased Na^+ accumulation in wheat plants. Seed priming is used for improvement of germination speed, germination vigour, seedling establishment and yield (Talebian *et al*., 2008). Afzal *et a*l. (2005) also found that the priming-induced salt tolerance was associated with improved seedling vigor, metabolism of reserve as well as enhanced K^+ and Ca^{2+} and decreased Na^+ accumulation in wheat plants.

Omid and Farzad (2012) observed the impacts of various concentrations of poly ethylene glycol 6000 (0, -9, -11, -13 and -15 bar) and hydro priming on Mountain Rye germination characteristic and enzyme activity under drought stress. Analyze of variance for hydro priming showed that temperature × time of priming interaction was significantly for germination percentage (GP), normal seedling percentage (NSP), coefficient of velocity of germination (CVG), seedling vigor index (SVI), coefficient of allometry (AC) and seedling length (SL) under drought stress and for osmo priming showed that Concentration of PEG × Temperature × Time of priming interaction was significantly for all traits under drought stress. Results of interaction effects for hydro priming showed that the highest GP (53%) and NSP (23.5%) were attained from hydro priming for 16h at 15°C and the highest CVG (0.21) and AC (0.49) were attained from hydro priming for 8h at 10°C, also hydro priming for 8h at 15°C increased SL (3.15) as compared to the unprimed. Osmo priming with concentration of -15 bar PEG for 24h at 15°C increased GP (80.5 %), GI (17.9), NSP (45 %), SVI (257.85) and SL (5.73 cm) and decreased MTG as compared to the unprimed and other treatments of osmo priming. The highest CVG was attained from concentration of -9 bar PEG for 24h at 10°C. the highest AC was attained from concentration of -9 bar PEG for 12h at 15°C. Also osmo and hydro priming increased catalase (CAT) and ascorbate peroxidase (APX) as compared to the unprimed.

Farnia and Shafie (2015) found that the probable reason for the highest vigour index might be due to photosynthetic capacity treated with bio fertilizers increases due to increased supply of nutrition. Safiatou (2012) reported that priming improved seedling vigour and seedling vigour index increased by using seed priming methods in sorghum and Bambara groundnut. Also, highest seedling vigour was achieved by osmo-priming (Mannitol priming) in Bambara groundnut and by hydro-priming in sorghum.

2.4 Relative water content (%), water saturation deficit (%) and water retention capacity

Relative water content is influenced by seed quality and seed priming technique. Significantly higher relative water content was recorded in leaves obtained from plots sown with higher quality seeds as compared to those obtained from plots sown with lower quality seeds. The leaves obtained from plots having seed primed with $CaCl_2.2H_2O$ (0.5%) showed significantly highest relative water content which was on par with the leaves from plots having seed primed with KH_2PO_4 (50 ppm) followed by leaves obtained from plots having seed primed with GA_3 (20ppm) (84.57%) while the lowest relative water content (79.02 %) was recorded in leaves obtained from plots having seed primed with KCl (100ppm). The interaction effect had also a significant effect with the highest relative water content recorded in leaves obtained from plots sown with the higher quality seeds treated by $CaCI_2.2H_2O$(0.5) (Assefa, 2008).

Baque *et al*. (2002) observed that higher doses of potassium in drought affected wheat generally showed the maximum relative water content, higher water retention capacity and exudation rate. Higher levels of K significantly reduced the water saturation deficit. Fertilizer potassium however, made leaf water potential more negative. The beneficial effect of fertilizer potassium on water stress tolerance in wheat plants were more pronounced under water stressed conditions than under control conditions.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials and methods that were used in conducting the experiment. A 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 are discussed at this section.

3.1 Description of the experimental site and period

The experiment was carried at the laboratory condition of the department of Agronomy which situated in the Central Laboratory, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, from August 2019 to July 2020. During the experimentation the temperature range of the laboratory was 25.6^0C- 33.2^0C and the relative humidity was 57.5 to 86.7% respectively. It was situated in 24.09^0N latitude and 90.26^0E 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 Potassium Chloride (KCI) used for nutrient priming and Distilled water used for hydro priming. In this experiment PEG was used as a factor which helps to create drought stress condition. 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.

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

3.3 Chemicals for seed priming

Potassium Chloride (KCI) and distilled water were used as priming agents. Polyethylene Glycol (PEG) 6000 was used for inducing drought stress. The 75% alcohol was used for treating seed.

3.4. Design and treatment of the experiment

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

3.5 Experimental treatments and design

The experiment comprises of

a) In the first experiment six levels of priming agent concentration viz. distilled water, 0%, 1%, 2%, 3%, and 4% Potassium Chloride (KCI)
b) In the second experiment five levels of drought stress viz. 0%, 5%, 10%, 15%, and 20% with Polyethylene Glycol (PEG) 6000.

3.6 Experimental details

The entire study was conducted under two different experiments.

3.6.1 First experiment

Study on the germination behavior of BARI Gom 30 at different concentrations of priming agents (KCI and Distilled water).

3.6.1.1 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.

3.6.1.2 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.

3.6.1.3 Treatments and design

The experiment was employed with one wheat variety and priming (six priming) with five replications.

Wheat variety

V_1: BARI Gam 30

Six types of priming solution

T_0 = Seeds without priming (control)
T_1 = Seeds primed with distilled water for 9 hours
T_2 = Seeds primed with 1% KCI for 9 hours
T_3 = Seeds primed with 2% KCI for 9 hours
T_4 = Seeds primed with 3% KCI for 9 hours
T_5 = Seeds primed with 4% KCI for 9 hours

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

3.6.1.4 Preparation of priming solutions

a) Potassium Chloride (KCI) preparations (1%, 2%, 3% and 4%)

The 1% KCI solution was prepared by mixing 2.5g of KCI at 250 mL distilled water. Similarly, 5g, 7.5g, 10g KCI was mixed with 250 mL of distilled water to prepare 2%, 3% and 4% solution of Potassium chloride respectively.

b) Distilled water

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

3.6.1.5 Priming technique

Potassium Chloride 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 KCI priming and last one for control (non-primed). For KCI priming seeds were divided into four parts and soaked in 1%, 2%, 3% and 4% KCI separately and hydro priming seeds are soaked in distilled water for 9hrs. Different petri dish with cover were used for avoiding evaporation loss. After 9hrs 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 72hrs to back the normal condition.

3.6.1.6 Germination of seeds

Initially, thirty seeds were selected randomly from each treatment and then place them in a 120mm diameters petri dishes and whatman no.1 papers were used as growth media. Whatman no.1 was kept saturated by spraying distilled water. All petri dishes 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 2mm radicle indicates as germination occurred. Every 24hrs 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 plants 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 petri dish by using a thick cloth to avoid sunlight which helps to reduce evaporation loss. After 24hrs 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 hrs. After that oven dry weight root and shoot were taken carefully and data recorded.

3.6.1.7 Relative water content (%), water saturation deficit (%) and water retention capacity

The fresh, turgid and dry weights of shoots were utilized to calculate relative water content (%), water saturation deficit (%) and water retention capacity (Baque *et al*., 2002).

3.6.2 Second experiment

Study on the germination behavior of primed seed (BARI Gom 30) under drought (Polyethylene Glycol) stress condition

3.6.2.1 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.

3.6.2.2 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.

3.6.2.3 Treatments and design

Five treatments were applied separately for BARI Gom 30-

T_0= Non-primed (control) and primed (2% KCI and distilled water) seeds placed without PEG (control)

T_1= Non-primed (control) and primed (2% KCI and distilled water) seeds placed with 5% PEG concentration

T_2= Non-primed (control) and primed (2% KCI and water) seeds placed with 10% PEG concentration

T_3= Non-primed (control) and primed (2%KCI and water) seeds placed with 15% PEG concentration

T_4= Non-primed (control) and primed (2% KCI and water) seeds placed with 20% PEG concentration

3.6.2.4 Priming solutions and time

The 2% of KCI solution and distilled water used for BARI Gom 30 due to its best performance in the first experiment. Seeds were soaked in 2% KCI and distilled water for 9 hrs.

3.6.2.5 Preparation of priming solutions

a) Potassium Chloride solutions (2% KCI)

The 2% KCI was prepared by dissolving 5g of KCI at 250ml distilled water by using a stirring machine.

b) Distilled water

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

3.6.2.6 Preparation of drought stress solutions

a) Polyethylene Glycol (PEG) solutions (5%, 10%, 15% and 20%)

The 5% PEG solution was prepared by dissolving 12.5g of PEG at 250 mL distilled water. Similarly, 25g, 37.5g, 50g PEG was dissolved with 250 mL of distilled water to prepare 10%, 15% and 20% solutions of PEG (6000) respectively.

3.6.2.7 Priming technique

Potassium Chloride 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 2% KCI priming and last one for control (non-primed). For KCI priming seeds were soaked in 2% KCI and hydro priming seeds are soaked in distilled water for 9hrs separately. Different petri dish with cover were used for avoiding evaporation loss. After 9hrs 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 72hrs to back the normal conditions.

