Unique Contributions of Chlorophyll and Nitrogen to Predict Crop Photosynthetic Capacity from Leaf Spectroscopy

Objective
The positive relationship between crop yield and CO₂-saturated photosynthetic rate ($V_{\text{max}}$) makes maximizing $V_{\text{max}}$ and its related traits, Chl and $N_{\text{mass}}$ (chlorophyll and nitrogen), an important management and engineering target for bioenergy crops. Spectroscopic methods have great potential for high-throughput trait measurement, but it is unclear which methods among radiative transfer modeling (RTM), partial-least squares regression (PLSR), and generalized PLSR (gPLSR) perform best. To address this issue, researchers in this study evaluated spectra-based methods for estimating $V_{\text{max}}$, Chl, and $N_{\text{mass}}$ and sought to understand the relationships among these traits.

Approach
- Conducted field and laboratory experiments to measure leaf spectra and traits in maize
- Comprehensively evaluated RTM, PLSR and gPLSR for estimating Chl, $N_{\text{mass}}$, and $V_{\text{max}}$ from spectra
- Performed RTM and PLSR-based spectral contributions to analyze the linkage of Chl, $N_{\text{mass}}$, and $V_{\text{max}}$
- Compared leaf trait-based regression models to predict $V_{\text{max}}$

Results
- Leaf RTMs considering bidirectional effects gave accurate estimates of Chl, while gPLSR had an added value to predict $N_{\text{mass}}$.
- When field measurements were used for model training, PLSR achieved the best $V_{\text{max}}$ prediction.
- Chl and $N_{\text{mass}}$ made complementary contributions to the prediction of $V_{\text{max}}$ and their combined use significantly improved $V_{\text{max}}$ prediction over the use of either one individually.

Significance
Results of this study may be used to improve $V_{\text{max}}$ prediction by incorporating both Chl and $N_{\text{mass}}$ data across leaf and canopy scales. This strategy can be applied to other bioenergy crops and could improve crop yield and carbon cycling predictions in ecosystem-scale models of bioenergy cropping systems.