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

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# 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 disease 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.

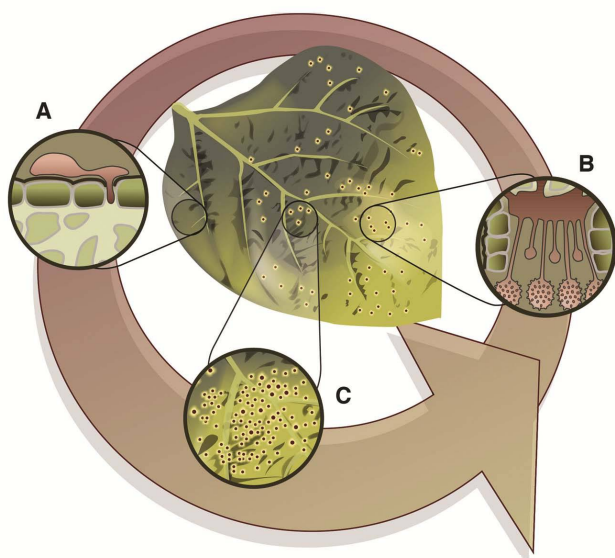
One of the first limitations to SBR management was that few foliar fungicides were labeled for use on soybean in North America in 2003. Fungicide applications are the primary management tool

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## Sidebar 1: Soybean rust disease cycle



**Sidebar Fig. 1.** Disease cycle of the soybean rust pathogen *Phakopsora pachyrhizi* (15). **A**, Urediniospore germination and leaf penetration. **B**, Pustules develop on infected leaves. **C**, Urediniospores produced in pustules can be dispersed on wind currents to other plants.

The urediniospore of *Phakopsora pachyrhizi* is the only spore stage known to infect host plants. The alternate host is still unknown. Urediniospores are carried to host plants by prevailing winds, and land on the upper surface of the leaf (Sidebar Fig. 1). If free water is present on the leaf surface, urediniospore germination will occur in 12 to 14 h under optimum temperatures (18 to 26°C). Relative humidity between 75 and 80% is generally necessary for urediniospore germination and leaf infection. Therefore, frequent rainfall and heavy dews favor infection and disease development. The fungus will form appressoria and directly penetrate the leaf. The first symptoms of the disease can be observed on the upper leaf surface approximately 4 days after infection. However, pustule formation and urediniospore release will not occur for at least 7 days after initial infection. A single pustule can produce urediniospores for up to 3 weeks. These urediniospores are wind-dispersed, resulting in additional infections near the initial disease focus, but long-distance dispersal also contributes to additional disease spread outside the local area. Rapid increases in disease incidence and severity coincide with soybean canopy closure and the beginning of crop flowering, which signifies reproductive growth (termed R1 in soybean [16]). The repeating stage of the disease cycle will continue until the plant is defoliated or environmental conditions no longer favor disease development. In rare situations, telia can form on infected leaves. However, the role of telia in soybean rust is unknown. In the United States, urediniospores survive on leaves of host plants, such as kudzu (*Pueraria montana* var. *lobata*), in areas that do not experience freezing temperatures. When conditions are favorable for disease development, urediniospore production increases, and urediniospores are dispersed to surrounding host plants, including soybean (*Glycine max*), thus initiating an annual disease cycle.

for this disease. In cooperation with the Environmental Protection Agency (EPA), a template was developed in 2003 to facilitate submissions 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).

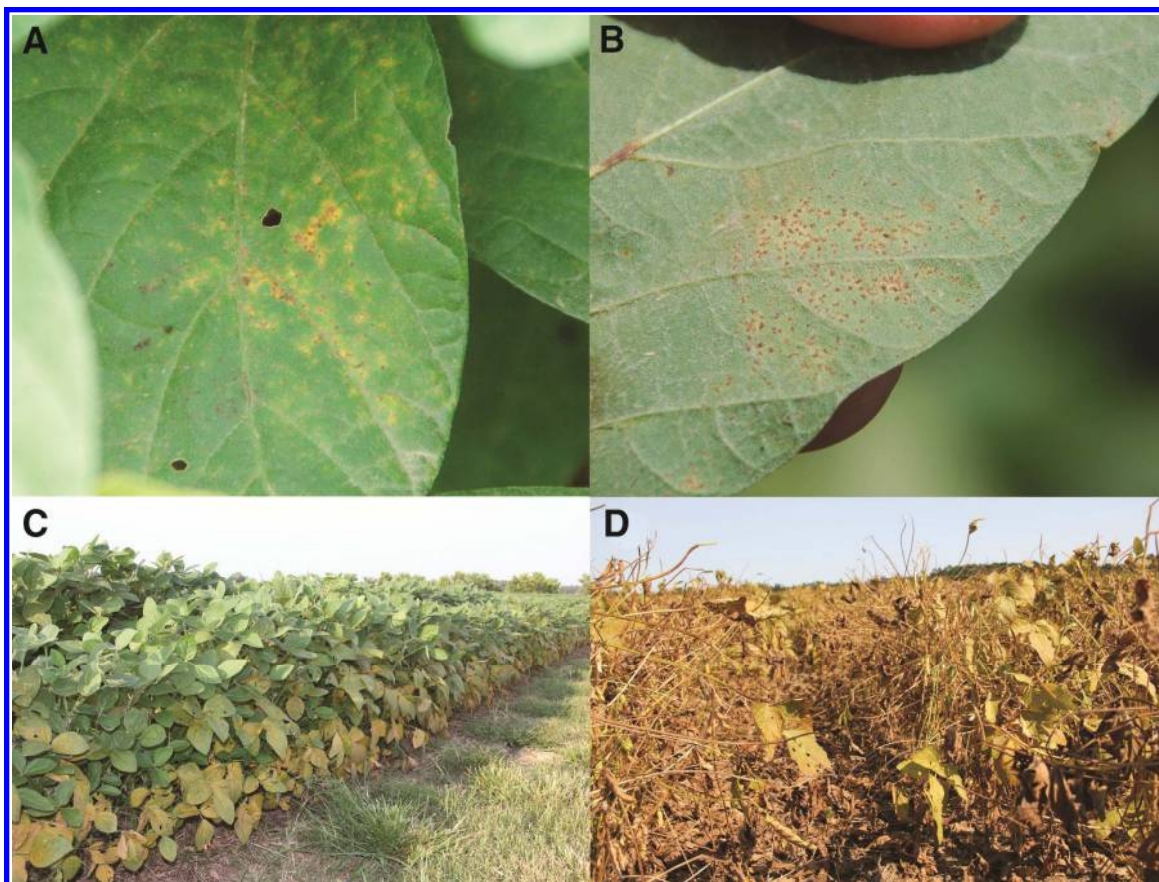
The aforementioned framework and collaborative effort among agencies was the driving force behind the development of the SBR-PIPE (32,33). One of the goals in developing the SBR-PIPE was to provide stakeholders with a coordinated and comprehensive website where they could obtain: (i) accurate and near 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* (Willd.) 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 Rytter 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.

