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RESEARCH ARTICLE

Seed priming with sodium silicate enhances seed germination and seedling growth in wheat (*Triticum aestivum L.*) under water deficit stress induced by polyethylene glycol

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ABSTRACT

Silicon has the potential for improvement of abiotic stress tolerance in crop plants. Effects of sodium silicate (SS) seed priming on seed germination and seedling growth under water-deficit stress induced by polyethylene glycol (PEG) were investigated. Seed priming treatments included hydropriming i.e. soaking of seeds for 8 h in aerated distilled water and sodium silicate priming i.e. soaking of seeds for 8 h in aerated solutions of 20 mM, 40 mM and 60 mM sodium silicate. Seeds were germinated in petri plates under water-deficit stress induced by 15 % PEG- 6000. Final germination percentage (FGP) was significantly increased by sodium silicate priming treatments. Priming with 40 mM sodium silicate induced highest increase in FGP (97 %). Sodium silicate priming also reduced the mean germination time (h) (MGT) of the seeds. Shortest MGT with most rapid germination was observed after 60 mM sodium silicate priming. The germination energy, vigor index, germination index, germination rate, shoot length and root length were efficiently improved by sodium silicate priming. Hydropriming of seeds reduced the MGT and improved the germination rate as compared with non-primed seeds. Hydropriming could not improve the FGP, germination energy, vigor index, germination index, root and shoot lengths. Therefore, enhancement in the seed germination and seeding growth was due to sodium silicate priming. In conclusion, sodium silicate seed priming improved the wheat seed germination and seedling growth under water-deficit stress that indicated the improved stress tolerance of seeds after priming.

INTRODUCTION

Seed priming is a simple, low cost and effective approach for enhancement of seed germination, early seedling growth and yield under stressed and non-stressed conditions. Seed priming is a form of seed preparation in which seeds are pre-soaked before planting (Ahmad et al., 2012). Seed priming with different chemicals, ions, organic compounds, hormones and antioxidants has been reported to enhance the salt tolerance in wheat (Hameed et al., 2010). Further, germination and seedling vigor has been reported to be enhanced by priming with polyamines in tomato cultivars (Afzal et al., 2009).

Sodium silicate is an anhydrous white powder of sodium metasilicate, commonly called as silicon. Silicon synchronized the crop growth and yield. Its application could improve the plant height, leaf area, dry mass and yield of crops under drought stress (Singh et al., 2006; Gong et al., 2003). Silicon as sodium silicate resulted in improved germination, growth, antioxidant enzymes activities and reduced lipid peroxidation during drought stress in wheat (Pei et al., 2010). Activities of antioxidants (SOD, POD and CAT) stimulated after sodium silicate treatment in wheat under stress (Ali et al., 2012). Moreover, sodium silicate treatment lowered down the oxidative stress by enhancement of antioxidant production (glutathione reductase, catalase, peroxidase, and superoxide dismutase) during drought stress in wheat, barley and soybean plants (Wang et al., 2011; Miao et al., 2010; Gong et al., 2005; Liang et al., 2003). Evidences have proved that sodium silicate treatment improved the cell membrane stability by reducing the lipid peroxidation in wheat and soybean under abiotic stresses (Wang et al., 2011; Pei et al., 2010; and Liang et al., 2007).

Osmotic stress results in rapid decline in growth of most of the plants (Flowers, 2004). Osmotic stress results in reduction of leaf chlorosis, antioxidants, plant growth and development and disturbs the hormonal balance in plants (Iqbal and Ashraf, 2010; Ashraf et al., 2010). However, osmotic stress induced reduction in growth depends upon the duration and level of stress and plant tissue types (Meloniet al., 2003). Moreover, scientists have reported the reduction in growth of leaves, stems, leaf area, number of tillers, development of new leaves, lateral buds, branches and root growth under osmotic stress (Shahid et al., 2011; Munns and Tester, 2008; Taiz and Zeiger, 2006). Poly ethylene glycol (PEG) is most commonly used to induce the osmotic stress in plants. PEG is used to induce the osmotic stress or water-deficit condition because it is not naturally produced in the plant tissue and cannot penetrate into cell from the media. PEG induced stress can eventually destroys the normal emergence, growth, biochemical attributes and yield of wheat (Pei et al., 2010).

