The role of variation in genetic susceptibility to soybean rust on the photosynthetic competence of infected leaves

Elena Prior[1], Brenda Kennedy[1], Don Hershman[1], Cláudia Godoy[2], Joe Omielan[1] and Saratha Kumudini[1]

[1] UK University of Kentucky [2] Embrapa

INTRODUCTION

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 a useful decision aid tool for managing SBR is needed. In order to develop such a model we need to understand the mechanisms involved in SBR induced photosynthesis and yield reductions. Kumudini et al., (3) reported that yield loss in soybean due to SBR has been associated with reduced light interception and radiation use efficiency (RUE) of even the non-lesioned green leaf area of diseased plants. 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 (1) proposed the calculation of a "virtual lesion" as a means of quantifying the effect of disease on leaf photosynthesis by relating 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 visible disease severity and β is defined as the ratio between the "virtual" and the "visual" lesions. The value of β indicates whether the effect of disease on photosynthesis is higher ($\beta > 1$), lower ($\beta < 1$) or equal ($\beta = 1$) to that accounted for by the visual lesion area. In order to incorporate the effect of disease on photosynthesis into a yield loss model Jesus Junior et al., (2) used a β-value as a tool in a calculation of effective leaf area index (ELAI):

$$ELAI = LAI(1-x)^{\beta},$$

where LAI is leaf area index. ELAI takes all three factors that affect SBR-induced yield loss into consideration and indicates the area of the leaf that is producing assimilates for yield development.

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

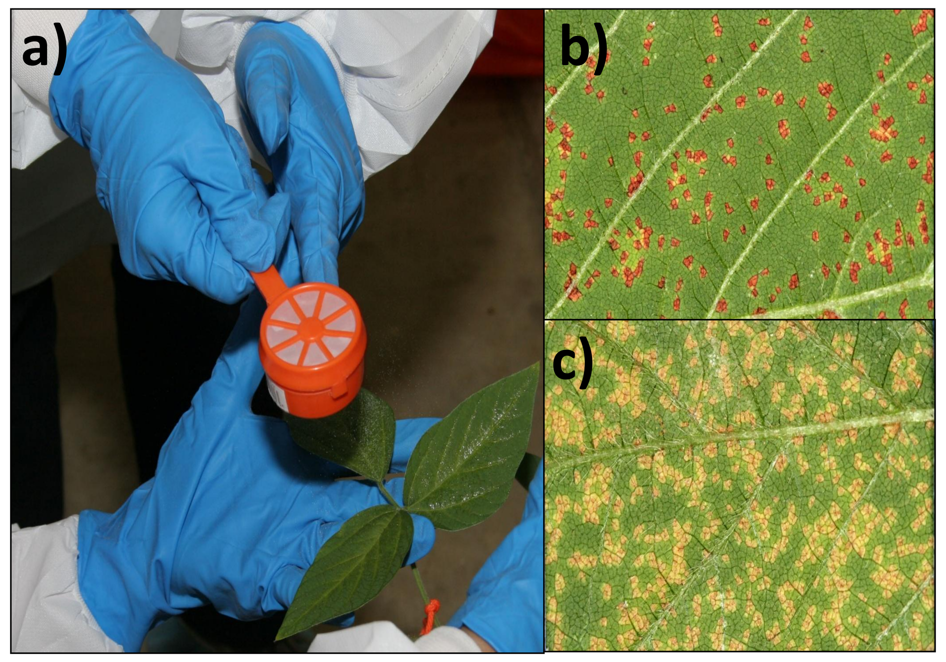

Figure 1:
(a) Inoculation of plant in controlled-environment experiment with SBR. Tagged leaves were sprayed with sterile, deionized, and carbon filtered water and a spore/talc mixture was dispersed over the leaves using a fine spore distributor.
(b) Image of soybean leaflet of resistant RIL PR 68 two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

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.

Field experiment (Exp.4)

Field experiment was conducted in Brazil. Design was a randomized complete block 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.

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.

Reference: 1) Bastiaans, L. 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 ; **2)** Jesus Junior, W.C., F.X.R. do Vale, R.R. Coelho, B. Hau, L. Zambolim, LC. Costa, and A. Bergamin Filho. 2001. Effects of Angular Spot and Rust on Yield Loss of *Phaseolus vulgaris*. Phytopath. 91:1045-1053; **3)** Kumudini, S., C.V. Godoy, J.E. Board, J. Omielan, and M. Tollenaar. 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 AND DISCUSSION

