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Issue

Early-Season Pests of Soybean in the United States and Factors That Affect Their Risk of Infestation

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Abstract

Soybean faces potential economic damage from a wide variety of early-season invertebrate pests. The objective of this article was to determine the extent and intensity of nine early-season soybean insect pests targeted for control by insecticidal seed treatments in the United States and to identify various management options for them: bean leaf beetle (*Cerotoma trifurcate* Förster, Coleoptera: Chrysomelidae); grape colaspis, *Colaspis brunnea* (F.) (Coleoptera: Chrysomelidae); leafhoppers (Hemiptera: Ciccadellidae); seedcorn maggot, *Delia platura* (Meigen) (Diptera: Anthomyiidae); soybean aphid (*Aphis glycines* Matsumura, Hemiptera: Aphididae); threecornered alfalfa hopper, *Spsistilus festinus* (Say) (Hemiptera: Membracidae); thrips (Thysanoptera: Thripidae); white grubs (Coleoptera: Scarabaeidae); and wireworms (Coleoptera: Elateridae). Seedcorn maggot, white grubs, and wireworms have been limited to a relatively small proportion of soybean fields with readily defined factors regarding their risk. However, questions about the pest status of the other six pests were identified. Bean leaf beetle, which vectors *Bean pod mottle virus* to soybean, has been present across major soybean-production regions, but frequency and proportion of soybean fields that economically impacted is not adequately documented. The impact of threecornered alfalfa hopper and thrips on soybean productivity varied within regions, but specific reasons for the variation were unclear. Early-season management of grape colaspis and leafhoppers has been infrequent, but factors that promoted economic injury and the need for management in specific fields were undetermined. Although early-season management of soybean aphid has not proven feasible for individual fields, questions remain regarding its management in fields near overwintering stands and the possibility for areawide suppression.

Key words: integrated pest management (IPM), crop protection, agricultural entomology, *Glycine max*

Soybean (*Glycine max* [L.] Merr.) is the second largest field crop in the United States, with over 75 million acres planted per year since 2009 (ERS 2017). The crop is grown predominantly in the eastern half of the country, and principally in inland states that are drained by the Mississippi River and its tributaries; most of the remaining acreage falls within the Atlantic and Gulf Coast states (Way 1994, NASS 2016).

Soybean fields in the United States collectively contain an amazing diversity of >700 herbivorous invertebrate species (Way 1994, Steffey 2015). For management purposes, these herbivores can be categorized according to pest status (Kogan and Turnipseed 1987, Steffey 2015) . About 20 species or species complexes of herbivorous arthropods are considered to be significant economic pests, according to surveys of research and extension entomologists from the major soybean-producing states of the United States in 2009 and 2014 (Steffey 2015). Another 20 species/species complexes of arthropods are categorized as occasional or sporadic pests of soybean (Steffey 2015). Additional ≈10 species are considered infrequent pests, and the remaining species of herbivorous arthropods are considered nonpests of soybean (Kogan and Turnipseed 1987, Higley and Boethel 1994).

Pest status of herbivorous arthropods in soybean depends on several factors. For instance, pest status may be seasonally dependent, with arthropods capable of causing damage during early-season soybean production, mid- to late season, or sometimes both (Steffey et al. 1994). For example, the seedcorn maggot [*Delia platura* (Meigen), Diptera: Anthomyiidae] is strictly an early-season pest from immediately after sowing through early seedling stages (Higley and Hammond 1994), whereas stink bugs (Hemiptera: Pentatomidae) are late-season pests that feed on soybean pods (Greene and Davis 2015). The bean leaf beetle (*Cerotoma trifurcata* Förster, Coleoptera: Chrysomelidae) is an example of an arthropod

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pest that can be potentially problematic in soybean throughout the growing season (Lundgren and Musser 2015).

In addition, arthropod pest status depends on geography. Several researchers have noted that pest status of particular arthropods varies among different soybean production regions (Lambert and Tyler 1999, Steffey 2015) and even among states within a given production region (Musser et al. 2014, 2015, 2016, 2017; Steffey 2015). Of course, this is due, in part, to the extent that an arthropod's geographic distribution overlaps with particular areas of soybean production (Kogan and Turnipseed 1987, Higley and Boethel 1994). However, several species of widely distributed arthropod pests can be economically significant in some soybean production areas but not others (Steffey 2015), indicating that other, sometimes undetermined factors influence pest status.

Knowledge that an arthropod's pest status varies within the growing season and by geography informs soybean growers and pest management practitioners of the time of season and places in which a particular arthropod could potentially be an economic threat to soybean production. Once pests have been identified for a particular area, then informed decisions about how to best manage the pest are also needed. A variety of management tactics can be used against arthropod pests of soybean, including the exploitation of natural enemies, crop management practices, host plant resistance, and the use of insecticides (Todd et al. 1994). Many of the tactics (e.g., insecticide seed treatment, modified planting date, elimination of alternate host plants, trap cropping) are used proactively to prevent economic pest levels, whereas others (e.g., foliar insecticide sprays, inundative release of a biocontrol agent) can be employed responsively when sampling indicates pest levels that threaten economic damage to soybean. Ideally, management decisions are based on systematic sampling of soybean pests and knowledge about infestation levels that cause economic damage (Todd et al. 1994). However, especially with early-season pests, management decisions are based on the history of pest problems or on perceived risks of economic pest problems in a particular field.

Recently, insecticidal treatment of soybean seed has greatly increased as a means of preventing economic damage from early-season pests, with more than half of soybean acreage planted to insecticide-treated seed in many production areas (Hodgson et al. 2012a, USGS 2014, Hurley and Mitchell 2016). Soybean seed is treated primarily with either of two neonicotinoid insecticides, imidacloprid, or thiamethoxam (USGS 2014, Douglas and Tooker 2015). Commercial products containing one of these insecticides for seed treatment have been registered in order to protect soybean plants from nine insect pests or pest complexes: the bean leaf beetle; seedcorn maggot; soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae), grape colaspis, *Colaspis brunnea* (F.) (Coleoptera: Chrysomelidae); leafhoppers (Hemiptera: Ciccadellidae); threecornered alfalfa hopper, *Spissistilus festinus* (Say) (Hemiptera: Membracidae); thrips (Thysanoptera: Thripidae); white grubs (Coleoptera: Scarabaeidae); and wireworms (Coleoptera: Elateridae).

