Identifying Soybean Rust-resistant and Susceptible Populations of Kudzu to Increase Disease Monitoring Efficiency in Alabama

Edward J. Sikora and **Mary A. Delaney**, Department of Entomology and Plant Pathology, Alabama Cooperative Extension System, Auburn University, AL 36949

Accepted for publication 24 October 2016.

ABSTRACT

Soybean rust (SBR), caused by *Phakopsora pachyrhizi*, is considered to be one of the most damaging diseases of soybean worldwide. Monitoring for the disease in Alabama relies heavily on scouting kudzu on a biweekly basis in south and central portions of the state from late January through the end of July in areas where soybean production is minimal and is critical to help growers avoid significant yield losses from SBR. Previous studies have reported that some kudzu populations are naturally resistant or immune to infection from the pathogen which can complicate early disease

detection. This study will apply that knowledge to determine locations of kudzu populations that are either resistant or susceptible to *P. pachyrhizi* in order to increase monitoring efficiency and reduce costs associated with the scouting program. Results show that approximately 34% of the 162 kudzu sites tested in Alabama were resistant to *P. pachyrhizi*. By focusing scouting efforts on SBR-susceptible kudzu sites, we will reduce costs associated with the monitoring program by approximately 25% which is critical at a time when funding for such efforts is decreasing.

INTRODUCTION

Soybean rust (SBR), caused by *Phakopsora pachyrhizi* Sydow, has been a recurring problem for soybean (*Glycine max* Merrill) growers in the southern United States since it was first reported in 2004 (Schneider et al. 2005; Sikora and Hershman 2008). The disease was a significant problem in Alabama in 2012 when SBR reduced yield by over 60% in over 500 acres of poorly managed soybean in the southern region of the state (Sikora et al. 2013; Sikora et al. 2014a). Fields with the greatest yield losses either received a fungicide application too late or failed to receive a fungicide. Estimated economic losses were upwards of \$135,000 to farmers who failed to apply a fungicide during the 2012 season (Alabama Cooperative Extension System 2013; Allen et al. 2014). Significant damage from SBR was also observed in 2013 where losses of up to 40% were estimated in unprotected or poorly protected fields (Allen et al. 2014; Sikora et al. 2014b). Greater losses appear to have been avoided with properly timed fungicide applications based on management suggestions strengthened by regional scouting for the disease.

KUDZU GONE WILD

Kudzu (*Pueraria montana* var. *lobata* (Willd) Sanjappa & Predeepis) is a semi-woody perennial climbing vine first introduced into the United States in 1876 as an ornamental plant (Everest et al. 1999; Miller and Edwards 1983). In the early 1900s, kudzu was promoted as an inexpensive forage crop for livestock, but reached its greatest level of prominence in the 1930s when it was widely planted in the southern United States to control soil erosion (Britton et al. 2002). Kudzu has been observed in 31 states and Ontario, Canada, and is estimated to cover over 7.4 million acres of the eastern United States (Sikora

2014). The major concentration of kudzu is in the southern United States, where some states (e.g., Alabama, Georgia, and North Carolina) report every county to be infested with the invasive weed (Allen et al. 2014).

Kudzu, a close relative of soybean, is now considered the primary overwintering host of *P. pachyrhizi* in the United States, and important to the potential for SBR epidemics in this country (Sikora 2014a; Sun et al. 2005). Soybean rust-infected kudzu leaves that survive the winter and new kudzu leaves that are infected prior to soybean emergence in the spring serve as a bridge for SBR inoculum increase and northward spread (Sikora 2014). SBR has successfully overwintered on kudzu in Alabama in eight of the past 11 years as well as on kudzu in Florida and Louisiana along the Gulf coast in most years since 2006. These

FIGURE 1

The perennial weed kudzu growing next to an abandoned building and along a railroad track in Dothan, AL.

Corresponding author: Edward J. Sikora. Email: sikorej@auburn.edu.

doi:10.1094/PHP-RS-16-0039

© 2016 The American Phytopathological Society

sites are almost always associated with urban heat islands in cities or towns that experience elevated temperatures compared to outlying rural areas (Oke 1997; Sikora 2014). Some of these infected kudzu sites have been identified as far north as the cities of Montgomery and Selma in central Alabama (Sikora 2014).

