Management of Asian Soybean Rust

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Introduction

The identification of Asian soybean rust in Paraguay in 2001 (Morel and Yorinori 2002) and its spread to more than 95% of the soybean production in Brazil through the 2004 growing season has heightened the awareness of this disease worldwide. The rapid spread of *Phakopsora pachyrhizi* and the potential for severe yield losses makes this the most destructive foliar disease of soybean. Yield losses of 20 to 60% were reported in Asia with losses of 80% reported from experimental fields in Taiwan (Hartman et al. 1992). Yield losses of 40 to 60% were reported in southern Africa with reports of 100% loss in individual fields (Caldwell et al. 2001). During the 2003–2004 growing season in Brazil, yield losses were estimated at 10% of the annual crop, an increase from the 5% yield loss estimate reported for the 2002–2003 growing season (Yorinori, personal communication). Soybean rust, if introduced into the United States, could have a major impact on both total soybean production and production costs.

In the near future, the primary tool to control soybean rust will be fungicides (Miles et al. 2003a). Fungicides have been used effectively in southern Africa and South America to manage the disease. Cultural practices have not been shown to be effective in controlling the pathogen; recommendations were inconsistent and varied by location. The most effective cultural practices were those that maximized yields in the absence of the disease or planting during seasons when the disease could be avoided. Incorporation of resistance into commercial cultivars is several years away and will be made more difficult by the need to use nonrace specific resistance.

Trade and manufacturers' 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 USDA implies no approval of the product to the exclusion of others that may also be suitable.

Fungicide Efficacy

Many fungicides have been evaluated to control soybean rust. Early research from Asia indicated that mancozeb was effective (Hartman et al. 1992). Other compounds available at the time were compared with mancozeb and were effective, but results varied by test (Miles et al. 2003b). Fungicide trials in India (Patil and Anahosur 1998) and southern Africa (Levy 2004) identified several triazole compounds and triazole mixes that controlled soybean rust. More recent trials in Africa and South America have identified additional triazoles, tebuconazole and tetraconazole, as well as several strobilurins and strobilurin mixes, including, azoxystrobin, pyraclostrobin, pyraclostrobin + boscalid, and trifloxystrobin + propiconazole (Miles et al. 2003c). Additional triazoles are commercially available in Brazil; among these are epoxiconazole, cyproconazole, and metconazole. These fungicides have been shown to be very effective when mixed with one of the strobilurin compounds.

Labeled and Section 18 Compounds

There are three fungicides that are registered for use on soybean, labeled for soybean rust, and are commercially available in the United States (Table 1). These fungicides are Bravo®, Echo®, and Quadris®. Quadris® is an azoxystrobin; Bravo and Echo are both chlorothalonil products. There has been a Section 18 Emergency Exemption request for seven compounds or mixtures of compounds submitted to the Environmental Prection Agency (EPA) by the Departments of Agriculture of Minnesota and South Dakota (http://plantsci.sdstate.edu/draperm/SoybeanRustSection18). At least 24 other soybean-producing states have followed with requests of their own. Not included on any of the lists are the sulfur, lime, elemental compounds, various oils, and other organic products that may not be viable management tools in large commercial operations.

The fungicides that will be available for managing soybean rust fit into three classes: chlorothalonil, strobilurin, and triazole. The strobilurins and triazoles have single site mode of actions. The strobilurins bind to the cytochrome in the mitochondria, which interferes with respiration, preventing spore germination and fungal growth. The triazole fungicides are sterol inhibitors, interfering with sterol biosynthesis in fungal membranes. Both strobilurins and triazoles are absorbed into leaf tissue and translocate within the leaf tissue. The triazoles move rapidly through the leaf and can be dissipated in as little as 10 days, depending on application rate. The strobilurin fungicides translocate much slower, giving them a longer residual period. Chlorothalonil products have multiple modes of action but are limited in having a longer (41 day) preharvest interval versus the 14-day preharvest interval of most other products. The chlorothalonil products are not absorbed into the plant tissue, as are the strobilurins and triazoles, but remain on the leaf surface where they are active. Within each of the fungicide classes the products differ in yield protection, translocation ability, and residual activity.

Table 1. Fungicides registered for use on soybean, labeled for Asian soybean rust or on a Section 18 Emergency Exemption request.

