A Coordinated Effort to Manage Soybean Rust in North America: A Success Story in Soybean Disease Monitoring

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Existing crop monitoring programs determine the incidence and distribution of plant diseases and pathogens and assess the damage caused within a crop production region. These programs have traditionally used observed or predicted disease and pathogen data and environmental information to prescribe management practices that minimize crop loss (3,69). Monitoring programs are especially important for crops with broad geographic distribution or for diseases that can cause rapid and great economic losses. Successful monitoring programs have been developed for several plant diseases, including downy mildew of cucurbits, Fusarium head blight of wheat, potato late blight, and rusts of cereal crops (13,36,51,80).

A recent example of a successful disease-monitoring program for an economically important crop is the soybean rust (SBR) monitoring effort within North America. SBR, caused by the fungus Phakopsora pachyrhizi Sydow, was first identified in the continental United States in November 2004 (59; Sidebar 1: Soybean Rust Cycle). SBR causes moderate to severe yield losses globally (6,25,42,54). The fungus produces foliar lesions on soybean (Glycine max Merrill) and other legume hosts. P. pachyrhizi diverts nutrients from the host to its own growth and reproduction. The lesions also reduce photosynthetic area. Uredinia rupture the host epidermis and diminish stomatal regulation of transpiration to cause tissue desiccation and premature defoliation (Fig. 1) (6). Severe soybean yield losses can occur if plants defoliate during the mid-reproductive growth stages (25,38).

Since 2004, soybean has been produced on approximately 30 million hectares annually in the United States, with a value between $18 billion and $32 billion (74). Therefore, the threat of this destructive disease warranted the attention of farmers, agricultural industries, university scientists, and national and state/provincial governmental agencies. The rapid response to the threat of SBR in North America resulted in an unprecedented amount of information dissemination and the development of a real-time, publicly available monitoring and prediction system known as the Soybean Rust-Pest Information Platform for Extension and Education (SBR-PIPE). Several comprehensive reviews of SBR and the SBR-PIPE were published (6,21,23,29,33,79). The objectives of this article are (i) to highlight the successful response effort to SBR in North America, and (ii) to introduce researchers to the quantity and type of data generated by SBR-PIPE. Data from this system may now be used to answer questions about the biology, ecology, and epidemiology of an important pathogen and disease of soybean.

Soybean Rust Origin and Impact

SBR was first reported in Japan in 1902 and confirmed in several other Asian countries and Australia by 1934 (7,27). The disease was reported in Africa (Kenya, Rwanda, and Uganda) in the mid-1990s (54,55). Wind currents may have dispersed the pathogen from southern Africa to South America, where it was first reported in Paraguay in 2001 (47,48,83). Within 3 years, SBR was widespread throughout South America, causing significant yield losses in soybean. During 2003, P. pachyrhizi was detected in the soybean-producing regions of Brazil and reduced yields by an estimated 2.2 million metric tons, or approximately 5% of annual production (48,57,83). Although SBR was first reported in the United States in 1994 on cultivated soybean in Hawaii (35), it is unlikely that P. pachyrhizi reached the mainland from this pathogen source (22).

Planning for SBR in North America

In a proactive approach to prepare for the potential arrival of SBR, scientists in the United States created predictive yield loss estimates for soybean production areas in North America, based on the pattern of spread of P. pachyrhizi in South America (29,83). These estimates were at least 10% of annual soybean yield in the north-central United States and 50% or greater in the southeastern United States if infection occurred at an early phenological stage of soybean development (82). Initial predictions, based on high levels of overwintering inoculum, suggested that without effective management, losses in soybean could exceed 80% (8,25). In 2004, the United States Department of Agriculture (USDA) Economic Research Service estimated that annual net economic losses would range from $240 million to $2 billion, depending on the severity and extent of subsequent outbreaks (40).

