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Polyethylene Glycol (PEG) Induced Changes in Germination, Seedling Growth and Water Relation Behavior of Wheat (*Triticum aestivum* L.) Genotypes

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Abstract Pre-sowing seed treated with Polyethylene Glycol (PEG) assumed to be a potential priming agent to increase the germination, seedling growth and water relation behavior of grain. With this view, a lab investigation was carried out to find out the effect of various PEG concentrations on the germination, seedling growth and water relation behavior of wheat. Seeds of ESWYT-5, ESWYT -6 and ESWYT-7 wheat genotypes and BARI Gom 28 were pre-soaked in water with 0%, 5%, 10%, 15% and 20% PEG solutions. Results of the study revealed that seed priming enhanced germination, seedling growth and water relation behavior of wheat genotypes. Among four wheat genotypes, ESWYT-5 performed the best regarding germination, seedling growth and water relation behavior where wheat genotypes ESWYT-6 and BARI Gom 28 performed moderately and ESWYT-7 showed consistently poor performance. All the characters showed the best results when wheat seeds treated with 10% PEG solution compared to nonprime and hydro primed seeds and the value decreased gradually with increasing PEG concentration. These results suggest that seed priming had significant effect to boost the germination, seedling growth and water relation behavior of wheat genotypes.

Keywords Germination, Seedling Growth, Water Relation Behavior, Polyethylene Glycol, Osmo Priming and Hydro Priming

1. Introduction

Wheat (*Triticum aestivum* L.), one of the most significant staples food crop, it accounts for about 20% of the human food supply and is cultivated on approximately 215 million hectors globally WHEAT [1]. Like other living organisms, the creation of defense mechanism under stress condition is a natural phenomenon of the plant, and that is why the yield of crops decreases but helps to enhance the seed quality Quamruzzaman *et al.* [2]. Despite the some positive impact of stress but it is not suitable for on seed germination, especially for salt and drought stress. And for this reason, seed priming is considered as an effective means to enhance stress tolerance capability of plant under adverse conditions (especially salinity and drought). Seed priming is a new innovative technique by which some physiological changes are gained into target grain with the use of natural and synthetic compounds prior to germination Seed priming is the induction of a particular physiological state in plants by the treatment of natural and synthetic compounds to the seeds before germination. The physiological condition of plants in which plants can faster or better activate defense responses or both is called the primed condition of the plant Beckers and Conrath, [3]. It optimizes seed performance by rapid and uniform germination, healthy and vigorous seedlings growth reaching a physiological condition resulted in faster and better germination and the emergence of different crops Basra *et al*. [4], Cantliffe [5], Powell *et al*. [6] and Taylor *et al*. [7]. Primed seedling can produced normal seedling under stress condition. Carbineau and Come [8] and Ashraf and Foolad [9] reported that, under stress condition primed seedling able to grow normally without any disturbance.

Priming allows some of the metabolic processes essential for germination to occur without germination take place. During priming, seeds are drenched in various priming solutions. Thus the seeds were prevented from absorbing enough water for radical protrusion and retarding the seeds in the lag phase Taylor [7]. Seed priming has been commonly used to minimize the time between seed sowing and seedling emergence and to ensure synchronize emergence Parera and Cantliffe [10]. These effects of priming are collaborated with repairing and building up of nucleic acids, increased synthesis of proteins as well as the repairing of membranes McDonald