			Registration status	
Compound	**Product**	**Company**	**Soybeans**	**Soybean rust**
Azoxystrobin	Quadris®	Syngenta	Yes	Labeled
Chlorothalonil	Bravo® Echo®	Syngenta Sipcam Agro	Yes Yes	Labeled
Myclobutanil	Laredo®	DAS		Section 18[a] Approved 4/04
Propiconazole	Tilt® Propimax® Bumper®	Syngenta DAS Makhteshim-Agan		Section 18[a] Approved 4/04
Pyraclostrobin	Headline ®	BASF		Section 18[a]
Pyraclostrobin + boscalid	Pristine ®	BASF	(Yes[b])	Section 18[a]
Tebuconazole	Folicur®	Bayer		Section 18[a] Approved 8/04
Tetraconazole	Eminent®	Sipcam Agro		Section 18[a]
Trifloxystrobin + propiconazole	Stratego®	Bayer		Section 18[a]

a. http://plantsci.sdstate.edu/draperm/SoybeanRustSection18

b. Boscalid has been registered for use on soybean, but will not be labled for use against soybean rust.

Timing and Number of Applications

The most recent experiments evaluating the timing and number of applications 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. There were no differences in yields when fungicide application started 28 days after planting (DAP) with five applications, or when application started 48 DAP with four applications. There was a slight yield loss when the first treatment was applied 68 DAP, with three applications in the season. Delaying fungicide application until 88 DAP, with two applications, and 108 DAP, with a single late application, resulted in significant yield losses. Flowering of the cultivars used in the study started between 50 and 60 DAP. When fungicides were applied during the vegetative growth stages, 28 DAP, yields did not increase compared with applications that protected the crop from flowering through grain fill, 48 and 68 DAP.

Experiments that evaluated the timing of applications in postflowering soybean were completed using 'Sonata' and 'Soprano', treated with 50 g of flusilazole + 100 g of carbendazim (Punch Xtra®) 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-application treatment, 50 + 70 + 90 DAP, simulated the recommendation being made to farmers, and a four-application treatment was included to provide total rust control. A single, properly timed application can protect yields compared with treatments with two or more applications (Levy 2004). The timing of the application was critical, because applications 10 days earlier or later showed significant yield losses. All treatments with two applications had yields similar to treatments with three or four applications. Late applications had slightly less protection in 'Soprano', the indeterminate cultivar, compared with the determinant 'Sonata'.

Recommendations

In southern Africa, the recommendation was made to use a program with two or three fungicide applications (Levy 2004). Three applications were considered necessary in high disease situations, whereas two applications were recommended when disease severities were light. For best yield protection the first application was recommended at 50 DAP, at or just ahead of flowering. Subsequent applications 20 days apart were sufficient to control the disease. These recommendations were made in an attempt to limit the exposure of the crop to the disease due to difficulties in obtaining exact timing of a single application. This recommendation was supported by limited data from Paraguay where a single application at flowering had less yield protection than two applications, one at flowering followed by another 20 days later (Miles, unpublished data).

The production practices in Brazil are changing from a single late fungicide application (growth stage R5), used to

Table 2. Comparison properties of protectant and curative fungicides for soybean rust management	
Protectant	**Curative**
May or may not be absorbed into leaf tissue	Adsorbed into leaf tissue
May or may not be translocated through leaf tissue. If translocated then moves slowly through tissue	Locally translocated through leaf tissue, usually rapidly
Longer period of residual activity	Short residual period
Interferes with fungal growth and spore germination	Kills fungal tissue, interferes with respiration
Can only be used after infection or when infections are very low, below 3-5% severity	Can be used after infection, most effective when less then 10% severity
Chlorothalonil and strobilurin products	Triazole and triazole-strobilurin mixes

protect against late-season diseases, to a two-application program with the first application at growth stage R3 or earlier. These recommendations differ from the recommendations in southern Africa. As the scenario plays out in South America, we will learn more about the timing and number of fungicides applications to manage soybean rust.