University plant pathologists and scientists from the USDA-Animal Plant Health Inspection Service (USDA-APHIS) and USDA-Agricultural Research Service (USDA-ARS) and the Ontario Ministry of Agriculture and Food mobilized in January of 2003 to form a North Central Regional Association (NCRA) committee designated NC-504 “Soybean Rust: A New Pest of Soybean Production” to prepare for the anticipated arrival of SBR in continental North America. The purpose of the committee was to develop plans for SBR detection, monitoring, and management, and to develop educational materials for other scientists and agribusiness personnel, including farmers.

One of the first limitations to SBR management was that few foliar fungicides were labeled for use on soybean in North America in 2003. Fungicide applications are the primary management tool...
In cooperation with the Environmental Protection Agency (EPA), a template was developed in 2003 to facilitate submisions of Section 18 emergency use application labels for each soybean-producing state. In Canada, a similar process of emergency use registrations was established by the Pest Management Regulatory Agency (14). Fungicides selected for Section 18 applications were based in part on product performance in fungicide efficacy trials conducted in Africa and South America (39,43–46). As a result, eight fungicides received EPA Section 18 emergency registration in the United States, and four fungicides were labeled in Canada.

In addition to increasing SBR management options, numerous education efforts were implemented before detection of SBR in North America. Plant pathologists in soybean producing states and Canadian provinces informed farmers and other stakeholders about SBR at county, state, and regional meetings. Meetings were also conducted in conjunction with the American Soybean Association (ASA) and national and state/provincial soybean commodity boards to help farmers become better informed about the impacts and potential spread of SBR within North America.

**Time to Monitor: Detection of SBR in North America**

SBR was first detected in the continental United States in the fall of 2004 in a soybean field near Baton Rouge, LA (60,68). The disease was observed in eight additional southern states in subsequent weeks (58). These detections followed the inland track of Hurricane Ivan, which made landfall on 16 September 2004 near Gulf Shores, AL. *P. pachyrhizi* may have been transported to the United States from the Caribbean or South America in this tropical weather system (31,33).

The detection of SBR in soybean resulted in the rapid development of tools to monitor and predict disease impact for the 2005 growing season and beyond. The NC-504 group began to disseminate information on SBR at state, national, and international levels. This group (which evolved into the North Central Extension and Research Activity or NCERA-208 “Response to emerging threat: Soybean rust” Committee in 2006) coordinated a weekly conference call during the growing season among state extension specialists and soybean researchers. The calls provided updates on SBR confirmations and coordinated management efforts across multiple states. These conference calls had as many as 40 participants weekly from North America.

During February of 2005, the USDA unveiled a coordinated framework for SBR surveillance, reporting, prediction, management, and outreach (33,75–78). The framework linked federal and state/provincial agencies, soybean farmers, and agricultural industry representatives. North American soybean stakeholders were
now equipped with a critical decision support system to assist in managing SBR. The USDA-Risk Management Association (RMA) provided funding for SBR surveillance and monitoring to allow real-time reporting and mapping of the disease and models to simulate and predict disease spread. The goal of the framework was to reduce economic losses from SBR. The framework included cooperation and support from USDA agencies such as APHIS, ARS, and the Cooperative State Research Education and Extension Service (CSREES), as well as national and state/provincial soybean commodity groups, and state departments of agriculture. A comprehensive overview of the SBR-PIPE development and funding structure can be found in VanKirk et al. (79).

The aforementioned framework and collaborative effort among agencies was the driving force behind the development of the SBR-PIPE (32,33). One of the goals in developing the SBR-PIPE was to provide stakeholders with a coordinated and comprehensive website where they could obtain: (i) accurate and near real-time information on the distribution and severity of SBR in North America; (ii) time-sensitive SBR risk assessments; (iii) information on SBR management options; and (iv) links to educational tools for SBR (5,18,29,63).

