Plants respond to light as an environmental factor to optimize growth and development and to regulate other physiological phenomena. Phytochrome (phy) and blue light receptors, such as cryptochrome (cry) and phototropin (phot), are the main photoreceptors for plant photomorphogenesis. The goal of our research is to elucidate the photoperception and signal transduction pathways of photomorphogenesis. One of our major subjects is chloroplast photo-relocation movement, which is mediated by phototropins and one of the simplest model systems to study photomorphogenesis. Because the phenomenon is cell autonomous, whole processes from photoperception to chloroplasts movement can be accomplished in a single cell without any influence from surrounding neighbor cells. Moreover, gene expression is not involved in the signal transduction pathways, unlike in those of phy- and cry-mediated phenomena. Chloroplast movement is not real plant morphogenesis, but we are studying it because chloroplast movement and photomorphogenesis share the same photoreceptors.

I. Chloroplast relocation movement

We use the fern Adiantum capillus-veneris as a model plant for our cell biological and physiological approach to chloroplast movement since the gametophytes are very sensitive to light and the organization of the cells is very simple. We also use Arabidopsis mutants as well as wild type plants to identify the genes regulating chloroplast movement and for analyses of the genes’ functions.

1-1 Velocity of signal transfer

Phototropins (phot1 and phot2) and a neochrome (which is a chimera photoreceptor of phytochrome chromophore binding domain and phototropin) were identified as photoreceptors for chloroplast movement (Kagawa et al. 2001, Kawai et al. 2003, Kagawa et al. 2004); however, a signal transferred from photoreceptors to chloroplasts remained to be clarified. We therefore studied the velocity of signal transfer using Adiantum gametophytes to find a clue to the identity of any possible candidates for the signal. The velocity in a long protonemal cell is confirmed to be different between the signal moving from the base to the tip (approximately 2.3 μm min⁻¹) and from the tip to the base (approximately 0.6 μm min⁻¹) of the protonemata both in the red and blue light-induced chloroplast movement. On the other hand, the velocity of signal transfer in two-dimensional gametophyte cells is the same (approximately 0.7 μm min⁻¹) irrespective of the direction of signal transfer or the wavelength (either red or blue light) that induces chloroplast movement. The velocities are slower than that of cytoplasmic streaming. The velocity of the signal transfer was very slow compared to our expectations, and we do not have any clear idea at the moment what is the signal and what is the mechanism of the transfer.

1-2 Chloroplast movement under cold condition

Chloroplasts movements were induced at about 4°C in Adiantum gametophytes. At low temperatures chloroplasts move to the anticlinal walls under either dark or light conditions. The position is similar to those of chloroplasts found in the dark or under strong light. Although the movement was even induced under darkness, it is not dark-induced movement, because the response could be induced in the mutant gametophytes defective of dark-induced chloroplast movement.

II. Photoreceptor functions

2-1 Photoreceptors mediating nuclear movement in the fern Adiantum

In gametophyte cells of the fern Adiantum capillus-veneris, nuclei as well as chloroplasts change their position according to light conditions (Kagawa and Wada 1993, 1995). Nuclei reside on anticlinal walls in darkness and move to periclinal or anticlinal walls under weak or strong light conditions, respectively (Figure 1).

Figure 1. The left half of an Adiantum gametophyte cultured under weak white light was irradiated with strong white light to induce nuclear avoidance response and then fixed with glutaraldehyde and stained with DAPI. Nuclei irradiated with strong light moved to the anticlinal walls from the center of cells. The response was mediated by a blue light receptor, phototropin2 (Tsuboi et al. 2007).
This year we tried to identify the photoreceptor(s) that mediates nuclear movement in the gametophyte cells using photoreceptor mutants, neo1 (neochrome1 defective), phot2 (phototropin2 defective), and neo1phot2 (Figure 2) and revealed that red and blue light-induced nuclear accumulation movement is mediated by neo1, and possibly phot1 and phot2, respectively, and that blue light-induced avoidance movement is mediated by phot2 (Tsuboi et al. 2007).

It was also found that phot2 is necessary for dark positioning of nucleus (Tsuboi et al. 2007). It is curious that a photoreceptor is needed for a physiological response in the dark, but it is similar to the case of Arabidopsis chloroplast positioning wherein phot2 is indispensable in dark positioning. Thus, both the nuclear and chloroplast photorelocation movements may share common photoreceptor systems.

2-2 Aureochrome as a blue light receptor in Vaucheria

Vaucheria is a member of the group of stramenopile algae, which includes brown algae and diatoms and shows blue light responses, such as phototaxis, phototropism, photomorphogenesis and chloroplast relocation (Kataoka et al. 1975). In collaboration with Professor Kataoka at Tohoku University, we tried to find a blue light receptor(s) that might involve the blue light responses. We cloned two genes containing sequences of one basic-region/leucine-zipper (bZIP) domain and one light-oxygen-voltage (LOV) domain that binds a flavin mononucleotide (FMN). Its bZIP domain binds the target sequence TGACGT. We named them AUREOCHROME1 and 2 (aureo1 and aureo2). RNAi of AUREO2 induces sex organ primordial instead of branches, implicating AUREO2 as a sub-switch to initiate the development of a branch, but not a sex organ. These are the photoreceptors for the blue light-induced branching of Vaucheria frigida. AUREO sequences are also found in the genome of the marine diatom but are not in green plants (Takahashi et al. 2007).

2-3 Binding proteins to a putative blue light receptor in Arabidopsis

PAS/LOV protein (PLP) is a putative blue light receptor with a PAS domain at its N-terminal region and an LOV domain at its C-terminal region (Crosson et al. 2003). PLP interacting proteins were isolated by the yeast two-hybrid system and were studied in collaboration with Dr. Kiyosue at Kagawa University. Those were VITAMIN C DEFECTIVE 2 (VTC2, Jander et al. 2002), and VTC2 paralog (VTC2L) and BEL1-LIKE HOMEODOMAIN 10 (BLH10) (Hackbusch et al. 2004). The interaction of PLPA with VTC2L was weakened at the intensity of >100 mmole m⁻² s⁻¹ of blue light, while that of PLPB with VTC2L was undetectable at that intensity (Ogura et al. 2008).

Publication List

Original papers


Review articles