3.6.2.8 Germination of seeds

Initially, thirty seeds were selected randomly from each treatment and then place them in 120mm diameters petri dishes and whatman no.1 papers were used as growth media. Whatman no.1 was kept saturated by spraying PEG solutions. Seeds were kept in different petri dishes and all seeds were sprayed separately by (5%, 10%, 15% and 20%) PEG separately. Here, PEG used as drought stress inducing agent. All petri dishes 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 2mm radicle indicates as germination occurred. Every 24hrs 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 petri dish by using a thick cloth to avoid sunlight which helps to reduce evaporation loss. After 24hrs 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 hrs. After that oven dry weight root and shoot were taken carefully and data recorded.

3.6.2.9 Relative water content (%), water saturation deficit (%) and water retention capacity

At 10th day of germination test, five seedlings were selected randomly from each treatment and fresh weight and length was measured immediate after removing roots. Then, the shoots and roots were soaked at distilled water at room temperature in the dark for 24hrs and Shoots and roots turgid weight was measured after removing the excess water by gently wiping with tissue paper. Then shoots were packed in brown paper and oven dried at 75°C for 72 hours for measuring dry weight. The fresh, turgid and dry weights of shoots were utilized to calculate relative water content (%), water saturation deficit (%) and water retention capacity (Baque *et al*., 2002).

3.7 Parameter measurement

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

3.7.1 Germination percentage

Germination percentage was measured in the 10^{th} day using the formula

GP (%) = (Total number of germinated seeds/ total seed) x 100

3.7.2. Shoot length (mm)

Shoot length was measured in the 10th day using millimeter scale.

3.7.3. Root length (mm)

Root length was measured in the 10th day using millimeter scale.

3.7.4. Seedling length (mm)

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

3.7.5 Total germination (TG %)

Total germination (TG) was calculated as the number of seeds which was germinated within total days as a proportion of number of seeds shown in each treatment expressed as a percentage (Othman *et al*., 2006).

TG (%) = $(\text{Number of germinated seed}/\text{Total number of seed set for germination}) \times 100$

3.7.6 Mean germination time (MGT)

Mean germination time (MGT) was calculated according to the equation of Moradi Dezfuli *et al*. (2008).

MGT = $\frac{\sum Dn}{\sum n}$

Where,

n = number of seeds germinated on day D, and

D = number of days counted from the beginning of germination

3.7.7 Germination index (GI)

Germination index (GI) was calculated as described in the Association of Official Seed Analysts (AOSA, 1983) as the following formula:

Germination index =$\frac{Gt}{Tt}$

Where,

Gt = number of seeds germinated on day t and Tt = the number of germinated seeds at

time Ti.

3.7.8 Coefficient of velocity (CV)

Coefficient of velocity (CV) = (number of germinated seeds per day) is measured according to the method described by Scott *et al*. (1998).

CV= 100 x ($\sum$Ni / $\sum$Ti Ni)

Where, Ti= number of days after sowing and Ni = number of seeds germinated on ith day.

3.7.9 Vigour Index (VI)

Vigour Index (VI) was calculated from total germination and seedlings length by using the formula of Abdul- Baki and Anderson (1970).

VI= TG (%) x seedling length (mm)/ 100

Here, TG = total germination

3.7.10 Relative Water Content (RWC %)

Relative water content was calculated from the fresh, turgid and dry weights of shoots by using the following formula used by Baque *et al*. (2002). Relative water content expressed in percentage.

Relative Water Content (RWC) = (Fresh weight- Dry weight)/ (Turgid weight- Dry weight)

× 100

3.7.11 Water Saturation Deficit (%)

Water saturation deficit was calculated from RWC by using the following formula used by (Baque *et al*., 2002).

Water Saturation Deficit (WSD) = 100- RWC

3.7.12 Water Retention Capacity (WRC)

Water retention capacity was calculated from the turgid and dry weights of shoots by using the following formula used by (Baque *et al*., 2002). Water retention capacity expressed in percentage.

Water Retention Capacity (RWC) = Turgid weight/ Dry weight

3.7.13 Shoot dry weight (mg), root dry weight (mg)

The dried shoots and roots were weighted to the nearest milligram (mg) by using an electrical balance.

3.7.14 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 5% 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 'Induction of drought tolerance in wheat through nutrient and hydro priming'. The result of the germination and growth parameters of wheat which influenced by different concentration of priming solutions (KCI), hydro priming (distilled water) in drought stress (PEG) 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 I to Appendix XII.

Experiment no: 1

Study on the germination behavior of BARI Gom 30 at different concentrations of priming agents (KCI and Distilled water).

4.1.1 Effect on total germination (%)

Germination percentage of wheat was influenced by different Potassium Chloride (KCI) concentrations (Fig. 1) and there was significant difference between control (non-primed seeds) and primed seeds (Appendix I & II). Hydro priming also showed significant result (Fig.1). Germination percentage of variety BARI Gom 30 increased with increasing priming concentrations with KCI up to 2% then decreases gradually with increasing KCI concentrations. The T_3 (primed with 2% KCI) showed the maximum germination percentage (98%) and decrease due to increasing concentration of KCI. The germination percentage of hydro priming (distilled water) was found T_1 (93%) and lowest germination percentage T_0 (control) was found 87%. The result of the study was the agreement with the findings of Keya (2018); Faijunnahar *et al*., (2017); Ahammad *et al*., (2014) and Baque *et al*., (2016). Priming with KCI can be used for increasing germination up to center level. According to Ajouri *et al*., (2004) priming induces a wide range of biochemical changes in the seed that required promoting the germination process i.e., breaking of dormancy, hydrolysis or metabolism of inhibitors, imbibitions and enzymes activation. Hydro priming significantly induced germination rate (Ghassemi-Golezani *et al*., 2008). Hydro priming is a useful technique for improving entire germination viz. tomato variety germination percentage was increased in response to 25 hydro-priming treatment (Maiti *et al*., 2013).

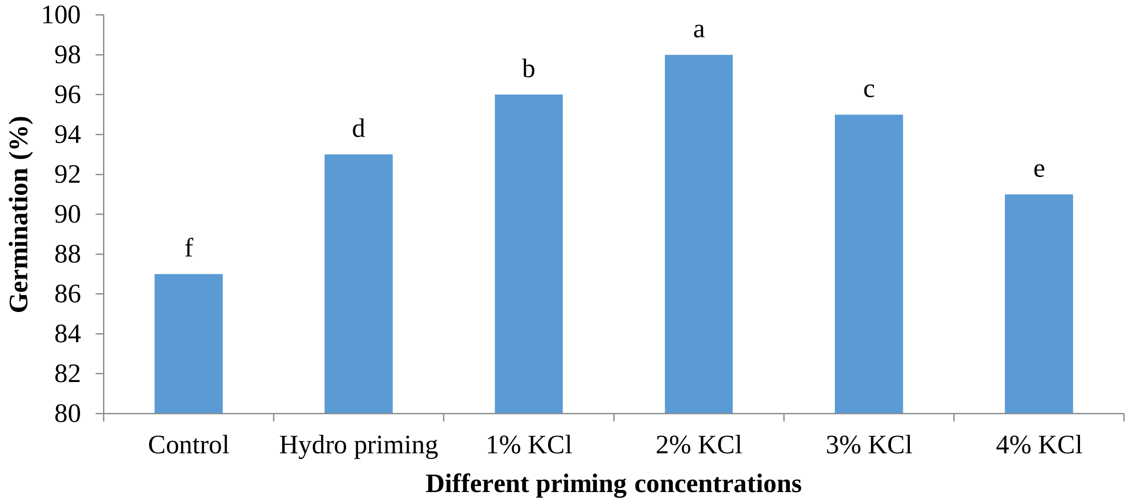


Figure 1. Effect of different priming concentration on germination percentage (%) of BARI Gom 30 ($LSD_{(0.01)}$ = 3.89)

4.1.2. Effect on Seedling fresh weight

Seedling fresh weight of wheat was influenced by different Potassium Chloride (KCI) concentrations (Fig. 2) and there was significant difference between control (non-primed) and primed seeds (Appendix I & II). Hydro priming also showed significant result (Fig. 2). Seedling fresh weight of variety BARI Gom 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. The T_3 (primed with 2% KCI) showed higher seedling fresh weight comparing with others concentrations. The fresh weight of seedlings in T_3 was found 276.40mg and after that decreased with increasing percentage of KCI concentrations. The seedling fresh weight in case of hydro priming (T_1) was found 257.43mg. The lowest seedling fresh weight was found in control (T_0). It was found 248.50mg which was lowest of all the treatments. Seed priming with distilled water increased shoot length and seedling weight of Nerica (Mamun *et al.*, 2018).

