Journal of Integrated Pest Management 7(1): 14; 1–6
doi: 10.1093/jipm/pmw013
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Ecology and Management of Kudzu Bug (Hemiptera: Plataspidae) in Southeastern Soybeans

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Received 4 August 2016; Accepted 15 September 2016

Abstract

Kudzu bug, *Megacopta cribraria* Fabricius (Hemiptera: Plataspidae), is an invasive exotic pest of soybeans that has been present in the southeastern United States since 2009 and has been rapidly spreading through soybean-producing states. Their primary reproductive hosts in the United States are soybean, kudzu, pigeon pea, black eye pea, lima bean, pinto bean, wisteria, white sweet clover, white clover, red clover, alfalfa, perennial peanut, and American joint vetch. In soybeans, the kudzu bug feeds on vascular fluids at the stem, petiole, and nodes, causing yield losses of up to 60%. The current management recommendation for this pest includes spraying of pyrethroids such as bifenthrin, but this method is not environmentally friendly, as this negatively impacts beneficial insect populations. Sustainable management tactics, including the development of economic thresholds for insecticide sprays, assessing the spatial and temporal distribution of this pest, manipulating cultivation practices, use of biological control, and host plant resistance, are currently being explored. We present an overview of the ecology of the kudzu bug in soybeans and available management tactics to assist with the management of this potentially devastating pest of soybeans as it spreads westward.

Key words: kudzu bug, soybean, insecticide, biocontrol, host plant resistance

Kudzu bug, *Megacopta cribraria* Fabricius (Hemiptera: Plataspidae) (Fig. 1), is an invasive pest of soybean, *Glycine max* L. Merrill, native to Southeast Asia, and was discovered in the United States for the first time in Georgia in 2009 (Suiter et al. 2010, Ruberson et al. 2013). As these insects are associated with kudzu, *Puereria montana* (Loureiro) Merrill variety *lobata* (Willdenow), in their native range, they are commonly referred to as the kudzu bug (Fig. 2). The kudzu bug can reduce kudzu biomass by almost 33% (Zhang et al. 2012). However, there is no evidence that the kudzu bug has reduced the distribution of this invasive weed in the United States. Instead, the presence of vast acres of kudzu in southeastern United States has helped this insect to spread widely ever since its discovery (Blaustein 2001).

The pest status of the kudzu bug on soybeans in its native range varies from serious to minor, but studies in the United States have shown that, if left unchecked, kudzu bugs can cause soybean yield losses of up to 60% (Seiter et al. 2013a). Although these pests do not feed on the pod or seed of the plants with their piercing-sucking mouthparts, yield loss is attributed to decreases in number and weight of seeds per pod (Seiter et al. 2013a). Soybean is an important commodity crop in the United States, generating billions of dollars in revenue annually. Therefore, this insect is a cause for alarm in the soybean-growing community. So far, kudzu bugs have spread through Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and the District of Columbia (Fig. 3). When kudzu bugs first appeared in Georgia, scientists had limited knowledge of effective insecticides, cultural practices, and natural enemies that could be useful for their management. However, dedicated research since its initial discovery has shed light on many different pest control methods that can be used.

Biology and Ecology

The kudzu bugs invading the United States originated from the Kyushu region of Japan (Jenkins and Eaton 2011, Hosokawa et al. 2014), showing a single female lineage (Jenkins et al. 2010). Kudzu bugs have piercing-sucking mouthparts, like the stink bugs (Pentatomidae) to which they are related. The adults typically pierce and feed on the plant sap from stem, petioles, and nodes of soybean and kudzu, preferring tender new growth to older growth (Tayutivutikul and Yano 1990, Thippeswamy and Rajagopal 2005, Suiter et al. 2010). The feeding injury is visible in the form of purplish-brown lesions on stems and nodes at the feeding locations (Thippeswamy and Rajagopal 2005, Seiter et al. 2013), and nymphs tend to aggregate around growing points and nodes of soybean and kudzu for feeding, as well. Even though kudzu

Fig. 1. *M. cribraria* adults and nymphs on soybeans. Photo credit: Marlin E. Rice.

