The Impact of Soybean Rust on Leaf Photosynthetic Rate: The Role of Lesion Age and Resistance Genes.

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INTRODUCTION

Asian soybean rust (ASR) is a serious disease caused by the fungus *Phakopsora pachyrhizi*. Soybean genotypes with variation in sensitivity to ASR have been developed, and recombinant inbred lines (RIL) with variation in sensitivity to this disease are available. One such set of RILs has sensitive lines which form tan, sporulating lesions (Fig.1a). Lines that are resistant form red-brown, non-sporulating lesions (Fig.1b) in response to ASR infection (Boerma, 2007).

The resistant lines form fewer disease lesions. This response may be important because disease lesions reduce the ability of the leaf to absorb radiant energy, necessary for photosynthesis. Therefore, resistant lines may lower the impact of ASR on leaf photosynthesis. Since the resistant lines also do not sporulate, it is possible that as the lesions on the sensitive lines begin to sporulate, the difference between resistant and susceptible genotypes in the reduction of photosynthesis due to ASR, will increase.

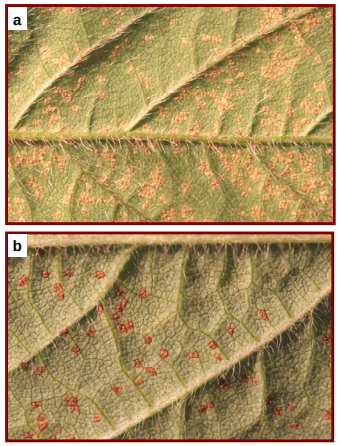

Fig 1. Images of soybean leaflets of (a) susceptible PR111, and (b) resistant PR 68 RILs, taken two weeks after inoculation with ASR. Note: sporulation in the susceptible genotype

OBJECTIVES

The objective of the current study was to determine the impact of Asian soybean rust on leaf production potential based on 1) lesion age and 2) plant resistance.

MATERIALS AND METHODS

Experiments were conducted in a controlled environment chamber.

Experiment 1: randomized split-split block experiment with four replications, two genotypes and two stages of disease development:

1) Plant genotype (resistant RIL PR 68 and susceptible RIL PR 111)
2) Inoculum level (zero versus high)
3) Lesion age (pre and post-sporulation)

Experiment 2: completely randomized design with two genotypes (PR111 and Asgrow 3905, both susceptible) and two levels of inoculum (zero versus high). Measurements were taken post-sporulation.

Fig. 2: Inoculation with ASR. Plants were sprayed with Nanopure water and a spore/talc mixture was dispersed over the leaves using a fine spore distributor.

Fig. 3: Measurement of net carbon exchange rate using the LI-6400 system, mounted with a red/blue LED light source (set at 1500 µmol s^{-1} m^{-2}).

Inoculation: ASR urediniospores were harvested, using a mini-spore cyclone collector, from previously infected plants, one day prior to inoculation and mixed with talc in a 3:2 ratio by weight. The top three fully expanded leaves were sprayed with Nanopure water and the spore/talc mixture was dispersed over them using a fine spore distributor (Fig.2). Control plants were inoculated only with talc powder. Immediately after inoculation all plants were placed in dew chamber for 24 hours. This inoculation method resulted in a wide range of disease severity.

Measurements:

Carbon exchange rate (CER): CER was measured with a LI-Cor LI-6400 (Fig.3). CER measurements were made: **Pre-sporulation** (7 days after inoculation when first chlorotic spots appeared) as well as **Post-sporulation** (10 to 15 days after inoculation when more than 80% sporulating lesions were detected in RIL PR111 and Asgrow 3905). At each assessment date CER was measured on disease-free control and diseased leaves and the 2 x 3 cm leaf area on which this was performed was marked and backlit digital images were taken.

Disease severity: Image analysis software SIARCS 3.0 (EMBRAPA, Brazil) was used to quantify disease severity as the proportion of the marked leaf area visibly affected by ASR.

RESULTS AND DISCUSSION

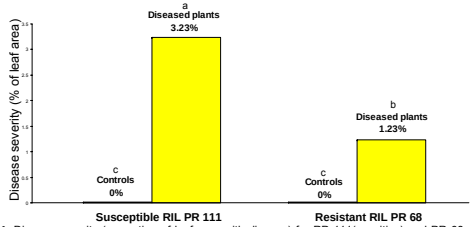

Fig. 4: Disease severity (proportion of leaf area with disease) for RP 111(sensitive) and PR 68 (resistant) RILs. Means are averages of both pre- and post-sporulation assessments for each RIL. The cultivar*treatment interactions were significant (P<0.0001).