The nine early-season pests targeted for control by planting insecticide-treated soybean seed were among the 20 most economically significant pests identified through survey results reported by Steffey (2015). Survey results also established that pest status for eight of the nine insect pests varied by soybean-growing region, with at least four early-season pests considered economically significant in each region (Steffey 2015). Despite a lack of information at times about the actual levels of risk within a particular soybean field from any of these pests, the aggregate risk to soybean posed by four or more of these early-season pests to fields within each region has arguably provided impetus for the extensive use of insecticide-treated seed as a means of avoiding stand loss (Munkvold 2009, North et al. 2016). Nevertheless, the widespread, often prophylactic planting of insecticide-treated soybean seed remains controversial (Papiernik et al. 2017).

The objective of this article is to highlight important factors involved in the pest status for these nine species or species complexes and to identify management options for the nine early-season pests named earlier. We postulate that factors that affect the economic infestations of several early-season soybean pests, as well as the options for their management, can be readily gleaned from pertinent literature on pest biology and management. Accordingly, scientific journal publications, review articles, and management guidebooks on soybean pests were consulted to determine the extent and intensity of pressure that various pests impose on early-season soybean in the United States, and to outline options for their management. The information is given for individual pests in separate sections below and then synthesized across pest species to draw general conclusions.

Selected Early Season Pests of Soybean in the United States

Bean Leaf Beetle

The bean leaf beetle is widely distributed over the eastern two-thirds of the United States and in south-central and southeastern Canada (Pedigo 1994, Lundgren and Musser 2015). After overwintering, adults emerge to feed upon the cotyledons and leaves of young soybean plants in late spring and early summer (Fig. 1), and females lay eggs in soil at the base of soybean plants (Smelser and Pedigo 1991, 1992). Larvae hatch within a week and feed for 15–30 days on soybean roots (Smelser and Pedigo 1991). Summer generations of adults feed on shoots and on pods when available (Smelser and Pedigo 1992). The number of generations of bean leaf beetle ranges from one at northern latitudes to three per year in the southern United States (Pedigo 1994).

Cumulative consumption of seedling shoot tissue (V1 to V3) by adults can reduce yield by 12% (Hunt et al. 1994). The economic significance of larval feeding on roots is undetermined, but generally considered minimal; heavy infestations (19 larvae per plant) substantially reduce nitrogenous assimilates within soybean shoots (Lundgren and Riedell 2008). More important than direct feeding damage, adult bean leaf beetles can transmit various plant pathogenic viruses including *Bean pod mottle virus* (BPMV), *Cowpea mosaic virus*, *Cowpea chlorotic mottle virus*, and *Southern bean mosaic virus* (Boethel 2004). BPMV reduces yield from 3 to 52%, depending on soybean variety and time of infection, with severity generally greatest when infection occurs at early growth stages of soybean development (Gergerich and Domier 2015). It is particularly widespread in major soybean production regions (Giesler et al. 2002), and bean leaf beetle is its main vector (Gergerich and Domier 2015). BPMV decreases pod formation and seed size, number, and weight (Gergerich and Domier 2015).

Bean leaf beetle is one of the most economically significant insects across all major soybean production regions (Steffey 2015). According to survey results from 2013, 11.6% of soybean farmers from 14 states actively managed for beetle pests such as bean leaf beetle, and 6.2% considered 'beetle' as the most important pest (Hurley and Mitchell 2016). Recent survey results showed that bean leaf beetle can cause roughly 3–20% loss due to damage and control costs in Arkansas, Mississippi, North Carolina, and Tennessee, although the amount of yield loss attributable to early-season damage was not specified (Musser et al. 2014, 2015, 2016, 2017).

The need for managing early-season bean leaf beetle usually depends on historic prevalence of BPMV in a particular area (Lundgren and Musser 2015) and focuses on minimizing adult feeding. Insecticides are the most reliable means to limit vectoring of BPMV (Krell et al. 2004, Bradshaw et al. 2008). Insecticides can be applied either as a seed treatment or as a foliar spray between emergence and the first trifoliolate stage (Bradshaw et al. 2008). An additional insecticide spray may be necessary to limit BPMV incidence, if high numbers of bean leaf beetles are present in the first summer generation (Krell et al. 2004, 2005; Bradshaw et al. 2008). In areas of historically low BPMV incidence, other management tactics can be viable. Early planting is a risk factor, and thus delaying soybean planting until one of the later recommended dates can decrease colonization by overwintered adults while maintaining yield potential, at least in Iowa (Zeiss and Pedigo 1996). However, delayed planting relative to emergence of overwintering bean leaf beetles was not a consistently useful management tactic for BPMV (Krell et al. 2005). In northern areas, 5–10% of a field can be planted as a trap crop by sowing 2–3 wk earlier than recommended. The trap crop can be treated with insecticide within 2 wk after emergence to kill colonizing bean leaf beetles, and thus limit infestation of adjacent soybean fields planted at recommended dates (Lundgren and Musser 2015).

Grape Colaspis

The grape colaspis, *Colaspis brunnea* (F.) (Coleoptera: Chrysomelidae), is a small, pale-brown leaf beetle (Fig. 2), whose adults and larvae feed on soybean foliage. In addition, adults feed on a variety of other crops including grape vines, alfalfa, apple, red clover, cowpea, strawberry, and silks of maize (Flint 1941, Rolston and Rouse 1965, Davidson and Peairs 1966). Eggs are laid in irregular clumps slightly underneath the surface of the soil adjacent to the crown of the plant (Lindsay 1943). Females can lay one or two batches of eggs, usually between 50–60 eggs per batch (Lindsay 1943). They overwinter as larvae and the great majority of these moves in the soil below the line of heaviest frost (Bigger 1928). The number of generations depends on its geographic distribution.

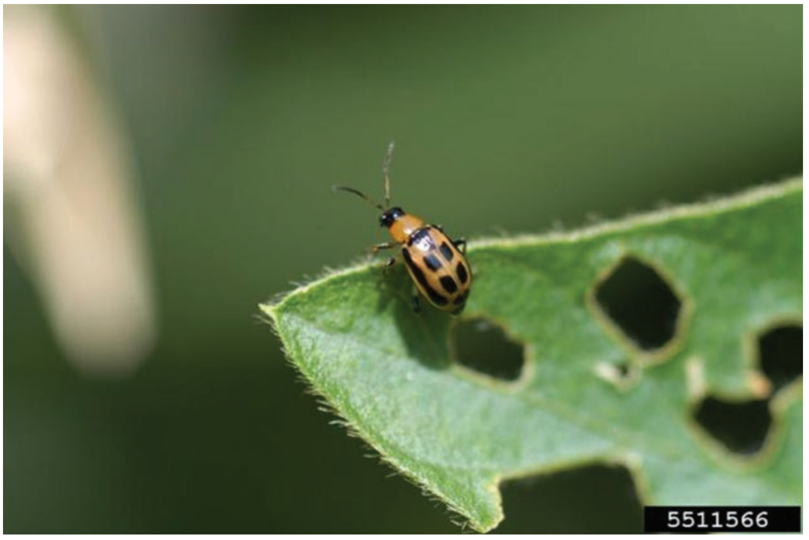

Fig. 1. A bean leaf beetle (*C. trifurcata*) and its characteristic chewing damage to a soybean leaf (photo credit: Ward Upham, Kansas State University, Bugwood.org).

