Role of seed priming in improving wheat performance in a changing climate

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Abstract

Climate change resulting from rising atmospheric CO_2 has been predicted to increase the incidence of heat and drought stresses experienced by plants in many parts of the world. The changing climate is strongly affecting grain production globally. In this study, we evaluated the role of seed priming in improving the wheat performance under heat and drought stresses. There were four sets of stress treatments *viz*. optimal conditions, drought stress (at 60% of field capacity), heat stress (3-4?C) higher than the ambient temperature and both drought and heat stress treatments combined. 'Priming' was achieved by soaking wheat seed in aerated solutions of $CaCl_2$ and ascorbate; while water soaked and dry seeds were used as controls. Seed priming treatments substantially improved the tissue water status, membrane stability and plant biomass under all the stress conditions tested with the greatest benefit occurring for heat stress. Seed priming with $CaCl_2$ was better than ascorbate. Seed priming with $CaCl_2$ offers the potential to improve wheat performance in changing climates.

Keywords

$CaCl_2$, drought, heat stress, yield

Introduction

Climate change may seriously threaten food production required for future generations across the globe. Climate change has many facets, for instance changes in long-term trends in temperature and rainfall regimes as well as increasing variability in extreme events (Semenov 2009); all affecting agricultural production. Wheat (*Triticum aestivum*) is one of the most important cereal crops; contributing about 21% of the world's food. It is grown on about 200 million hectares of farmland worldwide (http://www.fao.org). Changes in global warming are predicted to increase the frequency and severity of 'heat waves' in wheat growing areas in the world (Semenov 2009).

Heat and drought are the main abiotic constraints limiting the grain yield of cereals (Viswanathan and Renu Khanna-Chopra 2001). In major wheat growing regions, temperature exceeding 30?C during reproductive stages reduces grain yield and quality (Maestri et al. 2002), which may be due to a wide range of interlinked processes, including accelerated development. Heat stress to varying degrees at different phenological stages, may cause a substantial yield reduction, primarily because of acceleration of vegetative growth, reduced duration of phasic developmental stages and carbon starvation owing to reduced net assimilation (Blum, 1988; Wahid et al. 2007). The probability of heat stress around flowering, which can result in considerable yield loss, is predicted to increase significantly in coming years (Semenov 2009). As the world water supply is declining, drought is also threatening the world food security. Drought-induced losses in crop yield perhaps exceeds the loss from all other causes, as both severity and duration of stress are critical (Farooq et al. 2009).

Seed priming is a controlled hydration process followed by re-drying that allows pre-germination metabolic activities, to proceed rapidly (Farooq et al. 2008a). Seed priming techniques have been employed to improve resistance against several abiotic stresses in a range of field crops (Farooq et al.

2008a, b; 2009). In this study potential of two seed priming techniques in improving wheat performance in conditions of changing climate was evaluated.

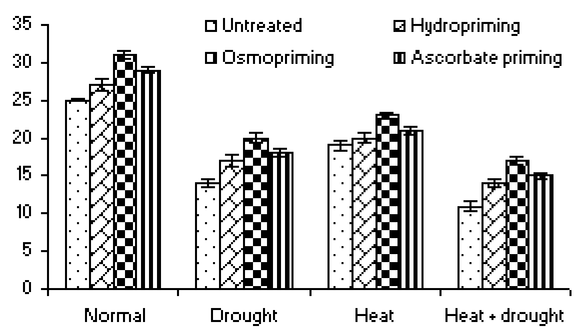
Methodology

Seeds of wheat cultivar SH-2002, used in this study were obtained from Wheat Research Institute, Faisalabad, Pakistan. Priming was achieved by soaked in aerated solutions of $CaCl_2$ (-1.25MPa) and ascorbate (2 mM) for 12 h; while water soaked and dry seeds were taken as controls. Plants were raised under normal conditions (at 22/11?C) in a growth chamber till 3 leaf stage; after which stress treatments were imposed. After that the plants were divided into four sets viz. ‘optimal’ conditions (100% of field capacity at 22/11?C), drought stress (50% of field capacity at 22/11?C), heat stress (100% of field capacity at 26/13?C) and both drought and heat stress (50% of field capacity at 26/13?C). The experiment was conducted in randomized complete block design with four replications. Data on relative leaf water contents, membrane permeability and plant biomass was recorded one week after the imposition of stress following protocol described elsewhere (Farooq et al., 2008b). Data were statistically analyzed by analysis of variance (ANOVA) techniques using compute software MSTATC. Graphical presentation of the data and computation of standard error bars was computed was made in Microsoft Excel.