Fig. 2. *M. cribraria* adults. Photo credit: Marlin E. Rice.

bugs have been found on many different legume and non-legume hosts, the primary reproductive hosts in the United States are reported as soybean, kudzu, pigeon pea (*Cajanus cajan* L.), black eye pea (*Vigna sinensis* L.), lima bean (*Phaseolus lunatas* L.), pinto bean (*Phaseolus vulgaris* L.) (Medal et al. 2013), wisteria (*Wisteria sinensis* Sims) (Ruberson et al. 2013), white sweet clover (*Melilotus alba* Medikus), white clover (*Trifolium repens* L.), red clover (*Trifolium pretense* L.), alfalfa (*Medicago sativa* L.), perennial peanut (*Arachis glabrata* Benth), and American joint vetch (*Aeschynomene Americana* L.) (Medal et al. 2016).

In the United States, kudzu bugs complete two generations per year (Zhang et al. 2012). The adults overwinter in forest leaf litter and tree bark adjacent to soybean fields and residential areas (Lahiri et al. 2015). They are attracted to light-colored surfaces (Horn and Hanula 2011, Waldvogel and Alder 2012), and because of their tendency to aggregate on walls of houses, they are regarded as a nuisance pest in winter. They release a foul odor when threatened or crushed and can stain skin (Ruberson et al. 2013). After the overwintered adults become active in spring, the first generation is typically completed on kudzu, volunteer soybean, or early-planted soybeans (Del Pozo-Valdivia and Reisig 2013, Seiter et al. 2013). The second generation can develop on kudzu or soybeans (Zhang et al. 2012, Seiter et al. 2013a).

Like all true bugs, kudzu bugs are hemimetabolous. Kudzu bugs lay egg masses (Fig. 4) on host plant surfaces in two parallel rows (Zhang et al. 2012), and each egg is provided underneath with a brown capsule containing nutritional bacterial symbionts for the survival of the nymphs (Hosokawa et al. 2006). Kudzu bugs have five nymphal instars (Fig. 5), and the neonates aggregate on their own hatched egg mass (Fig. 4) and feed on the capsules of endosymbiotic microbes, which have been linked to increased fecundity and pest status of kudzu bugs (Fukatsu and Hosokawa 2002, Jenkins et al. 2010). The symbionts are γ-Proteobacterium, *Candidatus Ishikawaella capsulate*, which help kudzu bugs to digest plant sap, combat plant defenses, and synthesize amino acids and vitamins that are missing in the phloem sap diet of this insect (Hosokawa et al. 2005, 2006).

Multistate collaborative research was initiated upon the discovery of this pest in the United States and focused on: spatial distribution of kudzu bugs in soybean fields, significance of cultivation in pest management of kudzu bugs, effective insecticides and economic thresholds, biological control agents of kudzu bugs, and soybean host plant resistance against kudzu bugs. Through the understanding of the biology, host preference, and many more factors, a number of management tactics are currently recommended.