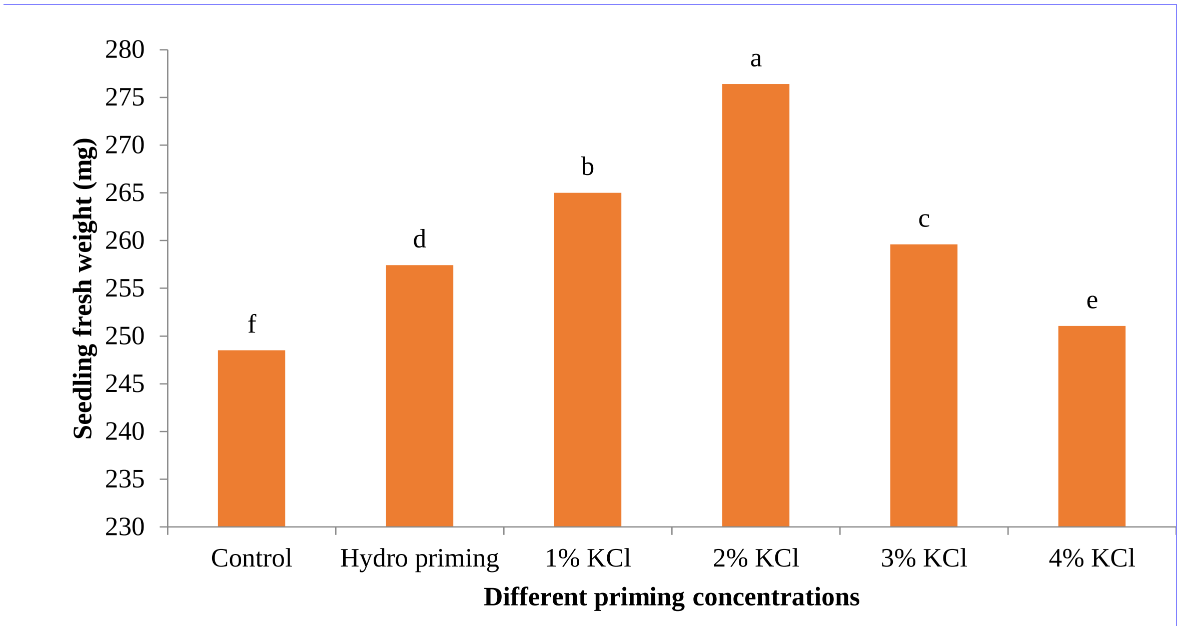


Figure 2. Effect of different priming concentrations on seedling fresh weight of BARI Gom 30 ($LSD_{(0.01)}$= 11.45)

4.1.3. Effect on shoot length

Shoot length (mm) of wheat affected by different Potassium Chloride (KCI) concentrations (Fig. 3) and there was significant difference between control (non-primed) and primed seeds. Hydro priming (distilled water) also given significant result. Shoot length of variety BARI Gom 30 increased with increasing priming concentration up to 2% KCI then decreased gradually with increasing KCI concentrations. The T_3 (primed with 2% KCI) showed higher shoot length (175.55mm) and decreased due to increasing KCI concentration. The shoot length of hydro priming (T_1) was found (159.33mm) and lowest result was found in control (T_0) 149.40mm. The study was corroborates with the study of previous researcher Sarwar *et al*. (2006) who reported that shoot length were better when treated with water and mannitol over control. Kumar *et al*. (2017) showed that osmo priming of seed increased shoot length than the non-primed seed.

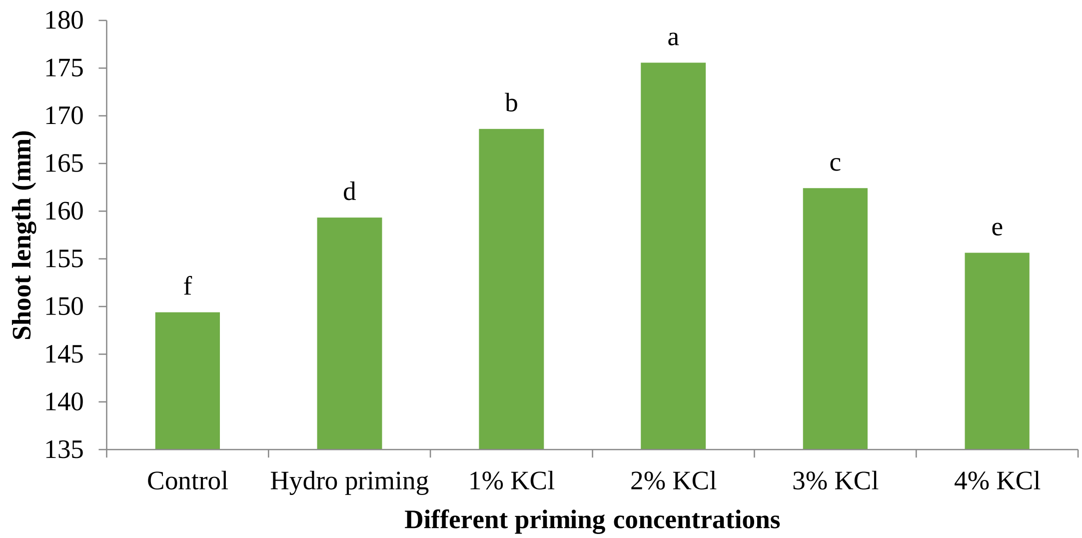


Figure 3. Effect of different priming concentrations on shoot length of BARI Gom 30 ($LSD_{(0.01)}$)= 8.51)

4.1.4 Effect on root length

Root length (mm) of wheat affected by different Potassium Chloride (KCI) concentrations (Fig.4) and there was significant difference between control (non-primed) and primed seeds. Hydro priming also given significant result. Root length of variety BARI Gom 30 increased with increasing priming concentration up to 2% KCI then decreased gradually with increasing KCI concentrations. The T_3 (primed with 2% KCI) showed higher root length (162.34mm) and decreased due to increasing KCI concentration. The shoot length of hydro priming (T_1) was found 151.67mm and lowest result was found in control (T_0) 138.81mm. The result of this study was the agreements with findings of Assaduzzaman (2014) who reported that root length were better when treated with water and mannitol over control. Seed priming with GA_3 increases field performance and fast radical protrusion in soybean plants (Maske *et al*., 1997).

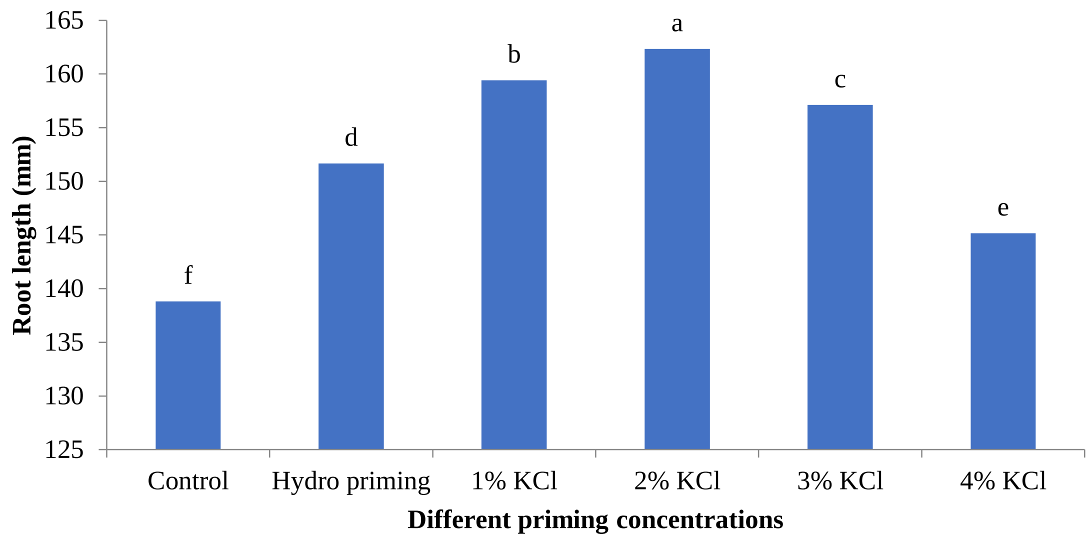


Figure 4. Effect of different priming concentrations on root length of BARI Gom 30 ($LSD_{(0.01)}$= 7.82).

4.1.5 Effect on shoot dry weight

Plant shoot dry weight of wheat was influenced by different Potassium Chloride (KCI) concentrations (Fig. 5) and there was significant difference between control (non-primed) and primed seeds (Appendix I & II). Hydro priming (distilled water) also showed significant result in (Fig. 5). Plant shoot dry weight of variety BARI Gam 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. The T_3 (primed with 2% KCI) showed higher plant shoot dry weight comparing with others concentrations. The shoot dry weight of seedlings in T_3 was found 13.48mg and after that decreased with increasing percentage of KCI concentrations. The plant shoot dry weight in case of hydro priming (T_1) was found 11.33mg. The lowest plant fresh weight was found in control (T_0). It was found 10.00mg which was lowest of all the treatments. The result of the present study was also agreed by Moghanibashi *et al*. (2012) who reported that the effect of hydro priming for 24 h increased root and shoot weight of seed sunflower as compared with the control. Harris *et al*. (2004) found that seed priming gives higher plant dry weight and seed yield.