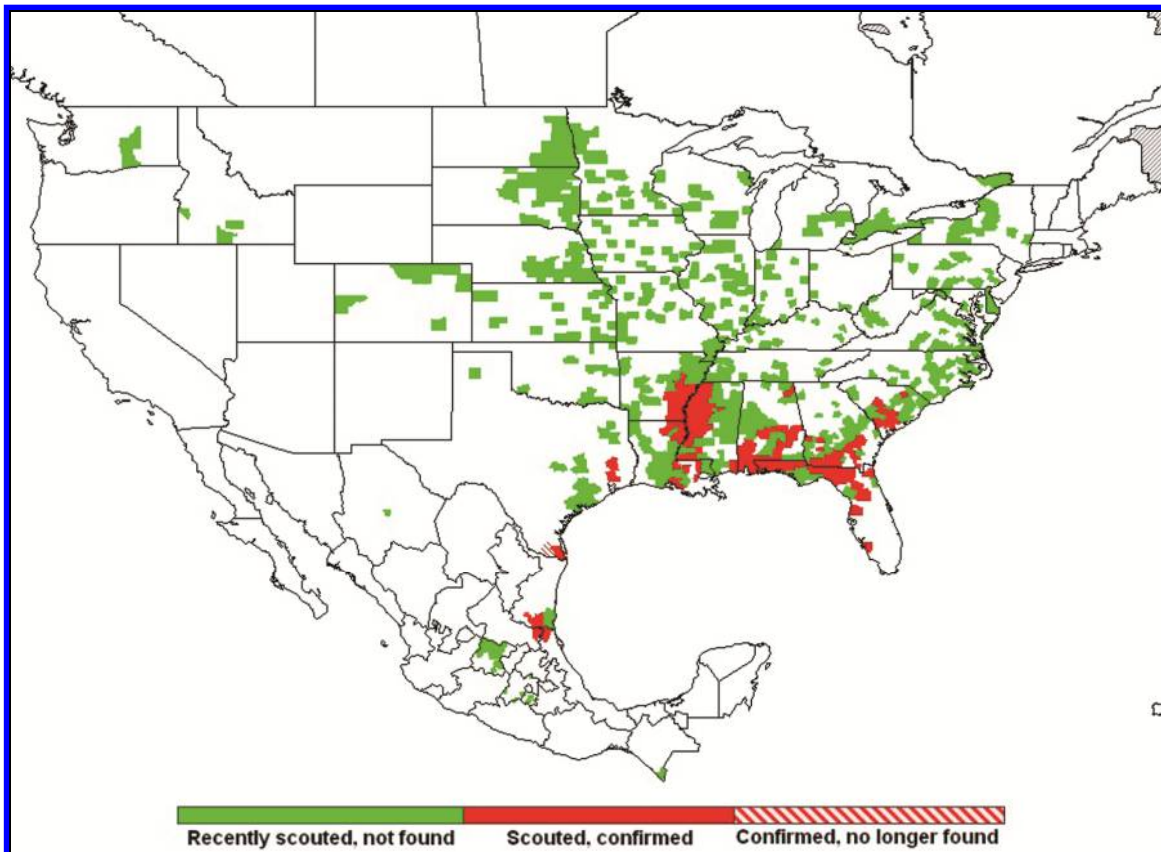


Fig. 2. Example of soybean rust monitoring observations from the publicly available SBR-PIPE website: <http://www.sbrusa.net>. Map depicts observations and reports from 30 September 2008.

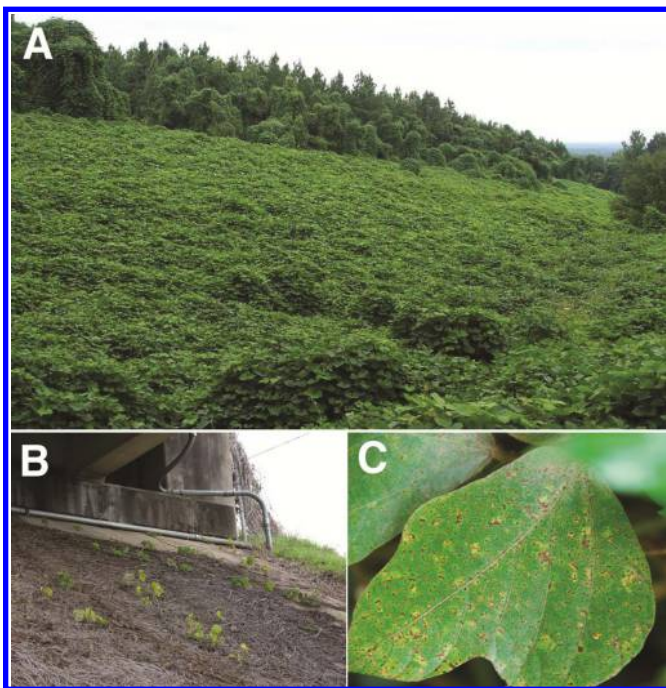


Fig. 3. The perennial weed kudzu (*Pueraria montana* var. *lobata*) serves as the primary overwintering host of *Phakopsora pachyrhizi* in the southern United States. Kudzu is an invasive plant prevalent throughout the southern United States, **A**, covering large open areas, and **B**, in secluded areas. *P. pachyrhizi*-infected leaves survive the winter months in several settings, including **(C)** urban areas.

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 publicly 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

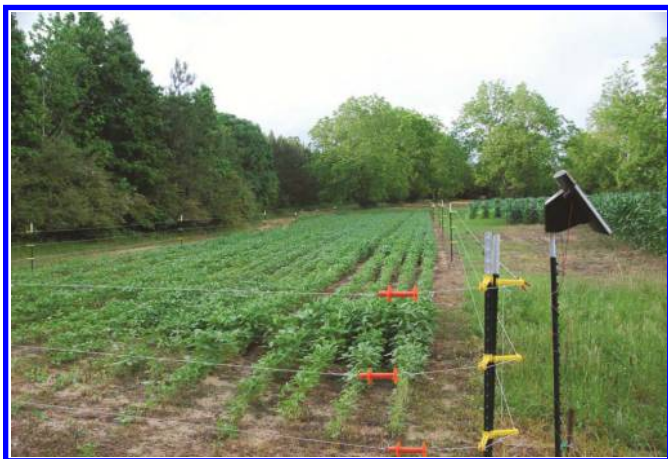
One of the active modeling systems adapted to monitor the movement of *P. pachyrhizi* is the Hybrid Single-Particle Lagrangian Integrated Trajectory, or HYSPLIT model (15). The HYSPLIT model is maintained by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, and was 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.

## 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.

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.