WHY SCOUT KUDZU FOR SOYBEAN RUST?

The Alabama SBR monitoring program was started in 2005 shortly after the disease was first detected in the state (Mullen et al. 2006; Sikora et al. 2009). The program is part of the Soybean Rust-Pest Information Platform for Extension and Education which relies on real-time disease monitoring information to track and predict in-season spread of the pathogen in North America (Giesler and Hershman 2005; Hershman et al. 2011; Sikora et al. 2014a). The program includes monitoring soybean sentinel plots as well as kudzu sites early in the year before the majority of commercial soybean fields have reached reproductive stages of plant growth to aid in early detection of the disease. In Alabama, monitoring of kudzu typically focuses on large patches in rural areas often along county roads that are accessible to scouts and where kudzu growth often goes unchecked by landowners (Figs. 1 to 3). Typically, kudzu populations, selected randomly by scouts, are monitored biweekly from late January through the end of July in south Alabama, covering a 24-week period. Eventually, kudzu monitoring becomes statewide as the season moves into the late summer/fall period, and as SBR begins to spread northward through the state. In Alabama, kudzu is the sole monitoring host throughout much of the southern third of the state because of the lack of commercial soybean production in this region (Price 2016) and the lack of suitable locations for establishing soybean sentinel plots. Therefore, the ability to scout kudzu is a vital component of the SBR monitoring program in Alabama.

Scouting kudzu consists of visiting multiple kudzu sites in an area and examining a minimum of 100 leaflets per site. In any given day, a scout may examine 25 to 30 sites in 10 to 12 counties for SBR. This method of scouting is laborious, time consuming and costly because there is so much kudzu and too few scouts. Another confounding aspect of kudzu is that some sites are naturally resistant or immune to infection from the fungus (Bonde et al. 2009; Jordan et al. 2010). This fact suggests that field scouts, who often pick kudzu sites arbitrarily, have likely surveyed patches that were resistant or immune to the disease.

The purpose of this study was to determine if kudzu sites frequently used for monitoring for SBR in southern Alabama were susceptible or resistant to *P. pachyrhizi*. Determining the exact location of kudzu sites that are susceptible to the disease will enable scouts to focus their efforts on kudzu populations more likely to exhibit early symptoms of the disease. Mapping susceptible kudzu populations could then be used as a guide for future scouts to focus their efforts on susceptible kudzu sites and to avoid resistant populations in order to save time and money.

TESTING KUDZU TO DETERMINE RESISTANCE TO SOYBEAN RUST

South and central Alabama kudzu sites located along roadways in rural areas, and historically used by scouts to monitor for SBR, were chosen. Criteria used for selecting individual sites included: heavily shaded areas that would promote environmental conditions conducive for SBR development; ease of access, including a wide shoulder or a driveway to park vehicles for the safety of scouts from on-coming traffic; and areas that offered some security from aggressive dogs, poisonous snakes, suspicious land-

owners, and the occasional kudzu-hidden ditch or ravine. The latitude and longitude for each site was determined and a physical description of the area was recorded. Kudzu leaves used for the experiment were collected in September and October of each year.

At each site, leaflets with no visible symptoms of SBR were removed from several locations within the patch. The middle leaflet of the 4th or 5th trifoliate leaf from the end of a vine was removed, placed in a plastic bag with a moist paper towel, and transported to the laboratory in an insulated cooler. The leaves were subsequently washed twice with tap water and patted dry with a paper towel. The petioles were recut with a scalpel and the petioles embedded in 1% water agar in a petri plate (100 by 15 mm) with one leaflet per plate. A minimum of five test leaves and two control leaves were used per site.

FIGURE 2

A soybean rust-infected patch of kudzu climbing up trees near Gordon, AL.

FIGURE 3

Soybean rust-infected leaves in a susceptible kudzu patch in Fairhope, AL.

