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Water stress and cell wall polysaccharides in the apical root zone of wheat cultivars varying in drought tolerance

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Summary

Glycosyl composition and linkage analysis of cell wall polysaccharides were examined in apical root zones excised from water-stressed and unstressed wheat seedlings (*Triticum durum* Desf.) cv. Capeiti ("drought-tolerant") and cv. Creso ("drought sensitive"). Wall polysaccharides were sequentially solubilized to obtain three fractions: CDTA+Na_2CO_3 extract, KOH extract and the insoluble residue (α-cellulose). A comparison between the two genotypes showed only small variations in the percentages of matrix polysaccharides (CDTA+Na_2CO_3 plus KOH extract) and of the insoluble residues (α-cellulose) in water-stressed and unstressed conditions. Xylosyl, glucosyl and arabinosyl residues represented more than 90 mol% of the matrix polysaccharides. The linkage analysis of matrix polysaccharides showed high levels of xyloglucans (23–39 mol%), and arabinoxylans (38–48 mol%) and a low amount of pectins and ($1\rightarrow3$), ($1\rightarrow4$)-β-D-glucans. The high level of xyloglucans was supported by the release of the diagnostic disaccharide isoprimeverose after Driselase digestion of KOH-extracted polysaccharides. In the "drought-tolerant" cv. Capeiti the mol% of side chains of rhamnogalacturonan I and II significantly increased in response to water stress, whereas in cv. Creso, this increase did not occur. The results support a role of the pectic side chains during water stress response in a drought-tolerant wheat cultivar.

Abbreviations: ANTS, 8-aminonaphtalene-1, 3, 6-trisulfonic acid; HPAEC-PAD, high-pH anion exchange chromatography with pulsed amperometric detector; PACE, polysaccharide analysis using carbohydrate gel electrophoresis; XTH, xyloglucan endotransglucosylase/hydrolase.

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Introduction

Roots are morphologically and functionally organized for the uptake of water, minerals and nutrients from the soil by apoplastic and/or symplastic pathways. These resources taken up by the soil are delivered, through xylem, to the aerial tissues (stem and leaves) for the growth and development of whole plant (Tester and Leigh, 2001). When roots fail in this function, plants show a large range of morphological, physiological, biochemical and molecular symptoms indicative of nutrient deficiencies that cause a limitation in plant productivity. This is particularly significant when crop plants are subjected to prolonged water shortage, which affects virtually all physiological processes, including growth (McDonald and Davies, 1996), signaling pathways (Chaves et al., 2003), gene expression (Denby and Gehring, 2005), respiration (Ribas-Carbo et al., 2005) and photosynthesis (Flexas et al., 2004).

The root represents the first organ in sensing water stress and, in particular, the root tip is the primary site for such perception (Shimazaki et al., 2005). In addition, the root tip responds to a variety of stimuli such as ions, electricity, touch and other soluble molecules to generate biological impulses that modulate the rate, direction and magnitude of root growth and movement. Roots have the capability to move toward water and required substances and to escape from toxic substances (Hawes et al., 2000).

When plants are subjected to water stress, the aerial tissues (leaves and stems) are drastically inhibited, whereas the roots continue to grow in order to explore new soil volume for water. This differential growth response of roots and shoots to low water potential (ψ_w) is considered to be an adaptation of terrestrial plants to dry environments (Sharp and Davis, 1989; Spollen et al., 1993). Thus, in light of the water shortage for agricultural use almost all over the world, it has become important to understand the mechanisms of root growth when plants are subjected to low ψ_w. This may provide vital information for improving, through genetic engineering and traditional breeding, the capability of crop plants to tolerate water shortage without affecting qualitative and quantitative productivity.

Several studies on root growth during water stress in plants of economical importance, such as wheat (Pritchard et al., 1991), maize (Spollen and Sharp, 1991; Wu et al., 1994; Wu and Cosgrove, 2000; Shimazaki et al., 2005), mung bean (Itoh et al., 1987), rice (Pérez-Molphe-Balch et al., 1996), pea (Bracale et al., 1997) and cotton (Zhong and Läuchli, 1993) have been reported. Most of these investigations have indicated that the modification of cell wall yielding properties plays an important role in root growth maintenance at low ψ_w. Cell wall yielding properties are modulated in a complex way, and in particular, by the chemical and physical organization of wall polymeric materials, the control of the activities of specific wall enzymes and the functionality of the secretory system, which continuously delivers polysaccharides and proteins to the wall (Wu et al., 1996; Wu and Cosgrove, 2000; Leucci et al., 2007). In spite of the important role of the roots in response to water stress and to numerous physiological processes, there is a lack of information about the chemical composition of cell wall polysaccharides in this organ. The cell wall, among its other functions, acts as an important site of response to environmental stresses (Hoson, 1998).

In a previous study, we focused our attention on the biosynthesis of cell wall polysaccharides in apical and subapical root segments excised from wheat seedlings of two genotypes varying in water-stress tolerance (Piro et al., 2003). We now report analyses of the wall polysaccharide glycosyl residue and linkage composition in the apical root zone of seedlings of the same wheat cultivars grown in water stressed and unstressed conditions.

Materials and methods

Chemicals

8-Aminonaphtalene-1,3,6-trisulfonic acid (ANTS) was obtained from Fluka, a Sigma-Aldrich Company, Switzerland. Driselase from Basidiomycetes sp. and all other chemicals were purchased from Sigma-Aldrich, Inc. St. Luis, MO, USA.

Plant growth conditions

Certified caryopses of wheat (*Triticum durum* Desf.) cv. Capeiti ("drought-tolerant") and cv. Creso ("drought-sensitive") were supplied by Dr. N. Di Fonzo, Istituto Sperimentale per la Cerealicoltura Foggia, Italy. The two cultivars are classified as drought-tolerant or -sensitive according to the Drought Susceptibility Index (DSI) (Flagella et al., 1995). Seeds were soaked for 2–3 h in running tap water, surface sterilized with 2% (v/v) commercial bleach solution for 20 min, then germinated and grown on aluminium trays containing two layers of water-moistened Whatman