Fig. 2. The grape colaspis (*C. brunnea*), adult (photo credit: Kansas Department of Agriculture, Bugwood.org).

In Iowa, it was reported to be univoltine (Lindsay 1943), while in Arkansas, it is bivoltine with two separate broods of adults occurring during the summer months (Rolston and Rouse 1965). In North Carolina, Eaton (1978) reported a single generation in the summer and a partial generation in the fall. Adults usually not only feed at the lateral margin of the host plant leaf, but also can begin at any point between the leaf margin and mid-rib, leaving various shaped holes in the leaf (Lindsay 1943). Adults are also vectors of BPMV (Gergerich and Domier 2015). Grape colaspis larvae injure crops by feeding on the surface of the root, removing root hairs which interfere with water and nutrient uptake (Lindsay 1943).

Larvae tend to be randomly distributed within soybean fields, but damage occurs in localized areas (Eaton 1978). Loose soils that hold higher amounts of moisture are associated with higher numbers of grape colaspis. Other risk factors associated with grape colaspis larval populations include no-till fields (Tonhasca 1994) and fields that were planted with soybean the previous year (Flint 1941).

One of the first reports of grape colaspis in soybean was that of a single overwintering larva in a soybean field in Illinois (Bigger 1928). Much of the literature regarding grape colaspis in soybean describes it as an occasional pest, but authors do not always specify which stage of the insect was sampled (larva or adult). Kogan and Turnipseed (1987) noted grape colaspis adults as incidental pests in soybean, while Lambert (1994) noted that adults and larvae are common in soybean fields, but seldom economically damaging. Only a few adults were collected in 1 of 3 yr in southeastern Texas, and it was listed as an occasional pest (Drees and Rice 1990). Grape colaspis was observed feeding on soybean in Maryland but caused no apparent economic damage (Ratcliffe et al. 1960).

Reports of serious economic damage include 10–50% stand reduction over thousands of soybean acres in Illinois from 1938 through 1940 (Flint 1941). Mayse and Tugwell (1980) also noted an increase in early-season stand reductions in soybean and rice fields caused by grape colaspis larvae in the Arkansas Delta during the 1970s. Nevertheless, recent surveys of pest management professionals in seven southern and Atlantic states (Alabama, Arkansas, Louisiana, Mississippi, North Carolina, Tennessee, and Virginia) attributed ≤0.3% loss of yield and control costs to grape colaspis (Musser et al. 2014, 2015, 2016, 2017). Farmers surveyed in 2013 failed to list grape colaspis as pest for which they actively managed (Hurley and Mitchell 2016).

There are no rescue treatments in soybean for damaging larval populations in the soil. Nonseed treatment management tactics include fall or early spring cultivation and delayed planting (Flint 1941). Kaeb (2006) reported that one or two pyrethroid applications later in the growing season reduced adult numbers in soybean plots, which decreased numbers of larvae in those plots the following year.

Leafhoppers

Leafhoppers are a type of insect with piercing-sucking mouthparts (Hemiptera: Cicadellidae), and many species feed on a wide variety (sometimes >100 species) of plants, including soybean (Helm et al. 1980, Borror et al. 1989). The potato leafhopper, *Empoasca fabae* (Harris), is considered the primary leafhopper in a complex of seven or so species that feeds on soybean in the United States (Blickenstaff and Huggans 1962, Kincade et al. 1970, Tugwell et al. 1973). It is generally distributed and abundant over the eastern United States, and occurs at low densities in western states (Beyer 1922, DeLong 1938, Helm et al. 1980). Potato leafhopper overwinters as an adult in southern states on various host plants (Beyer 1922, Helm et al. 1980, Taylor and Shields 1995). It is not known to overwinter in northern areas (Poos 1932, DeLong and Caldwell 1935, Specker et al. 1990) but moves into northward on air currents in spring and summer (DeLong 1938, Medler 1957, Huff 1963, Pienkowski and Medler 1964, Carlson et al. 1992) and returns to overwintering locations during the fall (Taylor and Reling 1986, Taylor et al. 1995). Potato leafhopper can have up to 10 continuous generations in southern latitudes and two or more generations in northern latitudes (Yeargan 1994).

Adults lay eggs in plant tissues (Simmons et al. 1984). In younger soybean plants, they lay eggs in the stems, but in older plants, they oviposit in leaf mid-veins and sometimes petioles (DeLong 1938, Simmons et al. 1985). Adult females laid an average of 30.5 eggs over her average lifetime of ~27 d on soybean (Simmons et al. 1984). Average developmental time of nymphs was ~14 d, and adult females can live an average of 64 d, but some live over 90 d.

Historically, soybean suffered from leafhopper feeding on leaves and potentially from the puncturing of stems and petioles during oviposition (DeLong 1938). Leaf veins and surrounding tissue became yellow from leafhopper feeding, and discoloration subsequently extended to the leaf tip. The leaf curled upward and rolled inward, changed from yellow to brown, and became dry and brittle. This type of damage is often called 'hopperburn' (Beyer 1922, DeLong 1938). Heavy infestation has been documented to rapidly kill soybean plants, with damage severity greatest under moisture stress (DeLong 1938).

However, modern commercial grain soybean cultivars in the United States have pubescent stems and leaves and, unlike glabrous cultivars, do not readily suffer economic damage from potato leafhopper (Johnson and Hollowell 1935, Broersma et al. 1972, Boethel 1999). Ogunlana and Pedigo (1974a) found that potato leafhopper can damage a pubescent grain soybean cultivar throughout the season but that progressively greater numbers of leafhoppers were required to cause economic damage with increasing plant age. Accordingly, they calculated an economic injury level of one leafhopper per plant on V1 stage soybean and five leafhoppers per plant for V4 plants, using market values at the time.

