CURRENT STATUS OF SOYBEAN RUST CONTROL BY FUNGICIDES[1]

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Background

The Asian soybean rust, caused by *Phakopsora pachyrhizi* (Figure 1), had been limited to the Eastern hemisphere, until it was found in Hawaii in 1994 (Killgore and Heu, 1994). Currently, the distribution of *P. pachyrhizi* includes Africa, Asia, Australia, South America, and Hawaii (Miles *et al*., 2003). The pathogen is readily disseminated by wind-borne urediniospores (Figure 2) and can drastically reduce yields. Yield losses ranging from 10% to 100% have been reported for individual fields and in experimental plots (Hartman, 1995; Levy *et al*., 2002; Morel and Yorinori, 2002). The rapid spread of *P. pachyrhizi* in less than a decade to new areas like Hawaii, Southern Africa, and South America, combined with its potential for severe yield losses makes this the most destructive foliar disease of soybean. The pathogen can infect soybean plants at any time after germination (Bromfield, 1984). In the early season rust pustules are found on the lower leaves in the canopy, and as plants flower, spore production increases, pustule development moves up the plant and the disease becomes more severe. Fields develop a bronze to yellow color and are rapidly defoliated. Yield losses occur due to decreases in seed size and seeds per pod, and increases in pod abortion.

The primary tool in the control of the disease will be the use of fungicides. Single gene resistance has not been durable and partial resistance has been difficult to work with, leaving tolerance or yield stability as an alternative method of management. Tolerance is defined as yield stability in the presence of the disease compared to plots protected by fungicides (Hartman, 1995). Cultural practices have not been shown to be effective in control of the pathogen; recommendations were inconsistent and varied by location. The most effective practices were avoidance or practices that maximized yields in the absence of the disease.

Figure 1. **Lesions on a soybean leaf caused by the soybean rust fungus *Phakopsora pachyrhizia*. (Photo © G. L. Hartman)**

Fungicide efficacy

Many fungicides to control soybean rust have been evaluated. Early research from Asia indicated that mancozeb was effective (Hartman *et al*., 1992). Other compounds available at the time were compared to mancozeb and were effective, but results varied by test (Table 1). More recently, fungicide trials in India (Patil and Anahosur, 1998) and

Figure 2. **Urediniospores of the soybean rust fungus (*P. pachyrhizi*). (Photo © G. L. Hartman)**

[1] Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Table 1. Summary of fungicides evaluated for control of soybean rust caused by *Phakopsora pachyrhizi*

Active ingredient	Products evaluated	Country where test were done	Summary of application trials and recommendations in the literature	References
Triadimefon	Bayleton®	India, Japan, Philippines, Taiwan, Thailand	Protection inconsistent when compared to Dithane and M45, although it was used as a control in yield loss studies. EDBC's appear to be more effective but in limited testing up to 33% yield increases were seen. First application at flowering, 10 to 20 day intervals.	Hartman *et al.*, 1992; Patil Anahosur, 1998
Thiabendazole	Benlate®, Topsin M®	Thailand	Off registration in US, not as effective as Dithane M45, effective only when used with Plantvax, but no yield increase. Phytotoxic as a seed treatment.	Hartman *et al.*, 1992
Chlorothalonil	Bravo®, Echo®	Brazil, India, Paraguay	Limited data available, yield protection similar to or less than mancozeb. Not as effective as other compounds in some studies.	Hartman *et al.*, 1992; Miles *et al.*, 2003; Patil and Anahosur, 1998
Ethylenebisdithio-carbamates (EDBC)*	Dithane-M45®, Mancozeb®, Manzate D®, Zineb®, Maneb®	Australia, China, India, Philippines, Paraguay, Taiwan	The EDBC products have been effective in controlling soybean rust when applied 7 to 21 days apart, with the first applications as early as three weeks after planting and as late as flowering. Not all studies showed control of yield increases.	Hartman *et al.*, 1992; Miles *et al.*, 2003
Oxycarboxin	Plantvax®	India, Taiwan, Thailand	Not as effective as Dithane M45 or Manzate D, did not always control rust, yield protection varied by study. Apply when lesions first appear, then at 7 day intervals.	Hartman et al., 1992;
Hexaconazole	Contaf®	India	Effective in reducing disease and protecting yield, 25% yield increase in limited testing.	Patil and Anahosur, 1998
Propiconazole	Propimax®, Tilt®	Brazil, India, Paraguay	Effective in reducing disease and protecting yield, 33% yield increase in limited study. Two applications, 15 days apart, starting at flowering.	Miles *et al.*, 2003; Patil and Anahosur, 1998
Difenoconazole	Score®	India, South Africa, Zimbabwe	Yield protection varied by study, more effective than mancozeb. Two or three applications needed, starting at flowering.	Levy *et al.*, 2002
Tridiamenol	Shavit®	India, South Africa, Zimbabwe	Extremely effective in reducing disease incidence. Highest yielding treatment. Two or three applications needed, starting at flowering.	Patil and Anahosur, 1998
Flusilazole+ carbendazim	Punch Xtra®	South Africa, Zimbabwe	One of most effective fungicides in Africa. Two or three applications needed, starting at flowering	Levy *et al.*, 2002
Tebuconazole	Folicur ®	Paraguay, Zimbabwe	Limited data, yield protection variable by location within studies.	Levy *et al.*, 2002; Miles *et al.*, 2003
Azoxystrobin	Quadris®	Brazil, Paraguay	Limited data, good control but single, late application did not control rust or protect yield.	Miles *et al.*, 2003
Tetraconazole	Eminent®	Brazil, Paraguay	Limited data	Miles *et al.*, 2003
Pyraclostrobin	Headline®	Paraguay	Limited data, good rust control with yield benefits	Miles *et al.*, 2003
Boscalid	Endura®	Paraguay	Limited data	Miles *et al.*, 2003
Pyraclostrobin + boscalid	Pristine®	Paraguay	Limited data, good rust control with yield benefits	Miles *et al.*, 2003
Trifloxystrobin + propiconazole	Stratego®	Paraguay	Limited data, good rust control with yield benefits	Miles *et al.*, 2003
Fenbuconazole	Enable®	Paraguay	Limited data	Miles *et al.*, 2003
Myclobutanil	Eagle®, Laredo®	Paraguay	Limited data	Miles *et al.*, 2003

