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Research article

Physiological and biochemical assisted screening of wheat varieties under partial rhizosphere drying

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ABSTRACT

Wheat is one of the major staple food of the world, which is badly affected by water deficit stress. To fulfill the dietary needs of increasing population with depleting water resources there is need to adopt technologies which result in sufficient crop yield with less water consumption. One of them is partial root zone drying (PRD). Keeping in view these conditions, a wire house experiment was conducted at University College of Agriculture and Environmental Sciences, The Islamia University Bahawalpur during 2015, to screen out the different wheat genotypes for PRD. Five approved local wheat cultivars (V_1= Galaxy-2013, V_2= Punjab-2011, V_3 = Faisalabad-2008, V_4 = Lasani-2008 and V_5 = V.8200) and two irrigation levels (I_1 = control irrigation and I_2 = PRD irrigation) with completely randomized design having four replications were used in the experiment. Among the varieties Galaxy-2013 performed the best and attained maximum plant height, leaf area, stomatal conductance, photosynthesis, total sugars, proline contents and antioxidant enzymes activities and minimum values of all growth and physiological parameters were recorded in variety V.8200. For irrigation levels, higher values of growth, physiological and water related parameters were recorded in control treatment (I_1) except leaf water potential, osmotic potential, total sugars and proline contents. However enzymes activities were higher under PRD treatment for all varieties. It was concluded that Galaxy-2013 was the most compatible and V.8200 was the most susceptible variety under PRD condition, respectively and more quality traits and enzymatic activities were recorded under PRD condition as compared to control treatment.

1. Introduction

The origin of wheat (*Triticum aestivum* L.) is South Western Asia and has been used as a major food commodity since ancient times (Rahman et al., 2008). It is commonly known as king of cereals and ranked second among the cereals crops in terms of production (Datta et al., 2009). More than one third of the world population use wheat as a staple food (Shirazi et al., 2001). Wheat grain contains 9.4–14 g/100 g protein, 1.8–2.3 g/100 g fiber, 1.2–2.5 g fat and have 69.1–75.4 g/100 g available carbohydrates (Ken, 2004). In Pakistan wheat is cultivated on an area of 9.180 million hectares with production of 25.47 million tones. It shares about 2.1% in GDP and 10% in value added (Economic survey of Pakistan, 2015–16).

Among the various abiotic stresses, crop productivity is badly affected by the shortage of water in many regions of the world (Raza et al., 2017; Sinclair, 2005). Water deficit conditions severely restrained the growth and yield of crops (Raza et al., 2014). Moderate to severe water stress drastically affects various morpho-physiological traits in wheat, such as leaf area, plant height, relative water content, chlorophyll contents, stomatal oscillation, leaf water and osmotic potential (Raza et al., 2012a; Raza et al., 2013). Drought stress consistently leads to oxidative stress in plant cells, due to a higher leakage of electrons towards O_2 during the photosynthetic and respiratory processes, which ultimately results in generation of reactive oxygen species (ROS) (Asada, 1999). At higher

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concentrations, ROS are very harmful for the plant cell as they can directly attack the various cellular organelles like mitochondria, chloroplast, membrane lipid, inactive certain metabolic enzymes and nucleic acids, leading to disfunctioning of cell physiological and biochemical processes and ultimately cell death (Mittler, 2002).

In order to survive under unfavorable conditions, plants have developed unique defense mechanisms and processes that increases their tolerance to detrimental conditions (Saleem et al., 2016; Xu et al., 2008). Turgor maintenance plays a major role in drought tolerance of plants as it has a direct effect on stomatal oscillation and ultimately photosynthesis (Ludlow et al., 1985). Leaf turgor depends upon leaf relative water contents, osmotic and water potential (Bueckert, 2013). Certain enzymes in plants also play an important role in counter acting the damaging effects of drought induced ROS. Some important enzymes against ROS are ascorbate peroxidase (APX), catalase (CAT), peroxidase (POD) and superoxide dismutase (SOD).

Due to increasing demand and competition from environmental, industrial and domestic sectors, supply of water to agriculture sector is likely to be reduced in the coming years. The economic and efficient use of water is one of the best way to tackle this problem (Nasrullah et al., 2011). Many management strategies like use of compatible solutes (Raza et al., 2012b; Raza et al., 2015), use of tolerant/resistant varieties (Mwadzingeni et al., 2016), partial root drying (Xie et al., 2012) and mulching have been developed to overcome the problem of water deficit (Ahmad et al., 2015).

Screening of different varieties can be used as a tool to select most suitable variety under abiotic stresses (Zafar-ul-Hye et al., 2007). Breeding for drought tolerance under field condition is the best strategy for screening of varieties (Richards, 1978), but this requires long time. Secondly it is not a good strategy all the time especially under mesic locations. An alternate way is to screen the varieties under different conditions (greenhouse, wirehouse or laboratory). Alfalfa and soybean accessions were grew under drought stress in lab and the accessions that perform better in lab also perform better under field conditions (Johnson and Rambaugh, 1981). While selecting the most drought tolerant and sensitive wheat variety it was assumed that the varieties that perform better under wire house conditions also perform better under field conditions (Raza et al., 2012c).