SBR-PIPE is a real-time system used to monitor distribution and severity of SBR and provide a “warning” network for tracking the spread of the disease in North America (18) (Fig. 2). A large, coordinated effort is required to obtain the data necessary to populate SBR-PIPE and develop predictive models on \( P. pachyrhizi \) dispersal and disease development. These data are generated primarily from the disease monitoring efforts of those involved in the SBR “sentinel” plot program. The sentinel plot program, although independent of the SBR-PIPE, provides the bulk of the data for SBR-PIPE observations and predictive models. Since 2005, the monitoring efforts essential for maintaining the sentinel plot network have been funded through the USDA, the United Soybean Board (USB), the North Central Soybean Research Program (NCSRP), the Grain Farmers of Ontario in Canada, and numerous Qualified State Support Boards (QSSBs).

The disease-monitoring network consists of soybean sentinel plots established in multiple locations within cooperating states and provinces. Several papers are available describing the details of the sentinel plot monitoring system (19,28,29). These plots typically are planted earlier than commercial soybeans to provide an early warning system for commercial soybean fields. The plots utilize a variety of soybean maturity groups to extend monitoring throughout the season. Additional hosts of \( P. pachyrhizi \) are also monitored for SBR, including kudzu (\( Pueraria montana var. lobata \) (Wild.) Sanjappa & Predeep) (Fig. 3), coral bean (\( Erythrina herbacea \) L.), and Florida beggarweed (\( Desmodium tortuosum \) (Sw) DC.) (11,17,62) (Sidebar 2: Kudzu in the city: Soybean rust overwintering in urban environments). For a complete list of currently recognized hosts of \( P. pachyrhizi \), see Ryttie et al. (59), and Slaminko et al. (66,67).

SBR monitoring begins with collecting and observing leaves from sentinel plots at regular intervals throughout the season (Fig. 4). For example, in Alabama and many other states, soybean sentinel plots are sampled every 2 weeks prior to soybean flowering (flowering signifies growth stage R1 [16]), then weekly thereafter. Plots are primarily monitored by individuals trained in SBR identification under the guidance of the state SBR coordinator. Because SBR is difficult to detect at low incidence within fields, many individuals collect leaves and confirm the disease under controlled laboratory conditions. Leaves are examined under a dissecting microscope (×100 magnification) following a 24- to 48-h incubation period to promote sporulation. At this magnification, pustules of \( P. pachyrhizi \) can be observed, confirming the presence of the pathogen. Consequently, SBR can be detected when three to four pustules are present on a single soybean leaflet, which can be difficult to detect using traditional field scouting methods.

Fig. 1. Symptoms and signs of soybean rust caused by Phakopsora pachyrhizi on soybean. A, Initial symptoms appear as small, brown or brick-red lesions on the upper leaf surface. B, Pustules form primarily on undersides of leaves. C, Infected leaves turn yellow. D, Soybean plants severely affected by soybean rust defoliate prematurely resulting in yield loss.
Monitoring for SBR also occurs in commercial soybean fields to supplement the data derived from sentinel sites. This “as needed” scouting approach has been termed “mobile-scouting” and evolved into the main form of SBR monitoring in states where SBR occurs rarely. Disease observations are collected and data uploaded into the SBR-PIPE database managed by ZedX, Inc., where they are available for a variety of uses. The primary purpose of the observation data are to populate a publically available map of North America to indicate presence and location of SBR and provide state-specific commentary on risk and management to stakeholders. Extension specialists also can access predictive models for the spread and dispersal of SBR. *P. pachyrhizi* urediniospores can be transported long distances by wind currents (1,2,37), and accurate predictions of pathogen movement and spore deposition can improve regional suggestions for timely fungicide applications.