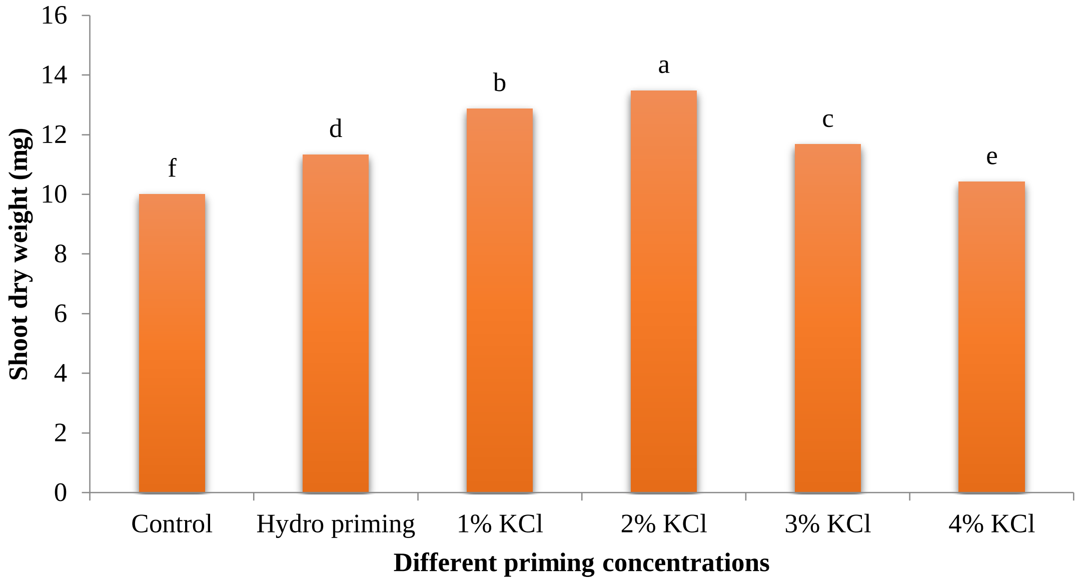


Figure 5. Effect of different priming concentrations on shoot dry weight of BARI Gom 30 ($LSD_{(0.01)}$)= 0.91

4.1.6 Effect on root dry weight

Drought stress had a significant repugnant effect on root dry weight for KCl, hydro primed and non-primed seeds (Appendix I & II). This effect was very low in KCl priming seeds than control. Hydro priming (distilled water) also showed significant result (Fig. 6). Plant root dry weight of variety BARI Gom 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. The T_3 (primed with 2% KCI) showed higher plant root dry weight comparing with others concentrations. The highest root dry weight of seedlings in T_3 was found 17.81mg and after that decreased with increasing percentage of KCI concentrations. The plant root dry weight in case of hydro priming (T_1) was found 11.97mg. The lowest root dry weight was found in control (T_0). It was found 10.30mg which was lowest of all the treatments. The result of this study corroborates with the study of Baque *et al.*, (2016) who reported that the effect of nutrient and hydro priming for 12hrs increased root and shoot dry weight of wheat as compared with the control.

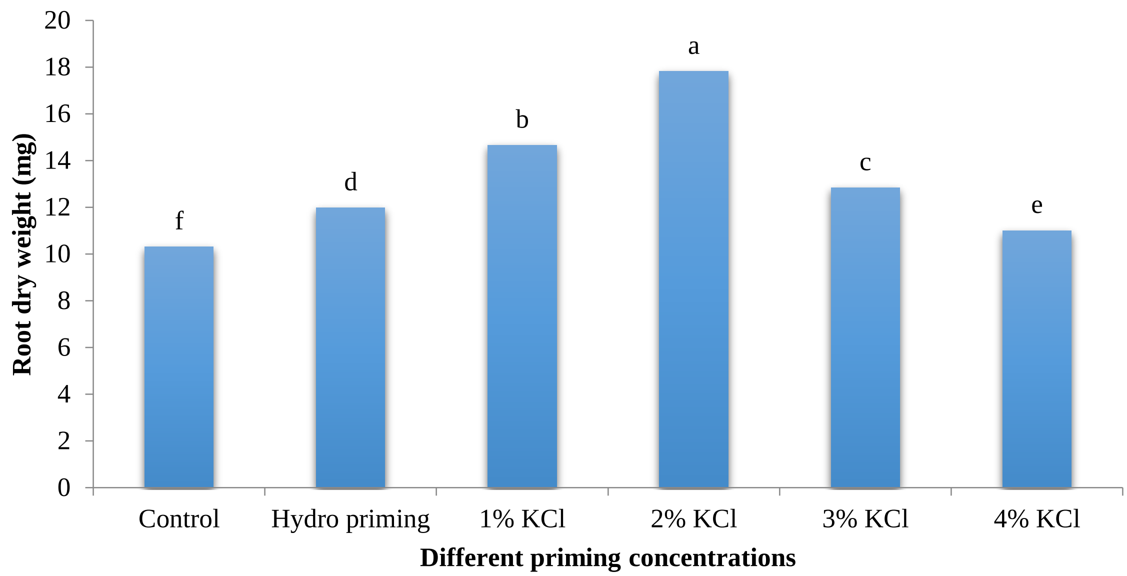


Figure 6. Effect of different priming concentration on root dry weight of BARI Gom ($LSD_{(0.01)}$= 1.06)

4.1.7 Effect on Vigor Index (VI)

Priming with various concentrations of KCl showed better result than non-primed seeds (control) (Appendix I & II). Hydro priming (distilled water) also showed significant result (Fig. 7). Plant vigor index of variety BARI Gom 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. Highest plant vigour index was found in T_3 (2% KCl) treatment which was 331.57. The plant vigor index in case of hydro priming (T_1) was found (297.98). The lowest plant vigor index was found in control (T_0). It was found (257.05) which was lowest of all the treatments. The result of this study corroborates with the study of Keya (2018) who reported that the effect of nutrient and hydro priming for 9hrs increased vigor index of wheat as compared with the control. Osmo priming increased seedling vigour of various vegetable crops and concerning sponge gourd was reported by Maiti *et al*. (2013).

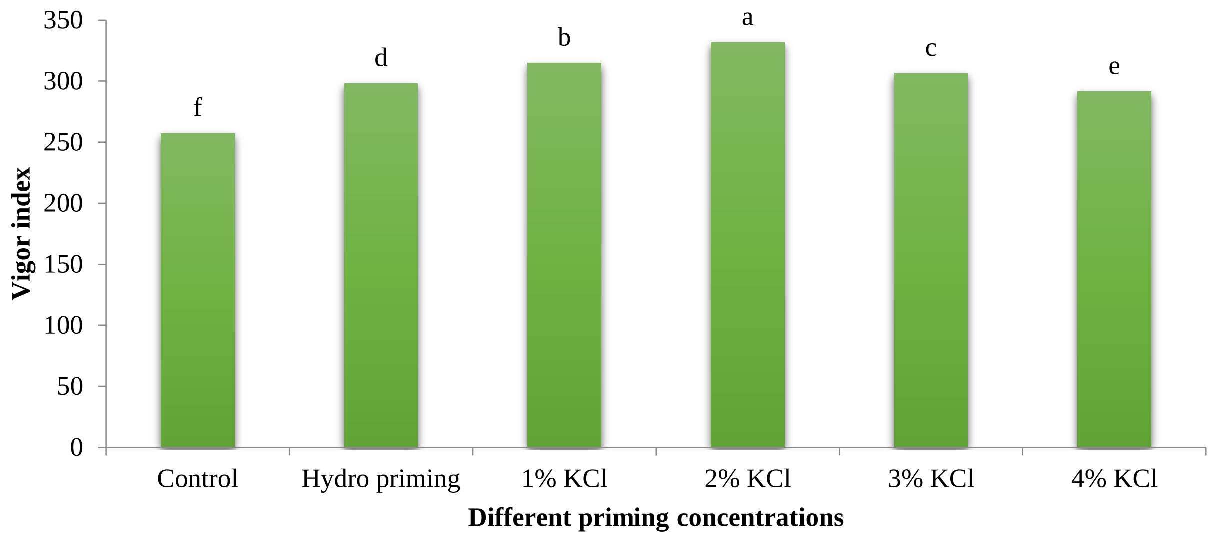


Figure 7. Effect on different priming concentrations on vigor index of BARI Gom 30 ($LSD_{(0.01)}$)= 16.48)

4.1.8 Effect on relative water content (RWC)

Different Potassium Chloride (KCI) concentrations (Table. 1) significantly influenced relative water content (RWC) of wheat and there was significant difference between control (non-primed) and primed seeds (Appendix I & II). Hydro priming (distilled water) also showed significant result in (Table. 1). Relative water content (RWC) of variety BARI Gom 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. Highest result was found in T_3 (primed with 2% KCI) comparing with others concentrations. The Relative water content (RWC) of seedlings in T_3 was found 92.80% and after that decreased with increasing percentage of KCI concentrations. Relative water content (RWC) in case of hydro priming (T_1) was found 86.30%. The lowest relative water content (RWC) was found in control (T_0). It was found 82.00% which was lowest of all the treatments. This result is similar with the findings of Faijunnahar *et al*. (2017) who reported that Osmo and hydro primed seedlings can give better water use efficiency thus plant growth not hampered than non-primed seeds under stress condition.