[11]. Priming also enhances the activities of anti-oxidative enzymes in treated seeds Hsu *et al.* [12] and Wang *et al.* [13]. Seed priming can be carried out using different techniques *viz.* hydro-priming (soaking in distilled water), osmopriming (soaking in osmotic solutions such as PEG, potassium salts, e.g., KCl, K_2SO_4) and plant growth inducers (CCC, Ethephon, IAA) Chiu *et al.* [14], Capron *et al.* [15] Harris *et al.* [16] and Chivasa *et al.* [17]. Under osmopriming (also addressed as osmoconditioning) the seeds are drenched into synthetic compound like: polyethylene glycol (PEG), sorbitol, mannitol solution and let to uptake water to primary metabolic activities of germination process is started, and radical emergence occurred Ashraf and Foolad [9]. Osmopriming in the PEG solution allows initiating the membrane repairing systems and metabolic preparation for germination via controlling the water absorption rate of seeds Jisha *et al.* [18]. This technique is frequently used in some countries for vegetables and flower crops Halmer [19]. Past studies were evident that PEG had no toxic effect since all seeds germinated. Mehra *et al.* [20] reported that PEG molecules do not enter to seed and there was no toxicity of PEG. According to McDonald [11], primed seeds acquire the potentiality to rapidly imbibe and revive the seed metabolism thus enhancing the germination rate. Osmopriming and hydropriming of wheat seeds may improve germination and emergence Ashraf and Abu-Shakra [21] and may promote proliferous and vigorous root growth Carceller and Soriano [22]. Moreover, priming increases the activities of glyoxysome enzymes in primed bitter gourd seeds Lin and Sung [23]. Baque *et al.* [24] reported that 10% PEG was best for enhanced germination behavior of wheat. In many crops, germination and early seedling growth are the most sensitive stages of water deficit and the water deficit may delay the onset and decrease the rate and uniformity of germination, leading to reduced crop performance and yield Demir *et al.* [25]. Therefore, the beneficial effects of priming may be more evident under unfavorable rather than favorable conditions Parera and Cantliffe [10]. These phenomena have empirical agronomic inference especially under adverse germination state. McDonald [11]. Therefore, the study was carried out to find suitable priming agent(s) for seed industry that might be used to enhance the tolerance capability of plants under adverse field conditions for successful crop production in different regions especially salt and drought-prone areas in Bangladesh.

2. Materials and Methods

The experiment was carried out in the Central Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka October, 2016. The temperature and relative humidity were 26^0C-33^0C and 55-85%, respectively during the experimentation period. Four wheat genotypes namely- BARI Gom 28, ESWYT-5, ESWYT -6 and ESWYT-7, screened out under salinity stress condition Hasan [26] were used for this experiment and were collected from seed technology division of Bangladesh Agricultural Research Institute were used as planting material. PEG and distilled water were used as Osmo and hydro priming agent, respectively in this study. To fulfill the study, growth chamber, electric balance, petri dish, filter paper, micropipette etc. equipments were used.

5 g of PEG was dissolved in 100 ml of water to prepare 5% solution of PEG. Similarly, 10g, 15g, 20g PEG was dissolved in 100 ml of water to make 10%, 15%, 20% solution of PEG, respectively.

Seeds of wheat genotypes were sterilized using 2% Safex solution for 5 minutes, rinsed those seeds using distilled water and air dried at room temperature. Then the seeds were ready for priming treatment.

The priming media were formulated using distilled water and the soaking duration was 12 h for osmo and hydropriming treatment. After incubation into primed solution seeds were air dried and placed in the petri dish. For each replicate, 30 seeds were placed in 12.5 cm petri dish on a layer of filter paper no. 102 which was previously moistened with 8 ml distilled water.

The experiment was carried out following Completely Randomized Design (CRD) with five replications. The wheat genotypes were examined under six priming conditions (distilled water and 5%, 10%, 15%, 20% PEGs solution). Seeds without priming used as control. After that data collected on various parameters such as mean data of germination percentage, shoot length, root length, shoot dry weight, root dry weight, relative water content, water saturation deficit, water retention capacity, germination coefficient and vigor index were recorded.

Germination was recorded one day after placing seeds for germination and continued up to eleven day with an interval of 24 hr. More than 2 mm long plumule and radicle seed was considered as germinated seed.

The germination rate was calculated using following formula:

Germination percentage (%) = $TotalNumberofgerminatedseeds\ Totalseedplacedforgermination$ Germination percentage (%) $=\frac{TotalNumberofgerminatedseeds}{Totalseedplacedforgermination}\times 100$

Germination Co- efficient (GC) was calculated using the following formula Copeland [27]:

$$\text{Germination Co- efficient (\%)} = \frac{A1+A2+\cdots+Ax}{A1T1+A2T2+\cdots AxTx} \times 100$$

Where,

A= Number of seeds germinated

T= Time corresponding to A

x= Number of days to final count

Vigour index was calculated using following formula Abdul-Baki and Anderson [28]:

$$\text{Vigour index} = \frac{Totalgermination \times Seedlinglength\ (mm)}{100}$$

At the eleventh day five seedlings of each petri dish were sampled. Shoot and root length of single seedling was measured with meter scale. Then the shoot and root of the seedling were dried for 48 hr then dry weight of shoot and root were recorded using electric balance.

After recording the fresh weight leaf of each seedling place into ptridish for 24 hr then leaf soaking with distilled water turgid weight was recorded when it was dried for 48 hr the dry weight was measured.

