Impact of *Phakopsora pachyrhizi* Infection on Soybean Leaf Photosynthesis and Radiation Absorption

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INTRODUCTION

Soybean rust (SBR), caused by *Phakospora pachyrhizi*, is a disease known to have a large impact on soybeans and can cause yield losses of up to 80% (Hartman, 1991).

Yield loss in soybean due to SBR has been associated with reduced radiation interception and reduced radiation use efficiency (RUE) of even the non-lesioned green leaf area of diseased plants (Kumudini, 2008). This reduction in RUE suggests that the pathogen reduced the photosynthetic capacity of the leaf in excess of that which can be accounted for by the reduction in green leaf area due to the disease lesions.

The effects of the disease on radiation absorption by the leaf were not measured simultaneously with photosynthetic rates to distinguish between the reduction in radiation absorption and the reduction in photochemistry on the photosynthetic efficiency of diseased leaves.

OBJECTIVES

The objective of this study was to determine the mechanisms involved in the SBR-induced reductions in radiation use efficiency by quantifying the effect of SBR on:

1) absorption of photosynthetic photon flux density (PPFD)
2) carbon exchange rate (CER) per unit absorbed PPFD
3) light and dark-adapted chlorophyll fluorescence in healthy and SBR-infected leaves.

MATERIALS AND METHODS

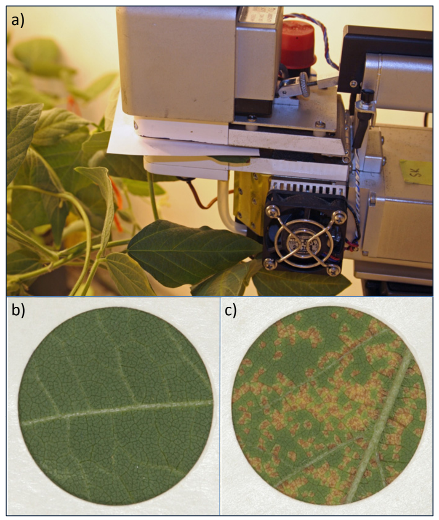

Fig. 1. a) Measurement of net CER using the LI-6400 system, fitted with the fluorometer chamber; b) Image of control soybean leaflet selection delineated with a template; c) Image of SBR infected leaflet selection delineated with a template.

A controlled-environment study was conducted using a randomized complete block design with treatments arranged as split-plots with three replications over time. The main plots were two inoculum rate (high versus zero) and subplots were two commercial soybean cultivars Asgrow 3905 and Delta and Pine 4331 RR .

Inoculation: **SBR urediniospores were harvested dry (Fig.2) and diluted 1:1 with talc. The top three fully expanded leaves were tagged and sprayed with sterile, deionized, and carbon filtered water water and the spore/talc mixture was dispersed over them using a fine spore distributor. Control plants were inoculated only with talc powder.**

Measurements: **All measurements began once diseased plants sporulated (11 days after inoculation), and continued until 23 days after inoculation.**

CER and Fluorescence Measurements: **At each assessment date measurements were taken using an portable photosynthesis system (Fig.1,a), in control (Fig.1,b) and diseased (Fig. 1,c) leaves. Leaf section measured by the chamber was delineated by placing a template to mark the location (Fig.1, b and c) and all other assessments were performed on the same location.**

Predawn, dark-adapted minimum (F_o) and maximum fluorescence (F_m), and respiration were measured.

Variable fluorescence (F_v): $F_v = F_m - F_o$.

***Electron transport rate (ETR)*:**

$$ETR = \Phi PSII\ f\ PPFD\ \alpha_{leaf},$$

where *f* is the fraction of absorbed quanta that is used by photosystem II (*PSII*) and ΦPSII is the quantum yield of photochemistry of *PSII*.

Fig. 2. Harvesting spores from SBR infected leaves by suctioning the leaf surfaces using a cyclone minispore collector, one day prior to inoculation.

Leaf Absorptance (α_{leaf}): **It was measured with a spectrometer and calculated:**

$$\alpha_{leaf}(\%) = 100 - \text{transmittance} - \text{reflectance}$$

SPAD Readings: **average of 20 SPAD readings per sample was recorded**

Disease Severity Assessment: **The abaxial surface of the leaf was photographed (Fig.1, b and c) and the digital images were processed using "Image J" software.**

Chlorophyll : **Chlorophyll extraction was performed as described by Inskeep and Bloom (1985).**

Reference: Hartman, G.L. 1991. Soybean rust development and the quantitative relationship between rust severity and soybean yield. Plant Dis. 75:596–600.
Inskeep, W.P., and P.R. Bloom. 1985. Extinction coeffi cients ofchlorophyll a and b in N,N-dimethylformamide and 80% acetone. Plant Physiol. 7:483–485.
Kumudini, S. 2008. Mechanisms involved in soybean rust-induced yield reduction. Crop Sci. 48: 2334–2342

For more information and updates about the yield loss prediction model for Soybean Rust please visit: http://www.uky.edu/Ag/Agronomy/Department/sbr/

RESULTS

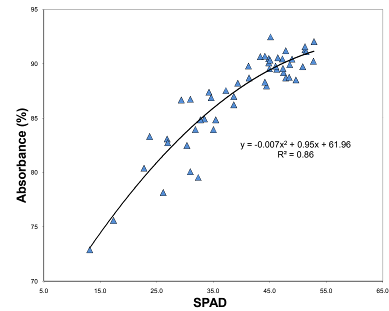

Fig. 3. Relationship between PPFD absorptance and SPAD of healthy and infected soybean leaves of two genotypes.

