Decision Models for Fungicide Applications for Soybean Rust

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ABSTRACT

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Soybean rust (SBR), caused by *Phakopsora pachyrhizi*, can be a devastating disease to southeastern U.S. soybean (*Glycine max*) production. Fungicides can be applied to avoid yield loss, but growers need to know when an application will be most beneficial. To better understand and manage SBR epidemics in the southeastern U.S., fungicide application decision models were developed and validated. Application decision models were developed based on SBR presence and hours of leaf wetness or amount of cumulative rain and compared to non-treated controls and applications based on crop growth stage. The models were evaluated in 2009, 2010, and 2011. High disease pressure and conducive weather conditions in 2009 resulted in significantly greater disease severity and lower yields in non-treated plots compared to treated plots. In 2010 and 2011, low disease pressure and drought conditions resulted in no significant differences in disease severity or yields among most treatments. Results indicate two fungicide applications during early reproductive stage can reduce yield loss due to SBR, but subsequent applications need to be determined based on disease pressure, weather conditions, and crop growth stage.

INTRODUCTION

Soybean rust (SBR), caused by the obligate fungal parasite *Phakopsora pachyrhizi*, can be a devastating disease of soybean in the southeastern United States. Each year, the pathogen overwinters on the alternative host kudzu (*Pueraria montana*) in Florida and other southeastern U.S. states boarding the Gulf of Mexico. These overwintering sites provide the initial inoculum for yearly epidemics in the United States (Jurick et al. 2008). Management of SBR epidemics in southern soybean production areas is necessary not only to avoid yield loss, but to also reduce inoculum that can potentially infect other soybean-producing areas of the country. To be efficient and effective at managing disease, growers need to know when applications will be most beneficial. The effectiveness of different fungicides and timings of applications for SBR have often depended on when SBR was first detected, the intensity of its development, recent weather conditions, and proximity to sources of SBR (Mueller et al. 2009, Sikora et al. 2009). To assess proximity to sources of SBR, the Integrated Pest Management–Pest Information Platform for Extension and Education (Ipm–PIPE, http://www.sbrusa.net) can be used to view reports of SBR in the United States on soybean and alternative hosts.

SBR development has been predicted using simulation and empirical models based on the effects of weather and environmental variables on epidemiological parameters such as infection rate, latent period, and senescence of disease lesions on soybean (Isard et al. 2005, Pivonia and Yang 2006). Data from Marchetti et al. (1976) on temperature and dew duration for maximal infection on soybean have been utilized in models to assess the potential impact of SBR on U.S. agriculture prior to its arrival in 2004 (Yang et al. 1991a, b). Similarly, daily weather variables, such as rain events, have been used to predict epidemic potential in field epidemics in Brazil (Del Ponte et al. 2006). Furthermore, Young et al. (2011) found some of the main factors contributing to SBR disease onset, severity, and incidence in north Florida sentinel plots included leaf-wetness hours and the amount of precipitation before and after infection. However, utilization of this information into a simple application decision model has not been attempted.

This research utilized previously developed weather and environmental parameters to develop and validate simple fungicide decision models for soybean rust in the southeastern United States. The objectives of this research were to: (i) develop simple fungicide decision models based on presence of *P. pachyrhizi* on soybean or kudzu, and leaf wetness duration or rain events; and (ii) evaluate the models and applications based on crop growth stage and non-treated controls by way of disease severity and yield.

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DEVELOPMENT OF DECISION MODEL

