The influence of genetic variation in disease susceptibility on the photosynthetic competence of soybean rust infected leaves

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INTRODUCTION

Soybean rust (SBR) caused by the fungus *Phakopsora pachyrhizi* Syd. is a serious threat to soybean production in a number of countries worldwide. In the United States, SBR epidemics have generally developed late in the growing season and it may not always be practical to spray fungicides. Therefore, a yield loss model that can predict expected yield losses and can serve as useful decision aid tool for managing SBR is needed.

SBR-induced yield loss was associated with reduction in green leaf area duration as well as reduced canopy-level radiation use efficiency (1). This suggests that yield loss due to SBR must take into consideration the impact of the disease on the plant's photosynthetic capacity. Bastiaans, 1991 (2) proposed the calculation of a "virtual lesion" as a means of quantifying the effect of disease on leaf photosynthesis. Bastiaans related the net photosynthetic rate of a diseased leaf (Px) to that of a healthy leaf (Po) as:

$$Px = Po\,(1-x)^{\beta}$$

where x is the proportion of the leaf area covered by visible lesions and β is defined as the ratio between the sizes of the "virtual" and the "visual" lesions. The value of β indicates whether the effect of disease on photosynthesis is higher (β >1), lower (β <1) or equal (β=1) to that accounted for by the visual lesion area.

Host-plant genetic variations in SBR disease resistance have been identified. In order to develop a yield loss prediction tool for both susceptible and resistant genotypes, it would be necessary to know the impact of resistance genes on the leaf photosynthetic potential of diseased leaves. Incorporation of genetic variation on the photosynthetic competence of diseased leaves may improve the accuracy and precision of yield loss models.

OBJECTIVES

The objectives of this study were:
(1) To quantify the impact of SBR on photosynthetic capacity
(2) To determine the influence of host plant genetic resistance on the photosynthetic competence of SBR infected leaves.

MATERIALS AND METHODS

Controlled-environment experiments:

All experiments were randomized complete block designs with split plot treatment arrangement. The main plots were two inoculum rates (high and zero).

Split plots were variation in plant genetics:

Experiment 1 (Exp.1): included resistant recombinant inbred lines (RIL) PR 68 (Fig. 1b) and susceptible RIL PR 111 (Fig. 1c), and commercial cultivar Asgrow 3905.

Experiment 2 (Exp.2): included two commercial soybean lines Asgrow 3905 and Delta Pine 4331 RR.

Experiment 3 (Exp.3): included PR 68 and PR 111 RILs.

Inoculation: SBR urediniospores were harvested dry one day prior to inoculation, weighed, divided according to the number of inoculation treatment pots, and diluted 1:1 with talc. The top three fully expanded leaves were tagged and sprayed with sterile, deionized, and carbon filtered water and the spore/talc mixture was dispersed over them using a fine spore distributor (Fig. 1a). Control plants were inoculated only with talc powder.

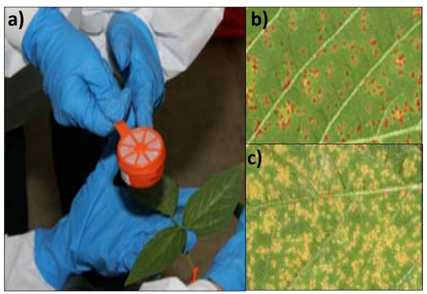

Figure 1:
(a) Inoculation of plant in controlled-environment experiment with SBR. Tagged leaves were sprayed with sterile, deionized, and carbon filtered water and a spore/talc mixture was dispersed over the leaves using a fine spore distributor.
(b) Image of soybean leaflet of resistant PR 68 RIL two weeks after inoculation.
(c) Image of soybean leaflet of susceptible PR111 RIL two weeks after inoculation.

Field experiment

A randomized complete block design with determinate cultivar "BRS 154" and treatments were number of applications of fungicide (zero, one and two) of 100 g a.i. ha^{-1} Tebuconazol.

Measurements:

Carbon exchange rate (CER): At each assessment date, CER measurements were taken on control and diseased leaves with portable photosynthesis system (Fig.2). The leaf section on which the measurements were performed was delineated with a permanent marker (Fig. 2) and all other assessments were performed at the same location.

Disease severity: The delineated area was photographed with a digital camera. Digital images were analyzed with software SIARCS 3.0 (EMBRAPA, Brazil) or Image J and disease severity was quantified as the proportion of the tagged leaf area visibly affected by SBR.