4.1.9 Effect on water saturation deficit (WSD)

Water saturation deficit (WSD) of wheat was influenced by different Potassium Chloride (KCI) concentrations (Table. 1) and there was significant difference between control (non-primed) and primed seeds (Appendix I & II). Hydro priming (distilled water) also showed significant result in (Table. 1). Water saturation deficit (WSD) of variety BARI Gom 30 decreased with increasing priming concentrations of KCI up to 2% then gradually increased with increasing concentrations of KCI. The T_3 (primed with 2% KCI) showed lower water saturation deficit (WSD) comparing with others concentrations. The lowest water saturation deficit of seedlings in T_3 was found 7.20% and after that increased with increasing percentage of KCI concentrations. Water saturation deficit in case of hydro priming (T_1) was found 13.70%. The highest water saturation deficit was found in control (T_0). It was found 18.00% which was highest of all the treatments. This result is similar with the findings of Faijunnahar *et al*., (2017) and Baque *et al*. (2002)who reported that Osmo and hydro primed seedlings can give better water use efficiency thus plant growth not hampered than non-primed seeds under stress condition.

4.1.10 Effect on Water retention capacity (WRC)

Drought stress showed adverse effect on water retention capacity (WRC) of wheat in different Potassium Chloride (KCI) concentrations, hydro primed and non-primed seeds (Table 1). Significant difference was found between control (non-primed) and primed seeds (Appendix I & II). Water retention capacity (WRC) of variety BARI Gom 30 increased with increasing priming concentrations of KCI up to 2% then gradually reduced with increasing concentrations of KCI. The T_3 (primed with 2% KCI) showed higher water retention capacity (WRC) comparing with others concentrations. Water retention capacity (WRC) of seedlings in T_3 was found 19.40% and after that decreased with increasing percentage of KCI concentrations. Water retention capacity (WRC) in case of hydro priming (T_1) was found 13.51%. The lowest water retention capacity was found in control (T_0). It was found 12.32% which was lowest of all the treatments. This result was similar with the findings of Faijunnahar *et al*. (2017); Baque *et al*. (2016) and Rahman *et al*. (2014). They found that priming helps to activate the metabolic enzymes responsible for germination of seed before germination takes place, so the hydro and osmo primed seedlings can uptake more water than the non-primed ones and gained the maximum turgid weight, in consequence, they gained the maximum water retention capacity.

Table 1: Effect of different priming concentrations on the growth and water relation behaviors of BARI Gom 30

Treatments	Root dry weight (mg)	Shoot dry weight (mg)	Relative water content (%)	Water saturation deficit (%)	Water retention capacity	Vigour index
T_0	10.30 e	10.00 d	82.00 d	18.00 a	12.32 e	257.05 d
T_1	11.97 cd	11.33 bc	86.30 bc	13.70 c	13.51 d	297.98 c
T_2	14.65 b	12.87 a	89.95 ab	10.05 e	16.75 b	314.67 b
T_3	17.81 a	13.48 a	92.80 a	7.20 f	19.40 a	331.57 a
T_4	12.83 c	11.67 b	87.65 bc	12.35 d	14.89 c	306.28 bc
T_5	11.00 de	10.42 cd	84.20	15.80 b	12.67 de	291.42 c
$LSD_{(0.01)}$	**1.06**	**0.91**	**4.03**	**1.12**	**1.00**	**16.48**
CV%	**3.97**	**3.85**	**2.27**	**4.30**	**3.32**	**2.70**

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= Hydro priming (primed with distilled water), T_2= Seeds primed with 1% KCl conc. for 9hrs, T_3= Seeds primed with 2%KCl conc. for 9hrs, T_4= Seeds primed with 3% KCl conc. for 9hrs and T_5= Seeds primed with 4% KCl concentration for 9hrs

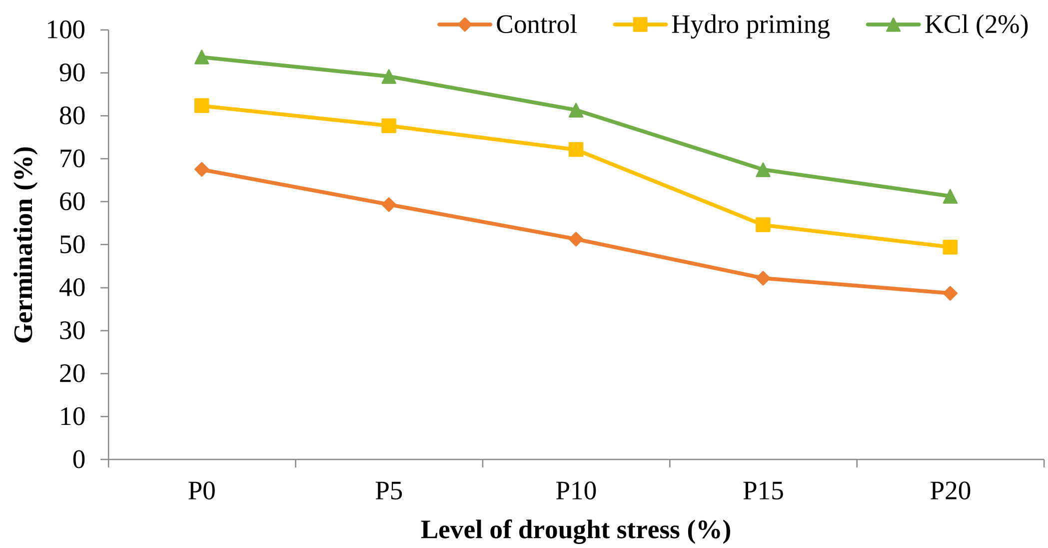
4.2 Experiment 2

Study on the germination behavior of primed seed (BARI Gom 30) under drought (Polyethylene Glycol) stress condition

The result of the study showed that every treatment was affected by the experimental factors and there was completely significant difference between primed seeds and non-primed seeds. Nutrient priming (KCI) and hydro priming increased the germination parameters (germination percentage, germination index, germination time) and growth parameters (shoot length, root length, total plant fresh weight, dry weight and vigor index) of wheat than non-primed seeds in drought stress condition. The increasing rate of drought stress in culture media reduces in germination parameters and growth parameters in primed seeds as well as non-primed. But the decrease was more prominent in non-primed seeds than nutrient and hydro priming.

4.2.1 Effect on germination percentage (%)

Different drought stress levels showed significant difference in germination percentage (Appendix III and Figure 8). Results found that germination from primed and non-primed seeds decreased gradually with increasing rate of drought stress level. But germination percentage of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The 2% KCI priming seed had maximum germination percentage (93.67%) followed by hydro priming (82.33%) and control seed had (67.51%) germination percentage found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment germination percentage of KCI priming, hydro priming and control seed was 89.15%, 77.67%, 59.33% respectively. On the other hand minimum germination percentage of 2% KCI priming, hydro priming and control seed were found in P_{20} (PEG 20%) treatment 61.27%, 49.43%, 38.67% respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Razaji *et al*. (2014) reported that priming resulted improvement in germination components and enzymes activity of rapeseed on drought stress condition and boost the resistance of rapeseed to drought stress condition. Baquer *et al*. (2016) concluded that germination percentage of priming seeds of wheat given higher result compared with without priming seeds in drought stress condition.

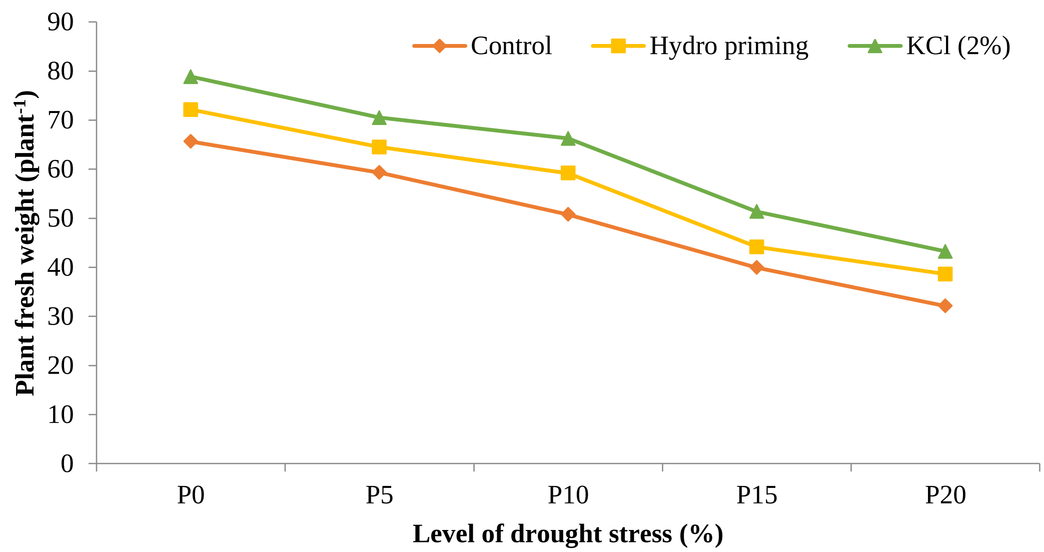


P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 8. Effect of different levels of drought stress on germination (%) of BARI Gom 30 ($LSD_{(0.01)}$= 7.84, 10.46, 8.29, 7.13 and 7.84 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.2 Effect on seedling fresh weight

Different drought stress levels showed significant difference in seedling fresh weight (Appendix IV and Figure 9). Results found that seedling fresh weight from primed and non-primed seeds decreased gradually with increasing rate of drought stress level. But seedling fresh weight of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The maximum seedling fresh weight was observed in 2% KCl priming 78.855mg followed by hydro priming 72.135mg and control seed had 65.63mg seedling fresh weight found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment seedling fresh weight of 2% KCI priming, hydro priming and control seed was 70.49mg, 64.50mg and 59.30mg respectively. On the other hand minimum plant fresh weight of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 43.23mg, 38.60mg and 32.16mg respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Keya, (2018) found that plant fresh weight of priming seed in wheat is higher compare with non-primed seed in drought stress condition where PEG was used as drought induced agents. Different phosphorus priming enhanced seedling growth, weight, grain and yield of maize experimented by Miraj *et al*. (2013).