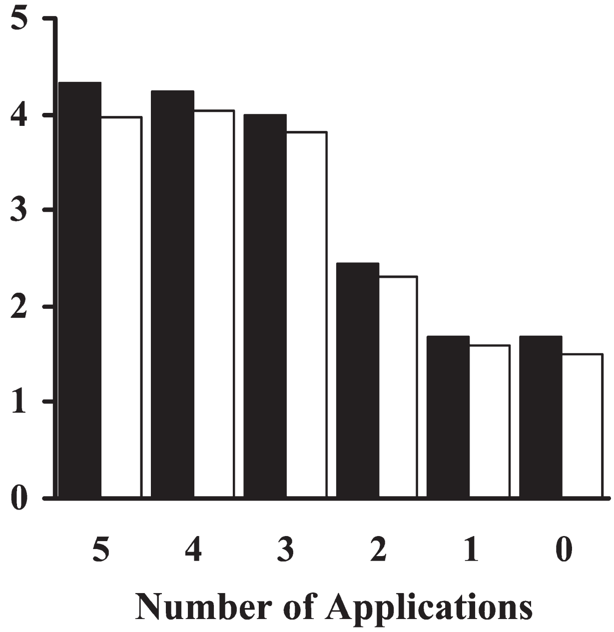

Figure 3. **Kernel yield (t ha⁻¹, at 11% moisture content) of two soybean cvs ('Soprano': ■; 'Sonata': ❑) either unsprayed (control) or sprayed with flusilazol + carbendazim (one time, 2, 3, 4 or 5 times) at the Rattray Arnold Research Station, Enterprise, Zimbabwe, in the 2000/2001 season**

Southern Africa (Levy *et al.*, 2002) have identified several triazole compounds and triazole mixes. Among the more effective were flusilazole + carbendazim, difenoconazole, and triadimenol. The most recent trials in Africa and South America have identified additional triazoles, (eg. tebuconazole and tetraconazole), as well as several strobularins and strobularin mixes including azoxystrobin, pyraclostrobin, pyraclostrobin + boscalid and trifloxystrobin + propiconazole (Miles *et al.*, 2003). Other compounds that reduce disease severity have been identified but yield protection has been inconsistent. Further efficacy trials are continuing in both Africa and South America to identify additional products.

Timing and number of applications

The most recent recommendations for chemical control of soybean rust have come from Zimbabwe and South Africa (Levy *et al.*, 2002). Early experiments evaluated the number of applications needed to protect the crop (Figure 3). Treatments differed by date of first application and all treatments except the non-protected control received the 108 days after planting (DAP) application. Applications were made at 20-day intervals starting at 28 DAP for the five application treatment. There were no differences in yields when fungicide application started 28 DAP (five applications) or 48 DAP (four applications). There was a slight yield loss when the first spray was delayed until 68 DAP (three applications). Delaying fungicide application until 88 (two applications) and 108 DAP (one late application) resulted in significant yield losses. Flowering of both cultivars occurred between 50 and 60 DAP. When fungicides were applied during the vegetative growth stages (28 DAP), yields did not increase compared to applications that protected the crop from flowering through grain fill (48 and 68 DAP).