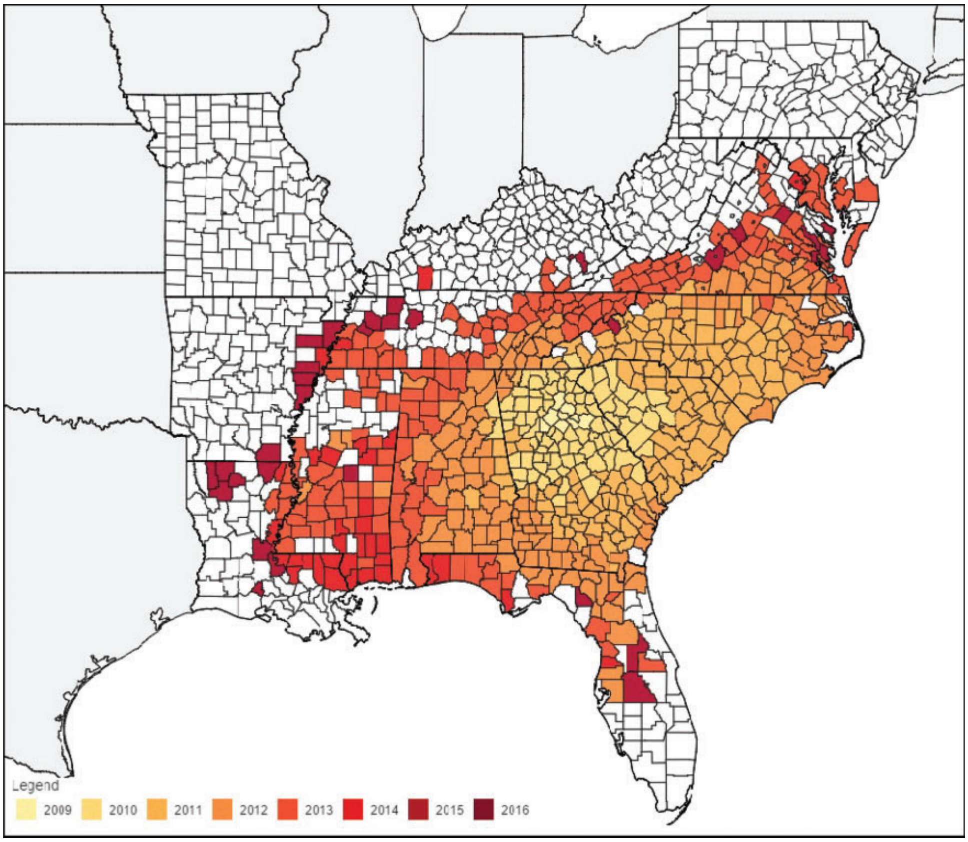

Fig. 3. Distribution map of *M. cribraria* in the United States as developed by The University of Georgia – Center for Invasive Species and Ecosystem Health.

Fig. 4. Egg mass of the kudzu bug with newly hatched first-instar nymphs. Photo credit: Scott Stewart.

Spatial Distribution of Kudzu Bugs in Soybean Fields

Improved pest sampling plans and more localized spray regimens can be designed if the dispersal behavior of a pest from an external refuge into a crop field is known. This helps reduce costs of crop production as well. Previous studies with stink bugs demonstrated that they have a tendency to aggregate at soybean field edges, which led to the recommendation that spraying the edges instead of the entire field could be highly effective in reducing stink bug populations. Similar information regarding kudzu bug distribution in soybean fields could be extremely useful.

The preference of kudzu bugs to aggregate at field edges versus the interior was demonstrated in South Carolina (Seiter et al. 2013).

Fig. 5. *M. cribraria* nymph (fifth instar). Photo credit: Marlin E. Rice.

The authors described the spatial distribution in South Carolina in 2011 and 2012. Soybean varieties from maturity groups VI and VII were planted in May, whereas VIII was planted in June. Peak levels of adults were reached in September to early October in both years in South Carolina, and this trend was also seen in previous studies in Georgia. Egg mass numbers peaked in early August during both years, which was also in agreement with studies in Georgia. Higher densities of kudzu bug adults and nymphs were seen at field edges, and the bugs exhibited an aggregated distribution as opposed to having a random or uniform distribution. Adults and nymphs were also spatially associated on individual sampling dates as well as throughout the season. This means that kudzu bugs colonized the field edges and remained aggregated at the edges throughout the season; when nymphs hatched, they were found foraging close to the adults. Therefore, scouting should commence on field edges to identify if the kudzu bug is present. If the kudzu bug is present, scouting should continue throughout the field.

Effect of Cultivation Practices on Management of Kudzu Bugs

Cultivation practices, such as selection of the ideal planting date, soybean maturity group selection, tillage, row spacing, and crop rotation, can help in the management of pests, but these are also dependent on certain financial limitations that growers face. Cultivation techniques are particularly useful for organic soybean growers. As kudzu bugs can easily develop on early-planted soybeans after emergence from overwintering habitats (Del Pozo-Valdivia and Reisig 2013, Seiter et al. 2013), cultivation practices can be modified as a preventative measure. In a study done in Georgia, soybeans planted monthly from April to July, with maturity groups V and VII, were examined for kudzu bug density (Blount et al. 2016). Kudzu bugs completed two generations on the early-planted April crop, a partial first generation and a second generation in the May crop, and only a second generation in June and July crop. Based on these observations, it can be concluded that planting date is an important factor in managing kudzu bug infestation in soybeans. However, some growers cannot afford to delay planting soybeans beyond the month of April.