**Predictive Modeling for SBR**

One of the active modeling systems adapted to monitor the movement of *P. pachyrhizi* is the Hybrid Single-Particle Lagrangian Integrated Trajectory, or HYSPLIT model (15). The HYSPLIT model is maintained by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, and was originally intended to track the atmospheric transport and deposition of pollutants and hazardous materials on wind currents from a known point source (15). The HYSPLIT model was adapted for use with SBR, and creates a three-dimensional prediction of possible spore dispersal and concentration using wind current data available from NOAA. Initially, this and other experimental spore deposition models were available to university specialists having access to a secure and restricted website within the SBR-PIPE platform. These models predicted potential inoculum dispersal and spread using confirmed disease observations from the monitoring program. Based on model predictions, additional scouting occurred in areas of putative inoculum deposition. Field observations from the disease-monitoring program are the most important data used to develop predictive models for SBR development (2,31,37,72,81). The HYSPLIT model is often used in predictive modeling for future SBR events.

![Fig. 2. Example of soybean rust monitoring observations from the publically available SBR-PIPE website: http://www.sbrusa.net. Map depicts observations and reports from 30 September 2008.](image)

![Fig. 3. The perennial weed kudzu (*Pueraria montana* var. *lobata*) serves as the primary overwintering host of *Phakopsora pachyrhizi* in the southern United States. Kudzu is an invasive plant prevalent throughout the southern United States, A, covering large open areas, and B, in secluded areas. *P. pachyrhizi*-infected leaves survive the winter months in several settings, including (C) urban areas.](image)
In addition to the HYSPLIT model, the Soybean Rust Aerobiology Prediction System (SRAPS) was created as an application of the Integrated Aerobiology Modeling System, or IAMS (31). Initially created to predict introduction potential of important invasive plant pathogens, IAMS uses large, archived meteorological data sets to determine potential *P. pachyrhizi* deposition events. The model uses disease-monitoring observations on the SBR-PIPE, and daily predicts where spores will be deposited. Predicted spore depositions are mapped and uploaded onto the restricted website to be used by university extension specialists (30,32). This model was used to further support the notion that SBR inoculum likely arrived in the continental United States in association with Hurricane Ivan (31,33).

At the public level, data from these and other SBR-PIPE models and the results from the disease-monitoring program are integrated into maps that illustrate SBR distribution. Stakeholders are advised of the status of SBR monitoring activities and risk of SBR development with an SBR-observation map of North America on the public SBR Website (Fig. 2). This map includes links to both national and state commentaries. State extension coordinators supply state-specific commentary as to where SBR has been detected, the extent of infection (incidence and severity), crop or plant growth stage, risk advisories, and suggested management practices.

Initially, a total of 35 states within the United States and five Canadian provinces established soybean sentinel plots for SBR monitoring in 2005. Since 2004, SBR has been reported from 20 states and as far north as Ontario, Canada. SBR has been monitored on a near-daily basis since 2005 through the use of over 4,500 sentinel plots. These data are analyzed and used to create maps and inputs for the models described above to predict where and when SBR is most likely to develop in North America. The number of sentinel plots (soybean and other hosts) in North America peaked at 984 in 2008, and has gradually declined to 285 in 2012. The decline is in part due to reduced funding for monitoring efforts across the United States, particularly in northern states where the disease has not been a significant problem to date (Sidebar 3: Soybean rust in the north: The disease that cried wolf).

In addition to documenting the location and distribution of SBR in the United States, the SBR-PIPE also collects and stores data for epidemiological research. The system quantifies the timing and amount of in-season and overwintering *P. pachyrhizi* spore produc-

**Sidebar 2: Kudzu in the city: Soybean rust overwintering in urban environments**

![Sidebar Fig. 2 A, Phakopsora pachyrhizi-infected kudzu surviving the winter in downtown Montgomery, AL along a southeast facing wall of an abandoned business; B, covering an abandoned building in an urban area; and C, growing on an abandoned house.](image)