Each year, a population of uredinospores of *P. pachyrhizi* was collected from naturally infected soybean plants from soybean sentinel plots located at Auburn University, Auburn, AL (Lee County). A suspension of uredinospores was prepared by brushing spores off infected leaflets using a #7 paint brush and diluting the resulting spores to 1×10^8 in sterilized distilled water using a hemocytometer. The leaflets were inoculated within 1 h of preparing the spore suspension. Two leaflets were designated as controls and sprayed with 0.5 ml sterile distilled water. The remaining leaflets were sprayed with 0.5 ml of the uredinospore suspension. The petri plates were covered and allowed to incubate at 23°C on the laboratory bench in natural light. Leaves were monitored for lesion development and sporulation of *P. pachyrhizi* for 28 days after inoculation at which time the test was terminated. Scoring was determined by the presence or absence of pustules with spores on the leaf surface. Sporulation on any leaflets, either inoculated or the controls represented a susceptible reaction by the population being screened (Fig. 4).

KUDZU POPULATIONS RESISTANT TO SOYBEAN RUST DETECTED IN ALABAMA

A total of 162 kudzu sites from 30 counties in south and central Alabama were screened for resistance to SBR between 2012 and 2015. Results showed that *P. pachyrhizi* was unable to develop on approximately 34% of the 162 kudzu populations during this period (Table 1). *Phakopsora pachyrhizi* was not able to develop on 36% of the 47 populations screened in 2012; 38% of the 73 populations tested in 2013; and on 24% of the 42 populations screened in 2015. Kudzu screenings were not conducted in 2014 because of the lack of SBR inoculum needed for testing due to the slow progression of the disease within Alabama that year. Attempts were not made to record differences in lesion color, size, or sporulation, and populations were only screened one time during the study period, as the main objective was to identify as

many susceptible populations of kudzu as possible in the region to aid future scouting efforts.

TABLE 1
County location, year tested, and longitude and latitude of each kudzu population screened for resistance/susceptibility to *Phakopsora pachyrhizi* and percentage of leaflets developing pustules with spores on the leaf surface within 28 days post-inoculation.

County	Year	Longitude	Latitude	% inoculated leaflets testing positive for <i>P. pachyrhizi</i> ^x
Baldwin	2012	-87.75900	30.96762	10
Barbour	2013	-85.14934	31.90994	100
Barbour	2013	-85.14874	31.90431	0
Barbour	2013	-85.16196	31.93298	12.5
Barbour	2013	-85.18905	31.94576	0
Barbour	2013	-85.23360	31.97561	12.5
Barbour	2013	-85.26073	31.98953	0
Barbour	2013	-85.27923	31.99910	0
Barbour	2013	-85.35558	32.02962	0
Barbour	2013	-85.31453	32.01681	12.5
Barbour	2013	-85.18494	31.77153	20
Bullock	2013	-85.68998	32.05811	87.5
Bullock	2012	-85.71538	31.98414	50
Bullock	2013	-85.70470	32.07835	100
Butler	2012	-86.64416	31.86629	100
Butler	2015	-86.77777	31.65241	100
Butler	2012	-86.84586	31.57591	0
Butler	2012	-86.64125	31.84932	10
Butler	2015	-86.64416	31.86629	100
Chambers	2015	-85.48568	32.75863	0
Chambers	2015	-85.41430	32.86209	25
Chambers	2015	-85.40324	32.95548	50
Chambers	2015	-85.34948	33.02060	0
Choctaw	2015	-88.11444	32.11714	0
Clarke	2012	-87.60200	31.58528	100
Clarke	2015	-87.68589	31.64058	75
Clarke	2015	-87.78336	31.68193	75
Clarke	2015	-87.88498	31.54017	0
Clarke	2012	-87.77693	31.69584	0
Clarke	2012	-87.60114	31.58479	100
Clay	2012	-85.64930	33.31216	100
Clay	2012	-85.74929	33.13404	25
Clay	2012	-85.75622	32.29405	100
Clay	2015	-85.64930	33.31216	100
Clay	2015	-85.74929	33.13404	25
Coffee	2013	-86.15775	31.28032	100
Coffee	2013	-86.08260	31.29145	100
Coffee	2013	-85.91559	31.31662	100
Coffee	2013	-85.87160	31.29508	100
Coffee	2013	-85.83258	31.29854	100
Conecuh	2012	-86.90841	31.48728	75
Conecuh	2012	-86.91116	31.43800	75
Conecuh	2012	-86.97419	31.42669	100
Conecuh	2012	-87.19254	31.41929	100
Conecuh	2012	-87.19676	31.41872	0
Conecuh	2012	-87.06113	31.42159	0
Conecuh	2015	-86.90841	31.48728	75
Conecuh	2015	-86.91116	31.43800	75
Conecuh	2015	-86.97419	31.42669	100
Conecuh	2015	-87.19254	31.41929	100
Covington	2013	-86.26158	31.40273	25
Covington	2013	-86.27372	31.37176	87.5