Relative water content was measured using following formula Baque *et al*. [29]:

$$\text{Relative water content (WRC) (\%)} = \frac{Freshweight - Dryweight}{Tugidweight - Dryweight} \times 100$$

Water saturation deficit was recorded using following formula Baque *et al*. [29]:

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

Water retention capacity was measured following formula Baque *et al.* [29]:

$$\text{Water retention capacity (WTC)} = \frac{Turgidweight}{Dryweight}$$

Statistical Analysis

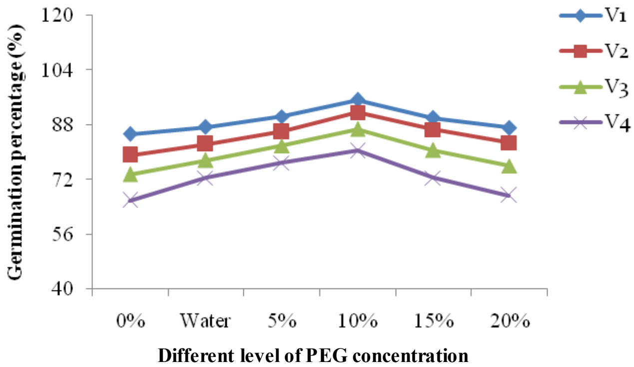
The data of the study were analyzed statistically following CRD design by MSTAT-C analysis software and the mean separation was done using Least Significance Differences (LSD) test at 1% level of probability.

3. Result and Discussion

3.1. Germination Percentage

Germination percentage of wheat genotypes significantly is influenced by different PEG solutions (Line graph 1). Hydro and osmo priming solutions affected the germination percentage of wheat genotypes. Germination percentage (GP) increases with the increasing of PEG concentration up to 10% then there was a gradual decrease observed with increasing the PEG concentration. The result of the experiment revealed that the maximum germination percentage (95.30%) was recorded from wheat genotype ESWYT-5 (V_1) with 10% PEG solution and the minimum germination percentage (65.90%) was recorded from wheat genotype ESWYT-7 (V_4) with 0% PEG concentration (control). Among the wheat genotypes ESWYT-5 (V_1) performed best, and ESWYT-7 (V_4) performed the poor performance and rest of the two genotypes showed moderately in most of the PEG concentrations. The result of the experiment collaborated with the results of Baque *et al*. [24], Yagmur and Kaydan [30], Kaya *et al.* [31], Afzal [32] Afzal *et al.* [33], Basra *et al.* [34], Demir and Ermis [35] and Roy and Srivastava [36]. Basra *et al*. [24] and Salinas [37] reported refinement in germination percent, emergence and seedling standby using seed priming techniques.

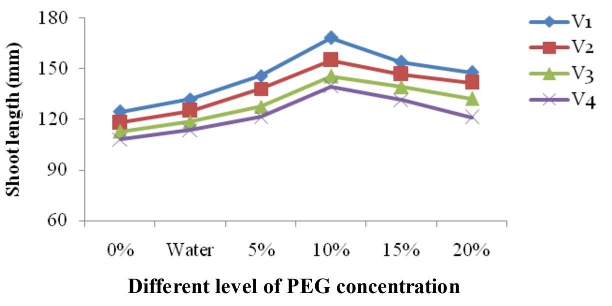
A wide range of biochemical changes occurred during seed priming which was crucial for germination, *i.e.,* breaking of dormancy, hydrolysis or metabolism of inhibitors, imbibitions and enzymes activation Ajouri *et al.* [38]. Researcher demonstrated that the priming process that antedate the germination is boosted by priming and preserved following the re-desiccation of the seed Asgedom and Becker [39]. Primed seed can rapidly consume and resuscitate the seed metabolism, as a result germination percentage was increased and the physiological heterogeneity was triggered down Rowse [40]. Moreover, seed priming most likely grants some fix-up of damage to membrane caused by deterioration and resulted in better germination pattern and higher vigor level compared with non-primed seeds Jisha *et al.* [18] and Ruan *et al.* [41]. Priming showed reviving effects in the early stages of germination by the mediation of cell division in germinating seeds Hassanpouraghdam *et al.* [42]. Similar mechanisms seem to perform in the course of our experiments so that PEG-primed seeds resulted in higher germination attributes and rapid seedling growth under osmotic stress. Hydropriming significantly boost germination rate Ghassemi-Golezani *et al*. [43] and is a useful technique for optimized overall germination Maiti *et al*. [44] and these beneficial effects of hydropriming have been attributed to the mobilization in embryonic tissues of enzyme activities required for rapid seed germination and of compounds such as free amino acids, proteins, and soluble sugars from storage organs Ashraf and Foolad [9]. Farooq *et al.* [45] proposed that physiological changes exerted by osmohardening increased the starch hydrolysis and made more sugars available for embryo growth which enhances germination. Baque *et al.* [24] reported that 10% PEG was best for improved germination behavior of wheat. The report of the Sun *et al.* [46] revealed the compatible PEG concentration were 20% for Gangyou 527 (*indica* hybrid rice) and 10%-15% for Nongken 57 (conventional *japonica* rice). During germination, PEG concentration above the optimum level had adverse effects. Singh and Gill [47] reported that over-priming (KNO_3) might be appeared toxic to primed seed due to prolonged soaking in primed solution (KNO_3) that might have injured the cellular organelles.