Applications of the triazole fungicide Folicur 3.6 (tebuconazole; Bayer CropScience, Research Triangle Park, North Carolina) at 293 ml/ha were determined based upon the presence of SBR, on soybean or kudzu, and environmental variables determined by data from Marchetti et al. (1976) on maximal infection or by rain events determined by data from Del Ponte et al. (2006) on maximum severity. Marchetti et al. (1976) reported maximal infection occurred on soybean when ambient temperatures were 20 to 25°C with 10 to 12 h of dew. Correlation analysis in Del Ponte et al. (2006) indicated that rain variables were more correlated with final disease severity than temperature variables over a 1-month period from the time of first disease detection. Specifically, severity was >30% in southern Brazil locations with rain events greater than 12.5 cm, distributed over 5 to 10 rainy days during the 1-month period. With this information, the following parameters were established to trigger an application: (i) Leaf wetness model—if SBR was present in the county, and if 3 consecutive days with 10 h or more of leaf wetness and night time temperatures (from 2200 hours to 0500 hours) between 20 to 25°C occurred, a fungicide was applied; (ii) Rain event model—if over 5 days within the past 30 days, cumulative rain was equal or greater than 13 cm, a fungicide was applied. These treatments were compared to a non-treated control (no fungicide application), as well as fungicide application based on growth stage at R1 (flowering) followed by an application at growth stage R3 (pod development). Models began running at reproductive growth stage R1 (beginning bloom) and when SBR was present on kudzu or soybean, except in 2009 where only SBR on kudzu was used as a parameter. Applications stopped at reproductive growth stage R6 (full seed). There was a 2-week delay between fungicide applications triggered by either model based on the average time period a foliar fungicide provides SBR protection in the field (Dorrance et al. 2008).

Presence of SBR in the county on soybean or kudzu was obtained from the Ipm-PIPE website (http://www.sbrusa.net). Fungicide application were made using a platform sprayer with seven 11002 Turbo teejet nozzles using 35 psi and 25.7 liter/ha. Environment and weather data were obtained from the Florida Automated Weather Network (FAWN) station located on the North Florida Research and Education Center campus in Quincy, FL, which records observations every 15 min at 60 cm above the soil. Hourly dew point temperatures were compared with the hourly average air temperature. The hours where the difference between the two variables was 0–2 were counted as leaf wetness hours for daily calculations (Gates 1968). Weather data, from the previously mentioned FAWN station, was also used for daily rain from March through September.

EVALUATION OF DECISION MODEL

Decision application models for SBR were evaluated in 2009 to 2011, with one soybean planting in 2009 and 2010 and two soybean plantings in 2011 at the North Florida Research and Education Center in Quincy, FL. Pioneer 97M50 RR soybean was planted 5 May 2009, 17 May 2010, 25 June 2011, and 18 July 2011 in a 700 m^2 area with 51-cm row spacing and 6–7 seeds per 30 cm. Each treatment plot was approximately 4 × 6 m with approximately 2–4 m between each plot. Approximately 2.5 m border of soybean was planted around the entire area. All treatments had four replicates arranged in a randomized complete block design. Beginning at reproductive growth (R1) and ending before natural senescence weekly disease severity was recorded at four corners (approximately one row and 2 m in from the border rows) and one central point within each plot. Severity was based on visual assessment of symptomatic leaf area using the scale 0 = no disease, 1 = up to 2.5%, 2 = 2.5 to 5%, 3 = 5 to 10%, 4 = 10 to 15%, 5 = 15 to 25%, 6 = 25 to 35%, 7 = 35 to 67.5%, and 8 = 67.5 to 100% of the leaf area affected by SBR (Godoy et al. 2006). Average severity rating was determined by converting each rating to the midpoint of its range, i.e., 0 = 0%, 1 = 1.25%, 2 = 3.75%, 3 = 7.5%, 4 = 12.5%, 5 = 20%, 6 = 30%, 7 = 51.25%, and 8 = 83.75% (Young et al. 2011). Severities were averaged to calculate overall disease severity in each plot each week. The center 9-m^2 area in the middle of each plot was hand harvested at the end of each season to obtain seed weight and moisture. Yields were adjusted to 13% moisture to calculate final yield. Mean yield and final disease severity was calculated and analyzed using the glimmix procedure in SAS 9.1(Statistical Analysis Software version 9.1, SAS Institute Inc., Cary, NC) with a significance value of $P \leq 0.05$.

Weather, environmental conditions, and disease pressure varied over the four plantings of soybean the decision models were evaluated, as indicated by the first observation of SBR on kudzu and soybean and the number of fungicide applications the models triggered (Table 1). Yields from each planting date were significantly different across years (*P* value <0.0001), hence treatment yields were analyzed within each year.