Most southeastern U.S. soybean growers practice conventional tillage in full-season soybean. However, a small percentage of growers opt for reduced or no-tillage in full-season soybean, and a majority use this practice in double-cropping systems, such as those where winter wheat is followed by soybean. Kudzu bug densities have been observed to be lower in no-till fields versus conventionally tilled fields (Del Pozo-Valdivia 2016). Soybean plant spacing in the southeastern United States ranges on a continuum from densely planted "drilled" soybean, to narrow 38-cm rows, to wide 97-cm rows. The narrow row spacing results in denser foliage due to rapid canopy closure during growing season, which, too, may be attractive to kudzu bugs (Del Pozo-Valdivia 2016). A single cultivation practice cannot be adopted by all soybean growers because of many different factors, but it should be pointed out that certain cultivation practices have been observed to attract higher densities of the kudzu bug in the soybean fields of southeastern U.S. states. The best solution in those cases is close monitoring of the field for detecting economic threshold levels of pest and taking remedial actions.

Effective Insecticides and Economic Thresholds

Kudzu bug feeding can cause significant yield loss in untreated soybeans. Necrotic lesions are visible on stems and other feeding sites, but the extent of tissue damage resulting from kudzu bug feeding lesions is currently unknown. It is speculated that the loss in yield may be attributed to plant stress from feeding activities. Several pyrethroid class insecticides have been seen to be most effective against kudzu bugs. Bifenthrin, which is the most effective pyrethroid (Miao et al. 2016), can reduce populations by as much as 97% (Seiter et al. 2015) and is currently the recommended insecticide. A single well-timed insecticide application targeting nymphs has been found to be as effective as multiple applications throughout the field season from vegetative to maturation stage (Seiter et al. 2015). Therefore, to avoid excess costs, while inadvertently killing beneficial insects in soybean fields that keep populations of more devastating pests such as corn earworm, *Helicoverpa zea* (Boddie), in check, it is recommended to sweep-sample the field for nymphs. Sweep nets with 38-cm diameter of canvas cloth have been used effectively in Georgia, South Carolina, and North Carolina to determine the economic threshold for kudzu bugs. One sweep consists of a side-to-side arc of the net 180° through the soybean canopy. The fields should be monitored for nymphs after the migration of adults into the field is complete. It is recommended that bifenthrin should be sprayed when populations reach one nymph per sweep (Seiter et al. 2015).

Biological Control Agents of Kudzu Bugs

As the kudzu bug is an exotic insect species in North America, limited information is available regarding its natural enemies. However, with time, a number of native insects and other invertebrates attacking kudzu bugs have been found, and their identification not only advocates for less use of insecticides and inclusion of reduced risk insecticides but also makes room for biological control in the integrated pest management (IPM) of kudzu bugs.

A number of biological control agents have the potential to be used to regulate populations of kudzu bugs. Generalist native predators, such as the big-eyed bug, *Geocoris punctipes* (Say) and *Geocoris uliginosus* (Say); minute pirate bug, *Orius insidiosus* (Say); spined soldier bug, *Podisus maculiventris* (Say); lady beetle, *Hippodamia convergens* (Guérin-Méneville); assassin bug, *Zelus renardii* (Kolenati); two spiders, *Oxyopes salticus* Hentz and *Peucetia viridians* (Hentz); and one exotic ant, *Solenopsis invicta* Buren, have been found to be feeding on the kudzu bug (Greenstone et al. 2014). Predatory stink bug *Euthyrhynchus floridus* (L.), the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Fig. 6; Seiter et al. 2014), the entomoparasitic nematode (Mermithidae) (Stubbins *et al.* 2015), and the native adult parasitoids *Strongygaster triangulifera* (Loew) (Diptera: Tachinidae) and *Phasia robertsonii* (Townsend) (Diptera: Tachinidae) (Golec et al. 2013, Ruberson et al. 2013) have also been found to cause mortality in the kudzu bug. Furthermore, an egg parasitoid, *Paratelenomus saccharalis* Dodd (Hymenoptera: Platygastridae), specific to the kudzu bug and previously only found in the Old World has been identified in field-collected egg masses in the southeastern United States (Gardner et al. 2013, Medal et al. 2015).

