SOYBEAN RUST RESEARCH IN THE UNITED STATES

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Introduction

This paper provides an update and overview of some of the soybean rust (*Phakopsora pachyrhizi)* research activities in the United States. In 1995, soybean rust was reported in the U.S. in the state of Hawaii (Killgore and Heu, 1994). Soybean rust was not reported in another state until late in the fall season of 2004 in Louisiana (Schneider et al., 2005) after which it was reported in 13 other states (http://www.sbrusa.net/). The first report of the disease occurring on another host in the U.S. was on kudzu in Quincy, Florida in 2004 (Harmon et al., 2005). The introduction of the rust fungus into the continental U.S. was thought be carried via Hurricane Ivan that hit the U.S. mainland in September 2004 (http://www.ceal.psu.edu/ivan04.htm).

In 2005, the fungus was first reported in Florida (http://www.sbrusa.net/) where it was believed to survive the winter on kudzu that remained green below the frost line. At the end of 2005, rust was reported in nine states (Kentucky, North Carolina, and Texas were new reports). In 2006, the fungus was again first found in Florida and to date rust has been found in Alabama, Florida, Georgia, and Texas (http://www.sbrusa.net/).

Since the introduction of soybean rust in the U.S, there has been an increase of research activity. This started soon after the first report of rust in Hawaii. A soybean rust workshop was held in 1995 that brought together researchers in the U.S. who had experience with rust and laid the foundation for subsequent research direction for soybean rust research in the U.S. (Sinclair and Hartman, 1995). Before soybean rust hit the continental U.S., a review in 2003 outlined the importance of the disease and evaluated the risk of rust to the U.S. soybean crop (Miles et al., 2003a). The following sections summarize some of the research in the U.S. since 2004. This is not a comprehensive review, but rather highlights what has been published in three main areas of research that includes (i) pathogen biology, (ii) host resistance and (iii) fungicides.

Biology and Pathology of *P. Pachyrhizi*

Urediniospore survival. It is well known that fungal spores are particularly sensitive to ultraviolet (UV) wavelengths of solar radiation. In a study that was conducted jointly between scientists in the U.S and in Paraguay, urediniospores were exposed to natural sunlight for different durations (Isard et al., 2006). Measurements of total solar irradiance (0.285-2.8 µm) predicted spore germination as much as UV measurements (0.295-0.385 µm) Spores exposed to doses of solar (≥ 28 MJ m^{-2}) and UV radiation (≥1 MJ m^{-2}) did not germinate. The proportions of the spores that germinated were a linear function of solar irradiance (R^2 = 0.83). The relationship between spore viability and exposure to solar radiation is important to the soybean rust aerobiological model that provides North American soybean growers decision support for managing soybean rust (http://www.sbrusa.net/).

Evaluation of isolates. Except for USDA-ARS Fort Detrick containment facilities located at Frederick, Maryland (Bonde and Peterson, 1995), there has been little effort to compare a world collection of *P. pachyrhizi* isolates. One recent study (Bonde et al., 2006), compared the virulence of *P. pachyrhizi* isolates from Asia and Australia and *P. meibomiae* from Puerto Rico and Brazil, collected as much as 30 years earlier, with isolates of *P. pachyrhizi* from Africa or South America collected in 2001. In greenhouse tests, susceptible reactions to *P. pachyrhizi* generally resulted in tan-colored lesions containing 1 to 14 uredinia varying greatly in size within individual lesions. On these same genotypes, resistance was typified by 0 to 6 small uredinia in reddish-brown to dark-brown lesions. *P. meibomiae,* a less aggressive rust pathogen, produced reddish-brown to dark-brown lesions with 0 to 7 uredinia, regardless of soybean genotype. This kind of research explains the virulence diversity of this pathogen, and may explain the lack of resistant durability in soybean lines.

Telia. The life cycle of the pathogen is well documented (Bromfield, 1984). One of the questions in the U.S. was whether the fungus could produce telia. In the fall of 2005, telia were diagnosed based on visual observation followed by PCR confirmation on leaves of kudzu in central Florida (Harmon et al., 2006). Telia were noted as dark brown to black flecks on the abaxial leaf surface intermingled with abundant tan to light brown uredinia. From 200 leaflets, 143 or 72% had telia. The number of telia ranged from a few scattered telia per leaflet (1 per sq cm) to many (73 per sq cm). Telia were approximately the same diameter as uredinia but were appressed to the leaf surface and pigmented. The importance of telia, teliospores and basidia remains elusive since no alternate host has been found.

Host range. The host range of the soybean rust fungus is known to be broad (Sinclair and Hartman, 1995). Native legume species in the U.S. have not encountered *P. pachyrhizi*. Several studies were conducted in 2005 to evaluate the host range of the fungus. In the field (Quincy, Florida) leaves of *Phaseolus coccineus* (scarlet runner bean), *P. lunatus* (lima bean), and *P. vulgaris* (kidney bean) had rust lesions when grown adjacent to a rust-infected soybean field (Lynch et al., 2006). Uredinia counts ranged from 2 to 43 per 2-cm square area of leaf samples. Additional hosts are being evaluated under greenhouse containment facilities at Fort Detrick and under field conditions to determine what native legumes may be hosts for *P. pachyrhizi*.