Line graph 1. Effect of various concentrations of Polyethylene Glycol (PEG) on the germination percentage of wheat genotypes (LDS $_{(0.01)}$ = 6.92, 4.59, 7.88, 5.89, 7.19 and 6.39 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.2 Shoot Length

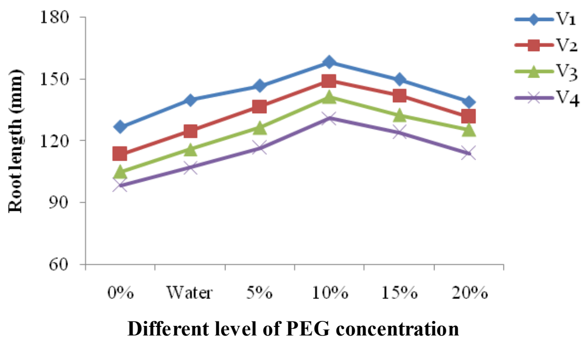
Shoot length of wheat genotypes significantly affected by different PEG solutions (Line graph 2). Shoot length of wheat genotype increased with the increasing of PEG concentration up to 10%, and there was a gradual decreased observed with increasing the PEG concentration. The result of the experiment revealed that the maximum shoot length (168.20 mm) was recorded from wheat genotype ESWYT-5 (V_1) with 10% PEG concentration whereas the minimum shoot length (108.20 mm) was recorded from wheat genotype ESWYT-7 (V_4) with control treatment (non-primed seed). Wheat genotype ESWYT-6 (V_2) performed similar with ESWYT-5 (V_1) under most of the PEG concentrations but ESWYT-7 (V_4) poorly performed under all the osmo and hydro priming solutions. This result is in agreement with the findings of several workers Baque *et al*. [24], Jisha *et al* [18] and Maiti *et al*. [11]. Rennick and Tiernan [48] reported that there was a rapid and more extended elongation of coleoptile occurred in treated seeds than non-treated and over primed seeds. Lee and Kim [49] revealed that, priming increased the metabolic activities of seed ultimately gained the substantial shoot length than nonprimed seed. Baque *et al.* [24] reported that the highest shoot length of wheat was secured when the seed primed with 10% PEG solution.



Line graph 2. Effect of various concentrations of Polyethylene Glycol (PEG) on the shoot length of wheat genotypes (LDS $_{(0.01)}$ = 10.54, 9.37, 13.53, 11.62, 11.68 and 11.20 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.3. Root Length