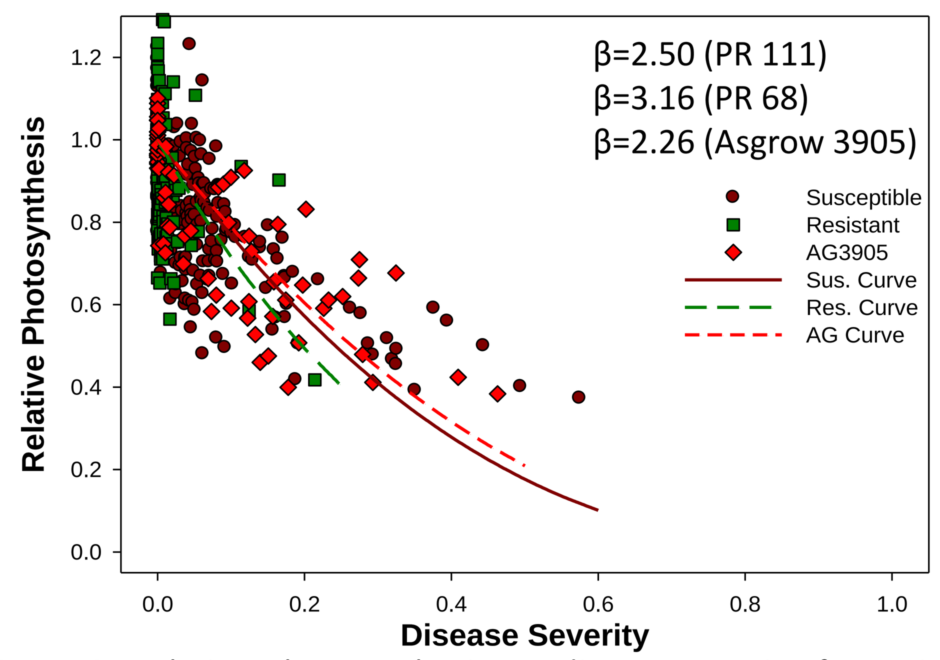

Figure 3: Relative photosynthesis vs. disease severity for resistant (PR68) and susceptible (PR111) RILs and "Asgrow 3905" in Exp. 1. No significant genotype effect for β coefficient values ($p > 0.30$).

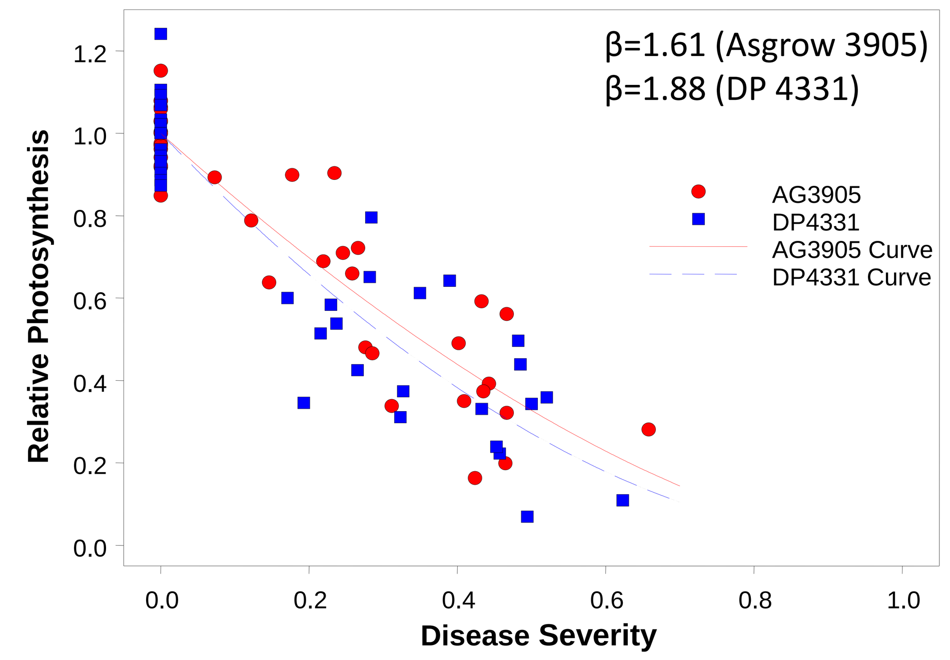

Figure 4: Relative photosynthesis vs. disease severity for "Asgrow 3905" and "Delta and Pine 4331 RR" in Exp. 2. No significant genotype effect for β coefficient values ($p > 0.26$)