(continued)

FIGURE 4

Phakopsora pachyrhizi sporulating on inoculated kudzu leaflet exhibiting a susceptible reaction by the host.

TABLE 1 (continued)

County	Year	Longitude	Latitude	% inoculated leaflets testing positive for <i>P. pachyrhizi</i> ^x
Covington	2013	-86.27454	31.35539	0
Covington	2013	-86.26357	31.32477	100
Covington	2013	-86.16821	31.28024	87.5
Crenshaw	2013	-86.30804	31.96614	100
Crenshaw	2013	-86.31364	31.95585	0
Crenshaw	2013	-86.31620	31.93470	75
Crenshaw	2013	-86.30049	31.89181	100
Crenshaw	2013	-86.29179	31.85618	100
Crenshaw	2013	-86.29148	31.76387	100
Crenshaw	2013	-86.26637	31.68729	87.5
Crenshaw	2013	-86.29149	31.76387	0
Crenshaw	2013	-86.24606	31.56206	100
Crenshaw	2013	-86.23651	31.52403	87.5
Crenshaw	2013	-86.26637	31.68729	0
Dale	2013	-85.67585	31.31226	75
Dale	2013	-85.60229	31.38341	100
Dale	2013	-85.61353	31.41917	87.5
Dale	2013	-85.75029	31.56161	100
Dallas	2015	-87.08010	32.38870	100
Dallas	2015	-87.23695	32.30776	100
Dallas	2015	-87.08010	32.38870	100
Elmore	2015	-85.89438	32.52064	40
Elmore	2012	-85.89008	32.49565	0
Elmore	2012	-87.47950	32.58639	0
Elmore	2012	-85.47558	32.58639	0
Elmore	2012	-85.49424	32.57386	0
Elmore	2012	-85.14740	32.57386	0
Elmore	2015	-85.87224	32.54546	100
Henry	2012	-85.31996	31.41271	0
Henry	2012	-85.47221	32.58617	30
Henry	2013	-85.27863	31.62697	25
Henry	2013	-85.27740	31.59893	0
Henry	2013	-85.28170	31.57510	75
Henry	2013	-85.29098	31.53439	0
Henry	2013	-85.31996	31.41271	0
Lee	2012	-85.48803	32.58060	0
Lee	2013	-85.50591	32.56130	0
Lee	2013	-85.49424	32.57386	0
Lee	2013	-85.50929	32.55336	0
Lee	2013	-85.52171	32.54137	0
Lee	2013	-85.54382	32.57376	12.5
Lee	2013	-85.52531	32.56102	0
Lee	2013	-85.33694	32.59236	0
Lee	2012	-85.48957	32.58756	0
Lee	2013	-85.47550	32.58639	75
Lee	2013	-85.47221	32.58617	75
Lee	2013	-85.47317	32.57864	37.5
Lee	2013	-85.47874	32.57949	25
Lee	2013	-85.54180	32.59364	0
Lee	2013	-85.50839	32.61006	0
Lee	2013	-85.50571	32.61922	0
Lee	2013	-85.37193	32.62571	0
Lee	2013	-85.34566	32.60605	0
Lee	2013	-85.29864	32.55483	0
Lowndes	2012	-86.57468	32.17520	100
Lowndes	2015	-86.55019	32.05046	100
Lowndes	2012	-86.72635	32.26972	30
Lowndes	2012	-86.75752	32.27716	60
Macon	2015	-85.75622	32.29405	10
Macon	2015	-85.54731	32.49684	100
Macon	2015	-85.57990	32.46782	100