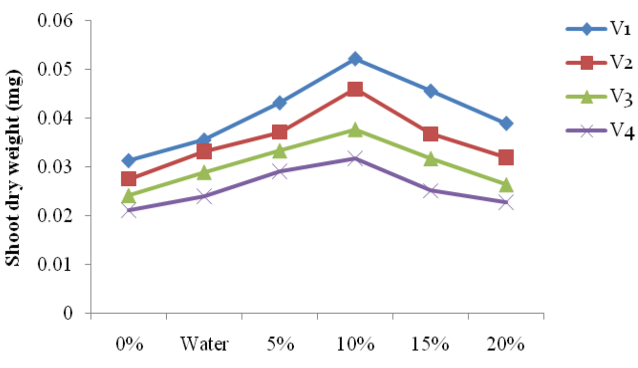
Root length of wheat genotypes significantly varied by different PEG solutions (Line graph 3). Root length of wheat genotype increased with the increasing of PEG concentration up to 10% and there was a gradual decreased with increasing the PEG concentration. The result of the experiment revealed that the maximum root length (158.30 mm) was scored by ESWYT-5 (V_1) with 10% PEG concentration whereas the minimum root length (98.46 mm) was recorded from ESWYT-7 (V_4) with control treatment (non-primed seed). Wheat genotype ESWYT-5 (V_1) performed the best, ESWYT-6 (V_2) and BARI Gom 28 (V_3) gave intermediate results but ESWYT-7 (V_4) consistently poor performance under all the osmo and hydro priming solutions. This result is in agreement with the findings of several workers Baque *et al*.[24], Jisha *et al.* [18] and Maiti *et al.* [11]. Experiments conducted by Ashraf and Abu-shakra [21] revealed that priming of wheat seed in osmoticum or water might improve germination and emergence and aggrandize vigorous root growth Carceller and Soriano [22] as a consequence root length of osmo and hydro primed seed exerted the highest length than non-primed seed. The considerable root length in the treated seeds might be due to increased metabolic activities in the primed seeds than non-primed Baque *et al*. [24] and Lee and Kim [23]. Jisha *et al.* [18] reported that overall growth of plants was enhanced due to the seed-priming treatments. Maiti *et al.* [44] observed that seed priming the seedling vigor of several vegetable crops. The priming techniques improved seedling growth of tomato and chili. Baque *et al.* [24] concluded that the most extended root length was recorded when the seed primed with 10% PEG solution.



Line graph 3. Effect of various concentrations of Polyethylene Glycol (PEG) on the root length of wheat genotypes (LDS $_{(0.01)}$ = 9.36, 10.78, 9.84, 12.45, 12.77 and 13.35 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.4. Shoot Dry Weight

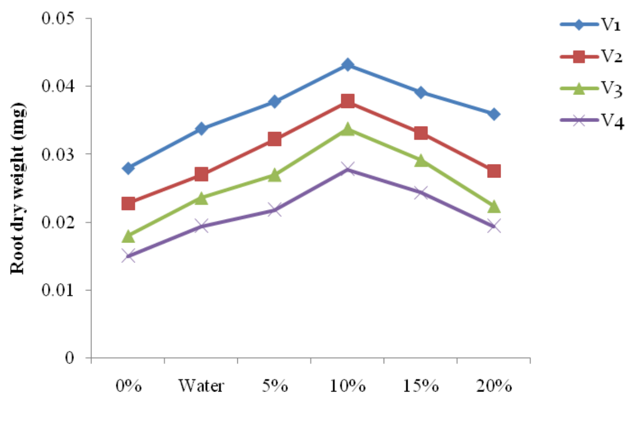
The result of the experiment revealed that the highest shoot dry weight(0.052 mg) was scored by ESWYT-5 (V_1) with 10% PEG concentration whereas the minimum shoot dry weight (0.021 mg) was recorded from wheat genotype ESWYT-7 (V_4) with 0% PEG solutions (non-primed seed) (Line graph 4). The result of the present study was also supported by the result of previous researchers Baque *et al*. [24], Khalil *et al*. [50], Ghassemi-Golezani *et al*. [43] and Sarwar *et al.* [51]. Priming presumably permitted some repairs of damaged to membrane caused by deterioration and exerted better germination pattern and higher vigor level than non- primed Ruan *et al*. [41]. Nascimento and West [52] mentioned minimizing of seed coat adherence during the emergence of muskmelon seeds. The refinement in germination and vigor of standard/low-vigor seed might be due to preserve transportation of food material, trigger and re-synthesis of some enzymes, DNA and RNA synthesis start during osmotic priming. Removing of obstacle speed up the germination of seed ultimately produced the vigorous shoot and increased shoot dry weight of wheat genotypes Basra *et al*. [4]. Khalil *et al.* [50] observed that dry matter yield increased with each increment of priming. Ghassemi-Golezani *et al.* [43] showed that hydro-priming significantly improved shoot weights and Sarwar *et al.* [51] reported that shoot length and biomass of shoots were better when treated with water and mannitol. Baque *et al.* [24] found that maximum shoot dry weight was recorded when the seed primed with 10% PEG solution compared to that of osmo and hydro primed seed.



