Revealing photosynthetic regulatory paradigms using natural variations and massive field measurements

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Photosynthetic organisms must tightly regulate their (often competing) needs for efficient collection of solar energy with the avoidance of toxic side products that can be produced by the photosynthetic machinery when energy input and use is unbalanced. To test these modes of regulation under real world conditions, we developed a series of phenotyping platforms that aim to bring the lab to the field (PhotosynQ.org) and the field to the lab (Dynamic Environmental Phenotype Imagers). For example, it was recently proposed that photosynthetic efficiency is limited by the slow rate of onset and decay of photoprotective nonphotochemical quenching (NPQ). Combining results from over 1M PhotosynQ experiments and over 5M DEPI data sets led us to a similar conclusion but for very different reasons. We found that photosynthesis is often strongly limited by the effects of the thylakoid electric field ($\Delta\psi$) that is generated during the initial events of photosynthesis, particularly under rapidly fluctuating light conditions, and results in a process that we call Field Recombination Induced Photodamage (FRIP), where large "spikes" in $\Delta\psi$ induce photosystem II recombination reactions that produce damaging singlet oxygen ($^1O_2$). We also show that FRIP is directly linked to the thylakoid proton motive force (*pmf*), and in particular the slow kinetics of partitioning *pmf* into its ΔpH and $\Delta\psi$ components that in turn are controlled by transmembrane ion movements. We then explored the possibilities and pitfalls of efforts to improve plant productivity by modifying this process. Finally, I will describe how community-based platforms, such as PhotosynQ.org can enable scientific data gathering and analyses to assess the limitations and modes of regulation of photosynthesis in different species and environments.