Economically damaging outbreaks of potato leafhopper have been rare with the advent of pubescent soybean cultivars (Ogunlana and Pedigo 1974b, Yeargan 1994). Cultivars of vegetable soybean (i.e., edamame) that lack pubescence can be potentially vulnerable to economic damage from potato leafhopper, but such plantings have constituted a very small proportion of soybean acreage in the United States. Consequently, potato leafhopper had been considered an economic pest of grain soybean only in the Midwest in extremely rare instances when large migratory populations invade fields of young, late-planted soybean (Yeargan 1994). However, recent surveys of research and extension entomologists in 2009 and 2014 identified potato leafhopper as one of the most significant pests in the Midwest and Great Plains areas but not in the Mid-South and Atlantic regions (Steffey 2015). The lack of significant pest status in Mid-South and Atlantic states is supported by recent surveys from seven southern and Atlantic states (Alabama, Arkansas, Louisiana, Mississippi, North Carolina, Tennessee, and Virginia) that attributed ≤0.3% loss of yield and control costs to potato leafhopper (Musser et al. 2014, 2015, 2016, 2017).

Seedcorn Maggot

The seedcorn maggot is a fly whose larval stage damages the germinating seeds of various crops, including soybean (Hodgson et al. 2012c). Feeding can destroy the growing tip of soybean, which results in plants with two main stems (Higley and Hammond

1994). Injury can delay seedling emergence and thereby increase the risk of reduced emergence from damping-off diseases (Higley and Hammond 1994). The maggots can hollow out seeds, leading to seed death and significantly reduced plant stand. Soybean can typically compensate for substantial stand reduction without yield loss, but heavy infestations of seedcorn maggot, though rare, can cause complete or nearly complete stand loss (Higley and Hammond 1994).

Several factors increase the risk of seedcorn maggot damage in soybean, such as sustained wet soil immediately after planting and cool soil temperatures that delay germination (Hodgson et al. 2012c). Manuring and incorporating green plant material increase attraction of fields to egg-laying adults (Hammond and Cooper 1993). Adults are active at low temperatures (about 45°F) but become less active and can even be killed at temperatures above 84°F (Higley and Hammond 1994). Thus, seedcorn maggots are more likely to be of economic concern in northern soybean-growing regions, where optimal temperatures for their activity coincide closely with the typical range of soybean planting dates.

Various agronomic practices can minimize seedcorn maggot infestations of soybean (Cullen and Holm 2013). Injury from seedcorn maggot increases with greater amounts of tillage and rarely occurs in no-till systems (Funderburk et al. 1983, Hammond 1997). Delayed soybean planting can take advantage of warmer soils that speed germination. In addition, delaying the planting of soybean 2.5–3 wk after spring incorporation of a green cover crop reduces the attractiveness to egg-laying adults (Hammond 1995). Insecticidal seed treatment is recommended if soybean planting is anticipated during sustained cool moist conditions or when planting immediately follows tillage and manuring (Hammond and Cooper 1993, Hodgson et al. 2012c).

Seedcorn maggot was identified as one of the most significant pests of soybean in the Midwest and Great Plains but not in the Mid-South and Atlantic regions (Steffey 2015). However, Hurley and Mitchell (2016) reported that a 2013 survey of farmers found ≤1% of soybean farmers from 14 states actively managed for seedcorn maggot, and 0.4% considered it as the most important pest. Among organic corn and soybean producers in Wisconsin, only 1% stated seedcorn maggot was a major pest; 4% viewed it as a minor pest, 51% perceived no problem, and 43% were unsure of its impact on their corn and soybean production (Cullen and Holm 2013).

Soybean Aphid

The soybean aphid has been recognized as a pest of soybean in North America since its detection in the north-central United States in 2000 (Alleman et al. 2002, Venette and Ragsdale 2004). It has spread to at least 30 states and 3 Canadian provinces, but it is a soybean pest only at middle and northern latitudes in the continental interior (Ragsdale et al. 2011). In 2009 and 2013 surveys, soybean aphid was considered one of the most significant insect pests of soybean in the Midwest, Great Plains, and Mid-South production regions (Steffey 2015). According to survey results from 2013, 38.2% of soybean farmers from 14 states actively managed for soybean aphid, and 31.0% considered it as the most important pest (Hurley and Mitchell 2016). Management of soybean aphid is confined overwhelmingly to northern soybean-producing states (Ragsdale et al. 2011, Bahlai et al. 2015), as only an extremely small fraction of acreage has been treated for this pest in southern states (Musser et al. 2014, 2015, 2016, 2017).

Rapid population growth of soybean aphid on soybean is facilitated by asexual reproduction (Ragsdale et al. 2004), and under favorable weather conditions, doubling time can be as short as 6 d ((Ragsdale et al. 2007, McCornack et al. 2008). Roughly 15 generations can occur on soybean plants within a growing season (McCornack et al. 2004, McCornack et al. 2008). In late summer, soybean aphids migrate from soybean plants to buckthorn (*Rhamnus* spp.), where sexual reproduction occurs in the fall. Eggs overwinter, hatch in spring, and two parthenogenetic generations develop on buckthorn (Ragsdale et al. 2004). By late spring and early summer, winged, parthenogenetic spring migrants leave buckthorn and colonize soybean plants (Ragsdale et al. 2004). However, soybean aphid is difficult to detect on early-season soybean, especially as alternate secondary hosts that are available in late spring and early summer (Clark et al. 2006)

Soybean aphids prefer to feed on the stems and undersides of leaves (Fig. 3), especially newly expanding trifoliate leaves (McCornack et al. 2008). Soybean aphid directly causes injury from large populations that feed on sap and draw assimilates and other nutrients from soybean plants (Macedo et al. 2003, Chandran et al. 2013), and this feeding can cause economic damage at high densites. Feeding under heavy infestation can stunt plant growth, negatively impact the number of pods, and reduce seed size and quality (Beckendorf et al. 2008),

Fig. 3. Soybean aphids (*A. glycines*) infesting leaves and stems of soybean plants (photo credit: Eric Beckendorf).

ultimately lowering yield up to 40% (Ragsdale et al. 2007). Soybean aphid is also an indirect pest of soybean through its ability to vector various viruses such as *Soybean mosaic virus*, although the presence of soybean aphid in the United States has not significantly increased incidence of this virus (Pedersen et al. 2007).

Infestations of soybean aphid can reach levels that require insecticide application to preserve yield (Johnson et al. 2009, Ragsdale et al. 2011), and treatment decisions for soybean aphid are made during the reproductive stages of soybean (Ragsdale et al. 2007). Decisions regarding insecticide applications are based on the number of aphids per plant between early bloom (R1) to beginning seed set (R5) (Ragsdale et al. 2007). Despite economic threshold guidelines (Ragsdale et al. 2007), prophylactic insecticide seed treatment, prophylactic foliar sprays, or both have been widely used against soybean aphid (Hodgson et al. 2012a,b; Douglas and Tooker 2015). However, application of insecticide based on weekly scouting and adherence to an economic threshold increases the profitability of soybean production over no application and prophylactic application (Johnson et al. 2009, Krupke et al. 2017).