In this view, the following experiment was designed to check the possible use of sodium silicate as seed priming agent for improvement of water-deficit stress tolerance in wheat. The effect of seed priming with different concentrations of sodium silicate on seed germination attributes and early seedling growth under water-deficit stress induced by PEG was also examined.

MATERIALS AND METHODS

Experimental details and seed priming

The spring wheat (*Triticumaestivum* L. cv. AARI-2011) seeds were obtained from wheat section, Ayub Agriculture Research Institute (AARI), Faisalabad, Pakistan. In the present study, seed priming treatments used were hydropriming, soaking of seedsfor 8 h in aerated distilled water and sodium silicate (SS) priming, soaking of seeds for 8 h in aerated solution of 20, 40 and 60Mm sodium silicate. After priming treatments, seeds were washed three times with water and re-dried near to original weight at 26 ±2 ^{o}C.

Germination test

Germination potential of the primed and non-primed wheat seeds was estimated according to the rules of seed testingby Association of Official Seeds Analyst (AOSA) (Anonymous. 1990). To test seed germination and seedling vigor under water-deficit stress, four replicates of 25 seeds in each replicate were germinated in petri platesof 12 cm diameter at 25°C. To test the effect of priming treatments under water-deficit stress condition, five ml of 15 % polyethylene glycol (PEG-6000) solution (-3.0 Mpa) was applied to each petri plate to induce stress. A seed was scored to be germinated when 2-3 mm long coleoptile and radicle emerged. Counts of germinating seeds were made twice a day at different time intervals (20, 28, 44, 52, 68, 76, 92 and 200 h) starting from the first day and terminated when maximum germination was attained.

Mean germination time

Mean germination time was also calculated by using equation of Ellis and Roberts (1981).

$MGT=\sum D_n / \sum n$

Where n represents the number of seeds germinated on day D and D represents number of days counted from the start of germination.

Final germination percentage

Germination percentage was measured by using the following formula.

$$FGP= \frac{\text{No of seeds germinated on final day}}{\text{Total no of seeds sown}} \times 100$$

Germination index

Germination index (GI) was estimated according to the rules of Association of official Seed Analysts (AOSA) (Anonymous. 1983) by using the following formula.

(Germination index = number of germinated seeds/ Days of first count + -------+ number of germinated seeds/ Days of final count)

Energy of germination

Germination energy was measured at 4th day of planting. It is the percentage of germinated seeds at 4th dayof planting to the total number of tested seeds (Ruan et al. 2002).

Growth response: For growth response, seedlings were allowed to continue growth after collecting the data for germination Ten day old seedlings were then harvested for comparison of growth under water-deficit stress after seed priming treatments. Root and shoot length was measured by spreading them on a scale calibrated in cm.

Statistical analysis

Significance of data was tested by analysis of variance and Tukey (HSD) Test at $p<0.05$ using XL-STAT software. Values presented in graphs are mean ± SD.

RESULTS

Effects of wheat seed priming with different sodium silicate concentrations and hydropriming were tested by comparing with non-primed seeds under water-deficit stress induced by PEG. Final germination percentage significantly increased after sodium silicate priming under water-deficit stress (Fig. 1) all concretions of sodium silicate caused significant increase over non-primed control seeds. However, highest increase in germination percentage (97 %) was observed after priming with 40 mM sodium silicate. Hydroprimingalso improved the final germination percentage of seeds as compared with non-primed control seeds. However, hydropriming induced increase in germination was less as compared to increase induced by seed priming with sodium silicate. This clearly indicates that observed enhancement in the final germination percentage of seeds was mainly due to seed priming with sodium silicate but not due to seed soaking treatment. Simple seed soaking in water do enhance the germination percentage but sodium silicate priming increased this effect to many folds. For non-primed seeds, mean germination time (MGT) was significantly more as compared to primed seeds. Seed priming with sodiumsilicate significantly reduced the MGT under water-deficit stress and all tested concentration proved to be effective in this regard. Highest decrease in MGT was observed after 60 mM sodium silicate priming. This also showed the most rapid seed germination under water-deficit stress after 60 mM sodium silicate priming. Seed priming with 20mM and 40mM sodium silicate almost equally reduced the mean germination time of wheat seeds. Hydropriming of seeds also reduced the MGT under water-deficit stress. However, the reduction was comparatively less as induced by sodium silicate priming. This observation again provides evidence for superiority of sodium silicate