Line graph 4. Effect of various concentrations of Polyethylene Glycol (PEG) on the shoot dry weight of wheat genotypes (LDS $_{(0.01)}$ = 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.5. Root Dry Weight

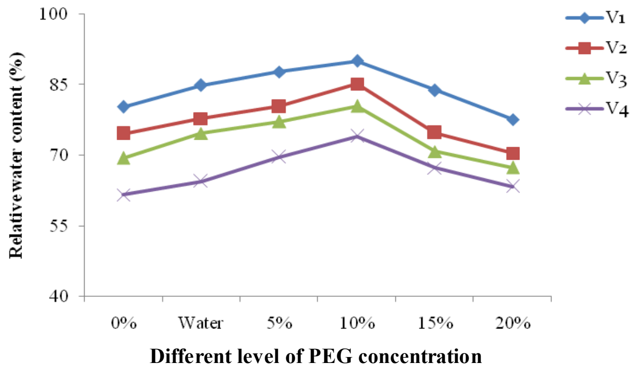
In case of root dry weight ESWYT-5 (V_1) consistently scored the highest value and ESWYT-7 (V_4) scored the lowest value under most of the priming treatments. The result of the experiment revealed that the highest root dry weight (0.043 mg) was observed in ESWYT-5 (V_1) with 10% PEG concentration whereas the minimum root dry weight (0.015 mg) was recorded in ESWYT-7 (V_4) with control treatment (non-primed seed) (Line graph 5). The result of the present study is also in line with the results of previous researchers Baque *et al*. [24], Khalil *et al*. [50], Ghassemi-Golezani *et al*. [43] and Sarwar *et al*. [51]. Khalil *et al.* [50] observed that dry matter yield increased with each increment of priming. Ghassemi-Golezani *et al.* [43] showed that hydro-priming significantly improved root weights and Sarwar *et al.* [51] reported that root length and biomass of roots were better when treated with water and mannitol. Baque *et al.* [24] found that maximum root dry weight was recorded when the seed primed with 10% PEG solution.



Line graph 5. Effect of various concentrations of Polyethylene Glycol (PEG) on the root dry weight of wheat genotypes (LDS $_{(0.01)}$ = 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.6. Relative Water Content

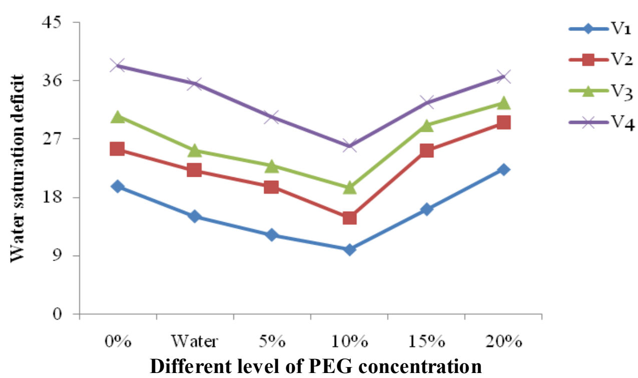
RWC could be the perfect indicator of plant hydrologic condition as it denotes the physiological consequences of cellular water deficit. Water potential that possess the energy status of plant water which is useful for the transportation of water in the soil-plant-atmosphere chain. A wide range of statistical difference was observed for the relative water content of wheat genotypes under different PEG solutions (Line graph 6). Corresponding water content followed the similar trend as the previous parameters of wheat genotypes. The result revealed that the maximum relative water content (90.05%) was found from ESWYT-5 (V_1) under 10% PEG concentration and the minimum relative water content (61.63%) was found from ESWYT-7 (V_4)with 0% PEG concentration. ESWYT-5 (V_1) performed distinctly superior to ESWYT-7 (V_4) where ESWYT-6 (V_2) and BARI Gom 28 (V_3) gave the intermediate results under all the osmo and hydro priming solutions. Under stress condition, osmo and hydro primed seedling can thrive and provide better water use efficiency thus plant growth not hampered than non-primed seeds Flower *et al.* [53]. A similar finding was reported by Sairam *et al.* [54].