Seed treatment of soybean with neonicotinoids may be used in soybean to control early-season colonization by soybean aphid, but the unfeasible use of prophylactic insecticide seed treatments against soybean aphid in individual fields has been attributed to the lack of residual efficacy to protect soybean from mid- to late-season colonization by soybean aphid (McCornack and Ragsdale 2006, Johnson et al. 2008, Krupke et al. 2017). However, as the risk of early-season colonization is greater for fields near buckthorn stands (Bahlai et al. 2010), it is conceivable that insecticide seed treatments might be useful in such fields. In addition, despite the limited period of soybean aphid suppression from insecticide seed treatment in individual fields, Bahlai et al. (2015) found that increased usage of imidacloprid and thiamethoxam between 2005 and 2011 in four Midwestern states was correlated with a decline in soybean aphid infestation. They suggested that preemption of aphid colonization within soybean fields planted with insecticide-treated seed might have sufficiently curbed early-season population growth of soybean aphids to effect season-long suppression at the landscape scale. Nonetheless, the validity of using insecticide seed treatments to manage soybean aphid higher risk fields and their ability to provide areawide suppression of soybean aphid remain untested.

Various other factors can limit soybean aphid populations and help preclude the need to manage them with insecticides (Hodgson et al. 2012b). For instance, soybeans planted into fall-seeded rye generally have lower densities of soybean aphid than those planted in monoculture (Koch et al. 2012, 2015). Strip cropping of soybean among maize, wheat or vetch reduces soybean aphid abundance compared to soybean monoculture in years of relatively high infestations, and 24-row strips of polycultured soybean had fewer soybean aphids than 48-row strips (Labrie et al. 2016). Plant nutrition impacts soybean aphid-infestation levels. Specifically, potassium (K)-deficient soybean plants are more favorable to soybean aphid infestations than those with adequate to high K levels (Myers et al. 2005, Myers and Gratton 2006, Walter and DiFonzo 2007, Noma et al. 2010). Amelioration of soil K deficiencies can reduce the severity of ensuing infestations (Walter and DiFonzo 2007). Results of varying soybean planting date as a means of managing soybean aphid have been inconsistent (Myers et al. 2005, Rutledge and O'Neil 2006). Furthermore, alteration of planting date impacts levels of other pests and diseases in soybean making unilateral modifications problematic. Therefore, no deviation from standard soybean planting dates is recommended for managing soybean aphid (Hodgson et al. 2012b).

Soybean cultivars with resistance to soybean aphid have been released in the United States, but their commercial availability and adoption rate by farmers have been minimal (Hesler et al. 2013). Limited adoption has been due to the low cost, efficacy, and widespread availability of insecticides for soybean aphid control and to discovery of virulent biotypes of soybean aphid that are able to populate soybean lines with resistance-genes (Hodgson et al. 2012b, Hesler et al. 2013). Pyramid lines, which have more than one aphid-resistance gene (Hill et al. 2012), have been effective against soybean aphid in field trials (McCarville et al. 2014, Chandrasena et al. 2015, Ajayi-Oyetunde et al. 2016). Soybean lines derived from crosses with aphid-resistant lines and containing either one or two major aphid-resistant genes have shown no effect or only minor effect on seed traits and yield (Kim and Diers 2009, 2013; Brace and Fehr 2012).

A diverse assemblage of arthropod natural enemies, consisting principally of generalist predators, is associated with soybean aphid in the north-central United States (Rutledge et al. 2004, Fox et al. 2005, Costamagna and Landis 2006, Brosius et al. 2007, Donaldson et al. 2007, Meihls et al. 2010, Hesler 2014). Several of these natural enemies can significantly limit population growth of soybean aphid (Costamagna and Landis 2006 Brosius et al. 2007, Meihls et al. 2010, Hesler 2014). Soybean aphids oscillate in successive years between relatively high and low infestation levels on soybean in the eastern part of its range (Rhainds et al. 2010, Bahlai et al. 2015, Labrie et al. 2016). Corresponding oscillations in the abundance of the Asian lady beetle, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae), in soybean indicate that these predators exploit the late-season abundance of soybean aphid, and suggest that cultural practices enhancing the conservation biological control of lady beetles can help restrict pest status to alternate years in the east (Rhainds et al. 2010). Furthermore, awareness of this 2-yr oscillation cycle among soybean producers and crop advisors could lead to reductions in prophylactic insecticide treatments during the years of relatively low soybean aphid abundance and analogously intensify scouting efforts in years when higher abundance is expected.

Threecornered Alfalfa Hopper

The threecornered alfalfa hopper, *Spissistilus festinus* (Say) (Hemiptera: Membracidae), is about ⅛ to ¼ in. long and green with a triangular shaped dorsum (Beyer et al. 2017). Adults and nymphs are similar in appearance, but nymphs have dorsal spines and lack wings. Threecornered alfalfa hopper is distributed throughout the entire southern and southwestern United States and lesser numbers occur in the northern United States and southern Canada (Osborn 1911, Wildermuth 1915, Caldwell 1949).

Threecornered alfalfa hopper feeds on a variety of plants but prefers legumes, including alfalfa, soybean, cowpeas, and various clovers. It also feeds on trees, shrubs, herbs, and grasses (Wildermuth 1915). Threecornered alfalfa hopper overwinters as an adult in a state of reproductive diapause (Newsom et al. 1983) but can remain active in warmer climates or during mild winters (Wildermuth 1915). Developmental time depends on host plant and temperature but takes approximately 35 d from oviposition to adult molt (Meisch and Randolph 1965, Mitchell and Newsom 1984). Two to three generations can occur on soybean during a growing season (Mueller 1980, Mitchell and Newsom 1984). Adults are long lived, and females can produce more than 220 offspring during a mean reproductive lifespan of 38 d (Mitchell and Newsom 1984).

Damage inflicted by three-cornered alfalfa hopper to soybean plants is caused by both adults and nymphs sucking plant fluids. Two types of feeding occur: one is random puncturing of stems, and the other is the regular puncturing in a continuous line that forms a ring or girdle around the stem (Wildermuth 1915). Girdling can effectively block the passage of nutrients through the phloem (Hicks et al. 1984) and can result in plant death or weaken the plant so that it becomes lodged or breaks from winds or rain (Mueller and Dumas 1975). The point of feeding varies with growth stage of the soybean plant. Early in plant development, girdling occurs low on the main stem (Fig. 4). Most girdling that causes lodging happens when plants are <25 cm tall (Bailey et al. 1970).

