Adventitious root and aerenchyma development in wheat (Triticum aestivum L.) subjected to waterlogging

Seyed Keyvan Marashi*, Mani Mojaddam*

*Department of Agronomy, College of Agriculture, Ahvaz branch, Islamic Azad University, Ahvaz, Iran

Key words: Adventitious root, aerenchyma tissue, waterlogging, wheat.

Abstract

Study of morphological and anatomical responses to waterlogging stress can help to identify mechanisms of waterlogging tolerance. A pot experiment was conducted in the Agricultural Research Station, Ahvaz-branch University, during 2012-2013 crop season. Experimental design was a factorial according to a randomized compete block design (RCBD) with three replications. Treatments were four levels of waterlogging duration (0, 7, 14, and 21 days) and four height of water above the soil surface namely 0, 5, 10 and 15 cm at the stage of stem elongation. In this experiment Chamran cultivar was used as wheat cultivar. Results showed that aerenchyma tissue and adventitious roots increased under waterlogging stress. The maximum and the minimum adventitious roots and aerenchyma tissue observed under 14 and 7 days waterlogging and the maximum and the minimum adventitious roots and aerenchyma tissue observed under 5 and 0 cm water above the soil surface, respectively.

*Corresponding Author: Seyed Keyvan Marashi Marashi_47@yahoo.com
Introduction

Waterlogging is the state of land in which the soil surface becomes saturated with water especially due to excessive rainfall or irrigation, particularly in areas with poor drainage or level (Samad et al., 2001; Ashraf and Harris, 2005). Approximately 10% of the global land area experiences waterlogging stress in each year (Setter and Waters, 2003; Michael, 2009). Since the speed of oxygen movement in waterlogged soils is about 10,000 times less than normal aerobic soil (Greenwood, 1961; Colmer, 2003), plants and microorganisms experience oxygen deficiency. In waterlogged condition, root growth decreases and gets restricted to small region near the soil surface. Behavior and perceptible variations of roots under waterlogging appeared after approximately 48 h. (Aslam and Prathpar, 2001; Brisson et al., 2002). In the absence of oxygen, root growth and functional relationship between root and shoot is disturbed due to insufficient energy generated by the root respiration (Setter and Waters, 2003; Taiz and Zeiger, 2003; Jin-Woong et al., 2006). There are different strategies that plants employ to waterlogging tolerance. Aerenchyma is a parenchyma tissue with large and abundant intercellular space that develops in roots. Aerenchyma is develops in roots independent of genetic characteristics of plants and environmental stimulation. In rice, production of aerenchyma is a genetically controlled characteristic, because aerenchyma is produced even in aerobic conditions (Evans, 2003; Suralta and Yamauchi, 2008; Pourabdal et al., 2008). In monocots such as maize and wheat, aerenchyma develops between root cortex external and endodermis, behind the root tips where cell expansion has been completed (Watkin et al., 1998; Drew et al., 2000; Grichko and Click, 2001; Taiz and Zeiger, 2003). Development of aerenchyma in response to waterlogging is usually associated with increased ethylene production. It is reported that ACC and ethylene can be produced by the activity of ACC synthase and ACC oxidase in the root tip under hypoxia condition. The ethylene leads to the death and disintegration of root cortex cells. The separation of the cells provide gas-filled void for oxygen movement (Kawase, 1981; Jackson et al., 1985; Hale and Orcutt, 1987; Sinha, 2004). Adventitious root is a mechanism to waterlogging tolerance. Adventitious roots usually develop from the submerged part of the stem. These roots emerge and grow horizontally near the water surface and they are connected to the stem close to the site of aerenchyma formation. It is reported that some hormones such as auxin, ethylene and carbohydrate status in plant have influenced on adventitious root formation. Adventitious roots increase the surface area of the root. Thus, aerobic respiration and oxidation of the rizosphere increases (Voesenek et al., 1996; Samad et al., 2001; Katashi et al., 2007; Changdee et al., 2009).

In the present work the responses of wheat (Triticum aestivum L.) under two treatments namely waterlogging duration and height of water above the soil surface investigated to identify mechanisms of waterlogging tolerance.

Materials and methods

Description of experiments

To evaluate the effect of waterlogging condition on adventitious roots and aerenchyma tissue in wheat (Triticum aestivum L.), a pot experiment was conducted in the Agricultural Research Station, Ahvaz-branch University, during 2012-13 crop season. Experimental design was a factorial according to a randomized compete block design (RCBD) with three replications. Treatments were four levels of waterlogging duration include: no waterlogging (control) (D0), 7 days waterlogging (D7), 14 days waterlogging (D14), 21 days waterlogging (D21) and four height of water above the soil surface namely: 0 cm above the soil surface (H0), 5 cm above the soil surface (H10), 10 cm above the soil surface (H10) and 15 cm above the soil surface (H15). Waterlogging treatments were given to the plants at the beginning of stem elongation stage (ZG31). In this experiment Chamran cultivar was used as wheat cultivar.