Results

Substantial reduction in plant biomass and relative leaf water contents was observed in wheat plants exposed to drought and heat stresses; none the less the extent of reduction was magnified when both the stresses were combined (Fig. 1, 2). Likewise the membrane stability was disturbed as indicated by higher electrolyte leakage (Fig.3). However seed priming techniques effectively alleviated the effect of drought and heat stress; osmopriming (with $CaCl_2$) being the most effective followed by ascorbate priming. Nevertheless the extent of improvement was higher under heat stress (Fig. 1-3).

Seedling dry weight (g)



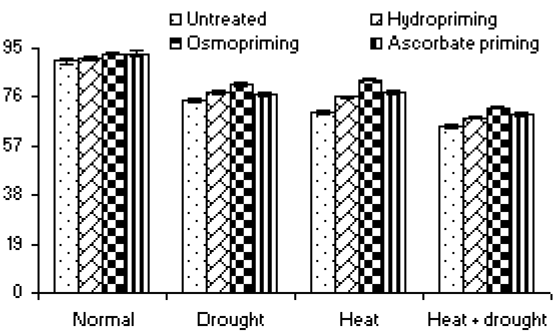
Stress treatments

Fig. 1: Influence of seed priming techniques on seedling dry weight in wheat under drought and heat stresses

Discussion

The study indicates that wheat performance will be strongly influenced by heat and drought stresses, the major climatic threats. Nonetheless seed priming treatments may be employed to mitigate the stress-driven effects. Moreover, seed priming may improve the wheat performance under normal conditions as well (Fig. 1-3).

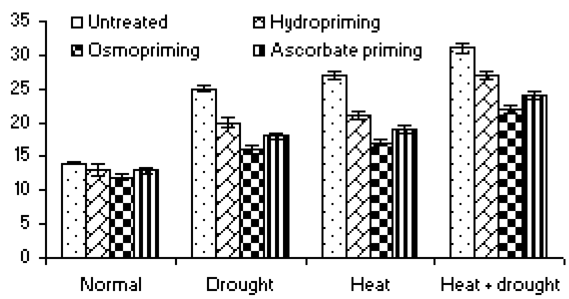
Relative leaf water contents (%)



Stress treatments

Fig. 2: Influence of seed priming techniques on relative leaf water contents in wheat under drought and heat stresses

Electrolyte leakage (%)



Stress treatments

Fig. 3: Influence of seed priming techniques on leaf electrolyte leakage in wheat under drought and heat stresses

Reduction in seedling biomass upon exposure to stresses (Fig. 1) may reflect altered leaf gas exchange attributes (data not shown) and/or tissue water status (Fig. 2). Lipid peroxidation of membrane lipids is one prominent effects of abiotic stresses, resulting in disturbed membrane structure (Fig. 3). Nonetheless seed priming treatments, in particular with $CaCl_2$, lessened the impact of the stresses assessed on seedling growth. Calcium, by maintaining the inter- and intra-molecular linkages (Clarkson and Hanson 1980), actually plays a pivotal role in the protection of membrane structures (Paliyath et al. 1984). In addition Ca^{2+} has been found to enhance the enzymatic antioxidants and also induce the heat shock protein synthesis o (Kuznetsov et al. 1997). Several other reports also indicate the calcium mediated improvement in resistance against abiotic stresses (Farooq et al. 2008a, b).

Conclusion

Seed priming techniques may be employed to improve the wheat performance in changing climate and priming with $CaCl_2$ may be better a choice in this regard.

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