References: 1) Kumudini, 2008. Mechanisms involved in soybean rust induced yield reduction. Crop Sci. 48:2334-2342.
2) Bastiaans, 1991. Ratio between virtual and visual lesion size as a measure to describe reduction in leaf photosynthesis of rice due to leaf blast. Phytopathology 81:611-615
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 AND DISCUSSION

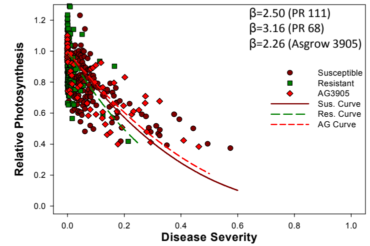

Figure 3: Relative photosynthesis vs. disease severity for resistant (PR68) and susceptible (PR111) RILs and "Asgrow 3905" in Exp. 1. No significant genotype effect for β coefficient values (p >0.30).

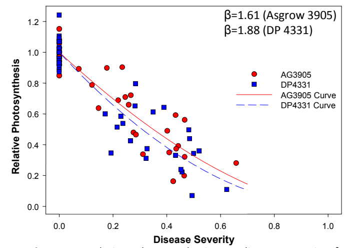

Figure 4: Relative photosynthesis vs. disease severity for "Asgrow 3905" and "Delta and Pine 4331 RR" in Exp. 2. No significant genotype effect for β coefficient values (p >0.26)

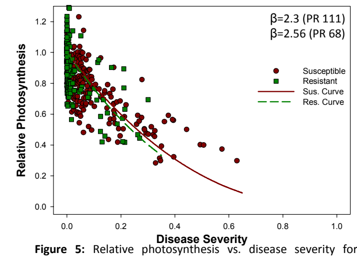

Figure 5: Relative photosynthesis vs. disease severity for resistant (PR68) and susceptible (PR111) RILs averaged across Exp. 1 and 3. No significant genotype effect for β coefficient values (p >0.20).

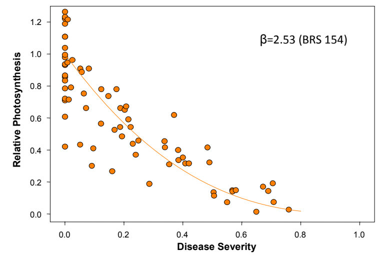

Figure 6: Relative photosynthesis vs. disease severity of a field-grown soybean cultivar, "BRS 154" in Brazil.

Genotype	Controlled-environment experiments			Field experiment
	Experiment 1	Experiment 2	Experiment 3	Experiment 4
	Disease severity (%)			
PR 111	8.1 ± 0.84		26.8 ± 2.42	
PR68	4.9 ± 0.84		15.5 ± 2.42	
Asgrow 3905	12.7 ± 2.32	32.4 ± 3.03		
DP 4331 RR		36.2 ± 3.03		
BRS 154				29.8 ± 4.9

Table 1: Disease severity (%) of soybean genotypes grown in three controlled-environment and one field experiments. Disease severity means are presented as percentage ± SE

Figure 2: Measurement of net carbon exchange rate using the LI-6400 system under field conditions (Londrina, Brazil) and tagging the location on which measurement was performed with permanent marker.

The four experiments conducted during the course of this study resulted in wide variation in SBR severity (Table 1). In response to the disease all susceptible genotypes, both commercial cultivars and the RIL PR111 (Fig.1,c), formed tan lesions that sporulated 10 to 11 days after inoculation. The RIL PR68, which contains a resistance gene from Hyuuga, formed red-brown lesions that did not produce urediniospores (Fig.1,b) and had significantly lower disease severity (Table 1) .

The impact of SBR on relative leaf photosynthesis of soybean genotypes was measured and the β coefficients calculated. The model proposed by Bastiaans (2) provided a good fit to the data in each of the four experiments (p< 0.0001). The mean β coefficient of soybean genotypes grown under controlled-environment and fungicide-free conditions ranged from 1.7 to 2.4. The leaf photosynthetic capacity of the commercial cultivar and the RILs tested in Exp. 1 were similarly affected by SBR as quantified by their respective calculated β coefficient values (Fig. 3). The impact of SBR on relative photosynthesis was the same for both commercial soybean cultivars (Fig. 4), as well as for resistant and susceptible RILs (Fig. 5). Therefore the impact of the disease on relative photosynthesis was consistent irrespective of whether the host-plant was a RIL or a commercial cultivar. Although no direct comparison was made in the current study, the calculated β coefficients of controlled-environment grown plants generally lay within the confidence limits of the β coefficient (2.09-2.98) of a field-grown soybean genotype (Fig. 6) that had varying number of fungicide applications.

CONCLUSION

Using the model proposed by Bastiaans demonstrated that the impact of SBR on photosynthesis was greater than that which can be accounted for by the visual lesion alone (β >1). Host plant genetic resistance did not reduce the negative impact of SBR on leaf photosynthetic competence. Although the resistant RIL may not offer protection from the negative impact of SBR on leaf photosynthetic competence, the reduction in disease severity and the lack of sporulation in those genotypes will likely minimize the impact of the disease on canopy photosynthesis and soybean yield.

The β coefficient values calculated can be used to determine the actual "effective" leaf area that is producing assimilates for yield development, and thus may prove useful in modeling SBR-induced yield loss.