

論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	PHYSIOLOGICAL CHARACTERIZATION OF NOVEL PHOTOSYNTHETIC REGULATORY PROTEINS IN <i>Arabidopsis thaliana</i>
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出典(和文)	学位:博士(理学), 学位授与機関:東京工業大学, 報告番号:甲第11578号, 授与年月日:2020年9月25日, 学位の種別:課程博士, 審査員:増田 真二,太田 啓之,久堀 徹,田中 寛,下嶋 美恵
Citation(English)	Degree:Doctor (Science), Conferring organization: Tokyo Institute of Technology, Report number:甲第11578号, Conferred date:2020/9/25, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)
Doctoral Program

論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	生命理工学 生命理工学	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Science)
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要旨（英文 800 語程度）

Thesis Summary (approx.800 English Words)

Photosynthesis is the most important reaction on Earth with ~100 billion tons of dry biomass produced annually. Since most plants convert only 6% of solar energy to biomass, genetic improvement of their photosynthetic efficiency has been expected to provide sufficient crop yield required for sustaining 10 billion people by 2050. Given the sunlight is always fluctuating in nature, photosynthetic organisms have established sophisticated regulatory mechanisms to control photosynthetic activities in cope with various light intensity. Non-photochemical quenching (NPQ), eliminating >75% of the excess absorbed light energy, is an efficient photoprotective mechanism for protecting photosynthetic machinery from photodamage caused by reactive oxygen species. Although mechanisms of NPQ induction have been well established, its regulation is still under investigation. Recently, new NPQ-regulatory proteins, Fluctuating-light acclimation protein1 (FLAP1), Day-length-dependent delayed greening1 (DLDG1), and Triplet cysteine repeat protein (TCR), were identified by reverse-genetic screening. This research was conducted to elucidate the unknown functions of the three components at the molecular level. Phenotypic analysis of loss-of-function mutants of <i>flap1</i>, <i>dldg1</i>, and <i>tcr</i> grown under short-day, long-day, constant-light, or fluctuating-light conditions indicated that photosynthetic activity and phenotypic appearance in the mutants were variable depend on the growth conditions. FLAP1 function is specifically required under fluctuating-light conditions; <i>flap1</i> showed pale-green color in leaves only under fluctuating light. DLDG1 is important for plant growth under long-term light-illumination conditions (> 16 h per day), since <i>dldg1</i> showed pale-green color in young leaves only under long-day and constant-light (24-h light) conditions. <i>tcr</i> showed WT-like phenotypes under all controlled conditions tested, suggesting that it is merely required under specific conditions. Detailed analysis of photosynthetic parameter changes in response to rapid increments of light intensity indicated that all FLAP1, DLDG1 and TCR have important roles for photosynthetic control, although impacts of their regulatory activities vary depend on growth conditions. Next, genetics-based characterization of FLAP1 and DLDG1 were performed. I first isolated double mutants of <i>flap1</i> by crossing it with the <i>npq4</i> mutant lacking ΔpH-dependent NPQ, (qE, and with the <i>pgr5</i> mutant showing lowered qE and proton motive force (<i>pmf</i>) formation. Since <i>npq4flap1</i> and <i>npq4</i> shared similar NPQ-induction kinetics, FLAP1 was shown to strictly control qE. On the other hand, <i>flap1</i> null mutation could recover lowered luminal acidification caused by the <i>pgr5</i> mutation,

demonstrating that FLAP1 controls proton gradient (ΔpH) across the thylakoid membrane. Interestingly, *flap1* could partly complement the *pgr5* phenotypes that include fluctuating-light sensitivity, lowered PSII quantum yield, and elevated PSI acceptor side limitation, suggesting that the lowered *pmf* in *pgr5* were recovered in *pgr5flap1*. Overall, FLAP1 controls NPQ via regulating H^+ -homeostasis, especially during the steady-state of photosynthesis.

dldg1 mutant was crossed with the *hope2* possessing a missense mutation in the gene encoding the γ -subunit of the chloroplast ATP synthase, resulting in a higher proton conductivity (g_H^+) during ATP synthase. The isolated *dldg1hope2* double mutant showed chimeric visible-phenotypes; it showed *dldg1*-like pale-green leaves and *hope2*-like retarded growth. This result is in consistent with the fact that DLDG1 and chloroplast ATP synthase localize in different membrane systems, which are the chloroplast envelope and the thylakoid membranes, respectively. However, detailed characterization of photosynthetic activities of *dldg1hope2* revealed the functional interaction between DLDG1 and chloroplast ATP synthase. Specially, *hope2* mutation could suppress qE component in a *dldg1* mutation background, indicating that DLDG1 can control NPQ induction through regulating the g_H^+ at the chloroplast ATP synthase.

TCR is specifically conserved in oxygenic phototrophs including algae and higher plants, and contains a unique triplex-cysteine-motif (CxxxCxxx) at the C-terminus, implying its regulatory function for photosynthetic electron transfer. Biochemical characterization of TCR recombinant protein indicated that TCR is a redox active iron-sulfur ([3Fe-4S] or [4Fe-4S]) binding protein, which could be reduced by ferredoxin, and oxidized by O_2 *in vitro*. Histochemical expression assay indicated that TCR is expressed in green tissues including cotyledons, mature leaves and other green tissues. GFP signals could be detected specifically in chloroplasts in plants expressing the recombinant TCR-GFP gene, suggesting that TCR functions in chloroplasts. Immunoblotting analysis indicated that TCR is a soluble protein, some of which associates with the thylakoid membranes. *tcr* mutant showed WT-like phenotype under normal growth conditions, but it showed growth retardation and increased accumulation of anthocyanin under fluctuating-light and/or intense-light conditions. Photosynthetic measurements showed that *tcr* mutation influenced on redox status of plastoquinone (PQ) pool(s) and oxidation levels of P700. Besides, *tcr* shared similarity in its photosynthetic activities with those of *ndho*, a null mutant of the NDH-complex, and *pgr5tcr* showed retarded growth like a double mutant lacking the NDH-complex and PGR5. Given that both NDH-complex and PGR5 are indispensable components of the cyclic electron transfer from the photosystem I acceptor side to the PQ pool, TCR may be an electron carrier involved in an alternative electron flow around photosystem I.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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