**Fig. 4.** Example of a soybean rust monitoring sentinel plot established in Amite County, Mississippi.

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 3: Soybean rust in the north: The disease that cried wolf

The unprecedented disease monitoring and education effort for soybean rust (SBR), while ultimately beneficial, also had unintended consequences. In the beginning, educational efforts in the major soybean producing regions in the North Central United States and Ontario, Canada, were especially intense, and hundreds of meetings were organized to train agribusiness personnel and farmers about the disease. The chemical industry prepared for SBR by ensuring ample amounts of fungicides were available to protect the millions of hectares of soybean in the north. After 2005, nearly everyone involved with soybean production and processing was informed about the threat of SBR. They could monitor the SBR-PIPE website and read updates in the media as they anxiously awaited the arrival of the disease in the north. There was much to prove with SBR—farmers had been assured that the disease could be detected and managed when it arrived in the north. So much work went into preparing for SBR that when the disease never materialized as a significant threat, it was a huge letdown for many. After a few years of constant vigilance for SBR, the tide turned and many in the northern agricultural community began to doubt that SBR was the threat it was portrayed to be. Interest in the disease waned, and the disease monitoring effort lost support financially and emotionally. The term “rust fatigue” was coined to describe the attitudes of people burned out on the intense disease monitoring programs, and also those in agribusiness who believed that the continued discussion of SBR by university personnel was similar to the classic Aesop’s fable: The Boy That Cried Wolf.

Despite this criticism, the monitoring and education programs made many in agribusiness more aware of other soybean diseases, foliar fungicides, and spray application technology. Chemical companies found new markets for fungicides, and agricultural retailers released stockpiled fungicides, beginning a trend of foliar fungicide use in soybean and other field crops, such as corn. The full impact that SBR could have on the northern United States may not yet be realized, but many university personnel still believe the concern about SBR was justified, given the lack of knowledge of this disease in temperate climates, the devastation it caused in Brazil, and a long history of rust diseases of other crops in North America.

tion for use in SBR aerobiology prediction models. The combination of long-term disease incidence and severity data, and environmental data housed within SBR-PIPE, represents the most extensive data set available on epidemic development and pathogen spread over eight growing seasons of any plant disease (71). Additionally, some datasets include multiple disease observations from the same site (sentinel plot or commercial soybean field) within a single growing season, strengthening the power of within-season and long-term data analysis. From 2005 to 2012, 82,649 observations were uploaded to the site (Table 1). These data are available to researchers by request, and could be used to answer many important epidemiological questions that still remain for SBR. For example, SBR-PIPE data collected from 2005 to 2011 have been modeled in several studies. One study concluded that the initial focus size of SBR is positively related to the final extent of continental disease spread on a national scale (50). Christiano and Scherm (10) used these data to study the epidemiological interactions of *P. pachyrhizi* in kudzu and soybean populations. Data used in each of these studies were all obtained from the publically available website (<http://SBR.ipmpipe.org/cgi-bin/SBR/public.cgi>) of the SBR-PIPE platform.

Although extensive data are available for analysis, the data interpretation can be difficult because not all datasets are uniform. Also, missing data or inconsistent data formats can complicate analyses. Even with a standard protocol in place, data are voluntarily contributed to SBR-PIPE, and not all data conform to protocol guidelines. These discrepancies can skew or bias analyses of data collected from public or private SBR-PIPE databases. NCERA-208 has formed a subcommittee to help those interested in analyzing available data to gain access to datasets and provide additional observations for accurate data interpretation.

#### Management Advances for SBR

The observations gained from disease monitoring have greatly improved our understanding of SBR and ability to manage the disease. For example, monitoring efforts have helped identify and quantify the role of additional hosts in rust development. Kudzu, the primary overwintering host of *P. pachyrhizi* in the southern United States, is genetically diverse. Biotypes exist that resist disease development, which influences the potential for inoculum development and predicted disease dispersal (4,34,70). Additional

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 *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 *P. pachyrhizi* in the United States also have influenced the development of management practices. The U.S. population of *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 (*Rpp1*, *Rpp2*, *Rpp3*, *Rpp4*, and *Rpp5*) have been identified for SBR (53). Due to the genetic diversity within *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

**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

Soybean rust monitoring location	Individual observations submitted <sup>a</sup>
Alabama	2,797
Arkansas	3,682
Colorado	259
Delaware	1,180
Florida	10,371
Georgia	9,298
Idaho	167
Illinois	2,763
Indiana	842
Iowa	793
Kansas	1,586
Kentucky	2,667
Louisiana	3,254
Maryland	356
Michigan	421
Minnesota	1,398
Mississippi	5,871
Missouri	2,425
Montana	2,425
Nebraska	1,095
New Jersey	290
New Mexico	253
New York	457
North Carolina	2,384
North Dakota	843
Ohio	1,492
Oklahoma	775
Oregon	133
Pennsylvania	1,822
South Carolina	1,872
South Dakota	1,640
Tennessee	2,176
Texas	1,242
Virginia	2,726
Washington	365
Wisconsin	439
West Virginia	249
Wyoming	120
Ontario, Canada	2,634
Mexico	7,087
Total	82,649

<sup>a</sup> 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*.

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/soyrustr/>) (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 fungicides, 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.



**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.

## Sidebar 4: Extension in action: Impact of soybean rust educational materials



**Sidebar Fig. 3.** Examples of the many educational materials developed in response to the threat of soybean rust in North America.

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/soyrustr/>). 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).

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

Personnel category <sup>a</sup>	Year					
	2007	2008	2009	2010	2011	2012
Extension educators	268	250	209	122	98	61
Extension specialists	65	54	53	43	35	27
Research associates	35	34	37	27	28	26
Graduate students	10	6	7	2	2	1
Department of Agriculture	18	14	1	18	2	9
Consultants	31	18	15	9	8	11
Undergraduates	30	20	21	21	5	1
Other	18	26	16	13	10	7
Total	475	422	359	255	188	143

<sup>a</sup> Individuals are classified according to personnel employment category.

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 develop-

ment. 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

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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Edward Sikora is a professor and extension plant pathologist for the Alabama Cooperative Extension System and Auburn University. He received his B.S. degree in zoology from Eastern Illinois University, and later earned M.S. and Ph.D. degrees in plant pathology from the University of Illinois. His extension/research program focuses on developing and implementing integrated pest management practices for commercial production systems for soybean, vegetable, tree fruit, and small fruit crops. Sikora has managed the soybean rust monitoring program for Alabama since 2004, and became the coordinator of the national sentinel plot monitoring program for soybean rust in 2010.



**T. W. Allen**

Dr. Allen received a B.S. degree in biology from Indiana University in 1994. After serving as a technical recruiter in northeast Indiana, he returned to graduate school in 1996. He received a M.S. in forestry and Ph.D. in plant pathology from Auburn University in 1999 and 2003, respectively. Following graduation, he worked as a postdoctoral research associate with the University of Georgia from 2003 to 2005 and Texas A&M University from 2005 to 2007, working on the biolog-

ical control of turfgrass diseases and Karnal bunt of wheat, respectively. He joined the faculty at the Delta Research Extension Center, Mississippi State University, in Stoneville, MS in 2007. Currently, he serves as an extension (80%) and research (20%) plant pathologist, where his program focuses on developing and demonstrating economical and sustainable disease management practices for agronomic field crops, including corn, cotton, grain sorghum, rice, soybean, and wheat. His research efforts examine the effects of disease management on plant disease biology, as well as elucidating disease management practices that improve crop production efficiency for Mississippi's farmers.