Results of experiment 1 confirmed that the resistant genotype produces fewer lesions (as evidenced by reduced disease severity) than the susceptible genotype, irrespective of lesion age (Fig. 4).

Rust severity in PR111 ranged from 0 to 17.3% and in PR 68 was never greater than 16.4%. In both cultivars the majority of diseased leaves had low ASR severity which resulted in an average of 3.23% for PR 111 and 1.23% for PR 68.(Fig. 4).

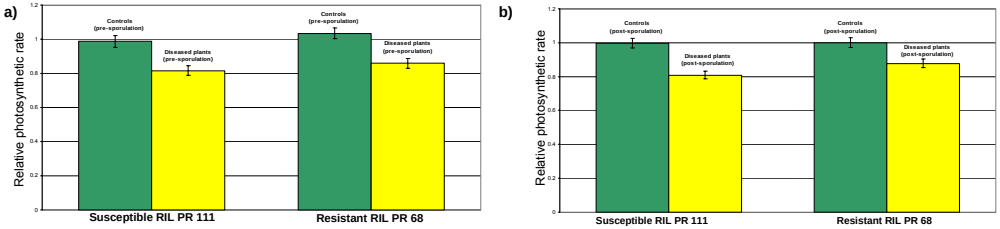

Fig.5: Relative photosynthesis (normalizing for the average of the disease-free control) of RP 111 and PR 68 RILs during the (a) pre-sporulating and (b) post-sporulating phases of lesion development.

Relative photosynthesis was significantly lower for the diseased leaves, irrespective of 'susceptibility' of the soybean genotype, disease level or lesion age (Figs. 5a and 5b).

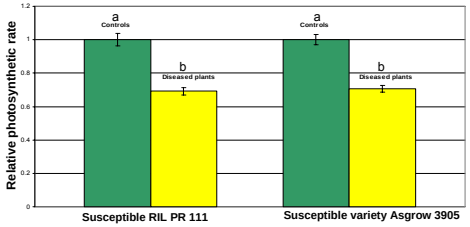

Fig. 6: Relative photosynthesis (normalized for disease-free control) of RIL RP 111 and Asgrow 3905 measurement of disease-free control and inoculated leaves. Means are averages of post-sporulation measurements.

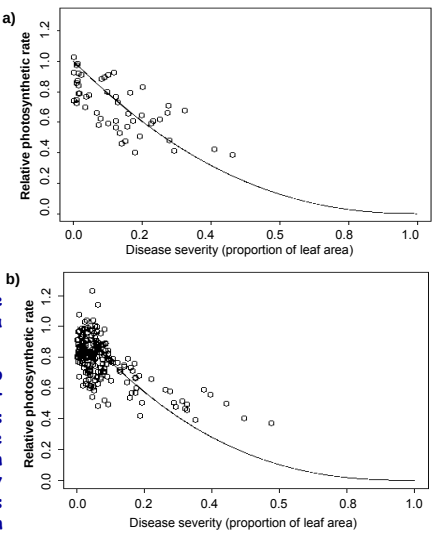

Fig. 7: Relative photosynthetic rate versus disease severity for Asgrow 3905 (a) and RIL PR 111 (b), measured 14 days after inoculation.

Results from experiment 2 show that the impact of the ASR on the susceptible RIL is equivalent to the impact on a commercial cultivar (Fig. 6).

If the impact of ASR on photosynthesis was equivalent to the reduction in leaf area available for absorption of light energy, then a linear decline in relative photosynthesis equivalent to the relative increase in disease severity would be observed. However, there was an exponential decline in relative photosynthesis due to the increase in disease severity suggesting that the decline in leaf photosynthesis extends beyond that which can attributed to reduced radiation absorption by the visible disease lesion (Fig.7a and Fig.7b).

CONCLUSION

Resistant genotype PR 68 had lower disease severity and did not produce sporulating lesions. However, leaf photosynthesis was substantially reduced by ASR in all genotypes tested; the resistant, and susceptible RILs as well as the commercial cultivar Asgrow 3905. The non-linearity of the decline in relative photosynthesis suggests that the decline in leaf photosynthesis appears to extend beyond that which can attributed to reduced radiation absorption by the visible disease lesion.

Reference: Boerma, H. R. 2007. Mapping and conformation of the 'Hyuuga' red-brown lesion resistance gene for Asian Soybean Rust. Crop Sci. 47:829-836