(continued)

TABLE 1 (continued)

County	Year	Longitude	Latitude	% inoculated leaflets testing positive for <i>P. pachyrhizi</i> ^x
Macon	2015	-85.64230	32.44640	100
Macon	2015	-85.71646	32.40694	20
Macon	2015	-85.85701	32.37781	80
Marengo	2015	-87.65491	32.03392	60
Marengo	2015	-87.78632	32.05818	80
Marengo	2015	-87.76596	32.19867	20
Marengo	2015	-87.61933	32.26664	100
Marengo	2012	-87.97730	32.11210	20
Mobile	2015	-88.01749	31.08700	75
Mobile	2015	-88.02584	30.99238	75
Mobile	2012	-88.15880	30.81597	70
Mobile	2012	-88.19938	30.91980	40
Monroe	2015	-87.38519	31.48940	100
Monroe	2012	-87.49858	31.51941	10
Monroe	2012	-87.29128	31.42879	80
Monroe	2012	-87.44185	31.50643	50
Montgomery	2013	-86.28918	32.02144	50
Montgomery	2013	-86.29149	31.98680	0
Pike	2013	-85.80569	31.62666	100
Pike	2013	-85.82790	31.71491	100
Pike	2013	-85.71538	31.98414	80
Pike	2013	-85.89204	31.76046	100
Pike	2013	-85.96848	31.78795	75
Pike	2013	-85.95784	31.82557	100
Pike	2013	-85.84092	31.81647	100
Pike	2012	-85.89204	31.76046	10
Randolph	2012	-85.40723	33.18975	25
Randolph	2015	-85.36218	33.11723	0
Randolph	2012	-85.50471	33.30888	25
Russell	2012	-85.17924	32.34747	100
Russell	2012	-85.17130	32.11315	0
Russell	2013	-85.17195	32.30000	0
Russell	2013	-85.17130	32.11315	100
Russell	2013	-85.17924	32.34747	30
Russell	2012	-85.33694	32.59236	0
Russell	2013	-85.18923	32.40083	0
Russell	2012	-85.18923	32.40083	0
Russell	2013	-85.18505	32.37006	0
Sumter	2012	-88.18961	32.36031	0
Tallapoosa	2015	-85.87224	32.54546	0
Washington	2012	-87.97923	31.49948	100
Wilcox	2015	-86.91171	31.99211	0
Wilcox	2015	-86.99848	32.00682	0
Wilcox	2015	-87.09767	31.98437	0
Wilcox	2015	-87.28701	31.99202	40
Wilcox	2015	-87.53231	31.97918	0
Wilcox	2012	-87.60654	32.00899	10
Wilcox	2012	-87.28333	32.00126	30
Wilcox	2012	-87.00548	32.00577	0

^x Minimum of 10 leaflets inoculated in 2012; eight leaflets in 2013; and five leaflets in 2015. Scoring was determined by the presence or absence of pustules with spores on the leaf surface.

In their distribution across the sampled areas, there was no consistent pattern of resistant sites (Fig. 5). This trend was also observed by Jordan et al. (2010) for kudzu patches in North Florida, and by Bonde et al. (2009) in Kentucky, Louisiana, Mississippi, and North Carolina. This result was not unexpected based on the genetic diversity observed among kudzu populations. Sun et al. (2005) reported that kudzu populations in the south-

eastern United States were genetically diverse among populations, but had little diversity within populations, indicating multiple introductions with inbreeding within these populations. However, there was at least one case where SBR-resistant kudzu populations appeared to be grouped together in a single county. This was observed in 2015 when four of five kudzu populations sampled from Wilcox County were determined to be resistant to *P. pachyrhizi*. There were other instances where populations located within a few miles of one another were also observed to be resistant to the pathogen. It is possible this goes back to how these populations were first established in the state. In the 1930s, the Soil Conservation Service employed hundreds of people in the Civilian Conservation Corps to plant kudzu for erosion control (Britton et al. 2002; Everest et al. 1999). It is likely that kudzu with a similar genotype was planted in clusters across the south, with further spread locally by birds and animals.