Line graph 6. Effect of various concentrations of Polyethylene Glycol (PEG) on the relative water content of wheat genotypes (LDS $_{(0.01)}$ = 5.66, 6.52, 4.76, 7.04, 4.16, 5.27 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.7. Water Saturation Deficit

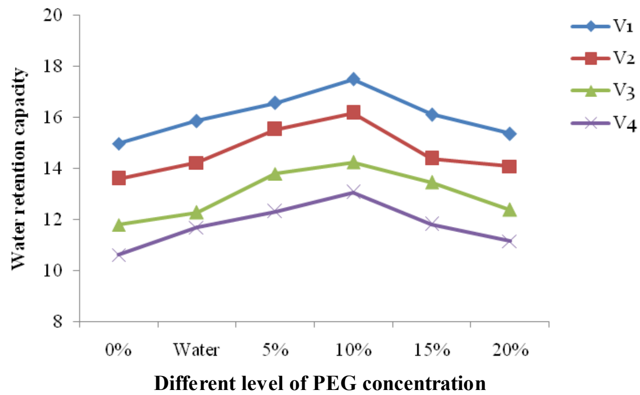
Water saturation deficit of wheat genotypes influenced significantly by different PEG solutions (Line graph 7). It followed the opposite trend compared to the previously described parameter, *i.e.,* the water saturation deficit was maximum at 0% PEG concentration and gradually decreased up to 10% PEG concentration and then steadily increased. ESWYT-7 (V_4) performed poor under all the PEG concentrations and scored the highest value distinctly under all the priming solution where ESWYT-5 (V_1) consistently scored the minimum value for water saturation deficit under all osmo and hydro priming solutions. The highest water saturation deficit (38.37) was recorded from ESWYT-7 (V_4) with 0% PEG solution and the lowest (9.95) were recorded from ESWYT-5 (V_1) with 10% PEG solution. Due to lack of defense mechanism, the non-primed seedling failed to uptake enough water necessary for running the physiological process smoothly than the primed seedling. Thus there was a massive water deficit occurred in case of non-primed genotypes than the primed genotypes. A similar result was reported by Baque *et al.* [29].



Line graph 7. Effect of various concentrations of Polyethylene Glycol (PEG) on the water saturation deficit of wheat genotypes (LDS $_{(0.01)}$ = 2.56, 1.80, 1.68, 1.21, 2.46 and 2.64 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.8. Water Retention Capacity

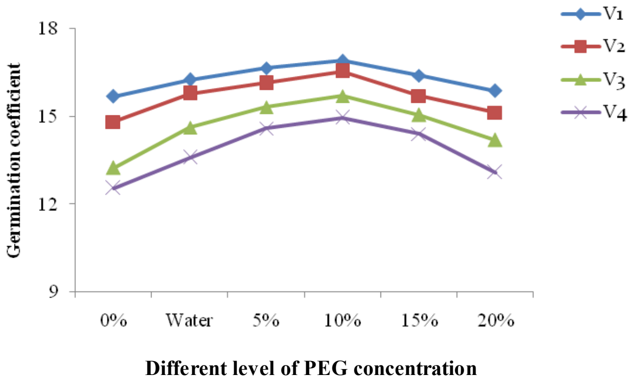
Water retention capacity of wheat genotypes influenced significantly by different PEG solutions (Line graph 8). ESWYT-5 (V_1) wheat genotype distinctly scored the highest value for water retention capacity under most of the osmo and hydro priming solutions where ESWYT-7 (V_4) consistently showed the poor performance. Result revealed that the maximum water retention capacity (17.50) was scored by ESWYT-5 (V_1) with 10% PEG solution while the minimum value (10.62) scored by ESWYT-7 (V_4) with 0% PEG solutions. As 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.



Line graph 8. Effect of various concentrations of Polyethylene Glycol (PEG) on the water retention capacity of wheat genotypes (LDS $_{(0.01)}$ = 0.97, 1.16, 1.33, 1.28, 1.25 and 1.25 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.9. Germination Coefficient

