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Molecular Mechanisms Optimizing Photosynthesis During High Light Stress in Plants

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Examinator: Professor Adrian Clarke, Institutionen för biologi och miljövetenskap, Göteborgs Universitet

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ABSTRACT: Oxygenic photosynthesis is the process by which plants, algae and cyanobacteria use solar energy to convert water and carbon dioxide into molecular oxygen and carbohydrates. Photosynthesis sustains life on Earth since it provides not only energy for individual growth, but also represents the starting point of the food chain for most living organisms. Sunlight is essential for driving photosynthesis, but it is also known that in excess it can be stressful with severe consequences for plant growth. In this thesis I have used the model plant *Arabidopsis thaliana* to study molecular mechanisms optimizing photosynthesis during high light stress.

One of these mechanisms is the reversible phosphorylation of proteins in the water-oxidizing photosystem II (PSII) complex. The serine/threonine-protein kinases STN7 and STN8 are involved in the phosphorylation of the PSII light-harvesting complex (LHCII) and core proteins, respectively. In Paper II, I found variation in the phosphorylation levels of these proteins in Arabidopsis natural accessions. In high light conditions, I found a correlation between the STN8 protein abundance and the D1 protein phosphorylation level. In growth light conditions, D1 and LHCII phosphorylation correlated with longitude and in the case of LHCII phosphorylation with temperature variability as well.

Another molecular mechanism for plants to overcome high light stress is via PSII repair. STN8- mediated PSII core phosphorylation is an early and crucial step for efficient PSII repair, since it alters the folding of the thylakoid membrane in a manner facilitating lateral migration of complexes to the sites of repair. Among three laboratory Arabidopsis accessions studied, Ws-4 displayed a reduced STN8 level resulting in decreased PSII core protein phosphorylation (Paper I). Nevertheless, the downstream steps in PSII repair proceeded normal or slightly faster. This phenomenon is probably due to compensatory mechanisms involving additional lipids and carotenoids to increase membrane fluidity and thus lateral migration of complexes.

The thylakoid ATP/ADP carrier (TAAC) transports ATP into the thylakoid lumen for nucleotide-dependent reactions. In Paper III, I have found that TAAC- deficient plants displayed wild-type levels of PSII protein phosphorylation but slower disassembly of complexes and slower D1 protein degradation. I propose that ATP supplied by TAAC into the lumen is used for nucleotide-dependent reactions with roles in various steps of PSII repair. I have also found that, via its transport activity, TAAC may consume part of the proton gradient across the thylakoid membrane, which is critical for the initiation of photoprotective mechanisms.

In a proteomics study of the stroma thylakoid membrane from Arabidopsis (Paper IV), I identified 58 proteins, including previously known ones as well as new putative thylakoid proteins with roles in photosynthesis transport, translation, protein fate, metabolism, stress response and signaling. This thesis deepens our understanding of photosynthetic regulation at the molecular level and improves the biochemical overview of the chloroplast thylakoid membrane.

Keywords: high light stress, natural variation, photosynthesis, protein phosphorylation, photoprotection, photosystem II, proteomics, STN kinase, thylakoid membrane, TAAC