MAPPING KUDZU POPULATIONS SAVE TIME AND MONEY

Results from our study show that approximately 34% of kudzu sites in south and central Alabama are resistant to *P. pachyrhizi*. Mapping these sites using GPS coordinates along with marking kudzu patches susceptible to the disease will enable scouts to focus their efforts on areas more likely to exhibit early symptoms of SBR. This increased efficiency will result in a cost-savings to the monitoring program.

Historically, monitoring the sites outlined in this study involves having two scouts traveling in one vehicle once a week for 24

weeks (late January through the end of July) on an approximately 300 mile journey that alternates between two set circular routes and takes 13 h to complete on average. The total cost to the SBR monitoring program for this 24-week period at this time comes to \$7,375.44, which includes a \$30 per diem, \$0.54 in mileage reimbursement, and \$188.50 in wages (@ \$7.25/hour). Using our new GPS coordinates of confirmed SBR-susceptible kudzu sites, we have been able to reduce our total cost to \$5,525.16 by requiring only one person to complete each scouting mission. By eliminating the per diem and wages for one individual, we have reduced our costs by approximately 25% for this portion of the SBR monitoring program in Alabama. These numbers will vary from year to year depending on various factors such as fluctuation in the movement of SBR within the state and/or how early the pathogen is detected in a county. Typically, when environmental conditions favor the rapid spread of SBR in Alabama, it can often be observed in multiple locations and counties in a single day. In our program, we rarely return to a county to scout for SBR after the disease has been detected. At that point, we have shifted our focus to soybean sentinel plots and commercial soybean fields in the central and northern sections of the state.

The ability to scout kudzu from late January through the end of July is a vital component of the SBR monitoring program in Alabama. By conducting this project, we have identified and mapped the location throughout central and south Alabama of kudzu populations that are susceptible or resistant to *P. pachyrhizi*. In doing so, we have increased our efficiency in monitoring for the disease and reduced the cost associated with the scouting program, thus potentially making the program more sustainable. This is important, as the funding available for SBR monitoring has declined significantly since 2005 (Allen et al. 2014; Sikora et al. 2014).

ACKNOWLEDGMENTS

This project was supported with funding from the Alabama Soybean Producers. We also thank Dr. Tom Allen from Mississippi State University for his thorough review of this manuscript.

LITERATURE CITED

- Alabama Cooperative Extension System. 2013. Making a difference in every corner of the state. 2012 Annual Report, ACES-0001. Auburn, AL. <http://www.aces.edu/pubs/docs/A/ACES-0001/ACES-0001.pdf>.
- Allen, T. W., Hollier, C. A., and Sikora, E. J. 2014. A continuing saga: Soybean rust in the continental United States, 2004 to 2013. *Outlooks Pest Manage.* 25:167-174.
- Bonde, M. R., Nester, S. E., Moore, W. F., and Allen, T. W. 2009. Comparative susceptibility of kudzu accessions from the southeastern United States to infection by *Phakopsora pachyrhizi*. *Plant Dis.* 93:593-598.
- Britton, K. O., Orr, D., and Sun, J. 2002. Kudzu. Pages 325-326 in: *Biological Control of Invasive Plants in the Eastern United States*. R. Van Driesche, ed. USDA Forest Service Publ. FHTET-2002-04. Washington, DC
- Everest, J. W., Miller, J. H., Ball, D. M., and Patterson, M. 1999. Kudzu in Alabama history, uses, and control. Alabama Coop. Ext. System (ACES), ANR-65. Auburn, AL.
- Giesler, L. J., and Hershman, D. E. 2005. Overview and value of sentinel plots for 2005. *Proc. 2nd Nat. Soybean Rust Sym. American Phytopathology Society*, St. Paul, MN.
- Hershman, D. E., Sikora, E. J., and Giesler, L. J. 2011. Soybean Rust PIPE: Past, present, and future. *J. Integr. Pest Manage.* doi:10.1603/IPM11001.
- Jordan, S. A., Mailhot, D. J., Gevens, A. J., Marois, J. J., Wright, D. L., Harmon, C. L., and Harmon, P. F. 2010. Characterization of kudzu (*Pueraria* spp.) resistance to *Phakopsora pachyrhizi*, the causal agent of soybean rust. *Phytopathology* 100:941-948.
- Miller, J. H., and Edwards, B. 1983. Kudzu: Where did it come from and how can we stop it? *South. J. Appl. For.* 7:165-169.