Initially, it was believed that *Phakopsora pachyrhizi* could only overwinter between growing seasons along the Gulf Coast because all known hosts could not survive extended periods of freezing temperatures (54). Opinions changed when soybean rust (SBR) was detected in kudzu patches in an urban Montgomery, AL neighborhood in January of 2006 (Sidebar Fig. 2A and B) (65). Although most of the kudzu patches observed were dormant, remaining green foliage in these protected environments was infected with *P. pachyrhizi* (Sidebar Fig. 2C), thus allowing the pathogen to overwinter to a limited extent much farther north than originally predicted. In 2013, SBR was detected under a bridge in downtown Selma, AL over 200 km north of the Florida panhandle and the northernmost point where SBR has successfully overwintered in the United States. In addition to these isolated inland locations, *P. pachyrhizi* has been readily detected on kudzu during the winter in urban areas close to the Gulf Coast in Alabama, Florida, Georgia, and Louisiana. The significance of these isolated kudzu sites in relation to the overall SBR inoculum levels prior to the soybean growing season is not known. Kudzu and other hosts of *P. pachyrhizi* found in South Florida, Mexico, and the Caribbean Basin are generally considered more important sources of inoculum when considering a potential SBR epidemic in the United States. However, with the potential of climate change providing milder weather in the south during the winter months (26), these urban islands of SBR-infected kudzu could become an important source of inoculum in North America.
information on the inoculum load contributed from other known hosts of SBR is important to continued disease prediction and modeling efforts. Research on the influence of environmental variables upon disease development also has aided modeling efforts. Young et al. (84) reported that sunlight reduces survival of spores of \textit{P. pachyrhizi} in the upper soybean canopy, whereas spore viability and disease severity increased in the shaded, lower canopy. These findings suggest that spore survival within a canopy could impact disease development and models for disease spread.

Advancements in understanding diversity of \textit{P. pachyrhizi} in the United States also have influenced the development of management practices. The U.S. population of \textit{P. pachyrhizi} contains a high level of genetic diversity, which influences the ability to assess impact of disease spread and development, as well as attempts to develop rust-resistant soybean varieties (73,86). Despite these challenges, efforts to detect resistance within soybean germplasm accessions are ongoing. To date, five major resistance loci (\textit{Rpp1}, \textit{Rpp2}, \textit{Rpp3}, \textit{Rpp4}, and \textit{Rpp5}) have been identified for SBR (53). Due to the genetic diversity within \textit{P. pachyrhizi} populations, there is a need to explore breeding for partial resistance, and to screen existing commercial and public lines for minor genes (24). Partial resistance may be a more durable and useful management tool, especially because questions remain as to how cultivars with monogenic resistance should be integrated into widespread commercial production, given the limited spread of the disease into the major soybean producing regions of North America.

The coordinated efforts by federal and state agencies, stakeholders, and the agricultural industry to combat the disease have largely fallen to the NCERA-208 committee, which continues today. It is estimated that this collaborative multi-state project saved North American soybean farmers over $600 million between 2006 and 2011 in unnecessary fungicide costs, thereby reducing chemical exposure to the environment and food supply, and diminishing apprehension within the soybean industry (12). NCERA-208 promotes productive interactions among extension and research scientists, soybean farmers, and the agricultural industry, mobilizes regional resources, and builds relationships with international partners in Canada and Mexico to provide a structured, North American response to SBR.

Currently, successful SBR management is achieved through well-timed applications of fungicides. Current members of
NCERA-208 continue to assist in evaluating fungicides for efficacy to determine effective rate, timing, and number of applications per season needed to protect against SBR (Fig. 5). The number of fungicide trade products labeled to manage SBR increased from five in 2002 to approximately 70 in 2010 (20). The SBR-PIPE also aids in preventing unwarranted fungicide applications by providing information on where SBR is not considered a threat to soybean production. It is estimated that the SBR-PIPE system saves farmers over $200 million annually in unnecessary fungicide applications (28,29,56). In a 2008 survey of U.S. certified crop advisors (CCAs), a majority of respondents indicated that the SBR-PIPE is a valuable tool and that they were somewhat to very confident in the observations provided by the sentinel plot network. Of the 361 survey respondents across 7 states, 60.8% responded that they would be very concerned if the SBR sentinel plot network were to be discontinued (5). These survey results indicate the value of this program to stakeholders.

