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RESEARCH ARTICLE

# BIOLOGY OF SOYBEAN APHID, *APHIS GLYCINES*. A REVIEW

[1]*Deepti Tomar and [2]Kaushik Shilpi

[1]*Department of Zoology, Dr. H. S. Gour Central University, Sagar, (M. P.)
[2]Department of Zoology, Barkatullah University, Bhopal, (M. P.)

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**ABSTRACT**

Soybean aphid, *Aphis glycines* was noted as an invasive pest of soybean and quickly spread within years. Its establishment across a large area of soybean growing regions was facilitated by the previous establishment and spread of its overwintering host, common buckthorn, *Rhamnus cathartica* L. The rapid population expansion suggests high mobility and if left untreated can reduce yield significantly, stunt plant growth. Heavy infestations can result in a covering of dark sooty mold. Large infestations can negatively impact seed quality, size and pod number. It can transmit plant viruses too. At present insecticides and biological control management has a significant impact on soybean aphid population growth.



## INTRODUCTION

### *Description*

The soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae) is an invasive pest that was first detected in the United States in 2000 (Alleman *et al*. 2002) and quickly became the dominant insect pest in soybean. Soybean aphid was first described by Matsumura (1917), but more defined body characters were published by Voegtlin *et al*. (2004a). Soybean aphid populations have the potential to increase rapidly and heavy infestations can stunt plant growth and development, leading to significant yield loss.

### *Feeding and Occurrence*

Soybean aphids have piercing-sucking mouthparts that are used to feed on phloem sap. Although soybean aphid feed on leaves, stems and pods, but they are most often found on the undersides of leaves. The distribution of soybean aphids on the plant varies during the growing season (McCornack *et al*. 2008). Early in the season, aphids are more likely to be found on newly expanding trifoliate leaves. As the season progresses and the plant matures, soybean aphids are more likely to be found lower in the canopy, on leaves that are attached to nodes further from the terminal bud. Soybean aphids may occur in low density of only a few aphids per plant, or may form large, persistent colonies of several hundred or even thousands per plant.

### *Limitations of Soybean aphid*

Soybean aphid colony size and infestation levels are influenced by ecological factors such as temperature and biological control, but also by their nutritional feeding environment. Like most aphids, soybean aphid growth is limited by the nutritional quality of its host plant. The limiting component of the soybean aphid's diet is often nitrogen, which has a relatively low concentration within the phloem. Studies have linked the population growth rate of the soybean aphid to nitrogen availability in soybeans. Population growth increases in plants with increased nitrogen concentration in phloem, such as plants growing in fields with potassium-deficient soils (Myers *et al*. 2005, Walter and DiFonzo 2007, Noma *et al*. 2010) or growth stages of the plant when nitrogen is more readily available.

### *Damage caused*

The injury caused by phloem feeding insects like soybean aphids may go undetected without close visual inspection, and feeding damage may become readily apparent only after large, yield-reducing populations have developed. At moderate infestation levels (i.e., 50 aphids per leaflet), soybean aphid can significantly reduce gas exchange and negatively affect photosynthetic rates (Macedo *et al*. 2003).

Heavily infested plants are stunted and may be covered with dark sooty mold growing on the sugary excretions or "honeydew" that aphids produce. Heavy infestations can result in yellow and wrinkled leaves, stunted plants and aborted pods (Lin *et al*. 1993) leading to significant yield loss of 40% or more (Ragsdale *et al*. 2007). Large infestations can negatively impact seed quality and size, pod number, plant height, and photosynthesis (Beckendorf *et al*. 2008).

### *Relation with viruses*

Soybean aphid, like many aphids, can transmit plant viruses (Clark and Perry 2002). It has been shown to transmit both Soybean mosaic virus and Alfalfa mosaic virus to soybean (Hill *et al*. 2001). It may also vector plant pathogens, typically nonpersistent viruses, to other temporally visited crops, such as Alfalfa mosaic virus and Cucumber mosaic virus in snap bean, *Phaseolus vulgaris* L. (Gildow *et al*. 2008) and Potato virus Y in potato, *Solanum tuberosum* L. (Davis *et al*. 2005). Soybean aphid is able to transmit several other viruses (Wang *et al*. 2006), but its economic importance as a vector in North American soybean and other crops is still to be determined.

* Corresponding author: **Deepti Tomar**
Department of Zoology , Dr. H. S. Gour Central University, Sagar, (M. P.)

***Life cycle***

The life cycle of the soybean aphid in the United States is similar to its native range (Wu *et al*. 2004). Like many aphid species, it has a complex life cycle that involves different physical forms (morphs) and two types of host plants. It is heteroecious (host-alternating) and holocyclic (generates sexual morphs with an egg that overwinters) (Ragsdale *et al*. 2004). Through the spring and summer, soybean aphids reproduce asexually (without mating) on soybean, which is actually considered the secondary host; the aphids are all female and give live birth to all-female offspring. These features give soybean aphids the ability to increase very rapidly when conditions are favorable.