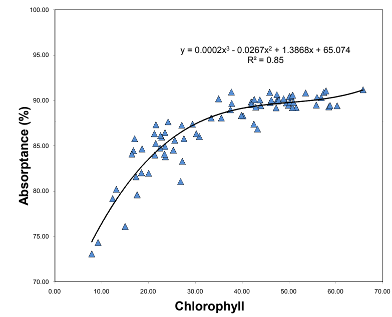

Fig. 4. Leaf absorptance vs. chlorophyll content of healthy and soybean rust–infected leaves of two soybean genotypes

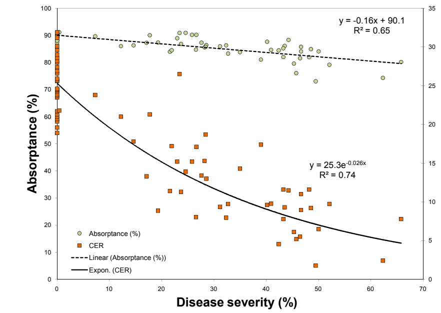

Fig. 5. Relationship between disease severity and PPFD absorptance and CER of healthy and soybean rust–infected leaves of two soybean genotypes.

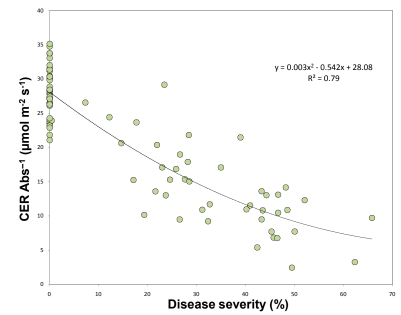

Fig. 6. Relationship between disease severity and CER per unit absorbed PPFD (CER Abs^{-1}) of healthy and soybean rust–infected leaves of two soybean genotypes.

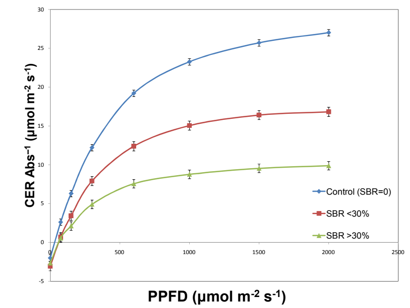

Fig. 7. CER–PPFD response curves of healthy and soybean rust–infected (with either <30 or >30% disease severity) leaves of two soybean genotypes. Bars represent means ± SE.

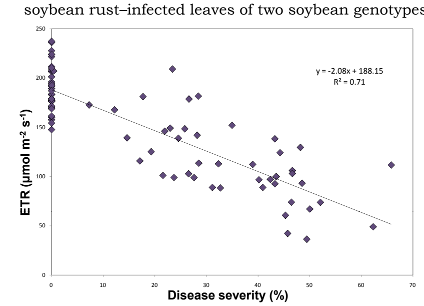

Fig. 8. Relationship between disease severity and ETR of healthy and soybean rust–infected leaves of two soybean genotypes
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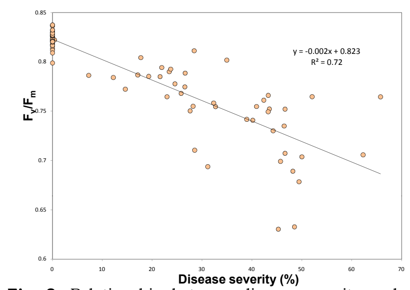

Fig. 9. Relationship between disease severity and dark-adapted chlorophyll fluorescence (F_v/F_m) of healthy and soybean rust–infected leaves of two soybean genotypes.

CONCLUSION

Results showed that SBR caused the loss of leaf chlorophyll content, which reduced the ability of the soybean leaf to absorb radiant energy and photosynthesize. Although the disease resulted in a small decline in PPFD absorptance, most of the reduction in leaf photosynthesis was attributable to the reduction in the CER per unit absorbed PPFD. SBR reduced CER Abs^{-1} likewise under both low and high PPFD levels. The decline in CER Abs^{-1} due to disease was associated with a reduction in the efficiency of ETR and with damage to the PSII reaction centers, as indicated by the decline in dark-adapted fluorescence. One of the implications of this study is that the impact of the disease on the plant's primary productivity is greater than the proportion of the leaf covered with visual lesions. Consequently, control of the disease to protect yield should occur before visual damage is substantial.