Fig. 3. Searching kudzu plants for rust (upper left dead from frost and upper right overwintering) and monitoring of Phakopsora pachyrhizi spores in the air from infected kudzu plants (lower left and right) in Florida.

Because the introduction of soybean rust is relatively new to the continental United States, much remains unknown about the potential in-season and overwintering distribution of the fungus. It seems likely, as it is with most invasive species, that it may take a decade to fully understand the distribution of the fungus and its capacity to cause economic losses to the U.S. soybean crop.

### References Cited


**Harmon, P. F., M. T. Momol, J. J. Marios, H. Dankers, and C. L. Harmon. 2005.** Asian soybean rust caused by Phakopsora pachyrhizi on soybean and kudzu in Florida. Online. Plant Health Progress:doi:10.1094/PHP-2005-0613-01-RS.

**Hartman, G. L., R. A. Hines, C. D. Faulkner, T. N. Lynch, and N. Pataky. 2007.** Late season occurrence of soybean rust caused by Phakopsora pachyrhizi on soybean in Illinois. Plant Dis. 91: (in press). **[Q 1]**

**Killgore, E., and R. Heu. 1994.** First report of soybean rust in Hawaii. Plant Disease 78: 1216.

**Lynch, T. N., J. J. Marios, D. L. Wright, P. F. Harmon, C. L. Harmon, M. R. Miles, and G. L. Hartman. 2006.** First report of soybean rust caused Phakopsora pachyrhizi on Phaseolus species in the United States. Plant Dis. 90: 970.

**Miles, M. R., G. L. Hartman, and R. D. Frederick. 2003.** Soybean rust: Is the U.S. crop at risk? [Online]

http://www.apsnet.org/online/feature/rust

**Ono, Y., P. Buritica, and J. F. Hennen. 1992.** Delimitation of Phakopsora, Physopella and Cerotelium and their species on Leguminosae. Mycol. Res. 96: 825–850.

**Schneider, R. W., C. A. Hollier, H. K. Whitman, M. E. Palm, J. M. McKemy, J. R. Hernandez, L. Levy, and R. DeVries-Paterson. 2005.** First report of soybean rust caused by Phakopsora pachyrhizi in the continental United States. Plant Dis. 89: 774.

**Sinclair, J. B., and G. L. Hartman, [Eds.] 1995.** Proceedings of the soybean rust workshop, 9–11 Aug. 1995, pp. i–vii, 68. National Soybean Research Laboratory, Urbana, IL.



**Glen Hartman** USDA–Agricultural Research Service, Department of Crop Sciences, National Soybean Research Center (NSRC), University of Illinois


**[AU: please add a sentence or two about yourself and any contact information.]**

Author Query

**Q 1. Please update this reference.**

Instant symposium

# Tiny Terrors: The Soybean Aphid


**Chris DiFonzo**


A successful invader follows the General Invasive Process of Arrive–Survive–Thrive (National Research Council 2002). That is, the organism must get to the new location, survive in that habitat, and then successfully reproduce. The soybean aphid (SBA), *Aphis glycines* Matsumura, is the "poster insect" for this process. Native to Asia, SBA was first noticed on soybeans in North America by University of Wisconsin researchers in late July 2000. Messages were sent to other entomologists and within days SBA was found in research plots and commercial fields in neighboring states. In mid-August 2000, its identity was confirmed at the USDA–ARS Systematic Entomology Laboratory in Beltsville, MD, as *A. glycines*. By the end of the 2000 field season, SBA was reported from eight states in the Midwest. Its wide distribution meant that state quarantines or eradication efforts were out of the question.

When and how did SBA arrive in the United States? Anecdotal reports from crop scouts in Wisconsin hint that SBA was present as early as 1995 (NCSRP 2004), although aphids were not collected and identified to species by entomologists until 2000. Venette and Ragsdale (2004) suggested that SBA was likely introduced from China and Japan, based on records of aphid interceptions at U.S. ports of entry. The season-end distribution of SBA in 2000 centered on the upper Midwest, which was the probable point of introduction. Given increased trade and direct flights from Asia to major cities like Chicago, Detroit, and Minneapolis, aphids may have moved on plant material in a matter of hours from Asia to the Midwest.

Once SBA arrived, it survived for several reasons. The Midwest is similar in climate to its original habitat, and has millions of acres of SBA's secondary host, soybean, providing ample, suitable habitat. Prior to 2000, soybean in northern production areas rarely suffered yield-limiting damage from insects, particularly from sucking pests. Thus soybean aphid found a relatively unexploited resource to colonize. Aphid biology itself is geared for colonization. On its secondary host, SBA reproduces parthenogenetically, giving live birth to daughters without mating (Ragsdale et al. 2004). Therefore, only a small number of female colonizers were necessary to establish a population in North America. Finally, and perhaps key, is the presence of primary overwintering hosts in the genus *Rhamnus* for egg-laying in the fall (Voegtlin et al 2004, 2005; Yoo et al. 2005). In particular, *Rhamnus cathartica* (common or European buckthorn) is a very suitable host for SBA reproduction in the spring (Yoo et al. 2005). *R. cathartica* was introduced from Eurasia in the 1800s as an ornamental shrub and shelterbelt planting, and it has since spread across the northern United States and Canada. In many areas, it is a nuisance invasive species, crowding out native vegetation; in Michigan, for example, buckthorn is routinely a target for removal in parks and other natural areas. The presence of large areas of woody *Rhamnus* shrubs in the landscape made it possible for SBA to successfully mate, lay eggs and overwinter, and thus survive into the successive field season.