Disease symptoms in plots were only observed in 2009 (Fig. 1). The rain event model triggered four fungicide applications and leaf wetness based model triggered six fungicide applications (Table 1). The applications controlled SBR by limiting severity to less than 4%, compared to the two fungicide applications in the crop stage treatment which had 60% final severity and non-treated control with 92% final severity (Fig. 1). However, yields from the rain event and leaf wetness-based decision applications were not significantly greater than crop stage applications (Table 1).

In 2010, the leaf wetness model based on SBR on kudzu triggered four fungicide applications while no applications were applied in the rain-based treatments due to the lack of significant rain events in 2010. Furthermore, the droughty conditions also resulted in late appearance of SBR on soybean which resulted in no fungicide applications based on the leaf wetness model based on SBR on soybean. Hence, all treatments that did not receive any fungicide applications were combined for data analysis. The two crop stage applications and the four applications triggered by the leaf wetness model based on SBR on kudzu resulted in significantly higher yields, with 4011 and 3912 kg/ha, respectively, compared to treatments that did not receive a fungicide application.

In 2011, yields across treatments and controls were not significantly different, due to the lack of disease pressure and non-conducive weather and environmental conditions. In the first planting, the rain event models triggered one fungicide

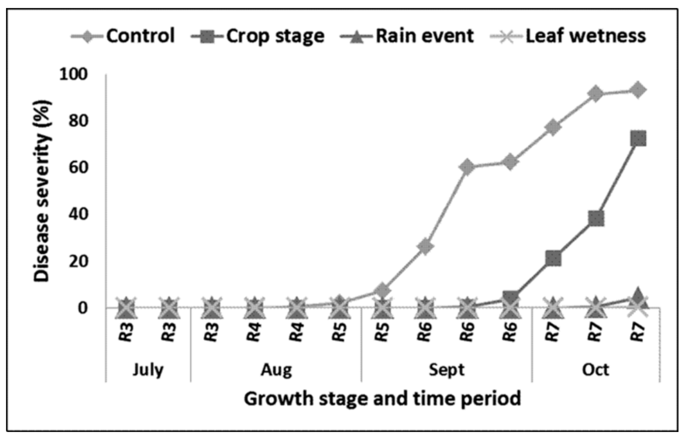

FIGURE 1

Severity of soybean rust (SBR) recorded in fungicide treatment plots in 2009 located at the North Florida Research Education Center in Quincy, FL. Treatments included Control - no application of fungicide; Crop stage - fungicide application at soybean growth stage R1 (flowering) and R3 (pod development); Rain event - fungicide applied if SBR present in county and if over 5 days within the past 30 days cumulative rain was equal or greater than 13 cm; Leaf wetness - fungicide applied if SBR present in county and if 3 consecutive days with 10 h or more of leaf wetness and night time temperatures (from 2200 to 0500 hours) between 20 to 25 °C occurred.

TABLE 1
Number of applications and yield for each treatment and planting of the application decision models; and first observations of soybean rust (SBR) on kudzu and soybean each year.

Plant date	SBR detection on kudzu[a] and soybean[b]	Treatment[c]	Applications[d] based on SBR on kudzu	Yield[e] (kg/ha)
5 May 2009	24 April 2009 (--)	Non-treated control	0	1181 b
	7 July 2009 (R1)	Crop stage	2	2193 a
		Rain event-kudzu	4	2632 a
		Leaf wetness-kudzu	6	2569 a
17 May 2010	15 July 2010 (V8)	Non-treated control	0	3350 b
	10 Sept. 2010 (R4)	Crop stage	2	4011 a
		Rain event-kudzu	0	3232 b
		Rain event-soybean	0	3371 b
		Leaf wetness-kudzu	4	3912 a
		Leaf wetness-soybean	0	3434 b
24 June 2011	12 July 2011(V6)	Non-treated control	0	3149 a
	25 Aug. 2011 (R1)	Crop stage	2	3123 a
		Rain event-kudzu	1	3465 a
		Rain event-soybean	1	3316 a
		Leaf wetness-kudzu	3	3215 a
		Leaf wetness-soybean	2	3261 a
18 July 2011	12 July 2011(V6)	Non-treated control	0	2810 a
	25 Aug. 2011 (R1)	Crop stage	2	2648 a
		Rain event-kudzu	1	2696 a
		Rain event-soybean	1	2928 a
		Leaf wetness-kudzu	2	2627 a
		Leaf wetness-soybean	2	2856 a

[a] First report of SBR establishment on kudzu after winter conditions and growth stage of soybean in study at time of first report in ().