Crop management practices

In order to apply waterlogging treatments, wheat cultivars were planted in pots made of polyvinylchloride (PVC) (40 cm height, 20 cm
diameter and 200 cm² soil surface area) and they were waterlogged in a basin filled with water. Water was periodically added to keep the levels of water above the soil surface. The soil of pots contained farm soil and soft sand (passing through 2 mm sieve) in the ratio 1:4, respectively. In each pot 16 seeds were planted and after germination, the seedlings were thinned to 8 plants per pot according to ideal seed density in location (400 seed per square meter).

Investigation of traits
For investigation of roots system, the pots were placed in the basin full of water for 12 hours. Thereafter, the pots torn and the roots were placed in 0.5 mm sieve and washed thoroughly. For determination of adventitious roots, one roots in each pot washed and investigated by special attention to adventitious roots. Aerenchyma tissue was assessed in cross section of adventitious roots (10-50 mm behind the root tip) after staining the cross sections with Safranin and light green, they were studied with the help of photomicrography and special reference to aerenchyma.

Result and discussion
Aerenchyma tissue development
Screening of cross section of root at stem elongation stage is shown in fig. 1. Results showed that aerenchyma tissue increased after increasing waterlogging duration. The maximum and the minimum aerenchyma tissue were observed under 14 and 7 days waterlogging, respectively. Waterlogging duration for 21 days caused in decay and corruption of aerenchyma tissues and the length of roots system were decreased. Thomson et al. (2006) showed that aerenchyma production in wheat begins after 5 to 7 days waterlogging. In other research indicated that behaviour and perceptible variations of roots under waterlogging appeared after approximately 48 h. (Brissom et al., 2002). Huang et al. (1994) suggested that tolerant to waterlogging is directly related to aerenchyma production and the aerenchyma productions is different in wheat cultivars. In other experiment reported that production of aerenchyma tissue is depending on water level and position of roots (Malik et al., 2001). Height of water above the soil surface increased the aerenchyma tissue. The maximum and the minimum aerenchyma tissue observed for 5 and 0 cm water above the soil surface, respectively. Increasing of height of water more than 5 cm did not affect on development of aerenchyma tissue in roots, significantly. Haque et al. (2010) reported that 5 days old wheat seedlings formed no aerenchyma tissue in root under well-drained soil condition (control), but it was formed at 2 to 5 cm behind the root tip after 72 h in 15 cm water level below the soil surface and after 48 h in at 3 cm water level above the soil surface.

![Fig. 1. Effect of duration of waterlogging and height of water above the soil surface on aerenchyma production](image-url)
Adventitious roots production
Adventitious roots usually develop from the submerged part of the stem. Adventitious roots increase the surface area of the root. Thus, aerobic respiration and oxidation of the rhizosphere increases. (Voosenek et al., 1996; Samad et al., 2001; Katashi et al., 2007; Changdee et al., 2009). Results showed that production of adventitious roots increased under waterlogging duration (Fig. 2). The maximum and the minimum adventitious roots were observed under 14 and 7 days waterlogging, respectively. Malik et al. (2001) showed an increase in adventitious roots per stem up to 1.5 times after 14 days waterlogging at the soil surface. Height of water above the soil surface increased adventitious root production. The maximum was observed under 5 cm and the minimum was under 0 cm water above the soil surface. It was seem that the production of adventitious roots is proportional to the increase in aerenchyma tissue development. Jackson et al. (1985) suggested that the production of adventitious roots is directly related to ethylene production. Results also showed that the production of adventitious roots was decreased after 21 days waterlogging, especially in treatments of H15 D21 and H10 D21.

Conclusion
The results confirmed that wheat (Triticum aestivum L.) has ability to waterlogging tolerance due to a change in adventitious roots and aerenchyma tissue. The ability is reduced with increasing of waterlogging duration more than 21 days due to disruption of root system. Meanwhile, waterlogging tolerance is less when height of water above the soil surface is 0 and 15 cm as compared to 5 and 10 cm.

References


http://dx.doi.org/10.3923/ajps.2009.515.525


http://dx.doi.org/10.1046/j.13653040.2003.00846.x

http://dx.doi.org/10.1146/annurev.arplant.48.1.223

http://dx.doi.org/10.1016/s1360-1385(00)01570-3


http://dx.doi.org/10.1007/bf01666294

http://dx.doi.org/10.1016/s0981-9428(00)01213-4


http://dx.doi.org/10.3117/plantroot.4.31

http://dx.doi.org/10.1093/jxb/45.2.193

http://dx.doi.org/10.1007/bf00398093


http://dx.doi.org/10.1626/pps.10.91

http://dx.doi.org/10.2307/2442791


http://dx.doi.org/10.3923/ajps.2008.90.94