**K. A. Wise**

Kiersten Wise is an associate professor and extension specialist at Purdue University, with primary responsibility for diseases of corn, soybean, and wheat. Kiersten earned her B.S. degree in plant health and protection from Iowa State University, and her M.S. and Ph.D. degrees in plant pathology from the University of Georgia and North Dakota State University, respectively. Her research and extension programs focus on developing economical and sustainable disease management practices for agronomic field crops.



**G. Bergstrom**

Gary C. Bergstrom is professor of plant pathology at Cornell University where he has been a faculty member since 1981 with responsibilities for research and extension on the biology, epidemiology, and integrated management of field crop diseases in New York. He received degrees from Purdue University (B.S. in microbiology and M.S. in plant pathology) and the University of Kentucky (Ph.D. in plant pathology). Bergstrom is a fellow and past president of the American Phytopathological Society, as well as a recipient of the Distinguished Agricultural Alumni Award from Purdue University and the Excellence in Applied Research Award from Cornell's College of Agriculture and Life Sciences. He currently co-chairs Cornell's Integrated Field Crop, Soil, and Pest Management Program Work Team.



**C. A. Bradley**

Dr. Bradley is an associate professor of plant pathology and extension specialist in the Department of Crop Sciences at the University of Illinois at Urbana-Champaign. He earned a B.S. in plant and soil science at Southern Illinois University and M.S. and Ph.D. in plant pathology at the University of Illinois. He worked as a postdoctoral research fellow at the University of Idaho and as an assistant professor at North Dakota State University prior to joining the faculty at the University of Illinois in 2007. His research focuses on management of diseases affecting soybean, corn, and wheat.



**J. Bond**

Jason P. Bond is an associate professor at Southern Illinois University-Carbondale. Dr. Bond teaches undergraduate and graduate courses in plant pathology and plant nematology. His research program focuses on the management of foliar and soilborne diseases of soybean including sudden death syndrome, soybean cyst nematode and frogeye leaf spot. Additional research priorities include the management of fungal and nematode pathogens in corn. Dr. Bond is a second-generation plant pathologist, and he was raised on a watermelon farm in southeastern Louisiana. He received his Ph.D. in Plant Health from Louisiana State University in 1999.



**D. Brown-Rytlewski**

Diane Brown-Rytlewski is an Extension Educator for Michigan State University Extension and received her MS from the University of Wisconsin Madison, 2000. Current areas of interest: production of small fruit, hops and consumer horticulture. Participated in IPM pipe and soybean rust scouting for Michigan, 2006-2008.



**M. Chilvers**

Martin Chilvers is an Assistant Professor in the Department of Plant, Soil and Microbial Sciences at Michigan State University. He earned his B.Ag.Sc. degree with honors and Ph.D. in the "epidemiology of botrytis onion neck rot" in 2003 from the University of Tasmania, Australia, with subsequent Post-doctoral training at Washington State University. Dr. Chilvers leads a field crop pathology program encompassing both basic and applied research, with current emphasis on seedling and root rot diseases including *Pythium*, *Phytophthora*, *Fusarium* and *Sclerotinia*, with interests in fungal biology, population genetics, and host-pathogen interactions.



**J. Damicone**

John Damicone is a professor and extension specialist in the Department of Entomology and Plant Pathology at Oklahoma State University in Stillwater. He received his B.S. in Botany from the University of Rhode Island in 1977 and his M.S. and Ph.D. degrees in Plant Pathology from the University of Massachusetts in 1980 and 1985, respectively. His interests are in the biology, epidemiology and management of economically important crop diseases in Oklahoma. He focuses on the development and delivery of solutions to disease problems faced by cano-

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**E. De Wolf**

Erick De Wolf is a Professor in the Department of Plant Pathology at Kansas State University where he serves as an extension plant pathologist specializing the diseases for wheat and other small grains. Erick received a Ph.D. in Plant Pathology from North Dakota State University in 2000, and was as a post-doctoral researcher at The Ohio State University/OARDC in Wooster, OH. Erick accepted a faculty position at The Pennsylvania State University in 2001 where he was an extension plant pathologist covering all field and forage crops. He assumed his current position at Kansas State University in 2007. Erick's research interests include plant disease epidemiology and disease management. He is particularly interested in the relationship of weather with disease epidemics and the development disease forecasting systems.



**A. Dorrance**

Anne Dorrance is a professor in the Department of Plant Pathology at The Ohio State University. She has a split appointment in research and extension with a focus on identification and management of diseases of field crops. She received her A.S. degree in 1978 from Herkimer County Community College, B.S. degree



in 1980 from the SUNY College of Environmental Science and Forestry, M.S. degree in 1985 from University of Massachusetts, and Ph.D. degree in 1995 from Virginia Tech. Dorrance's lab works on identifying and characterizing sources of resistance to soil borne pathogens of soybean; evaluating management strategies for soybean diseases in reduced and no-till production systems.



**N. Dufault**

N. Dufault received a B.A. in 2001 in biology from Saint John's University, an M.S. 2004 and a Ph.D. in 2008 in plant pathology from The Pennsylvania State University. His research program focuses on providing growers, Extension educators and industry personnel with applied solution to problems related to the integrated management and spread of fungal plant diseases. Currently, his research focuses on the epidemiology, diversity and development of fungicide resistance for the important plant pathogens *Sclerotium rolfsii* in peanuts and *Didymella bryoniae* in watermelons. His extension educational programs are aimed at increasing the plant pathology expertise of agricultural service personnel, educators, crop advisors and producers. He is working closely with horticulturalists, agronomists and other plant scientists to evaluate cultural, biological and chemical disease control strategies as a component of integrated pest management primarily for potatoes, watermelons, cabbage and peanuts in Florida.

**P. Esker**

Dr. Esker currently works at the University of Costa Rica in the School of Agronomy. He obtained his B.S. in Genetics and Bacteriology from the University of Wisconsin, M.S. in Plant Pathology from Iowa State University, and a PhD in Plant Pathology and Statistics, also from Iowa State. Dr. Esker's covers a wide array of topics, ranging from the epidemiology and modeling of a variety of plant diseases to risk assessment and mycotoxin

development in Costa Rica. Furthermore, Dr. Esker is a Consulting Statistician at UCR where he provides technical advice and assistance related to the design of experiments and the analysis of data obtained in agricultural experiments.



**T. R. Faske**

Dr. Travis Faske received his B.S. in plant and soil science from Tarleton State University in 1996, and M. S. degree in plant pathology from Oklahoma State University, in 2000 and Ph. D. degree in plant pathology from Texas A&M University in 2006. His current appointment is as an assistant professor and extension plant pathologist in the Department of Plant Pathology at the University of Arkansas Lonoke Research and Extension Center in Lonoke, AR. He has a 100% extension appointment with state wide responsibilities for most of the major row crops grown in the state. His research and extension interest have focused on the biology and management of plant-parasitic nematodes and fungal diseases of soybean, corn, peanut, cotton, and some vegetable crops.



