

Introduction

In higher plants, the plant body consists of functionally specialized organs, such as the leaf, stem, flower, and root. Since plants grow in changing environments, it is essential for different organs to interact each other to ensure that the entire plant body develops and functions properly. For example, the most important environmental factor, the diurnal cycle, is perceived mainly in leaves, but signal transduction downstream is controlled in many organs (McClung 2001). In this system, photoreceptors that perceive the light signal, such as phytochromes and cryptochromes, influence the expression of biological clock component genes via factors that interact with phytochromes and adjust the biological clock in 24 periods (Makino *et al.* 2002). The information from the biological clock distributed to each organ defines many aspects of development, such as flowering, leaf movement, and hypocotyl elongation (McClung 2001). Information transfer between organs is essential for synchronized plant development.

One of the major routes for the transfer of materials between organs is the vascular bundles, which are composed mainly of xylem and phloem; various materials are translocated over long distances via the vascular bundles. The roots take water and minerals from soil and supply them to the shoot, while the leaves provide the roots with photo assimilates (Kolek 1991). Moreover, the phloem plays a role in the symplastic transmission of physiological signals between organs. For example, a putative florigen is synthesized in the leaves and transferred to buds via the phloem (Bernier 1988). Wound signals, such as systemin (Enyedi *et al.* 1992, Bergey *et al.*

1996), and some phloem proteins (Golecki *et al.* 1999) are also translocated between leaves via the phloem.

The xylem is composed mainly of xylem vessels, which are a kind of apoplastic space. Organic nutrients, such as amino acids, sugars, and organic acids, as well as water and inorganic nutrients, are transported via the xylem to the aboveground organs (Schurr and Schulze 1995, Zornoza *et al.* 1996, Satoh *et al.* 1998). Moreover, the roots control aspects of the development of the aerial organs, possibly acting via growth-related compounds in the xylem sap (Kinet *et al.* 1993, Satoh 1996). In particular, cytokinin, abscisic acid, and other growth-related compounds that are synthesized in root tissues are involved in stomatal responses (Else *et al.* 1995, Liang *et al.* 1997), leaf senescence (Nooden *et al.* 1990, Soejima *et al.* 1992), lateral bud development (Bangerth 1994, Beveridge *et al.* 1997), flower bud formation (Kinet *et al.* 1993), leaf greening (Kato *et al.* 2002), and adventitious root formation (Kuroha *et al.* 2002).

Recently, the presence of macromolecules in the xylem sap has been reported; these include oligo- and polysaccharides (Satoh *et al.* 1992, Campbell *et al.* 1995), proteins, such as peroxidase (Biles and Abeles 1991) and chitinase (Masuda *et al.* 2001), and glycine-rich proteins, such as, cucumber root-specific glycine-rich protein (CRGRP) (Sakuta *et al.* 1998, Sakuta and Satoh 2000). However, the regulation of the production of xylem sap proteins and their physiological functions are not well understood.

In a previous study of cucumber xylem sap (Masuda *et al.* 1999), a novel 30-kDa protein (XSP30) was found. The sequence of XSP30 cDNA has significant

homology to the sequence of the B chain of ricin, a toxic protein from the seeds of *Ricinus communis*, which has galactose-specific lectin activity (Lord *et al.* 1994). Lectins are non-antibody proteins that bind reversibly to specific mono- or oligosaccharides and act as hemagglutinating factors. Many kinds of lectin have been isolated, and their carbohydrate-binding specificity, molecular structure, and biochemical properties have been characterized (Peumans *et al.* 1995). Ricin superfamily lectins are characterized by the presence of a ribosome-inactivating domain (A chain) and a galactose-binding lectin domain (B chain) (Lord *et al.* 1994). Several other lectins have carbohydrate-binding and toxic domains, and increase their toxicity by binding to the carbohydrates of predators (Peumans *et al.* 1995). However, the XSP30 molecule lacks a toxic domain, and consists only of a putative sugar-binding domain. XSP30 is expressed only in root tissue (Masuda *et al.* 1999), leading to speculation that XSP30 is a signaling molecule that is transported from the roots to aboveground tissues.

First, I demonstrated that XSP30 expression in cucumber roots is related to the development and existence of aboveground organs. XSP30 expression in cucumber roots follows a diurnal pattern, and the amplitude of this oscillation is upregulated by gibberellin produced in leaves. Moreover, XSP30 expression is restricted to the xylem parenchyma cells in the central cylinder of the root.

Then, I analyzed the sugar chains recognized by XSP30 using a lectin blot reacted with anti-XSP30 antiserum. I showed that XSP30 is transported from the roots

to the aboveground organs via xylem sap, and binds to core GlcNAc-GlcNAc in *N*-linked glycans of leaf glycoproteins in cucumber plants.

This study offers novel information about the interaction between the roots and aboveground organs.