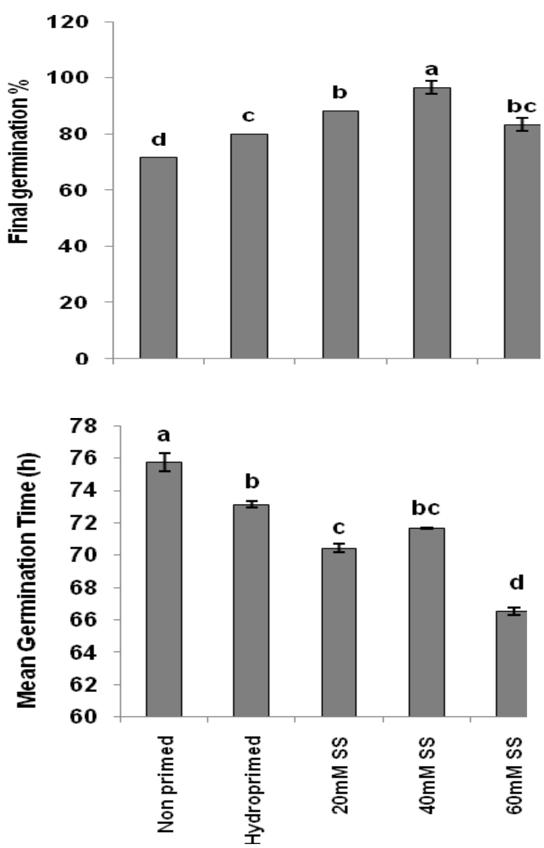

Fig. 1: Effect of sodium silicate seed priming on final germination percentage and mean germination time under water-deficit stress induced by PEG

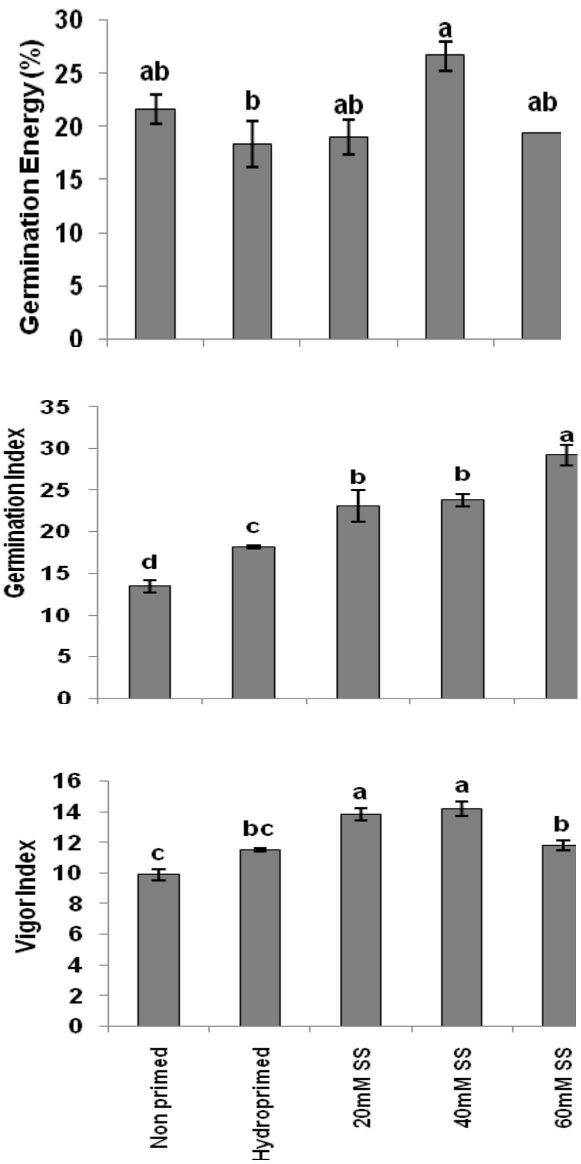

Fig. 2: Effect of sodium silicate seed priming on germination energy, germination index and vigor index under water-deficit stress induced by PEG