The optimal developmental temperature is 82°F/27.8°C (McCornack *et al*. 2004). The upper developmental temperature is 94.8°F/34.9°C and the lower developmental temperature is 47.5°F/8.6°C (McCornack *et al*. 2004). In general, aphid reproduction is affected by the growth stage of the host plant, with greater rates of reproduction during vegetative and late reproductive stages when senescence occurs (Dixon, 1985) but these plant growth stage effects do not prove to be strong (Rutledge and O'Neil 2006, Rhainds *et al*. 2010). Under favorable conditions (e.g., 77–86°F/25–30°C), soybean aphids are highly reproductive and can double in population size in as little as 1.5 to 2 days (McCornack *et al*. 2004). However, in the field where aphids experience multiple forms of mortality (weather, natural enemies, diseases) population doubling time is typically 6–7 days (Ragsdale *et al*. 2007). During the entire growing season, soybean aphid has 15 asexual generations on soybean and three or more generations on the primary host (buckthorn), which is equivalent to the 18–20 generations that were recorded in China (Li *et al*. 2000). During midsummer population increase, many wingless aphids will produce winged offspring that can colonize other areas within-field or can disperse great distances on the wind in mid to late summer (Hodgson *et al*. 2005, 2009) and later-season influx of aphids into fields may be an important contributing factor in outbreaks. Factors that typically contribute to aphids producing migrants in other systems include plant nutrition, crowding (Dixon, 1985), temperature (Johnson and Birks, 1960), plant phenology (Howard and Dixon, 1992), and the presence of beneficial insects (Roitberg *et al*. 1979). Several of these factors are currently under investigation for soybean aphid.

***Alternative host***

At the end of the soybean growing season soybean aphids migrate in September and October back to their primary host plant, common buckthorn (*Rhamnus cathartica* L.), a deciduous shrub common in shelterbelts and woods in northern states. Buckthorn is a critical part of the soybean aphid life cycle; without this plant, they cannot spend the winter in a given area. *R. cathartica* is most widely infested, though it may also overwinter on *Rhamnus alnifolia* among other *Rhamnus* species (Voegtlin *et al*. 2004b, 2005; Hill *et al*. 2010).

Common buckthorn is itself an invasive species and is widespread across North America, particularly north of 41$^{o}$N latitude where plant densities of 10,000/acre are known to occur (Ragsdale *et al*. 2004). It often appears as a shrub around 8 feet/2.4 m high but can also resemble a small tree up to 25 feet/7.6 m tall. It has gray bark and glossy dark green leaves with curved veins and notched edges. The fall migration of soybean aphids to buckthorn is regulated by photoperiod and temperature. Winged females (gynoparae) leave soybean in search of buckthorn, where they feed and deposit a cohort of wingless, sexual females (oviparae). Winged males from soybean seek the oviparae on buckthorn, where mating occurs, followed by oviposition. Overwintering eggs are deposited along buckthorn buds (Ragsdale *et al*. 2004). The overwintering egg is cold-hardy and can survive temperatures as low as 29°F/34°C (McCornack *et al*. 2005). Eggs suffer significant mortality on buckthorn, likely because of a combination of abiotic and biotic factors including predators. Survivors hatch during spring and three or more generations develop on buckthorn (Welsman *et al*. 2007, Bahlai *et al*. 2008). During the time when soybeans germinate, colonies on buckthorn produce winged females, which colonize soybeans in the early vegetative growth stage (V1-V5) in late spring/early summer (Bahlai *et al*. 2008). Soybean fields in close proximity to buckthorn may be at greater risk of early infestation (Bahlai *et al*. 2010); however, soybean fields distant from buckthorn are also at risk of secondary infestations occurring later in the growing season.

***Natural enemies***

Field studies of soybean reveal a diverse community of natural enemies, which help suppress soybean aphid colonization and population growth. These natural enemies include ladybeetles, lacewings, pirate bugs, predatory flies and entomopathogenic (insect disease causing) fungi (Rutledge *et al*. 2004, Nielsen and Hajek 2005, Mignault *et al*. 2006, Brewer and Noma 2010). The community of insect predators within soybean has apparently been altered by the arrival of the soybean aphid, and now includes more species that focus on aphids (Schmidt *et al*. 2008). Included in this community is the multicolored Asian ladybeetle, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), which contributes to biological control of soybean aphid in its native range (Van den Berg *et al*. 1997) and is one of the dominant soybean aphid predators in the United States (Gardiner *et al*. 2009a, 2009b). Natural enemies cause significant mortality of soybean aphid.

