Cellular and whole organism aspects of iron transport and storage in plants

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Abstract

Plants depend upon iron for their growth and development. However, availability of this metal is low in soils, because of its insolubility at basic pH in presence of oxygen. Plants have, therefore, evolved various mechanisms to actively acquire iron from the soil, based either on reducing or chelating strategies. The molecular characterization of these uptake systems and the regulation of their synthesis have been widely documented the last few years. Distribution of iron to the various parts of a plant, and its compartmentation in various subcellular organelles is also described, but the molecular determinants required for these functions are yet poorly documented. Beside transport activities to establish iron homeostasis in plants, storage is also an important parameter. Part of this function is achieved by ferritins. These iron storage proteins are located within the plastids in plants, and regulated by iron at a transcriptional level.

1 Introduction

Plants are an essential component of the food chain because they are responsible for mineral acquisition from the soil and for carbon, sulfur and nitrogen assimilation leading to amino- acid and vitamin synthesis. They bring, therefore, essential nutrients to the animal and human diets. Among essential mineral elements, iron is important because of its physicochemical properties. Coordinated at metalloprotein active sites, it participates in most of the basic redox reactions required in both the production (photosynthesis) and the consumption (respiration) of oxygen. Iron is also involved in many enzymatic reactions required for nitrogen fixation, DNA, and hormone synthesis, for example. However, iron physicochemical properties make this element uneasy to use by aerobic living organisms. In aqueous phase, at physiological pH, iron tends to precipitate under insoluble (oxidized) form. Furthermore, its redox cycling contributes to activation of reduced forms of oxygen through Fenton chemistry, leading to lipid peroxidation, protein oxidation, and DNA mutations, and consequently to cellular damage and possible cell death. As a consequence, plants have evolved mechanisms to control iron uptake, transport in various organs, and storage to ensure an optimal development by preventing both iron deficiency and toxicity. Various transporters are required to achieve

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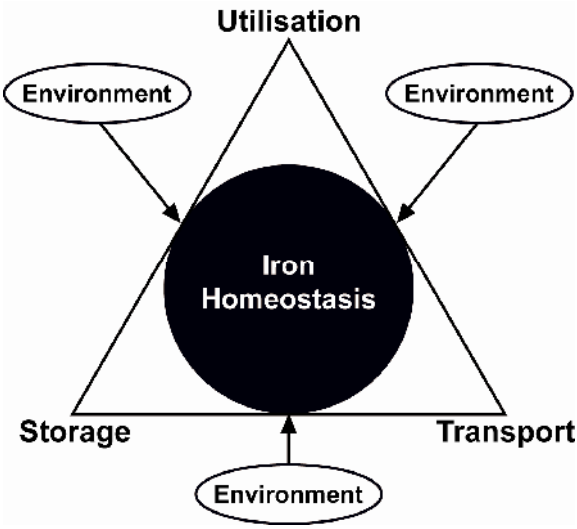

Fig. 1. Schematic representation of the determinants of iron homeostasis in plants. Normal plant growth and development are possible within a sharp range of iron concentrations avoiding deficiency or toxicity. This homeostasis is genetically determined at the level of iron transport, storage, and utilization. These three functions are deeply influenced by environmental factors.

these iron fluxes (Curie and Briat 2003). Iron storage takes place in the apoplasmic space, between the plasma membrane and the cell wall of plant cells, and also likely in the vacuoles, where low pH and high organic acid concentrations represent optimal conditions for iron deposit (Briat and Lobréaux 1998). Ferritins are iron storage proteins located in the plastids of plant cells. They are also part of these mechanisms by their capacity to store up to 4500 iron atoms in their cavity in a soluble and bioavailable form (Harrison and Arosio 1996).

Iron homeostasis in the various plant tissues during growth and development, throughout the life cycle, is a dynamic process resulting from an integrated regulation of the expression of the various genes encoding proteins acting in the transport, storage and utilization of iron. It requires coordinated action of cellular and systemic mechanisms. These processes depend upon the plant species and genotypes considered and are deeply influenced by environmental cues (Fig. 1).

2 Iron acquisition and trafficking

The dynamic fate of iron accumulation in various organs and tissues of a plant during the course of its growth and development is an integrated process, which results from the coordinated regulation of iron uptake from the rhizosphere, iron