The detection of SBR in North America also allowed extension specialists and educators to train a generation of soybean farmers and agricultural professionals in the science of plant pathology. Training programs incorporate educational materials including scouting videos, field identification cards in multiple languages, radio and television broadcasts, telephone hotlines, twitter accounts, websites, newsletters, and blogs. Additionally, over 200,000 manuals entitled *Using Foliar Fungicides to Manage Soybean Rust* were distributed (http://oardc.osu.edu/soyrust/) (Sidebar 4: Extension in action: Impact of soybean rust educational materials). Scientists have also shared their knowledge through symposia, conferences, and workshops devoted to SBR (Fig. 6). Monitoring and education programs for SBR have also made many in agribusiness more aware of other soybean diseases, foliar fungi-cides, and spray application technology. Farmers now have a greater understanding of the role of the environment on disease development and have new management tools at their disposal.

**Table 1.** Total number of soybean rust monitoring observations uploaded to the Soybean Rust-Pest Information Platform for Extension and Education (SBR-PIPE) by individual country, state, and province collaborators from 2005 to 2012

<table>
<thead>
<tr>
<th>Soybean rust monitoring location</th>
<th>Individual observations submitteda</th>
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</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>2,797</td>
</tr>
<tr>
<td>Arkansas</td>
<td>3,682</td>
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<tr>
<td>Colorado</td>
<td>259</td>
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<td>1,180</td>
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<td>Florida</td>
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<td>Georgia</td>
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<td>Idaho</td>
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<td>Indiana</td>
<td>842</td>
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<td>Iowa</td>
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<tr>
<td>Kansas</td>
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<td>Ontario, Canada</td>
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<td>Mexico</td>
<td>7,087</td>
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<td>82,649</td>
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</table>

*a Totals by state/province or country include both positive and negative observations of disease on soybean and other hosts of *Phakopsora pachyrhizi*.

Fig. 5. Example of field plots set up for fungicide efficacy trials to determine effective rate, timing and number of applications needed to protect soybean against *Phakopsora pachyrhizi*.

Fig. 6. Participants in a soybean rust identification workshop held in Quincy, FL. The facility trained more than 700 people over 8 years.

Fig. 7. Commercial soybean field in Alabama experiencing severe defoliation from soybean rust in 2012.
Despite having extensive disease monitoring programs and predictive efforts in place, yield losses due to SBR still occur. The disease was especially problematic in Alabama during 2012, where SBR reduced yield by up to 60% in over 200 hectares of poorly managed soybeans (64) (Fig. 7). These losses are the greatest observed in the United States as a result of SBR, and are equivalent to those recorded in South America in the early 2000s (48,83). Farmers who lost yield to SBR claimed they did not apply a fungicide because the disease was not problematic for them in the two preceding years, which had been characterized as having environmental conditions unfavorable for SBR development. The farmers also did not react to SBR alerts provided through SBR-PIPE and the Alabama Cooperative Extension System early in the production season.

Unfortunately, SBR predictive models have not always been effective as an early warning system for potential disease development. The inability to accurately predict disease development may be due to several factors, most importantly the number and extent of unreported SBR infections in potential source regions. This factor has been enhanced by the recent reductions in disease monitoring observations uploaded to the SBR-PIPE. Additional research is needed to determine the impact of environment and production practices, such as fungicide use, on model accuracy. More importantly, despite gains in knowledge and improved prediction and management tools, challenges to implementing effective SBR management programs still exist.