In the United States, recommendations for management of soybean rust will be based on information obtained from southern Africa and South America. The products listed in the Section 18 Emergency Exemption request have been evaluated in common trials Zimbabwe and Paraguay (Miles et al. 2003c, 2004a,b), as well as by individual companies in Brazil. All of the fungicides, registered and labeled for soybean rust, as well as those on the Section 18 Emergency Exemption list, reduced the severity of soybean rust. Among the products, Dithane®, Bravo®, and Echo® reduced soybean rust severities the least. This result is not unexpected. These three fungicides are not absorbed into the leaf but are protectant fungicides that provide control by limiting infection and spore germination on the leaf surface; once an infection occurs these products do not interfere with fungal development. The experimental protocol was to apply fungicides at 20-day intervals; this interval is too long for these products. Labeled recommendations for these fungicides are to apply at 7- to 14-day intervals, depending on rainfall. These products have a place in managing soybean rust, but they will be most effective when applied as labeled.

The triazole and strobilurin fungicides, as well as mixes of the two, were effective in reducing soybean rust severity. However, individual fungicides differ in their strengths. As a class, the triazoles have short residual periods, moving rapidly through the leaf where they are effective in killing the pathogen by interfering with fungal respiration. Under application schedules longer than 14 days, the triazole products may dissipate from the plant tissue, unless high rates are used. The strobilurin products have a longer residual, moving slower through the leaf tissue. However, their mode of action limits spore germination and fungal growth, so they are not as effective in controlling the pathogen once it is established. If infection levels are too high, above 3 to 5% severity, when the strobilurin fungicides are first applied, they may not protect yields. Additional research on the timing of application and rotation of triazoles and strobilurin fungicides is needed. Additional research also needs to be done on the interaction of soybean rust severities at application and subsequent yield loss for each of the different fungicides. Because both the triazoles and strobilurins have a single site mode of action, it is necessary to limit their use to one application per season for each. The relative curative ability of the triazoles and the interaction between application rates and residual effects need to be evaluated.

The development of a management plan using fungicides to minimize losses to soybean rust will not be simple. 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 as well as the econo-

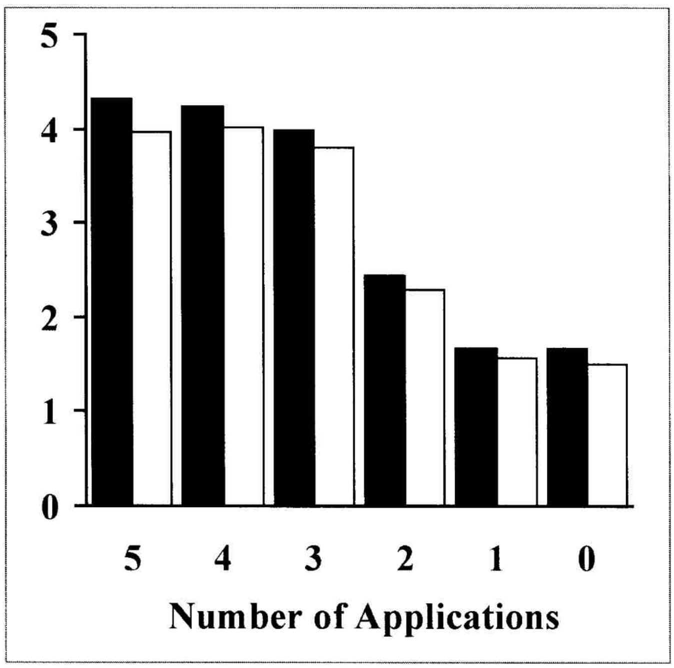

Figure 1. Kernel yield (tons ha^{-1}, at 11% moisture content) of two soybean cultivars ('Soprano': ■ ; 'Sonata': □) either sprayed with flusilazol + carbendazim, or left unsprayed at various dates after planting at the Rattray Arnold Research Station, Enterprise, Zimbabwe, in the 2000–2001 season (from Miles et al. 2003c).

