The signaling role of basic metabolites in the phototropin-controlled chloroplast responses
Popular description

The redistribution of chloroplasts in the cell is a physiological process which, at low illumination, helps the plant to make the best of the light available for photosynthesis, and at the same time, protects the photosynthetic apparatus against damage. In weak light chloroplasts form layers which absorb light very efficiently, in strong light they move to the side cell walls and shade each other, thereby absorbing much less energy.

Chloroplast movements in higher terrestrial plants are controlled only by blue light. Two photoreceptors, phototropin1 and phototropin2, mediate chloroplast redistribution. These blue light-absorbing proteins are localized outside the chloroplast, at the cell membrane. Both phototropins mediate chloroplast movements in weak light, while only phototropin2 is responsible for the response to strong light. In the mechanical sense, chloroplasts move using the actin cytoskeleton and myosin, proteins also localized outside chloroplasts. Although the studies of chloroplast movement mechanisms lasted for decades, the pathways by which signals created by light travel from photoreceptors to the cytoskeleton are only partly known. In particular, we do not know whether the chloroplast takes part in the signaling that leads to its movement. The aim of our project is to find signals coming from chloroplasts, that could inform the cell about the state of photosynthesis that takes place inside them. Such signals might modulate chloroplast movements, for example they could change the chloroplast’s trajectory or the velocity of its movement. We believe that sugars, products of photosynthesis, or amino acids that are synthesized in chloroplasts may be carriers of such information.

In this project, we plan to develop four research issues. Firstly, we plan to elucidate why sugars delivered to the leaf inhibit chloroplast movements, an effect that we observed some time ago. We suspect that this effect is connected with plant defence against pathogens, for example fungi. Plants, defending themselves against pathogens, deliver more sugars to cell walls.

Secondly, from preliminary experiments we learned that some amino acids delivered to the leaf also modify chloroplast redistribution. We would like to find out exactly which amino acids can do it and how they do it. It is possible that the mechanism is similar to the one functioning in animal cells. Well known NMDA channels are present in animal nerve cells. They take part in signal transmission via synapses. NMDAs are ionic channels which open after binding an amino acid. In animal cells these amino acids interact with the actin cytoskeleton. We know also that free amino acids protect the animal cell against glycation, i.e. sugar binding to various proteins including actin. All these facts known from animal studies will be tested in plants in the context of chloroplast movements.

Thirdly, aminoacids are a part of nitrogen metabolism. We will test chloroplast movements in mutants which lack key enzymes of nitrogen metabolism. These will be the mutants of glutamine synthetase and a mutant of nitrate reductase. The latter enzyme may be controlled by blue light. We will also investigate chloroplast movement in legumes, under conditions of low nitrogen supply and after supplementing them with additional nitrogen in the form of nitrate ions.

Our fourth idea is to check whether malate, a metabolite transported from chloroplast to cytoplasm, may be a signal coming from the chloroplast and informing its vicinity about the level of photosynthesis. For that purpose, we will study mutants of malate dehydrognase.

Studying the mechanisms of chloroplast redistribution belongs to basic sciences but their elucidation may have fundamental significance for plant productivity and their protection. In the planned investigations we will use techniques of molecular biology, biochemistry, bright field and confocal microscopy and photometry of living objects. The latter method allows us to measure chloroplast movements by recording changes of light transmittance through the leaves. A part of the experiments will be carried out in cooperation with specialists from Polish and German research institutions who will help us to study problems that are new for us, for example plant responses to pathogens.