priming over hydro priming or simple seed soaking in distilled water. Moreover, results depicted that wheat seed priming with sodium silicate can accelerate the seed germination process under water-deficit condition that points toward an improvement in the stress tolerance.

The germination energy (%) of primed and non-primed seeds was also calculated under water deficit stress imposed by PEG. The germination energy (%) of seeds increased by 40 mM sodium silicate priming (Fig. 2). However, other concentrations of sodium silicate as priming treatment were not able to enhance the germination energy of seeds as compared with non-primed control. Hydropriming was also unable to improve the germination energy of wheat seed under water deficit stress. Sodium silicate priming improved the germination index of wheat seeds under water deficit stress. Seed priming with 60 mM sodium silicate induced highest increase in the germination index. While priming with 20 and 40 mM sodium silicate almost equally increased the vigor index. Hydropriming was not able to significantly improve the vigor index of seeds under water deficit stress.Seed priming with sodium silicate enhanced the germination rate as compared to non primed seeds (Fig. 3).Seed priming with 40 mM sodium silicate induced highest increase in the germination rate of seeds. Seed priming with 20 mM and 60 mM sodium silicate were also improved the germination rate, however, degree of improvement was comparatively less as induced by 40 mM sodium silicate. Hydropriming also improved the germination rate as compared with non-primed seeds. However, hydropriming improved the seed germination rate to a lesser extent as compared to seed priming with sodium silicate.

Growth of seedlings from primed and non-primed seeds was measured in terms of root and shoot lengths. Seed priming with 20 mM sodium silicate only increased the shoot length of seedlings (Fig. 4). However, other priming treatments could not significantly enhance the shoot length of seedlings. On the other hand, seed priming with all sodium silicate concentrations increased the seeding root length under water deficit stress. Highest increase in shoot length was observed in seedlings emerged from seeds primed with 20 mM sodium silicate. In contrast, hydropriming of seeds could notimprove the shoot length of seedling under water deficit stress. However, root length was slightly increased after hydropriming but the difference with control was non-significant.

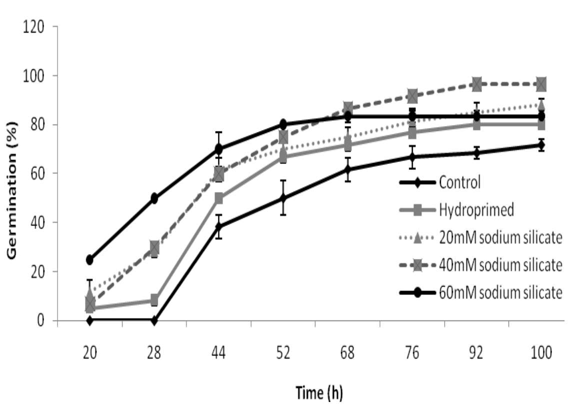

Fig. 3: Effect of sodium silicate seed priming on germination rateof wheat seeds under water-deficit stress induced by PEG