Different wheat varieties respond different under drought stress with tolerant varieties having more turgor potential, relative water contents, stomatal conductance and photosynthesis than the sensitive one (Keyvan, 2010). Moreover drought tolerance of some genotypes to environmental stresses has been associated with higher activities of antioxidant enzymes. For example, the drought-tolerant species of pigeon pea (*Cajanus cajan*) (Kumar et al., 2011), wheat (*Triticum aestivum*) (Hasheminasab et al., 2012; Omar, 2012) and black gram (*Phaseolus mungo*) (Pratap and Sharma, 2010) had higher activities of SOD, POD and CAT than the drought sensitive genotypes.

Partial root zone drying (PRD) is an irrigation technique in which half of the root zone is wetted and other half remains dry. The process is then reversed, allowing the dry area of the root to become wet and wet area to becomes dry (Kang and Zhang, 2004). The idea of using PRD as a tool to manipulate plant water deficit stress is based on the fact that root-generated abscisic acid (ABA) can be transported to shoot, where it regulates stomatal oscillation as reported in a number of crop species like soybean (Liu et al., 2003), maize (Bahrun et al., 2002) and wheat (Ali et al., 1998). As a consequence of plant response, partial closing of the aperture of stomata at a certain soil water level may results in water conservation (Liu et al., 2005). To maintain the effect of PRD on stomata, it is essential to regulate the alternate wetting and drying of soil and the period may vary from crop species and soil conditions (Stoll et al., 2000).

PRD has been reported successfully in a number of crops like tomatoes, grapes, oranges, olive trees, maize, wheat and cotton in which it reduced the water consumption more than 50% without significant negative effects on yields (Gu et al., 2004; Bacon, 2003; Dry et al., 2000; Loveys et al., 1997). On the other hand, no extensive research has been made to study the effect of PRD in cereal crops, especially in arid and semi-arid regions (Dodd, 2009). So, the present study was conducted in order to select the best suited wheat genotypes for PRD irrigation system in semi arid region.

2. Materials and methods

2.1. Plant growth conditions and irrigation regimes

A wirehouse experiment was conducted at agronomic research area of University College of Agriculture and Environmental Sciences, The Islamia University Bahawalpur. Experimental site has semi arid climate. Average temperature during the experiment duration was 18.5 °C while no rain fall occurred. Experiment comprised of five wheat varieties (V_1= Galaxy-2013,V_2= Punjab-2011, V_3 = Faisalabad-2008, V_4 = Lasani-2008 and V_5 = V.8200) and two irrigation levels (I_1 = control irrigation and I_2 = PRD irrigation) and arranged in completely randomized design (CRD), having four replications. Plastic tubs were used for sowing of plants. Tubs were filled with soil having sandy loam texture and 7.6 pH. Different wheat varieties were obtained from regional agricultural research institute (RARI) Bahawalpur and surface disinfected. Then these seeds were sown on 1st November in 10 cm apart lines in tubs. All plants were irrigated equally.

Ten days after sowing plants were uprooted from the tubs, root system of each plant was divided in two equal parts and repotted into two separate plastic bags containing the same soil. The plastic bags were then joined by plastic tape and placed together in tubs. In this way root system of each plant was separated in two equal parts. These tubs were irrigated daily for 5 days in order to reestablish root system. Water requirement of wheat was calculated on the basis of acre inches irrigation was applied as normal irrigation (control) and partial root drying (half of control irrigation) on daily basis till 40 days after repotting. Polyethylene plastic sheet was used to make vertical partitions in order to induce PRD and minimize the water seepage between control and PRD compartments.

2.1.1. Recorded parameters

Forty days after repotting plant height, leaf area index and leaf chlorophyll contents were recorded by using meter rod, portable laser leaf area meter model CI- 2002L (CID Bio Science, United States) and chlorophyll meter model CL-01 (Hansatech instruments Ltd., United Kingdom), respectively.

Fully expanded youngest leaf was used to determine the leaf relative water contents (RWC). After cutting, leaves were placed in plastic bag and immediately transferred to the lab to record the fresh weight (FW). Then the leaves were soaked in distilled water for 16–18 h at room temperature to become turgid. After that leaves were dried with tissue paper to calculate turgid weight (TW). For calculating dry weight (DW) leaves were placed in oven at 70 °C for 72 h. Relative water contents were calculated by using the following formulas

$$\mathrm{RWC}\ (\%) = \mathrm{FW} - \ \mathrm{DW}/\ \mathrm{TW} - \mathrm{DW} \times 100$$

For recoding leaf water potential (-MPa), a fully expanded youngest leaf fourth from the top was excised from each plant and measurements were made with a pressure chamber model 600 L (Chas W. Cook and sons Ltd., England).