[b] First report of SBR establishment on soybean after winter conditions and growth stage of soybean in study at time of first report in ().

[c] Treatments included: Non-treated control—no application of fungicide; Crop stage—fungicide application at soybean growth stage R1 (flowering) and R3 (pod development); Rain event—fungicide applied if SBR present in county and if over 5 days within the past 30 days cumulative rain was equal or greater than 13 cm; Leaf wetness—fungicide applied if SBR present in county and if 3 consecutive days with 10 h or more of leaf wetness and night time temperatures (from 2200 to 0500 hours) between 20 to 25°C occurred.

[d] The number of applications of the triazole fungicide Folicur 3.6 (tebuconazole) at 293 ml/ha.

[e] Average soybean yields (kg/ha) from fungicide application treatment plots, adjusted to 13% moisture. Different letters indicate significant differences among soybean yields based on averages analyzed by least significant differences at $P \leq 0.05$, across treatments within each planting date.

application, but at different timings. Rain event model based on SBR on kudzu was triggered on 19 August 2011 and the rain event model based on SBR on soybean was triggered on 30 August 2011. Similarly, the leaf wetness model based on SBR on kudzu triggered three fungicide applications on 19 August, 12 September, and 29 September 2011; while the leaf wetness model based on SBR on soybean triggered the same latter two fungicide applications in the early planting of 2011. In the second planting in 2011, there were no differences in the number or timings of fungicide applications within the leaf wetness models (two fungicide applications triggered) and the rain event models (one fungicide application triggered) based on SBR present on kudzu or soybean.

MANAGEMENT OF SBR WITH DECISION MODELS

Across the years evaluated, only 2009 had significant SBR pressure and a wet season with 158 mm monthly average rainfall from March through September and cumulatively 1107 mm. In such an epidemic year, the leaf wetness and rain event models were over sensitive and triggered six and four fungicide applications, respectively (Table 1). The yields resulting from the four and six fungicide applications triggered by the models in 2009 were not greater than the two fungicide applications from the crop stage treatment which yielded 2193 kg/ha (Table 1). The lack of significant difference in yield between these treatments is most likely due to SBR not developing until reproductive stage R7 (beginning maturity) after seed fill in the crop stage treatment (Fig. 1). Using the models after SBR was present on soybean in 2009 would have only reduced one fungicide application in each model due to the early detection of SBR on soybean on 7 July 2009.

In contrast, 2010 and 2011 experienced low SBR pressure and had cumulative rainfall of 719 and 739 mm from March through September and 103 and 106 mm monthly average rainfall, respectively. In such conditions, the rain event model had reduced numbers of applications compared to other models. The leaf wetness model continued to be over sensitive even in the low disease pressure environments in 2010 and 2011, although the leaf wetness model based on SBR on soybean required less applications compared to the leaf wetness model based on SBR on kudzu in 2010 and the early planting of 2011.

Depending on the soybean growth stage when symptoms of SBR are first detected, as well as weather and environmental conditions, additional fungicide applications may or may not result in greater yields. In this study, additional fungicide applications (more than the two applications at soybean growth stages R1 and R3) did not result in significantly greater yield which was probably due to the lack of SBR pressure or the late appearance of SBR symptoms at soybean growth stage R7. However, three applications of tebuconazole at R1, R3, and R5 did result in significantly greater yields than two applications at R1 and R3 when SBR was first detected at R4 in 2006 in an Alabama study (Mueller et al. 2009). Therefore, as first disease detection occurs earlier in the growing season (i.e., on earlier soybean growth stages) additional fungicide applications may provide greater protection from yield loss due to SBR if conducive weather conditions persist. The decision models developed and tested in this study could be further refined to initiate fungicide applications to protect yield from SBR. Particularly the rain-based model based on SBR on soybean shows promise in reducing fungicide applications during seasons with low SBR pressure, but still needs to be adjusted for high disease pressure situations.

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