Girdling of soybean by threecornered alfalfa hoppers has the potential to cause economic damage. On a per area basis, Mueller and Dumas (1975) reported approximately 60% of plants girdled low on the main stem early in the season did not survive until harvest, and mean yields from girdled plants were significantly lower than those from plants that were not girdled. However, appreciable yield loss on a per area basis does not occur until approximately 65 to 70% of soybean plants were girdled (Mueller and Jones 1983).

Various factors influence population levels of three-cornered alfalfa hopper in soybean fields. Wild hosts, including clover and vetch, can aid in the build-up early-season populations of three-cornered alfalfa hopper that infest these fields (Mitchell and Newsom 1984). In Texas, Rice and Drees (1985) noted adults girdling plants immediately after plant emergence and main stem girdles exceeded 85% in some fields. Planting date can also impact numbers infesting a particular field. In earlier planted soybeans, three-cornered alfalfa hoppers were more common during June through August than in later plantings (Baur et al. 2000, McPherson et al. 2001) and exceeded the economic threshold more frequently (Baur et al. 2000). However, Mueller and Dumas (1975) noted that late-planted soybeans could be more susceptible to early girdling damage to the main stem. Soybean fields that have below-optimum plant populations appear to be at greatest risk of economic damage by this insect.

Based on survey results from 2009 and 2014, three-cornered alfalfa hopper was considered to be a significant pest of soybean in the Mid-South and Atlantic production regions but not in the Midwest and Great Plains (Steffey 2015). Inconsistency among state management guides indicates that its pest status varies among Mid-South and Atlantic states, and recent studies suggest pest status of three-cornered alfalfa hopper has declined in early-soybean production systems in those regions (Beyer e t al. 2017). Nonetheless, three-cornered alfalfa hopper has been present in a large majority of soybean fields in Alabama, Arkansas, Louisiana, Mississippi, and Tennessee in recent years, and it has diminished soybean production by roughly 25% due to yield loss and control costs in some years in those states (Musser et al. 2014, 2015, 2016, 2017).

Insecticides are available for control of three-cornered alfalfa hopper, but the ability of compensatory soybean cultivars makes it difficult to establish a threshold for application (Sparks and Newsom 1984). Tugwell et al. (1972) reported no difference in yield between insecticide-treated plots with 17% of the plants girdled versus untreated plots with 42% girdle damage. In studies that simulated damage by three-cornered alfalfa hopper, Caviness and Miner (1962) did not note yield reduction until 45% of the plants were removed at flowering, although Cook et al. (2014) reported a yield reduction of 6.4–15.0% when plant loss exceeded 20% at the same growth stage. The lack of differences in yields in some of these studies can be explained by the ability of soybean plants to compensate for adjacent plants that have been killed or stunted, and by girdled plants that recovered from damage (Mueller and Jones 1983, Sparks and Newsom 1984). In addition, re-infestation by adults shortly after treatment a problem associated with lack of efficacy with some insecticide applications (Sparks and Boethel 1987).

Thrips

Thrips (Thysanoptera: Thripidae) are elongate, small (1/16 in. long) insects with rasping-sucking mouthparts. Various species of phytophagous thrips can be found in soybean fields in the United States (Blickenstaff and Huggans 1962, Irwin et al. 1979, Irwin and Yeargan 1980, Reisig et al. 2012, Bloomingdale et al. 2017). Four species are typically common in soybean, depending on geographic location: the soybean thrips *Neohydatothrips variabilis* (Beach); flower thrips, *Frankliniella tritici* (Fitch); tobacco thrips, *Frankliniella fusca* (Hinds); and western flower thrips, *Frankliniella occidentalis* (Pergrande).

Fig. 4. Damage to early season soybean by three-cornered alfalfa hopper (*Spissistilus festinus*) (photo credit: John C. French Sr., Universities: Auburn, GA, Clemson and U of MO, Bugwood.org).

Soybean thrips has six developmental life stages: egg, first instar larva, second instar larva, prepupa, pupa, and adult (Irwin and Yeargan 1980). At 22°C, the period from egg hatch to takes ~11 d (Vance 1974). Larvae are almost always found on the underside of leaves and never move far from the hatching site (Vance 1974). Prepupae and pupae occur in the soil near the base of the host plant (Vance 1974).

Thrips injure plants by feeding on the surfaces of leaves, stems, buds, and flowers (Pedigo and Rice 2009) and feed on exudate from ruptured plant cells (Mueller and Luttrell 1977). The soybean thrips has been documented to injure soybean, with injury most evident as elongate feeding scars on leaves. Injury is often most severe on young soybean plants, but they usually outgrow the injury (Mueller 1994). Insecticide-treated and untreated soybean plots that differ in thrips damage have not been shown to differ in yield (Mueller and Luttrell 1977, Huckaba et al. 1988, Reisig et al. 2012). Occasionally, young soybean plants die when large populations of soybean thrips occur during hot, dry weather (Mueller 1994).

Thrips are vectors of soybean disease viruses. Soybean thrips is a relatively efficient vector of *Soybean vein necrosis virus* (SVNV), whereas tobacco thrips and flower thrips are less efficient vectors of the virus (Keough et al. 2006). SVNV is the most widespread soybean virus in the United States (Zhou and Tzanetakis 2013), but its effect on yield is unknown (Hill and Whitham 2014). A 2013 survey of soybean farmers across 14 states did not identify thrips as a pest that is actively managed in soybean fields (Hurley and Mitchell 2016). From recent surveys in seven southern and Atlantic states (Alabama, Arkansas, Louisiana, Mississippi, North Carolina, Tennessee, and Virginia), thrips impacted soybean profitability up to 6.3% in Tennessee, but other states consistently estimated that thrips cost producers <<1% due to yield loss and control costs in soybean.

White Grubs

The term 'white grubs' refers to two multi-species complexes of polyphagous, root-feeding larvae of scarab beetles (Rice and Riley 1994). True white grubs are the larvae of May and June beetles (*Phyllophaga* spp., Fig. 5), and annual white grubs are the larvae of masked chafers (*Cyclocephala* spp.). The life cycle of true white grubs lasts 1–2 yr in southern states and 3–4 yr in northern states, whereas annual white grubs complete their life cycle in 1 yr. Both types of white grubs are uncommon pests of soybean (Rice and Riley 1994, Hodgson et al. 2012c). Of the two, true white grubs are typically more serious and more widespread pests of soybean than annual white grubs (Rice and Riley 1994, Hodgson et al. 2012c). First-larval instars feed on soybean roots but seldom cause economic damage. Second- and third-larval instars also feed on soybean roots, sometimes to the point of killing individual plants. One or more white grubs per cubic foot of soil can cause stand loss of soybean (Lentz 1985, Rice and Riley 1994). In northern states, the risk of injury from second- and third stage larvae of true white grubs can persist over two growing seasons, as each stage feeds and develops for a year (Hodgson et al. 2012c).

