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A New Tool for Sensitive Detection of Phosphorus Deficiency in Plants under Field Conditions

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Summary

- Phosphorus (P) deficiency is a global challenge to agriculture.
- Reliable tools to predict the requirement for P fertilization are currently lacking.
- We show that even mild and latent P deficiency can be detected using chlorophyll *a* fluorescence, and it is possible to quantify the P concentration in crops using the fluorescence transients.
- We have developed a new handheld device to detect P deficiency directly in the field, and it is accompanied with a smart phone based app to record GPS coordinates and store data.

Evaluating P status

Estimation of crop P requirement by classic soil analysis is usually very unreliable, and it can be very difficult to visually diagnose P deficiency under field conditions **(Figure 1)**.

Figure 1: Control and P-deficient barley plant cultivated in hydroponics. It is very difficult to visual distinguish between the two treatments[1].

Results: Chlorophyll *a* fluorescence reveals P deficiency

Chlorophyll *a* fluorescence is known to reflect the status of the photosynthetic electron transport chain. Phosphorus deficiency will acidify the chloroplast interior, which reduces the ability of PQH_2 to pass on electrons, thereby altering the flow of electrons between the two photosystems. This response is revealed by the so-called I-step of the OJIP transient **(Figure 2)**.

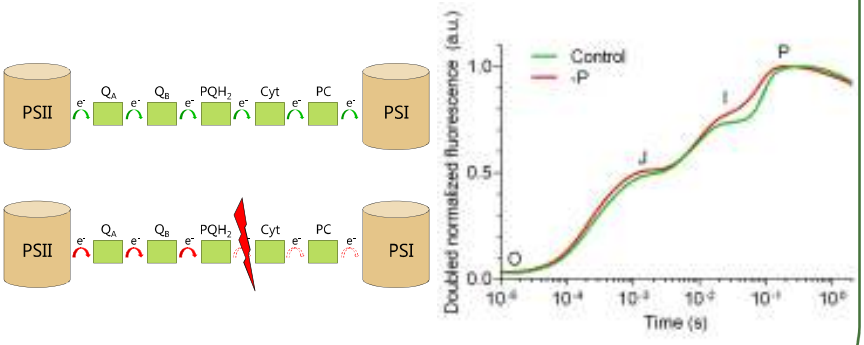

Figure 2: Phosphorus deficiency is revealed on 21-day old barley plants by measuring chlorophyll *a* fluorescence. Low P-availability will decrease the ability of PQH_2 to pass on electrons towards PSI. The transients are averaged (n=20) and double normalized[1].

Results: Quantification of P content

Based on the specific changes of the OJIP transient, a mathematical model has been developed, which is able to estimate the current P status of plants **(Figure 3)**.

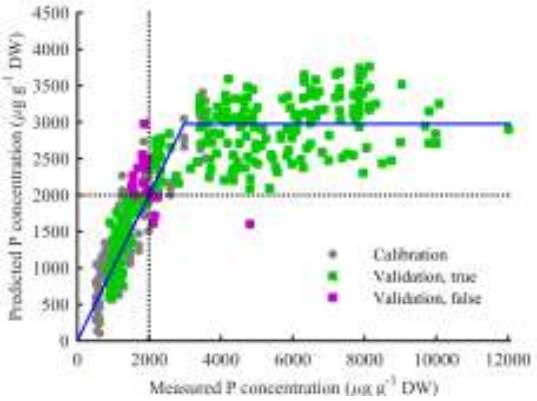

Figure 3: Predicted versus measured P concentrations for 448 OJIP transients. The two dotted lines indicate the P sufficiency level at 2,000 μg g^{-1} dry weight[1].

The new P-tester

A new P-tester has been developed using OJIP transients, which estimates the current P status of plants by simple measurements performed in the field. The measurements are instantaneously transferred to your smartphone, matching them with GPS coordinates, and uploaded "to the cloud" for easy data access at all times. The P status is immediately returned, indicating if actions should be made to avoid a potential yield loss **(Figure 4)**.

Figure 4: With the new device, the estimated P concentration is immediately present on your phone, allowing day-to-day decision making.

Materials and methods

Barley (*Hordeum vulgare*) and tomato (*Solanum lycopersicum*) was cultivated at different P availabilities. Chlorophyll *a* fluorescence was measured using a handheld fluorescence meter (SpectraCrop IVS, Denmark) and the reference leaf concentration was determined by ICP-OES. A chemometric PLS model was developed for prediction of P concentrations. In addition, experiments have been performed in low-P soils to test the method under conditions naturally occurring in agricultural fields.

Conclusions and outlook

- It is possible to quantify the P concentration in plants and reveal latent P deficiency at an early stage using chlorophyll *a* fluorescence.
- With the new P-tester, it is possible to detect P deficiency much earlier and much more accurately than previously.
- By this approach, fertilization can be optimized to match the actual plant need, which will significantly benefit both the farmer and the environment.

[1] *Frydenvang et al. (2015): Sensitive detection of phosphorus deficiency in plants using chlorophyll a fluorescence. Plant physiology, Breakthrough Technologies, 169:353-361.*
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