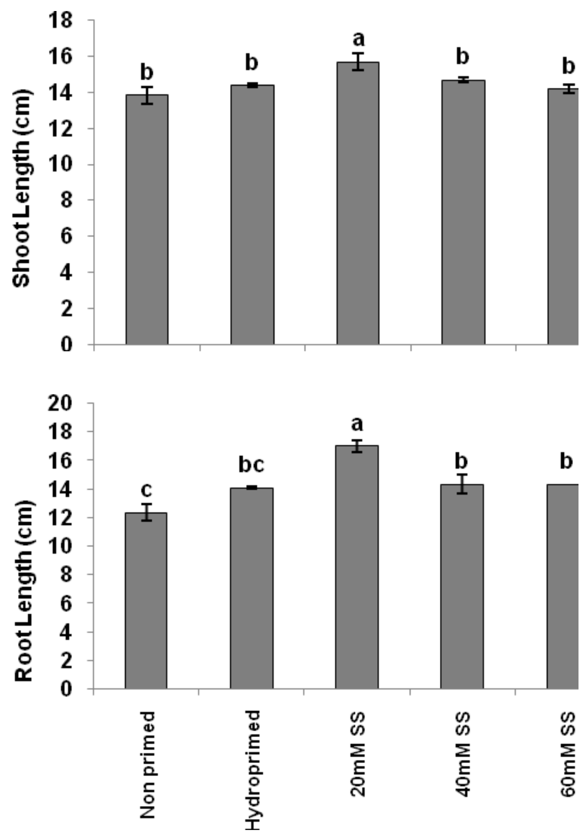

Fig. 4: Effect of sodium silicate seed priming on shoot length and root length of wheat seedlings under water-deficit stress induced by PEG

DISCUSSION

Rapid and uniform seed germination and enhanced emergence is key factors in better and synchronized crop establishment. Seeds are susceptible to abiotic stresses during germination and growth period (Carter and Chesson, 1996). Seed priming treatments have potential to enhance crop emergence and stand establishment under non-stressed conditions (Afzal et al., 2005; Khan, 1992) and have potential in stress full environments (Hameed et al., 2010). Similarly, in present study, seed priming with sodium silicate improved the all germination attributes and seedling growth under water deficit stress.

Evidence has been provided that sodium silicate application resulted in higher germination percentage and index of wheat seedlings which ultimately leads to improved yield (Abro et al., 2009). We also observed that final germination percentage, germination energy (%), vigor index, germination rate and germination index were improved by sodium silicate priming in wheat. Moreover, mean germination time was also reduced under water deficit stress by sodium silicate priming. Actually, seed priming initiates the germination process by induction of required set of biochemical changes in the seed. These processes or changes include activation of enzymes, dormancy breaking, imbibitions and metabolism of germination inhibitors (Ajouriet al., 2004; Asgedom and Becker, 2001). Thus, primed seeds rapidly germinated upon sowing as compared to non primed seeds (Rowse, 1995). Similar mechanisms seem to operate in the sodium silicate primed seeds in present study that resulted in the higher germination percentage and rapid seedling growth under osmotic stress. Seed priming can repair the damage to membranes caused by deterioration during seed storage or under abiotic stresses (Ruan et al., 2002). Thus, present observations strengthen this view that sodium silicate improves tolerance to water deficit stress in plants in general and in wheat in particular.

Ruan et al., 2002 has also been reported that primed seeds showed higher vigor level and better germination pattern than non- primed seeds. Similarly, better germination and seed vigor by sodium silicate seed priming were also observed in present study. The mean germination time was reduced under water-deficit stress in present study by sodium silicate priming. This positive effect was probably due to the stimulatory effects of priming on the early stages of germination process by mediation of cell division in germinating seeds (Hassanpouraghdam et al., 2009).

Silicon has been reported to promote the growth and development of plants under water stress and potassium deficient medium (Miao et al., 2010; Gong et al., 2005, 2008; Hattori et al., 2005). Seed priming with sodium silicate also improved the shoot and root growth of seedlings under water deficit stress in present study. Similarly, Basra et al., 2003 has also been reported the improved emergence and better seedling stand establishment after seed priming. Moreover, sodium silicate application has been reported to enhance the germination and nutrient use leading to better seedling development in soybean (Miao et al., 2010).

In conclusion, tested seed priming treatments not only improved the seed germination but also enhanced the wheat seedling growth under water-deficit stress induced by PEG. Observed beneficial effects on seed germination and seedling vigor indicated an improvement in water deficit stress tolerance of the primed seeds.

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