**L. Giesler**

Loren J. Giesler is a Professor and Extension Plant Pathologist in the Depart-

ment of Plant Pathology at the University of Nebraska-Lincoln. He earned his PhD from the University of Nebraska-Lincoln in 1998, M.S. from the University of Nebraska-Lincoln, and B.S. at Chadron State College. He is responsible for soybean disease identification and management in Nebraska and delivering educational programs to improve soybean disease awareness and management. His program has extended throughout U.S. soybean production as a coordinator of several regional projects focused on various aspects of soybean disease management and identification. He was a co-coordinator and leader of the northern region for the original soybean rust IPM PIPE program when sentinel plots were established in all the major soybean states in the U.S.

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Julie Golod is a Projector Coordinator for the ipmPIPE and iPiPE at the Pennsylvania State University. She earned a B.S. degree in biology/zoology from Michigan State University, and a Postbaccalaureate certificate in GIS from the Pennsylvania State University. She has been involved in the ipmPIPE program since its inception in 2005 as a decision support system for soybean rust. Her interests continue to revolve around improving and expanding these programs and enhancing the user experience.

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Craig Grau is Professor Emeritus at the

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**A. Grybauskas**

Dr. Grybauskas is an associate professor emeritus in the Plant Science and Landscape Architecture department at the University of Maryland. He received his B.S. (1976) in Forestry from the University of Illinois, and his M.S. (1977) in plant pathology with studies in soybean seed pathology directed by Dr. James B. Sinclair at the University of Illinois. He completed his Ph.D. in plant pathology in 1982 studying the epidemiology of footrot of wheat under the direction of Dr. Robert Powelson at Oregon State University. From 1982 until 2012, Dr. Grybauskas was a faculty member with Extension, research and teaching responsibilities at the University of Maryland. He taught courses in epidemiology and disease management, introductory plant pathology and co-taught a modular course in integrated pest management. His Extension responsibilities revolved around the development and delivery of disease management strategies for diseases of corn, soybeans, winter wheat, winter barley, tobacco, alfalfa and other forage crops. He and his students conducted research primarily on the epidemiology and management of diseases of winter wheat and in particular on the epidemiology of gray leaf spot of corn. Dr. Grybauskas directed graduate studies for five Ph.D. and six M.S. candidates and served on 36 (15 Ph.D. and 21 M.S.)

additional graduate programs. Currently, although retired, he continues to conduct field studies and provide support for Extension programs on diseases of importance to Maryland grain and soybean production.



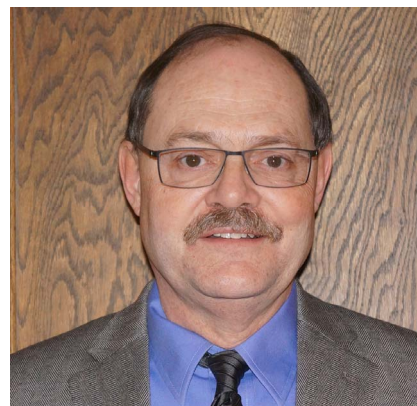
**G. Franc**

Gary Franc was raised on a dairy farm in Wisconsin and received his B.Sc. from the University of Wisconsin-Madison, his Master's from the University of Minnesota and, in 1988, his Ph.D. from Colorado State University. There he was initially employed as a research associate and extension agent specializing in potato diseases. He joined the University of Wyoming in 1991, becoming Professor of Plant Pathology in 2001. Over 32 years, Gary accumulated an extraordinary portfolio of research and extension experience, which included many works published on viruses, bacteria, fungi and nematodes. He was an editor of the Potato Compendium (2001) and APSnet Features Editor, before handing over to his respected friend Linda Hanson. In addition to aerobiology, Gary's focus was the epidemiology and control of fungal, bacterial and nematode diseases of dry bean, potato (especially seedpiece treatments), sugar beet and small grain crops. Diseases of concern included *Cercospora* leaf spot and *Rhizoctonia* root and crown rot of sugar beet, ringrot of potato and early and late blight diseases of potato. Recent work, conducted with William Stump, included annual field trials of fungicide efficacy in potato, sugar beet and cereals; the molecular characterization of fungicide resistance in *Cercospora beticola*, the Ph.D. studies of James Obuya; and a comprehensive annual screening for the appearance of *C. beticola* fungicide resistance across the Central High Plains. As an extension specialist, Gary had state-wide responsibilities for Wyoming plant pathology programs providing diagnostics and expertise to a broad client base. Gary passed away peacefully at his home on Oct. 17, 2012.



**R. Hammerschmidt**

Ray Hammerschmidt is professor of plant pathology and associate chair in the Department of Plant, Soil and Microbial Sciences at Michigan State University. He received B.S. and M.S. degrees in biochemistry (1974) and plant pathology (1976), respectively, from Purdue University. In 1980 he received his Ph.D. in plant pathology from the University of Kentucky. He also serves as the Coordinator of MSU's Plant Diagnostic Services and Director of the North Central Plant Diagnostic Network. His research focuses on mechanisms of host defense, acquired resistance, and pathogenesis.



**G. L. Hartman**

Dr. Hartman is a research plant pathologist with USDA Agricultural Research Service and a professor of plant pathology in the Department of Crop Sciences, University of Illinois. He earned a B.S. degree in plant health technology and M.S. and Ph.D. degrees in plant pathology from the University of Illinois. He started his post Ph.D. career in 1988 and worked for 5 years at two international centers as the leader of the cowpea pathology program and as head plant pathologist responsible for host resistance research on bacterial and fungal diseases of vegetables including soybean. Since 1993, his research focus has been on variability and biology of soybean

pathogens, epidemiology of soybean diseases, the nature and genetics of host plant resistance, and soybean disease management located at the University of Illinois. His publications include over 200 refereed journal articles, 38 papers in proceedings, seven book sections, six book chapters, three edited books, two edited proceedings, one book, and two patents.

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**C. Hollier**

Dr. Hollier is a professor of plant pathology with both Extension and Research responsibilities for small grain and feed grain crops in Louisiana. He received the B.S. (1975) and M.S. (1977) degrees in biology (botany) from Delta State University, Cleveland, MS and the Ph.D. in plant pathology from Mississippi State University in 1981 studying the epidemiology of *Puccinia polysora*, the southern corn rust pathogen. Since 1982 he has focused on the educational and applied aspects of field crops diseases and crop loss assessment of foliar pathogens of corn, grain sorghum, rice, soybeans and wheat.



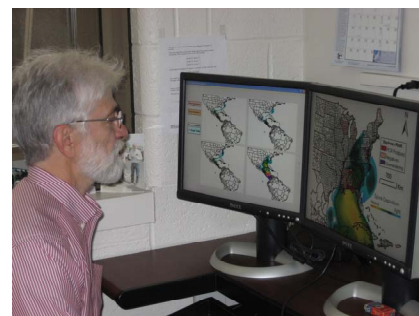
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Dr. Hershman is an Extension professor and plant pathologist in the University of Kentucky's Department of Plant Pathology. He earned a B.A. in biology at West State College in 1978, and M.S. and Ph.D. degrees in plant pathology at Rutgers University in 1981 and 1983, respectively. He joined the faculty at UK in 1984, housed at the Research and Education Center in Princeton. He has statewide Extension and applied research responsibilities for small grains and soybean. In addition, he supervises the Plant Disease Diagnostic Laboratory located at the UKREC and is the current extension coordinator for the department. His research interests focus on chemical and nonchemical control of diseases of wheat and soybean, as well as soybean cyst nematode management. He was the co-coordinator for the national soybean rust monitoring network from 2005 to 2009.