Soybean Host Plant Resistance Against Kudzu Bugs

Plants possess resistance mechanisms in the broad categories of antixenosis, antibiosis, and tolerance to protect themselves against the attack of phytophagous insects. Host plant resistance has great potential in IPM, as using this technique reduces the need to spray broad-spectrum insecticides and is a more environmentally friendly option. Soybeans, too, have the ability to defend themselves against biotic and abiotic stress. Soybean breeders have developed many resistant varieties through traditional plant breeding resulting in nematode-, stink bug-, aphid-, and defoliator-resistant soybean lines (Bray et al. 2016, Fritz et al. 2016). Over 40 soybean varieties from maturity groups V–VIII with diverse traits in pubescence type, leaf shape, seed size, nitrogen fixation, drought tolerance, seed protein content, and pest resistance were evaluated in North Carolina in 2013 and 2014 for resistance to kudzu bugs (Fritz et al. 2016). The study found that narrow-leaf, small-seeded cultivars 'Vance' and 'N7103'as well as the non-nodulating cultivar 'Nitrasoy' showed the highest resistance to the kudzu bug. Vance belongs to MG V and both N7103 and Nitrasoy belong to MG VII. Knowledge about these lines and many more being currently studied will assist soybean breeders in developing resistant soybean lines that will suffer minimal yield loss without the need to spray insecticides multiple times at high doses.

Fig. 6. Kudzu bug infected with entomopathogenic fungus *B. bassiana*. Photo credit: Alejandro I. Del Pozo-Valdivia.

Future Directions

Kudzu bugs continue to spread west into states with large acreages of soybeans. It is therefore prudent to consider the following management options for this pest, as it has proven to be a significant pest in areas of its expansion.

- Kudzu bug adults and nymphs tend to aggregate at soybean field edges versus field interiors; therefore, scouting efforts should start at field edges to identify presence. Once presence has been established, scouting should continue throughout the field.
- Early-planted soybeans, conventionally tilled fields, and fields with narrow row spacing are at greater risk of developing higher populations of kudzu bugs. These types of fields should be closely monitored for kudzu bugs.
- Soybean fields can be monitored by sweep net sampling, with special focus on kudzu bug nymphs. When the density reaches one nymph per sweep, an insecticide should be sprayed. The most effective insecticide is the pyrethroid bifenthrin.
- Many native natural enemies have been identified as predators of kudzu bugs and *P. saccharalis*, a specialist egg parasitoid, is being considered as a classical biological control agent of kudzu bugs. The most effective insecticide, bifenthrin, also kills predators and parasites of the kudzu bug. Therefore, an acceptable IPM tool needs to work complementarily with biological control.
- Various soybean varieties have been identified that possess resistance against kudzu bugs. Using resistant host plants will reduce the need to spray broad-spectrum insecticides, such as bifenthrin, and will promote healthier agro-ecology.

Acknowledgments

We thank Hannah Joy Burrack and Clyde Sorenson for reviewing this manuscript and providing us with valuable suggestions. We also thank Marlin E. Rice, Scott Stewart, and Alejandro I. Del Pozo-Valdivia for sharing their kudzu bug images. The authors thank the Special Research Grants Program-Pest Management Alternatives from the USDA National Institute of Food and Agriculture and the Agricultural Research Service, as well as the United States Department of Agriculture (USDA) National Institute of Food and Agriculture HATCH project, under accession number 1004698.

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