Surveys of research and extension entomologists in major soybean-producing states showed that white grubs were considered significant pests in the Midwest, Mid-South, and Atlantic regions (Steffey 2015). However, white grubs were not listed among insects contributing to soybean losses in seven southern and Atlantic states in recent years (Musser 2014, 2015, 2016, 2017). According to survey results from 2013, only 0.8% of soybean farmers from 14 states actively managed for 'grub' pests, and none considered them as the most important pest (Hurley and Mitchell 2016).

Several factors increase the risk of white grub damage in soybean. Risk of economic injury by white grubs is greater in soybean fields that have been converted from pasture. Planting adjacent to willow or cottonwood trees, which serve as adult host plants, also increases white grub infestation in soybean fields (Glogoza et al. 1998). Spring tillage before soybean planting can reduce the number of white grubs near the soil surface (Rice and Riley 1994). Controlling weeds, especially grassy weeds, in the crop preceding soybean can reduce the attractiveness to egg-laying beetles (Metcalf et al. 1962). A soil insecticide or insecticidal seed treatment is recommended when soybean is planted in fields with high risk of true white grub injury (Hodgson et al. 2012c).

Wireworms

Wireworms are soil-dwelling larvae of click beetles (Pedigo and Rice 2009). Several different species of wireworm can be found in soybean fields, including *Agriotes mancus* (Say) (Coleoptera: Elateridae) (the wheat wireworm), *Limonius dubitans* LeConte (Coleoptera: Elateridae), and *Melanotus* spp. (Coleoptera: Elateridae) (Wintersteen

Fig. 5. Larval instars of a white grub (*Phyllophaga* sp.) (photo credit: Steven Katovich, USDA Forest Service, Bugwood.org).

Table 1. Summary of prevalence, pressure, risk factors, and management options for sporadic pests of seedling soybean listed on labels of neonicotinoid seed treatments

Pest	Region of concern	Presence in seedling soybean	Importance in seedling soybean	Risk factors	Management options[a]			Comments
					Rescue treatment?	Cultural	Other	
Bean Leaf Beetle	Eastern 2/3 of United States *BPMV* widespread in major production regions	Common	Population densities high enough to cause direct economic injury by feeding are uncommon or rare *BPMV* prevalence fairly high, but intensity varies year-to-year	Historic prevalence of *BPMV* Spring rainfall that prevents proper timing of foliar treatments Warm winter	Yes (one or two foliar sprays, beginning before first trifoliate)	Delay planting to latest recom. date Plant small part of field early as trap crop		Most important as vector of *BPMV* Management of *BPMV* mainly via minimizing adult beetle feeding
Grape Colaspis	North-central United States, south to Arkansas and North Carolina	Occasional to common	Seldom economic	Loose soils No-till Early planting 2nd year soybean field	No	Delayed planting Fall or early spring cultivation		Damage localized within a field
Leafhoppers	Widespread; Many species in complex, but potato leafhopper most abundant	Frequent, but timing sporadic	Rare, requires severe infestation to reduce yield	Dry conditions Late planting Smooth-leaf varieties	Yes	Early planting Pubescent varieties		Potato leafhopper migratory from overwintering areas in South making infestations in North sporadic in time and space
Seedcorn Maggot	North America	Widespread	Uncommon, with rare, locally severe infestations; Actively managed in <1% of fields, Greater concern in northern regions	Delayed germination (e.g., cool, moist conditions) Manuring Green plants incorporated during spring tillage	No	Late planting Delay planting 2–3 wk after tillage No-till		Soybeans can compensate (increased yield) for substantial stand reduction
Soybean Aphid	Middle and northern latitudes, continental interior	Variable	Midseason pest, but can colonize some fields with V2–V4 seedlings in low numbers	Potassium deficient soil	Yes	Resistant cultivars Natural enemies (especially generalist predators) Rye cover crop Adequate soil potassium	Preventive insecticide treatments widely used but less profitable than threshold-based rescue treatments	Colonization from overwintering host by late spring, but most fields beyond seedling stage. Early colonization can result in higher populations later, but value of control on seedlings is unclear.

Table 1. *Continued*

Pest	Region of concern	Presence in seedling soybean	Importance in seedling soybean	Risk factors	Management options[a]			Comments
					Rescue treatment?	Cultural	Other	
Three-cornered Alfalfa Hopper	Southeast and Midsouth	Common	Occasional economic injury at high populations probable, but determining the EIL has been problematic	Nearby early-season hosts (wild and cultivated legumes) Early planting	Yes (but consensus treatment thresholds not established)	Higher planting population		Soybeans can compensate (increased yield) for substantial stand reduction; this is main reason for lack of consensus EIL
Thrips	North America (particular species composition varies)	Common	No evidence for effect on yield, but may be possible with severe infestation	Cool weather Dry conditions	Yes (but treatment thresholds not established)			Plants outgrow thrips populations Can vector soybean viruses Can contribute to other stress factors to reduce yield
White Grubs (true)	East of Rocky Mtns.	Widespread	Uncommon, usually not a concern Can be locally severe	CR out of pasture Nearby willow or cottonwood trees Grassy weeds in previous crop Infestation the previous year	No	Spring tillage to reduce numbers	At-planting soil insecticide	Annual white grubs of lesser concern True white grubs have multiyear life cycle, so risk can persist for two seasons after initial infestation
Wireworms		Widespread	Uncommon, usually only a problem in presence of risk factors	CR out of grassland Early planting Sustained cool spring	No	Fallowing field with good weed control Shallow spring tillage Plowing Higher planting population	At-planting soil insecticide	Many species in complex Multiyear lifecycle

Abbreviations: CR, crop rotation; SI, soil insecticide.
[a]Neonicotinoid seed treatments are a current management option in all cases, so not listed in table.

1994). Depending on species, wireworms live 2–6 yr in the soil. Adults eclose in the fall, but generally do not emerge from the ground until spring, when they lay eggs in soil, generally near grasses (Wintersteen 1994, Pedigo and Rice 2009, Hodgson et al. 2012c).