**T. Isakeit**

Thomas Isakeit is a professor and extension plant pathologist located at Texas A&M University in College Station. His responsibility is conducting extension programs managing field crop diseases, particularly corn and cotton. He has been with Texas A&M University since 1993. He obtained his Ph.D. and M.Sc. degrees in plant pathology at Michigan State University in 1984 and 1988, respectively. He also obtained post-doctoral experience at the University of California – Berkeley and the University of Arizona.



**S. Isard**

Present position: Professor of Aerobiology in the Department of Plant Pathology and Environmental Microbiology and the Department of Meteorology at Pennsylvania State University. Degrees: Ph.D. Indiana University, Department of Geography 1984; M.S. University of Pennsylvania, Department of Education 1978; M.A. University of Pennsylvania, Department of History 1976; B.A. University of Wisconsin, Department of History 1974. Major area of interest: Biological and meteorological factors that govern the aerial movement of biota.



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**D. Jardine**

Dr. Jardine is a professor and Extension State Leader in the Department of Plant Pathology at Kansas State University. He has an M.S. degree in horticulture in 1977 and a Ph.D. degree in plant pathology in 1985, both from Michigan State University. He is responsible for the diagnosis and management of soybean, corn, grain sorghum and sunflower diseases in the state. His research focuses on the evaluation of fungicide seed treatments as well as management of charcoal rot and soybean cyst nematode using an integrated approach.



**R. Kemerait**

Robert C. Kemerait, Jr. received his Ph.D. from the Plant Pathology Department at the University of Florida and has been a member of the faculty at the University of Georgia since 2000. Currently a professor and Extension specialist, Kemerait is stationed at the Coastal Plain Experiment Station in Tifton where he has statewide extension responsibilities for disease and nematode management of corn, soybeans, peanuts and cotton. In addition to

his Extension activities, Kemerait is involved in projects in Guyana, Haiti, and the Philippines as well as being committed to graduate student education. Dr. Kemerait is married to Pamela Lopez Kemerait and they have two children, Perrine and Jimmy.



**S. Koenning**

Dr. Koenning received a B.S. in Biology and a M.S. in Plant Pathology from the University of Arizona. He received a Ph.D. from North Carolina State University in 1984 in the Department of Plant Pathology. Postdoctoral research included two years at the University of Missouri Delta Center in Portageville, MO working on the soybean cyst nematode. His current appointment is as a Research Associate Professor and Extension Specialist at North Carolina State University. He is currently the Departmental Extension Leader with extension responsibilities for all diseases of corn, cotton, small grains, and soybean. He received the Best Economic Nematology Paper Award in 1986, and the Novartis Award for Excellence in Research in 2000 from the Society of Nematologists. Current research interests include management of diseases of field crops and disease diagnosis.



**M. Langham**

Dr. Langham is a professor of Plant Pathology in the Plant Science Department at South Dakota State University (SDSU) in Brookings, SD. She received her Ph.D. in Plant Pathology from Texas A&M University, and she did postdoctoral work at the University of Arkansas. Dr. Langham

has specialized in plant viral diseases since she joined SDSU in 1991. She has worked primarily with viral diseases affecting soybeans, wheat and other legumes. One of the most fulfilling activities that she has participated in is serving with Dr. Howard Schwartz as the National Coordinators for the Legume ipmPIPE. The extension and research scientists comprising the Legume ipmPIPE are collaborative and knowledgeable, and the accomplishments of the Legume ipmPIPE could not have been done without their dedication. It is an honor to represent their contributions to soybean rust detection.



**D. Malvick**

Dean Malvick is an Associate Professor of Plant Pathology and Extension Specialist at the University of Minnesota in St. Paul. He received an M.S. degree in Botany and Plant Pathology from Oregon State University and a Ph.D. in Plant Pathology from the University of Minnesota. His responsibilities include conducting problem-solving and discovery research on the biology and management of corn and soybean diseases and developing and delivering educational extension programs. Previously, Dr. Malvick was an Assistant Professor with similar responsibilities at the University of Illinois in Urbana, and he worked for several years as a research pathologist for a seed company. He worked on soybean rust monitoring efforts and more in Illinois and Minnesota.



**S. Markell**

Dr. Markell is an associate professor and Extension plant pathologist in the department of plant pathology at North Dakota State University. His Extension and research program focuses on developing and disseminating disease management tools and information to address economically important diseases of eight broad-leaf crops in North Dakota. Dr. Markell received a B.S. (Biology) and M.S. (Plant Pathology) before receiving a Ph.D. (Plant Science {Plant Pathology}) from the University of Arkansas in 2007.



**S. Monfort**

Scott Monfort is the peanut specialist at the Edisto Research and Education Center in Blackville. Scott joined the Extension Team at Edisto Research and Education Center on June 6, 2010 and collectively has over 10 years work experience in plant diseases, nematodes, and precision agriculture technologies in peanut and other row crops. His primary focus area is the Development of cost-effective crop management systems including cultivar evaluation, tillage systems, fertility, pest management, and Precision Ag Technologies in peanut. He earned the BSA and MS in Plant Pathology at the University of Georgia and the Ph.D. in Plant Science from the University of Arkansas. Prior to becoming the Peanut Specialist at Clemson University, Scott was the State Extension Plant Pathologist with the University of Arkansas working with growers on disease and nematode management for cotton, corn, soybean along with agronomic practices and disease management of peanut.



**D. Mueller**

Daren Mueller is an Assistant Professor and Extension Plant Pathologist at Iowa State University (ISU). He is also the coordinator of the ISU Integrated Pest Management (IPM) Program. Daren received his B.S. in Animal Science from the University of Wisconsin- Madison in 1996 and his M.S. and Ph.D. in Plant Pathology from the University of Illinois-Urbana in 1999 and 2001. Daren's main research interests involve understanding the biology and management of soybean diseases. The ISU IPM program, among other things, develops several publications about field crops pests, leads the ISU Field Extension Farm, and is involved in several STEM education projects.

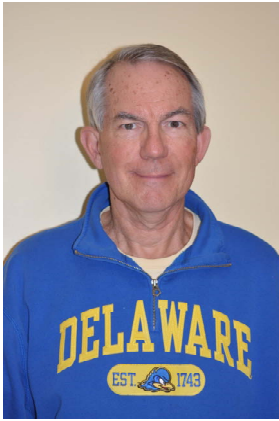


**J. J. Marois**

Education: Florida Atlantic University, B.A., 1975, Conservation Biology, University of Florida, Ph.D., 1980, Plant Pathology. Current Employment: Professor, Department of Plant Pathology, University of Florida, 1995-present. Present Responsibilities: He is a Professor in the Department of Plant Pathology stationed at the North Florida Research and Education Center. His duties include conducting research on agronomic and horticultural crops appropriate for north Florida production systems, especially peanuts, cotton and corn. Present projects include epidemiology and control of soybean rust, etiology and control of Fusarium hardlock of cotton, and a regional project integrating livestock into cropping systems. All projects have a strong interdisciplinary perspective and incorporate systems level strategies and objectives to develop viable farm production systems.

