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Promotionsverfahren von **Frau M.Sc. Yuxi Niu**
Auslage der Dissertation und Gutachten sowie Termin der mündlichen Prüfung
Anlage: Einseitige Zusammenfassung der Dissertation

Sehr geehrte Damen und Herren,

in dem oben genannten Promotionsverfahren wird die Annahme der Dissertation

Probing Dynamic Regulation of Photosynthesis Using Harmonically Oscillating Light

von den Berichterstattenden PD Dr. S. Matsubara und Prof. Dr. O. Ebenhöh beantragt. Sie kann zusammen mit den Gutachten in der Zeit

vom 06.06.2024 bis 17.06.2024

eingesehen werden. Bitte wenden Sie sich zur Einsicht an das Promotionsbüro (promotionmnf@hhu.de).

Einsprüche gegen diese Dissertation können nur zwei Tage nach der vorgenannten Frist geltend gemacht werden. Erfolgt kein Einspruch, so gilt die Dissertation als angenommen (§ 7 Ziffer (5) PO).

Sofern die Dissertation angenommen wird, findet die mündliche Prüfung am

20.06.2024 um 15:00 Uhr

im **Raum 26.24.U1.014** statt. Als Prüferinnen bzw. Prüfer sind vorgesehen:
Prof. Dr. P. Jahns, Prof. Dr. U. Armbruster und Prof. Dr. G. Grossmann.

Die Öffentlichkeit ist bei der Befragung zugelassen.

Mit freundlichen Grüßen
im Auftrag

Silke Krispin

Probing Dynamic Regulation of Photosynthesis Using Harmonically Oscillating Light

Yuxi Niu

The sunlight utilized in plant photosynthesis is highly variable. Multiple regulatory mechanisms have evolved to cope with light fluctuations, presumably leading to the resilience and robustness of photosynthesis. However, an in-depth understanding of these fine-tuning mechanisms is hindered by the complexity of photosynthetic regulatory networks, the variability of light environments, and the limitations of sensing techniques.

This study employed a frequency-domain method, utilizing harmonically oscillating light, to systematically investigate the dynamics of plant photosynthesis in response to light oscillations with varying frequencies and amplitudes. By exposing *Arabidopsis thaliana* wild-type plants and mutants to oscillating light, the operational frequency ranges or frequency limits of multiple photoprotective mechanisms determined by specific molecular processes were revealed, thereby elucidating their roles in regulating responses to light fluctuations across different time scales in natural environments. Additionally, the study aimed to improve the harmonically oscillating light method and demonstrate its potential for studying the dynamics of photosynthesis.

Frequency limits were identified by monitoring changes in dynamic photosynthetic responses to light oscillations of different frequencies. A qualitative comparison between wild-type *A. thaliana* and mutants lacking rapidly reversible non-photochemical quenching (NPQ) components revealed two frequency limits associated with PsbS- and violaxanthin de-epoxidase (VDE)-dependent NPQ. The PsbS-dependent mechanism operated around 1/10 Hz-1/30 Hz, while the VDE-dependent process had a frequency limit of about 1/60 Hz-1/120 Hz. Contrasting responses in mutants lacking specific cyclic electron transport (CET) pathways also indicated that regulatory mechanisms with apparently similar functions may possess distinct frequency limits in oscillating light. The PGR5/PGRL1-dependent CET potentially operated beyond the tested frequencies (>1 Hz), while the NDH-like complex-dependent CET might operate at around 1/30 Hz-1/60 Hz. The results suggest that each regulatory mechanism has its own operational frequency range within which the contributing molecular processes can function.

Further experiments, utilizing the 1/60 Hz frequency, explored the impact of oscillation amplitude on the dynamic regulation of photosynthesis. PSI- and PSII-quantum yields and the redox changes of PC and Fd were examined in the same *A. thaliana* genotypes by superimposing saturation pulses on oscillating light. Results suggest that the PGR5/PGRL1-dependent CET protects photosynthesis systems even in light fluctuations with small amplitudes, while the NDH-like complex-dependent CET may act as a safety valve in light fluctuations with large amplitudes.

Furthermore, relationships between irradiance and photosynthetic responses in changing light conditions were characterized by the chlorophyll fluorescence (ChlF) fingerprint under oscillating light. These relationships were more complex than those obtained from steady-state measurements. Responses at fast oscillation frequencies (1 Hz-1/10 Hz) were attributed to constitutive non-linearity arising from saturation of photosynthetic pathways or filling and emptying of photosynthetic redox pools. Regulatory non-linearity emerged at slower frequencies (> 1/30 Hz), where dynamic regulation of rapidly reversible NPQ distorted irradiance-ChlF relationships, leading to a decrease in ChlF yield during the light-increasing phase. At sufficiently slow frequencies (< 1/120 Hz), photosynthesis reached a stationary state, indicating that effective regulatory processes maintain the dynamic equilibrium of photosynthesis systems despite changing light intensities.

Photosynthetic dynamics in oscillating light are largely non-linear and exhibit information richness. Sensing and analyzing the frequency characteristics of regulatory processes and non-linear responses of photosynthesis using harmonically oscillating light can provide insights into different regulatory mechanisms and their functions in changing light environments.