Once it survived, SBA certainly thrived in the Midwest, spreading from eight states in 2000 to at least 23 states and three Canadian provinces by 2006. It has a tremendous reproductive capacity, doubling its population under favorable laboratory conditions in as few as 1.5 d (McCornack et al. 2004) and producing up to 15 generations during the growing season on soybean in the field (Wang et al. 1962). As the season progresses, a proportion of the population develops wings, allowing individuals to disperse on wind currents and colonize new fields. An example of SBA dispersal capacity occurred in 2001, when Michigan experienced its first widespread outbreak. A field sampled in Saginaw County on 1 August 2001 had an average of 7,000 SBA per plant. This field population was typical of commercial fields in the area. Factoring in the proportion of alatoid nymphs (90%) and the plant population, there was a potential for 800 million alates per acre at this site. By 4 August, most aphids in the field had dispersed. Where did they go? On 3 August, the *Toronto Star* newspaper reported a winged aphid invasion as "clouds of bugs" descended on the city; the Toronto Blue Jays baseball game in SkyDome was delayed as aphids "swarmed" fans. Similar aphid invasions were experienced that same week in downtown Detroit. Weather maps indicated that wind currents in early August moved across Michigan into Ontario, carrying aphids en masse over the border.

Infestations of thousands of aphids per plant are possible in outbreak years. As SBA numbers rise, plants become covered with sticky honeydew and black sooty mold.

Since SBA became established in North America, regional outbreaks occurred in 2001, 2003, and 2005. Infestations of thousands of aphids per plant are possible in outbreak years. As SBA numbers rise, plants become covered with sticky honeydew and black sooty mold. In China, and now the United States, SBA feeding impacts all components of yield, leading to reductions in plant height and nodes, early leaf drop, a reduction in flowers and pods, fewer beans per pod, and changes in oil or protein content (Wu et al. 2004). Under heavy aphid pressure, yield differences between treated and untreated research plots range from 40% to 70%. On a landscape level, SBA outbreaks correspond in certain locations with potyvirus outbreaks in dry beans, snap beans, vine crops, and potato. From an economic standpoint, SBA not only reduces yield, but increases the cost of production. In 1999, the year prior to discovery of SBA, less than 1% of the soybean acres in Illinois, Indiana, Michigan, Minnesota, and Ohio were treated with insecticide (NASS 2000). In 2005, an outbreak year, estimates for insecticide use in these same states ranged from 9% (IL) to 42% (MI) (NASS 2006). At least 17 foliar and seed-applied insecticides are now used for aphid control in Michigan (DiFonzo et al. 2007), adding $10–20 per acre to production costs (Song et al. 2006), plus increasing human pesticide exposure and environmental impacts.

Soybean aphid has fundamentally changed soybean production in the northern United States and Canada, but the picture is not bleak. In a relatively short time, scientists have published research on identification, overwintering hosts, life tables, and plant impacts (See the Special Feature on SBA in the *Annals of ESA*, March 2004). Several years after the discovery of SBA, extension entomologists developed regional management recommendations and, working with soybean commodity organizations, distributed this information to all soybean growers in the Midwest (NCSRP 2004). From a chemical standpoint, many effective insecticide options are available for SBA control during outbreaks in the United States. To promote the judicious use of insecticides, scouting techniques (Hodgson et al. 2007) and a threshold for SBA of 250 aphids per plant (Ragsdale et al. 2006) have been validated and widely adopted in the Midwest. The recent introduction of soybean rust (another Asian pest) into the southern United States focused attention on better scouting and spray coverage in soybean, further improving SBA control. To plan for SBA outbreaks, a regional aphid suction trap network of 40 traps in 10 states was developed by David Voegtlin at the Illinois Natural History Survey (http://www.ncpmc.org/traps/index.cfm). Based on the magnitude of fall suction trap catches (SBA produced on beans, flying to buckthorn), the network has correctly predicted SBA outbreaks for the past four seasons.

Beyond pesticides, many research projects show the important role of native and established predators (for example, Fox et al. 2004, Desneux et al. 2006) and entomopathogens (Nielsen and Hayek 2005) in non-outbreak years. In the next few years, classical biological control introductions are expected to be made of parasitoids collected in Asia and currently under quarantine in the United States. Finally, progress has been made in host plant resistance. Several resistance genes have already been identified (Mensah et al. 2005, Hill et al. 2006a,b) for use in commercial breeding programs. Thus soybean aphid, although an invasive pest, is now a manageable problem, and the outlook for the long-term control is promising.

### References Cited

**Desneux, N., R. J. O'Neil, and H. J. S. Yoo. 2006.** Suppression of population growth of the soybean aphid, Aphis glycines Matsumura, by predators: The identification of a key predator and the effects of prey dispersion, predator abundance, and temperature. Environ. Entomol. 35: 1342–1349.