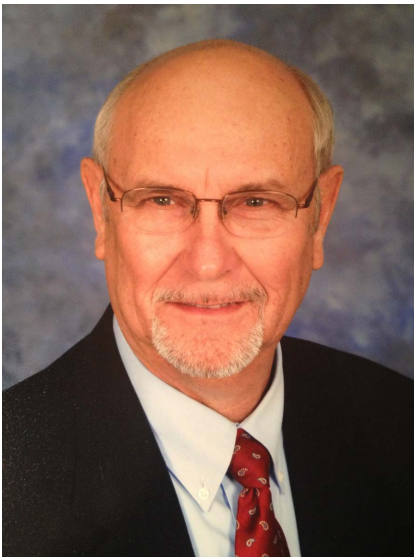
**J. Mueller**

Present Position of the Author - Soybean/Cotton Pathologist, Clemson University. Degrees 1978 B.S. Agronomy, University of Missouri, Columbia; 1981 M.S. Plant Pathology, University of Illinois at Urbana-Champaign; 1983 Ph.D. Plant Pathology, University of Illinois at Urbana-Champaign. Major Area of Interest - Site-specific management of nematodes on cotton and soybean.



**R. Mulrooney**

Robert P. Mulrooney. Extension Plant Pathologist, Retired. University of Delaware, Newark, DE 19716. BAAS Biological Sciences, University of Delaware, 1972, M.S. Plant Pathology, University of Delaware 1974. Responsibilities included educational programming for the control and management of plant diseases and diagnostics for field crops, commercial vegetables and turf and ornamentals. Initiated the Nematode Assay Information Program for Delaware growers and was responsible for conducting the assays which has continued into retirement. Applied research work included fungicide efficacy evaluations for a wide variety of crops including soybeans, small grains, potatoes, lima beans, pickling cucumbers, corn, small grains, roses and flowering dogwood as well as resistant variety evaluations for small grains, soybeans including soybean cyst and root knot nematode.



**M. Newman**

Dr. Newman served as state-wide Extension plant pathologist at the University of Tennessee in the department of Entomology and Plant Pathology from 1973 to 2012. The majority of his time has been concentrated on the control of cotton, corn, soybeans and wheat diseases. He completed his B.S. in Agriculture and his M.Ed. at Sam Houston State University,

Huntsville, Texas. He then completed his Ph.D. in Plant Pathology at Texas A&M University, College Station Texas. Next he received a Postdoctoral Fellowship from NASA on wheat virus diseases for one year at Kansas State University, Manhattan, Kansas. Dr. Newman retired from the Univ. of TN and is Professor Emeritus in the Dept. of Entomology and Plant Pathology, University of Tennessee. He is currently field crops disease specialist for BASF.



**L. Osborne**

Larry Osborne is presently a product agronomist with DuPont Pioneer and was formerly on faculty at South Dakota State University the State Extension Specialist for Plant Pathology. He holds a Ph.D. in Plant Pathology from South Dakota State University (2006), and M.S. in Plant Pathology from the University of Nebraska (1999). He is currently part of a team of folks working on final characterization of corn and soybean products for release in South Dakota, Minnesota, North Dakota and Wisconsin and had particular interest in examining resistance or tolerance to major diseases including Phytophthora root rot and sudden death syndrome in soybeans and Goss's wilt and blight and Northern leaf blight in corn.



**G. B. Padgett**

Boyd Padgett is currently the regional director for the LSU AgCenter Central Region and resides at the Dean Lee Research and Extension Center near Alexandria, LA. Responsibilities include overseeing/assisting in programming efforts associated with 4-H, Agricultural and Natural Resources, and Family and Consumer Science programs. He is also involved with research/extension efforts at the Dean Lee Research and Extension Center and activities at the State Evacuation Center. Dr. Padgett received his B.S. from Louisiana Tech University, his M.S. from the University of Georgia, and his Ph.D. from Louisiana State University. From 1996-1999 he was employed by the LSU AgCenter as the Louisiana Cooperative Extension Service State Cotton Specialist. From 1999-2012 he served the AgCenter as a research/extension (40%/60%) plant pathologist working in the area of disease management in row crops. Boyd was housed at the Macon Ridge Research Station near Winnsboro, Louisiana. His responsibilities included conducting research and developing extension programs for cotton, field corn, grain sorghum, soybean, and small grains. The research component emphasized disease management, epidemiology, disease forecasting, fungicide evaluations, and screening crop varieties for genetic resistance to pathogens. Results from some of this research were disseminated in professional journals, university publications, regional, and national meetings. The extension component was used to disseminate research-based information to the agricultural community using on-farm demonstrations, field tours, state and regional meetings, and individual farm visits. The majority of his efforts during the past two years have focused on evaluating and developing management strategies for soybean rust, *Cercospora foliar blight*, and leaf rust in wheat. These efforts were supported through federal, commodity, and industry grants.



**B. E. Ruden**

Brad Ruden serves as Director of Agronomy Technical Services with the South Dakota Wheat Growers Association in Aberdeen, SD, a leading full-service agricultural co-op and 2012 ARA Ag Retailer of the Year. Brad's educational background is in Production Agronomy with a touch of Ag Engineering. He holds a B.S Degree in Agronomy (1990) and a Master of Science degree in Plant Breeding (1995), both from South Dakota State University. Brad has also completed coursework and research supporting a PhD in Plant Pathology from SDSU, with emphasis on pesticide application parameters for optimizing the control of Fusarium Head Blight. Brad is native of northeastern South Dakota and has nearly 25 years experience as a professional and research agronomist in South Dakota and the surrounding area. Brad's professional experiences prior to Wheat Growers include work as a Technical Service and Product Development Representative for Bayer CropScience, several years as the Plant Diagnostician at SDSU, and 12 years working in various USDA, EPA and IPM-related pest management-related roles for the SDSU Cooperative Extension Service. Brad's areas of interest include providing agronomic support and training for Agronomy programming with South Dakota Wheat Growers and conducting research and demonstration trials to support the Agronomy business for the organization.



**J. Rupe**

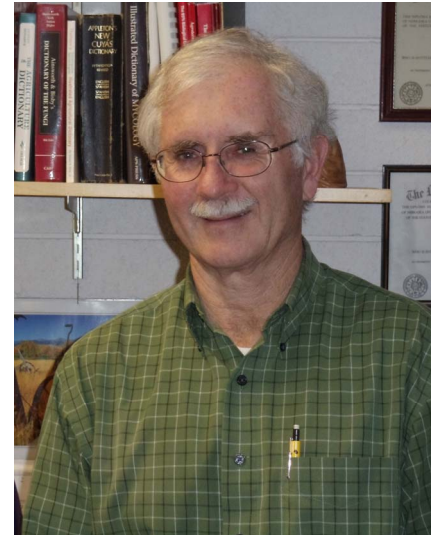
Dr. Rupe is a professor of plant pathology at the University of Arkansas. He received a B.A. degree in biology from Goshen College in 1973 and a B.S. degree in plant pathology from Colorado State University in 1978. From the University of Kentucky, he received an M.S. degree in plant pathology in 1981 and a Ph.D. degree in 1984. Since joining the University of Arkansas in 1984, Dr. Rupe has concentrated on the etiology and epidemiology of soybean diseases important in Arkansas including sudden death syndrome of soybean, charcoal rot, seedling diseases, and seedborne pathogens.