FIGURE 5

Map of Alabama showing locations of 162 kudzu populations in 30 southern counties marked SBR-susceptible/positive (red) or SBR-resistant/negative (blue) by GPS coordinates.

- Mullen, J. M., Sikora, E. J., McKemy, J. M., Palm, M. E., Levy, L., and Devries-Paterson, R. 2006. First report of Asian soybean rust caused by *Phakopsora pachyrhizi* on soybeans in Alabama. *Plant Dis.* 90:112.
- Oke, T. R. 1997. Urban climates and global change. Pages 273-287 in: *Applied Climatology: Principles & Practices*. R. D. Thompson and A. Perry, eds. Routledge, London, UK.
- Price, C. 2016. Alabama county estimates: Soybeans 2014-2015. USDA-NASS, Washington, D.C. <http://www.nass.usda.gov>.
- Schneider, R. W., Hollier, C. A., Whitam, H. K., Palm, M. E., McKemy, J. M., Hernandez, J. R., Levy, L., and Devries-Patterson, R. 2005. First report of soybean rust caused by *Phakopsora pachyrhizi* in the continental United States. *Plant Dis.* 89:774.
- Sikora, E. J. 2014. Kudzu: Invasive weed supports the soybean rust pathogen through winter months in southeastern United States. *Outlooks Pest Manage.* 25:175-179.
- Sikora, E. J., Allen, T. W., Wise, K. A., Bergstrom, G., Bradley, C. A., Bond, J., Brown-Rytlewski, D., Chilvers, M., Damicone, J., DeWolf, E., Dorrance, A., Dufault, N., Esker, P., Faske, T. R., Giesler, L., Goldberg, N., Golod, J., Gomez, I. R. G., Grau, C., Grybauskas, A., Franc, G., Hammerschmidt, R., Hartman, G. L., Henn, A., Hershman, D., Hollier, C., Isakeit, T., Isard, S., Jacobson, B., Jardine, D., Kemerait, B., Koenning, S., Langham, M., Malvick, D., Markell, S., Marois, J. J., Monfort, S., Mueller, D., Mueller, J., Mulroony, R., Newman, M., Osborne, L., Padgett, G. B., Ruden, B. E., Rupe, J., Schneider, R., Schwartz, H., Shaner, G., Singh, S., Stromberg, E., Sweets, L., Tenuta, A., Vaiciunas, S., Yang, X. B., Young-Kelly, H., and Zidek, J. 2014a. A coordinated effort to manage soybean rust in North America: A success story in soybean disease monitoring. *Plant Dis.* 98:864-875.
- Sikora, E. J., Conner, K., Delaney, D., Zhang, L., and Delaney, M. 2014b. Observations on soybean rust and soybean vein necrosis virus in Alabama in 2013. Page 14 in: *Proc. Southern Soybean Dis. Workers. 41st Annu. Meeting.*
- Sikora, E. J., Delaney, D., and Delaney, M. 2009. Developing an innovative team approach to address a newly introduced disease of soybeans in the United States. *JOE* 47:41AW7.
- Sikora, E. J., Delaney, D. P., and Delaney, M. 2013. Observations on soybean rust management in Alabama in 2012. Page 13 in: *Proc. Southern Soybean Dis. Workers. 40th Annu. Meeting.*
- Sikora, E., and Hershman, D. 2008. Soybean rust in review: 2004-2007. Pages 20-28 in: *Using Foliar Fungicides to Manage Soybean Rust*. A. E. Dorrance, M. A. Draper, and D. E. Hershman, eds. NC-504 Land-Grant Univ. Coop. SR-2008. <http://oardc.osu.edu/soyrustr/>.
- Sun, J. H., Li, Z. C., Jewett, D. K., Britton, K. O., Ye, W. H., and Ge, X. J. 2005. Genetic diversity of *Pueraria lobata* (kudzu) and closely related taxa as revealed by inter-simple sequence repeat analysis. *Weed Res.* 45:255-260.