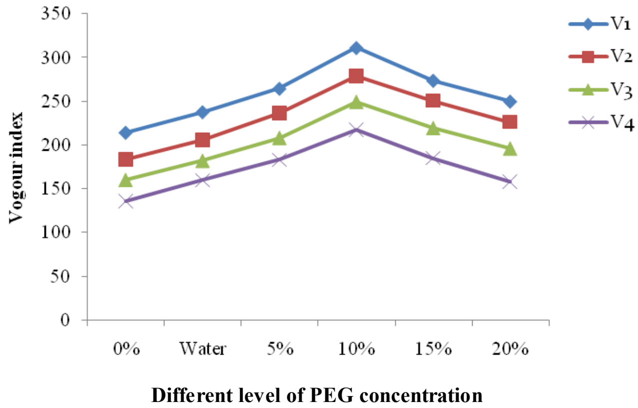
Different Polyethylene Glycol (PEG) solutions significantly influenced the germination coefficient of wheat genotypes except under 15 and 20% (Line graph 9). The maximum germination coefficient (16.90) was recorded from ESWYT-5 (V_1) when the seed primed with 10% PEG concentration whereas the minimum germination coefficient (12.55) was recorded from ESWYT-7 (V_4) when the seed was not primed with osmo or hydro priming solutions. ESWYT-6 showed similarity with ESWYT-5 under all the priming solutions. This result was in line with the findings of *Baque et al*. [24] and Huns and Sung [55] who reported that seed priming resulted from anti-oxidant increment as glutathione and ascorbate in the seed. These enzymes trigger germination speed via reduction of lipid peroxidation activity; as a result germination coefficient was higher in osmo and hydro primed seed compare to that of non-primed seeds. Baque *et al.* [24] reported that the highest germination coefficient was recorded when the seed primed with 10% PEG solution compared to that of osmo and hydro primed seed. Osmopriming of Italian ryegrass (*Lolium multiflorum*) and sorghum (*Sorghum bicolor*) seeds with 20% PEG-8000 for 2 d at 10°C enhanced germination coefficient of wheat genotypes under water stress, waterlogging, cold stress and saline conditions Hur [56]. It has been evident that priming had resulted in more germination speed especially in salt and drought stress, saline stress and low temperatures in sorghum, sunflower, and melon Kaya *et al.* [31], Sivritepe *et al.* [57] and Foti *et al.* [58].



Line graph 9. Effect of various concentrations of Polyethylene Glycol (PEG) on the germination coefficient of wheat genotypes (LDS $_{(0.01)}$ = 1.17, 1.07, 0.62, 0.85, 0.82 and 0.86 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

3.10. Vigor Index

Line graph 10 showed that, the maximum vigor index (311.30) was accounted from wheat genotype ESWYT-5 (V_1) when the seed primed with 10% PEG solution and minimum vigor index (136.20) was achieved from ESWYT-7 (V_4) when the seeds were not primed either osmo or hydro priming solutions. In case of vigor index, ESWYT-5 distinctly scored the highest value under all the osmo and hydro priming solutions whereas ESWYT-7 consistently performed poor and ESWYT-6 and BARI Gom 28 scored intermediate value. This result was also in agreement with the findings of Baque *et al*. [24], Maiti *et al.* [59] and Maiti *et al.* [44] who reported that seed priming increases the seedling vigor of several vegetable crops and concerning sponge gourd, osmo-priming increased seedling vigor. Nascimento and West [52] mentioned that, the minimization of seed coat adherence during the emergence of muskmelon seeds after priming. The advancement in germination and vigor of soybean plant was probably due to the reserve mobilization of food material, activation and re-synthesis of some enzymes, DNA and RNA synthesis started during osmotic priming Sadeghi *et al*. [60]. There might be the possibility that similar germination responsive genes may be activated because of chitosan priming under osmotic stress. Baque *et al.* [24] found that maximum vigor index was recorded when the seed primed with 10% PEG solution. Osmopriming of Italian ryegrass (*Lolium multiflorum*) and sorghum (*Sorghum bicolor*) seeds with 20% PEG-8000 for 2 d at 10°C increased the vigor index.



Line graph 10. Effect of various concentrations of Polyethylene Glycol (PEG) on the vigour index of wheat genotypes (LDS $_{(0.01)}$ = 13.38, 17.31, 23.62, 23.76, 24.61 and 17.18 at 0%, water, 5%, 10%, 15% and 20% PEG concentrations, respectively); V_1= ESWYT-5, V_2= ESWYT-6, V_3= BARI Gom 28 and V_4= ESWYT-7

4. Conclusions

Considering the above results obtaining from the present piece of work it may be concluded that PEG has a positive effect on germination, seedling growth and water relation behavior on wheat seed. Among four wheat genotypes, ESWYT-5 wheat genotypes were performed best in most of the germination, seedling growth and water relation behavior of wheat where wheat genotypes ESWYT-6 and BARI Gom 28 showed moderate results and ESWYT-7 showed consistently poor performance. All the parameters of wheat genotypes gave the best results when seeds treated with 10% PEG solution compared to nonprimed and hydro primed seeds and the recorded results decreased gradually with increasing PEG concentration. So, it can be concluded that seed treated with Polyethylene Glycol (PEG) helps to increase the germination, seedling growth and water relation on wheat genotypes.

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