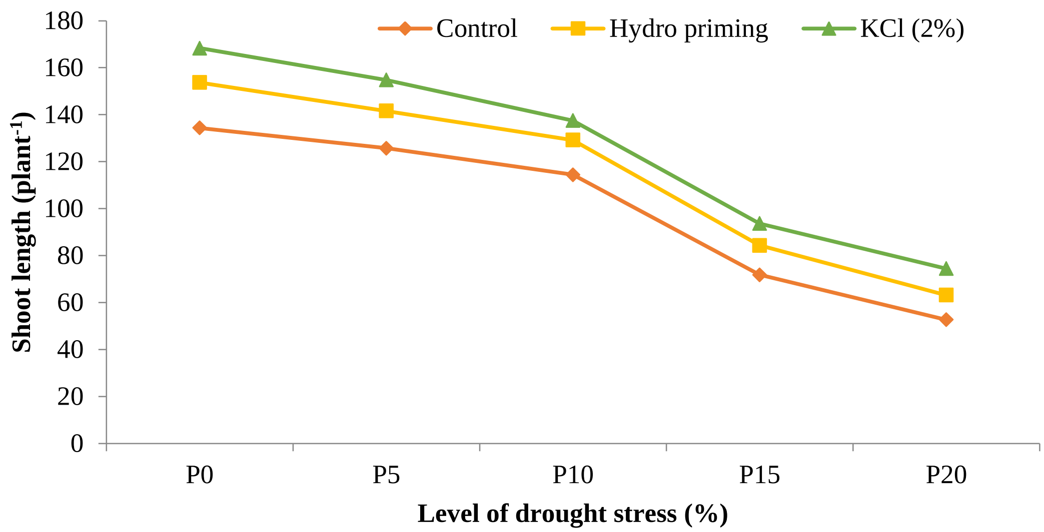


P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 9. Effect of different levels of drought stress on plant fresh weight of BARI Gom 30 ($LSD_{(0.01)}$= 9.46, 8.38, 8.48, 7.77 and 7.49 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.3 Effect on shoot length

Priming significantly influenced shoot length in drought stress condition induced by PEG (Appendix V and Figure 10). Results found that shoot length from primed and non-primed seeds decreased gradually with increasing rate of drought stress level. But shoot length of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The 2% KCI priming seed had maximum shoot length 168.35mm followed by hydro priming 153.67mm and control seed had 134.33mm shoot length found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment shoot length of 2% KCI priming, hydro priming and control seed was 154.77mm, 141.55mm and 125.72mm respectively. On the other hand minimum shoot length of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 74.43mm, 63.15mm and 52.67mm respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Kaur *et al*. (2002) reported that hydro priming showed three to four fold more growth with respect to root and shoot length in comparison with seedlings obtained from non-primed seeds in drought condition.

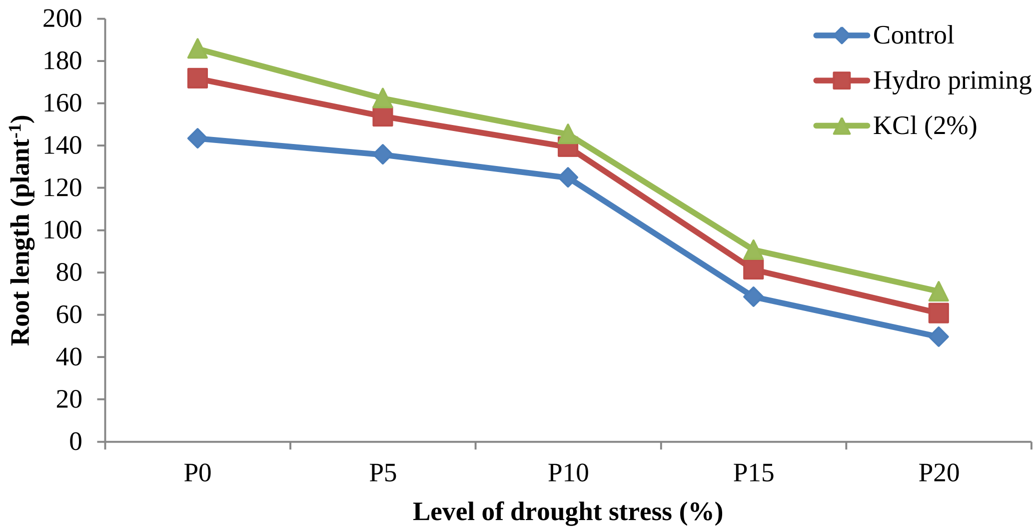


P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 10. Effect of different levels of drought stress on shoot length of BARI Gom 30 ($LSD_{(0.01)}$= 26.51, 22.80, 19.29, 14.97 and 11.34 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.4 Effect on root length

Significant variation of root length was found in case of osmo priming and hydro priming (Appendix VI and Figure 11). With increasing rate of drought stress level root length of primed and non-primed seeds decreased gradually. But root length of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The 2% KCI priming seed had maximum root length 185.75mm followed by hydro priming 171.67mm and control seed had 143.33mm root length found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment root length of 2% KCI priming, hydro priming and control seed was 162.33mm, 153.75mm and 135.67mm respectively. On the other hand minimum root length of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 71.00mm, 60.67mm and 49.50mm respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Salehzade *et al*. (2009) reported that the increased shoot and root length with osmo priming treatments may be due to increasing nuclear replication in root and shoot.

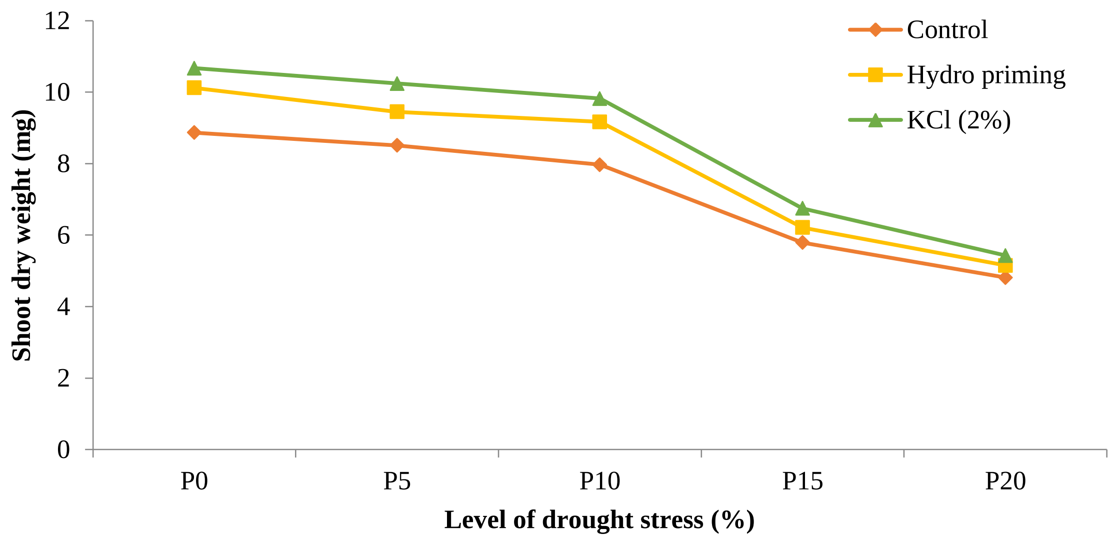


P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 11. Effect of different levels of drought stress on root length of BARI Gom 30 ($LSD_{(0.01)}$= 13.56, 20.67, 19.55, 13.03 and 7.35 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.5 Effect on shoot dry weight

Shoot dry weight also significantly influenced by seed priming (Appendix VI and Figure 12). Shoot dry weight from primed and non-primed seeds decreased gradually with increasing rate of drought stress level. But shoot dry weight of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The maximum significant shoot dry weight was found at 2% KCI priming which was 10.67mg followed by hydro priming 10.12mg and control seed had 8.87mg shoot dry weight found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment shoot dry weight of 2% KCI priming, hydro priming and control seed was 10.24mg, 9.45mg and 8.51mg respectively. On the other hand minimum shoot dry weight of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 5.43mg, 5.15mg and 4.81mg respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Arji and Arzani (2000) studied that decreasing shoot dry weight under drought conditions may be due to decreasing accumulation of shoot carbohydrates.