Several field studies have demonstrated the contributions of existing communities of natural enemies to soybean aphid suppression (Fox *et al*. 2004; Rutledge and O'Neil 2005; Costamagna and Landis 2006, 2007). In the absence of predation, soybean aphid population growth is significantly faster (2–7 times) (Costamagna and Landis 2006). Prophylactic application of broad-spectrum insecticides (Ohnesorg *et al*. 2009) or fungicides (Koch *et al*. 2010) has the potential to ultimately exacerbate aphid pressure or cause secondary outbreak of other pests such as spider mites by removing the natural enemies that often keep pest populations in check. Conversely, management practices that encourage the recruitment and preservation of natural enemies in soybean have the potential to provide future conservation biological control strategies (Brewer and Noma 2010). Landscape ecology can have a significant impact on biological control of soybean aphid. The soybean aphid is typically a pest of soybeans in areas where the crop is grown in large monocultures. This setting can influence the insect predators that provide biological control. In areas where the landscape is comprised mostly of corn and soybeans, the impact of insect predators will be lower than in regions where there is more landscape diversity (Gardiner *et al*. 2009a).

Soybean fields located in landscapes that have a greater amount of perennial habitat are more likely to have a greater abundance of ladybeetles (Gardiner *et al*. 2009b). Such habitats include woodlots, where important predators like the multi-colored Asian ladybeetle overwinter. Noma *et al*. (2010) found that landscapes with more diverse land cover tend to have lower aphid populations. Soybean fields in landscapes comprised of grassland habitats and annual crops are likely to have a lower density of natural enemies and subsequently, less biological control. Landis *et al*. (2008) have suggested that as more land is used for corn production, the current level of soybean aphid biological control may decline and Noma *et al*. (2010) found that habitats more dominated by corn and soybean were associated with greater soybean aphid populations. Though soybean aphid can be heavily impacted by the natural enemies that already exist in the United States, as an invasive species it is also a candidate for classical biological control. Invasive species often have higher populations in their introduced ranges than in their native ranges; in part this is related to an escape from natural enemies, which are typically less abundant for a given pest across its introduced range than in its native range (Colautti *et al*. 2004). Though surveys of natural enemies in the United States reveal a rich community of natural enemies, parasitoids - a type of parasitic insect that is often nearly as large as its host and can specialize on particular prey species - have been notably lacking from this community (Rutledge *et al*. 2004, Kaiser *et al*. 2007, Noma and Brewer 2008, Schmidt *et al*. 2008).

***Parasitoid***

Parasitoids that attack soybean aphids are an important part of the community of predators that suppress soybean aphid in China (Liu *et al*. 2004); however, it is not uncommon for a newly introduced pest insect to arrive without its specialist natural enemies. A classical biological control program, whose goal is to introduce parasitoid species from the native range that specializes on soybean aphid, is underway. One particular species, *Binodoxys communis* (Gahan) (Hymenoptera: Braconidae) has undergone intense scrutiny for environmental impact, host specificity and ecological interactions with soybean and other aphids (Wyckhus *et al*. 2009). Based on these studies, *B. communis* received federal approval for release in the United States in 2007. Releases of *B. communis* in the Midwest are on-going, though their impact on soybean aphid has not been measured and depends in large part on the ability of populations of the parasitoid to establish and spread within the new range. Additional candidate species are in quarantine and may be released in the future (Heimpel *et al*. 2004).

***Control measures***

Though natural enemies can have a significant impact on soybean aphid population growth (Costamagna and Landis 2006, Noma and Brewer 2008) and host plant resistance is an emerging tool, insecticides are currently the most-used control method for soybean aphid.

Before the arrival of the soybean aphid, very little insecticide was used on soybean for insect pests in the north-central region (Fernandez - Cornejo and Jans 1999). In response to soybean aphid, growers have dramatically increased the use of insecticides for soybean production (USDA-NASS) in some cases spraying up to three times in outbreak years, usually with broad-spectrum insecticides. Insecticides from multiple classes (organophosphates, pyrethroids, neonicotinoids) are effective for rapid soybean aphid control but are most profitably used in an Integrated Pest Management (IPM) program based on scouting and the use of economic thresholds to guide application decisions. Significant field-based research has demonstrated that IPM strategies can limit yield loss while preventing unnecessary input-costs (Ragsdale *et al*. 2007, Johnson *et al*. 2009).

A great deal of research still has to be done in the scouting and management of soybean aphid. Further investigations to control this serious pest can be done by plant-derived products. Plant-derived materials are more readily biodegradable. They are less toxic, may be more selective in action and may retard the development of resistance. Their main advantage is that they may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts. The efficacy of plant products has often been shown to be due to an active principle contained therein. This could be the best alternative in this direction and safe too.

## CONCLUSION

Though natural enemies can have a significant impact on soybean aphid population growth and host plant resistance is an emerging tool, insecticides are currently the most used control method for soybean aphid. Aphid-resistant varieties have the potential to augment natural enemies by reducing insecticide load. Host-plant resistance to soybean aphid has been found and molecular mapping is ongoing. It significantly reduces aphid populations.

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