**R. Schneider**

Dr. Schneider is professor of plant pathology in the Department of Plant Pathology and Crop Physiology at the Louisiana State University Agricultural Center. He earned his B.S. in biology and chemistry at the University of Alabama (1969) and his M.S. (1971) and Ph.D. (1973) from the University of Illinois. He spent 11 years in California where he was a post-doctoral researcher at UC Davis and assistant professor at UC Berkeley. He came to the LSU AgCenter in 1984 and is

now the soybean pathologist where he concentrates on soybean rust, *Cercospora* leaf blight and other diseases. Dr. Schneider has published extensively in the area of population genetics of selected plant pathogenic fungi, disease suppressive soils, and disease management in soybean and other crop species. One of the highlights of his career was the first discovery of soybean rust in North America in 2004, which resulted in a cascade of events, collaborative research projects, and international travel experiences.



**H. Schwartz**

Dr. Schwartz is Professor of Plant Pathology, Extension Specialist & Assoc. Dept. Head. Education: B.S., Agronomy (Business Minor), 1970, University of Nebraska – Lincoln; M.S., Plant Pathology (Plant Breeding Minor), 1975, University of Minnesota - St. Paul; Ph.D., Life Sciences (Plant Pathology), 1977, University of Nebraska – Lincoln. He is a research and extension plant pathology specialist and Associate Dept. Head for the Department of Bioagricultural Sciences and Pest Management at Colorado State University. Responsibilities consist of research and extension programs for major row (dry edible beans) and commercial vegetable (onions) crops grown in Colorado. Onion research priorities include bacterial diseases such as *Xanthomonas* leaf blight (*Xanthomonas axonopodis* pv. *allii*), thrips-transmitted virus (*Iris Yellow Spot Virus*), and foliar/storage diseases such as *Botrytis* neck rot (*Botrytis* species). Dry bean research priorities include rust (*Uromyces appendiculatus*), white mold (*Sclerotinia sclerotiorum*), Fusarium wilt (*Fusarium oxysporum* f. sp. *phaseoli*), and common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*). The program is designed to identify and monitor economically limiting diseases, to study their epidemiology and to develop and implement appropriate disease management strategies. His applied and basic research and extension programs have focused upon integrated disease management through host resistance, cultural practices, environmental monitoring, disease forecasting and pesticide

scheduling. He served as the national coordinator for the Legume ipmPIPE (20 states) and Onion ipmPIPE (7 states) projects during 2010-2013.



**G. Shaner**

Greg Shaner earned his B.S. and Ph.D. degrees from Oregon State University. He joined the Department of Botany and Plant Pathology at Purdue University in 1968, where he conducted research on diseases of wheat and oat, focusing on epidemiology and disease resistance. Later, he became an extension specialist for diseases of field crops, and added work on diseases of corn and soybean to his work with small grains. He taught various courses in plant pathology, a course in plant taxonomy, and a course in scientific writing. He retired in 2008, and now volunteers with various urban forest and horticulture nonprofit groups, spends a lot of time with his grandchildren, gardens, and does woodworking.

**S. Singh**

Department of Plant, Soil and Entomological Sciences, University of Idaho, Kimberly 83341.

**E. Stromberg**

Department of Plant Pathology, Physiology, and Weed Science, Virginia Polytechnic Institute and State University, Blacksburg 24061.



**L. Sweets**

Dr. Sweets is an extension plant pathologist in the Division of Plant Sciences at the University of Missouri specializing in diseases of field crops. She received her B.A. degree from Carleton College, Northfield, MN, and her M.S. and Ph.D. degrees in plant pathology from the University of Minnesota. She began her career as extension plant pathologist at Iowa State University in Ames, IA, then worked as the plant

pathologist for Ag Research at Pillsbury-Green Giant in LeSueur, MN, before accepting her current position at the University of Missouri. At Missouri, she has statewide extension responsibilities for diseases of corn, soybean and winter wheat. Her applied research program focuses on integrated disease management programs for corn, soybean and winter wheat and seed treatment and foliar fungicide treatments for managing diseases of corn, soybean and winter wheat with emphasis on Fusarium head blight of wheat and soybean cyst nematode. She has been active in the SBR-PIPE and sentinel plot monitoring program since its initiation.



**A. Tenuta**

Albert Tenuta is the Field Crop Extension Plant Pathologist since 1991 with the Ontario Ministry of Agriculture and Food and Ministry of Rural Affairs (OMAF and MRA) based at the University of Guelph Ridgetown Campus in Ridgetown, Ontario, Canada. His academic major is in Plant Pathology from the University of Toronto (B.Sc 1988). Albert's involvement in the North American Soybean Rust Monitoring Efforts has been recognized with the International IPM Award of Excellence as well as the Experiment Station Committee on Organization and Policy (ESCOMP) National Multi-State Research Award. Albert's contribution to extension, communication and applied research has been recognized in Ontario (Ontario Agricultural College – "T.R. Hillard Distinguished Extension Award" (1999), Canada (inaugural recipient Canadian Phytopathological Society – "Achievements in Plant Disease Management (Extension) Award" (2003) and North America (American Phytopathological Society North Central Division – "Distinguished Service Award" (2013).

**S. Vaiciunas**

New Jersey Department of Agriculture, Trenton 08625.



**X. B. Yang**

X. B. Yang is a professor at Iowa State University. He received his under-grade education and a Master degree from China Agriculture University. He began to work on soybean rust in USDA-ARS Foreign Disease and Weed Science Research Unit after received his Ph.D. degree from Louisiana State University in 1989. After soybean rust was first detected in Louisiana, he took a lead for the US soybean rust sentinel plot project and chaired USDA Soybean Rust Committee. He was elected as an APS Fellow in 2005 and received several other awards.



**H. Young-Kelly**

Dr. Heather Young-Kelly is an assistant professor and extension field crops plant pathologist within the Department of Entomology and Plant Pathology at the University of Tennessee. She received bachelor's and master's degrees from Florida State University in Biological Sciences and Science Teaching in 2007 and 2008. Dr. Young-Kelly was awarded her Ph.D. from University of Florida in Plant Pathology in 2012. Her program emphasizes an IPM approach to disease management and utilizing forecast modeling.





**J. Zidek**

Jeremy Zidek graduated with a bachelor's degree in meteorology (2002) and a master's degree in ecology (2007) with major areas of interest in plant pathology and aerobiology, both from Pennsylvania State University. Jeremy currently is a senior research scientist at ZedX, Inc. primarily focused on integrated pest management, environmental sustainability and watershed restoration. Jeremy is also interested in issues in agriculture and water management for the Middle East and North Africa (MENA) region.