Future of the Monitoring Network

The SBR monitoring program is now entering a new phase. Concern about the disease in the north-central United States has waned, and effective management strategies are now available across the southern United States. These factors have reduced the

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**Table 2. Number of individuals involved in soybean rust monitoring in the United States and Canada from 2007 to 2012**

<table>
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<th>Personnel category*</th>
<th>2007</th>
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<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<td>Extension educators</td>
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<td>250</td>
<td>209</td>
<td>122</td>
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<td>61</td>
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<td>Research associates</td>
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<td>34</td>
<td>37</td>
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<td>26</td>
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<tr>
<td>Graduate students</td>
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<td>1</td>
<td>18</td>
<td>2</td>
<td>9</td>
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<td>Consultants</td>
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<td>15</td>
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<td>11</td>
</tr>
<tr>
<td>Undergraduates</td>
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<td>20</td>
<td>21</td>
<td>21</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
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<td>Total</td>
<td>475</td>
<td>422</td>
<td>359</td>
<td>255</td>
<td>188</td>
<td>143</td>
</tr>
</tbody>
</table>

* Individuals are classified according to personnel employment category.

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University Extension specialists and researchers have provided many educational materials that have assisted farmers in identifying and managing soybean rust (SBR). These include scouting videos and DVDs, field disease identification cards printed in English, Spanish, and French, and numerous national or state-based fact sheets on the disease (Sidebar Fig. 3). The Extension product that has likely had the greatest impact is the *Using Foliar Fungicides to Manage Soybean Rust* manual (http://oardc.osu.edu/soyrust/). This 111-page manual was developed through the NCERA-208 “Response to emerging threat: Soybean rust” Committee, and printed by The Ohio State University. This book compiled the current knowledge on SBR, including information on the following topics: soybean growth and development, the causal pathogen *Phakopsora pachyrhizi*, sentinel plot monitoring, and disease risk assessment. Additionally, this manual provided important information on fungicide use in soybean, which was a new practice to many farmers in 2007. To date, more than 200,000 copies of this manual have been distributed in the United States, Canada, and Mexico. This book also served as one of the precursors of the new APS Press book, *Fungicides for Field Crops* (49).
interest and funding available for the applied field research required to adequately monitor and manage SBR. Even though the number of sentinel plots in North America has decreased by over 70% since 2008, the level of disease monitoring is still regarded as acceptable, due to increased efficiency and familiarity with the monitoring system and adoption of mobile scouting methods. In fact, the number of personnel (as determined by an annual survey of sentinel plot coordinators) involved in SBR scouting has been reduced from 475 people in 2007 to 143 people in 2012 (Table 2). The SBR monitoring program will remain effective as long as the SBR-PIPE infrastructure is maintained, and plant pathologists in the southern United States continue to monitor for early-season outbreaks.

The NCERA-208 group has shifted focus from responding to an emerging threat to maintaining an ongoing program of SBR monitoring and management. The group meets annually and conducts conference calls as needed to discuss SBR development during the growing season. Although the intensity of education efforts for SBR has decreased since 2005, the group has evolved to focus on improving management tools for SBR, and is applying lessons learned from SBR to other economically important diseases of soybean. For example, beginning in 2013, results from disease monitoring programs for the detection of QoI-fungicide-resistant isolates of Cercospora sojina Hara, causal organism of frogeye leaf spot of soybean, were added to the SBR-PIPE (85). The location of QoI-resistant isolates of C. sojina in the United States is available to farmers and agribusiness personnel via the public SBR-PIPE website. In addition, the PIPE platform coordinates programs and distributes information on other crops, including corn, cucurbits, legumes, and pecans (9,41,52,61). The SBR-PIPE will also provide access to data for those interested in analyzing and interpreting long-term data on P. pachyrhizi distribution and movement in North America. This vast database can now be used to answer epidemiological and biological questions on the pathogen and the disease. Additionally, the database encourages collaboration among plant pathologists and climatologists as we attempt to answer questions on the impact of changing environmental patterns and impact of tropical storms and hurricanes on SBR development and spread. Most importantly, scientists addressing emerging plant diseases can use the SBR monitoring program as an example of how to quickly and collaboratively provide effective disease monitoring and management information to stakeholders.

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