Wireworms damage germinating soybean seeds, small roots, and shoot tissue before it emerges from the soil (Wintersteen 1994, Hodgson et al. 2012c). Risk of attack is increased by early planting, conversion of fields from grassland, and sustained cool soil temperatures in the spring that delay germination and plant growth (Wintersteen 1994, Hodgson et al. 2012c). Various management tactics can reduce populations of wireworms and their risk of economic injury to soybean (Wintersteen 1994, Hodgson et al. 2012c). Fallowing fields and achieving good weed control during fallow will limit food sources for these pests. Shallow tillage in the spring can kill wireworms near the soil surface. Increased seeding rates can be used to compensate for anticipated plant attrition due to wireworms. Soil insecticides or insecticide seed treatments are warranted in fields where sampling reveals large infestations, in fields with a history of significant damage, or where soybean follows conversion from long-term grassland.

Wireworms are usually problematic in situations with risk factors described earlier. They were listed as a significant pest of soybeans in the Mid-South region but not in other soybean production regions, based on surveys in 2009 and 2014 (Steffey 2015). According to survey results from 2013, 2% of soybean farmers from 14 states actively managed for wireworms, and 0.8% considered them as the most important pest (Hurley and Mitchell 2016).

Summary and Conclusions

Nine insect pests of early-season soybean that are targeted for control by insecticidal seed treatments in the United States were considered in this review: bean leaf beetle, grape colaspis, leafhoppers, seedcorn maggot, soybean aphid, threecornered alfalfa hopper, white grubs, and wireworms (Table 1). Review of the nine species (complexes) characterized various factors involved in their pest status in early-season soybean and identified management options applicable to each pest (complex). The pest status of seedcorn maggot, white grubs, and wireworms is limited to a relatively small proportion of soybean fields with readily defined factors regarding the risk of early-season damage from each of these pests. Subsequently, ≤1% of soybean growers manages specifically for each of these three pests. Risk of economic damage from seedcorn maggot is uncommon and linked to green manuring and delayed seedling growth due to wet, cool soil. Similarly, risk from white grubs and wireworms is associated with soybean that it is planted on land coming out of pasture, grassland, and similar situations. The higher risk situations identified for these three pests seem to present clear examples that can justify preventative measures if soybean is planted or consideration of planting a less vulnerable crop.

For the remaining six species (complexes), the extent and intensity of their pest pressure vary among and sometimes within soybean production regions, and some of the factors responsible for the variation are unknown. Bean leaf beetle was regarded as a significant economic pest by research and extension entomologists in all four major soybean-producing areas. However, despite the extensiveness of its perceived pest status, there is a lack of actual data that specify the frequency and proportion of soybean fields with significant economic infestation early in the season from bean leaf beetle. Moreover, risk of yield loss associated with BPMV is generally greater than that associated with bean leaf beetle per se, but quantification and management of BPMV risk are complicated by yearly variation in bean leaf beetle abundance and infectivity, timing of beetle populations in relation to soybean planting and development, and alternative transmission routes of BPMV (Bradshaw et al. 2008, Hill and Whitham 2014),

Some pests, namely, grape colaspis and thrips, have been regarded as economically significant by research and extension entomologists (Steffey 2015), but not actively managed by growers (Musser et al. 2014, 2015, 2016, 2017; Hurley and Mitchell 2016). For instance, grape colaspis has been regarded by entomologists as a significant economic pest in the Mid-South and Atlantic production areas. However, pest management professionals in seven Mid-South and Atlantic states attributed ≤0.3% loss in yield and control costs to grape colaspis, and soybean farmers from various states failed to list grape colaspis as an actively managed pest. Numerous general factors are involved with increased risk of economic damage to soybean from grape colaspis, such as no-till and planting soybean for a second consecutive year. To date, however, the explanatory power of these factors is inadequate and must be refined because many fields with such risk factors do not suffer economic damage from grape colaspis. Similarly, leafhoppers have been regarded as an economically significant pest complex in the Midwest and Great Plains, but one for which growers do not actively manage. These results with grape colaspis and leafhoppers beg questions regarding the discrepancies between higher perceptions of their pest status versus lower percentages of their management as pests.

Threecornered alfafa hopper is an example of a pest regarded as economically significant within some regions, but for which lost productivity and control may be limited only to individual states within the regions. It has been regarded as an economically significant pest in the Mid-South and Atlantic production regions. Indeed, three-cornered alfalfa hopper has diminished soybean production by roughly 25% because of yield loss and control costs in some years in several Mid-South states. However, inconsistency among state management guides for three-cornered alfalfa hopper suggests that its pest status varies among Mid-South and Atlantic states, and recent studies indicate that pest status of threecornered alfalfa hopper may have declined in early-soybean production systems in those regions. Some factors such early planting and the presence of nearly alternate hosts can increase the risk from three-cornered alfalfa hopper, but such factors are not consistently associated with economically damaging populations. Hence, more research is needed to refine factors regarding its pest status (North et al. 2016). In addition, three-cornered alfalfa hopper can cause significant stand reduction, but the compensatory ability of contemporary soybean cultivars has made consensus about its pest status difficult. Validated thresholds for this pest are needed for early plantings of soybean (Beyer et al. 2017).

Similarly, thrips is an example of a pest complex regarded as economically significant within the Mid-South, but for which lost productivity and active management may be limited to only particular states within the region. It is also unclear to what extent thrips are managed specifically as an early-season pest among regions. Furthermore, future determination of the pest status of thrips may need to consider its role as a plant virus vector and the relation of SVNV on soybean yield.

Soybean aphid can colonize soybean fields in the late spring and early summer (Ragsdale et al. 2011). These early season populations in soybean have the potential to build to economically significant populations later in the season (McCornack and Ragsdale 2006, Beckendorf et al. 2008). However, early-season management of soybean aphid with insecticide seed treatment has not proven feasible for individual soybean fields. Nonetheless, questions remain regarding the feasibility of early-season management specifically for soybean fields with a high risk of infestation and whether early-season management contributes substantially to an areawide suppression of soybean aphid. Research is needed to address those questions.

This article reviewed the pest status and management of nine insect species complexes that are early-season pests of soybean and currently targeted for management with insecticidal seed treatments. Given the large number of large number of insect herbivores that feed on soybean, the dynamic nature of the soybean agroecosystem, and the extent of world trade (Kogan and Turnipseed 1987, Ragsdale et al. 2011), additional early-season pests of soybean will likely arise in the future in the United States, either as emerging pests or as newly introduced pests. Reviews of factors involved in their pest status and management, as well as updated information on the current nine pests, may prove useful in providing a broader perspective on insect pest management in soybean.

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