Experiments that evaluated the timing of applications in post flowering soybean were completed using two cultivars, Sonata and Soprano, treated with 50 g flusilazole + 100 g carbendazim, in single applications at either 50, 60, 70, 80 or 90 DAP, and two application treatments at 50+70 dap, 60+80 DAP or 70+90 DAP. A three-spray treatment (50+70+90 DAP) simulated the recommendation being made to farmers, and a four-spray treatment was included to provide total rust control. Data indicate that most single applications did not protect yield (Figure 4). However, if properly timed, a single application has been seen to protect yields when compared to treatments with two or more applications. The timing of the application was critical as applications 10 days earlier or later showed significant yield losses. This trend has been repeated in high and low disease situations. All treatments with two applications had yields similar to those with three and four applications. Late applications had slightly less protection for Soprano, the indeterminate cultivar.

In Southern Africa, the recommendation was made to use a chemical control program with two or three applications (Levy *et al.*, 2002). Three applications were considered necessary in high disease situations, while two applications were recommended when disease severity was light. Recommendations of 2–3 applications were made given the difficulty of correctly timing a single application. This recommendation was supported by limited data from Paraguay where a single application at flowering provided less yield protection than two applications, one at flowering and another 20 days later (Miles unpublished data).

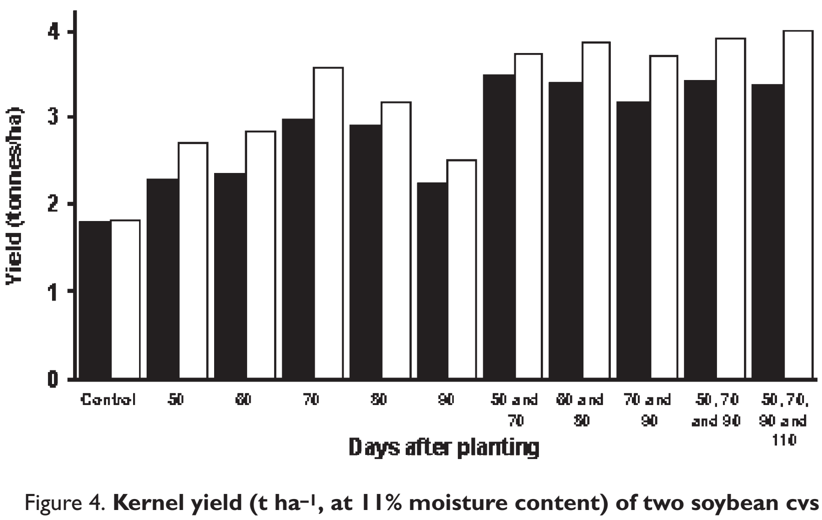

Figure 4. **Kernel yield (t ha⁻¹, at 11% moisture content) of two soybean cvs ('Soprano': ■; 'Sonata': ❑) either unsprayed (control) or sprayed with flusilazol + carbendazim (once at 50, 60, 70 ,80 and 90 days after planting; twice at 50 and 70, 60 or 80, 70, 90 days after planting; three times at 50, 70 and 90 days after planting; or four times at 50, 70, 90 and 110 days after planting) at the Rattray Arnold Research Station, Enterprise, Zimbabwe, in the 2000/2001 season.**

The number and timing of applications are critical for the control of soybean rust. The most efficient applications are applied during early reproductive growth, which allow protection through to crop maturity. The exact number of applications will depend on the length of the reproductive phase of the crop, duration of the compound and severity of the epidemic. Fungicide applications in early vegetative stages, although effective in reducing disease severity, have not been shown to be effective in protecting yield.

Future outlook

With the movement of soybean rust into major production areas the use of fungicides on soybeans has increased. With the USA as the world's largest soybean producer it would be expected that there would be another dramatic increase of fungicides used on the crop should soybean rust enter the continental states. It is not known what kind of application methods would predominate in the U.S.A., but aerial application has been the primary method in Brazil and Paraguay with some fungicides applied with ground equipment. Multiple application methods are being used in Southern Africa, with the most effective methods being those where penetration and canopy coverage are the greatest. Examples of effective methods include air assist and high-pressure lateral discharge equipment with increased pressure delivery and increased water volume per hectare. Since cropping systems, field sizes, and total area needing fungicides varies by country, the methods that provide the best canopy penetration and coverage, and thus the most potential effective control of rust, are the ones that will predominate. A management scheme that uses fungicides effectively will provide the primary tool in the control of soybean rust, which in time will hopefully be complemented by some form of host resistance and/or tolerance.

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