**DiFonzo, C. D., M. Jewett, F. Warner, D. Rytlewski, and W. Kirk. 2007.** Insect, nematode, and disease control in Michigan field crops. Michigan State University Extension Bulletin E-1582.

**Fox, T. B., D. A. Landis, F. F. Cardosa, and C. D. DiFonzo. 2004.** Predators suppress Aphis glycines Matsumura population growth on soybean. Environ. Entomol. 33: 608–618.

**Hill, C. B., Y. Li, and G. L. Hartman. 2006a.** A single dominant gene for resistance to the soybean aphid in the soybean cultivar Dowling. Crop Sci. 46: 1601–1605.

**Hill, C. B., Y. Li, and G. L. Hartman. 2006b.** Soybean aphid resistance in soybean Jackson is controlled by a single dominant gene. Crop Sci. 46: 1601–1605.

**Hodgson, E. W., B. P. McCornack, K. A. Koch, D. W. Ragsdale, K. D. Johnson, M. E. O'Neal, H. Kraiss, E. Cullen, C. D. DiFonzo, and L. M. Behnken. 2007.** Field validation of speed scouting for soybean aphid. Crop Management (in press).

**McCornack, B. P., D. W. Ragsdale, and R. C. Venette. 2004.** Demography of soybean aphid (Homoptera: Aphididae) at summer temperatures. J. Econ. Entomol. 97: 854–861.

**Mensah, C., C. DiFonzo, R. L. Nelson, and D. Wang. 2005.** Resistance to soybean aphid in early maturing soybean germplasm. Crop Sci. 45: 2228–2233.

**NASS (National Agricultural Statistics Service). 2000.** Agricultural chemical usage 1999 field crops summary. Agricultural Statistics Board, NASS, USDA, May 2000.

**NASS (National Agricultural Statistics Service). 2006.** Agricultural chemical usage 2005 field crops summary. Agricultural Statistics Board, NASS, USDA, May 2006.

**National Research Council, Board of Agriculture and Natural Resources, National Academy of Science. 2002.** Predicting invasions of nonindigenous plants and plant pests. National Academy Press, Washington, DC.

**NCSRP (North Central Soybean Research Program). 2004.** Soybean aphid research update. Available at http://www.planthealth.info/aphids_researchupdate.htm

**Nielsen, C., and A. Hayek. 2005.** Control of invasive soybean aphid, Aphis glycines (Hemiptera: Aphididae), populations by existing natural enemies in New York State, with emphasis on entomopathogenic fungi. Environ. Entomol. 34: 1036–1047.

**Ragsdale, D. W., D. J. Voegtlin, and R. J. O'Neil. 2004.** Soybean aphid biology in North America. Ann. Entom. Soc Am. 97: 204–208.

**Ragsdale, D. W., E. W. Hodgson, B. P. McCornack, K. A. Koch, R. C. Venette, and B. D. Potter. 2006.** Soybean aphid and the challenge of integrating recommendations within an IPM system, pp. 103–110. In Illinois Crop Protection technology Conference 2006 Proceedings. University of Illinois Extension, Champaign, IL.

**Song, F., S. M. Swinton, C. DiFonzo, M. O'Neal ,and D. W. Ragsdale. 2006.** Profitability analysis of soybean aphid control treatments in three Northcentral states. MSU Dept of Agricultural Economics. Staff Paper 2006-24.

**Venette, R. C., and D. W. Ragsdale. 2004.** Assessing the invasion by soybean aphid (Homoptera: Aphididae): Where will it end? Ann. Entomol. Soc. Am. 97: 219–226.

**Voegtlin, D. J., R. J. O'Neil, and W. R. Graves. 2004.** Tests of suitability of overwintering hosts of Aphis glycines: Identification of a new host association with Rhamnus alnifolia L'Heritier. Ann. Entomol. Soc. Am. 97: 233–234.

**Voegtlin, D. J., R. J. O'Neil, W. R. Graves, D. Lagos, and H. J. S. Yoo. 2005.** Potential winter hosts of soybean aphid. Ann. Entomol. Soc. Am. 98: 690–693.

**Wang, C. L., N. J. Siang, G. S. Chang, and H. F. Chu. 1962.** Studies on the soybean aphid, Aphis glycines Matsumura. Acta Entomol. Sinica. 11: 31–44.

**Wu, Zhishan, D. Schenk-Hamlin, W. Zhan, D. W. Ragsdale, and G. E. Heimpel. 2004.** The soybean aphid in China: A historical review. Ann. Entomol. Soc. Am. 97: 209–218.

**Yoo, H. J. S, R. J. O'Neil, D. J. Voegtlin, and W. R. Graves. 2005.** Host plant suitability of Rhamnaceae for soybean aphid (Homoptera: Aphididae). Ann. Entomol. Soc. Am. 98: 926–930.

**Chris DiFonzo**, Field Crops Entomologist & PSEP Coordinator, Michigan State University
[AU: Please add a sentence or two about yourself and any contact information.]