Host Resistance

Soybean germplasm. Some of the early screening results and the genetics of resistance from previous decades were reviewed recently (Hartman et al., 2005). One of the recent objectives of the USDA-ARS research on soybean rust was to evaluate the USDA Soybean Germplasm Collection located at the University of Illinois. These soybean accessions were evaluated for resistance to *P. pachyrhizi* in the ARS Fort Detrick containment facilities. There were 3,512 out of 16,595 accessions screened that were selected for a second round of evaluation, and of those, 805 lines were selected as potential resistant sources for further evaluations (Miles et al., 2006). Some of these lines have been screened under field conditions in several locations, including in Attapulgus, Georgia in 2005 and Paraguay in 2006. There are further plans to test most of these lines at multiple locations in the U.S. during the 2006 summer season. In addition, a number of these lines have been crossed and being used for breeding, mapping, and genetic analysis.

Identification and development of resistance to soybean rust in Nigeria. In a cooperative project, selected accessions from the USDA Soybean Germplasm Collection and those from the International Tropical Research Institute were used to identify sources of resistance and find polymorphic markers between combinations of resistant and susceptible lines (Bandyopadhyay et al., 2006). To identify sources of resistance, field, screen house and laboratory environments were used to test more than 250 accessions. One line from the U.S. germplasm collection was most resistant showing only hypersensitive flecks without sporulation. Another U.S. line and a breeding line from Uganda had red brown resistant lesions. Several of these lines are being used in a crossing program to breed for rust resistance in Nigeria and to identify polymorphic markers between combinations of resistant and susceptible lines.

Evaluation of resistance to soybean rust in Vietnam. The USDA soybean germplasm collection as well as other germplasm was evaluated for resistance at the Vietnam Agriculture Science Institute (Vuong et al., 2005). Plants were inoculated at the V6 and R1 growth stages. Disease severity was assessed from growth stage R2 through R6. Several U.S. soybean plant introductions (PIs) had soybean rust assessments similar to the local resistant check in both net house and field evaluations. These PIs and local cultivars may serve as resistance sources for developing lines with soybean rust resistance in Vietnam and other locations.

Non-soybean. Some additional resistance sources have been identified in wild perennial relatives (Hartman et al., 1992). In more recent studies, intersubgeneric hybrids have been created between soybean and *G. tomentella*. Amphiploid hybrid lines (2n=118) were the result of this hybridization, and when tested at the ARS greenhouse containment facility at Ft. Detrick, MD, the amphiploid hybrid clones retained the resistance that had been found in the *G. tomentella* parent (Patzoldt et al., 2006). Re-instituting the backcross procedure, while testing for resistance at every generation, could move the resistance gene(s) from *G. tomentella* to cultivated soybean.

Fungicide Evaluations

Fungicide testing. Fungicide testing for control of soybean rust started in 2003 through a USDA program. The testing sites were located where rust was a problem including Paraguay, South Africa, and Zimbabwe. Early reports of fungicide efficacy was compiled in 2003 (Miles et al., 2003b). In addition to fungicide efficacy tests, fungicide application technology and timing of fungicides have been investigated both in the U.S. and in Paraguay.

Efficacy studies. These experiments were completed in Paraguay, South Africa and Zimbabwe from 2003 to 2006. The studies tested different fungicides using two and three applications. The first application started 50-69 days after planting (DAP), followed by a second application approximately 20 days after the first, and the third application approximately 20 days after the second. Results showed that almost all fungicides controlled rust compared to the non-fungicide treatment with yields often were greater in fungicide plots than non-fungicide plots (Miles et al., 2005a; Miles et al., 2005b; Miles et al., 2005c; Mueller et al., 2005a). In some locations, the difference between the 2-application program and the 3-application program was also significant and these differences show a trend where the residual activity differs among the products. In other locations in other years, trends varied depending on the onset and severity of rust.

Effect of timing of fungicide applications. Timing of fungicide applications may be critical in managing soybean rust and may, if used effectively, reduce the number of applications needed for economic benefit. Trials were conducted in Paraguay (three locations) and in the U. S. (four locations) (Mueller et al., 2005b). In Paraguay, all three locations were infected with soybean rust; in two locations rust significantly impacted yield. Trials in the U.S. had no soybean rust. Treatments in each field included applications with: triazole (Folicur), strobilurin (Headline), or a triazole-strobilurin combination (Quilt) applied at various times and an non-sprayed control. In Paraguay two locations yield was significantly greater than the control for all treatments. In one location in the U.S., all but one treatment had significantly greater yield than the control, and in two other locations, there was no statistical difference between the control and most treatments.

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