mics of the situation. The number and timing of applications are critical for the control of soybean rust. The most efficient applications were during early reproductive growth, allowing for protection through to crop maturity Fungicide applications in early vegetative stages, although effective in reducing disease severity, have not been shown to be effective in protecting yield. The choice between an application before infection (protective) and an application after infection (curative) also needs to be considered (Table 2). In South America and southern Africa, the most effective management programs have been those where fungicides were used in a protective application before infection. For U.S. producers, the choice of a protective application will allow the use of all products that are labeled for soybean rust control or on the Section 18 Emergency Exemption list. If the first fungicide application is curative or applied after infection, then the choice of product is limited to the triazoles. Strobilurin fungicides have not been effective when used after infection. Yield losses have been observed when soybean rust severity was as low as 3 to 5% before treatment with a strobilurin. However, when disease severity before application was high, above 10%, then yield loss occurred even when a triazole product was used. If more than one fungicide application is needed in the growing season, then resistance management will play a role in choice of product. Both strobilurin and triazole products have a single site mode of action, they can be used only once per season. Repeated application of a single site mode of action may lead to the loss of the product if the pathogen population adapts to the fungicide. A product that is a mixture of a strobilurin and a triazole can be used twice in the same season. These products have the best of both classes of fungicides with the rapid translocation and curative effects of the triazole combined with the slower translocation and long residual of the strobilurin. An additional benefit with mixtures is the reduced risk of resistance to the single site mode or action fungicides developing in the pathogen population. However, this benefit may be lost if product are reduced to a level that will allow the pathogen to adapt. Reducing rates to save cost may allow resistance to be selected in the pathogen population.

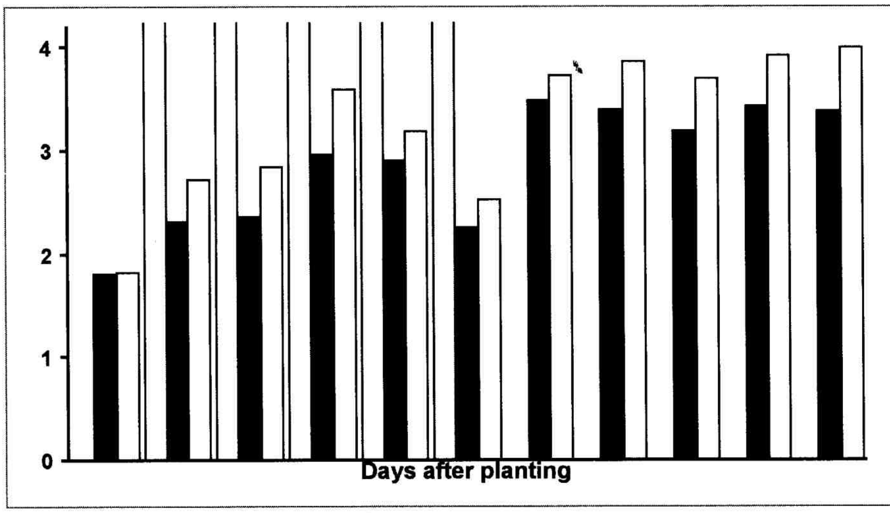

Figure 2. Kernel yield (tons ha^{-1}, at 11% moisture content) of two soybean cultivars ('Soprano': ■ ; 'Sonata': □) either sprayed with flusilazol + carbendazim, or left unsprayed at various dates after planting at the Rattray Arnold Research Station, Enterprise, Zimbabwe, in the 2000–2001 season (from Miles et al. 2003c).

Conclusions

All of the fungicide products that are registered and labeled for soybean rust management or listed on the Section 18 Emergency Exemption request are effective in managing soybean rust. The products are known to differ in both yield protection and reduction of disease severity. There are still many questions to be answered about the use of fungicides to manage soybean rust in the United States. The most effective rotation of products, the return on cost of the fungicide and its application, and the risks associated with pre- or postinfection management strategies still need to be determined. The epidemiology of the pathogen, where it will overwinter, as well as how often and when it will occur in local areas are questions that cannot be answered until after the pathogen becomes established. To reduce the risk of yield loss and unnecessary fungicide applications, a forecast system for soybean rust needs to be developed. The economics of the crop, time and severity of infection, along with the availability of fungicides and equipment needed to apply them will determine the response for individual producers.

Acknowledgements

We thank Clive Levy for the data from Zimbabwe, his discussions on the subject, and his support in conducting fungicide efficacy trials on products for use in the United States. We also thank the following for financial support: United Soybean Board, USDA–ARS, USDA–CSREES, BASF, Bayer, Crompton, Dow Ag Sciences, ISAGRO, and Sipcam Agro and Syngenta.

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