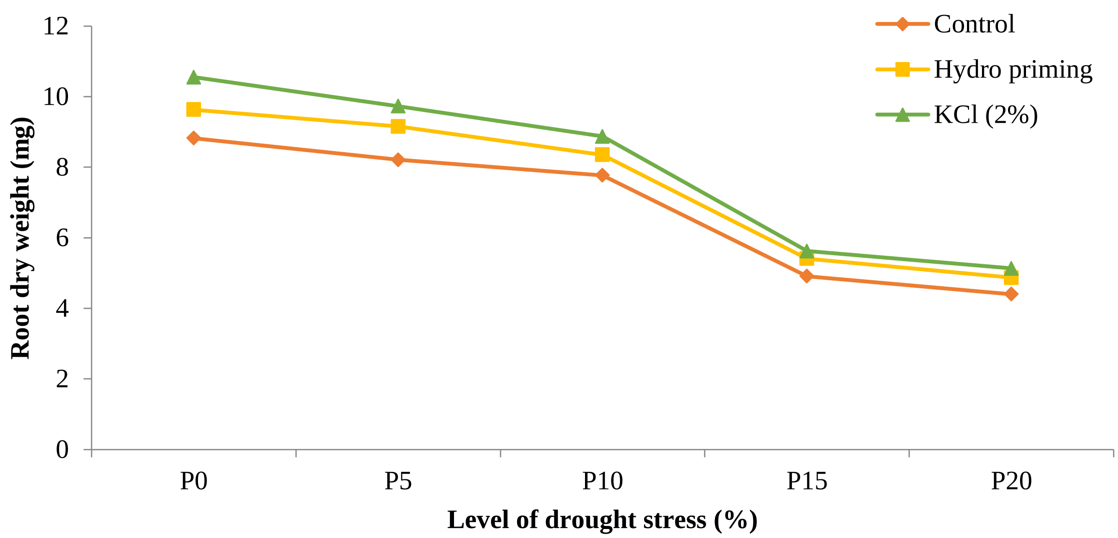


P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 12. Effect of different levels of drought stress on shoot dry Weight of BARI Gom 30 ($LSD_{(0.01)}$= 1.27, 1.35, 1.43, 0.92 and 0.54 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.6 Effect on root dry weight

Different drought stress levels showed significant difference in root dry weight (Appendix VIII and Figure 13.). Results found that root dry weight from primed and non-primed seeds decreased gradually with increasing rate of drought stress level. But root dry weight of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). The 2% KCI priming seed had maximum root dry weight 10.55mg followed by hydro priming 9.63mg and control seed had 8.82mg root dry weight found from P_0 (0% PEG) treatment. In P_5 (5% PEG) treatment root dry weight of 2% KCI priming, hydro priming and control seed was 9.73mg, 9.15mg and 8.21mg respectively. On the other hand minimum root dry weight of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 5.13mg, 4.87mg and 4.40mg respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Sarwar *et al.* (2006) also stated that shoot length and biomass of shoots and root were better when treated with water and mannitol than unprimed seeds.



P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 13. Effect of different levels of drought stress on root dry weight of BARI Gom 30 ($LSD_{(0.01)}$= 0.94, 1.22, 1.07, 0.65 and 0.56 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

4.2.7 Effect on relative water content (RWC)

Relative water content (RWC) showed significant difference in drought stress condition (Appendix IX and Table 2). With increasing rate of drought stress level relative water content of primed and non-primed seeds decreased gradually. But relative water content (RWC) of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). Maximum relative water content 31.39% was found in 2% KCl priming followed by hydro priming 29.58%. Control seed had 27.42% relative water content found from P_0 treatment (0% PEG) treatment. In P_5 (5% PEG) treatment relative water content of 2% KCI priming, hydro priming and control seed was 29.71%, 27.13% and 26.09% respectively. On the other hand minimum relative water content of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 21.27%, 20.05%, and 18.32% respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Flower *et al*. (1998) reported that osmo and hydro primed increases better water use efficiency thus helps to improves plant growth than non-primed under stress condition. Faijunnahar *et al*. (2017) also found that optimum osmo priming under drought stress condition enhanced enzymatic activities of seed which helps to healthy growth of plant than non-primed seeds.

Table 2. Effect of different level of drought stress (%) on relative water content (%) of BARI Gam 30 seeds treated with different primed agents

Treatments	Relative water content at				
	PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Control	27.42 b	26.09 b	24.33 b	20.56 b	18.32 b
Hydro priming	29.58 ab	27.13 ab	25.67 ab	22.72 ab	20.05 ab
KCl (2%)	31.39 a	29.71 a	27.56 a	24.01 a	21.27 a
$LSD_{(0.01)}$	3.36	2.90	2.93	2.42	2.24
CV%	4.97	4.57	4.93	4.69	4.91

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, PEG= Polyethylene Glycol

4.2.8 Water saturation deficit (WSD)

Different drought stress levels showed significant difference in Water saturation Deficit (WSD) (Appendix X and Table 3). Results found that Water saturation deficit (WSD) from primed and non-primed seeds increased gradually with increasing rate of drought stress level. But Water saturation deficit of 2% KCI priming and hydro priming was lower compared with control seeds (without priming). In P_5 (5% PEG) treatment water saturation deficit of 2% KCI priming, hydro priming and control seed was 70.29%, 72.87% and 73.91% respectively which was minimum. On the other hand maximum water saturation deficit of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 78.73%, 79.95% and 81.68% respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. Baque *et al*. (2014) reported that the enzymatic activities were lower in non-prime seed which result produced the weak and lean seedling on the other hand due to over priming time, ageing process was accelerated and produced weak and lean seedling which were failed to uptake enough water and provided more water saturation deficit value under stress condition.

Table 3. Effect of different level of drought stress (%) on water saturation deficit (%) of BARI Gom 30 seeds treated with different primed agents

Treatments	Water saturation deficit at				
	PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Control	72.58 a	73.91 a	75.67 a	79.44 a	81.68 a
Hydro priming	70.42 ab	72.87 ab	74.33 ab	77.28 ab	79.95 ab
KCl (2%)	68.61 b	70.29 b	72.44 b	75.99 b	78.73 b
$LSD_{(0.01)}$	3.48	3.32	2.76	2.83	2.62
CV%	2.15	2.00	1.62	1.59	1.42

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, PEG= Polyethylene Glycol

4.2.9 Water retention capacity (WRC)

Drought stress highly influenced water retention capacity (WRC) of wheat (Appendix XI and Table 4).Water retention capacity (WRC) of primed and non- primed seeds decreased gradually with increasing rate of drought stress level. But water retention capacity (WRC) of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). Highest water retention capacity 15.15% was found in 2% KCI priming seed followed by hydro priming 13.87% and control seed had 12.25% in P_0 treatment (0% PEG) treatment. In P_5 (5% PEG) treatment water retention capacity of 2% KCI priming, hydro priming and control seeds were 14.39%, 13.23% and 11.77% respectively. On the other hand lowest water retention capacity of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment 10.63%, 10.25%, and 10.03% respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values. According to Baque *et al*. (2002) higher doses of potassium resulted the maximum relative water content, higher water retention capacity and exudation rate in drought affected wheat.

Table 4. Effect of different level of drought stress (%) on water retention capacity of BARI Gom 30 seeds treated with different primed agents

Treatments	Water retention capacity at				
	PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Control	12.25 b	11.77 b	11.21 b	10.58 b	10.03 b
Hydro priming	13.87 ab	13.23 ab	12.67 a	11.42 a	10.25 ab
KCl (2%)	15.15 a	14.39 a	13.45 a	11.87 a	10.63 a
$LSD_{(0.01)}$	1.67	1.52	0.97	0.67	0.50
CV%	5.30	5.04	3.39	2.57	2.13

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, PEG= Polyethylene Glycol

4.2.10 Vigour index (VI)

Different drought stress levels showed significant difference in vigour index in wheat seedlings (Appendix XII, Table 5 and Figure 14). Results found that vigour index from primed and non- primed seeds decreased gradually with increasing rate of drought stress level. But vigour index of 2% KCI priming and hydro priming was higher compared with control seeds (without priming). 2% KCI priming seed had maximum seedling vigour index (328.94) followed by hydro priming (265.77) and control seedlings had (223.43) vigour index found from P_0 treatment (0% PEG) treatment. In P_5 (5% PEG) treatment seedlings vigour index of 2% KCI priming, hydro priming and control seeds were (283.62), (248.31) and (205.82) respectively. On the other hand minimum seedlings vigour index of 2% KCI priming, hydro priming and control seeds were found in P_{20} (PEG 20%) treatment (87.78), (75.92) and (56.31) respectively. The result found from all other treatments showed intermediate result compared to highest and lowest values.