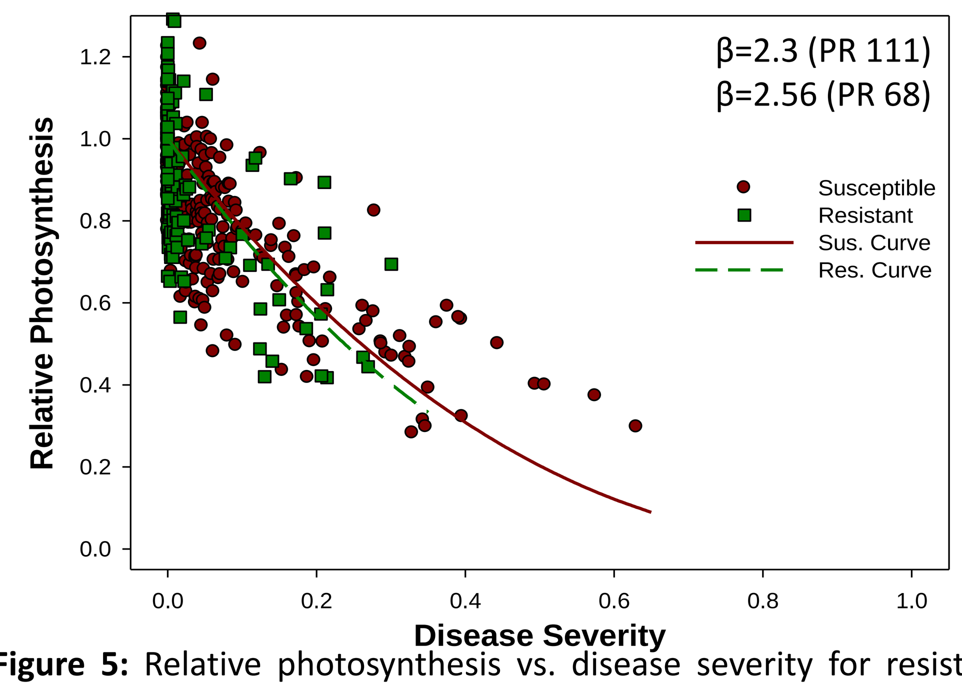

Figure 5: Relative photosynthesis vs. disease severity for resistant (PR68) and susceptible (PR111) RILs averaged across Exp. 1 and 3. No significant genotype effect for β coefficient values ($p > 0.20$).

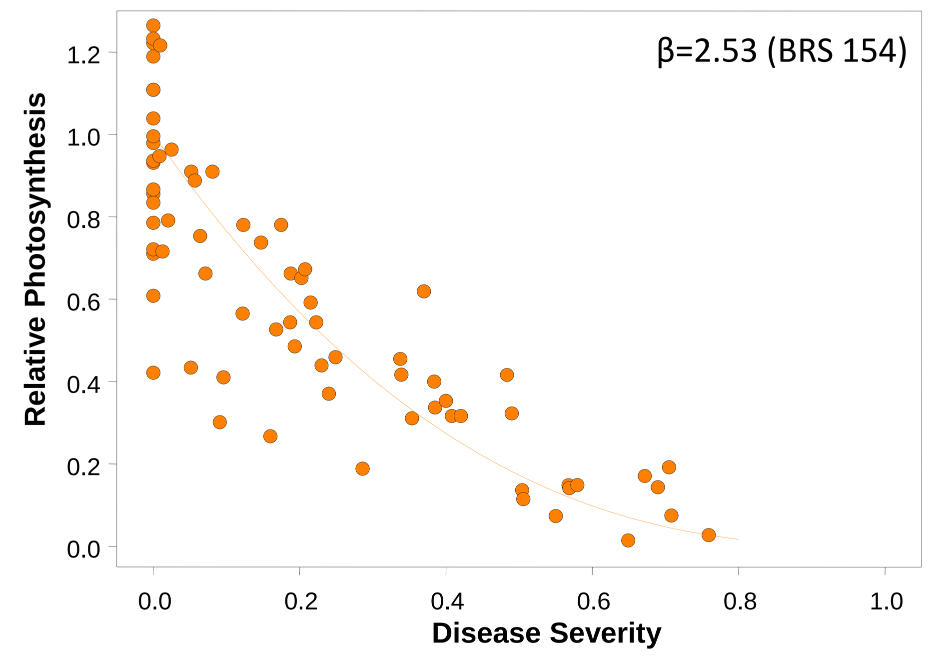

Figure 6: Relative photosynthesis vs. disease severity of a field-grown soybean cultivar, "BRS 154" in Brazil.

Genotype	Controlled-environment experiments			Field experiment
	Exp.1	Exp. 2	Exp. 3	Exp. 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

Exp. No. and Growing conditions	No. of observations	Soybean genotype	Maximum disease severity (%)	Lesion stage	β	Confidence limits of β	
						Upper	Lower
Exp. 1 Chamber	432	RILs and commercial	58	Post-sporulation	2.4	2.16	2.73
Exp. 2 Chamber	78	Commercial	66	Post-sporulation	1.7	1.5	1.99
Exp. 3 Chamber	67	RILs	63	Post-sporulation	2.1	1.76	2.51
Exp. 4 Field	73	Commercial	76	Pre- and post-sporulation	2.5	2.09	2.98
Combined	870	RILs and commercial	76	Pre- and post-sporulation	2.4	2.52	2.20

Table 2: Number of observations and effects of growing conditions, soybean genotype, and lesion stage on maximum disease severity and β value for the individual experiments as well as combined across all experiments

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 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 (Table 2) 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 ($\beta > 1$). 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 value of 2.4 can be used to determine the actual effective leaf area and thus may prove useful in modeling SBR-induced yield loss.