Variation of *Phakopsora pachyrhizi* isolates on soybean

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Abstract

Phakopsora pachyrhizi Sydow, the causal fungus of soybean (*Glycine max* (L.) Merrill) rust, occurs in most soybean-growing areas of the world except continental North America. Initial studies on soybean rust isolates from the Western Hemisphere indicated that they were different than isolates from the Eastern Hemisphere. In 1992, the Eastern Hemisphere species, *P. pachyrhizi*, and the Western Hemisphere species, *P. meibomiae*, were established for the soybean rust fungi based on morphological differences. The first molecular differentiation of the two species was reported in 2002. A number of studies have reported the occurrence of race in *P. pachyrhizi* either on soybeans or on other hosts. In 1984, a set of four native Australian *Glycine* species were used to identify six different virulence combinations of *P. pachyrhizi*. Much of the research on differentiating isolates on soybean was completed in a containment facility at in the U.S. Genetic characterization on four plant introductions (PIs) indicated the occurrence of four independently inherited dominant genes. These genes are known to be effective to a limited number of isolates. There are many studies that need to be completed to determine if all isolates respond equally in terms of survival, urediniospore production, telia formation, and host range under different environments. Over the next few years, our understanding of pathogen diversity will increase as more concerted research efforts take place in different parts of the world.

Introduction

Soybean rust is caused by two fungal species, *Phakopsora meibomiae* and *P. pachyrhizi*. The Asian soybean rust pathogen, *P. pachyrhizi*, is the species of greater concern since it is the more aggressive species and has been identified in new geographical locations beyond Asia. *P. meibomiae*, the less virulent species, has only been found in the Western hemisphere, and it is not known to cause severe yield losses in soybean (Sinclair and Hartman

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1999). Soybean rust, caused by *P. pachyrhizi* is one of the major diseases of soybean in many Asian countries (Sinclair and Hartman 1999) and now in Brazil, since its recent introduction in 2001 (Yorinori et al. 2003). Significant yield losses due to rust have been reported in most soybean-producing countries throughout Asia, where the disease is endemic and may limit soybean production. North America is one of the last major soybean production areas without soybean rust.

On the African continent, the distribution of soybean rust was not well known before 1996, but since then a more expanded view of soybean rust in Africa has been reported indicating that it was found in 1996 in Uganda, Kenya, and Rwanda, in Zambia and Zimbabwe during 1998, Nigeria in 1999, Mozambique in 2000, and South Africa in 2001 (Levy 2003).

The first detection of *P. pachyrhizi* in South America was in Paraguay in the 2000-2001 growing season (Yorinori et al 2003). The disease was found on soybeans grown in the Parana River basin on the eastern border with Brazil in a limited number of fields. Argentina confirmed the occurrence of soybean rust in early 2002 (Rossi 2003). During the 2003 growing season the pathogen was found in most of the soybean growing regions of Brazil and came late in the season for the first report in Bolivia (Yorinori et al. 2003).

The objective of this paper is to provide an overview of what is known about the variation of *Phakopsora pachyrhizi* isolates. This will include a review of some of the studies that confirmed that two species infect soybean, and the variation observed in pathogenicity on soybean and other hosts. Because of the restrictions in length, this overview will highlight some of the refereed papers published and is not meant to be a review of all of the literature on this subject.

Studies on species differentiation

One of the earliest reports of soybean rust in the Western Hemisphere was when it was found on soybean and other legumes in Puerto Rico (Vakili and Bromfield 1976). Along with soybean, rust was found on *Centrosema pubescens* (butterfly pea), *Dolichos lablab* (hyacinth bean) *Phaseolus coccineus* (scarlet runner bean), *P. lunatus* (lima bean) and *P. vulgaris* (bean). It also was shown that the Puerto Rican cultures were less virulent than three strains from the Eastern Hemisphere on soybean cv. Wayne.

In 1980, Bonde and Brown (1980) examined isolates from Australia, India, the Philippines, Taiwan and Puerto Rico on cv. Wayne. Isolates were indistinguishable in their pre- and post-penetration, colonization phases,

and morphology of uredinia. The only observable difference was the appearance of germ pores, in which those of the Puerto Rican isolates were more easily seen suggesting that their spores may have thinner germ pore plugs. A more thorough examination of isolates was reported in 1988 when isozymes of *P. pachyrhizi* from the Eastern and Western Hemispheres were compared (Bonde et al. 1988). No differences in isoenzyme banding patterns were detected among any of the eleven isolates from the Eastern Hemisphere or among those from the Western Hemisphere; however, distinct isoenzyme polymorphisms were observed when comparing isolates from the two hemispheres.

Ono et al. (1992) established two species for the soybean rust fungi. This was based on morphological differences between their anamorphic and teleomorphic stages, and was based primarily on layering of telia and wall thickness of teliospores. *P. pachyrhizi* [uredinal anamorph *Malupa sojae* (syn.: *Uredo sojae*)] included the Eastern Hemisphere populations before its known spread and confirmation in Africa, Hawaii, and South America, and *P. meibomiae* [uredinal anamorph *Malupa vignae* (syn: *Uredo vignae*)] isolates from the Western Hemisphere, before the first report in Hawaii in 1994 (Killgore 1995).

The first molecular differentiation of the two species was reported by Frederick et al. (2002). They showed that the nucleotide sequence of the internal transcribed spacer region had only 80% sequence similarity between the two species. Based on these differences, four sets of polymerase chain reaction primers were designed specifically for *P. pachyrhizi* and two sets for *P. meibomiae*. Classical and real-time fluorescent polymerase chain reaction assays were used to identify and differentiate the two species from inoculated and field samples from South America.

Variation on hosts other than soybean

One of the earliest reports of *P. pachyrhizi* races is from Lin (1966) in Taiwan. Nine isolates were used to inoculate six soybean genotypes and five leguminous plants. No marked differences in pathogenicity of the isolates were observed on the soybean genotypes; however, the nine isolates were separated into six pathogenic groups differing mainly in their reactions types with and without sporulation or no infection on *Vigna unguiculata* subsp. *sesuquipedalis* (asparagus bean), *P. vulgaris* (kidney bean), and *Pachyrhizus erosus* (short-podded yam bean).

In 1984, Burdon and Speer (1984) established a set of differential *Glycine* hosts for the identification of *P. pachyrhizi* races. They used 257 accessions