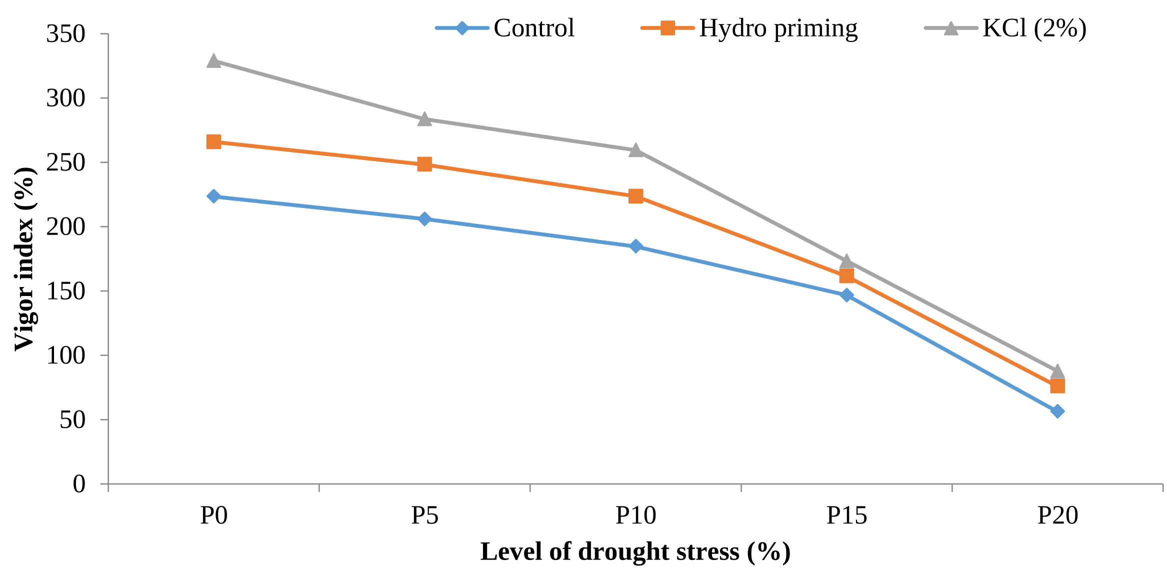
Janmohammadi *et al*. (2008) reported that hydro priming significantly improved seedling vigour index under both stress and non-stress conditions. Ghiyasi and Tajbakhsh (2013) reported that the imbibition of seedling vigour index under drought stress condition should be overcome by using osmo priming treatment in soybean. Safiatou (2012) reported that by using osmo priming with mannitol in Bambara groundnut and sorghum given highest seedling vigour index under drought stress condition.

Table 5. Effect of different level of drought stress (%) on vigour index of BARI Gom 30 seeds treated with different primed agents

Treatments	Vigour index at				
	PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Control	223.43 c	205.82 c	184.65 c	146.67 b	56.31 c
Hydro priming	265.77 b	248.31 b	223.55 b	161.48 ab	75.92 b
KCl (2%)	328.94 a	283.62 a	259.44 a	173.25 a	87.78 a
$LSD_{(0.01)}$	36.54	35.13	27.68	18.79	10.03
CV%	5.83	6.22	5.41	5.09	5.95

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, PEG= Polyethylene Glycol



P_0= only water, P_5= 5% PEG solution, P_{10}= 10% PEG solution, P_{15}= 15% PEG solution and P_{20}= 20% PEG solution

Figure 14. Effect of different levels of drought stress on vigor index of BARI Gom 30 ($LSD_{(0.01)}$= 36.54, 35.13, 27.68, 18.79 and 10.03 at P_0, P_5, P_{10}, P_{15} and P_{20}, respectively)

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 August 2019 t0 July 2020 to study the induction of drought tolerance in wheat through nutrient and hydro priming. 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%, 1%, 2%, 3% and 4% KCI respectively and untreated seeds are used as control treatment. Hydro priming seeds also done by pre-soaking seeds in distilled water. Results found that all the characteristics related to germination (germination percentage, germination index, germination time), growth parameters (fresh weight of plant, shoot length, root length, shoot dry weight, root weight, vigour index) and water relation behaviors (relative water content, water retention capacity and water saturation deficit) were significantly influenced by different concentrations of KCI followed by hydro priming. All the parameters were given best result in 2% KCI compared with other treatments. Hydro priming seeds has given better result than control but not more than 2% KCI priming seeds. Growth, germination and water relation behaviors of all parameters were increases up to 2% KCI priming and decreased gradually with increasing KCI concentrations.

In the 2nd experiment primed seeds (2% KCI priming and hydro priming) and non-primed seeds were germinated under drought stress condition (Polyethylene Glycol) to calculate the germination behavior. 2% KCI priming, hydro priming and control (non-primed) seeds were germinated under 0%, 5%, 10%, 15% and 20% PEG solution induced drought stress condition. Results showed that under drought 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, plant fresh weight, relative water content, water retention capacity, coefficient of germination and vigour index). Under control condition means without stress or 0% stress condition all the characters germination percentage, plant fresh weight, shoot length, root length, shoot and root dry weight, relative water content, water retention capacity, vigour index and water saturation deficit showed best results. From the third experiment, priming with 2% KCI solution with 9 hours priming for BARI Gam 30 expressed better results over non-primed and hydro primed seeds at drought stress condition. Results revealed that germination behavior and seedling growth of non- primed and hydro primed seeds decreased drastically as drought stress increased but osmo primed seeds with 2% KCl showed considerable tolerance capability up to stress level then significantly decreased with increasing drought stress.

CONCLUSION

In this study nutrient/osmopriming in wheat variety showed better response. Germination, growth and water relation behaviors of BARI Gam 30 gave the best result when treated with 2% KCI solution compared to hydro primed and non-primed seeds and decreased gradually with increasing concentrations of KCI. So, priming wheat seeds with 2% KCI for 9hrs is considered as best priming concentration and priming time to induce drought tolerance capability of wheat for increasing germination behavior, seedling growth and water relations behavior under a certain level of drought stress condition.

RECOMMENDATION

In this study seeds treated with 2% KCI for 9hrs gave the best result compared to hydro primed and non-primed seeds. Osmo primed seeds enhances germination, growth and water relations behaviors of wheat varieties. Under drought stress conditions, it is recommended that seeds should be treated with 2% KCI for 9hrs. 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.

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APPENDICES

Appendix I. Effect of priming concentrations on the germination behaviors and seedling growth of BARI Gom 30

Source of variation	Degrees of freedom	Mean square of				
		Germination percentage	Fresh plant weight	Root length	Shoot length	Root dry Weight
Treatments	5	61.87**	409.95**	326.21**	347.19**	30.55**
Error	18	3.66	31.69	14.75	17.48	0.27

**Significant at 1% level of significance

Appendix II. Effect of priming concentrations on growth and water relation behaviors of BARI Gom 30

Source of variation	Degrees of freedom	Mean square of				
		Shoot dry weight	Relative water content	Water saturation deficit	Water retention capacity	Vigor index
Treatments	5	7.34**	60.77**	60.77**	29.78**	2538.83**
Error	18	0.20	3.93	0.31	0.25	65.57

**Significant at 1% level of significance

Appendix III. Effect of different drought levels on germination percentages of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of germination percentages on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	688.38**	904.92**	948.41**	638.62**	511.15**
Error	9	11.65	20.70	13.00	9.62	11.65

** Significant at 1% level of significance

Appendix IV. Effect of different drought levels on plant fresh weight of BARI Gom 30 seeds treated with different primed agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of plant fresh weight on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	174.92**	125.54**	240.56**	132.93**	124.33**
Error	9	16.95	13.28	13.62	11.43	10.63

** Significant at 1% level of significance

Appendix V. Effect of different drought levels on shoot length of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of shoot length on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	1164.60**	846.17**	546.93**	481.23**	473.71**
Error	9	133.11	98.44	70.53	42.44	24.36

** Significant at 1% level of significance

Appendix VI. Effect of different drought levels on root length of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of root length on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	1867.24**	740.84**	448.28**	498.84**	462.49**
Error	9	34.80	80.91	72.39	32.13	10.24

** Significant at 1% level of significance

Appendix VII. Effect of different drought levels on shoot dry weight of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of shoot dry weight on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	3.40**	3.00**	3.52**	0.93**	0.39**
Error	9	0.31	0.35	0.39	0.16	0.06

** Significant at 1% level of significance

Appendix VIII. Effect of different drought levels on root dry weight of BARI Gom 30 with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of root dry weight on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	2.99**	2.35**	1.21**	0.53**	0.55**
Error	9	0.17	0.28	0.22	0.08	0.06

** Significant at 1% level of significance

Appendix IX. Effect of different drought levels on relative water content of BARI Gom seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of relative water content on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	15.80**	13.89**	10.53**	12.15**	8.79**
Error	9	2.14	1.59	1.62	1.11	0.95

** Significant at 1% level of significance

Appendix X. Effect of different drought levels on water saturation deficit of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of water saturation deficit on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	15.80**	13.89**	10.53**	12.15**	8.79**
Error	9	2.29	2.08	1.44	1.51	1.30

** Significant at 1% level of significance

Appendix XI. Effect of different drought levels on water retention capacity of BARI Gom seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of water retention capacity on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	8.45**	6.89**	5.17**	1.71**	0.37**
Error	9	0.53	0.44	0.18	0.08	0.05

** Significant at 1% level of significance

Appendix XII. Effect of different drought levels on vigour index of BARI Gom 30 seeds treated with different priming agents [Control, Hydro priming and KCl (2%)]

Sources of variation	Degrees of freedom	Mean square of vigour index on different drought level				
		PEG 0%	PEG 5%	PEG 10%	PEG 15%	PEG 20%
Treatments	2	11277.00**	6070.02**	5596.56**	707.58**	1010.38**
Error	9	252.80	233.70	145.12	66.83	19.03

** Significant at 1% level of significance